Amendment of the Market Ancillary Service Specification (MASS) – Very Fast FCAS

Draft Report and Determination

Published: July 2022

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New South Wales | Queensland | South Australia | Victoria | Australian Capital Territory | Tasmania | Western Australia

Australian Energy Market Operator Ltd ABN 94 072 010 327

Notice of Second Stage Consultation – Amendment of the Market Ancillary Service Specification (MASS) – Very Fast FCAS

National Electricity Rules – Rule 8.9

Date of Notice: [22 July 2022]

This notice informs all Registered Participants and interested parties (Consulted Persons) that AEMO is commencing the second stage of its consultation on amendments to the Market Ancillary Service Specification (MASS) to accommodate two new markets for Very Fast FCAS.

This consultation is being conducted under clauses 3.11.2 and 11.140.2 of the National Electricity Rules (NER), in accordance with the Rules consultation requirements detailed in rule 8.9 of the NER.

Invitation to make Submissions

AEMO invites written submissions on this Draft Report and Determination (Draft Report).

Please identify any parts of your submission that you wish to remain confidential, and explain why. AEMO may still publish that information if it does not consider it to be confidential, but will consult with you before doing so.

Consulted Persons should note that material identified as confidential may be given less weight in the decision-making process than material that is published.

Closing Date and Time

Submissions in response to this Notice of Second Stage of Rules Consultation should be sent by email to mass.consultation@aemo.com.au, to reach AEMO by 5.00pm (Melbourne time) on 19 August 2022.

All submissions must be forwarded in electronic format (both pdf and Word). Please send any queries about this consultation to the same email address.

Submissions received after the closing date and time will not be valid, and AEMO is not obliged to consider them. Any late submissions should explain the reason for lateness and the detriment to you if AEMO does not consider your submission.

Publication

All submissions will be published on AEMO's website, other than confidential content.

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Executive summary

The publication of this Draft Report and Determination (Draft Report) commences the second stage of the Rules consultation process conducted by AEMO to amend the market ancillary service specification (MASS) under the National Electricity Rules (NER) to accommodate two new markets for very fast frequency control ancillary services (Very Fast FCAS) as required by the National Electricity Amendment (Fast frequency response market ancillary service) Rule 2021 No. 84 (Amending Rule).

AEMO commenced this consultation by publishing an Issues Paper that proposed a specification with the following attributes:

- 1-second response time.
- 6-second total timeframe.
- Raise/Lower reference frequency at ±0.5 Hz for the Mainland and ±2 Hz for Tasmania, in line with other, comparable services, known as Contingency FCAS.
- An assumed frequency ramp rate of 1 Hz/s.

Following an industry forum on 19 May 2022 and, in response to queries raised by Consulted Persons, AEMO also published an Addendum to the Issues Paper on 7 June 2022.

AEMO received 13 valid written submissions, which largely addressed the questions posed by AEMO in its Issues Paper and Addendum. One late submission was received and will be considered in the next stage of this consultation.

At a high level, the majority of submissions were supportive of AEMO's proposals for the creation of Very Fast FCAS markets.

Of note was the matter of how sampling rates for FCAS control systems appeared to be adjusted by some to match measurement sampling rates. AEMO proposes to address this by clearly specifying a different scan rate for control systems.

There was much commentary on the University of Melbourne's analysis of assessment errors on measurement sampling rate. To expand the scope of independent advice in this consultation, AEMO engaged a metering expert, Michael Guy, to provide additional expertise on the topic of metering. Based on his recommendations, AEMO proposes to introduce requirements for each type of FCAS measurement equipment to be certified to the IEC 61557-12 standard.

AEMO also proposes to address a long-standing outcome of the MASS' measurement methodology, known as the 'multiplier effect', which results in some FCAS Facilities being registered for participation in the Contingency FCAS markets at levels that are significantly higher than 100% of their capacity. A number of submissions on this issue objected to this change. In response, AEMO conducted further analysis to demonstrate the exacerbation of the discrepancy between the amount of FCAS enabled and that delivered in the case of Very Fast FCAS. As a result, AEMO proposes to amend the MASS to reflect the objective that the amount of FCAS enabled and that delivered be as close to identical as possible.

Matters that AEMO proposes to defer until further operational experience has been gained include the imposition of a limit on the use of switching controllers in the Very Fast FCAS markets, and whether the overload capacity of an FCAS Facility should be counted as Very Fast FCAS.

Consistent with recent practice, AEMO is also taking the opportunity in this consultation to make further drafting improvements to make the information in the MASS easier to find and understand.

After considering the submissions received and the results of the University of Melbourne's analysis and advice from Michael Guy, AEMO's draft determination is to amend the MASS in the form published with this Draft Report.

Consistent with the Amending Rule, the amended MASS will take effect on 9 October 2023, which is the expected date for commencement of the Very Fast FCAS markets.

1. Stakeholder consultation process

As required by clause 3.11.2 of the NER, AEMO is consulting on amendments to the Market Ancillary Service Specification (MASS) to accommodate two new markets for Very Fast FCAS in accordance with the Rules consultation process in rule 8.9.

AEMO's indicative timeline for this consultation is outlined below. Future dates may be adjusted depending on the number and complexity of issues raised in submissions.

Deliverable	Indicative date
Notice of first stage consultation and Issues Paper published	2 May 2022
Addendum to Issues Paper published	7 June 2022
First stage submissions closed	21 June 2022
Draft Report & Notice of second stage consultation published	22 July 2022
Submissions due on Draft Report	19 August 2022
Final Report published	30 September 2022

The publication of this Draft Report marks the commencement of the second stage of consultation.

Note that there is a glossary of terms used in this Draft Report at Appendix A.

2. Background

2.1. NER requirements

AEMO is required by clause 3.11.2(b) of the National Electricity Rules (NER) to make and publish a market ancillary service specification (MASS), which AEMO may subsequently amend at any time subject to the rules consultation process in rule 8.9.

2.2. Context for this consultation

In July 2021, the Australian Energy Market Commission (AEMC) published the National Electricity Amendment (Fast frequency response market ancillary service) Rule 2021 No. 84 (Amending Rule), which introduces two new market ancillary services (FCAS) to help control power system frequency and keep the power system secure. These new services are the very fast lower service and very fast raise service (collectively, Very Fast FCAS).

The Amending Rule requires AEMO to amend and publish the MASS by 19 December 2022, with the amended MASS to take effect on 9 October 2023.

As for all existing FCAS, the MASS needs to incorporate:

- A detailed description of Very Fast FCAS in accordance with clause 3.11.2(b)(1) of the Amending Rule.
- The performance parameters and requirements for a service to qualify as Very Fast FCAS, and to be met when Very Fast FCAS is delivered, each in accordance with clause 3.11.2(b)(2) of the NER.

2.3. First stage consultation

AEMO issued a Notice of First Stage Consultation[1] on 2 May 2022 and an Issues Paper[2] that examined relevant issues and proposed a specification for Very Fast FCAS.

AEMO also held a public forum on 19 May 2022 and met with Rheem & CET representatives on 17 June 2022 to address their questions on the Issues Paper.

Following an industry forum on 19 May 2022 and, in response to queries raised by Consulted Persons, AEMO also published an Addendum[3] to the Issues Paper on 7 June 2022 after conducting additional modelling of Very Fast FCAS options with increased FCAS volumes.

AEMO received 13 valid written submissions in the first stage of consultation. One late submission was received from Viotas and will be considered in the next stage of the consultation.

Copies of all written submissions, minutes of meetings and issues raised in forums (excluding any confidential information) have been published on AEMO's website at: https://aemo.com.au/consultations/current-and-closed-consultations/amendment-of-the-mass-very-fast-fcas.

3. Summary of material issues

Appendix B lists all issues arising from the Issues Paper raised by Consulted Persons. The key material issues arising from the proposal and raised by Consulted Persons are summarised in the following table and discussed in section 4:

No.	Issue	Raised by
1	Market Design	AEMO, Enel X, Iberdrola Australia, Rheem & CET, Tesla
2	Key Parameters for Very Fast FCAS	AEMO, Akaysha Energy, Delta Electricity, Enel X, EnergyAustralia, Iberdrola Australia, Rheem & CET, Shell Energy, sonnen, Tesla
3	Capability of different Technologies to deliver Very Fast FCAS	AEMO, Akaysha Energy, Delta Electricity, Enel X, Evergen, Iberdrola Australia, Rheem & CET, sonnen, Tesla
4	Control System Requirements	AEMO, Akaysha Energy, Delta Electricity, Enel X, Iberdrola Australia, Rheem & CET, sonnen, Tesla
5	Verification and Measurement Requirements	AEMO, Delta Electricity, Enel X, Evergen, Iberdrola Australia, Ready.Energy, Reposit, Rheem & CET, Shell Energy, sonnen, Tesla
6	Overload Capacity	AEMO, Akaysha Energy, Delta Electricity, EnergyAustralia, Iberdrola Australia, Tesla
7	Impact on other FCAS	AEMO, Akaysha Energy, Delta Electricity, Enel X, EnergyAustralia, Iberdrola Australia, Rheem & CET, sonnen, Tesla
8	Revision to FCAS Measurement	AEMO, Akaysha Energy, Enel X, EnergyAustralia, Iberdrola Australia, sonnen
9	Contingency Event Time	AEMO, Akaysha Energy, Delta Electricity, EnergyAustralia, Iberdrola Australia, Shell Energy,

[1] Available at https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2022/amendment-of-the-mass/notice-of-first-stage-consultation.pdf?la=en.
[2] Available at https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2022/amendment-of-the-mass/mass-issues-paper.pdf?la=en.
[3] Available at: https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2022/amendment-of-the-mass/mass-issues-paper-addendum-1.pdf?la=en.

