AEMC

DETERMINATION

Australian Energy Market Commission

DRAFT RULE DETERMINATION

NATIONAL ELECTRICITY AMENDMENT (FAST FREQUENCY RESPONSE MARKET ANCILLARY SERVICE) RULE 2021

Infigen Energy

22 APRIL 2021

INQUIRIES

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Reference: ERC0296

CITATION

AEMC, Fast frequency response market ancillary service, Draft rule determination, 22 April 2021

ABOUT THE AEMC

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

EXECUTIVE SUMMARY

1 As we move towards a lower emissions energy future, system security is the most critical issue in the National Electricity Market (NEM). Lower cost, variable inverter connected generation is displacing dispatchable thermal generation and this is creating challenges for how the security of the power system is managed. New and evolved ways to procure enough essential services to keep the power system stable and secure are needed in order to maintain the system in a secure state, and at lowest cost to consumers, as the energy sector transitions.

2 The Australian Energy Market Commission (AEMC or Commission) along with the Energy Security Board (ESB) and other market bodies see work focusing on the security of the power system as a priority. The ESB's p2025 work is to advise on a long-term, fit for purpose market framework to support reliability, modifying the NEM as necessary to meet the needs of future diverse sources of non-dispatchable generation and flexible resources, including demand side response, storage and distributed energy resource participation. The essential system services and scheduling and ahead mechanisms work stream is a key part of the ESB's p2025 work. Frequency control is one of the four key services that the ESB is considering through this work and the development of market ancillary service arrangements for faster frequency response are an immediate priority area for reform.

3 The AEMC has made a draft rule to introduce two new market ancillary services in the NEM, which will help keep the future system secure and foster innovation in faster-responding technologies that will help lower costs for consumers. The new market ancillary services would allow for fast frequency response (FFR) to be procured by the Australian Energy Market Operator (AEMO) to help control system frequency following sudden and unplanned generation or power system outages, known as contingency events. The use of these new services is expected to lower the cost of frequency control ancillary services relative to the expected future costs under a continuation of the current market ancillary service arrangements or other alternative arrangements. The draft rule is consistent with the long-term direction for essential system services as set out in the ESB's p2025 work. This rule change delivers a key part of the ESB's system services work program.

4 In order to maintain the power system in a secure operating state and avoid unplanned system or plant outages, power system frequency must be controlled within a narrow range around 50Hz. This is achieved by dynamically balancing electricity generation and consumption under both normal system conditions and in response to sudden larger changes in frequency caused by contingency events.

5 FFR generally refers to the delivery of a rapid active power increase or decrease by generation or load in a time frame of two seconds or less, to correct a supply-demand imbalance and assist in managing power system frequency. FFR is a relatively new service that can be offered by inverter-based technologies such as wind, solar photovoltaics (PV), batteries and demand-side resources.

6 FFR services are expected to play a growing role in managing contingency events, particularly during periods when there is a lower level of inertia on the power system. Inertia

is an inherent characteristic of large spinning synchronous machines such as coal-fired steam turbines. The level of synchronous inertia in the power system is projected to decline over coming years as the power system transforms. AEMO's integrated system plan projects that the levels of large scale coal- and gas-fired thermal generation will gradually reduce over the coming years and be replaced by inverter connected generation including large scale solar PV, wind power, batteries and behind-the-meter distributed resources like rooftop solar.

7 At lower operating levels of inertia, increased volumes or fasting acting frequency control services are required to arrest and stabilise the system frequency within the existing system operating standards. In the absence of a change to the current market arrangements, AEMO expects that increased quantities of the current fastest service, which operates over a time frame of six seconds, will be required to arrest sudden changes in power system frequency following contingency events under low inertia operating conditions. This could lead to a significant increase in the costs for fast frequency control ancillary services (FCAS), which could be partially mitigated by the procurement of faster responding services, such as FFR. The introduction of FFR services, which operate over much shorter time frames, would provide an alternative source of frequency control thereby reducing the overall costs of managing the frequency of the power system relative to the status quo or other alternative arrangements.

8 The introduction of FFR markets would also incentivise technology development and innovation, given that the types of resources that are most likely to provide such services are those inverter-based technologies, such as wind, solar PV, batteries and demand-side resources. The introduction of these new markets would further encourage entry of these types of resources into the market, and so the proposed change would also have flow on effects to reliability and security, beyond that associated with management of frequency control.

9 The draft rule

10 The Commission has made this draft rule with respect to a rule change request submitted by Infigen energy. Infigen proposes that the National Electricity Rules (NER) be amended to introduce new market ancillary service arrangements for the procurement of FFR to help efficiently manage system frequency following contingency events during low inertia operation.

11 The Commission's draft rule determination is to make a draft rule that is consistent with the solution proposed by Infigen Energy. While Infigen's rule change request did not include proposed rule drafting, the draft rule is consistent with the proposed solution in the rule change request. The differences between the draft rule and the proposed solution are limited to the naming of the new market ancillary services and the inclusion of transitional arrangements.

12 The draft rule introduces two new market ancillary service categories into the NER for:

- the *very fast* raise service
- the *very fast* lower service

13 The Commission considers that it is appropriate for FFR to be procured through spot market

arrangements, consistent with the ESB's spectrum for how essential system services should be procured. Spot market based provision of essential system services is preferred, where practicable, given it allows for full co-optimisation between services and energy, resulting in more efficient dispatch and pricing of services, driving innovation in the provision of various combinations of essential system services from different technologies. FCAS markets are currently procured through co-optimised spot markets, and so it follows that a very fast FCAS service is procured through this process as well.

14 The market arrangements for the new market ancillary services would be the same as those for the existing *fast* raise and *fast* lower services. This includes the arrangements for registration, scheduling, dispatch, pricing, settlement and cost allocation.

15 The implementation and transitional arrangements for the new market ancillary services include:

- That AEMO revise the market ancillary services specification (MASS) within 18 months of the date that the rule is made, to specify the detailed description and performance parameters for the *very fast* raise service and the *very fast* lower service.
- That the FFR market ancillary service arrangements commence 3 years from the date that the rule is made.

16 The Commission notes that these time-frames may be bought forward as a result of further detailed planning associated with the ESB post-2025 work program and stakeholder feedback on the FFR draft rule. The Commission is of the view that these time frames represent the latest time as to when arrangements should be implemented.

17 AEMO's FFR implementation options report

18 The Commission's draft determination is supported by technical advice provided by AEMO, as part of its frequency control work plan, with this published alongside this draft determination. It sets out AEMO's analysis of technical considerations and preliminary market analysis to inform the design of FFR market arrangements.[1] The key recommendations from AEMO's advice were:[2]

1. FFR services should be developed for efficiently managing frequency containment under system intact conditions.
2. Out of market arrangements should be considered as a transitional measure to help manage market implementation risks
3. FFR services, as an extension to FCAS, are suited to 5-minute markets in the longer term.
4. From a market systems implementation perspective, combining the 6-second and 60-second services would be preferable to introducing new services. However, the significant use of 6-second and 6-second services suggests that market participants should be consulted before consolidating services.

1 AEMO, FFR implementation options report, March 2021.

2 AEMO, *Fast frequency response implementation options - Technical advice on the development of FFR arrangements in the NEM*, April 2021, p.4.

5. Introduction of speed factor parameterisation is not recommended at this time, as this would require significant development in the NEM context and may not provide clear signals on the required speed of response.
6. Inertia and FFR should not be combined within the same service.

19 Relationship between inertia and FFR

20 There is a close interaction between the development of market arrangements for FFR services and the valuation of inertia. Inertia acts to resist changes in frequency due to sudden changes in supply and demand. It is provided inherently by large spinning machinery associated with synchronous generators such as coal, hydro and gas-fired power stations. In contrast, frequency responsive reserves are provided by a range of technologies, including generation, storage and demand response.

21 FFR and inertia are different services. Although FFR has the potential to assist with frequency management at lower levels of system inertia, FFR and inertia are delivered via different physical mechanisms, and play roles that are not directly interchangeable. FFR is not a direct substitute for synchronous inertia. While FFR can help control system frequency during low inertia operation, a minimum quantity of synchronous inertia will continue to be required over at least the medium term.

22 Currently, the NER includes an inertia framework that supports the provision of security critical inertia for each of the NEM regions. However, the NER does not support the full valuation of inertia above these minimum levels. The introduction of a FFR market would likely address much of the system needs under low inertia conditions for the immediate future, but further needs may emerge over time. The consideration of reforms to value inertia services in the longer term is being considered by the ESB. Detailed investigation on inertia in order to understand the technical aspects of it are still required.

23 The Commission is interested in stakeholder feedback on this interaction, and whether there are any changes to the draft rule that could better accommodate the interactions between inertia and FFR.

24 Interactions between FFR and mandatory PFR

25 The Commission's assessment of AEMO's *Primary frequency response incentive arrangements* rule change request is occurring alongside the assessment of Infigen's *Fast frequency response market ancillary service* rule change request. In contrast to the rapid active power response provided by FFR, continuous primary frequency control helps to control system frequency during normal operation by responding to small frequency variations.

26 In the period 2014 to 2019, the control of power system frequency during normal operation degraded, such that the power system frequency was spending more time further away from the target frequency of 50Hz than had historically been the case. AEMO identified the degradation of frequency control in the NEM as being driven by a decline in the responsiveness of generation plant to system frequency combined with an increase in the variability of generation and load in the power system.

27 In response to a rule change request submitted by AEMO, and a similar request made by Dr

Peter Sokolowski, the Commission made a rule in 2020 that introduced an obligation for all scheduled and semi scheduled generators in the NEM to support the secure operation of the power system by responding automatically to small changes in power system frequency. In its final determination, the Commission noted that a mandatory requirement for primary frequency response (PFR) was required to address an immediate need to restore effective frequency control in the NEM but that, on its own, it is not a complete solution and that further work needed to be done to understand the power system requirements for maintaining good frequency control. The Commission noted that it would be preferable to introduce alternative or complementary arrangements that incentivise and reward the provision of PFR. As a result, the Commission determined that the Mandatory PFR rule would be an interim arrangement which would sunset on 4 June 2023.

28 AEMO is currently in the process of coordinating changes to generator control systems in accordance with the *Mandatory primary frequency response* rule. The monitoring of plant and power system impacts due to the roll out of the Mandatory PFR requirement will help inform the Commission's determination of the enduring PFR arrangements.

29 The Commission's draft rule with respect to Infigen's rule change request does not include any specific provisions or revisions in relation to potential interactions between the provision of FFR and the existing requirement for mandatory PFR. AEMO's advice is that affected plant can manage the interaction between provision of FFR and the mandatory PFR obligation through application of variable droop settings, which act to reduce plant sensitivity to small frequency changes while still complying with the mandatory PFR obligation.

30 The Commission will further consider the interaction between the mandatory PFR requirement and the provision of contingency FCAS through its assessment of AEMO's *Primary frequency response incentive arrangements* rule change request and the related draft determination scheduled for publication by 16 September 2021.

31 Consultation

32 The AEMC invites submissions on any aspect of this draft determination by **3 June 2021**.

33 Stakeholder input on this draft determination will further inform the AEMC's analysis of the issues and the development of final rules, which will be reflected in a final determination in July 2021.

34 The AEMC also welcomes individual meetings with interested stakeholders. Those wishing to meet with the AEMC should contact Ben Hiron on (02) 8296 7855 or ben.hiron@aemc.gov.au.

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1 INTRODUCTION

System security is the most critical issue in the NEM. Cheaper, variable inverter connected generation is displacing dispatchable thermal generation at great speed, making blackout prevention more difficult. Accordingly this is a priority for the ESB and market bodies. Power system security is a priority for the AEMC - essential power system services that were previously a free by-product of traditional power generation - like voltage and frequency control and inertia - are not necessarily provided by new generation because they have different technical features. This means new ways to procure enough essential services to keep the power system stable and secure are needed.

The ESB's p2025 work is to advise on a long-term, fit for purpose market framework to support reliability, modifying the NEM as necessary to meet the needs of future diverse sources of non-dispatchable generation and flexible resources, including demand side response, storage and distributed energy resources. A key part of this is the work stream on essential system services and scheduling and ahead mechanisms.

Frequency control is one of the four key services that the ESB is considering through this work. The Australian Energy Market Commission's (AEMC or Commission) two rule change requests that relate to frequency control form part of this work. These rule changes provide us with an opportunity to complement the thinking and assessment done in the ESB work program, as well as technical input from AEMO through its Renewable Integration Study. The two rule changes are:

- **Infigen Energy — *Fast frequency response market ancillary service*** — This rule change request proposes the introduction of spot-market arrangements for fast frequency response (FFR) to help efficiently manage system frequency following contingency events during low inertia operation. This is the subject of this draft determination.
- **AEMO — *Primary frequency response incentive arrangements*** — This rule change request proposes changes to the NER to support improved frequency control during normal operation. This is not discussed in this paper, with a draft determination due on this rule change request by 16 September 2021.

The Commission has made a draft rule, in response to Infigen's rule change request, to introduce new market ancillary services for fast frequency response. Such an arrangement would help to efficiently manage system frequency following contingency events during low inertia operation, allowing the system to be securely and reliably operated and doing so in a cost effective way for consumers. These new 'very fast' frequency control ancillary services (FCAS) will be similar to the existing contingency FCAS currently being used to manage sudden changes in power system frequency, but would operate more quickly in order to arrest rapid changes in system frequency that can occur under lower inertia operation.

The increasing uptake of inverter-based generation in the NEM is increasing the occurrence of low inertia conditions, which can lead to high rates of change of frequency when system disturbances occur. AEMO is currently able to maintain a secure power system under conditions of low inertia and could continue to be able to do so for the foreseeable future by procuring increasing volumes of fast six-second FCAS. However, the introduction of new 'very

fast' FCAS will provide a faster source of frequency control which is expected to be more economically efficient than procuring larger volumes of the existing six-second FCAS under the current arrangements, or any alternatives, lowering costs for consumers of managing system security by giving AEMO this additional tool to manage security of the system.

This chapter:

- provides an overview of Infigen's rule change request, including the problem statement and proposed solution
- sets out the Commission's process for making this draft determination
- outlines the process of coordination with the Energy Security Board (ESB)
- outlines the process for making submissions on this draft rule determination and draft rule
- sets out the structure of this draft rule determination

1.1 The rule change request

On 19 March 2020, Infigen Energy (proponent) made a request to the Australian Energy Market Commission (AEMC or Commission) to make a rule regarding market ancillary services for fast frequency response (rule change request). The rule change request seeks to amend the NER to introduce new market ancillary service arrangements for the procurement of fast frequency response (FFR).[3]

Infigen's rule change request identifies that the projected decline in system inertia will negatively impact on AEMO's ability to control power system frequency and could result in an increased need for fast FCAS that typically respond to frequency variations within a period of six seconds after a contingency event.

Infigen proposes the introduction of new contingency FCAS products that would respond more quickly to changes in power system frequency and better manage frequency variations during reduced inertia operation. Infigen's proposed FFR services would operate in a similar way to existing contingency FCAS, with service provision being based on enablement through the NEM dispatch on a five-minute basis. Infigen proposes an FFR service specification where full active power response is delivered within two seconds, as opposed to the six seconds specification for the existing "fast raise" and "fast lower" services.

The rule change request did not include proposed rule drafting.

1.1.1 Rationale for the rule change request — problem statement

Infigen considers that inverter-based generating technologies are displacing synchronous thermal generators at certain times of the day and, in some cases, contributing to early retirement of thermal generators.[4] It considers that the cumulative impact of these effects is leading to a steady decline in the amount of inertia that is present on the power system.

3 Infigen Energy, Fast frequency response market ancillary service — Electricity rule change proposal, 19 March 2020. Available at https://www.aemc.gov.au/rule-changes/fast-frequency-response-marketancillary-service

4 Infigen Energy Limited, F*ast frequency response market ancillary service — Electricity rule change proposal*, 18 March 2020, p.1-2.

This expected reduction in inertia presents operational challenges associated with maintaining a secure power system and controlling system frequency following contingency events. At lower levels of operating inertia, faster and/or more frequency control services are required to stabilise the system frequency following power system disturbances.

Stable frequency is a measure of the instantaneous balance of power supply and demand. To avoid damage to, or failure of, the power system, the frequency may only deviate within a narrow range below or above 50 hertz (Hz). If frequency goes outside the allowed range, additional generating units or load map trip, further exacerbating the supply/demand mismatch and moving frequency further away. The rate of change of frequency (RoCoF) is the speed at which the frequency deviates from 50 Hz following a contingency (an event on the power system). When RoCoF is too high, frequency can move outside of the allowed range before mitigating measures have time to respond.[5]

Broadly, Infigen considers that the reduction in system inertia is impacting the ability of AEMO to control power system frequency and the operation of the NEM in two ways:

- **an increase in the instantaneous rate of change of frequency (RoCoF)**. As synchronous inertia in the power system decreases, the RoCoF following contingency events increases.
- **an increased requirement for six second contingency FCAS in the absence of faster responding reserves**. Higher RoCoF increases the need for more and faster acting frequency response to meet the requirements of the power system frequency operating standard.

Infigen notes that these changes are occurring in the context of an increase in the variability and unpredictability associated with power system operation. Variability in the operation of wind and solar generators as well as more frequent and intense weather events are leading to new and different modes of network failure, with contingency events more likely and their impacts harder to predict. Therefore, Infigen considers that there is an increasing need to develop arrangements to preemptively address power system risks, and that any arrangements for new system services designed to address these issues should occur via transparent market-based frameworks

1.1.2 Solution proposed in the rule change request

Infigen seeks to resolve the issues discussed above by proposing a rule (proposed rule) to introduce new market ancillary service arrangements for the procurement of FFR raise and FFR lower services. Infigen considers that the introduction of these new FFR services would provide AEMO with more appropriate tools to manage system frequency following contingency events during low inertia operation.[6]

Under the proposal, FFR providers would respond automatically to any local frequency deviations that occur, and would need to provide their full response within two seconds.

5 An overview of the principles of frequency control in the power system is included in section 2.1 and further detail is provided in Appendix A.

6 A contingency event is an event that affects the power system in a way which would likely involve the failure or sudden and unexpected removal from operational service of a generating unit or transmission element.

The proposed new FFR service would operate in the same fashion as the existing contingency services. Participants would submit bids to provide the service. AEMO would determine the specifications for the FFR service in the Market Ancillary Services Specification (MASS).[7] The market for provision of FFR services would be open to generation and loads. AEMO would operate the markets similarly to how it operates existing contingency FCAS markets. FFR providers could participate in all FCAS contingency markets (6s, 60s, 5min) and would need to sustain their response for at least six seconds (in time to pass it on to the next 6s contingency FCAS market).[8]

1.2 The rule making process

This section provides an overview of the rule making process for the draft rule - *Fast frequency response market ancillary service.*

1.2.1 Consultation paper

On 2 July 2020, the Commission published a consultation paper to commence the rule making process and consultation in respect of this rule change request *Fast frequency response market ancillary service*.[9] This consultation paper also covered six other rule change requests that relate to the provision of system security services in the NEM.[10] Submissions to the consultation paper closed on 13 August 2020.

The Commission received 43 submissions as part of the consultation.[11] In making this draft determination and draft rule, the Commission has considered all issues raised by stakeholders in submissions in relation to Infigen's rule change request. Issues raised in submissions are discussed and responded to throughout this draft rule determination.

1.2.2 Directions paper

On 17 December 2020, the Commission published a directions paper for both rule change requests that relate to the arrangements for frequency control in the NEM, *Fast frequency response market ancillary service* and *Primary frequency response incentive arrangements*.[12] The directions paper set out the Commission's initial views and high-level policy directions on key issues in relation to the arrangements for fast frequency response and primary frequency response in the NEM.

The Commission received 29 submissions as part of the second round of consultation. In making this draft determination and draft rule, the Commission has considered all issues raised by stakeholders in submissions in relation to Infigen's rule change request. Issues

7 The market ancillary service specification (MASS) is prepared by AEMO in accordance with clause 3.11.2(b) of the NER. It includes a detailed description of each of the market ancillary services together with relevant performance parameters and requirements

8 Infigen Energy Limited, *Fast frequency response market ancillary service — Electricity rule change proposal*, 18 March 2020, p.5.

9 This notice was published under s.95 of the National Electricity Law (NEL).

10 AEMC, System services rule changes - consultation paper, 2 July 2020. Available at: https://www.aemc.gov.au/rule-changes/fast-frequencyresponse-market-ancillary-service

11 These can be found on the project web page.

12 AEMC, Frequency control rule changes — Directions paper, 17 December 2020. Available at: https://www.aemc.gov.au/rule-changes/fast-frequency-response-market-ancillary-service

raised in submissions are discussed and responded to throughout this draft rule determination.

1.2.3 Technical working group

The Commission has continued to engage with experts from industry, and consumer groups through the frequency control technical working group, which was formed in October 2019 to discuss issues related to frequency response rule change requests. In the lead up to this draft determination, technical working group meetings were convened on 8 October 2020 and 4 March 2021.

1.3 Energy Security Board post-2025 market design interactions

As discussed above, the Energy Security Board (ESB) is advising on a long-term, fit-for-purpose market framework to support reliability, modifying the NEM as necessary to meet the needs of future diverse sources of non-dispatchable generation and flexible resources, including demand side response, storage and distributed energy resource participation. A key part of this work is the ESB's thinking on essential system services and scheduling and ahead mechanisms, which includes consideration of the control of power system frequency.

The ESB and market bodies have undertaken a substantial amount of work on frequency control frameworks in the NEM, to ensure that these frameworks keep up with the needs of the transition.

The Commission's draft rule to introduce new markets for FFR ancillary services is consistent with the preferred framework developed for procurement of system services as set out in the essential system services market design initiative in the ESB's 2025 work, and has taken into account feedback provided through the ESB process.

The ESB has identified new markets for fast frequency response as an immediate area of reform to help manage system frequency following contingency events with reducing system inertia. This draft determination implements arrangements to address this.

The ESB also identifies the development of enduring primary frequency response (PFR) arrangements as another immediate reform need to support frequency control during normal operation. The draft determination in September 2021 on *Primary frequency response incentive arrangements* rule change request will address the second of these reforms.

The ESB also acknowledges the close interaction between the development of market arrangements for FFR services and the valuation of inertia provided above the minimum security-critical levels. The NER currently includes an inertia framework that supports the provision of security-critical inertia for each of the NEM regions - where if an inertia shortfall is declared then a TNSP must provide inertia to fulfil that gap. This can come through installing network equipment or contracting with generators, including contracting with generators for fast frequency response. However, the NER does not currently support the full valuation of inertia above these minimum levels. The ESB has set out that its long-term direction is to work on a spot market approach for valuing and procuring inertia.

1.4 Consultation on draft rule determination

The Commission invites submissions on this draft rule determination, including the draft rule, by **3 June 2021**.

Stakeholder input on this draft determination will further inform the AEMC's analysis of the issues and the development of final rules, which will be reflected in a final determination in July 2021.

Any person or body may request that the Commission hold a hearing in relation to the draft rule determination. Any request for a hearing must be made in writing and must be received by the Commission no later than 29 April 2021.

Submissions and requests for a hearing should quote project number ERC0296 and may be lodged online at www.aemc.gov.au.

The AEMC also welcomes individual meetings with interested stakeholders. Those wishing to meet with the AEMC should contact Ben Hiron on (02) 8296 7855 or ben.hiron@aemc.gov.au.

1.5 Structure of this draft determination

The remainder of this draft determination is structured as follows:

- Chapter 2 sets out relevant context and background
- Chapter 3 sets out the Commission's draft rule determination, provides a summary of reasons, and outlines how the Commission made its decision with respect to its assessment framework.
- Chapter 4 provides further detail on the principal elements of the draft rule, including stakeholder feedback and the Commission's analysis and conclusions.
- Chapter 5 discusses a number of issues related to the Commission's determination which are not part of the draft rule.

2 CONTEXT AND BACKGROUND

This chapter provides an overview of the context and background for the rule change, *Fast frequency response market ancillary service.*

2.1 What is fast frequency response?

Fast frequency response (FFR) generally refers to the delivery of a rapid active power increase or decrease by generation or load in a time frame of two seconds or less, to correct a supply-demand imbalance and assist in managing power system frequency. FFR is a relatively new technology that can be offered by inverter-based technologies such as wind, solar photovoltaics (PV), batteries and demand-side resources.

In 2017, AEMO published a report that outlined technical considerations with respect to FFR. It provided guidance on the suite of services that could be offered by FFR to assist in the efficient management of power system security. In this paper AEMO defined FFR as:[13]

> Any type of rapid active power increase or decrease by generation or load, in a time-frame of less than two seconds, to correct supply-demand imbalances and assist with managing frequency

There are a number of use-cases for FFR as discussed below. However, Infigen's rule change request, and by extension this determination, is predominantly concerned with the application of FFR capability for contingency response in the NEM.

Infigen's rule change request identifies that the projected decline in system inertia will negatively impact on AEMO's ability to control power system frequency. This could result in an increased need for fast FCAS that typically respond to frequency variations within a period of six seconds after a contingency event.

AEMO's 2020 Integrated system plan (ISP) forecasts that power system inertia levels will continue to decline as more inverter-based generation plant connect to the power system and existing synchronous plant progressively retire. In addition, AEMO's Renewable Integration Study stage 1 report confirms Infigen's view that more and faster frequency responsive contingency reserves are required to keep the power system secure under reduced inertia operation.

2.1.1 What are technical characteristics of FFR?

In its 2017 technical paper, AEMO identified the following areas where FFR may provide value in the NEM in approximate order of importance:[14]

- **Emergency FFR** — For arresting frequency following specific rare, extreme events such as non-credible separation of a region. It was noted that this form of FFR is currently being used by AEMO in collaboration with TNSP's through the development of emergency

13 AEMO, Fast frequency response in the NEM — Working paper, 21 August 2017, p.17.

14 Ibid.

frequency control schemes, such as the South Australian system integrity protection scheme(SIPS).

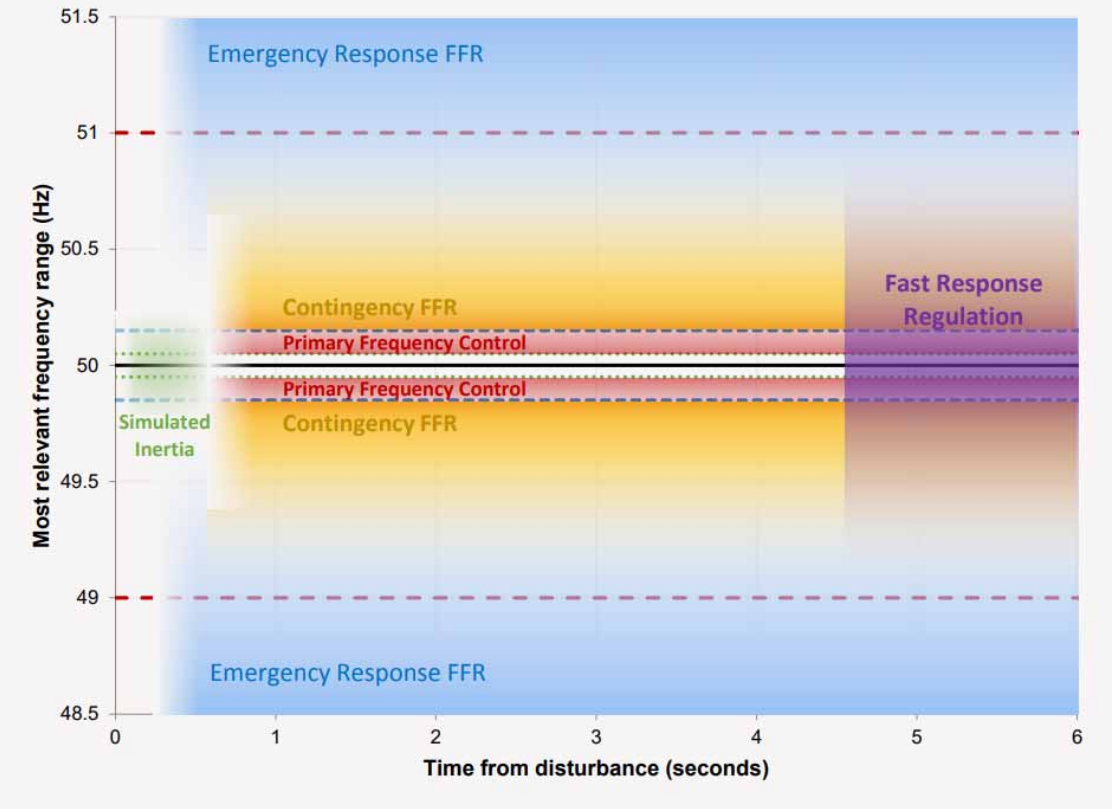
- **Fast primary frequency control** — for continuous automatic response to small frequency deviations. AEMO identified this option as having promise in assisting in managing security outcomes in the near term.
- **FFR contingency response** — for automatic response to large frequency deviations.AEMO identified this option as showing promise in assisting in managing security outcomes in the near term.
- **Fast response regulation** was identified as being a technically feasible option, but noted that this may become more important in future
- **Simulated or synthetic inertia** were identified as requiring further commercial demonstration — although AEMO noted that the existing inertia framework may be able to be adapted to support the provision of simulated or synthetic inertia.[15]
- **Grid-forming technologies** — AEMO considered that these showed promise for the future. However, further research and required to develop and demonstrate this technology for application in large power systems (>300MW).