4. Discussion of material issues

4.1. Market design

4.1.1. Issue summary and submissions

In the Issues Paper[4], AEMO set out several guiding principles and then proposed a market design with those in mind. The guiding principles are:

- Power system security considerations are paramount.
- Very Fast FCAS should be utilised to fulfil a need that Fast FCAS cannot.
- If possible, the markets should be simple.
- If possible, the markets should maintain consistency with the existing Contingency FCAS markets.
- Unless there is a clear power system need to adjust the requirements for registration, the registration of existing Fast FCAS Providers should remain unaffected.
- If possible, existing FCAS Providers who wish to provide Very Fast FCAS should be able to integrate their provision of Very Fast FCAS with the provision of other types of Contingency FCAS and use the same measurement equipment.
- If practicable, the design should be technology neutral.

The market design proposed for Very Fast FCAS would maintain consistency with the existing Contingency FCAS markets through the following characteristics:

- Overlap with Fast FCAS.
- Inertia will not be treated as Very Fast FCAS.
- Remain independent of, but compatible with, primary frequency response (PFR) requirements.
- Include similar specifications, such as assumed frequency ramp rates, reference frequencies.

Submissions were made on several of these matters[5].

Enel X

> Electricity Authority's Review of instantaneous reserve markets in 2018 ultimately found that no near-term changes to the frequency procurement were required. However, the paper does contain an interesting analysis of the adequacy of the current market design compared to alternative scenarios that involve other design tweaks, such as co-optimizing the SIR (sustained instantaneous reserve) and FIR (fast instantaneous reserve) products, implementing a 2-s FIR product, and event-based payments for DR providing ancillary services.
>
> It also sets out what it sees as the features of the current market design that make it efficient and fit for purpose, including competition, co-optimisation, resources being able to participate in either or both FIR and SIR, leading to a wider pool of

[4] See section 4.3.

[5] Note that submissions quoted in this document are in this font; a footnote in this font indicates that the footnote is copied from the submission. In the interests of saving space, AEMO has replaced descriptions in the submissions with acronyms that are defined in the Glossary.

participants in each market, and incentives for providers of the slow product to respond quickly, leading to diversity of response times.

Iberdrola Australia

As commented during the initial Industry Consultation, while the amount of Very Fast FCAS would change based on system conditions, the Very Fast FCAS market should be designed independent of the inertia level. That is, the physical response of a plant should remain unchanged for the same frequency disturbance.

Figure 8 shows a different MW output at 1s depending on the inertia level. For the avoidance of doubt, if this due to different volumes procured, this is fine, but this cannot work at a plant level, i.e. the response for Very Fast FCAS will not change (in comparison to other FCAS) based on inertia conditions.

Rheem & CET

If the energy market is to be truly democratised, it is extremely important that any changes to market rules and associated technical specifications for participation in grid services (such as FCAS) are made with the consumer at the centre of the solution. This will ensure that current and future investment in smart DER by households continues to be made. Fundamental to this approach will be that new rules do not favour a particular technology, technology class, or technology manufacturer, and that technology neutrality is not impeded by barriers to entry in creating or modifying energy market rules. Our specific responses attached are underpinned by this approach.

Tesla

AEMO should take a principles based ('technology neutral' and 'scale agnostic') view that reflects the optimised provision of services over the long-term.

…

Ideally AEMO could provide comfort by providing additional visibility on how it forecasts FCAS volumes will evolve (total MW to be procured).

This will ensure investment signals for new battery storage projects are maintained and future projects avoid uncertainty from price and volume risk. For example, statements such as "the amount of Very Fast FCAS required could be zero, or small, when the power system is interconnected and significant inertia is available" are concerning and at a minimum should be accompanied with surety that R6 volumes would still be maintained relative to status quo.

…

Tesla does not agree that inertial response should be excluded from the Very Fast FCAS market, as it will be many years until a proper inertia mechanism / spot market will be implemented, but as AEMO has highlighted, this is a rising challenge already and the technical capability is already demonstrated by grid-forming inverters (ref Tesla's trials at HPR). By collectively considering inertia and Very Fast FCAS this will also allow alignment with the parallel focus on PFR incentives, which is being developed, which also has a preference for proportional controllers.

Inverter-based technologies will, by design, be configurable and able to provide both synthetic inertia and Very Fast FCAS. AEMO notes that FCAS and inertia are not "directly interchangeable" but it will be critical that a new Very Fast FCAS market is designed to enable assets to provide both services.

This will be equally as important for both utility scale inverter based assets and victual power plants (VPPs) – with services procured on a technology agnostic basis.

4.1.2. AEMO's assessment

Consulted Persons were largely supportive of the proposed design principles of Very Fast FCAS and agreed that AEMO adhered to its guiding principles in proposing the design.

All technology types will be allowed to participate in the Very Fast FCAS markets as long as they can meet the proposed technical and metering requirements. A consequence of these requirements is that some FCAS Facilities, which are slower to respond to a frequency excursion, will be ineligible to register in the Very Fast FCAS markets, however, AEMO must consider what the power system needs to recover from a high rate of change of frequency

(RoCoF) event during low inertia conditions, rather than specify a slower response time to enable all existing technology types to participate.

While AEMO agrees with submissions highlighting that there will be an increasing need to manage and source inertia as major synchronous facilities progressively exit the NEM, AEMO does not believe the FCAS markets are currently a suitable mechanism for AEMO to procure inertia. As detailed in the Issues Paper, FCAS has many significant differences to inertia, for example:

- FCAS requires guaranteed headroom and footroom.
- FCAS response must be sustained until power system frequency has recovered or until they have reached the end of the relevant FCAS product timeframe.
- FCAS involves in the injection of additional energy into the system.

Changing the approach to inertia for Very Fast FCAS would therefore be a major departure from the assumptions currently underpinning FCAS and, if pursued, would arguably require similar modification of other FCAS, especially Fast FCAS. AEMO suggests it would be more prudent to let the inertia rule change process run its course[6], which is tasked with identifying the most appropriate and efficient procurement approach for inertia. If that process were to find that FCAS is suitable for inertia procurement, then a program of work to change the FCAS arrangements would take place at that time.

AEMO appreciates Tesla's point that inertia requirements could outpace the rule change process, however there are various existing pathways for inertia procurement in the meantime.

4.1.3. AEMO's conclusion

There are no changes proposed to the MASS as a result of any of the issues raised in section 4.1.

4.2. Key parameters for Very Fast FCAS

4.2.1. Issue summary and submissions

In the Issues Paper[7], AEMO proposed a specification for Very Fast FCAS with the following attributes:

- A 1-s timeframe to reach maximum response.
- A total timeframe of 6 s.
- Raise/Lower reference frequency to remain at ±0.5 Hz for the Mainland and ±2 Hz for Tasmania.
- Standard fast frequency ramp rate of 1 Hz/s for the Mainland and for Tasmania.

Submissions were made on several of these matters[8].

[6] See the AEMC's webpage for more information: https://www.aemc.gov.au/rule-changes/efficient-provision-inertia

[7] See section 5.2.

[8] Note that submissions quoted in this document are in this font; a footnote in this font indicates that the footnote is copied from the submission. In the interests of saving space, AEMO has replaced descriptions in the submissions with acronyms that are defined in the Glossary.

Response time and service timeframe

Akaysha Energy

Akaysha are supportive of the proposed Very Fast FCAS integration including decisions to move from a 2 s to 1 s service.

…

… most technologies able to provide 1-s FCAS will also be able to provide a 0.5-s response. The limitation will be the methods by which their FCAS controller is implemented. FCAS controllers in the Power Plant Controllers take longer to response to frequency disturbances as they must transmit new dispatch target signals to individual inverters. Some assets may need to implement control system changes to move their FCAS controllers to be within the inverter controls or provide a different control system architecture.

…

AEMO's modelling showing the decreased amount of system inertia required with a 0.5-s FCAS as opposed to 1-s is the primary benefit. A faster service would also require less Very Fast FCAS to manage the same contingency event for a given level of system inertia. We suspect that the service may need to become faster as the NEM moves toward becoming a lower inertia power system.

…

Analysis on the size of the Very Fast FCAS market for varying levels of system inertia would be beneficial for developers to consider market sizes going forward. However ultimately if delivered from an inverter as inertia or a Fast FCAS, assets can only do one or the other service at any instant in time. Fundamentally by control system theory if you do things early and fast e.g. inertia, the smaller the action required to manage RoCoF, hence inertia response is more valuable.

Delta Electricity

If specified correctly, it should define whether the response time is measured from detection (by any detection system no matter how slow it is) or from a specified continuous and fast frequency record. It is suggested AEMO should reject any controller that is not rapidly tracking and detecting what frequency actually is and reacting to that signal regardless of how fast a system can deliver a response after any unspecified speed of detection of the need for a response.

…

The design should try to separate out response time from reaction time. If response time is delayed because of the time it takes to detect frequency to initiate a reaction, this should be considered separately to how fast the response from the system following initiation. They can be separate things as can be the method of detection. The mechanical-hydraulic reaction is detected by a change in speed on a mechanical system and is almost instantaneous following detection because the detection system movement is mechanical coupled to the delivery mechanisms. The Unit DCS reaction, in contrast, relies on multiple elements including detection, deadband assessment and delivery and therefore is slower, having process time to develop frequency in a frequency transducer, read the frequency measurement from the transducer, detect a level outside deadband requiring a FCAS reaction, and then setting the subsequent adjusted setpoint on the turbine governor.

…

Coordination between various systems is an important consideration. AEMO should seek systems that can be tuned and undertake frequency tuning activities with FCAS Providers to improve overall frequency control, including PFR and FCAS delivery. However, the mechanical-hydraulic systems of conventional machines, which provide the fastest delivery, are complicated and expensive to tune or adjust so it is better if the proportional response as found to exist in these systems is accepted as already configured.

…

AEMO could consider changing the Fast FCAS to be a 1 to 7s service and therefore the equivalent declining period of the Very Fast FCAS would change to be a 1 to 7s period also. Subsequent changes to Slow FCAS and Delayed FCAS could be also considered to arrange the timing necessary for the best overall application.

Enel X

We consider 1s sufficient on the evidence provided … in the Issues Paper. This is because it appropriately balances the effectiveness of the service with sufficient and competitive provision of the service from a wide(r) range of providers.

EnergyAustralia

EA agrees that higher RoCoF following contingency events will be seen as the NEM transitions. The technical settings of the new Very Fast FCAS will, therefore, be a key tool to manage this challenge. Based on the technical evidence presented, we agree with and support the general settings for Very Fast FCAS proposed in the Issues Paper. These include:

- a 1 s response time,
- a 6 s total timeframe,
- raise/lower reference frequency set in line with other Contingency FCAS,
- an assumed frequency ramp rate of 1 Hz/s, and
- procurement volumes to be adjusted for inertia levels and the size of the largest credible risk.

Iberdrola Australia

Site-controller based response (e.g. Lake Bonney Battery or hybrid plants) have longer response time than those whose response is directly initiated at the inverter level (without intermediary power converter), because of the communication delays introduced. In the example of Lake Bonney Battery, this decision was made because of the need to manage a common transmission asset.

Given the trend towards developing hybrid plants, and the likelihood of various technologies collocating with future or existing assets, it would be preferrable not to exclude those.

As such, … a sub 1s response requirement could end up preventing wind and solar farms to participate. Either new ones or older ones that couldn't be retrofitted to participate.

Given that an increased procurement of 1s service tends to improve the frequency nadir and trends toward a 0.5s service (with a lower procurement level), it seems appropriate to allow a bigger pool of FCAS Providers by designing the system at 1s and adjust the procurement level.

…

While we don't know how much FFR capacity the NEM needs, it seems that there is value in making the threshold higher to enable a higher number of FCAS Providers.

Technology will do what they are capable of doing. i.e. batteries will respond quicker than 1 s and won't slow down their response time. In other words, the "overall" response as a whole will be faster than 1s.

If this market works in the same way other markets currently do (multiplier effect), the faster the response, the higher the registration will be, hence creating a financial incentive for plants to provide faster responses. Iberdrola supports a 1s Very Fast FCAS, with a multiplier effect. … this will provide the right incentive to provide faster response, without limiting the pool of FCAS Providers.

Rheem & CET

We do not think the benefits of a 0.5-s response time (vs. 1-s) justify the increased technical demands on Very Fast FCAS technologies and the resulting reduction in the pool of solutions for Very Fast FCAS.

Shell Energy

In our submission to the AEMC's draft determination on the Amending Rule, Shell Energy proposed that a 2-s market, could form part of a broader change to increase participation in FCAS markets and improve market outcomes. We suggested that a 2-s market could allow for the current 6-s FCAS to be pushed out to an 8- or 10-s service. The Slow FCAS (60-s) and Delayed FCAS (5-min) should remain as they are now.

The rationale for a change to an 8- or 10-s service is that introduction of the Very Fast FCAS could support a change to the delivery requirements for Fast FCAS and allow a number of potential FCAS Providers who are currently unable to deliver 6-s FCAS to participate in the Fast FCAS markets. These FCAS Providers would be able to provide FCAS under an 8- or 10-s service regime. Further, we understand that providers of the 2-s very fast frequency response would be able to maintain their response for the 8 or 10 s required in order to "hand-off" their service to Fast FCAS. By increasing the potential volumes of Fast FCAS, whilst still maintaining secure operation of the power system, we contend that this would increase competition in the Fast FCAS markets. This should then deliver improved market outcomes in the form of lower overall costs to consumers. We suggest that this change would not require the need for re-registration for existing FCAS Providers as AEMO's registration list[9] indicates that all Fast FCAS Providers are also registered as Slow FCAS (60 s) Providers.

Shell Energy considers that the proposed 1-s Very Fast FCAS design risks limiting competition in the Very Fast FCAS market under system normal conditions. We would prefer an approach that recognises the importance of competition in FCAS markets and allows for a diversity in supply. This should assist in delivering lower cost supply, therefore providing benefits to energy consumers.

We note AEMO's additional report on further studies with increased FCAS volumes suggests that a 2-s service will be insufficient to maintain frequency within the Frequency Operating Standard (FOS) in South Australia and Queensland when they are islanded. However, we observe there are differing results between those presented in the Issues Paper and the addendum for the same input assumptions. Table 5 of the Issues Paper shows that the R2 service was sufficient to keep frequency with the FOS in the mainland for both 2022 and 2026. However, Table 2 of the addendum shows that an R2 service would breach the FOS in the mainland. The addendum also indicates that an R2 service in Queensland fails on the frequency nadir against the largest contingency reserve (LCR)[10]. Yet, the addendum does not discuss whether it passes the 1 Hz/s RoCoF requirement. We consider this outcome to be important as the Reliability Panel is currently considering the FOS and currently a RoCoF standard has yet to be set and may include different standards for an interconnected mainland or system islanding conditions. Shell Energy wishes to understand the discrepancy in results presented in the two documents. Based on the conflicting data AEMO has made available, it is not possible to accurately compare the outcomes of an R1 or R2 service.

In addition, when considering the impacts of regions operating on an islanded basis, the commissioning of Project Energy Connect by 2026 in South Australia, is likely to reduce the probability of the region operating in islanded conditions. It would require the failure of four transmission lines on two separate routes. As such, it would be a highly unlikely event.

We also query the allocation of 220 MW for the LCR in an islanded South Australia. In practice when South Australia is islanded, we understand Pelican Point comes down to stable minimum load (180 MW). This means the LCR is 180 MW and not the 220 MW indicated in the Issues Paper. Similarly, in Queensland the LCR is listed as 750 MW when the region is islanded. However, when islanded, we also understand generation output at the 750 MW Kogan Creek power station, and other generating units in the 420 to 450 MW maximum capability range, is reduced to 350 MW due to the lack of Raise FCAS overall. … where an interconnector flow path becomes the LCR due to prior outage of reclassification, this risk is also managed by the invoking of constraint equations to limit interconnector flows to low levels. If these lower LCR values are used, which is more akin to what happens in islanding situations, it may be possible for a 1.5 or 1.25 multiple of the LCR to support a 2-s Very Fast FCAS.

Regions operating on an islanded basis is already an infrequent event. As more transmission infrastructure is constructed, we would expect that islanding becomes increasingly rare. We consider that application of an LCR multiple during periods of infrequent regional islanding may be more economically efficient than imposing an outcome that exists all the time, in case an improbable event were to occur. We encourage AEMO to bear this in mind as it designs the requirements for the Very Fast FCAS. From Shell Energy's perspective, AEMO appears to be taking a highly risk averse approach. This may not necessarily be in the best interests of consumers over the long term as it potentially reduces the scope for participation in the Very Fast FCAS market.