The draft rule relates to FFR for contingency response. The arrangements for primary frequency control including the potential application of faster responding technologies to help control system frequency are being considered through the *Primary frequency response incentive arrangements* rule change which is discussed in section 2.4. The characteristics for the FFR services under the draft rule are described in section 4.1.

AEMO's mapping of potential applications for FFR is shown below with respect to frequency variation size and response times.

15 The inertia framework in the NER establishes a process for the identification and maintenance of minimum levels of inertia to support secure operation for each of the NEM regions following separation and during islanded operation. Further detail on this framework is included in appendix A.2.2

Figure 2.1: Mapping of potential FFR services (frequency ranges and response times)



Source: AEMO, Fast frequency response in the NEM — Working paper, 21 August 2017, p.5

2.2 Relationship between inertia and FFR

There is a close interaction between the development of market arrangements for FFR services and the valuation of inertia. FFR is described above. Inertia acts to resist changes in frequency due to sudden changes in supply and demand. It is provided inherently by large spinning machinery associated with synchronous generators such as cola, hydro and gas-fired power stations. In contrast, frequency responsive reserves are provided by a range of technologies, including generation, storage and demand response.

FFR and inertia are different services. Although FFR has the potential to assist with frequency management at lower levels of system inertia, FFR and inertia are delivered via different physical mechanisms, and play roles that are not directly interchangeable. FFR is not a direct substitute for synchronous inertia. While FFR can help control system frequency during low inertia operation, a minimum quantity of synchronous inertia will continue to be required over the medium term.[16]

16 Further detail on the interaction between inertia and contingency FCAS is included in section 5.1 and appendix A.3.

Currently, the NER includes an inertia framework that supports the provision of security-critical inertia for each of the NEM regions.[17] However, the NER does not support the full valuation of inertia above these minimum levels. The introduction of FFR market ancillary services will likely address much of the system needs under low inertia conditions for the immediate future, they may not over time. The consideration of reforms to value inertia services in the longer-term is being considered by the ESB. Detailed investigation on inertia in order to understand the technical aspects of it are still required.

We are interested in stakeholder feedback on this interaction, and whether there are any changes to the draft rule that could better accommodate the interactions between inertia and FFR.

2.3 AEMO's technical advice — Fast frequency response implementation options

The consultation on changes to the NER for each of the frequency control rule changes is supported by technical advice provided by AEMO, as part of its frequency control work plan. This work plan provides a cohesive summary of a range of actions that AEMO is undertaking to support effective frequency control in the NEM as the power system transforms. It sets out AEMO's view of what changes are required to the arrangements for frequency control along with the priority and timing for making these changes.

A key element of AEMO's work plan, and a primary input to the Commission's assessment of this rule change request, is AEMO's *Fast frequency response implementation options(FFR Implementation options)* report which sets out technical advice to guide the development of FFR arrangements in the NEM. AEMO's advice has been published with this draft determination and includes AEMO's analysis of technical considerations and preliminary market analysis to inform the design of FFR market arrangements. [18]

The AEMC's directions paper on the frequency control rule change requests set out a range of options for the implementation of FFR in the NEM, as discussed further in chapter 4. For each of these proposed solutions, AEMO's *FFR implementation options* report aims to outline the ability of the solution to meet the physical system requirements, and any implementation considerations from AEMO's perspective as the market and system operator. The key recommendations of AEMO's advice are set out in Table 2.1.

Table 2.1: Summary of recommendations from AEMO's FFR implementation options report

TOPIC	RECOMMENDATION	COMMISSIONS RESPONSE
1. Utility of FFR	**FFR services should be developed for managing**	Agreed, discussed

17 The existing inertia framework is described in appendix A.2.2.

18 AEMO, *Fast frequency response implementation options - Technical advice on the development of FFR arrangements in the NEM*, April 2021. Available on the project web page: https://www.aemc.gov.au/rule-changes/fast-frequency-response-market-ancillary-service

TOPIC	RECOMMENDATION	COMMISSIONS RESPONSE
	frequency containment under system intact conditions. In the longer term, use of existing services at greater volumes will be an inefficient way to ensure the required speed of frequency response under lower inertia conditions. Introduction of FCAS-like FFR services would recognise the existing speed capability within current FCAS provider facilities, as well as allowing new providers to enter the market to assist in reducing 6-second raise (R6)/6-second lower (L6) volume requirements. The introduction of an FFR FCAS may also allow for improvements to the arrangements already in place for use of FFR for the management of islanded regions.	in section 4.1
2. Transitional arrangements	**Out of market arrangements should be considered as a transitional measure.** The use of out of market procurement as a transitional measure would allow the service specification to be more readily refined in advance of market implementation. Coupled with locational requirements, it would also help minimise the technical integration challenges and allow procedures to be developed to manage these challenges in the initial stages of the market.	Draft rule does not include additional out of market procurement arrangement for FFR, this is discussed in section 4.3
3. Enduring arrangements	**FFR services, as an extension to FCAS, are suited to 5-minute markets in the longer term.** Provided locational limits and requirements can be managed in 5-minute markets, FFR can be implemented in these markets. The market impacts of these requirements should be considered in market design.	Agreed, discussed in section 4.1
4. Reconfiguration of existing FCAS	**Market participants should be consulted on combining 6 and 60-second services.** From a market systems implementation perspective, reconfiguration of the existing contingency FCAS arrangements to procure FFR, keeping three raise and three lower services, is preferable to introducing new services. It also results in simpler ongoing	Draft rule introduces new market ancillary services for FFR, discussed in section 4.1

TOPIC	RECOMMENDATION	COMMISSIONS RESPONSE
	arrangements. Combining 6 and 60-second raise services in parallel to introducing a raise and lower FFR services would allow for this reconfiguration. There is a significant level of use of 6-second and 60-second services that would be affected by consolidating these services, and market participants should be further consulted on this potential change.	
5. Scaling factors / differential pricing	**Introduction of speed factor parameterisation is not recommended at this time.** Speed factor parameterisation of FCAS provision would require significant development in the NEM context. The application of this approach in the NEM may not provide the transparency of market outcomes that other approaches could provide, or provide clear signals on the required speed of response.	Agreed, discussed in section 4.2.3
6. Interaction with inertia	**Inertia and FFR should not be combined within the same service.** Inertia and FFR both provide a valuable response, however, they are fundamentally different and should not be combined within the same service.	Agreed, discussed in section 5.1

Source: AEMO, *Fast frequency response implementation options — Technical advice on the development of FFR arrangements in the NEM*, March 2021, p.4.

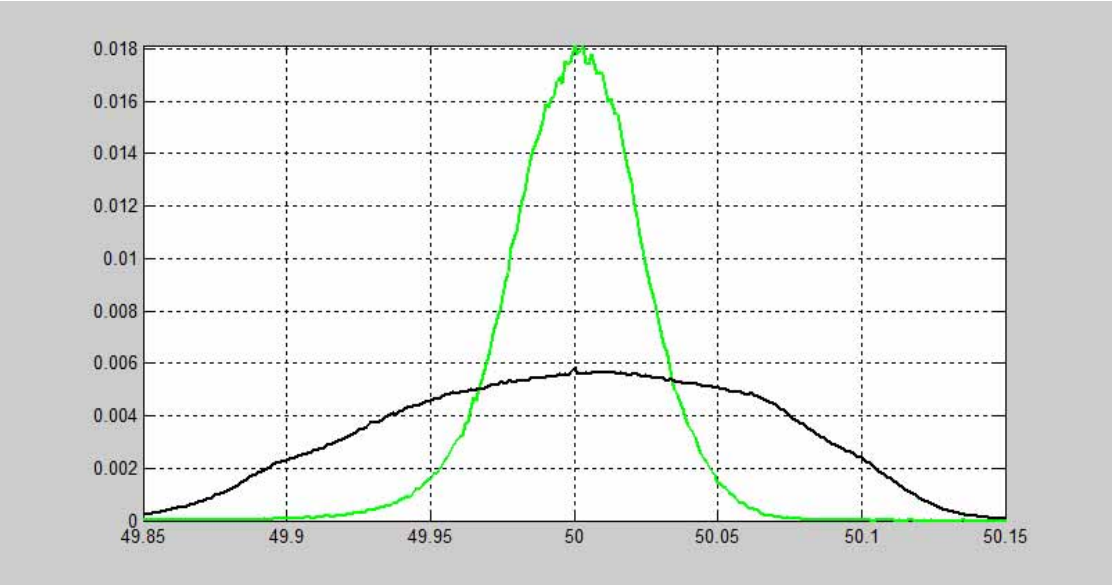
2.4 Relationship with AEMO's *Primary frequency response incentive arrangements* rule change request

The Commission's assessment of AEMO's rule change request on primary frequency response is occurring alongside the consideration of this rule change request. Continuous primary frequency control helps to control system frequency during normal operation by responding to small frequency variations.

In the period 2014 to 2019, the control of power system frequency during normal operation degraded, such that the power system frequency was spending more time further away from the target frequency of 50Hz than had historically been the case. This degradation of frequency performance is evidenced by a broadening of the frequency distribution as shown below in Figure 2.2. AEMO identified the degradation of frequency control in the NEM as

being driven by a decline in the responsiveness of generation plant to system frequency combined with an increase in the variability of generation and load in the power system.[19]

Figure 2.2: Frequency distribution within the normal frequency operating band in theNEM2005 snapshot v. 2018 snapshot



Source: AEMO, Primary frequency response incentive arrangements— Electricity rule change proposal, 1 July 2019, p.14
Note: : X-axis: Frequency (Hz)
Note: the green line shows 2005 data, the black line shows 2018 data.

By 16 August 2019, AEMO had formed the view that the decline in frequency control in the power system had reached the point where AEMO was increasingly unable to control the power system frequency under normal operating conditions. AEMO attributed the primary cause for the lack of control as the reduced provision of primary frequency response (PFR) from generation. In its rule change request, Mandatory primary frequency response, AEMO considered that there was an immediate need for additional frequency response to restore effective frequency control in the NEM during normal operation and following contingency events.

In response to AEMO's rule change request, and a request made by Dr Peter Sokolowski (which were consolidated by the Commission as one rule change request), the Commission made a rule in 2020 that introduced an obligation for all scheduled and semi scheduled generators in the NEM to support the secure operation of the power system by responding automatically to small changes in power system frequency.[20] In its final determination, the Commission noted that a mandatory requirement for PFR on its own is not a complete solution and that further work needed to be done to understand the power system

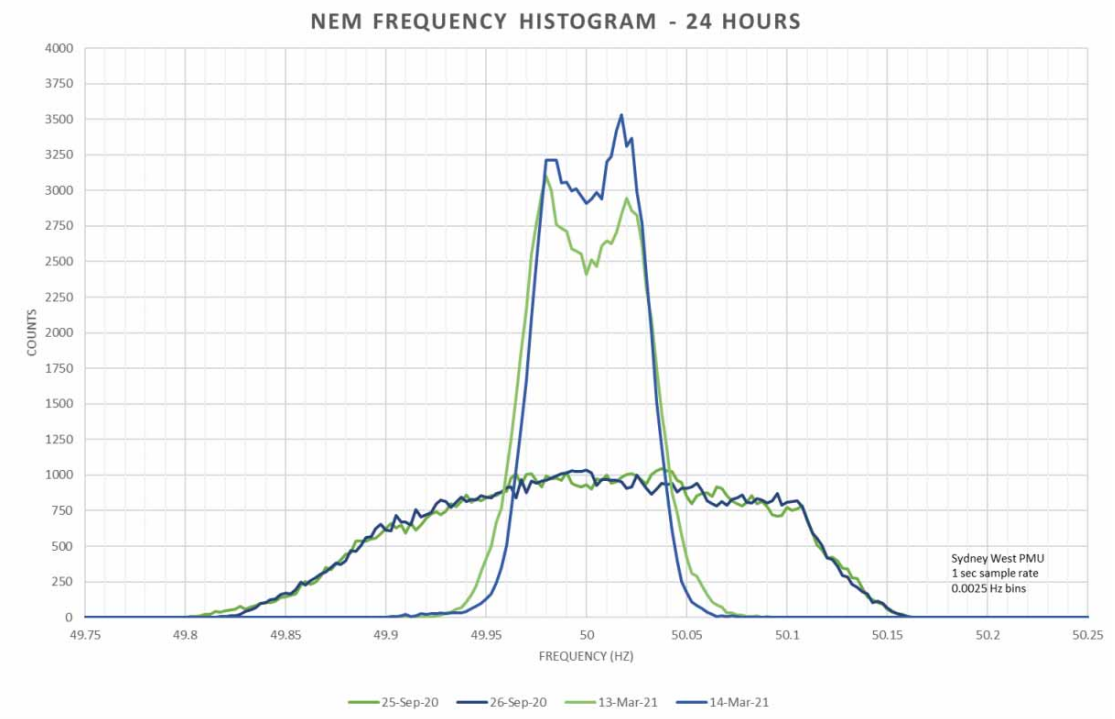
19 AEMO, Rule change proposal - Primary frequency response incentive arrangements, 3 July 2019, p.14

20 AEMO, Mandatory primary frequency response — Electricity rule change proposal, 16 August 2019. Dr Sokolowski, Primary frequency response requirement — Electricity rule change proposal, 30 May 2019.

requirements for maintaining good frequency control. The Commission noted that it would be preferable to introduce alternative or complementary arrangements that incentivise and reward the provision of PFR. As a result, the Commission determined that the Mandatory PFR rule would be an interim arrangement which would sunset on 4 June 2023.

AEMO is currently in the process of coordinating changes to generator control systems in accordance with the *Mandatory primary frequency response* rule. The monitoring of plant and power system impacts due to the roll out of the Mandatory PFR requirement will help inform the Commission's determination of the enduring PFR arrangements. As shown in Figure 2.3 the early results of the implementation of this is promising - frequency control is improved.

Figure 2.3: Comparison of NEM frequency distribution – Sep 2020 vs Mar 2021



Source: AEMO, *Implementation of the National Electricity Amendment(Mandatory Primary Frequency Response) Rule 2020 — Status as at 15 Mar 2021*, 16 March 2021,p.19.

The Commission is developing enduring arrangements for PFR through its ongoing assessment of the *Primary frequency response incentive arrangements* rule change request.

In the December 2020 directions paper, the Commission set out three viable pathways towards enduring PFR arrangements.[21] These three pathways are defined by three different approaches to the enduring role for mandatory PFR and the associated frequency response band:

21 AEMC , *Directions paper — Frequency control rule changes*, 17 December 2020, p.v.

1. Maintain the existing Mandatory PFR arrangement with improved PFR pricing.
2. Preferred option — Revise the Mandatory PFR arrangement by widening the frequency response band and develop new FCAS arrangements for the provision of PFR during normal operation (Primary regulating services).
3. Remove the Mandatory PFR arrangement and replace it with alternative market arrangements to procure PFR during normal operation.

Subject to the receipt of technical advice that will be informed by the monitoring of the roll-out for the Mandatory PFR arrangements, the initial position is that pathway two is likely to provide a balance between providing operational certainty and system resilience while incorporating new market arrangements that are likely to promote efficient investment in, and efficient operation and use of, electricity services for the long term interests of electricity consumers. The arrangements under pathway two incorporate elements of both mandatory and market-based procurement, albeit for different types of PFR. While further detailed policy development is required, this hybrid approach would provide AEMO with additional operational tools and is likely to provide greater flexibility to future power system developments.

A draft determination on primary frequency response is due by 16 September 2021.

3 DRAFT RULE DETERMINATION

3.1 The Commission's draft rule determination

The Commission's draft rule determination is to make a draft rule that is consistent with the solution proposed by Infigen Energy in its rule change request (which did not include a proposed rule). The differences between the draft rule and the proposed solution are limited to the naming of the new market ancillary services and the inclusion of transitional arrangements.

The draft rule is attached to and published with this draft rule determination. The draft rule:

- introduces two new market ancillary services into the NER for:
  - the *very fast* raise service
  - the *very fast* lower service

  which are to operate more rapidly than the existing *fast* raise and *fast* lower services in response to the locally sensed frequency of the power system in order to arrest a rise and fall in frequency respectively;
- provides for recovery of the costs of procuring the *very fast* raise service and *very fast* lower service in a manner consistent with the existing contingency raise and lower services, as set out in clause 3.15.6A(f) and 3.15.6A(g) of the NER respectively
- requires AEMO to revise the Market Ancillary Services Specification (MASS) within 18 months of the date that the rule is made, to specify the detailed description and performance parameters for the *very fast* raise and *very fast* lower services

All other market arrangements for registration, scheduling, dispatch, pricing, and settlement for the new market ancillary services will be similar to those for the existing fast raise and fast lower services.

The draft rule sets out that the FFR market would commence no later than three years from the date that the rule is made in order to allow AEMO to develop a product specification as well as undertake the necessary IT and market design changes in order to meet the product specification.

The Commission's reasons for making this draft determination are set out in Section 3.4.

This chapter outlines:

- the rule making test for changes to the NER
- the assessment framework for considering the rule change request
- a summary of the Commission's reasons for making the draft rule

Further information on the legal requirements for making this draft rule determination is set out in Appendix B.

3.2 Rule making test

3.2.1 Achieving the NEO

Under the NEL, the Commission may only make a rule if it is satisfied that the rule will, or is likely to, contribute to the achievement of the national electricity objective (NEO).[22] This is the decision making framework that the Commission must apply.

The NEO is:[23]

> 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:
>
> (a) price, quality, safety, reliability and security of supply of electricity; and
>
> (b) the reliability, safety and security of the national electricity system.

3.2.2 Rule making in relation to the Northern Territory

The NER, as amended from time to time, apply in the Northern Territory, subject to derogations set out in regulations made under the Northern Territory legislation adopting the NEL.[24] Under those regulations, only certain parts of the NER have been adopted in the Northern Territory.[25]

As the draft rule either relates to parts of the NER that currently do not apply in the Northern Territory, or have no practical application in the Northern Territory, the Commission has not assessed the rule against the additional elements required by the Northern Territory legislation.[26]

3.3 Assessment framework

In making a draft determination with respect to Infigen's rule change request, the Commission has considered the system services objective(as set out below) which provides a means of applying the National Electricity Objective (NEO) to system services trade-off decisions.

This assessment framework is based on the framework set out in the System services rule changes - Consultation paper, published on 2 July 2020, incorporating stakeholder feedback made to that process.[27]

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22 Section 88 of the NEL.

23 Section 7 of the NEL.

24 The regulations under the NT Act are the National Electricity (Northern Territory) (National Uniform Legislation) (Modifications)Regulations.

25 The version of the NER that applies in the Northern Territory is available on the AEMC website.

26 From 1 July 2016, the NER, as amended from time to time, apply in the NT, subject to derogations set out in regulations made under the NT legislation adopting the NEL. Under those regulations, only certain parts of the NER have been adopted in the NT. (See the AEMC website for the NER that applies in the NT.) National Electricity(Northern Territory) (National Uniform Legislation) Act2015.

27 Consultation paper available on the project web page: https://www.aemc.gov.au/rule-changes/fast-frequency-response-market-ancillary-service

3.3.1 System services objective

The Commission has developed a 'system services objective' in relation to the assessment of the system services rule change requests against the NEO. It reflects the trade-offs that are expected when considering issues related to the provision of system services.

The system services objective seeks to:

> Establish arrangements to optimise the reliable, secure and safe provision of energy in the NEM, such that it is provided at efficient cost to consumers over the long-term, where 'efficient cost' implies the arrangements must promote:
>
> - efficient short-run operation of,
> - efficient short-run use of,
> - efficient longer-term investment in,
>
> generation facilities, load, storage, networks (i.e. the power system) and other system service capability.

In providing further context for the system services objective:

- **Promoting efficient operation** refers to factors associated with the ability of the service design option to achieve an optimal combination of inputs to produce the demanded level of the service, at least cost i.e. for a given level of output, the value of those resources (inputs) for this output are minimised.
- **Promoting efficient use** refers to factors associated with the ability of a service design option to allocate limited resources to deliver a service, or the right combination of services, according to consumer preferences (or system need). This may include allocating resources between the provision of multiple services, to achieve an efficient mix of overall service provision. It may also require consideration of meeting multiple system needs, including security, reliability, and resilience.
- **Promoting efficient investment** refers to factors associated with the ability of the service design option to continue to achieve allocative and productive efficiencies, overtime. This means developing flexible market and regulatory frameworks, that can adapt to future changes. This involves the following considerations:
  a. It is likely that the technologies that *provide* system services, as well as the technologies that drive the *need* for these services, will change significantly over time.
  b. Technical understanding of these services will also change over time.
  c. The robustness of service design options to climate change mitigation and adaptation risks will also contribute to dynamic efficiency over time.

Achieving dynamically efficient outcomes requires flexible regulatory frameworks. The design of these frameworks should show explicit regard for how best to facilitate investment in the operation and use of system services over time, and how allocative and productive efficient outcomes in the short run can be maintained into the future.

3.3.2 System service design – Planning procuring, pricing and payment

The system services objective is used to assess service design options developed through the '4Ps' service design framework.

The Commission considers the development of new market and regulatory frameworks based on thinking about how system services can be planned for, procured, priced and paid for. Within these categories, there exist a range of options, which are explored in the Figure 3.1 below:

Figure 3.1: Planning, Procuring, Pricing and Paying for system services

Source: AEMC

3.3.3 Principles for assessment

In assessing the rule change request, the Commission has considered whether the proposal set out in the rule change request is likely to support and improve the security of the power system along with impacts on the effectiveness and efficiency of frequency control frameworks.

The Commission has applied the following principles in its assessment of Infigen's rule change request against the NEO:

- **Promoting power system security and reliability:** The operational security of the power system relates to the maintenance of the system within predefined limits for technical parameters such as voltage and frequency. System security - including frequency - underpins the operation of the energy market and the supply of electricity to consumers. Reliability refers to having sufficient capacity to meet consumer needs. It is therefore necessary to have regard to the potential benefits associated with improvements to system security and reliability brought about by the proposed rule change, weighed against the likely costs.
- **Appropriate risk allocation:** The allocation of risks and the accountability for investment and operational decisions should rest with those parties best placed to manage them. The arrangements that relate to frequency should recognise the technical and economic characteristics and capabilities of different types of market participants to engage with the system services planning, procurement, pricing and payment. Where practical, operational and investment risks should be borne by market participants, such as businesses, who are better able to manage them.
- **Technology neutral:** Regulatory arrangements should be designed to take into account the full range of potential market and network solutions. They should not be targeted at a particular technology, or be designed with a particular set of technologies in mind. Technologies are changing rapidly, and, to the extent possible, a change in technology should not require a change in regulatory arrangements.
- **Flexibility:** Regulatory arrangements must be flexible to changing market and external conditions. They must be able to remain effective in achieving security outcomes over the long-term in a changing market environment. Where practical, regulatory or policy changes should not be implemented to address issues that arise at a specific point in time. Further, NEM-wide solutions should not be put in place to address issues that have arisen and are only likely to arise in a specific jurisdiction. Solutions should be flexible enough to accommodate different circumstances in different jurisdictions. They should be effective in facilitating security outcomes where required, while not imposing undue market or compliance costs.
- **Transparent, predictable and simple:** The market and regulatory arrangements for frequency control should promote transparency and be predictable, so that market participants can make informed and efficient investment and operational decisions. Simple frameworks tend to result in more predictable outcomes and are lower cost to implement, administer and participate in.

3.4 Summary of reasons

In assessing whether the proposed rule is likely to meet the NEO, the Commission has balanced the power system needs and related benefits associated with improving system security, resilience and power system frequency control against the cost of delivering those outcomes.

In making its determination, the Commission has taken into account the proponent's views and stakeholder views as well as technical advice provided by AEMO, both through its *Renewable integration study* and its more recent *FFR implementation options* advice. AEMO's analysis and advice helps to describe the emerging problems related to operating the NEM in the absence of arrangements to provide for FFR. Based on the continuation of current market and regulatory arrangements, the Commission understands that the following impacts will occur to the power system's operation:

- system inertia is expected to continue to decline over the period 2020 through 2035 in accordance with projections from AEMO's 2020 *Integrated system plan* (ISP)
- under reduced inertia operation, the frequency nadir following a contingency event that results in a loss of generation is expected to become increasingly deep, increasing the likelihood of under frequency load shedding
- increased quantities of fast (R6) contingency services will be required to maintain the frequency within the containment bands specified in the frequency operating standard

Each of these issues is described in more detail in appendix C.1.

The Commission notes AEMO's advice that the provision of faster responding frequency reserves can mitigate the requirement for increased fast (R6) reserves. As noted by AEMO in its advice:[28]

> Under low inertia conditions, larger volumes of Fast Raise (R6), as well as Fast Lower (L6) will be needed to manage frequency containment for credible events under system intact conditions, recognising that provision of response faster than the R6/L6 requirements will reduce the volumes of R6/L6 required and is likely to provide a more efficient mix of frequency control ancillary services (FCAS)-type products under projected levels of inertia.

The Commission considers that FFR provided through an explicit FFR mechanism would be effective at mitigating the need for increased fast FCAS to manage frequency during low inertia operation, and so in a lower cost way than do nothing and increasing the provision of fast (R6) reserves or other alternative options.

3.4.1 Economic benefits of FFR provision

As noted above, technical analysis by AEMO indicates that the availability of faster acting frequency control services will help manage system frequency more efficiently in the future during periods of low power system inertia. In order to inform the Commission's considerations,analysis was undertaken to determine the scale of the potential increases in the requirement for fast (R6) raise services in the NEM, based on the projected decline in system inertia and the relationship between inertia and the need for fast raise services. The AEMC analysis indicated the scale of the potential increases in requirement for fast raise

28 AEMO, Fast frequency response implementation options - Technical advice on the development of FFR arrangements in the NEM, April 2021, p.10.

services in the NEM under a future where the level of inertia in the power system is decreasing but where there are no new arrangements for provision of FFR.

In the absence of changes to the existing market arrangements, the requirement for R6 services is projected to increase as system inertia declines.[29] AEMO projected that, following implementation of dynamic inertia constraints, the R6 requirement would be expected to rise from the current static level of 655.7MW for a 750MW contingency under low load conditions, to around 1200MW in 2029-30 under the ISP central scenario or by 2024-25 under the ISP step change scenario.[30]

The Commission's analysis showed that in the absence of FFR services the decline in system inertia and doubling of the requirement for fast (R6) services could translate into increased costs for R6 services in the order of $60 million per annum, based on historical revenues for R6 services.[31] More targeted, granular procurement of FFR services would result in lower costs compared to the current status quo arrangements of increasing procurement of R6 over time, or other alternative arrangements.

Further detail on the AEMC analysis of the potential economic impacts of inaction with respect to the projected decline in system inertia and the related increase in requirement for R6 is included in appendix C.

The Commission acknowledges that AEMO currently has the capability to manage system security issues that may arise under low inertia operating conditions through the procurement of greater volumes of fast contingency reserves. Therefore, in the medium term, the provision of FFR is not required as an additional system security measure in order to maintain the security of the system. However, the Commission's analysis suggests that the use of R6 as per the existing MASS, is an inefficient tool to manage frequency during lower inertia operation, resulting in higher costs for consumers in terms of managing the system securely. As a result, the analysis suggests that the cost increase related to the increased requirement for R6 services could be reduced through the optimal dispatch of FFR services, and in future through the co-optimisation of inertia, FFR and R6 services.

The Commission understands that there is significant uncertainty in relation to the projected system inertia levels and the potential impact on requirements for fast raise services. This uncertainty relates to the dynamic nature of the technological transition underway in the power system and the potential impact that changes to the regulatory and market arrangements may have on the projected system characteristics. For example, the implementation of new system services for FFR and inertia is likely to shift the projected increased requirements for R6 services.

This analysis provides a good indication that the implementation of arrangements to integrate FFR into the NEM can help to mitigate projected increased requirements for R6

29 As described in appendix A.3, AEMO intends to implement a process from Q3/Q4 2021 to determine contingency FCAS requirements on a dynamic basis to recognise the link between reserve requirements and inertia. Refer to AEMO's Frequency control work plan, 25 September 2020, p.11.