Tesla

The issue [some technology types being locked out of Very Fast FCAS markets if response time is 0.5s] will most likely not be in the response time, but rather in the level of granularity that's expected from compliance and verification data. If AEMO are looking for x number of data points per response then reducing the response time by half will also increase the granularity of the measurement resolution.

This will result in either more expensive equipment being required or more systems locked out of providing Very Fast FCAS and as AEMO notes it's already a small pool of potential available capacity, and "the additional cost associated with higher speed meters will also result in less participation, particularly from aggregators".

1-2 s markets are also more compatible with the international FFR markets that are being introduced including the UK and Irish markets (with the EirGrid market design being similar in principle to Australia). Provided it still delivers the desired market outcome, then alignment with international market activity is preferable as it will likely support the largest pool of FCAS Providers being able to technically provide Very Fast FCAS. As AEMO notes on page 31 of the Issues Paper "a Very Fast FCAS response of either 0.5 or 1 s response is adequate to contain frequency within the applicable containment

[9] Available at https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/participate-in-the-market/registration.

[10] AEMO understands that Shell is referring to 'Largest Credible Risk' with the of the term LCR.

band…" Based on this the 1 s response appears to be both suitable for serving the market needs and more likely to attract a larger pool of systems that are technically able to provide the service.

As AEMO notes in Table 3, a 0.5 s response is the upper limit in capability for wind turbines and solar PV and may result in these technologies being excluded from the market from the outset.

…

AEMO has captured the power system security benefits and trade-offs well

…

Tesla supports the justifications outlined for 1-s response and 6 s sustain time for Very Fast FCAS.

Market ancillary service offer requirements

Akaysha Energy

How do AEMO plan to subtract any inertial response from the calculation of the registered Very Fast FCAS level? This is most relevant for Virtual Synchronous Machine (VSM) BESS which may provide virtual inertia in addition to a large amount of Very Fast FCAS. The inertia response would come in first and then followed by a more considered response through Very Fast FCAS meaning you can offer both at the same time.

Delta Electricity

As mentioned previously, the detection time and the reaction time may be separate in some systems. AEMO are encouraged to determine a permitted time period between detection and initiation of a response to avoid future challenges in the overall coordination of frequency. A proportional reaction to a real frequency condition is useful. A delayed yet rapid proportional reaction to an earlier frequency deviation is, by virtue of the delay, uncoordinated and could contribute to dysfunctional frequency control.

Enel X

As highlighted throughout the Issues Paper, quick response times are key for Very Fast FCAS to help inertia. As such, market design should encourage faster response times without excluding potential Very Fast FCAS Providers. As a result, Enel X does not consider caps or requirements on response times should be used as proposed in this Issues Paper.

Instead, the promotion of greater diversity of, and competition between, different Very Fast FCAS Providers with various response times should be incentivised by the MASS that encourage the best possible market response. We consider this is best done using the current R6 incentivises (existing measurement processes, including the multiplier effect) and applying them to the new R1 market.

…

Portfolios of switched controllers, such as those operated by Enel X, should be viewed as providing a proportional response ... FCAS Provider's offers should be considered in light of the type of response they provide, rather than the controller or technology through which they provide that response. AEMO should describe the required response and allow all avenues of providing ... This approach will broaden the market and not unnecessarily limit supply … resulting in increased competition and lower prices for consumers as well as a great suite of assets for AEMO to call on to provide FCAS.

Iberdrola Australia

The FCAS multiplier effect currently provides an incentive to source faster responses. Once a Very Fast FCAS is introduced, it seems fair to reward faster responses.

Ready.Energy

This brings the second issue [**Future impacts of higher frequency control for FFR on FCAS (esp VPPs)**] into focus.

Inertia in a machine generation system is to all intents and purposes "instantaneous" and output control is later exercised through the governor. Synthetic Inertia will bring with it new challenges.

A live issue - particularly important for Consumer Protection - is what the future might hold with separate operation of FFR and FCAS and a reasonable expectation that the faster control, and significantly higher contribution to FFR (battery) resources, is likely to dominate the mix of frequency services and therefore revenue opportunities.

With FFR systems, Synthetic Inertia is trying to emulate the near instantaneous inertia of the current system however, now as a service, it's therefore likely that it will diminish the opportunities (or "money pot") for FCAS in general but especially VPPs. That VPPs might have a lesser control frequency is just not an option!

sonnen

Capping the delivered FCAS response to the actual peak active power is inconsistent with the principle need of rapid energy injection or withdrawal to rebalance the power system. Resources capable of a more responsive droop characteristic maybe be discouraged from providing this capability under the proposed requirements and seek to amend registered droop capabilities. Not all impacted resources will be able to take advantage of the new Very Fast FCAS due to other limitations such as high-speed metering

Reference frequency levels

Delta Electricity

Focusing on islanded conditions for the design of FCAS seems to focus on conditions rarely experienced and undermines the effectiveness of the controllers that for more than 99% of the time are applied to non-islanded conditions. The FCAS reassignment process in NEMDE after the development of islands might be useful to consider and may require more rapid assignment than is generally considered possible by manual operator intervention. However, the maximum delivery of many systems, and the sustainable response, is a function of other factors rather than simply how large the frequency deviation is and it seems that the assignment of caps based on maximum MWs will cause necessity for this reconsideration of capacities of all systems in general regardless of which reference frequency is used to define the capacity.

Enel X

We support leaving the reference frequencies as is.

Iberdrola Australia

Iberdrola Australia supports a consistent Reference Frequency across all Contingency FCAS.

Specific to batteries, the current droop and reference frequency means that a battery can only provide ~50% of its capacity in cFCAS[11]. Given batteries are currently the best assets (most commonly deployed compared to supercapacitor or flywheels) to provide this service, and given the potential lack of resource for fast responses, it would be beneficial to allow batteries to operate with a lower droop coefficient (i.e. 0.7%) so that they can provide a full response at ±0.5Hz. AEMO previously indicated security concerns with “faster” droop coefficient. A “faster” droop surely would not create more concerns than switched responses (or a combined FCAS controller) and … it would also help correct potential over-delivery of switched responses.

In our view, and in consideration of AEMO’s observations, the best combination would be to keep the ±0.5Hz reference frequency but allow a full response at that reference frequency.

Shell Energy

We consider AEMO has covered the issues associated with the proposed changes in detail. Consistent with our views already set out in this submission we also support AEMO’s view that:

There is no obvious case to change the definitions of ‘Raise Reference Frequency’ and ‘Lower Reference Frequency’ for an interconnected system, which is by far the situation most commonly served by FCAS.

Accordingly, we do not support any proposed change to the reference frequency levels.

Tesla

Tesla is open to exploring this issue further and is willing to engage with AEMO to understand how these changes may flow through to both existing and new registrations if it is progressed further.

[11] AEMO understands that Iberdrola is referring to ‘Contingency FCAS’ with the term ‘cFCAS’.

Updating the reference frequency bands to align with Tasmania and support an increased response makes sense from an engineering perspective and is worth considering further. However, as per point 8[12], it would be helpful if any shift to the frequency reference bands was also accompanied by greater transparency regarding the overall FCAS procurement required and/or an overall increase in the level of procured FCAS. This will ensure that any shift in reference bands does not have the perverse impact of discouraging new FCAS capacity entering the market.

Frequency ramp rate

sonnen

sonnen supports AEMO aligning frequency estimation dynamic accuracy requirements for control system and verification purposes with a 1 Hz/s frequency ramp rate.

Tesla

We strongly encourage AEMO to maintain timelines to introduce Very Fast FCAS in full, as quickly as possible. This will ensure a strong signal is sent to providers of fast response (both existing and potential) to ensure credible contingencies can be adequately managed in the short-term, and to provide sufficient buffer for potential inertia shortfalls which, as AEMO acknowledges, are increasingly harder to forecast ahead of any formalised inertia arrangements. This seems the most optimal low-risk/ high-reward approach.

Generally

Tesla

At a high level, Tesla supports the specifications outlined in the Issues Paper, namely the proposal for a 1-s response time, 6-s total timeframe, Raise/Lower reference frequency in line with other Contingency FCAS, and an assumed frequency ramp rate of 1 Hz/.

4.2.2. AEMO's assessment

Response time and service timeframe

Arguably, the most important aspect of the design of Very Fast FCAS is how much faster it should be than Fast FCAS.

In the Issues Paper, AEMO demonstrated how a 1-s FCAS response can arrest power system frequency within the relevant containment band following a credible contingency event equivalent to the size of the LCR for the scenarios considered. AEMO also demonstrated that a 2-s FCAS would not be adequate to prevent power system frequency from falling below 49 Hz in a QLD island in 2022, and in an SA and QLD island in 2026[13].

Two of the thirteen submissions proposed alternative response and service timeframes.

Shell Energy supported a response time of 2 s for Very Fast FCAS and an extension of the timeframe for Fast FCAS up to 10 s, in the interests of increasing competition and lowering consumer costs. Delta Electricity suggested a 1-s to 7-s timeframe for Fast FCAS to preserve the 6-s timing of Fast FCAS.

AEMO notes that these submissions did not argue for these adjusted timings on a technical basis but rather on economic or market grounds. As demonstrated in the Issues Paper, AEMO's concern is that a 2-s service would be less effective at managing high RoCoF events during low inertia conditions, and that as the ISP modelling shows, such inertia levels are quite plausible within the the coming decade. It is also not apparent that system security needs could be addressed by specifying a timeframe in the 7 s to 10 s range for Fast FCAS, particularly in a future with less inertial response from synchronous generation.

[12] See submission quoted in section 4.1.1.
[13] See section 5.1.3 of the Issues Paper.

Furthermore, extending the critical timeframe for Fast FCAS would require most FCAS Facilities to be substantially re-assessed, including planning and execution of new tests for the purposes of registration. This would be a major impediment to delivering Very Fast FCAS within the required timeframe, which requires the MASS to be finalised by December 2022, with the two new VFFCAS markets to commence operation from October 2023. Note that while AEMO is proposing to revise registrations to remove the 'multiplier effect' (see section 4.8), this only affects a subset of FCAS Providers, does not require re-testing (as it is simply the application of a cap), and mainly impacts those that are likely to be registering in the Very Fast FCAS markets, where testing registration will be required in any case.

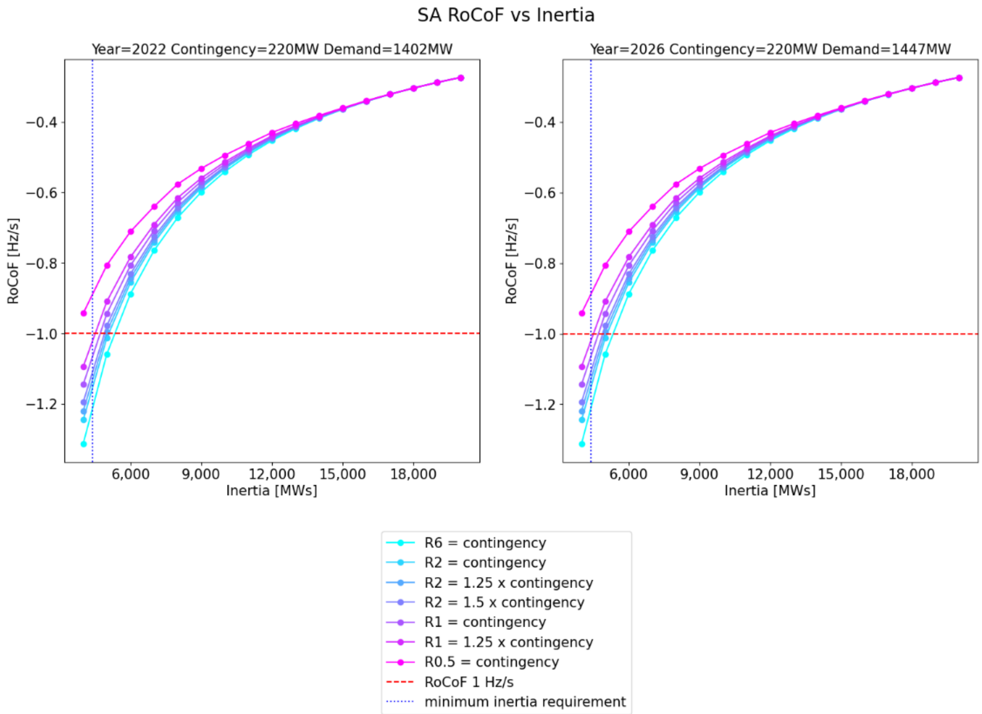
Setting aside the technical issues with extending the timeframe of the Fast FCAS market, Shell's submission argued that extending the timeframe of Fast FCAS could allow more capacity to be registered in the Fast FCAS markets (rather than being registered in the Slow FCAS markets). This may be true for slower responding technologies; they would have the time to potentially produce more of a response. However, this is unlikely to apply to a large proportion of FCAS providers, and in particular to much of the FCAS capacity that has been registered recently. There does not seem to be a lack of Fast FCAS at the moment, and the development pipeline suggests that there is a significant number of new facilities likely to be commissioned that will be capable of meeting existing Fast FCAS requirements. Therefore, it is difficult to see that the cost and effort of extending the Fast FCAS timeframe would be justified by economic benefits, even if the technical concerns could be managed.

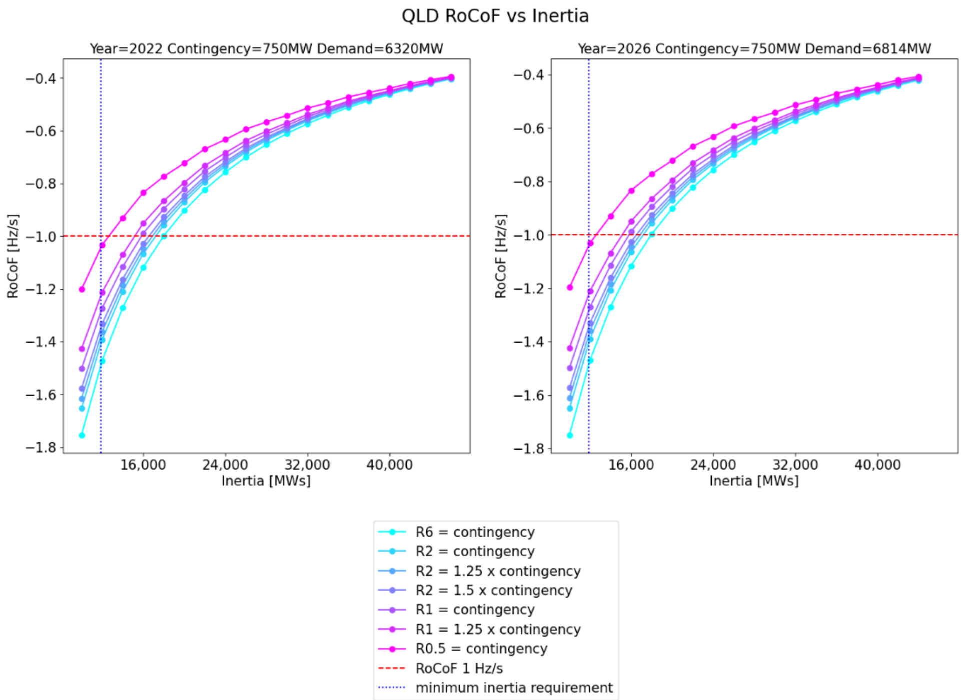
Shell Energy suggested that the results presented in Table 5 of the Issues Paper and Table 2 of the Addendum for the same input assumptions are different. AEMO agrees that the results of both studies are not comparable, because Table 5 of the Issues Paper shows the frequency nadir and RoCoF based on projected minimum observed inertia levels in 2022 and 2026 from the Draft 2022 ISP, whereas the results in Table 2 of the Addendum are based on the minimum threshold level of inertia requirements[14]. Consulted Persons should also note that the aim of the study for the purposes of the Addendum was to demonstrate the effectiveness of a 1-s response time as compared with a 2-s response time. In practice, while the size of the LCR could be different to the assumed LCR in the study, it is clear that a 1-s response time will be more efficient and effective than a 2-s response time, which would require additional Very Fast FCAS to be enabled to achieve the same frequency nadir following a contingency event.