30 AEMO, *Renewable Integration Study* – Stage 1 report - Appendix B: Frequency control, March 2020, p.21-22.

31 This indicative analysis does not account for dynamic market impacts such as increased FCAS prices associated with any increased R6 requirement.

services over the coming five to ten years in a lower cost way for consumers. In particular, the Commission notes that the ISP step change scenario indicates that the potential benefit offered by FFR services will become increasingly material over the next five years, starting from the commencement of the constraints for dynamic FCAS requirements as flagged by AEMO for action in Q3/Q4 2021.[32]

3.4.2 Spot markets for FFR

The Commission considers that it is appropriate for FFR to be procured through spot market arrangements, consistent with the ESB's spectrum for how essential system services should be procured. Spot market based provision of essential system services is preferred, where practicable, given it allows for full co-optimisation between services and energy, resulting in more efficient dispatch and pricing of services, driving innovation in the provision of various combinations of essential system services from different technologies. FCAS markets are currently procured through co-optimised spot markets, and so it follows that a very fast FCAS service is procured through this process as well.

The ESB noted that spot markets should be used for frequency control services given that:[33]

- The volume of frequency control services can be readily defined in MW
- There is good scope for competitive provision of frequency control services, with locational issues limited to regional considerations and generally limited market power concerns
- There is significant international experience for spot market procurement of frequency control services
- Frequency control services can be readily co-optimised with energy and other system services, such as operating reserves.

This approach of using spot markets to procure FFR is supported by the majority of stakeholder submissions to the consultation paper and directions paper.

The market design principles in the NER underpin the existing market and regulatory arrangements in the NEM and also provide a guide to the consideration of changes to the market frameworks, including the development of arrangements for new market ancillary services, such as FFR. The market design principles state that:[34]

> ...market ancillary services should, to the extent that it is efficient, be acquired through competitive market arrangements and as far as practicable determined on a dynamic basis.

Where arrangements can function competitively through a market, they are more likely to support the economic dispatch of power system resources and help to reduce the long-term costs of power system operation in the long term interests of electricity consumers.

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32 AEMO, *Frequency control work plan*, 25 September 2020, p.11.

33 ESB, *Post 2025 Market Design — Consultation Paper*, 7 September 2020, pp.60-63. Available at https://esb-post2025-market-design.aemc.gov.au/32572/1599383248-p2025-market-design-consultation-paper-final.pdf

34 NER Clause 3.1.4(6).

Therefore, these arrangements are preferred where the capability is able to be provided through a market — as it is in this case.

The Commission notes the concerns of large energy users, and consumers more generally, in relation to electricity costs, including the concern that the introduction of new market arrangements for FFR may lead to increases in the price for electricity or the uncertainty associated with electricity bills.[35] However, the Commission does not agree that costs will increase in total — our initial economic analysis as outlined above indicates that the introduction of an FFR service is likely to help mitigate future increases in the costs of frequency control services compared to the status quo or other alternative options, resulting in a secure system provided at lower costs for consumers. While there may be increased costs for the provision of FFR, this will likely lead to more efficient outcomes in the wholesale market more generally and so the ultimate impact on consumer bills may be less. A summary of the Commission's economic analysis in relation to the introduction of FFR services is included in appendix C.

35 Submissions to the Consultation paper – System services rule changes: EUAA, pp.2-3.; Brickworks, pp.4-5.; South Australian Chamber of Mines and Energy, p.1-3.

4 ELEMENTS OF THE DRAFT RULE

The draft rule includes the following key elements:

- the introduction of two **new market ancillary services** for a:
  a. very fast raise service
  b. very fast lower service
- **market arrangements** for registration, scheduling, dispatch, pricing, settlement and cost allocation for the new market ancillary services that are similar and consistent with those for the existing fast raise and fast lower services.
- **implementation and transitional arrangements** for the new market ancillary services including:
  - that AEMO revise the MASS within 18 months of the date that the rule is made, to specify the detailed description and performance parameters for the very fast raise and very fast lower services
  - that the FFR market ancillary service arrangements will commence on a date that is three years from the date that the rule is made.

The following sections set out the Commission's considerations in relation to each of these elements of the draft rule.

4.1 New market ancillary services for FFR

The draft rule would create two new categories of market ancillary services in the NEM. These new categories would support the establishment of market ancillary service arrangements for procurement of contingency FFR, enabling lower cost outcomes in order to manage system security in the NEM. As is the case for the existing market ancillary services, AEMO would be responsible for determining the detailed service descriptions and specifying the relevant performance parameters in its market ancillary service specification.

The new market ancillary services for FFR will operate in a similar way to the existing contingency services, to help AEMO maintain the power system in a secure operating state and manage risks associated with credible contingency events. This is consistent with the problem statement in the rule change request. The Commission recognises that there are other use cases for FFR, including fast regulation and synthetic inertia. Stakeholder responses are welcomed on these alternative applications for FFR to feed into the ESB p2025 work.

The Commission considers this change to the NER would support the efficient dispatch of energy and market ancillary services in the NEM during low inertia operation. AEMO's *Renewable integration study* demonstrated that, in the absence of faster acting contingency reserves, the requirement for the existing fast raise and fast lower services would need to increase to help manage lower levels of system inertia.[36] The Commission's analysis shows that, in the absence of new arrangements for fast frequency response, the requirement for the existing fast raise service could double by 2025 under the ISP step change scenario or by

36 AEMO, Renewable integration study: Stage 1 report, March 2020, p.45.

2030 under the ISP central scenario. This could lead to a significant increase in the costs for fast FCAS under a do nothing approach. The procurement of very fast market ancillary services would help mitigate this impact and deliver lower overall costs for market ancillary services under the projected future operating conditions, promoting the long-term interests of consumers.

4.1.1 Proponent's view

In its rule change request, Infigen proposes the introduction of two new faster responding contingency FCAS markets, FFR raise and FFR lower. Infigen considers that the introduction of these new FFR services would provide AEMO with more appropriate tools to manage system frequency following contingency events during low inertia operation.

Under the Infigen's proposal, FFR providers would respond automatically to any local frequency deviations that occur, and would need to provide their full response within two seconds. As is currently the case for the existing market ancillary services, AEMO would determine the detailed service specifications for the FFR services in the MASS.

4.1.2 Stakeholder views to the consultation paper

In stakeholder submissions to the consultation paper in July 2020, most stakeholders expressed support for the development of market arrangements to support the provision of FFR in the NEM.[37]

Brickworks however, did not support the creation of new arrangements for FFR, on the basis that they opposed any measures that would increase the costs or price uncertainty for electricity consumers. Brickworks proposed that the issue of reducing system inertia be addressed through more stringent regulatory obligation on connecting generators, for example that non-synchronous plant be required to provide the level of synchronous inertia required to stabilise the power system.[38]

4.1.3 Overview of the policy options from the directions paper

In the directions paper, the Commission expressed its initial views on the procurement arrangements for FFR services. This included:

- that the development of spot market arrangements for FFR are preferred
- two potential options to incorporate spot market arrangements for FFR into the NEM:
  - Option 1 – new market ancillary services for FFR (eight contingency services in total)
  - Option 2 – reconfiguration of the existing FCAS arrangements to include FFR (six contingency services in total)

Stakeholder views were sought on these matters.

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37 Submissions to the Consultation paper – System services rule changes: Ausgrid, p.4.; ARENA, p.1.; AEMO, p.18.; CEC, p.2.;CleanCo, p. 3.; Enel X, p.3.; ENGIE, p.2.; ERM Power, p.7.; Infigen, pp.2, 19.; Maoneng, p.2.; Snow Hydro, p.7.; TasNetworks,p.4.; Tesla, p.4.; Tilt Renewables, p.2.

38 Brickworks, Submission to the Consultation paper – System services rule changes, 13 August 2020, pp.4-5.

The preference for the development of spot market arrangements for FFR

The directions paper set out the Commission's preliminary view that it is appropriate for FFR to be procured through spot market arrangements. Procurement of FFR would use the existing market ancillary service arrangements for contingency FCAS. This approach builds on and is consistent with the framework developed for procurement of essential system services as set out in the essential system services market design initiative in the ESB's 2025 work.[39] As noted above, this approach was also supported by the majority of stakeholder submissions to the consultation paper.

Where arrangements can function competitively through a market, they are more likely to support the economic dispatch of power system resources and help to reduce the long-term costs of power system operation in the long term interests of electricity consumers. Therefore, these arrangements are preferred where the capability is able to be provided through competitive market arrangements — as it is in this case.

FFR market ancillary service options

In line with the development of spot market arrangements for FFR, the directions paper set out two potential options for how FFR markets could be implemented. The characteristics of these two options are described below.

Option 1 — new market ancillary services for FFR

This option would involve the development of additional market ancillary service categories for FFR raise and FFR lower services. The key characteristics of this approach would be:

- The two new FFR services would operate with the existing six contingency FCAS markets which would facilitate the co-optimised dispatch with energy, contingency and regulation services. There would be ten market ancillary services in total, including eight contingency services and two regulation services.
- The service descriptions in the NER for the existing contingency services would not change and the related service specifications in the MASS would not require significant consequential changes. Similarly, the market and settlement arrangements for the existing contingency services would require minimal revision. It is also likely that participant registration for the provision of the existing market ancillary services would be minimally affected.
- Increased transparency would be expected in relation to reporting of market dispatch outcomes including service prices and quantities due to the increased number of service categories.

Option 2 — FFR through the existing market ancillary service arrangements

An alternative to the creation of new market ancillary service arrangements for FFR would be the procurement of FFR through the existing FCAS arrangements. It is conceivable that the specification for the existing fast raise and fast lower services could be revised by AEMO to include the provision of FFR. Such an approach would not require the creation of additional

39 ESB, Post 2025 Market Design — Consultation Paper, 7 September 2020, pp.60-63.

market ancillary service classifications under the NER, although supporting changes to the rules may be required to give effect to the desired policy outcome and provide for any transitional arrangements if required. The key characteristics of this option would be:

- There would be no additional market ancillary service classifications required under the NER. The number of market ancillary services would remain at eight (six contingency services and two regulation services).
- AEMO would need to revise the definition for the fast raise and fast lower services in the MASS to accommodate automatic active power response within timescales under 2 seconds for full-service delivery, consistent with the general definition of contingency FFR.
- One way this could be achieved is through re-specification of the fast services to incorporate FFR along with the existing six-second response. This approach could be supported by differential pricing using performance multipliers, to reward faster response based on the value that it provided the system. The implementation of differential pricing may require supporting changes to the NER.
- Any re-specification of the existing fast services would likely drive the need for consequential changes to the specifications for the other contingency services. This is particularly the case for the slow (60 second) services, noting the need for careful specification design to provide a smooth handover between the fast and slow services to deliver a consistent active power response following a contingency event.
- Changes to the existing service specifications would likely lead to changes in registration eligibility for some market ancillary service providers.

4.1.4 Stakeholder views to the directions paper

In response to the directions paper, most stakeholders agreed with the AEMC's problem statement of a "missing market" for a faster responding contingency services.[40]

The following key themes were raised by stakeholders in submissions to the directions paper with respect to market arrangements:

- the priority for new market arrangements
- re-tasking existing market arrangements or creating new market arrangements

New FFR arrangements as a priority

There was large support from stakeholders[41] who agreed with the development of spot market arrangements for the procurement of FFR with ERM noting:[42]

> We consider that it is an opportune time to design and implement the market before the need for such a service becomes urgent. Making these decisions now will provide

40 Submissions to the Directions paper – *Frequency control rule changes*, AEC, p2.; Neoen, p.2.; Infigen, p.2.; the University of Queensland, p.2.; UNSW CEEM, p.7.; Tilt Renewables, p.1.; Alinta, p.2.; Enel Green Power, p.1.; ENGIE, p.3.; EnelX, p.2.; Snowy Hydro, p.6.; CEC, p.1.; Tesla, p.6.; AGL, p.3.; Hydro Tas, p.1.; Delta Energy, p.3.; Ausgrid, p.2.; SA Department of Energy and Mining, p.2.; Origin, p.3.

41 Submissions to the Directions paper – *Frequency control rule changes*, AEC, p.2.; Neoen, p.2.; Infigen, p.2.; the University of Queensland, p.2.; UNSW CEEM, p.7.; Tilt Renewables, p.1.; Alinta, p.2.; Enel Green Power, p.1.; ENGIE, p.3.; EnelX, p.2.; Snowy Hydro, p.6.; CEC, p.2.; Tesla, p.6.; AGL, p3.; Hydro Tas, p.3.

42 ERM Power, submissions to the Directions paper – *Frequency control rule changes*, 9 February 2021, p.2.

> participants with time to adapt their own systems and adjust strategies to participate.

In contrast, EnergyAustralia expressed reluctance for a FFR market highlighting the costs and benefits should be further analysed to compare against other possible reform options. They also noted that a key driver behind the FFR rule change are levels of inertia and any reform which mitigates the expected reduction in inertia would undermine an FFR market.[43]

Ausgrid also noted it was important that the AEMC consider non-market solutions in establishing an efficient FFR service. Ausgrid raised concerns that a market approach may leave network assets underutilised, while non-market solutions with appropriate regulatory oversight could mitigate any distortion to NEM markets.[44]

Re-tasking existing services vs new services

Comments from stakeholders centred on three main issues when evaluating between a new service or re-tasking the existing services:

- FFR services being specified as new services
- Impacts on registration for FCAS services under re-tasking of the current services
- Support for re-tasking of the existing services

Most stakeholders supported the development of new FCAS products for FFR. Stakeholders preferred this approach as it would have the least impact on the specification of the existing services and by extension the registration outcomes for FCAS providers. [45] The AEC noted:[46]

> creating two additional FCAS categories is preferred as it does not require respecification of existing categories and thereby complicating them and potentially excluding some existing providers.

ERM Power noted that re-tasking existing FCAS markets for deliver FFR would adversely impact current FCAS providers. Most participants would have to re-register in line with the new specifications. With FFR having drastically different characteristics to the current fast services, FCAS providers may have to register for reduced capacity.[47]

The SA Department of Energy and Mining expressed a preference for re-tasking the existing FCAS products to provide FFR as they considered that it was not clear that new markets for FFR were justified, given the option of re-tasking the existing services. SA Department of Energy and Mining did however highlight that AEMO will be providing critical technical advice which will inform this view.[48]

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43 EnergyAustralia, submission to the Directions paper – *Frequency control rule changes*, 4 February 2021, p.3.

44 Ausgrid, submission to the Directions paper – *Frequency control rule changes*, 4 February 2021, p.1.

45 Submissions to the Directions paper – *Frequency control rule changes*, AEC, p.2.; Neoen, p.2.; Infigen, p.2.; the University of Queensland, p.2.; UNSW CEEM, p.7.; Tilt Renewables, p.1.; Alinta, p.2.; Enel Green Power, p.1.; ENGIE, p.3.; EnelX, p.2.; Snowy Hydro, p.6.; CEC, p.2.; Tesla, p6.; AGL, p.3.

46 AEC, submission to the Directions paper – *Frequency control rule changes*, 4 February 2021, p2.

47 ERM Power, submission to the Directions paper – *Frequency control rule changes*, 9 February 2021, p.2.

48 SA Department of Energy and Mining, submission to the Directions paper – *Frequency control rule changes*, 4 February 2021, p.1.

While Origin noted that in the long term FFR is likely to become more important, there did not appear to be an immediate need to implement a new service. Revising the existing services would offer the least impact and would provide a first step forward.[49]

4.1.5 AEMO's advice — Market implementation options

Following the directions paper, AEMO has provided technical advice and input to the Commission, which has been incorporated into this determination. AEMO's *FFR implementation options* advice includes an analysis and assessment of a range of market implementation options for FFR, based on the high level policy options outlined by the AEMC in its directions paper. AEMO assessed each of the policy options with respect to system security, operability, implementation, transparency and efficiency criteria. AEMO's advice provides an assessment of the following policy options: [50]

- Baseline: no change to the NER or MASS. Contingency risk during low inertia operation managed through the inertia dependent constraints to determine R6/L6 volumes.
- Option 1: Introducing new market ancillary services to procure FFR FCAS
- Option 2: Reconfiguration of the existing FCAS arrangements to procure FFR
- Option 3: The use of differential pricing enabled through the application of scaling factors that reflect varying levels of performance from individual providers.

AEMO's assessment is that each of the options would be able to support the secure operation of the power system, although it does note that the baseline option may expose the power system to risk of capacity shortfalls for R6 services under very low inertia conditions.[51] AEMO concludes that:[52]

> **FFR services should be developed for managing frequency containment under system intact conditions -** In the longer term, inertia dependent R6/L6 will be an indirect and inefficient way to ensure the required speed of frequency response under lower inertia conditions. Introduction of an FCAS-like FFR service would allow the existing speed capability within current FCAS providers to be recognised, and allow new providers to assist in reducing R6/L6 volume requirements.

AEMO notes that the introduction of speed factor parameterisation, or differential pricing (option 3), is not recommended at this time. This approach to implementation of FFR would require significant development for application in the NEM resulting in an increase in the complexity of the market ancillary service arrangements and a longer time frame for implementation. This approach is also expected to provide less transparency around market outcomes compared with the other options.[53]

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49 Origin, submission to the Directions paper – *Frequency control rule changes*, 5 February 2021, p.3.

50 AEMO, Fast frequency response implementation options - Technical advice on the development of FFR arrangements in the NEM, April 2021, p.41.

51 Ibid., p.44.

52 Ibid., p.41.

53 Ibid., p.42, 59.

AEMO's advice is that the baseline option (no change) and option 3 (differential pricing) are not recommended approaches for the future frequency control frameworks in the NEM. AEMO considers that both option 1 and option 2 are viable frequency control reforms. A summary of AEMO's assessment of the FFR implementation options is included in Figure 4.1 and its advice in relation to these options is discussed further below.

Figure 4.1: Summary table — AEMO assessment of FFR implementation options

	System security and operability	Efficiency	Simplicity and transparency	Implementation
Baseline: Inertia dependent R6 FCAS (without an FFR service)	✓ Maintain system security of the short and medium term. ✗ Very low inertia levels could result in R6 shortfalls.	✗ Inefficient reserve volume: expected to require much greater amounts of R6. ✗ Scheduling efficiency should risk size co-optimisation be introduced.	✓ Maintains the existing contingency FCAS markets.	✓ Inertia dependant FCAS for islanding already implimented. ✓ Could extend practice for to usual system condition.
Option 1: New market ancillary services to procure FFR FCAS	✓ Can maintain system security, provided the technical requirements for the provision of FFR are managed. ✓ Can be scheduled by FCAS constraints.	✓ Recognises the speed of response. ✓ Recognises and rewards existing FFR capacity within FCAS market.	✓ Extension to the existing FCAS markets, better understood.	✗ Requires new FCAS markets. ✗ New constraints required. ✗ Possible changes to MASS for existing services. ✗ Cost more than baseline option.
Option 2: Reconfiguration of the existing FCAS arrangements to procure FFR	✓ Can maintain system security, provided the technical requirements for the provision of FFR are managed. ✓ Can be scheduled by FCAS constraints.	✓ Recognises the speed of response. ✓ Recognises FFR capacity within existing services. ✗ Some provision from 6 and 60 sec providers will be affected.	✓ Minimises the number of existing services.	✓ Minimises changes to FCAS market systems. ✗ Changes to registration of 6 and 60 sec service required.
Option 3: Differential FCAS pricing based on scaling factors for faster response	✓ Able to maintain system security. ✗ *Security:* may need additional limits or requirement on FFR providers. ✗ *Operability:* scheduling is more complex. May result in less flexibility in the future.	✓ More granular differentiation in response speed.	✓ Allows for fewer contingency services. ✗ Market outcomes less transparent. ✗ Signals for the required speed may be less clear.	✗ Complex implementation requiring development of new systems. ✗ More costly than Option 1 and 2.

Source: AEMC summary based on AEMO's advice:*Fast frequency response implementation options* — Technical advice on the development of FFR arrangements in the NEM, April 2021, pp.41-60.

Comparison between option 1 and option 2

AEMO's advice includes a range of illustrative sketches that indicate the potential approaches to the incorporation of FFR services as part of the suite of market ancillary services under option 1 and option 2.[54] These include:[55]

- Option 1 — new FFR services in addition to the existing contingency services. Figure 4.2 provides an illustration of this conceptual suite of contingency raise services.
- Option 2 — introduce FFR by re-specifying the existing contingency services, including:
  a. Consolidating FFR within the Fast (R6/L6) services, slow and delayed services remain unchanged.
  b. Re-specify the fast services to be FFR, combining the R6/L6 with the R60/L60 under the slow service categories and delayed service remains unchanged.
  c. Re-specify the fast services to be FFR, slow service remains unchanged and R60/L60 is combined with R5/L5 as the delayed service

AEMO advises that the consolidation of FFR and R6/L6 (option 2a) and the consolidation of R60/L60 and R5/L5 (option 2c) are not recommended as in each case the service characteristics are not compatible. AEMO notes that:[56]

- Option 2a would exclude or restrict the utilisation of plant that can provide a 6-second type response but are not capable of providing a 1-second, FFR type response. Such response is expected to be valuable when there is a higher level of system inertia.
- Option 2c is not advised as the R5/L5 services play a different role by acting to restore system frequency to 50Hz within 5 minutes of a frequency disturbance. This function is typically provided by different plant such as manual load reduction and fast start hydro and gas turbines. AEMO also note that the dispatch of the delayed service is currently co-optimised with the regulating service, while there are operational similarities between the delayed service and the regulating service, this is not the case for the slow (R60/L60) service which provides an automatic active power response to stabilise system frequency following a disturbance.

Option 1 and option 2b are the preferred examples for how FFR could be incorporated through the development of new market ancillary services or through re-specification of the existing services. Figure 4.2 shows AEMO's conceptual illustration of the contingency raise services including the addition of a new FFR raise service with full service delivery at one second. Figure 4.2 shows AEMO's conceptual illustration of the preferred approach to the reconfiguration of the existing market ancillary services to include FFR as a discrete service and consolidate the R6/L6 with the R60/L60 services under the "slow" service category.

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54 These specifications are included as concepts for illustrative purposes only, they do not relate to the draft rule. Under the NER and the draft rule, AEMO is responsible for determining the detailed service descriptions and specifying the relevant performance parameters in its Market ancillary service specification.

55 AEMO, *Fast frequency responseimplementation options* - Technical advice on the development of FFR arrangements in the NEM , April 2021, p.45, 47.

56 Ibid.

Figure 4.2: Option 1: Contingency raise services with new FFR raise service

Source: AEMO, Fast frequency response implementation options — Technical advice on the development of FFR arrangements in the NEM, April 2021, p.45.

Note: The service specifications are intended to be illustrative of the policy concept. The detailed service specifications for the market ancillary services are determined by AEMO through consultation on the *Market ancillary service specification*.

Figure 4.3: Option 2b: Reconfiguration of the contingency raise services to include FFR — consolidation of R6/L6 and R60/L60

Source: AEMO, Fast frequency response implementation options — Technical advice on the development of FFR arrangements in the NEM, April 2021, p.49.

Note: The service specifications are intended to be illustrative of the policy concept. The detailed service specifications for the market ancillary services are determined by AEMO through consultation on the *Market ancillary service specification*.

AEMO's analysis

In relation to the comparison between option 1(new servcies) and option 2b(reconfiguartion of existing services), AEMO considers that option 2b is preferable from a market implementation perspective. AEMO identifies the following benefits associated with this option:[57]

- it would minimise changes to AEMO market and settlement systems
- it provides a simpler set of market ancillary services which would reduce administrative costs for AEMO and market participants

At the same time, AEMO noted that there would be material impacts on the registration of FCAS providers under option 2b. This impact is driven by the need for revision of the service specifications for the fast and slow contingency services which would require service providers to re-register their plant capacity under the revised specifications. AEMO notes that there are also likely to be registration impacts under option 1(Figure 4.2), although to a lesser degree and with a lower impact.[58]

AEMO's advice includes further analysis in relation to the potential impacts on the registration outcomes for providers of the fast raise (R6) and slow raise (R60) services that may be combined as shown under option 2b(Figure 4.3). AEMO's analysis of FCAS registration and enablement indicates that there is not a high level of use of the R6 service to value responses that are not sustained. The use of R60 from providers that are not registered in R6, and the use of R6 from providers that are not registered in R60, is also small.[59]

4.1.6 The Commission's draft analysis and conclusions

In the directions paper, the Commission provided analysis to support its view that in the absence of changes to the existing market arrangements to support the integration of FFR, the projected decline in system inertia may lead to a doubling in the requirement for fast raise services by 2025 under the ISP step change scenario or by 2030 under the ISP central scenario. This could lead to a significant increase in the costs for fast FCAS, which could be partially mitigated by the procurement of faster responding services, such as FFR. Further detail on the technical and economic analysis that supports this view is included for reference in appendix C.

The Commission considers that it is appropriate for FFR to be procured through spot market arrangements. This approach is consistent with the ESB's long-term strategic direction for the NEM as set out in its post 2025 work. It is also supported by the majority of stakeholder submissions to the consultation paper and directions paper. Spot market arrangements for FFR are also consistent with the existing market ancillary service arrangements for the other contingency FCAS.

57 Ibid., p.60.

58 Ibid.

59 Further information on AEMO's analysis in relation to the registration impacts associated with consolidation of the R6 and R60 services is available in section 6.8.8 and Appendix A.2 of AEMO's advice, *Fast frequency response implementation options*.

The market design principles in the NER underpin the existing market and regulatory arrangements in the NEM and provide a guide to the consideration of changes to the market frameworks, including the development of arrangements for new market ancillary services, such as FFR. The market design principles state that:[60]

> ...market ancillary services should, to the extent that it is efficient, be acquired through competitive market arrangements and as far as practicable determined on a dynamic basis.

Where arrangements can function competitively through a market, they are more likely to support the economic dispatch of power system resources and help to reduce the long-term costs of power system operation in the long term interests of electricity consumers.

Options assessment

The Commission has considered two options for integration of FFR, as outlined in the directions paper, set out in AEMO's technical advice, and described in Section 4.1.3. The Commission considers that the creation of new market ancillary service categories for contingency FFR is superior to the alternative of incorporating FFR by reconfiguring the existing market ancillary service specifications. The reasons for this are:

- AEMO's advice is that
  - both of the high level policy options set out in the directions paper are able to satisfy the technical requirements for secure power system operation.
  - FFR services should be specified separately to the existing fast (6 seconds) raise and lower services as the need for FFR is dynamically related to inertia levels, whereas the need for 6 second response need not be. Following full implementation of the spot market arrangements for FFR, the requirement for FFR services is expected to vary over time due to variation in system inertia levels. The specification of FFR services separately to the other market ancillary services will allow for FFR volumes to vary with respect to inertia and for this variable requirement to be independent of the requirement for the other market ancillary services.
- The integration of FFR through reconfiguring the existing market ancillary service specifications is expected to have material impacts on registration outcomes for FCAS capable plant. In particular the proposal to consolidate the R6/L6 and R60/L60 services is expected to result in a reduction of registered capacity for plant capable of delivering this type of active power response.
  - Feedback from stakeholders at the technical working group meeting on 4 March 2021 indicated that the consolidation of the existing R6/L6 and R60/L60 services as slow raise and lower (under policy option 2) would result in a reduction of registered FCAS capacity for the consolidated service as compared to the separate services.

60 NER Clause 3.1.4(6).

- This is consistent with AEMC analysis of current FCAS registrations which indicates that there would be a reduction in available capacity as a result of the consolidation of the R6/L6 and R60/L60 services.

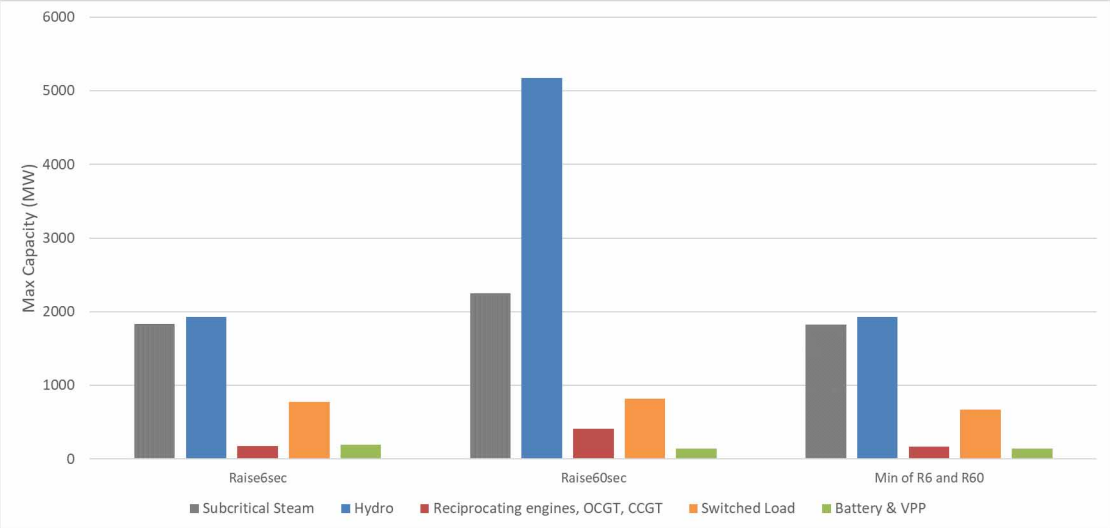
- There is relatively broad support from stakeholders for the integration of FFR services through the introduction of new market ancillary service arrangements. Such an arrangement promotes clear signals for stakeholders about what services are required in order to promote innovation and investments in equipment that can provide this service.

Impacts on registration of FCAS capable plant

The Commission notes AEMO's view that the reconfiguration of the existing service categories is preferred over the creation of new categories of market ancillary services. However, the Commission considers that the consolidation of existing contingency services may result in a reduction of registered capacity for FCAS capable plant. Consultation with stakeholders and analysis by the AEMC indicates that the reduction in registered capacity for FCAS capable plant may represent a significant reduction in market capacity for the affected market ancillary services. This reduction in market capacity may lead to reduced competition and a reduction in market efficiency resulting in a risk of higher prices for FCAS.

Figure 4.4 shows the potential minimum quantity of existing registered capacity under the R6 and R60 services that would be likely to qualify for a combined R6 and R60 FCAS product. A comparison between this value and the existing registered volumes for R6 and R60 services shows the potential registration impacts associated with combining the R6 and R60 services.

Figure 4.4: Registered volumes for R6, R60 and combined service



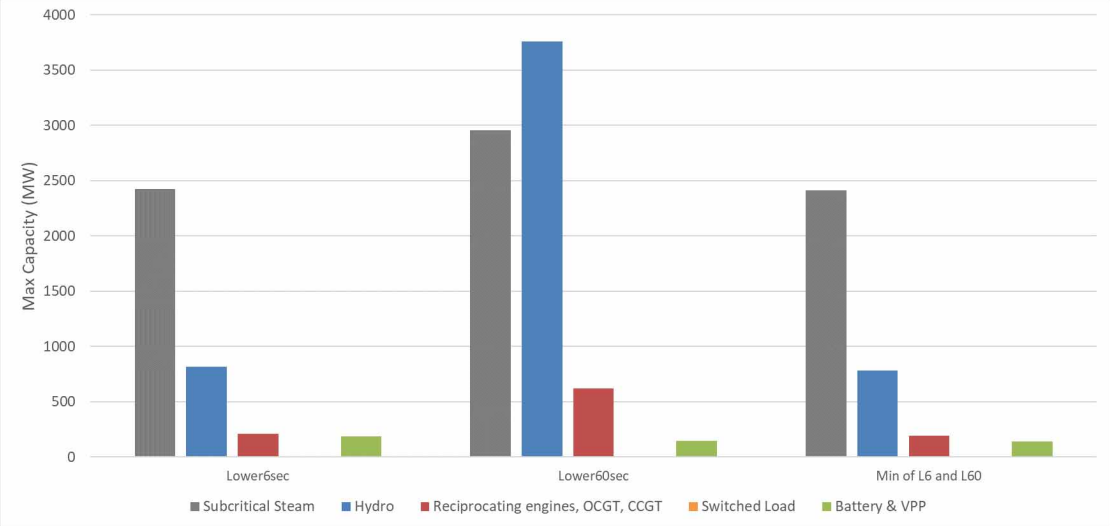
Source: AEMC analysis of AEMO market registration data

Note: Min of R6 and R60 represents the worst case registered volume for a combined R6/R60 service. Actual registration impacts may not be as severe.

Figure 4.5 shows the potential minimum quantity of existing registered capacity under the L6 and L60 services that would be likely to qualify for a combined L6 and L60 FCAS product. A

comparison between this value and the existing registered volumes for L6 and L60 services shows the potential registration impacts associated with combining the L6 and L60 services.

Figure 4.5: Registered volumes for L6, L60 and combined service



Source: AEMC analysis of AEMO market registration data

Note: Min of L6 and L60 represents the worst case registered volume for a combined L6/L60 service. Actual registration impacts may not be as severe.

Naming the new market ancillary services

Clause 3.11.2(a) of the draft rule includes the two new market ancillary service categories for

(9) the *very fast raise service*; and

(10) the *very fast lower service*.

The Commission considers that the names for the new market ancillary services in the draft rule achieve the following:

- they differentiate the new FFR services and indicate that the new services are faster (very fast) as compared to the existing fast raise service and fast lower service
- they avoid the need to revise the names for the existing market ancillary services.

The Commission expects that this approach will have a reduced impact on the market systems for both AEMO and market participants compared to a naming convention for FFR that would require re-naming of some or all of the existing contingency services (fast, slow & delayed).

The Commission has identified an alternative naming convention for the new FFR services based on the use of the term "fast frequency response". However, the alternative would require a renaming of the existing fast services in order to avoid confusion. The naming

approach used in the draft rule and the proposed alternative naming approach are set out below in Table 4.1.

Table 4.1: Contingency service names

CONTINGENCY SERVICE FUNCTION	SERVICE NAMES UNDER THE DRAFT RULE	ALTERNATIVE SERVICE NAMES
Fast frequency response	*very fast raise service* and *very fast lower service*	*fast frequency response raise service* and *fast frequency response lower service* *or* *fast frequency arresting raise service* and *fast frequency arresting lower service*
Frequency arresting services	*fast raise service* and *fast lower service*	*frequency arresting raise service* and *frequency arresting lower service*
Frequency stabilisation services	*slow raise service* and *slow lower service*	*frequency stabilising raise service* and *frequency stabilising lower service*
Frequency recovery services	*delayed raise service* and *delayed lower service*	*frequency recovery raise service* and *frequency recovery lower service*

Source: AEMC
Source: Alternative service names included to prompt stakeholder feedback

The Commission is interested in stakeholder feedback on the service names set out in the draft rule as well as the potential alternative naming convention for the contingency services as set out in Table 4.1.

The draft rule includes the following chapter 10 definitions for the new market ancillary services:

very fast lower service

The service of providing, in accordance with the requirements of the *market ancillary service specification*, the capability of very rapidly (more rapidly than the *fast lower service*) controlling the level of *generation* or *load* associated with a particular *facility* in response to the locally sensed *frequency* of the *power system* in order to arrest a rise in that *frequency*.

very fast raise service

The service of providing, in accordance with the requirements of the *market ancillary service specification*, the capability of very rapidly (more rapidly than the *fast lower service*) controlling the level of *generation* or *load* associated with a particular *facility* in response to the locally sensed *frequency* of the *power system* in order to arrest a fall in that *frequency*.

4.2 Market ancillary service arrangements

This section describes the Commission's consideration of the market ancillary service arrangements for the very fast raise and very fast lower services, including the processes for:

- registration of FFR capable plant to participant in the new FFR ancillary service markets
- scheduling & dispatch which involves the determination of the required quantity of FFR ancillary services to meet system needs and the enablement of individual service providers through the competitive dispatch process
- pricing & settlement to determine the market price paid for FFR market ancillary services
- allocation of costs associated with the provision of FFR market ancillary services

The Commission notes that some aspects of the market ancillary services framework are the subject of another rule change that is currently underway. The *Integrating energy storage system into the NEM* rule change is investigating potential changes to the NER related to the participation framework and the arrangements for recovery of non-energy costs. This includes aspects of the NER that relate to the registration of plant to provide market ancillary services and the arrangements for the allocation of non-energy costs, including costs associated with the provision of market ancillary services. The Commission plans to publish a draft determination for the *Integrating energy storage system into the NEM* rule change on 29 April 2021. Refer to the project page on our website for more information.

Stakeholder responses to the consultation paper

Several stakeholders, in response to the Consultation paper, who supported market arrangements for the provision of FFR also supported an FFR market based on the current contingency FCAS markets.[61]

A number of stakeholders also noted that a market ancillary service arrangement for FFR should also include valuation of inertial response, at least as an interim measure in advance of the development of specific arrangements for the valuation of inertia above minimum requirements. [62]

4.2.1 Registration

Proponent's view

In its rule change request, Infigen proposed the introduction of two new faster responding contingency FCAS markets, FFR raise and FFR lower. Infigen's proposal is based on the understanding that the market arrangements for the new services would be based on the arrangements for the existing market ancillary services (i.e. FCAS), with the key difference being the specification for the new FFR services to provide faster response.[63]

61 Submissions to the Consultation paper — System services rule changes; CS Energy, p.8.; ERM Power, p.7.; EnelX, p.4.;

62 Submissions to the Consultation paper – System services rule changes: AEC, pp.2-3.; Stanwell, p.8.; CleanCo, p.3.; Hydro Tasmania, p.4.; OMPS Hydro, p.2.

63 Infigen Energy, Fast frequency response market ancillary service - electricity rule change proposal, 19 March 2020, p. 4. This view is clarified in its submission to the directions paper: Infigen Energy, submission to the directions paper - frequency control rule changes, 7 February 2021, p.3.

Overview of the directions paper

The directions paper set out that registration as a service provider for FFR services would be coordinated by AEMO in a similar manner to the existing process for registration of other FCAS capable plant. This includes the registration of capable plant as either an ancillary services generating unit or ancillary services load. The process for registration of an ancillary services generating unit is currently set out in NER clause 2.2.6. The process for registration of ancillary services load is set out in NER clause 2.3.5.

Stakeholder views to the directions paper

In its submission to the directions paper, Infigen suggested that the existing market ancillary service registration arrangements may require revision to allow for full participation of FFR capable plant in the new FFR markets. Infigen noted that the existing registration arrangements under AEMO's MASS, including the standard frequency ramp, restrict the participation of FFR capable plant such as batteries. Infigen considered that the development of a uniform set of performance parameters for FFR services will be necessary to maximise participation to deliver efficient outcomes through the FFR markets. More specifically, Infigen proposed an alternative method for determining the available capacity of FFR capable plant where:[64]

> FFR provision could be measured as the MW response at 0.5-2 seconds of frequency step-changing from 50Hz to 50.5 Hz, for example.

Tesla also commented that the upcoming MASS review should address and include clear guidance on how droop limitations and MW response are set. Tesla noted this is an ongoing area of opaqueness for participants who operate batteries specifically, with AEMO's MASS verification process effectively derating the full capacity of storage through the contingency FCAS registration. This creates capacity trade-offs for batteries between FCAS services, with undervaluation of speed and accuracy of response.[65]

AEMO's advice

Registration process

AEMO noted in its advice that the integration and use of FFR in the power system could present challenges for power system operation if not managed appropriately.[66] AEMO advised that the application of regional and unit based constraints on the dispatch of FFR may be required to manage the integration and ongoing use of FFR services. Therefore, AEMO proposed that the registration process for FFR capable plant include additional technical studies to provide improved transparency in relation to integration issues and the application of regional and unit based constraints on FFR dispatch. AEMO stated that:

> International studies into the design of wide area monitoring and control systems

64 Infigen Energy, Submission to the directions paper — Frequency control rule changes, 7 February 2021. p.3-4.
65 Tesla, submission to the Directions paper – *Frequency control rule changes*, 4 February 2021, p.6.
66 AEMO, FFR Implementation options, April 2021, p.33-34.

> utilising FAPR [Fast Active Power Response] have found that if delivered in the wrong location it can affect angular separation between regions, increasing the risk of regional separation. It is conceivable that similar challenges could arise in the NEM, if large locational concentrations of FFR were to develop.
>
> [...]
>
> There are other considerations for high locational concentrations of FFR including local voltage management, coordination with UFLS/over-frequency generation shedding (OFGS), and interaction with Special Protection Schemes (SPS).

AEMO considers that FFR proponents may have limited visibility in relation to the impact of security constraints on the dispatch of FFR plant. The identification and effective resolution of operational issues related to FFR may require detailed technical analysis by AEMO and the relevant TNSP in order to configure the network and power system to make the best use of FFR services.[67]

AEMO proposed that integration issues related to FFR capable plant be investigated during the registration process and managed in a similar manner to the process for the registration of generating plant in the NEM. AEMO suggested that:[68]

> processes of a similar nature to (or even connected with) the approval of plant performance standards could be applied to assess integration issues before FCAS market registration. This would give greater certainty to potential providers, and allow AEMO and TNSPs to assess and identify issues in advance.

Under this approach, the approval of a request for registration of FFR capable plant would be contingent on the outcomes of technical studies by AEMO.

Measurement and verification of FFR capacity

AEMO's advice provided an illustrative service specification for an FFR service and notes that the measurement and verification process for determining the capacity of an individual facility is related to its performance with respect to the standard frequency ramp in the MASS. AEMO notes that:[69]

> The frequency profile used to test and value FFR delivery should match the response speed. The current FCAS standard frequency ramp has a 4 second nadir, so is not suited to the valuation of FFR.

AEMO's advice included an illustrative specification for contingency FFR service based on active power response to a linear frequency ramp from 50 Hz at the start of the event to 49.5 Hz at 1.0 seconds from the start of the event. AEMO noted that the specification for FFR services would be developed in consultation with stakeholders and market participants and

67 Ibid.

68 AEMO, Fast frequency response implementation options — Technical advice on the development of FFR arrangements in the NEM, April 2021, p.34.

69 Ibid. p.15.

would include consideration of the appropriate frequency response time based on current and future power system needs.[70]

Commission's draft analysis and determination

Under the draft rule, the arrangements for the registration of plant to provide the new very fast raise service or very fast lower service are the same as the existing arrangements for registration of plant capable of providing the existing market ancillary services.

The following section sets out the Commission's reasoning in relation to:

- the registration process for FCAS capable plant under the NER
- the process for measurement and verification of FCAS capacity

Registration process

Currently, market participants who wish to participate in the FCAS markets must apply to AEMO to have their plant registered as ancillary services generating units or ancillary services loads (ancillary services facilities).[71]

AEMO must approve such an application if it is reasonably satisfied that:

- the generating unit or load is able to be used to provide the market ancillary services referred to in the application in accordance with the market ancillary service specification;[72]
- the market generator, market ancillary service provider or the market customer (as the case may be) has adequate communication and/or telemetry to support the issuing of dispatch instructions and the audit of responses;[73]
- for registration of ancillary service loads only, the market ancillary service provider or the market customer (as the case may be) has an arrangement with the retail customer at the relevant connection point for the supply of market ancillary services.[74]

The Commission notes AEMO's concerns in relation the benefits of it undertaking technical studies to inform the registration process for ancillary services facilities, in a similar manner to the Generator registration process.

In order to register generating plant as a generator to participate in the NEM, the NER require that AEMO be satisfied that the generating system comply with the relevant performance standards established through the generator connection process set out in Clause 5.3.4A of the NER.[75] The generator connection process is run by the local network service provider.[76] As part of this process AEMO may request that an application for connection of a Generator be revised or rejected in relation to an 'AEMO advisory matter' or where the connection is expected to adversely affect power system security.[77]

70 Ibid.
71 NER clause 2.2.6, clause 2.3.5.
72 NER clause 2.2.6., clause 2.3.5
73 NER clause 2.2.6., clause 2.3.5
74 NER clause 2.3.5.
75 NER Clause 2.2.1(c)(3)
76 NER clause 5.3.2

AEMO's proposed changes to the registration process for FFR capable plant would be expected to lengthen the time taken to assess an application for registration of ancillary services facilities. While a more conservative registration process would provide increased certainty in relation to the dispatchability of registered plant, this would come at the cost of reduced flexibility in relation to integration of available plant capacity in the event that network constraints are relaxed over time, due to network upgrades and operational changes.

The Commission considers that the existing generator connection process provides adequate provisions to manage and mitigate system security risks related to new connections. In addition, AEMO can also manage system security impacts related to the dispatch of plant for provision of energy or market ancillary services through the dispatch process. This includes through the application of network constraints on the dispatch of ancillary service facilities for the provision of FFR.[78]

The Commission does not consider it necessary or appropriate for the NER to include additional requirements as part of the process for registration of ancillary service facilities in order to introduce a market for FFR. AEMO already has the ability under the NER to set out in the MASS the performance parameters and requirements which must be satisfied in order for a service to qualify as a market ancillary service.[79] This could include a requirement to undertake technical studies.

In addition, the existing arrangements allow AEMO to undertake technical studies as required to support the security constrained dispatch of the NEM in accordance with AEMO's general power system security responsibilities and the application of network constraints.[80] AEMO may also impose constraints on central dispatch due to the quantity and nature of ancillary services provided or procured by AEMO under the Rules that are required to be managed in conjunction with central dispatch.[81] In addition, for each dispatch interval AEMO must impose constraints upon the dispatch algorithm to determine the quantity of each global market ancillary service requirement and any local market ancillary service requirements.[82]

Transparency around the application of constraints is provided by AEMO through the following process:

- its consultation on, and publication of the network constraint formulation guidelines under clause 3.8.10(c); and
- the requirement on AEMO under cl 3.8.13 to publish the parameters used in the dispatch algorithm for the modelling of certain types of constraints, including ancillary services constraints.[83]

77 NER clauses: 4.14(q), 5.3.4A(a) and 5.3.4A(f).
78 NER clause 3.8.10
79 NER clause 3.11.2(b)
80 NER clause 3.8.10
81 NER clause 3.8.11
82 NER clause 3.8.11(a1)
83 AEMO issue market notices relating to market and operational matters via its website. Refer to https://aemo.com.au/en/market-notices

AEMO proposes that the registration process for FFR capable plant include additional steps such that AEMO may reject an application for registration of FFR capable plant if the plant is capable of having an adverse impact on system security. The draft rule does not include any changes to the existing arrangements for the registration of FCAS capable plant as the Commission considers that the existing arrangements allow AEMO to manage system security risks through constrained dispatch and the application of constraints on generator capacity is consistent with the current arrangements for dispatch in the NEM. The Commission is interested in stakeholder views in relation to the draft determination on whether the existing process for registration of ancillary service facilities provides adequate transparency in relation to potential restrictions on FFR capable plant as a result of the application of constraints through the dispatch process.

Measurement and verification of plant capacity

The Commission notes the concern from Infigen and Tesla in relation to the process for measurement and verification of FCAS capacity and the limitations related to the application of the standard 4-second frequency ramp for the valuation of FFR services.

The Commission considers that AEMO is best placed to determine the detailed service specifications for the market ancillary services, including FFR. As noted in its advice, AEMO recognises the limitations of the standard 4-second frequency ramp and has indicated that this aspect of the service specification would be subject to review as part of the development of the specification for any new FFR services. The Commission note that AEMO is required to consult on changes to the MASS, including the changes required to develop the detailed service specifications for the very fast raise and very fast lower services.

Under the draft rule, the existing registration process for FCAS capable plant would be extended to include registration of plant for provision of the very fast raise service and the very fast lower service.

As is the current practice, AEMO is responsible for determining the detailed specification for the market ancillary services through its determination of the MASS. In amending the MASS, AEMO must consult with stakeholders in accordance with the Rules consultation procedures.[84] In its advice, AEMO indicated the detailed specification for contingency FFR services would include consideration of the appropriate standard frequency response time for measurement and verification purposes.

4.2.2 Scheduling & dispatch

Proponent's view

In its rule change request, Infigen recognised that there is an interaction between the levels of FFR, primary frequency response and inertia to maintain the power system in a secure operating state. Infigen proposed that the volume of FFR service procured should be calculated based on contingency size with the consideration of system inertia.[85]

84 NER Clause 3.11.2 (d)

85 Infigen Energy, Fast frequency response market ancillary service - electricity rule change proposal, 19 March 2020, p.5.

Overview of the directions paper

The directions paper set out that the arrangements for scheduling and dispatch would be based on the existing arrangements, whereby AEMO determines the required amount of each market ancillary service, and optimises the dispatch of energy and ancillary services, in order to maintain the power system within a secure operating state as defined by the technical envelope. The technical envelope means the technical boundary limits of the power system for achieving and maintaining the secure operating state of the power system for a given demand and power system scenario.[86] AEMO must operate central dispatch to maximise the value of spot market trading, which is determined as the value of dispatched load less the value of generation, network services and market ancillary services.[87] The Commission noted that the introduction of explicit markets for FFR services could facilitate co-optimised dispatch of FFR with energy and contingency services.

Stakeholder views to the directions paper

While not asked to provide direct commentary on scheduling and dispatch, stakeholders did make note that co-optimisation between FFR market ancillary services, levels of inertia, and other FCAS markets is an important consideration. Several stakeholders noted that co-optimisation between FFR and system inertia would be expected to deliver more efficient market outcomes, with overall lower cost, when compared to the current interaction between inertia and the fast raise and lower services.[88]

Infigen highlighted it is also important for the size of maximum contingency and protected events to be co-optimised between FFR market ancillary services and the existing contingency services. Ensuring AEMO has an explicit trade-off will be critical in minimising system costs.[89]

AEMO's advice

With respect to scheduling FFR services, AEMO notes that:[90]

> FFR (raise and lower), as the fastest FCAS services, would be best suited to scheduling with dynamic volumes that account for system inertia and the dynamic effect of load relief. If FFR is introduced, slower FCAS services, including R6/L6, can be scheduled with static volumes, accounting for the static effect of load relief. Scheduling static FFR volumes may be appropriate as interim measures for procurement of FFR.

With respect to the arrangements for the optimal dispatch of FFR services, AEMO notes the following:[91]

86 NER clause 4.2.5(a)
87 NER clause 3.8.1(a,b)
88 Submissions to the Directions paper – *Frequency control rule changes*, ERM, p.1.; CS Energy, p. 12.; Tilt, p.1.
89 Infigen, submission to the Directions paper - *Frequency control rule changes*, 7 February 2021, p.3.
90 AEMO, FFR Implementation options, April 2021, p.21.
91 Ibid.

- Extending contingency FCAS co-optimisation with Risk Size to system intact operation should be further investigated [...]
- 5-minute co-optimisation between FFR and inertia is not a high priority component of FFR service development [...]
- 5-minute co-optimisation between FFR and other FCAS services is not a priority component of FFR service development [...].

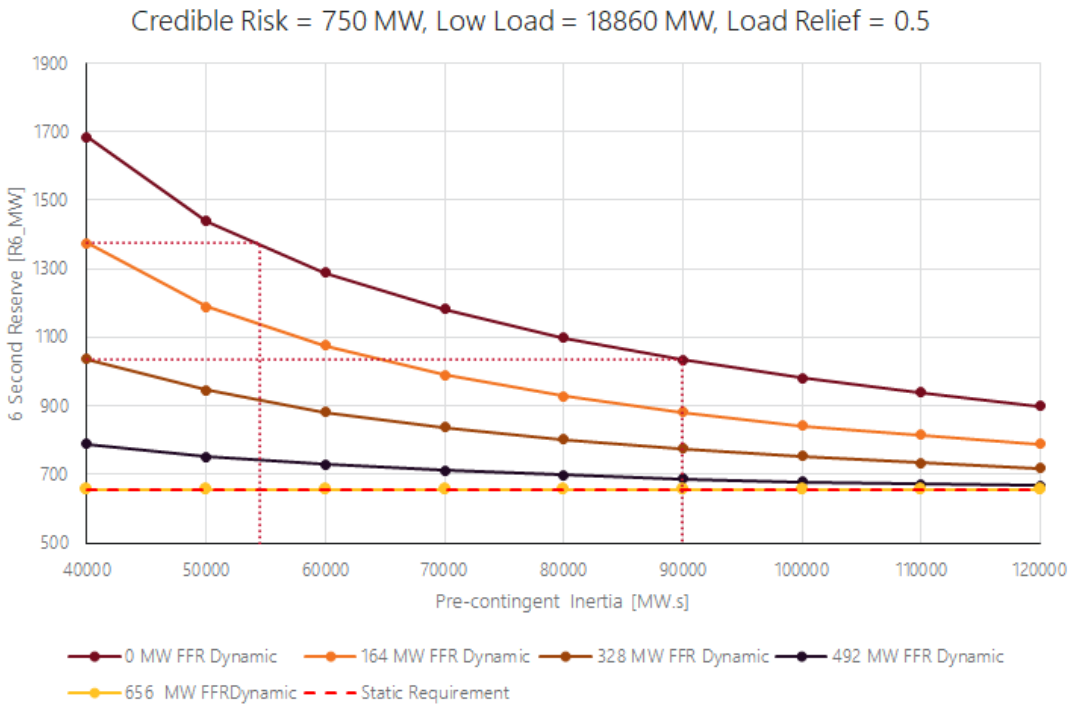
AEMO's advice provides further discussion on each of these points with the key themes being that:

- Co-optimisation of FFR and inertia may be theoretically possible through the future development of arrangements for the procurement of inertia above minimum levels. However, such changes would increase the complexity of the schedule systems and further investigation is recommended to carefully consider if the material efficiencies provided would justify this step.[92]
- Similarly, AEMO notes that the co-optimisation of FFR and the fast (R6/L6) services would require the development of relatively complex system constraints. AEMO proposes that if it were found that increased R6/L6 volumes were more economic than provision of additional FFR, then the service specifications may need to be revised. This view is based on the assumption that the service specification for FFR and R6/L6 would be defined in such a way as to provide continuous active power response while minimising the overlap between the services as much as is practical.[93]
- AEMO notes that the impact of the largest credible risk size on FCAS volume requirements can be significant and that the co-optimisation of risk size based on energy dispatch with FCAS costs is likely to provide greater efficiency improvements than the other co-optimisation options. AEMO notes that co-optimisation of risk size and FCAS requirement is not currently implemented in the NEM during interconnected operation, although it is implemented for operation of islanded regions. AEMO notes that while extending risk size co-optimisation to interconnected operation would have its own implementation challenges, it has the potential to realise substantial efficiency gains.[94]

AEMO's advice includes modelled results, reproduced in Figure 4.6, that describe the relationship between inertia, FFR and R6 under certain system conditions. This modelling shows that FFR is expected to have the greatest impact on system operation under low inertia conditions. For example, when system inertia is 55,000 MW.s the dispatch of 164 MW of FFR is expected to result in a reduction in R6 requirement equivalent to an approximately 14,500 MW.s of additional inertia (equivalent to 6 to 9 large thermal units).[95]

92 Ibid., pp.27-28.
93 Ibid., pp.3.
94 Ibid., pp.30-32.
95 Ibid., pp.27-28.

Figure 4.6: Relative impact of inertia and FFR on R6 requirement



Source: AEMO, Fast frequency response implementation options - Technical advice on the development of FFR arrangements in the NEM, April 2021, p.28.

Interaction with minimum inertia requirements and islanded operation of NEM regions

In its advice AEMO notes that the introduction of contingency FFR market ancillary services would need to be coordinated with the existing minimum inertia arrangements for secure operation of islanded regions. AEMO notes that the operating requirements for interconnected operation and islanded operation are likely to be different and that this may drive different FFR service specifications for interconnected and islanded operation. AEMO considers that the coordination of the FFR market ancillary service arrangements with the minimum inertia arrangements could be achieved by either:[96]

- Not scheduling FFR via FCAS for islanded regions, and using the arrangements in place with Inertia Service Providers, or
- Taking the FFR available through FCAS markets into account when setting Minimum and Secure inertia levels, and scheduling FFR via FCAS for the management of islanded regions.

AEMO notes that under the existing in Inertia Requirements Methodology, the availability of fast FCAS is included in the determination of the inertia requirements for each inertia sub-

96 Ibid., p.29.

network. The Inertia requirements methodology could be revised to also consider the availability of FFR, following the introduction of market ancillary service arrangements for FFR. AEMO considers that the procurement of FFR through market ancillary service arrangements is likely to reduce the need for Inertia Service Providers to contract for FFR to provide inertia support services in accordance with the minimum inertia framework.[97] The Commission therefore understands that AEMO will account for provision of FFR through the new market ancillary service arrangements, as part of its assessment of inertia requirements.

The Commission's draft analysis and conclusions

AEMO is required to operate the central dispatch for the NEM to determine the optimal combination of resources based on market bids for provision of energy and market ancillary services, subject to physical constraints.[98] The NER set out a number of elements and variables that this dispatch optimisation should be subject to, including:

- dispatch offers, dispatch bids and market ancillary service offers
- generation and network constraints
- power system security requirements
- intra-regional losses and inter-regional losses;
- current levels of dispatched generation, load and market network services
- the management of any negative settlements residue

However, the NER do not require AEMO to consider the impact of the largest credible risk, nor any other specific interactions between individual market ancillary services, such as relationships between FFR and R6/L6.

The Commission accepts that the economic co-optimisation of different system services, such as energy and FCAS can be a complex process and accepts that the complexity of establishing processes that drive the co-optimisation must be weighed up against the potential benefits offered through improved dispatch efficiency.

However, the Commission notes that AEMO's advice includes modelling results that describe the relationship between inertia and FFR and dynamic R6 volumes. Such a relationship could be used as the basis for the co-optimal dispatch of FFR and R6/L6 services. This relationship is shown above in Figure 4.6.

The draft rule does not place any new requirements on AEMO in relation to the optimal dispatch of market ancillary services. The Commission notes that AEMO is responsible for operating central dispatch in order to maximise the value of dispatched load less the cost of energy, market ancillary services and network services.