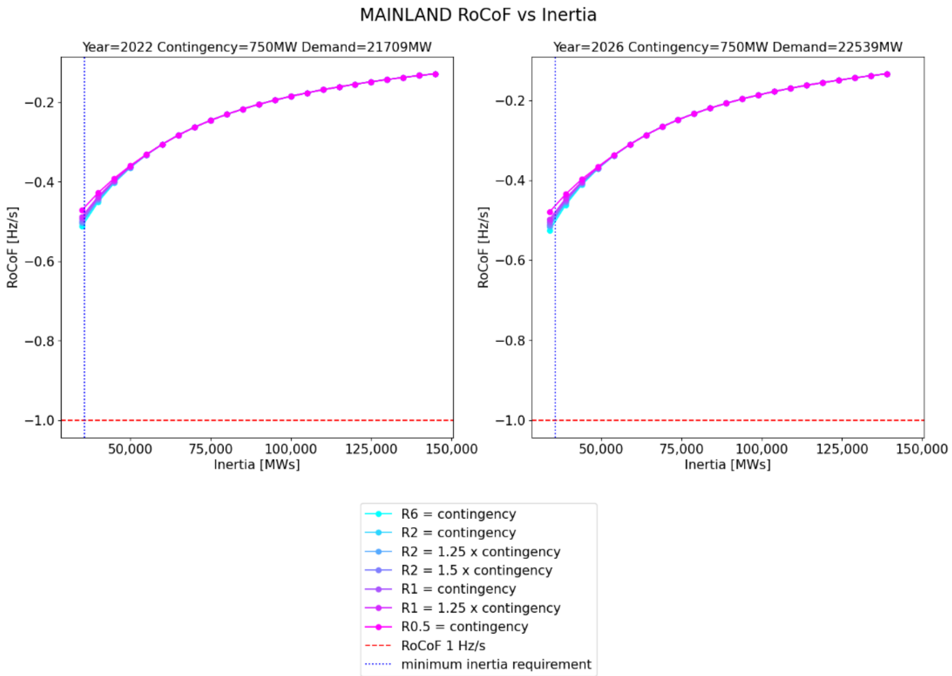
Shell Energy also submitted that the studies completed by AEMO for the Issues Paper should have considered the impact of different response times for Very Fast FCAS on RoCoF and not just the frequency nadir. While AEMO compared the RoCoF observed when varying the response times for Very Fast FCAS in Table 5 of the Issues Paper, the study was based on projected minimum inertia levels for 2022 and 2026 from the Draft 2022 ISP modelling. To address Shell Energy's suggestion, the same model used to complete the studies shared in the Addendum was updated to compare RoCoF against inertia rather than the frequency nadir agsinst inertia. These results are shown in Figure 1.

[14] See AEMO's 2021 System Security Report. available at https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/ operability/2021/system-security-reports.pdf?la=en.

Figure 1 Comparison of Very Fast FCAS response times and inertia levels on RoCoF in South Australia, Queensland and the mainland NEM in 2022 and 2026







AEMO considers that while this additional study shows the effectiveness of a faster response time at maintaining RoCoF closer to 1 Hz/s, it cannot be used in isolation as the basis to determine the appropriate response time for Very Fast FCAS. As shown in the summary in Table 1, a 1-s response time fails to contain RoCoF below 1 Hz/s for SA and QLD, and even a 0.5-s response time was ineffective for QLD. Furthermore, due to the combined minimum inertia requirement for the mainland, the study shows that a 6-s response time would be adequate. While the FOS specifies the containment bands for a credible contingency, a RoCoF standard is yet to be specified and the results of the study cannot be assessed against any particular requirement.

Table 1 Comparison of RoCoF for varying Very Fast FCAS response times

Response Time	Year	Region	RoCoF below 1 Hz/s
R6	2022	SA	FAIL
		QLD	FAIL
		MAINLAND	PASS
	2026	SA	FAIL
		QLD	FAIL
		MAINLAND	PASS
R2	2022	SA	FAIL
		QLD	FAIL
		MAINLAND	PASS
	2026	SA	FAIL
		QLD	FAIL
		MAINLAND	PASS
R1	2022	SA	FAIL

Response Time	Year	Region	RoCoF below 1 Hz/s
		QLD	FAIL
		MAINLAND	PASS
	2026	SA	FAIL
		QLD	FAIL
		MAINLAND	PASS
R0.5	2022	SA	PASS
		QLD	FAIL
		MAINLAND	PASS
	2026	SA	PASS
		QLD	FAIL
		MAINLAND	PASS

Market ancillary service offer requirements

In response to Akaysha Energy's question on synthetic inertia, AEMO will not register the additional change in active power as a result of the synthetic inertial response in the FCAS markets. When verifying the performance of an FCAS Facility, AEMO will seek to confirm whether the change in active power reflects the FCAS capacity enabled, and the agreed droop and deadband settings.

AEMO agrees with Delta Electricity's comment on the reaction time and detection time and is proposing a new section in the MASS to ensure that the control system scans for changes in frequency every 50 ms or less, and automatically initiates or adjusts active power in accordance with the agreed settings of the FCAS controller.

As mentioned in the Issues Paper, the accelerated response from an FCAS Facility will be recognised by the Very Fast FCAS markets. In response to Enel X and sonnen's comments supporting the current arrangements with the multiplier effect, the results of the new study discussed in section 4.8 demonstrates the impact on the power system if the gap between the change in active power following a power system incident and the size of the contingency keeps increasing. AEMO must consider the needs of the power system over the incentives provided by the multiplier effect to FCAS Providers.

Reference frequency level and frequency ramp rate

Submissions were largely supportive of the proposed reference frequency level and frequency ramp rate for Very Fast FCAS.

4.2.3. AEMO's conclusion

AEMO proposes that the specification for Very Fast FCAS will be:

- A 1-s timeframe to reach maximum response.
- A total timeframe of 6 s.
- Raise/Lower reference frequency to remain at ±0.5 Hz for the Mainland and ±2 Hz for Tasmania.

- Fast frequency ramp rate of 1 Hz/s.
- Inertia will not be treated as Very Fast FCAS.

4.3. Capability of different technologies to deliver Very Fast FCAS

4.3.1. Issue summary and submissions

While reviewing the capability of different technologies to delivery Very Fast FCAS, AEMO considered whether there were any barriers that could impact operators of certain technologies in participating in the Very Fast FCAS markets[15]. Questions were posed for consideration by Consulted Persons about the inherent capabilities of different types of technologies and the technical barriers and proposed specifications.

Submissions were made on several of these matters[16].

Very Fast FCAS capabilities of different technologies

Akaysha Energy

> Akaysha Energy suggest that time to full response for BESS can be lower than 0.2s, potentially 0.1s.
>
> All other technologies
>
> We suggest that synchronous generators should be divided by energy type (coal, OCGT, CCGT, Hydro, etc) as each technology has widely varying response capabilities.
>
> All other technologies and responses appear correct.

Delta Electricity

> Generally, the list [Table 3 in Issues Paper] is Ok. When considered in detail, the initial mechanical-hydraulic governor reaction from relevant conventional steam turbines takes place in less than 0.5s. This reaction is applicable to the Very Fast FCAS. It is also relevant that, where DCS support is inactive and/or not well coordinated with the governor reaction, the initial mechanical-hydraulic reaction will be countered by correction to setpoint response. When DCS support is included in the response considerations, 2s for "Time to full response" is more accurate but, in many cases, is faster. The peak MW response will often be in the first second with the sustained response (from the DCS), although of similar droop proportion, usually lower due to the size of the frequency deviation at the specific (later) time during normal frequency recovery or limited by the design of the DCS supported response.

Enel X

> Enel X agrees with the table that some load can react within 0.25-0.5 s with a sustained response but … load response times can vary much greater than that presented in the table. Response times vary greatly depending on the way the load asset is responding, ranging from 0.25 to 2 s (for a service like Very Fast FCAS). This means a faster response time requirement will result in fewer load assets available to provide the new Very Fast FCAS.

Evergen

> Table 3 suggests battery storage requires 0.2-1 s for time to full response. Evergen has limited data to speak to this point on a residential level since our telemetry is 1-s maximum granularity. However, we note from high-sample rate frequency injection testing for the VPP demonstration program that at least some residential battery vendors have small-scale BESS capable of reaching maximum response within 1-s. At least one VPP demonstration program hardware vendor required closer to 3 s to reach maximum power, however … this is for older/initial technology for the demonstration program and this vendor is working on improvements for new models.

[15] See section 3.

[16] Note that submissions quoted in this document are in this font; a footnote in this font indicates that the footnote is copied from the submission. In the interests of saving space, AEMO has replaced descriptions in the submissions with acronyms that are defined in the Glossary.

Iberdrola Australia

Mostly agree, with the below observations:

For wind farms, capability depends on wind turbine type. Type 3 WTG would mostly have an inertial response but have a slower rotational speed. Type 4 WTGs are fully inverter connected and therefore would have similar characteristics than other grid following inverter technology, depending on the wind resource.

Solar farm would have similar characteristics than other grid following inverter technology, depending on the solar resource.

For synchronous generation, the capability will vary depending on the technology:

- Synchronous generation response can't necessarily be sustained for a prolonged period of time, depending on the technology.
- Ignoring the inertial response, most synchronous generators will be limited by their mechanical ramp rates

Rheem & CET

In our experience across thousands of BTM mixed DER sites that we control / orchestrate across the NEM and WEM, we consistently find that solar PV is slow to ramp up and we have observed inconsistent speed of ramp down.

Tesla

Yes, battery storage capabilities are accurately captured in Table 3. However, … the time response of supercapacitors should also be limited by its inverter and therefore should be equivalent to battery capabilities.