97 Ibid., pp.29-30.
98 NER Clause 3.8.1.

4.2.3 Pricing & settlement

Proponent's view

Infigen supported establishing an explicit FFR market, modelled on the existing contingency FCAS markets.

Overview of the directions paper

The directions paper set out that the pricing and settlement arrangements would be based on those for the existing market ancillary services. The existing FCAS pricing arrangements have been shown to be relatively fit for purpose over the history of the NEM. The Commission also sought stakeholder views on the potential application of unit-based pricing multipliers applied to the spot market price to reflect the value offered by individual plant response profiles.

Stakeholder views to the directions paper

There was large support from stakeholders to maintain the pricing and settlement arrangements from the existing FCAS markets for the procurement of FFR market ancillary services. Stakeholders noted that this offered the least amount of complexity.[99] The University of NSW noted that there are benefits to retaining the same mechanism for a new FFR market, creating pricing consistency across all contingency markets.[100]

CS Energy specifically noted the following against the use of price multipliers:[101]

- All contingency FCAS response should be equally valued
- Contingency response relies on a suite of responses, it is not clear why one should be valued over another
- The addition of a price multiplier approach would add cost and complexity for little demonstrated efficiency gain.

Infigen Energy highlighted that the use of price multipliers does not necessarily provide AEMO with certainty of availability. AEMO could do this by preferentially dispatching resources with a higher price multiple, or fast response. In this case both Infigen and EnelX point out that a separate market would be more efficient.[102]

AEMO's advice

AEMO's advice includes an assessment and commentary of the applicability of applying performance based price multipliers to reward faster frequency response in the NEM. AEMO concludes that:[103]

99 Submissions to the Directions paper – *Frequency control rule changes*, ERM, p.9.; UNSW CEEM, p.11.; Delta Electricity, p.6.; CS Energy, p.11.; AGL, p.3.; Snowy Hydro, p.6.; Tesla, p.6.; Alinta, p.2.; AEC, p.3.

100 UNSW CEEM, Submission to the Directions paper – *Frequency control rule changes*, 4 February 2021, p.11.

101 CS Energy, Submissions to the Directions paper – *Frequency control rule changes*, 4 February 2021, p.11.

102 Submission to the Directions paper – *Frequency control rule changes*, Infigen, p.3.; EnelX, p.2.

103 AEMO, Fast frequency response implementation options - Technical advice on the development of FFR arrangements in the NEM, April 2021, p.42, 57-59.

Introduction of speed factor parameterisation is not recommended at this time: Speed factor parameterisation of FCAS provision would require significant development in the NEM context. The likely complexity of speed factor parameterisation in the NEM context would extend implementation time and costs and potentially limit flexibility to make future changes. This application of this approach in the NEM may not provide as transparent market outcomes as other approaches, or provide clear signals on the required speed of response.

The Commission's draft analysis and conclusions

The Commission accepts the feedback provided by stakeholders and advice provided by AEMO that the development of differential pricing arrangements based on spot price multipliers is not a priority area of reform and is not likely to result in improved market outcomes in the NEM at the current time. Such an approach is likely to increase the complexity of the market ancillary service arrangements and reduce the transparency around market outcomes, relative to the current arrangements. Furthermore, the benefits offered by differential pricing arrangements are likely to be muted in the NEM due to the time based segmentation of contingency response across the fast, slow and delayed service categories.

Under the draft rule, the arrangements for the pricing of the new very fast raise service or very fast lower service would be the same as the arrangements for the existing market ancillary services. The existing arrangements allow AEMO to adequately differentiate contingency response profiles to meet power system requirements and deliver efficient market outcomes. The inclusion of the new very fast services would provide AEMO with an additional FCAS segment in order to further refine the dispatch of market ancillary services to meet the power system requirements at an efficient cost.

4.2.4 Allocation of costs

Proponent's view

Infigen supported establishing an explicit FFR market, modelled on the existing contingency FCAS markets.

Overview of the directions paper

The directions paper set out that the approach to the allocation of costs for the contingency raise and lower services are identical to the allocation of costs associated with the procurement and payment for FFR raise and lower services.

Stakeholder views to the directions paper

Most stakeholders expressed the view that costs associated with FFR services should be allocated in a similar way to the existing process for the allocation of contingency FCAS costs.[104] Comments from stakeholders highlighted the following:

104 Submissions to the Directions paper - *Frequency control rule changes*, UNSW CEEM, p.11.; ERM, p.9.; Delta, p.6.; Snowy Hydro, p.6.; Tesla, p.6.; AEC, p.3.

- The impact of inertia on cost allocation
- Alternative cost allocation methods including runaway pricing and beneficiary pays

Consideration of providers of inertia

AGL, Alinta, Hydro Tas and CEC proposed that the arrangements for the allocation of costs related to FFR services should recognise the relationship between the FFR and inertia. These stakeholders noted that this would be an interim solution to the future work to be done in valuing inertia and the development of separate inertia market.[105]

Not all providers of system inertia supported changes to cost allocation for the provision of inertia. CS Energy noted changes would add layers of complexity and inertia should be valued in a separate mechanism.[106]

Tilt supported using the current FCAS cost allocation mechanism and advocated against any changes due to the provision of inertia, noting the requirement for FCAS is due to the consideration of contingency events and should continue to follow causer pays principles.[107]

Alternative cost allocation arrangements

Grids Energy proposed an alternative cost allocation mechanism, runway pricing. Sighting the current FCAS cost allocation as being outdated, and FCAS costs having grown sharply since the introduction of the current cost allocation. With the context of cost recovery options having changed drastically, Grids noted:[108]

> The use of runway pricing values the resilience benefits of more distributed energy generation and should contribute to more efficient investment and operational decisions in the NEM.

PIAC expressed support for a beneficiary pays approach to cost allocation and noted that the coast allocation arrangement should adapt as the quantity and distribution of benefits are likely to change over time.[109]

AEMO's advice

AEMO's advice did not comment on this issue.

The Commission's draft analysis and conclusions

The existing cost allocation arrangements for contingency raise and lower services provide a basis for the allocation of costs associated with FFR services.

105 Submissions to the Directions paper - *Frequency control rule changes*, AGL, p.3.; Alinta, p.2.; Hydro Tas, p.3.; CEC, p.3.
106 CS Energy, submission to the Directions paper – *Frequency control rule changes*, 4 February 2021, p.11.
107 Tilt Renewables, submission to the Directions paper – *Frequency control rule changes*, 4 February 2021, p.1.
108 Grids Energy, submission to the Directions paper – *Frequency control rule changes*, 4 February 2021, p.2.
109 PIAC, Submission to the Directions paper – *Frequency control rule changes*, 10 February 2021, p.1.

Under the NER, the costs of contingency services are allocated based on a loosely applied causer pays principle. Costs for contingency raise services are recovered from registered generators and costs of lower services are recovered from market customers.[110]

This approach is consistent with the NEM market design principles that state that:[111]

> where arrangements require participants to pay a proportion of AEMO costs for ancillary services, charges should where possible be allocated to provide incentives to lower overall costs of the NEM. Costs unable to be reasonably allocated this way should be apportioned as broadly as possible whilst minimising distortions to production, consumption and investment decisions.

The Commission considers that the existing approach provides an incentive for market participants to adjust their plant operation to reduce the overall cost of ancillary services. For example, during high wind periods, the availability of low cost wind generation may drive synchronous hydro and thermal generators to bid unavailable. This can also cause a reduction in the available capacity for frequency raise services, leading to increased market prices for these services. At these times, the increased cost of FCAS is borne by plant that is generating at that time, which are therefore incentivised to reduce output to reduce their exposure to high FCAS costs. This provides a feedback to improve the efficiency of market outcomes while at the same time avoiding distortions in the allocation of FCAS costs.

Therefore, the Commission considers that it is appropriate that the costs are recovered from market participants in this fashion, consistent with the causer pays principles as articulated above.

The Commission recognises that there are opportunities to improve the arrangements for the allocation of costs associated with contingency services, including more sophisticated application of the causer pays principles and potential inclusion of consideration for provision of related power system services, such as inertia. One such potential improvement is the application of the runway pricing approach proposed by Grids.[112] Under the runway pricing approach the costs of contingency services would be allocated based on the degree to which a market participant's plant contributes to the size of the largest credible risk and therefore the overall need for contingency services.

While the Commission considers that there may be benefits to introducing more sophisticated causer pays arrangements for contingency FCAS, there are also a range of complexities that would need to be worked through. The Commission considers that a reform of this nature that applies to all existing contingency services would be beyond the scope of introducing new markets for the provision of FFR services.

110 NER clause 3.1.4 (f) & clause 3.1.4 (g)

111 NER clause 3.1.4 (a) (8)

112 Grids Energy, submission to the Directions paper – *Frequency control rule changes*, 4 February 2021, p.2.

4.3 Implementation and transitional arrangements

The draft rule includes the following transitional arrangements for the implementation of the new market ancillary services for FFR:

- That AEMO revise the MASS within 18 months of the date that the rule is made, to specify the detailed description and performance parameters for the very fast raise and very fast lower services.
- That the FFR market ancillary service arrangements commence three years from the date that the rule is made.

The Commission notes that these time-frames may be bought forward as a result of further detailed planning associated with the ESB post-2025 work program and stakeholder feedback on the FFR draft rule. The Commission is of the view that these time frames represent the latest time as to when arrangements should be implemented.

4.3.1 Proponent's view

Infigen's rule change request does not include specific discussion in relation to implementation or transitional arrangements for FFR market ancillary services. However, its submission to the directions paper clarified its view that:[113]

> FFR should be implemented as soon as practical, to ensure that frameworks are in place for when they are needed.

Infigen noted that the procured quantity for FFR services may initially be low or zero depending on AEMO's assessment of power system needs, but that it would be preferable to have FFR market arrangements operational sooner rather than later. Infigen noted that further delays in defining and procuring FFR will place the system at risk of not having the service when it is needed in future.[114]

4.3.2 Stakeholder views to the consultation paper

Stakeholders were relatively silent on implementation and transitional arrangements in submissions to the Consultation paper, AEMO did note that a contracting approach to procure FFR may be appropriate as a possible first step, prior to the establishment of market arrangements for FFR. [115]

4.3.3 Overview of the discussion from the directions paper

The directions paper included an overview of issues related to the process for the implementation of market arrangements for FFR and whether there is any need for transitional arrangements to support the implementation process.

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113 Infigen energy, Submission to the directions paper - *Frequency control rule changes*, p.1.

114 Ibid., p.7.

115 AEMO, Submission to the Consultation paper – *System services rule changes*, 13 August 2020, pp. 18 – 20

Initial views on the process for the implementation of FFR

The Commission's initial view put forward in the directions paper was that the implementation arrangements for FFR services would need to accommodate the following steps and processes following the rule being made:

- AEMO to consult on revisions to the MASS to include arrangements for FFR
- AEMO to revise its market dispatch systems, including the development and implementation of constraints for FFR
- AEMO to revise its settlement systems for payment and allocation of costs

Initial views on transitional arrangements

The Commission also noted that there may be a role for transitional arrangements to facilitate the necessary learning and development required for the safe and efficient integration of this new technology. The Commission noted AEMO's view that contract based procurement be considered as a possible first step to help manage system impacts associated with the implementation of new FFR services.[116]

4.3.4 Stakeholder views to the directions paper

Stakeholders expressed a range of views in relation to the process and timing for implementation of FFR arrangements.

Implementation process and time frame

In their submissions, CEC, Tesla, Neoen, EnelX and Infigen advocated for immediate reform.[117] with the rapid roll out of FFR market arrangements. Tesla noted:[118]

> Tesla is strongly supportive of the introduction of an FFR market, as soon as 2021/22, and suggests AEMC accelerate implementation as a 'no-regrets' reform (high benefit, negligible cost) [...]

In contrast, Delta Electricity expressed support for a delayed implementation, highlighting there is likely to be implications from the design and implementation of enduring PFR arrangements and that a FFR market should be re-evaluated post PFR implementation.[119]

Transitional arrangements

ENGIE noted that transitional arrangements should be avoided due an increase in costs. ENGIE did recognise that there are issues raised by AEMO which need to be addressed prior to implementation.[120]

116 AEMO, Submission to the Consultation paper – System services rule changes, 13 August 2020, pp.18 – 20
117 Submissions to the Directions paper – *Frequency control rule changes*, CEC, p.2.; EnelX, p2; Infigen, p.3.; Neoen, p.2.
118 Telsa, Submission to the Directions paper – *Frequency control rule changes*, 4 February 2021, p.6.
119 Delta Electricity, submissions to the Directions paper – *Frequency control rule changes*, 4 February 2021, p.12.
120 ENGIE, submission to the Direction paper – *Frequency control rule changes*, 4 February 2021, p.4.

AGL supported implementation as soon as possible. However, it stated that transitional arrangements may be needed for AEMO and participants to properly work through problems. AGL noted:[121]

> It may be the case that transitional arrangements are necessary to implement market arrangements for FFR. For example, AEMO will need to develop its understanding of network conditions and any specific locational requirements or constraints. On the participant-side, the registered FFR capacity values may need to be reconsidered once a participant's real-world FFR performance is assessed following a contingency event.

The University of New South Wales noted that if a market is introduced, interim or transitional arrangements should be implemented to allow AEMO to obtain operational experience with FFR in the NEM. Learnings from this can then be used to inform and develop a FFR market.[122]

4.3.5 AEMO's views

AEMO's advice includes discussion in relation to the process and time frames for implementation of market ancillary service arrangements for FFR services. The advice also outlines AEMO's view that out of market procurement arrangements for FFR would help AEMO manage risks associated with the process for integration of the new FFR services.

Implementation process and time frame

AEMO's advice includes the following overview of the process for the implementation of new market ancillary service arrangements for FFR as an extension to the existing contingency FCAS framework.[123]

> Implementing FFR as an extension to the existing contingency FCAS services may require:
>
> - Development of FCAS constraints to schedule FFR.
> - NEMDE changes related to energy/FCAS co-optimisation arrangements.
> - Changes to the settlements systems and processes.
> - Registration of FFR providers and associated testing and compliance measures.
> - Amendment to MASS specification for R6/L6 and potentially changes to existing FCAS registered volumes.
>
> The implementation process will be dependent on the final rule made. As a high-level estimate, based on previous experience with market system changes, AEMO estimates that the implementation would be in the order of three years. This implementation would include:

121 AGL, submission to the Directions paper – *Frequency control rule changes*, 4 February 2021, p.5.

122 UNSW CEEM, submission to the Directions paper – *Frequency control rule changes*, 4 February 2021, p16.

123 AEMO, Fast frequency response implementation options — Technical advice on the development of FFR arrangements in the NEM, April 2021, p.46.

- Engineering work on FFR service definition including telemetry and data recording requirements.
- Engineering work on the scheduling arrangements for FFR services, including FCAS constraint development.
- Market system and IT system changes, including NEMDE changes.
- Consultation with industry, including consultation on MASS changes.

Transitional arrangements

In its *FFR implementation options* advice, AEMO expressed the view that:[124]

> **Out of market arrangements should be considered as a transitional measure.**
>
> The use of out of market procurement as a transitional measure would allow the service specification to be more readily refined in advance of market implementation. Coupled with locational requirements, it would also help minimise the technical integration challenges and allow procedures to be developed to manage these challenges in the initial stages of the market.

According to AEMO, transitional arrangements that allow for the procurement of FFR services via out of market bilateral contracts would deliver the following benefits:[125]

- **Support the refinement of the service specification** — AEMO considers that it would be preferable for the initial development and refinement of the FFR service specification and other related arrangements to be managed through out of market mechanisms prior to the establishment of a standard service specification for FFR market ancillary services. AEMO considers that this approach would allow for, "issues with the specification, delivery, testing and compliance to be worked through without having large market impacts."
- **Allow for operational learning in relation to system security issues and constraints** — AEMO considers that "locational concentrations of FFR could present security issues, and there are implementation challenges related to FFR, that may not be easily anticipated by prospective FFR providers." While AEMO notes that it can manage system security issues through the application of constraints on the dispatch of FFR services, it notes that the application of such constraints may initially be conservative and subject to change.

AEMO proposed that transitional contracting arrangements would be time limited to assist in the smooth implementation of the new FFR market ancillary services. AEMO considered that the regulatory framework that supports the transitional contract procurement would be relatively simple, noting that:[126]

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124 AEMO,Fast frequency response implementation options — Technical advice on the development of FFR arrangements in the NEM, April 2021, pp.4, 38.

125 Ibid., p.38-40.

126 Ibid.

> Complex out-of-market arrangements would likely incur implementation and operational costs not commensurate with time limited interim measures, likely used for procurement of lower service volumes.

Finally, AEMO noted that an important aspect of the implementation process for new FFR services would be the gradual increase of FFR volumes in a similar manner to the recent changes to contingency FCAS requirements due to the revision of the assumed value for load relief. AEMO noted that this approach would allow it to progressively assess FFR introduction and respond if power system or market issues become evident.[127]

4.3.6 The Commission's draft analysis and conclusions

The **implementation** time frame under the draft rule is consistent with AEMO's advice that two new FFR market arrangements would commence no later than three years after the final rule is made. This time frame allows for the following activities as advised by AEMO:

- Engineering work on FFR service definition including telemetry and data recording requirements.
- Engineering work on the scheduling arrangements for FFR services, including development of FCAS constraints.
- changes to Market and IT systems, including NEMDE changes.
- Consultation with industry, including consultation on changes to the MASS.

These time-frames may be bought forward as a result of further detailed planning associated with the ESB post-2025 work program and stakeholder feedback on the FFR draft rule. The Commission is of the view that these time frames represent the latest time as to when arrangements should be implemented.

In relation to **transitional arrangements**, including AEMO's proposal for transitional out of market procurement for FFR, the Commission understands that AEMO's rationale for recommending these transitional arrangements does not relate to its ability to manage the secure operation of the power system, but instead relates to the management of the risks that may be borne by investors in newly developed FFR projects. Therefore, it is appropriate to seek stakeholder views on the nature and extent of these risks, how material they are, and views on how these could be managed.

Potential risks

AEMO has highlighted the following risks:

- Specification - AEMO has flagged the potential for revision of the service specification for FFR within a short period of its initial determination to account for operational learnings. Revision of the FFR service specification may impact participants who have invested in FFR capability based on the initial FFR service specification.

127 Ibid.

- Dispatch constraints - During the initial operation of the FFR market, AEMO may apply conservative operational constraints to the dispatch of FFR services. These constraints would be expected to evolve over time as AEMO gains operational experience in the FFR services. Market participants may initially face a degree of uncertainty in relation to the maximum dispatchable capacity for FFR capable plant.

The Commission is interested in stakeholder views on the extent of the risks, and how material they may be. The Commission is also interested in stakeholder views on whether there are additional measures that may be used to help with the smooth implementation of the new FFR market ancillary services.

Potential ways to address these risks

If these risks are material for participants, then there are different ways that this risk could be managed. AEMO's technical advice sets out one potential way of having out of market procurement arrangements as a transitional measure in order to mitigate these risks, to allow for learning through these contracts such that once a market is implemented the risks are minimised. However, there are alternatives. The options and their pros and cons are set out below in Table 4.2.

Table 4.2: **Management of implementation risks**

ISSUE/RISK	TRANSITIONAL OUT OF MARKET PRO-CUREMENT	ALTERNATIVE OPTIONS
Specification AEMO has flagged the potential for revision of the service specification for FFR within a short period of its initial determination to account for operational learnings. Revision of the FFR service specification may impact participants who have invested in FFR capability based on the initial FFR service specification.	Out of market procurement would allow for the FFR service specification to be refined through out-of-market processes prior to the determination of a specification for FFR market ancillary services. As a result, the inaugural FFR specification in the MASS would be more developed at its inception, and less likely to be revised. The specification may still be subject to change through consultation on the MASS in accordance with NER clause 3.11.2(c).	The draft rule sets out that AEMO will have 18 months to develop an initial FFR service specification after the rule is made. Increasing the consultation associated with this process (beyond that required under the rules consultation process), or increasing the time frame to undertake this, would result in a more robust service specification being developed. Developing a robust service specification up front would likely mean that the resultant market and system changes would be fit for purpose and so could be specified exactly, minimising costs. Adjusting the service specification through the MASS is likely to provide more certainty to future investors as to what the service characteristics are required for FFR, while also promoting flexibility in the arrangements to evolve over time.
Dispatch Constraints During the initial operation of the FFR market, AEMO may apply conservative operational	Out of market procurement would provide AEMO with a means to trial and develop operating process and constraints to manage the limits on the dispatch of FFR.	AEMO could initially procure small FFR volumes,with these increased progressively over time. This would allow AEMO to monitor and respond to any system or market issues as they

ISSUE/RISK	TRANSITIONAL OUT OF MARKET PRO-CUREMENT	ALTERNATIVE OPTIONS
constraints to the dispatch of FFR services. These constraints would be expected to evolve over time as AEMO gains operational experience in the FFR services. Market participants may initially face a degree of uncertainty in relation to the maximum dispatchable capacity for FFR capable plant.	This process is intended to produce a set of operational constraints at the inception of the FFR market arrangements that are less subject to change. This would be expected to reduce the risks associated with dispatch uncertainty for new FFR projects. Market and network constraints are still subject to change in accordance with AEMO's general power system security responsibilities and obligation in relation to the operation of central dispatch under NER clause 3.8.11.	eventuate. AEMO recognises that this could be an alternative to out of market arrangements.

Further, in the case of risks associated with transparency in relation to the application of constraints on the dispatch of FFR capable plant,

- AEMO has established processes to develop, apply such constraints, and notify market participants in relation to any related changes to the application of constraints.

  AEMO may apply constraints on central dispatch in accordance with its general power system security responsibilities.[128]. AEMO may also impose constraints on central dispatch due to the quantity and nature of ancillary services provided or procured by AEMO under the Rules that are required to be managed in conjunction with central dispatch.[129] In addition, for each dispatch interval, AEMO must impose constraints upon the dispatch algorithm to determine the quantity of each global market ancillary service requirement and any local market ancillary service requirements.[130] Transparency around the application of constraints is provided by AEMO through the following process:

  - its consultation on, and publication of the network constraint formulation guidelines under clause 3.8.10(c); and
  - the requirement on AEMO under NER clause 3.8.13 to publish the parameters used in the dispatch algorithm for the modelling of certain types of constraints, including ancillary services constraints.[131]

The Commission is interested in stakeholder views on the risks identified by AEMO in relation to the implementation of new arrangements for FFR market ancillary services, how material they are, and the different options for addressing these risks (if they are material).

Implementation costs

The Commission understands that AEMO considers that the implementation costs for new FFR market ancillary services would be lower than the Commission's estimate of the potential benefits of implementing new market ancillary service arrangements for FFR.[132] Therefore, the Commission is of the view that the benefits associated with introducing FFR arrangements outweigh these costs.

AEMO is currently in the process of planning out the process, schedule and estimated costs for the implementation of the range of market reforms related to the ESB post 2025 market design program. This includes the preparation of a cost estimate for the implementation of new market ancillary service arrangements for FFR. The Commission expects the revised cost estimate to be available in May 2021 for reference as part of the final determination for the FFR rule change.

The development and implementation of the FFR market will be a regulatory obligation imposed on AEMO which will result in expenditure to undertake technical studies,

128 NER clause 3.8.10

129 NER clause 3.8.11

130 NER clause 3.8.11(a1)

131 AEMO issue market notices relating to market and operational matters via its website. Refer to https://aemo.com.au/en/market-notices

132 Refer to section 3.4.1 for a summary of the expected economic benefits of the draft rule.

consultation on the MASS, and changes to AEMO systems. AEMO's recovery of its budgeted revenue requirements through participant fees (including its expenditure requirements relating to power system operation activities and expenditure relating to the electricity industry generally) is addressed in rule 2.11 of the NER, and which sets out that AEMO can recover development and implementation costs through electricity participant fees.

5 OTHER ISSUES THAT ARE NOT PART OF THE DRAFT RULE

This chapter provides an overview of the Commission's consideration of issues raised in the rule change assessment process but that are not part of the draft rule.

5.1 Valuation of inertial response

The development of market ancillary service arrangements for faster frequency response is an immediate priority area for reform for the ESB's post 2025 market design. This draft determination implements arrangements to address this. However, in line with AEMO's advice, the draft rule does not require that inertial response be valued as part of the new market ancillary services for FFR.

There is a close interaction between the development of market arrangements for FFR services and the valuation of inertia. However, FFR and inertia are different services, as described in section 2.2. Although FFR has the potential to assist with frequency management at lower levels of system inertia, FFR and inertia are delivered via different physical mechanisms, and play roles that are not directly interchangeable.

The Commission recognises the interactions between FFR and inertia arrangements and stakeholder interest in relation to the valuation of inertia above minimum levels. The AEMC and ESB are continuing to consult with stakeholders on arrangements for the valuation of essential system services through the ESB post 2025 market design process and the assessment of active rule changes requests: *Capacity commitment mechanism for system security and reliability services (UCS rule change) and Synchronous services markets (SSM rule change).*

5.1.1 Background

The existing NER do not support the full valuation of inertia above minimum levels. The NER currently includes an inertia framework that supports the provision of inertia to meet the power system requirements for satisfactory and secure operation for each of the NEM regions. This framework is described in appendix A.2.2. The existing inertia framework provides a minimum level of inertia for safe and secure operation of each of the NEM regions. However, any further market and security benefit that could be obtained through the provision of additional inertia is not yet valued in the NEM.

The development of a co-optimised spot-market arrangement for valuation of inertia has been identified by the ESB as an objective for development through the post-2025 market design process.[133] Whereas the development of FFR market arrangements is relatively discrete in nature, the consideration of a market arrangement for inertia is complex due to inter-dependencies with a number of reforms being considered as part of the essential

133 Energy Security Board, *Post 2025 Market Design — Consultation Paper*, September 2020, p.59.

system services work-stream. These include operational arrangements for unit commitment and other required services that are essential for power system security.

5.1.2 Proponent's view

Infigen notes the interaction that exists between the levels of FFR, primary frequency response, and inertia required to support a secure system.[134] Infigen considers that procuring the right amount of FFR becomes particularly important as inertia decreases, and that the volume of FFR service procured should be calculated based on contingency size with the consideration of system inertia. Infigen does not comment on the means of valuing inertia, either through the FFR market or through a separate market, but notes that a FFR market would allow for FFR to be co-optimised with contingency size under low inertia conditions.

5.1.3 Submissions to the consultation paper

In response to the consultation paper a number of stakeholders proposed that a FFR market should be technology neutral and that the valuation of inertial response through the FFR arrangement would support a technology neutral outcome.[135]

System service arrangements that are technology neutral are preferred and in the absence of separate arrangements for valuation of inertia, it may be appropriate for inertial response to be valued as part of new market arrangements for FFR. However, there are challenges associated with this proposal that require further investigation. For example, FFR contingency reserves are measured in MW, whereas inertia is measured in MW seconds as noted by AEMO in its submission to the consultation paper.[136]

5.1.4 Discussion in the directions paper

In the directions paper, the Commission did not envisage that a complete arrangement for the valuation of inertia would be developed and implemented through the FFR rule change. As noted above, the development of spot market arrangements for inertia is being led through the ESB's Essential system services market design initiative. However, the Commission set out that it considered the interaction between FFR and inertia, including whether it would be appropriate for the NER to require that inertial response be valued as part of the new FFR market ancillary services.

5.1.5 Submissions to the directions paper

Most stakeholders agreed that a "missing market" for FFR, as the ESB notes, is a direct result of a reduction in the level of system inertia. As the level of inertia continues to reduce, a greater level of FFR will be needed. However, there was a degree of recognition that FFR and inertia are technically separate, and have different characteristics.[137]

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134 Infigen Energy, *Fast frequency response market ancillary service* rule change request, 18 March 2020, p.5.

135 Submissions to the *Consultation paper – System services rule changes:* AEC, pp.2-3.; Stanwell, p.8.; CleanCo, p.3.; Hydro Tasmania, p.4.; OMPS Hydro, p.2.

136 AEMO, Submission to the *Consultation paper — System services rule changes*, 13 August 2020, p.18.

137 Submissions to the Directions paper — *Frequency control rule changes*, AGL, p.4.; CS Energy, p.12-13.; Origin, p.4.; Delta, p.9-10.; AEC, p.3-4.; Energy Australia, p.5.; Hydro Tas, p.3.; Alinta, pp.3-4.

A number of stakeholder submissions to the directions paper express support for the valuation of inertia as a priority, either as part of the FFR market arrangements or through separate arrangements.[138]

Other stakeholders agreed that the valuation of inertia was important but that it could be considered following the development of the NER arrangements to provide for FFR market ancillary services.[139]

Valuation of inertia as part of the FFR market arrangements

Several market participants advocated strongly for the valuation of inertia to be included within the FFR market, given the close connection between the two, and that this approach would allow for the earliest initial valuation of inertia and establishment of market price signals. These market participants identified several areas of concern that would need to be addressed to make this solution feasible:[140]

- The complexity of fully valuing inertia within the contingency FCAS framework.
- Valuing inertia in the MASS, while keeping the MASS consistent across all other frequency control services.
- Avoiding delays to the implementation of FFR market arrangements due to the inclusion of inertia

A number of other stakeholders advocated instead for a distinct market and viewed the inclusion of inertia valuation within a FFR market as an interim solution.[141]

Valuation of inertia through separate arrangements

Stakeholders identified several benefits to valuing inertia through a distinct new market:[142]

- FFR market development can continue without delay, as this would be structured in the same way as the current FCAS markets.
- Developing a mechanism for the valuation of inertia where the full benefit is represented is very complex and this is best done outside of contingency FCAS services.

They did however agree that this would mean a delay to any sort of valuation of inertia.

ERM along with previous comments from CS Energy highlighted that the final market design needs to be holistic, not only between FFR, energy and other FCAS markets, but also with any form of valuation of inertia.[143]

138 Submissions to the Directions paper - *Frequency control rule changes*, AGL, p.4.; CS Energy, pp.12-13.; Origin, p.4.; Delta, p.9-10.; AEC, pp.3-4.; Energy Australia, p.5.; Hydro Tas, p.3.; Alinta, p.3-4.

139 Submissions to the Directions paper - *Frequency control rule changes*, AGL, p.4.; CS Energy, pp.12-13.; Origin, p.4.; Delta, p.9-10.; AEC, pp.3-4.; Energy Australia, p.5.; Hydro Tas, p.3.; Alinta, pp.3-4.

140 Submissions to the Directions paper - *Frequency control rule changes*, AGL, p.4.; CS Energy, pp.12-13.; Origin, p.4.; Delta, p.9-10.; AEC, pp.3-4.; Energy Australia, p.5.; Hydro Tas, p.3.; Alinta, pp.3-4.

141 Submissions to the Directions paper - *Frequency control rule changes*, Tesla, p.6.; AGL, p.4.; CEC, p.2.; ERM, p.4.; Infigen, p.5.

142 Submissions to the Directions paper - *Frequency control rule changes*, Tesla, p.6.; ERM, p.4.; University of NSW, pp.13-14.; EnelX, p.4.; Infigen, p.5.; Tilt Renewables, p.1.; CEC, p2.; ENGIE, p.3.

143 Submissions to the Directions paper - *Frequency control rule changes*, ERM, p.4, CS Energy, p.12.

University of NSW agreed with the need for a procurement mechanism for inertia. However, it noted this arrangement should allow for inertia to be valued as a distinct service, separate from the generation or consumption of energy, saying:[144]

> "Our preference for the procurement of physical inertia is for a transparent and competitive structured procurement mechanism for the provision of inertia that is not tied to the generation or consumption of energy."

5.1.6 AEMO's views

AEMO's advice in relation to the interactions between FFR and inertia is that:[145]

> **Inertia and FFR should not be combined within the same service.**
>
> Inertia and FFR both provide a valuable response, however, they are fundamentally different and should not be combined within the same service.

AEMO notes that the FFR provided as a contingency FCAS type service is expected provide an automatic and sustained active power injection (or withdrawal) in response to a change in system frequency, whether through dynamic droop control or as a static switched response. This type of response is different from inertia that acts to resist changes in system frequency but does not provide a sustained active power response.[146]

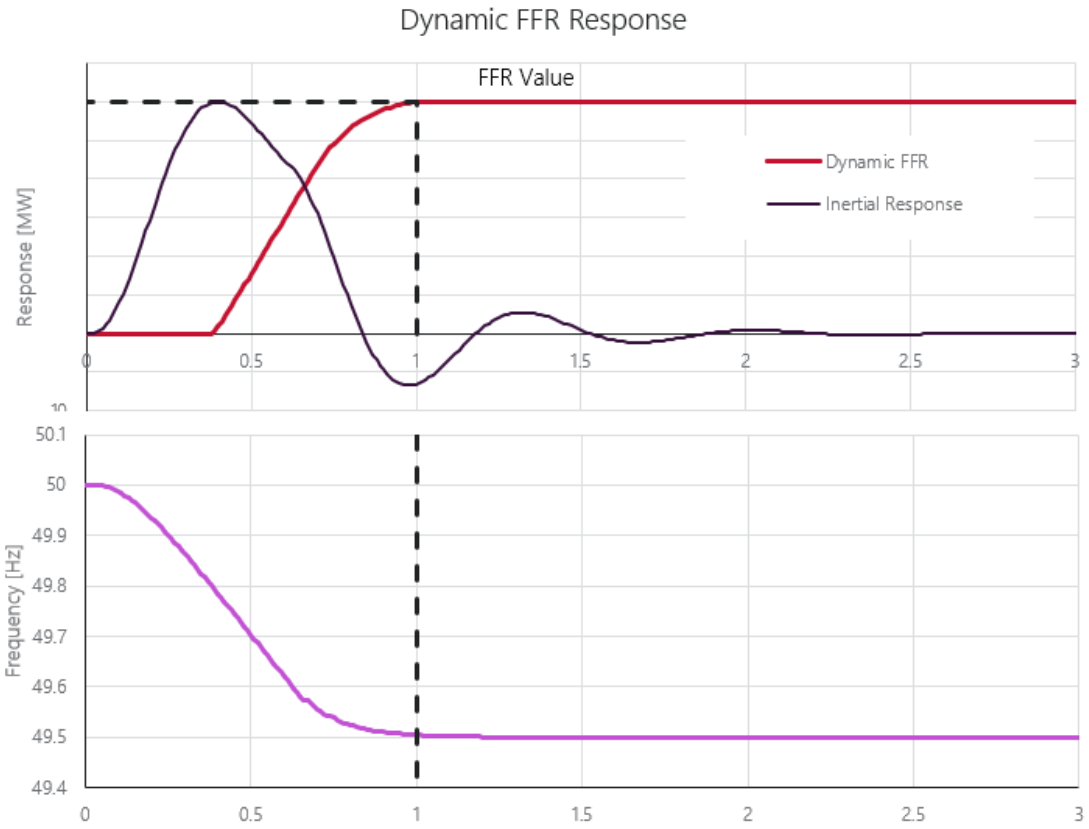
A comparison of Dynamic FFR and inertial response is shown below in Figure 5.1.

144 University of NSW, submission to the Directions paper – *Frequency control rule changes*, 4 February 2021, p.14.

145 AEMO, Fast frequency response implementation options - Technical advice on the development of FFR arrangements in the NEM, April 2021, p.4.

146 AEMO, Fast frequency response implementation options - Technical advice on the development of FFR arrangements in the NEM, April 2021, pp.24-25.

Figure 5.1: Comparison of dynamic FFR and inertial response



Source: AEMO, Fast frequency response implementation options - Technical advice on the development of FFR arrangements in the NEM, April 2021, p.25.

AEMO notes that there are other forms of FFR from inverter based plant that can provide an inertia-like, or synthetic inertial response, but that is not the same as inertia. [147]

> There are other forms of fast active power injection, that may be referred to as FFR, but provide different forms of response. Synthetic inertia provided by wind farms and virtual inertia provided by batteries are examples of responses related to RoCoF, and are closer to the response of synchronous inertia.

The consideration of inertia market arrangements is outside the scope of AEMO advice, *FFR implementation options*. Further consideration of potential market and regulatory reforms in relation to valuation of inertia response is being coordinated through the ESB's *Essential System Services Post 2025 Market Design initiative* which is discussed below in section 5.1.7. It is recognised that further technical considerations need to be undertaken into the characteristics of inertia.

147 AEMO, Fast frequency response implementation options - Technical advice on the development of FFR arrangements in the NEM, April 2021, p.24.

5.1.7 The Commission's draft analysis and conclusions

The Commission notes stakeholder interest in relation to the interaction between inertia and FFR and the potential valuation of inertia as part of the market arrangements for FFR. The NER is currently silent on whether or not inertia is valued as part of the registration process for provision of market ancillary services. AEMO's advice is that inertia and FFR have fundamentally different technical properties and inertial response should not be valued as part of an FFR service.[148] Therefore, the Commission do not consider that it is appropriate for the NER to require that inertia be valued as part of the new FFR services.

The Commission notes that the ESB considers that the long-term direction is to implement an inertia market.

The *Post 2025 Market design directions paper*, noted that:[149]

> The ESB will continue to work on a spot market approach for valuing and procuring inertia as a long-term priority, in the first instance assessing the value of procuring inertia under structured procured arrangements if required in the interim, noting that many stakeholders noted that valuing and procuring missing system services is a priority that cannot wait until 2025.

In the meantime, the valuation of essential system services that are not procured through spot markets (which could include inertia) are being considered through the ESB process and separate ongoing regulatory processes including the assessment of rule changes requests for:

- *Capacity commitment mechanism for system security and reliability services (UCS rule change)* (ERC0306)[150]
- *Synchronous services markets (SSM rule change) (ERC0290)*[151]

Stakeholders are encouraged to engage in the relevant ESB and AEMC consultation processes in relation to future arrangements for the valuation of inertia in the NEM.

5.2 Interaction between FFR and Mandatory PFR

The draft rule does not include any specific provisions or revisions in relation to potential interactions between the provision of FFR and the existing requirement for mandatory PFR. AEMO's advice is that affected plant can manage the interactions between the provision of FFR and the mandatory PFR obligation through application of variable droop settings, which can act to reduce plant sensitivity to small frequency changes while still complying with the mandatory PFR obligation.

148 AEMO, Fast frequency response implementation options - Technical advice on the development of FFR arrangements in the NEM, April 2021, pp.4, 24- 25.

149 ESB, *Post 2025 Market design directions paper, January 2021, p.7.*

150 *Refer to the project page: https://www.aemc.gov.au/rule-changes/capacity-commitment-mechanism-system-security-and-reliability-services*

151 *Refer to the project page: https://www.aemc.gov.au/rule-changes/synchronous-services-markets*

The Commission will further consider the interactions between the mandatory PFR requirement and the provision of contingency FCAS through its assessment of the P*rimary frequency response incentive arrangements* rule change request and the related draft determination scheduled for publication by 16 September 2021.

5.2.1 Proponent's view

Infigen notes the interactions that exist between FFR and PFR and accepts that there is a need for PFR to be provided from generators.[152] Infigen considers that the current mandatory arrangement for PFR is flawed as it does not identify how much response is required, does not ensure headroom will be available to deliver the response, and does not follow sound market design principles for adequately pricing the required resources. Infigen considers that a clear market mechanism for both PFR and FFR will reduce the risk of further ad hoc interventions and inefficient obligations in the future.

5.2.2 Discussion in the directions paper

The directions paper set out that there is the potential for a new FFR arrangement to interact with the mandatory requirement for PFR. In particular, where there is a mandatory requirement outside of a narrow frequency response band very close to 50 Hz, this may also see FFR being provided at a narrow band. In these circumstances, there is the potential for enabled capacity for FFR to be dis-proportionally utilised to respond to small frequency variations during normal operation. Frequent use of the service may undermine its effectiveness at responding to larger frequency deviations caused by contingency events.

5.2.3 Stakeholder views

Stakeholder responses to the directions paper expressed a degree of concern in relation to potential interactions between new FFR market ancillary services and the existing requirement for generators to be responsive to small changes in frequency outside a narrow frequency response band very close to 50 Hz.[153] A number of stakeholders expressed a preference for the removal or relaxation of the mandatory PFR arrangements to avoid negative interactions with the provision of FFR contingency services.[154]

On the other hand, the University of NSW supported the continuation of the mandatory PFR arrangement and agreed with the use of variable droop settings to mitigate potential negative impacts on plant providing FFR. [155]

> we support explicitly procuring and remunerating headroom for each service and the use of a variable droop approach (as implemented by National Grid ESO in their dynamic containment service) where possible.

152 Infigen Energy, *Fast frequency response market ancillary service* rule change request, 18 March 2020, p.7.

153 Submissions to the Direction paper - *Frequency control rule changes:* Delta, p.12.; ERM, p.4.; Infigen, p6.; Tilt, p.1.

154 Submissions to the Direction paper - *Frequency control rule changes:* Alinta, p.4.; AEC, p.5.; AGL, p.5.; ENGIE, p.4.; Energy Australia, p.2.

155 UNSW CEEM, Submission to the Directions paper - Frequency control rule changes, p.16.

A number of stakeholders noted that the design of market and regulatory arrangements for FFR and PFR should be developed in a coordinated way. [156] CS Energy noted that,[157]

> It is imperative that any final market design recognises the linkages between inertia, FFR, 6 sec raise/lower services and narrow Mandatory PFR, so that the procurement of these services is harmonised. Each of these services provide a response to arrest and restore frequency deviations. As illustrated in the diagram below, following a contingency event (where the frequency deviation exceeds 50.15Hz or falls below 49.85Hz) the following services will be delivered:
>
> - inertial response will be automatically provided;
> - an initial narrow Mandatory PFR response will be provided;
> - any remaining PFR capability (acknowledging there is no obligation to maintain headroom or footroom) will be delivered on a proportional basis;
> - FFR contingency FCAS will be delivered on a proportional basis; and
> - assuming no changes to the existing FCAS markets, a proportion of the 6 sec contingency FCAS will be delivered in the proposed FFR 2 sec timeframe.
>
> In the event of a contingency event, PFR is effectively the delivery of 'contingency FCAS' before it is required.

Both Infigen Energy and Meridian Energy requested further detail on the Interaction between FFR and the mandatory PFR arrangements, including confirmation of the role of contingency services during normal operation.[158]

5.2.4 AEMO's views

AEMO notes that the current Mandatory PFR arrangement will sunset in June 2023 and that the Commission is considering the enduring PFR arrangements through its assessment of the *Primary frequency response incentive arrangements* rule change. In this context it notes that the future enduring PFR arrangements may affect FFR providers in two ways; the enduring PFR arrangements may:[159]

- place an obligation on FFR providers to respond to frequency outside of a deadband
- influence the quality of frequency control under normal conditions, which may change the way FFR is activated in response to frequency variations.

In relation to the existing Mandatory PFR arrangement, AEMO notes that FFR can be accommodated through the use of variable droop settings for relevant plant.[160]

> The Interim Power Frequency Response Requirements (IPFRR) allow for a variable

156 Submissions to the Direction paper - *Frequency control rule changes*. CS Energy, p.14.; Infigen, p.6.; CEC, p.3.; Origin, p5-6.; UNSW CEEM, p.16.

157 CS Energy, submission to the Directions paper – *Frequency control rule changes*, 4 February 2021, p.14.

158 Submissions to the Direction paper - *Frequency control rule changes:* Infigen Energy, p.6. Meridian Energy, p.2.

159 AEMO, Fast frequency response implementation options - Technical advice on the development of FFR arrangements in the NEM, April 2021, pp.23-24.

160 Ibid.

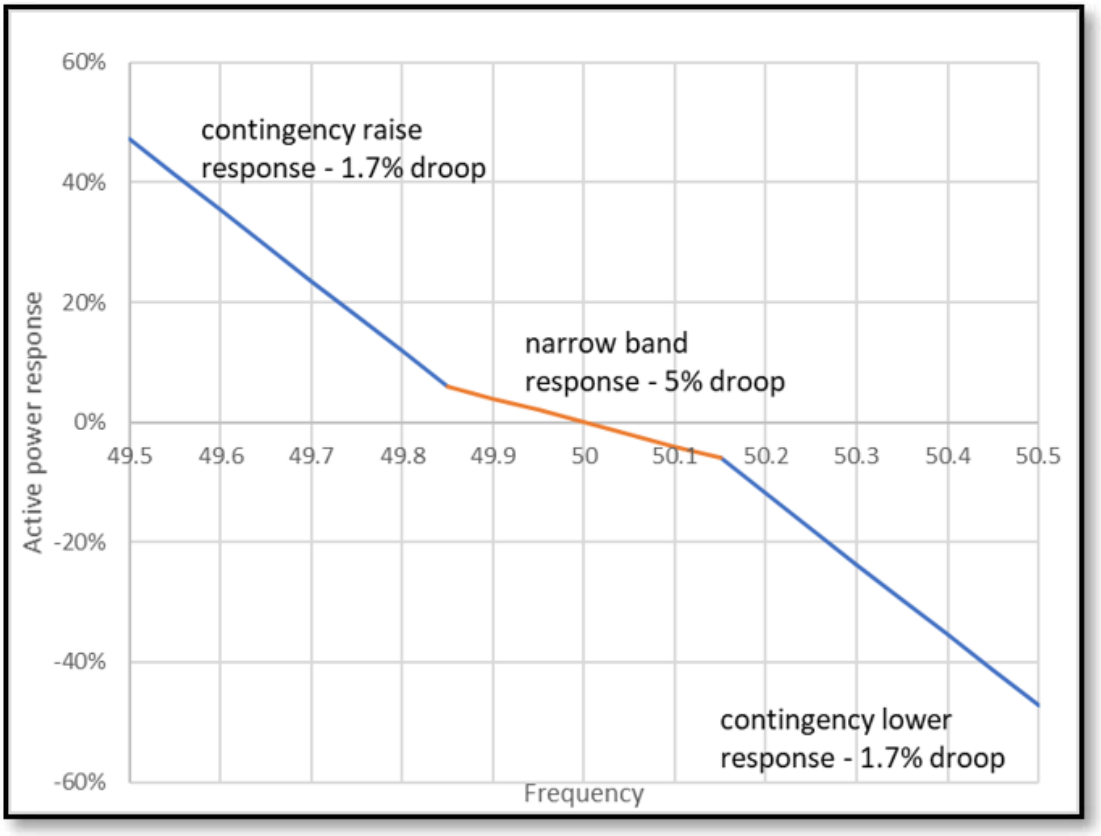
droop setting to be applied. Dynamic FFR providers wanting to apply a lower (more reactive) droop setting to maximise FFR delivery would have no obligation to use the same aggressive droop at a narrow frequency band. These providers would be able to apply the maximum (least aggressive) droop setting of 5% close to 50 Hz, reducing their level of response to ongoing frequency movement. Variable droop is part of the specification for National Grid's Dynamic Containment service, which is an FFR type service that has a +/-15 mHz deadband. The IPFRR obligations do not apply to providers of switched FCAS from load providers.

5.2.5 The Commission's draft analysis and conclusions

Under the current NER, the performance parameters for FCAS and mandatory PFR are specified by AEMO through the Market Ancillary service specification (MASS) and the Primary frequency response requirements (PFRR) respectively.

AEMO's advice notes that narrow band PFR and FFR are compatible and that the respective service specifications for the different types of frequency response can be set in such a way that any potential negative impacts are avoided. Where a narrow mandatory PFR requirement is in effect, as is currently the case, the application of variable droop settings can reduce the negative impacts to responsive generation plant. The application of variable droop settings reduces plant sensitivity to small frequency variations while maintaining an aggressive response to larger power system disturbances. One application of this concept is shown below in Figure 5.2.

Figure 5.2: Variable droop primary frequency response



Source: AEMC
Note: Assumes no deadband.
Note: 5% droop is the maximum allowable droop under the Interim primary frequency response requirements.
Note: 1.7% droop represents the most aggressive droop that AEMO will approve for a battery energy storage system providing contingency FCAS. Ref. Battery energy storage system requirements for contingency FCAS registration, 14 January 2019, p.5.

The *Mandatory primary frequency response rule 2020* (Mandatory PFR rule) was made in March 2020 and commenced in June 2020. Related changes to generator control systems are currently being implemented by AEMO. The final rule included provisions for the Mandatory PFR arrangements to sunset after a period of three years on 4 June 2023 in order to allow time for enduring arrangements to be developed. Prior to the sunset date, the Commission intends to develop enduring arrangements for PFR through its assessment of AEMO's rule change request, *Primary frequency response incentive arrangements*. These enduring arrangements may include the specification of any enduring technical obligation for frequency responsiveness as well as the related incentive arrangements.

5.3 Price responsive demand

This section outlines the Commission's analysis and stakeholder views in relation to the concept of price responsive demand for power system services.

5.3.1 Discussion in the directions paper

The directions paper set out that potential further improvement to the existing arrangements for the procurement of contingency FCAS would be for the NER to recognise and support the procurement of a variable quantity of service subject to the costs and benefits for providing the service. The existing arrangements support the dispatch of sufficient quantities of frequency responsive reserves to meet the operational requirements defined in the frequency operating standard.[161]This effectively sets a minimum requirement for FCAS in each dispatch interval.

The ESB identified that an additional increase in the resilience of the power system to contingency events could be realised through procurement of additional frequency responsive reserves when the price of those reserves is low, and they present good value to consumers. This "demand curve" concept has been developed as part of the ESB's work on its 2025 project. The ESB's September consultation paper set out how the existing market ancillary service arrangements for FCAS could be extended to allow for the variation of the quantity of FCAS procured based on the price of the services. As noted:[162]

> The key advantage of a demand curve approach is that it maximises the value of procurement, setting a minimum requirement when the price is high and procuring more of a service when efficient to do so.

The demand curve approach to the procurement of FCAS would include the definition of a minimum requirement for each service along with a predetermined demand function that reflects the value provided by additional quantities of frequency responsive reserve over and above the minimum requirement.

5.3.2 Stakeholder views

Most stakeholders recognised the potential value offered by a price responsive demand procurement approach.[163] However, stakeholders noted that further development of price responsive demand curves for FCAS procurement was of a lower reform priority, compared with other market reforms, such as the implementation of market arrangements for FFR. [164] The AEC suggested, [165]

> "[...] that the AEMC separates this question from the design of the FFR market. Instead, the AEMC should set up a separate review to investigate how demand curves could be simultaneously introduced across all ancillary services."

161 NER Clause 4.4.1 & Clause 4.4.2.

162 COAG Energy Security Board, Post 2025 market design – consultation paper, September 2020, p.63

163 Submissions to the Directions paper- *Frequency control rule changes*, ERM, p.3.; Delta, p.11.; EnelX, p.4.; Origin, p.4.; ENGIE, p.4.; Infigen, p.5.; AEC, pp.4-5.

164 Submissions to the Directions paper- *Frequency control rule changes*, ERM, p.3.; Delta, p.11.; EnelX, p.4.; Origin, p.4.; ENGIE, p.4.; Infigen, p.5.; AEC, pp.4-5.; AGL, pp.4-5.; Tesla, p.6.; ERM, p.4.; UNSW CEEM, pp.13-14.; EnelX, p.4.; Infigen, p.5.; Tilt Renewables, p.1.; CEC, p2.; ENGIE, p.3.

165 AEC, submission to the Directions paper - *Frequency control rule changes*, 4 February 2021, p4-5.

A number of stakeholders noted that further investigation should be undertaken to determine the value offered through a price responsive approach to FCAS procurement to understand practical difficulties related to the implementation of this concept, including:[166]

- How price responsive demand curves may impact other markets.
- The extent to which an increase in procurement complexity may offset any benefits.
- The technical feasibility of price responsive demand curves within the technical envelope.

5.3.3 The Commission's draft analysis and conclusions

The Commission notes that AEMO can already determine the required quantity for market ancillary services based on its assessment of the power system needs for the purpose of maintaining system security. The demand curve concept would go further and allow for additional quantities of FCAS to be procured when prices were low. The intention would be that the benefit to consumers from increased power system resilience would exceed the costs for the additional FCAS above the minimum requirement.

The implementation of a demand curve concept could apply generally to the procurement of each of the market ancillary services, not just FFR. This approach to FCAS procurement would require the establishment of a supporting framework in the NER which would include a process for the determination of demand curves outside of the existing market arrangements. Under such a framework, it is likely that AEMO would be responsible for developing the detailed procedures for the application of the price responsive demand along with the related demand curves for each of the market ancillary services. Such a process would likely be guided by principles set out in the NER, with a potential role for the AER to assess the costs and benefits of the proposed FCAS demand curves.

Further consideration of the costs and benefits associated with the demand curve concept in the context of the NEM will be progressed through the ESB's post-2025 work program.

166 Submissions to the Direction paper - *Frequency control rule changes*, CS Energy, pp.13-14.; ENGIE, p.4.; AEC, pp.4-5.; EnelX, pp.4.; AGL, pp.4-5.

ABBREVIATIONS

ACCC	Australian Competition and Consumer Commission
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
AGC	Automatic generation control system
Commission	See AEMC
DER	Distributed energy resources
DSCP	Double-sided causer-pays
ESB	Energy Security Board
ESS	Essential system services
FCAS	Frequency control ancillary service(s)
FFR	Fast frequency response
FI	Frequency indicator
FOS	Frequency operating standard
IBFFR	Inverter based fast frequency response
ISP	AEMO's Integrated system plan
MASS	Market ancillary service specification
MCE	Ministerial Council on Energy
NEL	National Electricity Law
NEM	National Energy Market
NEMDE	National Electricity Market dispatch engine
NEO	National electricity objective
NERL	National Energy Retail Law
NERO	National energy retail objective
NGL	National Gas Law
NGO	National gas objective
NOFB	Normal operating frequency band
PFCB	Primary frequency control band
PFR	Primary frequency response
PFRR	Primary frequency response requirements
QNI	Queensland - New South Wales Interconnector
SOLI	secure operating level of inertia
RoCoF	Rate of Change of Frequency
TNSP	Transmission network service provider
VPP	virtual power plant
VRE	variable renewable energy (generation)
WEM	Wholesale electricity market (Western Australia)

A OVERVIEW OF FREQUENCY CONTROL

This appendix outlines the concepts related to power system frequency control and describes the existing market and regulatory frameworks that support frequency control in the NEM.

A.1 What is frequency control

In Australia all generation, transmission, distribution and load components connected to the power system are standardised to operate at a nominal system frequency of 50 Hertz (Hz).

Control of power system frequency aims to maintain a steady power system frequency close to 50 Hz during normal operation, and to react quickly and smoothly to stabilise the system frequency following contingency events that cause larger frequency deviations.

The power system frequency will be stable when the electrical power supplied into the system is equal to the instantaneous customer demand, including losses. Changes to the balance of supply and demand for electricity lead to variation of power system frequency as the system speeds up or slows down. Further background on frequency control is available through the energy explained series on AEMO's website.[167]

In each synchronous generating unit, the large rotating mass of the turbine and alternator has a physical **inertia** which must be overcome in order to increase or decrease the rate at which the generator is spinning. In this manner, large conventional generators that are synchronised to the system act to dampen changes in system frequency.

The **rate of change of frequency (RoCof)** following a contingency event, such as the disconnection of a large generating unit, determines the amount of time that is available to arrest the decline or increase in frequency before it moves outside of the permitted operating bands described in the frequency operating standard. In general, more inertia leads to a slower rate of change of frequency and a longer window of time for frequency responsive reserves to act to stabilise the system frequency.

Effective frequency control requires the coordinated application of a range of control actions that are referred to as primary, secondary and tertiary frequency control.

Primary frequency control provides the initial response to frequency disturbances. It reacts quickly and automatically to locally detected changes in system frequency in accordance with agreed parameters. This response is provided by the automatic modification of generator output or customer demand.[168] Continuous primary frequency control helps to control system frequency during normal operation by responding to small frequency variations. Primary frequency control can also be configured to provide active power response only following larger disturbance events, this is referred to as Contingency response.

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167 See AEMO's Energy Explained: Frequency Control, 24 June 2020. https://aemo.com.au/en/newsroom/energy-live/energy-explained-frequency-control

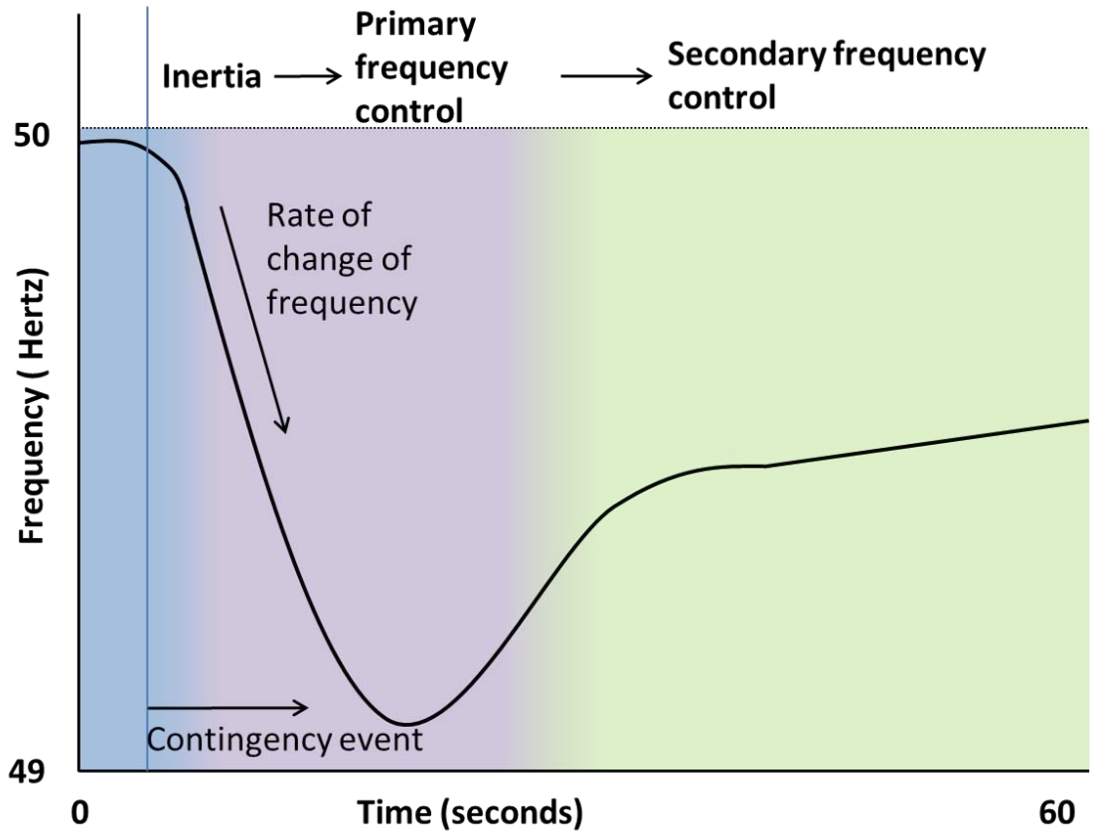
168 International Council on Large Electric Systems (CIGRE), 2010, Ancillary Services: an overview of International Practices, Working Group C5.06, pp.7-8.