Technologies not included in Table 3 of Issues Paper

Delta Electricity

Heavy weights and gravity storage systems using disused mine-shafts or railway corridors

Evergen

- Fuel cells (e.g., https://www.sciencedirect.com/science/article/pii/S0378775318300995)
- Hydrogen Electrolysers (e.g., Ghazavi, Mehdi & Mancarella, Pierluigi. (2022). Fast Frequency Response Capabilities of Utility-scale Hydrogen Electrolyser: Benefits and Challenges in the Context of Australian NEM Grid with High Share of Renewable Generation.)

Iberdrola Australia

AEMO refers to "Aggregators" in its last bullet point, but this is not included in the table.

It depends on the nature of the aggregation, but same characteristics would apply to aggregated loads and aggregated battery storage (subject to any additional communication/control schemes)

sonnen

Hybrid (DC coupled solar PV) residential battery systems utilising a single inverter may approach the discrete battery storage response times identified in Table 3.

Tesla

Aggregated DER/ VPPs are not explicitly included in the table, but it would be helpful to capture them as a sub-set of battery storage and note they can operate with similar characteristics (e.g. response times) as utility-scale assets. The response time of the Tesla Powerwall is < 250ms of a frequency deviation.

As with the feedback provided to AEMO in the 2021 MASS review focused on DER, the issue with aggregated DER is not the ability of the system to meet the speed of response required for Very Fast FCAS, but rather the granularity of the data that is available from DER to verify compliance. To support both the capability of VPPs and aggregated inverter based

DER in providing Very Fast FCAS, Tesla has developed the Application Note[17] looking at Measurement Error rates associated with aggregated systems providing a 1 s frequency response.

Wind and solar technologies

Akaysha Energy

There is no need for additional incentives to encourage wind and solar generators to participate in the Very Fast FCAS. AEMO should provide guidance of the expected future volumes to the market for forecast of prices. Market prices should be the only incentive for FCAS participation to facilitate development of the lowest cost FCAS Provider.

Iberdrola Australia

Technically we cannot see issues for new technologies. Participation will be based on regulatory and commercial issues.

…

To be able to provide raise services, headroom is required which directly translates into a production loss and needs to be justified by market economics and/or allowed by any commercial arrangements (I.e. PPA). The cost of including an autobidding system to revise the bids every 5 min is also seen as a barrier. Furthermore, the capability depends on wind and solar resource and conditions.

For lower services, the plant can self-constrain.

However, in both scenarios, the capability of those plants relies on the wind and solar resource. If the resource disappears, so does the FCAS availability.

This also creates a reliability and compliance issue, which can partially be addressed by modifying the energy output to maintain FCAS compliance, therefore trading off FCAS compliance with Energy compliance.

Impact on Synchronous Technologies

Akaysha Energy

Akaysha agrees with AEMO that many synchronous technologies will be excluded from providing 1-s FCAS due to technical limits. Our experience with synchronous generators suggests that active power ramping sub-1-s for many of these assets is unachievable due to mechanical plant limits such as control valve movement, actuator movement and with additional cycling would be detrimental to plant condition and future availability. This should not however prevent the market from having sufficient 1-s FCAS capability in the next couple of years as a number of large BESS projects come online.

Iberdrola Australia

1-s response time specification will most likely exclude existing older synchronous generators. Given that this market is designed for the future grid to prepare for the retirement of older synchronous generators, this may be an appropriate trade off given a 1s service provides a more valuable response.

Maximising pool of Very Fast FCAS providers

Akaysha Energy

AEMO should consider more aggressive droop curves from large BESS where these are located in stronger network areas and commissioning tests verify their response is well controlled. Limiting the amount of power a BESS can provide to the FCAS market reduces available supply to the market and subsequently increases prices.

Enel X

Enel X strongly supports a 1-s response time given the modelling provided by AEMO demonstrates the inability of a 2-s service to adequately provide the desired outcomes. … a 1-s response time will exclude some load assets from participating in the Very Fast FCAS market when compared to the amount available for a 2-s market. This is because we consider 1-s appropriately balances response effectiveness with competition and availability of prospective providers.

[17] See Appendix C.

…

We consider the longest possible effective response time will maximise the market, hence our support for the 1-s response time. As such, the movement to a 0.5-s response time would significantly reduce Very Fast FCAS Providers and is not supported at this time given the current assets available....

Additionally, as discussed further in our response to Q39[18], incentivising faster responses and not limiting responses to active power provision in each market will maximising the pool of potential Very Fast FCAS Providers. The proposal currently includes unnecessarily 'black and white' restrictions on who can and cannot provide the service. We consider the current MASS approach of rating faster responders through the 'multiplier effect' as an appropriate and effective way of maximising the pool of FCAS Providers. … this also applies to the restriction on response to begin within 0.5s, as the current methodology de-rates response after this window, whilst still allowing it to participate.

…

Some load assets would be locked out if a 0.5s time is selected. We understand the need for a sufficiently fast response time to meet the design characteristics of the new FCAS market, but consider it should not be faster than required to ensure a workably competitive market size.

… the MASS should incentivise faster response times without excluding slower times. This is currently appropriately and effectively done by the MASS through rating delivery based on response times so the market experiences a stratified response by time rather than excluding slow and getting a big block response at the "cut-off" response time. This will maximise participation whilst adequately encouraging quick response.

As noted previously, this approach is less 'black and white' than that which is proposed and will result in greater diversity and competition while meeting AEMO's FFR requirements. We encourage AEMO to reward fast response times without excluding slower response times as a principle when amending the MASS.

Evergen

There are a multitude of residential DER battery vendors, many of whom will be able to achieve fast response times in response to detected frequency excursions. However, at present, granularity of telemetry may be a limitation. Evergen is aware of only 2 battery/inverter vendors that can deliver 200ms telemetry via API for FCAS verification without additional hardware at this point in time, although more have indicated they are targeting this level of capability in 2022. If telemetry granularity required for Very Fast FCAS assessment were 100ms or less, this may exclude control-via-API residential battery-based aggregators from participating in this market, at least in the short term.

3rd party hardware based solutions for control and monitoring of DER may be able to deliver higher granularity telemetry in the short term, though the requirement of additional hardware will mute the capability and growth of residential DER to participate, especially if the incremental value for an end user to purchase this hardware is only for eligibility in the Very Fast FCAS market.

…

A 6s market with 200ms granularity telemetry reporting for verification and application of discounts is already a challenging benchmark that the residential battery sector is working towards meeting. While Evergen is optimistic about the possibility of residential, battery-based aggregators participating in a 1 s market with 200ms granularity and discounting, Evergen expects a 0.5s market (with likely higher granularity telemetry requirements than 200ms) to be sufficiently challenging to render most residential VPPs unable to participate in the Very Fast FCAS market in the short term. Whether residential battery/inverter vendors decide to improve their offering to meet the requirements of a 0.5s market would depend on the incremental financial returns available for entering the Very Fast FCAS market over and above the other Contingency FCAS markets.

Iberdrola Australia

AEMO should ensure that the required volume of Very Fast FCAS response that AEMO will need can be delivered. It is important that the specified parameters for the service are not a barrier to entry in providing the service and are set to ensure there is sufficient market competition to deliver an efficiently priced service.

Rheem & CET

In our experience across thousands of BTM mixed DER sites (generation and flexible load) that we control / orchestrate across the NEM and WEM, we consistently find that many Solar PV Inverters and Battery Energy Storage Systems

[18] See section 4.8.1 under the Capping Maximum Capacity sub-heading.

(BESS) may be excluded by a 1 s response time requirement due to vendor specific ramp rate limits, external and environmental factors, operational status and interface latency. We have thousands of BESS across our fleet of deployed BTM HEMs orchestrated sites on which to base our statements.

All of our sites have 50ms … metering. Our consistent observations and empirical data gathered from the field indicate that lab-based and "point in time" field based analysis of BESS performance are not good indicators or predictors of future field-based performance (response times etc) of any particular battery technology. We see many factors affecting the ramp rates (up and down) of BESS technology in the field including but not limited to battery/ambient temperature, battery charge state, line voltage, local disturbances (ripple etc), battery operational status etc. These all affect the response times of a battery. Conversely, for loads such as Rheem's smart grid interactive water heater, our response times are consistent and predictable and not effected by the aforementioned external factors, as are batteries. We are happy to share further with AEMO our extensive experience in this area.

...

50ms metering is appropriate to ensure the greatest confidence in the deployment of the widest technology pool for participation in Very Fast FCAS.

…

While there are no specific technologies that are completely excluded by a change to a 0.5-s response time, we expect the pool of available solutions in each technology category would be significantly reduced due to technical timing constraints. For example, charge-pump anti-glitch protections for relay drivers used in discrete load control often have hardware-defined delay times in the order of 100-300ms, leaving little headroom for metering, control, and communications delays.

sonnen

It is likely that a substantial portion of existing distributed residential battery energy storage systems currently registered to provide fast FCAS are unable to meet a 1-s response target. New generation residential BESS with faster inverter control loops maybe less affected.