Secondary frequency control refers to active power response that is centrally controlled and typically responds in real time, to signals or directions given by the system operator. Secondary frequency control services are intended to respond to frequency variations more slowly than primary frequency control to correct the power system frequency over a period of minutes.

Tertiary frequency control refers to reserve generation capacity that is able to be utilised to reset the primary and secondary frequency control services. This capacity does not automatically respond to frequency, rather it is available reserve that can be called on to restore the system to a secure operating state following contingency events. In the NEM, tertiary reserve is managed through the energy market dispatch, which matches generation supply with forecast demand every five minutes.

The role of these frequency control elements in responding to a contingency event is shown below in figure A.1.

Figure A.1: Frequency control following a contingency event



Source: AEMC

The existing arrangements that support frequency control in the NEM are described below in appendix A.2.

The ability to maintain control of power system frequency following a contingency event, such as the loss of a large generator, load or transmission line is determined by a number of factors, including:

1. The size of the contingency and the level of system inertia which defines the initial rate of change of frequency (RoCoF).
2. The amount of frequency responsive reserves and the characteristics of those reserves, including speed of response and the length of time the response can be sustained.

A.2 The existing frequency control arrangements

System security is necessary for the efficient functioning of the power system. Under the National Electricity Law (NEL), AEMO's statutory functions include maintaining and improving power system security.[169]

AEMO is required under the National Electricity Rules (NER) to operate and maintain the power system in a "secure operating state".[170] In order for the electricity system to be in a secure operating state, there are a number of physical parameters that must be maintained within a defined operating range, including an allowance for system recovery following disturbances.

Specifically, AEMO is responsible for maintaining the power system in a **secure operating state** by satisfying the following two conditions:[171]

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.[172]

One aspect of this is that AEMO must use its reasonable endeavours to control power system frequency in accordance with the *Frequency operating standard* (FOS).[173] AEMO controls

169 See section 49(1)(e) of the NEL

170 NER clause 4.2.6(a)

171 NER cl 4.2.4(a)

172 A protected event is special class of non-credible contingency event which is determined by the Reliability Panel based on an application made by AEMO. Ref NER Cl 4 .2.3 (f). AEMO may use a combination of ex-ante measures; including constraints, directions and dispatch of FCAS; to limit the impacts of a protected event consistent with the post-contingency operating state determined by the Reliability Panel.

173 NER clause 4.4.1(a)

frequency during normal operation and manages the impact of contingency events through a coordinated use of the following mechanisms:

- **Generator technical performance standards (GTPS)** — establish a set of technical standards and a negotiation framework for the connection of registered generators to the power system.
- **Inertia framework** — places an obligation on TNSPs to maintain minimum levels of inertia in areas of the NEM where AEMO has declared there to be a shortfall.
- **Mandatory primary frequency response (MPFR)** — AEMO is in the process of implementing the requirement for all registered generators to respond to frequency deviations, subject to energy availability, outside of a narrow response band close to 50Hz. This is required by the *Mandatory primary frequency response rule 2020,* which came into effect on 4 June 2020 and will sunset on 4 June 2023.
- **Frequency control ancillary services (FCAS**) — provide AEMO with a suite of ancillary services through which frequency responsive reserves are procured to help control system frequency.
- **Emergency frequency control schemes (EFCS)** — These automatic control schemes act to disconnect generation (over frequency generation shedding, OFGS) or load (under frequency load shedding, UFLS) to help re-balance the power system following significant non-credible contingency events.

A.2.1 Generator technical performance standards (GTPS)

Equipment that makes up and connects to the power system must perform to certain levels of technical capability. This helps AEMO maintain the power system in a secure and safe operating state and manage the risk of major supply disruptions. The levels of performance for equipment connecting to the power system are set out in performance standards for each connection. These performance standards are reached through a negotiating framework that is set out in the NER.

'Access standards' in the NER define the range of the technical requirements for the operation of equipment when negotiating a connection. These access standards include a range from the minimum to the automatic access standard. For each technical requirement defined by the access standards, a connection applicant must either:

- meet the automatic access standard, in which case the equipment will not be denied access because of that technical requirement; or
- negotiate a standard of performance with the local network service provider that is at or above the minimum access standard and below the automatic access standard.[174]

174 The connection applicant may also need to negotiate with AEMO on access standards that are AEMO advisory matters

The generator access standards in the NER cover a range of technical capabilities for connecting generators, including, among other things, frequency control and response to frequency disturbances during and following contingency events.[175] Clause 4.4.2(b) of the Rules sets out the obligations on Generators in relation to compliance with the technical requirements in clause S5.2.5.11, including being capable of operating in frequency response mode. Clause 4.4.2(c1) of the Rules sets out the obligations on Scheduled and Semi-Scheduled Generators in relation to the operation of their generating systems in accordance with the Primary Frequency Response Requirements.

Broadly, the automatic access standard that applies to generator frequency control is that:

- the generating system's output should not worsen any frequency deviation
- the generating system must be capable of automatically increasing or decreasing its output to help restore the system frequency to within the normal operating frequency band.[176]

The minimum access standard for generator frequency control does not directly refer to the frequency operating standard. It requires that a generator's output must not:

- increase in response to a rise in system frequency
- decrease more than 2 per cent per Hz in response to fall in system frequency.[177]

A.2.2 Inertia framework

The NER require AEMO to determine the inertia requirements for inertia sub-networks (typically NEM regions) through the application of the inertia requirements methodology that is developed by AEMO.[178]

For each inertia sub-network, the inertia requirements are:[179]

1. the **minimum threshold level of inertia**, required to operate the inertia sub-network in a satisfactory operating state when it is islanded
2. the **secure operating level of inertia** (SOLI), required to operate the inertia sub-network in a secure operating state when it is islanded

For each inertia sub-network, AEMO is required to assess whether there is likely to be an inertia shortfall between the inertia typically provided and the required level of inertia (minimum threshold and SOLI).[180]

Once an inertia shortfall has been declared by AEMO in an inertia sub-network, the TNSP who is the Inertia Service Provider for that sub-network is obliged to make inertia network services available that when enabled will provide inertia to the required level. Inertia

175 This section summarises the requirements in the NER that apply to generators connected after the 8 March 2007, when the National Electricity Amendment (Technical Standards for Wind Generation and other Generator Connections) Rule was made. Chapter 11 of the NER contains a transitional rule, clause 11.10.3, that allows for preexisting access standards to continue to apply.

176 See S5.2.5.11(b) of the NER

177 See S5.2.5.11(c) of the NER.

178 NER Clause 5.20B.2(a)

179 NER Clause 5.20B.2(b)

180 NER Clause 5.20B.3(a)

network services could include contracting with synchronous generators or providing a network solution such as the operation of synchronous condensers).[181] The TNSP may also ask AEMO to approve inertia support activities (which are not inertia network services and which act to adjust the relevant minimum level of inertia) as an alternative solution, and AEMO can approve those activities if it is satisfied that the activities will contribute to the operation of the inertia sub-network in a satisfactory or secure operating state.[182] Inertia support activities may include installing or contracting for the provision of frequency control services, (such as FFR) installing emergency protection schemes or contracting with Generators in relation to the operation of their generating units in specified conditions.

A.2.3 Mandatory primary frequency response (MPFR)

The Mandatory PFR rule was made on 26 March 2020, in line with AEMO's advice that there was an immediate need for improved frequency control in the national electricity system during normal operation and following contingency events.[183]

The *Mandatory PFR rule* introduced an obligation for all scheduled and semi-scheduled generators, who have received a dispatch instruction to generate to a volume greater than 0 MW in the NEM to support the secure operation of the power system by responding automatically to small changes in power system frequency.[184] This requirement was intended to provide improved frequency control in the NEM during normal operation and following contingency events, resulting in a more resilient power system.

The performance parameters for the mandatory PFR are set out by AEMO in the *Primary frequency response requirements*. In setting the performance parameters (which may be specific to different types of plant), AEMO must define the maximum allowable dead band which must not be narrower than the Primary frequency control band (PFCB).[185] The PFCB is defined in the NER as the range of 49.985 Hz to 50.015 Hz or such other range as specified by the Reliability Panel in the FOS. This governance arrangement recognises the implications of the mandatory frequency response band for both system operation, as well as the operation of the markets for electricity and ancillary services in the NEM.

In its final determination, the Commission noted that a mandatory requirement for PFR on its own is not a complete solution and may not be sufficient to meet the operational needs of the power system now and into the future. The Commission recognised that the mandatory approach would ideally be replaced or complemented by market or incentive based arrangements for PFR. To inform the development of such arrangements, the Commission considered that further work needed to be done to understand the power system requirements for maintaining good frequency control.[186]

181 NER Clause 5.20.B.4
182 NER Clause 5.20B.5
183 AEMO, Mandatory primary frequency response — Electricity rule change proposal, 16 August 2019, pp.26-28.
184 NER Cl 4.4.2(c1)
185 NER Cl 4.4.2A(b)
186 AEMC, *Mandatory primary frequency response — final determination*, 26 March 2020, p.24

Many stakeholders also expressed support for the development of market or incentive based mechanisms for PFR.[187] However, given the time needed to develop such arrangements, the Commission considered that it was not possible to implement incentive or market based arrangements at the same time as addressing the immediate system security needs identified by AEMO.

To reflect the interim nature of the mandatory arrangement on its own, the final rule included provisions for the Mandatory PFR requirement to sunset after three years on 4 June 2023.

A.2.4 Frequency control ancillary services (FCAS)

The NER includes a framework for the provision of eight market ancillary services for active power reserves and control of power system frequency.[188] These services, known collectively as frequency control ancillary services (FCAS), include the raise and lower regulation services, for the centrally controlled regulation of frequency under normal operating conditions, and the six raise and lower contingency services, for the provision of active power response following contingency events that result in a shortage or excess of generation.

Participants must register with AEMO to participate in each of the FCAS markets. Once registered, a service provider can participate in an FCAS market by submitting an appropriate FCAS offer or bid for that service. AEMO determines the amount of FCAS that is required to manage the power system frequency in accordance with the frequency operating standard. For each five-minute dispatch interval, the National Electricity Market dispatch engine enables sufficient FCAS in each market, and the price for each service is set by the highest enabled bid in each case. Providers of FCAS are paid for the amount of FCAS in terms of dollars per megawatt enabled per hour. That is, generators receive a payment irrespective of whether the service is required to be delivered. Where the service is required to be delivered, the generator also receives payment for any energy associated with the provision of the service.

Frequency control services in the NEM are referred to as either raise or lower services.

- A **raise service** is a service that acts to raise system frequency through the provision of additional active power delivery or the reduction in consumer demand.
- A **lower service** is a service that acts to lower system frequency through the reduction in active power delivery or the increase in consumer demand.

There are two types of **regulating FCAS**:[189]

1. Regulating raise service. Used to correct a minor drop in frequency.
2. Regulating lower service. Used to correct a minor rise in frequency.

These regulation services provide secondary frequency control that is centrally coordinated by AEMO's automatic generator control (AGC) system. The AGC monitors minor changes in the power system frequency and adjusts the output of units enabled to provide regulating

187 Submissions to the *PFR rule changes — consultation paper*, 19 September 2019: CS Energy, p. 2, Delta Electricity, p. 6, Neoen p. 1, Enel X, p. 8, IES, p.2, Enel GreenPower, p. 2, ARENA, p.3.

188 NER Clause 3.11.2(a).

189 NER Clause 3.11.2(a)

FCAS to correct small frequency deviations, and to correct the accumulated frequency error over time.[190]

There are six types of **Contingency FCAS** divided into raise and lower services at three different speeds of response and sustain time: fast slow and delayed. As such, there are six distinct contingency FCAS services:[191]

- Fast raise and lower services
- Slow raise and lower services
- Delayed raise and lower services

In accordance with the NER, AEMO specifies the requirements for each of the market ancillary services in its Market ancillary service specification (MASS).[192] The MASS sets out how the market arrangements for FCAS work, including the description and specification for each of the various products. The MASS includes a detailed description of each of the FCAS products along with the performance parameters and requirements which must be satisfied to register as a provider and participate in the market arrangements for the dispatch of these services. Under the MASS, potential market ancillary service providers are allocated a maximum quantity for each service they wish to provide as part of the registration process. The registered quantity is based on the unit's response to a standard frequency ramp for each of the contingency products. Valuation for each of the contingency services is based on the ability to respond over a set time frame as follows.

- Fast services (six-second raise and lower or R6/L6) — the ability to respond to a rapid change in system frequency within the first six seconds of a frequency disturbance. The standard response for an R6/L6 product reaches maximum delivery after six seconds before tapering off to zero after 60 seconds.[193]
- Slow services (sixty-second raise and lower or R60/L60) — the ability of the unit to respond to a rapid change in system frequency in the period between six and sixty seconds following a frequency disturbance. The standard response for an R60/L60 product reaches maximum delivery after sixty seconds before tapering off to zero after five minutes.[194]
- Delayed services (five-minute raise and lower or R5/L5) — the ability of the unit to respond to a rapid change in system frequency in the period between six seconds and five minutes following a frequency disturbance. The standard response for an R5/L5 product reaches maximum delivery after five minutes before tapering off to zero after ten minutes.[195]

The current service specifications for the contingency services are illustrated below in Figure A.2.

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190 This accumulated frequency error over time is known as accumulated time error, which is a measure of the cumulative sum of the difference between the actual power system frequency over time and the nominal system frequency of 50Hz.

191 NER Clause 3.11.2(a)

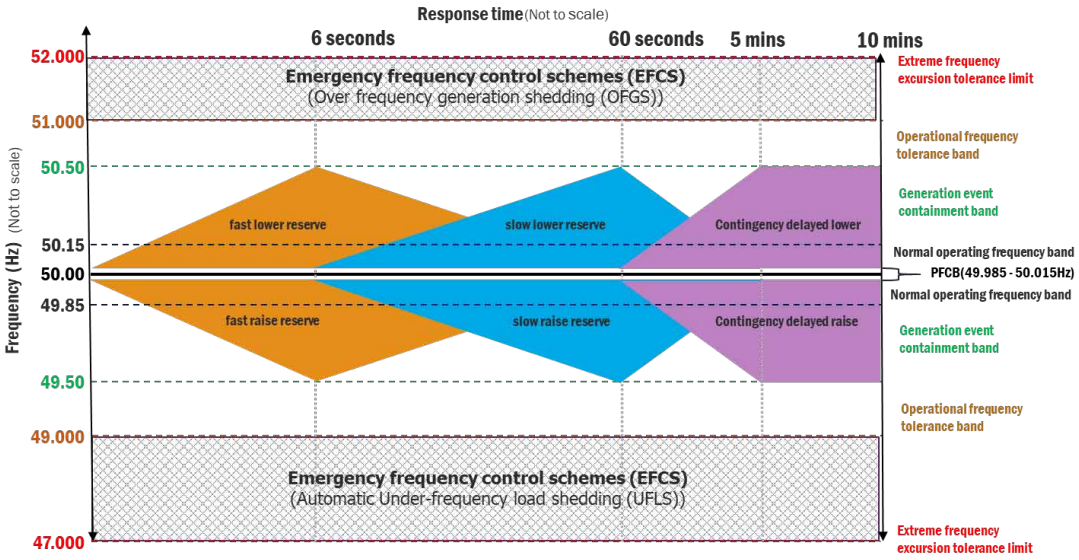
192 NER Clause 3.11.2(b)

193 AEMO, *Market ancillary service specification — V6.0*, 1 July 2020, pp.13-14.

194 Ibid. pp.17-18.

195 Ibid. pp.21-22.

Figure A.2: Contingency frequency response arrangements



Source: AEMC

Note: Based on the service specifications under AEMO's *Market ancillary service specification — V6.0*, published 1 July 2020.

Note: Shaded area denotes the indicative region of operation for Emergency frequency control schemes in the mainland NEM — further detail can be found in AEMO's 2020 *Power System Frequency Risk Review.*

FCAS market operation

In the NEM, FCAS is sourced from markets that operate in parallel to the wholesale energy market, with the dispatch outcomes in the energy and FCAS markets being optimised simultaneously so that total costs are minimised.

Participants must register with AEMO to participate in each distinct FCAS market. Once registered, a service provider can participate in an FCAS market by submitting an appropriate FCAS offer or bid for that service.

AEMO determines the amount of FCAS that is required to manage the power system frequency in accordance with the frequency operating standard. For each five minute dispatch interval, the National Electricity Market dispatch engine enables sufficient FCAS in each market, and the price for each service is set by the highest enabled bid in each case.

Providers of FCAS are paid for the amount of FCAS in terms of dollars per megawatt enabled per hour. That is, generators receive a payment irrespective of whether the service is required to be delivered. Where the service is required to be delivered, the generator also receives payment for any energy associated with the provision of the service.

Allocation of regulation service costs - Causer pays

The recovery of AEMO's payments to providers for regulating FCAS is based upon the "causer pays" methodology. This approach allocates regulation service costs to Market Generators Market Small Generation Aggregators and Market Customers based on the degree to which they contribute to the need for regulation services.

AEMO is responsible for preparing a procedure which sets out the process for the determination of contribution factors for each market participant for the allocation of regulation service costs. This procedure is known as the causer pays procedure.

Allocation of contingency service costs

The costs of contingency raise services are recovered from Market Generators, as these services are required to manage the loss of the largest generator on the system. The costs of contingency lower services are recovered from Market Customers, as these services are required to manage the loss of the largest load or transmission element on the system.

A.2.5 Emergency frequency control schemes (EFCS)

Emergency frequency control schemes are schemes that help restore power system frequency in the event of extreme power system events, such as the simultaneous failure of multiple generators and/or transmission elements. The operational goal of emergency frequency control schemes is to act automatically to arrest any severe frequency deviation prior to breaching the extreme frequency excursion tolerance limit, and hence avoid a cascading failure and widespread blackout.

Traditional emergency frequency control schemes operate via frequency sensing relays that detect a frequency deviation beyond a predefined set point and act to disconnect any connected generation or load behind the relay. However, schemes can be set up to operate based on the occurrence of a particular contingency event, such as the failure of an interconnector. The installation and operation of emergency frequency control schemes is the responsibility of the relevant transmission network service provider (TNSP), while AEMO coordinates the overall performance of the schemes as part of its system security responsibility.[196]

AEMO is required to undertake a *Power system frequency risk review* at least every two years.[197] Through the *Power system frequency risk review* AEMO must assess the risks posed to the power system by non-credible contingency events and review the appropriateness of the mitigation measures in place, including the need for the declaration of protected events or changes to Emergency frequency control schemes.

196 NER cl 4.2.6(c)
197 NER cl 5.20A.1

A.3 Link between inertia and contingency FCAS

AEMO determines the requirement for contingency FCAS volumes based on an assessment of the largest credible system risk adjusting for the impact of load relief.[198] During system intact operation, the current approach does not explicitly recognise a link between the required volumes of frequency responsive reserves and the amount of inertia on the power system.

However, AEMO's recent analysis through its Renewable Integration Study demonstrates that an operational trade-off exists between inertia levels and the requirement for fast responding contingency reserves.[199]

As part of its *Frequency control work plan*, that was published in September 2020, AEMO has indicated that it intends to implement dynamic constraints for contingency FCAS volumes in Q3/Q4 2021. These new constraints are intended to recognise the link between R6 requirement and the level of inertia for system intact operation of the mainland power system.[200] This will more explicitly link inertia and frequency arrangements.

The focus of Infigen's rule change request on Fast frequency response ancillary service markets is the development of arrangements to provide for FFR to help manage low inertia operation of the power system. However, the Commission notes that separate arrangements for valuation of inertia are being considered through the ESB's essential system services market design initiative. This approach is based on the understanding that inertia is a separate power system variable that requires a separate regulatory arrangement.[201]

The Commission invites stakeholder feedback on how an FFR arrangement may interact with existing and future arrangements for inertia and whether inertial response should be valued (implicitly or explicitly) through an FFR arrangement.

The interaction between inertia and FFR is demonstrated by AEMO's approach to the recent declaration of an inertia shortfall in South Australia as described in Box 1.

BOX 1: **AEMO'S INERTIA SHORTFALL DECLARATION FOR SA – 2020 - 2022**

AEMO published a *Notice of South Australia inertia requirements and shortfall* for the SA region on 27 August 2020. As part of the notification AEMO indicated its intention to coordinate with ElectraNet for the provision of FFR through contractual arrangements to help maintain the SA region in a secure operating state when there is a credible risk of separation and during islanded operation. This notification was made under the NER inertia framework which is described in Appendix B.2.

198 The variation of demand due to a change in frequency is known as load relief. When the frequency falls, synchronous motors, such as pumps and compressors, connected to the power system slow down and consume less power. This results in a net reduction in system load. Conversely, if the system frequency increases, the demand for power will increase.

199 AEMO, *Renewable Integration Study – Stage 1 report*, March 2020, p.47.

200 AEMO, *Frequency control work plan*, 25 September 2020, p.11.

201 AEMO, Fast frequency response in the NEM - Working paper, 21 August 2017, p.4.

This is the second shortfall notice for SA and applies immediately out to 2021-22.

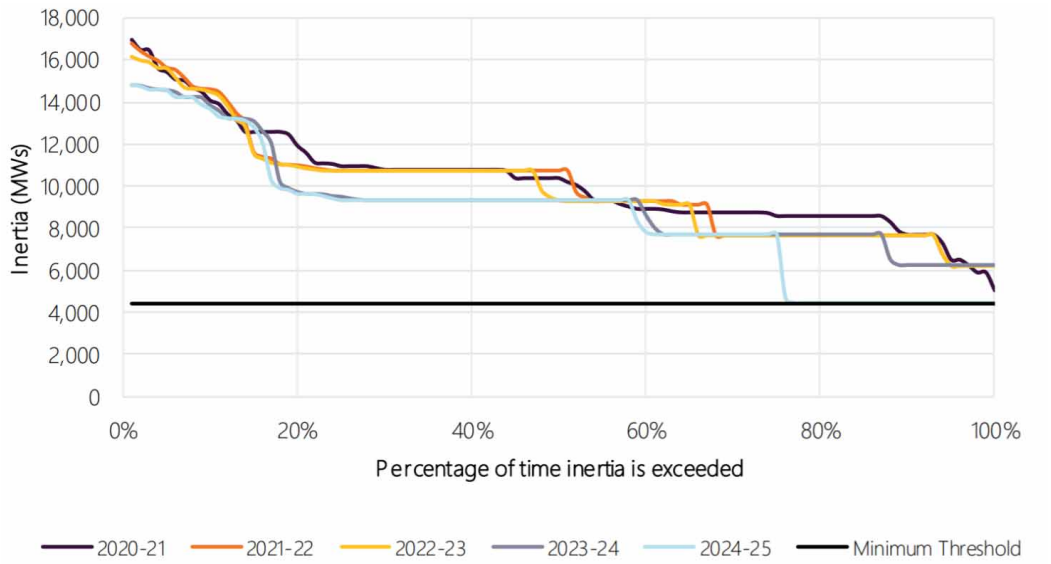
AEMO proposed to resolve the shortfall through the provision of FFR as inertia support activities, which would act to adjust the secure operating level of inertia. This was the first time that AEMO proposed to use the inertia support activities provisions in the NER for the procurement of FFR.

The shortfall notification was based on AEMO's revised assessment of the SA inertia requirements over two stages covering 2020-21 and 2021-22.

- Stage 1 is for the islanded operation of SA prior to the commissioning of four synchronous condensers by ElectraNet expected in Q2 2021.
- Stage 2 is for the islanded operation of SA following the commissioning of the synchronous condensers

AEMO's revised assessment determines that a shortfall exists if the ninety-ninth percentile level of inertia does not exceed the required amount. AEMO's projection of inertia levels for SA are shown in figure 2.2.

Figure A.3: Projected inertia in the South Australia region 2020 - 2025



Source: AEMO, *Source: Notice of South Australia inertia requirements and shortfall,* Source: August 2020, p.21.

AEMO determined that the minimum threshold level of inertia for SA will remain unchanged at 4,400MWs and that this level of inertia is likely to be met for the period to 2024-25.

However, based on this revised assessment, AEMO has declared an immediate shortfall for the SOLI in SA. The shortfall applies for 2020-21 and is predicted to increase for the period 2021-22. AEMO has not made any forecasts of the inertia requirements in SA beyond 2022, due to high levels of uncertainty regarding the impact of distributed PV beyond this time-frame.

In light of the constraints on the secure outcomes for operation of the SA island, AEMO

describes how the SOLI can be adjusted through the addition of FFR being provided by ElectraNet as an inertia support activity, with 115MW of FFR required to satisfy the SOLI in stage 1 (2020-2021) and 200MW of FFR required in stage 2 (2021-2022). AEMO has requested that ElectraNet make available the required inertia support activities (FFR) for stage 1 by October 2020 and for stage 2 by 31 July 2021.

Source: AEMO, *Notice of South Australia inertia requirements and shortfall,* August 2020.

B LEGAL REQUIREMENTS UNDER THE NEL

This appendix sets out the relevant legal requirements under the NEL for the AEMC to make this draft rule determination.

B.1 Draft rule determination

In accordance with s.99 of the NEL the Commission has made this draft rule determination in relation to the rule proposed by Infigen Energy Ltd.

The Commission's reasons for making this draft rule determination are set out in section 3.4.

A copy of the draft rule is attached to and published with this draft rule determination. Its key features are described in section 3.1 and the Commission's analysis in relation to each of the elements of the draft rule is discussed in chapter 4.

B.2 Power to make the rule

The Commission is satisfied that the draft rule falls within the subject matter about which the Commission may make rules. The draft rule falls within s. 34 of the NEL as it relates to the operation of the national electricity market and the operation of the national electricity system for the purposes of the safety, security and reliability of that system.

B.3 Commission's considerations

In assessing the rule change request the Commission considered:

- it's powers under the NEL to make the rule
- the rule change request
- submissions received during first round consultation
- the Commission's analysis as to the ways in which the proposed rule will or is likely to, contribute to the NEO.

There is no relevant Ministerial Council on Energy (MCE) statement of policy principles for this rule change request.[202]

The Commission may only make a rule that has effect with respect to an adoptive jurisdiction if satisfied that the proposed rule is compatible with the proper performance of Australian Energy Market Operator (AEMO)'s declared network functions.[203] The draft rule is compatible with AEMO's declared network functions because it leaves those functions unchanged.

202 Under s.33 of the NEL the AEMC must have regard to any relevant MCE statement of policy principles in making a rule. The MCE is referenced in the AEMC's governing legislation and is a legally enduring body comprising the Federal, State and Territory Ministers responsible for energy. On 1 July 2011, the MCE was amalgamated with the Ministerial Council on Mineral and Petroleum Resources. The amalgamated council is now called referred to as the Energy ministers meeting.

203 Section 91(8) of the NEL.

B.4 Civil penalties

The Commission cannot create new civil penalty provisions. However, it may recommend to the COAG Energy Council that new or existing provisions of the NER be classified as civil penalty provisions.

The draft rule does not amend any clauses that are currently classified as civil penalty provisions under the NEL or National Electricity (South Australia) Regulations. The Commission does not propose to recommend to the COAG Energy Council that any of the proposed amendments made by the draft rule be classified as civil penalty provisions.

B.5 Conduct provisions

The Commission cannot create new conduct provisions. However, it may recommend to the COAG Energy Council that new or existing provisions of the NER be classified as conduct provisions.

The draft rule does not amend any rules that are currently classified as conduct provisions under the NEL or National Electricity (South Australia)Regulations. The Commission does not propose to recommend to the COAG Energy Council that any of the proposed amendments made by the draft rule be classified as conduct provisions.

C TECHNICAL AND ECONOMIC ANALYSIS OF THE BENEFITS OF NEW FFR ARRANGEMENTS

This appendix gives a summary to AEMO's technical analysis and economic analysis undertaken by the AEMC of the benefits of new FFR arrangements.

C.1 Summary of AEMO's technical analysis

Recently published analysis by AEMO in its *Renewable Integration Study* helps to expand on and confirm the problem statement put forward by Infigen in its rule change request. This analysis helps to further describe the emerging problems related to operating the NEM in the absence of arrangements to provide for FFR.

This analysis shows that, based on the continuation of current market and regulatory arrangements the following impacts will occur to the power system's operation:

- **System inertia is projected to continue to decline**

  AEMO's 2020 Integrated System Plan (ISP) projects declining inertia levels in the national electricity system over the period 2020 through 2035. The projected inertia duration curves under the ISP central and step-change scenario are shown below in Figure C.1. The figure also includes an unbroken black horizontal line at 45,350MWs which represents the expected level of inertia provided through the existing minimum system strength arrangements.[204]

  A dashed line at 65,000MWs indicates AEMO's proposed initial inertia safety net.[205] AEMO has proposed further investigation of an inertia safety net for system intact operation in the order of 55,000MWs to 65,000MWs. AEMO considers that an inertia safety net could be progressively revised as operational experience is built and additional measures are put in place to ensure system security at lower levels of system inertia.[206]

- **The size of frequency deviations following contingency events is expected to increase**

  Under reduced inertia operation, the frequency nadir following a contingency event that results in a loss of generation is expected to become increasingly deep.[207] In the absence of corrective action, AEMO's analysis shows that for mainland inertia levels below 40,000MWs the frequency nadir following the disconnection of a 750MW generator would approach 49.0Hz.[208] 49.0Hz is the lower limit of the containment band specified in the

204 The sum of the regional requirements for the minimum threshold level of inertia for the mainland regions, which applies at all times, is 39,800MWs. The sum of the regional requirements for secure operating level of inertia for the mainland regions is 49,800MWs. However, this requirement only applies on a regional basis during islanded operation, or when there is a credible risk of islanding. It does not impact on system intact operation. Inertia requirements sourced from: AEMO, *Renewable Integration Study – Stage 1 report – Appendix B; Frequency control*, March 2020, p.7.

205 AEMO, *Renewable Integration Study — stage 1 report — Appendix B: Frequency control*, 30 April 2020, p.7.

206 AEMO, *Renewable Integration Study – Stage 1 report*, March 2020, p.10, 47-48.

207 The term frequency nadir refers to the lowest value of system frequency immediately following a system disturbance.

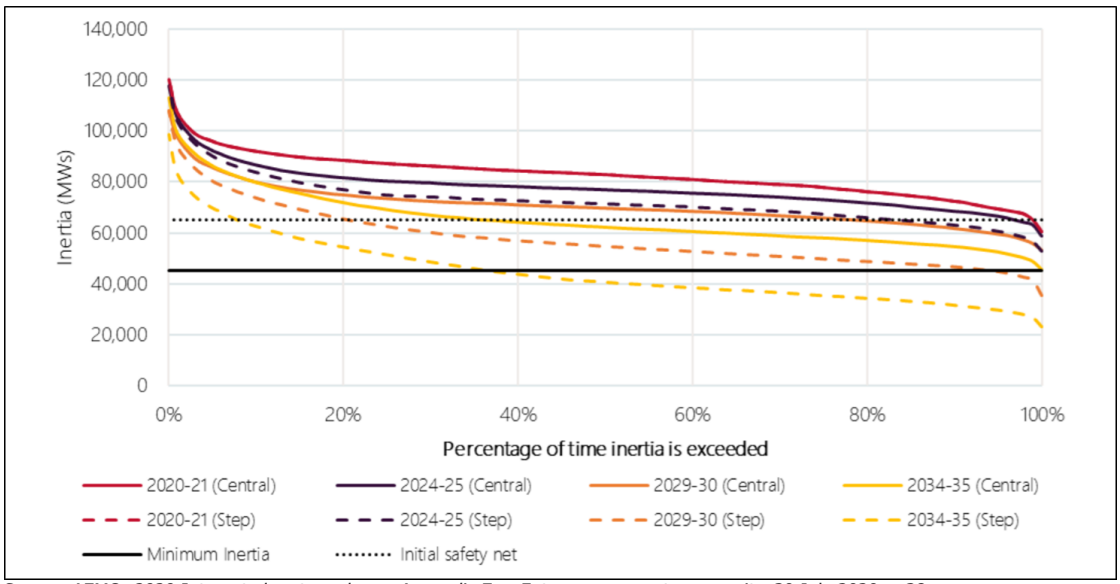
208 The frequency operating standard specifies that the system frequency for the mainland power system be contained within the range 49.5Hz – 50.5Hz for a credible contingency event relating to a generation or load event. The containment band for a credible network event in the mainland NEM is 49.0Hz – 51.0Hz.

frequency operating standard for a credible contingency event and beyond this point under frequency load shedding commences to help re-balance supply and demand. The impact of reducing system inertia on frequency nadir is demonstrated in Figure C.2.

- **Increased fast raise FCAS will be required to manage system frequency**

  AEMO's stage 1 report for its Renewable Integration Study shows that for low inertia system operation in the absence of FFR, increased quantities of fast (R6) contingency services will be required to maintain the frequency within the containment bands specified in the frequency operating standard. AEMO's analysis also shows that the provision of faster responding frequency reserves can mitigate the requirement for increased fast (R6) reserves. This is demonstrated in Figure C.3. The AEMC has undertaken additional analysis to explore this impact further. The results of the AEMC analysis are presented in appendix C.2.

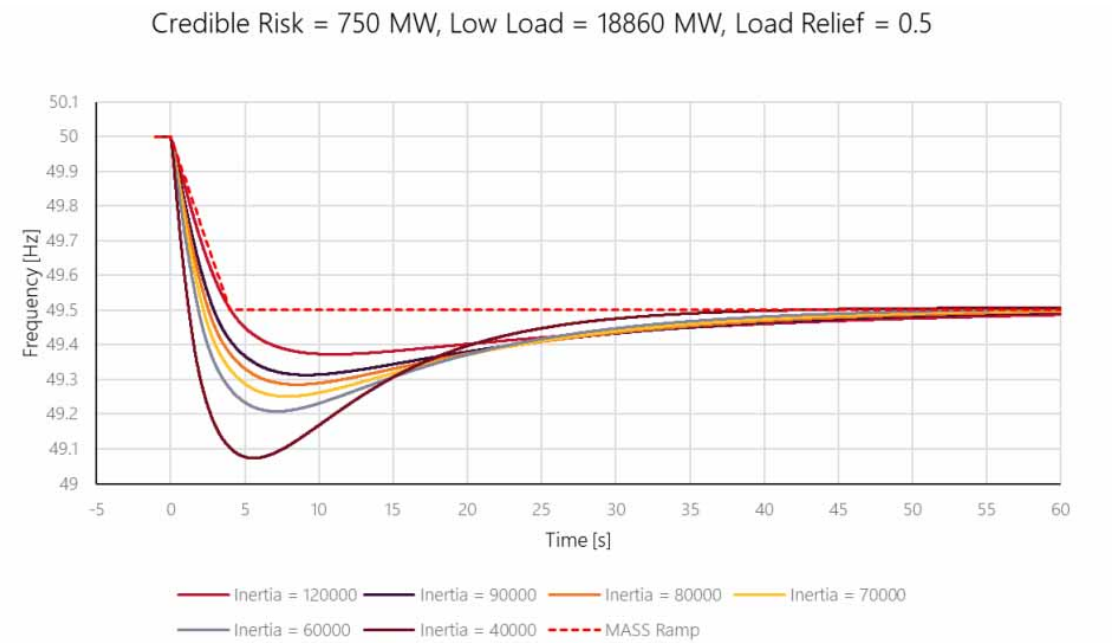
Figure C.1: AEMO ISP projected inertia duration curves for the NEM



Source: AEMO, *2020 Integrated system plan — Appendix 7 — Future power system security*, 30 July 2020, p.38

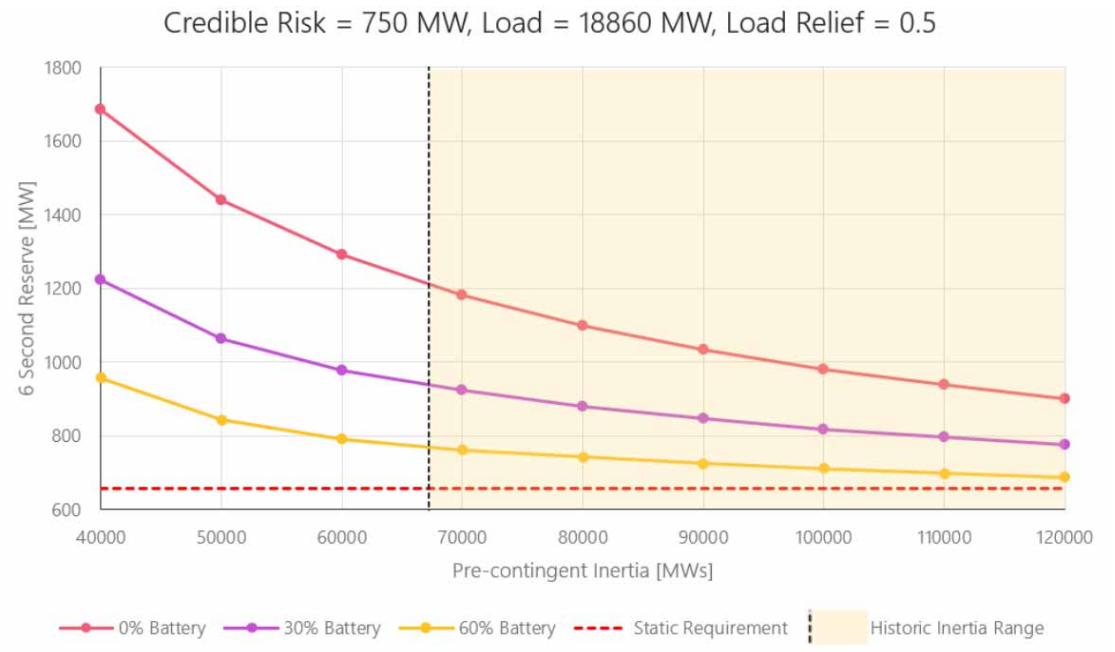
Note: The method and assumptions AEMO's calculation of projected system inertia in the NEM are set out in section A.9.4.4.6 of the 2020 ISP. AEMO, 2020 Integrated system plan — Appendix 9 — ISP methodology, 30 July 2020, pp.24-25.

Figure C.2: Impact of decreased system inertia on frequency nadir



Source: AEMO, *Renewable Integration Study – Stage 1 report - Appendix B*; Frequency control, March 2020, p.24.

Figure C.3: Requirement for 6 second raise service vs inertia and the impact of faster response

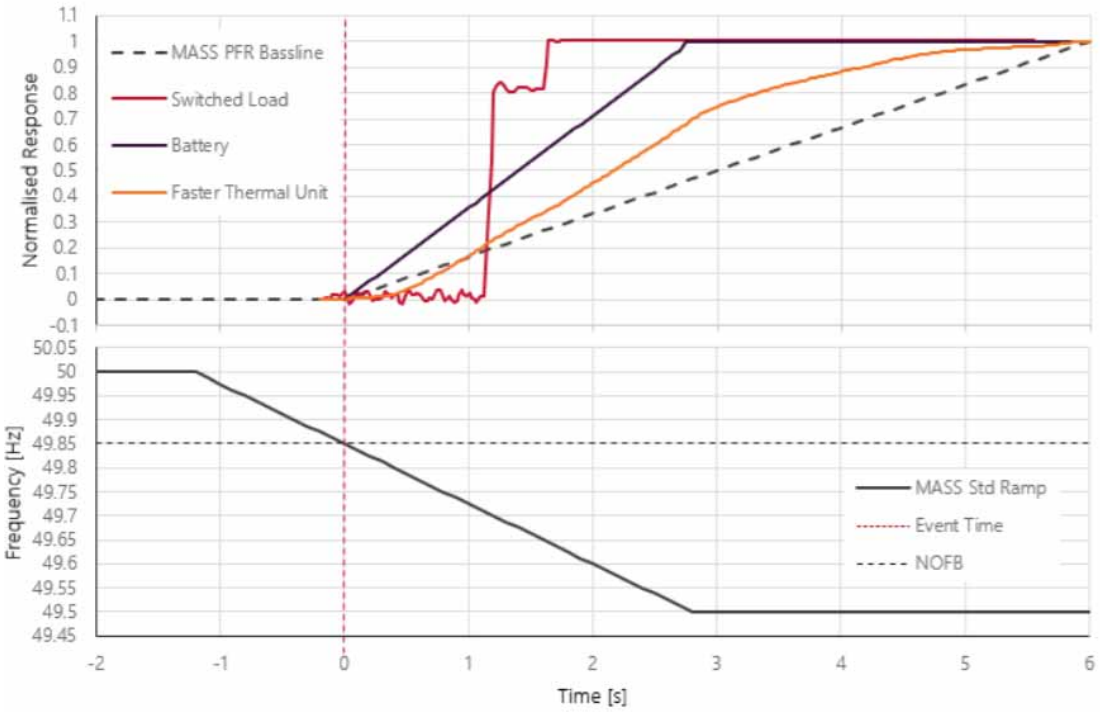


Source: AEMO, *Renewable Integration Study – Stage 1 report*, March 2020, p.47.

Note: Figure show the impact of increased proportion of R6 requirement provided by battery storage on the R6 reserve requirement. Battery response under the R6 service specification is expected to be faster than standard response.

Figure C.4 shows the typical unit response for different providers of fast raise FCAS as used by AEMO in its analysis for the *Renewable Integration Study — stage 1 report.* The results in Figure C.3 show how increasing the proportion of faster six-second (R6) contingency response that is provided from batteries, can mitigate the need for increased fast raise service. It is expected that FFR response provided through an explicit FFR mechanism could be even more effective at mitigating the need for increased fast FCAS to manage system frequency during low inertia operation.

Figure C.4: Indicative unit response to standard frequency ramp



Source: AEMO, *Renewable Integration Study – Stage 1 report - Appendix B*: Frequency control, March 2020, p.35.

C.2 Economic analysis

The Commission has undertaken analysis to describe the potential increase in requirement for fast raise services in the NEM under a future where the level of inertia in the power system is decreasing but where there are no new arrangements for provision of FFR. The analytical method is based on the relationships developed by AEMO through its Renewable Integration Study between the dynamic requirement for R6 and inertia as shown in Figure C.3 to the projected inertia levels from the ISP central and step change scenarios shown in Figure C.1.

The following assumptions underpin this analysis:

- Projected system inertia is for the mainland NEM, excluding Tasmania
- Largest credible risk is static at 750MW
- System load is static at 18 680MW – RIS low load scenario
- System load relief is static at 0.5%

The analysis is not expected to be an accurate forecast of the future state of the power system, but instead it provides an indication of the general trends with respect to system inertia and the requirement for fast responding contingency reserves. This is informative in considering the materiality of the issues raised by Infigen in its rule change request.

The projected decrease in mainland NEM inertia levels is likely to be limited by AEMO's proposal to consider the implementation of an inertia safety net for system intact operation in the order of 55,000MWs to 65,000MWs. In making this proposal, AEMO noted that historical levels of inertia in the mainland NEM have not been below 68,000MWs. AEMO considers that the transition to lower levels of system inertia requires a staged approach, through which an inertia safety net would be progressively revised as operational experience is built and additional measures are put in place to ensure system security.[209] AEMO intends to further consider the potential benefits of implementing an inertia safety net through item 10 of AEMO's *Frequency control work plan*, which is scheduled to commence in March 2021.[210] The AEMC will work with AEMO to consider the role of the regulatory framework in relation to this.

Figure C.5 shows the projected increase in dynamic R6 requirements relative to the static requirement of 655.7MW for the assumed system conditions listed above. The static requirement is based on the value set out in AEMO's *Renewable Integration Study – stage 1 report* for the calculation assumptions listed above.[211] The static requirement represents the minimum required replacement energy to stabilise system frequency based on the assumed system conditions.[212] The dynamic requirement recognises the dynamic nature of frequency response, including the impact of system inertia and delays in delivery of replacement energy. Faster responding active power response acts to reduce the gap between the dynamic and the static requirement. The shaded cells in Figure C.5 show projected future states that result from system inertia levels below AEMO's proposed initial inertia safety net of 65,000MWs.

However, it is unlikely that these future states will come to pass in the event that there are remedial measures implemented through new market arrangements for FFR and/or inertia. They are included to provide a broader context of the relationship between inertia and fast responsive reserves.

Figure C.5: Projected increase in R6 requirements - ISP central and step change scenarios

	2020-21	2024-25	2029-30	2034-35	2039-40
Percentage change - R6 requirement – ISP central scenario	168%	174%	184%	194%	241%
Percentage change - R6 requirement - ISP step change scenario	167%	181%	210%	241%	254%

Source: AEMC analysis

Note: Based on the projected inertia levels under the 2020 ISP central and step change scenarios combined with the relationship between inertia and the dynamic R6 requirement from AEMO's — *Renewable Integration Study — stage 1*.

209 AEMO, *Renewable Integration Study – Stage 1 report*, March 2020, p.10, 47-48.

210 AEMO, Frequency control work plan, 25 September 2020, p.11.

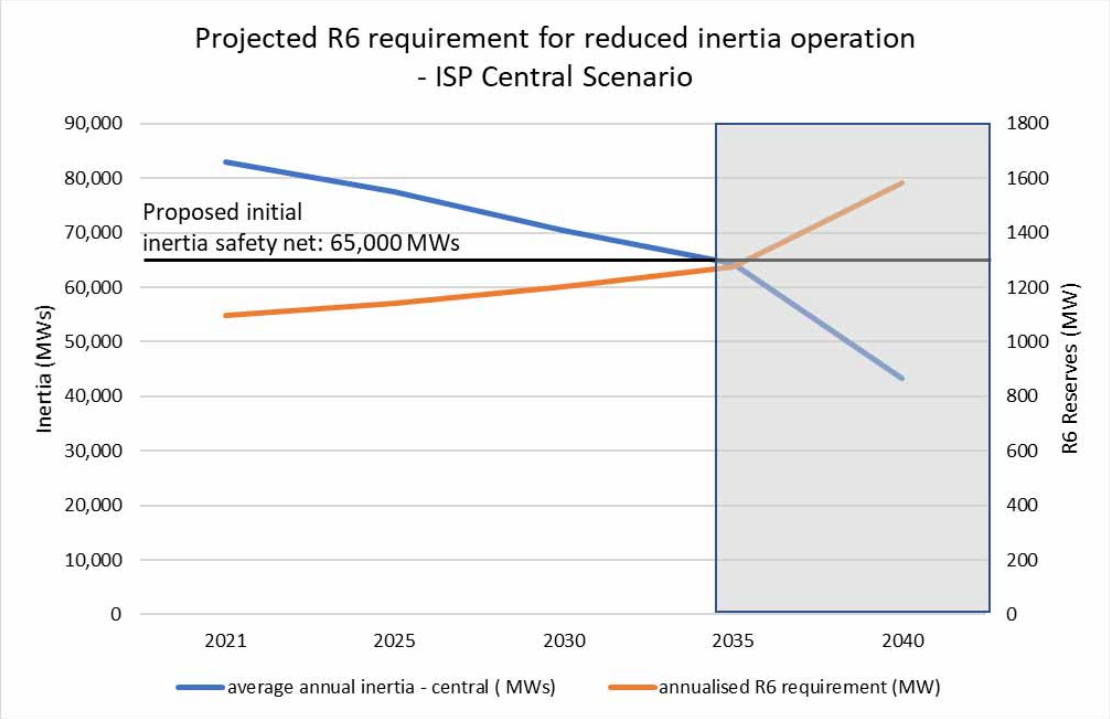
211 AEMO, *Renewable Integration Study – Stage 1 report - Appendix B*: Frequency control, March 2020, p.21-22.

212 Ibid. p.21.

The results of this analysis for the mainland NEM are shown in Figure C.6 and Figure C.7 below. In each case a black line is included in the chart showing the proposed initial value of 65,000MWs for an inertia safety net. As above, the projections that show mainland average inertia levels below 65,000MWs are shaded grey, indicating that the confidence over these projections is low.

Figure C.6 shows the projected average annual inertia and corresponding R6 values based on the ISP central scenario. Under this scenario the average annual inertia level reduces steadily from the current level of 83,000MWs in 2020-21 to around 70,000MWs in 2029-30. In the absence of arrangements to provide for additional FFR or inertia, the R6 requirement would be expected to rise from the current static level of 655.7MW for a 750MW contingency under low load conditions, to around 1200MW in 2029-30. Based on the 5-year average historical annual revenues for R6 services this could translate into increased costs for R6 services in the order of $60 Million per annum by 2030. The historic average requirements for R6 and annual revenues are included for reference in Figure C.8.

Figure C.6: Projected R6 requirement – ISP central scenario



Source: AEMC analysis

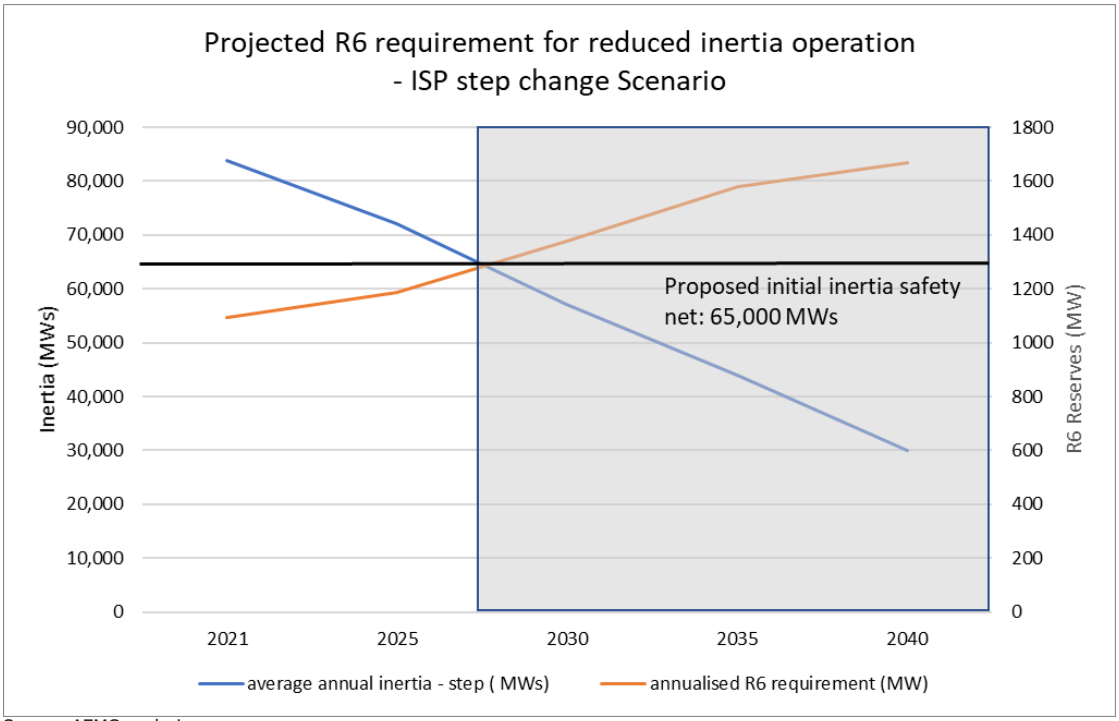
Note: Based on the projected inertia levels under the 2020 ISP central scenario combined with the relationship between inertia and the dynamic R6 requirement from AEMO's — *Renewable Integration Study — stage 1*.

The static level represents the minimum R6 requirement for the given system conditions, that is it is based on the contingency size and the impact of load relief. In theory FFR could help reduce the R6 requirement toward the static level. In theory, the dispatch of R6, FFR and inertia could be co-optimised to deliver efficient outcomes based on the relative price of each

service and an improved understanding of system operation supported by dynamic contingency analysis.

Figure C.6 shows the projected average annual inertia and corresponding R6 values based on the ISP step change scenario. Under this scenario the average annual inertia level decreases more quickly from the current level of 83,000MWs in 2020-21 to around 57,000MWs in 2029-30. In the absence of arrangements to provide for additional FFR or inertia, the R6 requirement would be expected to rise from the current static level of 655.7MW for a 750MW contingency under low load conditions, to around 1200MW five years earlier in 2024-25.

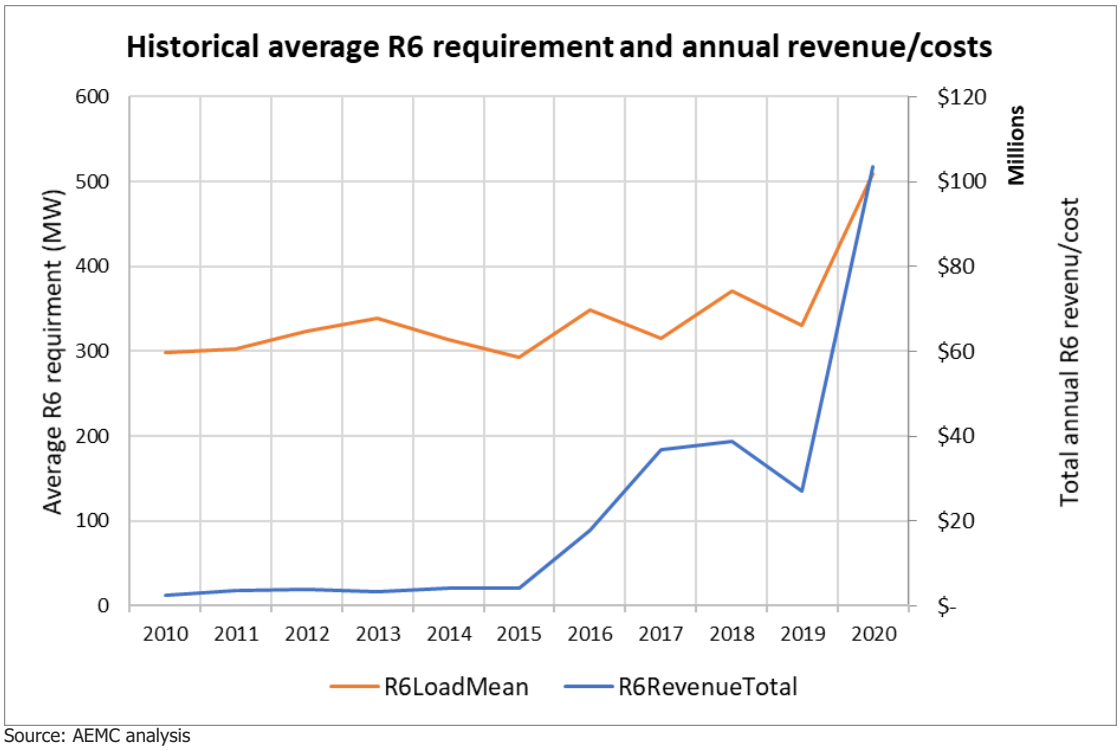
Figure C.7: Projected R6 requirement — ISP step change scenario



Source: AEMC analysis

Note: Based on the projected inertia levels under the 2020 ISP step change scenario combined with the relationship between inertia and the dynamic R6 requirement from AEMO's — *Renewable Integration Study — stage 1*.

Figure C.8: Average R6 requirement and annual revenue 2010 - 2020



Source: AEMC analysis
Note: Based on data from AEMO's Market management system(MMS) database.

D HISTORY OF FAST FREQUENCY RESPONSE

The *System security market frameworks review* was initiated by the Commission in July 2016 to consider changes to the regulatory frameworks to support the current shift towards new forms of generation in the NEM. The focus of the review was on addressing priority issues to allow AEMO to continue to maintain power system security as the market transitions. The final report for the *System security market frameworks review* made a number of recommendations that were largely subsequently actioned, which sought to address a number of issues related to frequency arrangements.[213] One of these recommendations included the consideration of how to incorporate FFR services into the FCAS market arrangements.

Subsequently, the AEMC commenced the *Frequency control frameworks review* in July 2017 to explore changes to the market and regulatory frameworks that may be required to meet the challenge of maintaining effective frequency control arising from, and harness the opportunities presented by, the changing generating mix in the power system. In relation to the progression of the FFR recommendation from the *System security market frameworks review*, the *Frequency control frameworks review* recommended action be undertaken by AEMO in relation to how new technologies such as FFR may be valued under the AEMO's Market Ancillary Service Specification (MASS).[214]

213 AEMC, System security market frameworks review - Final report, 27 June 2017. Available at: https://www.aemc.gov.au/marketsreviews-advice/system-security-market-frameworks-review

214 AEMC, Frequency control frameworks review, 26 July 2018, p.xii.