…

Distributed residential BESS and solar PV system market penetration continues to grow rapidly. Increases in the speed of inverter control loops to meet more stringent network protection requirements has the potential to deliver a large pool of fast responding FCAS resources. However, due to the small size of these systems the economics of aggregation is highly sensitive to any additional costs associated with compliance or verification such as supplementary very fast metering devices.

A Very Fast FCAS response verification framework based principally on high per unit cost very fast metering risks locking this highly distributed resource out of the Very Fast FCAS market.

Tesla

… it would be helpful to explicitly recognise the capabilities and potential participation volume of coordinated DER/ VPPs, particularly as this subset is forecast to be the largest type of storage in the NEM by 2030 (as per AEMO's draft 2022 ISP figures for step change)

Other issues AEMO should consider

Akaysha Energy

We also recommend further investigation on the impacts of switched FCAS controllers in a low inertia power system. … very high rate of change of active power from a switched controller is detrimental to power system performance and further limits should be applied to the maximum volume of switching controllers enabled for FCAS.

…

Virtual Synchronous Machine (VSM) BESS with overload capability may potentially be providing system strength and inertia in addition to FCAS. Provision of a system strength or virtual inertia service require large amounts of inverter current causing short-term over-heating which may limit these assets ability to provide subsequent FCAS as the inverter cools down. AEMO should consider the potential impacts of a future system strength / inertia market and how this may reduce the available FCAS capability in market. Markets for system strength, inertia and Very Fast FCAS are all the optimal lowest-cost solution, however impacts of one capability on another need to be understood.

Enel X

… we would welcome more exploration of these issues about switched providers by AEMO. We note the proposed changes in section 5.3 of the Issues Paper don't apply to switched load. Also, AEMO used a simplistic, theoretical example and we would ask that a real-life or modelled example is undertaken to demonstrate the real issue. This should be done ahead of such a change being made that we consider would greatly impact the current operation of the market.

sonnen

Robust determination by control systems within an acceptable time frame of frequency estimates in the presence of disturbances typically occurring during contingency events including but not limited to:

- high RoCoF
- network switching transients
- harmonic distortions
- DC offset
- Local noise

Tesla

We note continued focus on PCC (generating system) performance and inflexibility to accommodate faster inverter based (generating unit) responses continues to impede the provision of inverter-based response.

- Tesla has already moved to a centrally dispatched frequency-watt control loop which is inherently slower due to communication delays
- This was driven by difficulty during the connection application process including: (1) the fact the frequency-watt response is open loop and can potentially exceed the registered nameplate MW value by a small amount; and (2) AEMO requiring injection testing on site.
- It is very difficult to test an inverter response – as it requires primary injection testing using a grid simulator. Tesla has testing capability in the lab, but this is not possible to do on site.
- Due to the above inflexibilities during the connection process, we have moved the response to central dispatch (which has the advantage of being easy to test on site using frequency spoofing), however this approach is slower and therefore of less value to the power system

On a more general point, Tesla questions the continued focus on switched controllers in this market, noting that high speed markets are required to recover the frequency as well as overshoot due to load drop/switched controllers.

4.3.2. AEMO's assessment

The purpose of section 3 of the Issues Paper was to demonstrate, at a high level, the types of technology that could be harnessed to deliver Very Fast FCAS. It was not a definitive list of technologies and their capabilities. Submissions did not yield any new information that could have a bearing on the proposal to amend the MASS.

As explained in section 4.4.2, the proposal for AEMO to consider more aggressive droop curves from large BESS warrants further work due to the potential impact on power system security, and AEMO is proposing to engage with stakeholders on this outside of the current consultation.

Switching controllers are discussed further in section 0.

4.3.3. AEMO's conclusion

There are no changes proposed to the MASS as a result of any of the issues raised in section 4.2.

4.4. Control system requirements

4.4.1. Issue summary and submissions

In the Issues Paper[19], AEMO considered the advantages and disadvantages of variable (proportional)[20] and switching controllers during the 2021 MASS consultation and noted that the proper operation of the power system requires adequate levels of frequency response to be provided by way of variable control; that is, controls that continually monitor and adjust the relevant FCAS Facility's response to frequency.

While most existing Contingency FCAS Providers implement either proportional or switched controllers, the MASS also contemplates 'combination' controllers, where an FCAS Facility uses a hybrid of proportional and switched controls. AEMO considered whether to extend these options for Very Fast FCAS and posed questions for consideration by Consulted Persons.

Submissions were received on this issue[21].

Akaysha Energy

> … any switched controller (hybrid or standalone) is non-ideal for management of power system frequency, particularly for low inertia systems. Control should be droop or PID[22] based to ensure no large step-changes in generator output. If a hybrid controller is proposed, why would this be better than a droop controller with slope more aggressive than 1.7%?
>
> Switched controllers could be included as FCAS for extreme conditions of very high or very low frequency.

Delta Electricity

> The triggering mechanisms and recorded frequency values, and the specifications of them, is probably even more relevant to be accurately specified for effective Very Fast FCAS compared to Fast FCAS, Slow FCAS and Delayed FCAS. Mechanical-hydraulic systems do not trigger on speed or frequency really. They trigger on change of speed as determined by centrifugal movement of spinning weights and the same detection action initiates the response instantaneously. Systems that wait to make decisions based on a reading of frequency need very good specifications to precisely indicate how fast the detection to activation needs to be. There will be poor overall system frequency coordination if a Very Fast FCAS is being triggered by a very slow determination of what the frequency actually is followed by another very slow determination of whether frequency has left a particular deadband or not followed by another slow activation relay that then releases the very fast reaction. By the time a slow detection system detects and releases a fast responding system, the reaction may be uncoordinated with the overall system reaction required at the eventual time it reacts.
>
> …
>
> Coordination of faster controls is important and best achieved with proportional systems working off rapid detection regimes drawing on equivalent specifications. Switched control is unlikely to coordinate well with fast proportional reactions and could damage systems if out of phase and poorly timed or producing conflicting or undamped reactions and counterreactions. Switched control is considered better suited to slower FCAS. Slower FCAS already contain hybrid mixtures of proportional and switched which demonstrates that hybrid systems can be considered appropriate already.
>
> …
>
> Very Fast FCAS and Fast FCAS should be delivered exclusively by proportional controls. Switched controls are better suited to Delayed FCAS corrections that in the timing of response are procured to follow on from presumably ineffective faster controls where, despite delivery of all fast proportional service, overall frequency remains incompletely corrected. Such conditions presumably occur if energy storage was exhausted in the very fast, fast and slow proportional reactions, overall system requirements were miscalculated and/or system events represented a multiple contingency.

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[19] See section 5.3.

[20] The MASS refers to controls of this nature as 'variable' controllers.

[21] Note that submissions quoted in this document are in this font; a footnote in this font indicates that the footnote is copied from the submission. In the interests of saving space, AEMO has replaced descriptions in the submissions with acronyms that are defined in the Glossary.

[22] Proportional, integral, derivative.

Enel X

Yes [AEMO's proposal to permit the use of a 'combination' controller is appropriate] – Enel X considers a greater diversity of assets that can respond to be a good thing for the market and consumers.

…

AEMO should thoroughly investigate and demonstrate the root cause and therefore need for any limits on switched and proportional response controllers as a proportion of the market before they are introduced in any FCAS market...

There are two main points related to this that AEMO should consider as part of that deliberation:

1. Switched controllers can provide a proportional-like response by stratifying a portfolio of assets responses: Enel X utilises switch controllers on our portfolio of FCAS assets, but does so such that they respond similarly to that of a proportional response asset. Treating all switch controllers like they provide big block FCAS responses is not an accurate representation of the way switch controllers are used ... Oversimplification of the way these controllers can be used will be detrimental to the market – both in terms of the assets available for AEMO to use as well as the cost to consumers due to lower competition in the FCAS markets.

2. New Zealand experience shows large over-response causing an overshoot from a switched controller is highly unlikely: is evidenced in the Investigation into Over-Provision of Interruptible Load[23]. The 2014 report by Transpower … looked at the concern expressed that since the only requirement was to deliver at least as much response to an under-frequency event as operators have been told to enable, they might be conservative and deliver far too much. In the extreme, operators might not disarm sites, even when they hadn't cleared. It was suggested that requirements could be tightened, such that providers of instantaneous reserves would have to respond within a particular tolerance of their dispatch target.

   The danger was that a large over-response would cause an overshoot: the under-frequency event would be followed immediately by an over-frequency event, causing generators to trip. If this happened, since the underfrequency reserves would already be depleted, there would be a risk of going to system black. These concerns are very similar to those for the contemplation of a limit to be placed on switched response controllers.

   However, the modelling showed that this scenario was not plausible: it would require 25% of North Island load, or 16% of South Island load to be providing instantaneous reserves. It recommended that no further action be taken. We consider similar modelling must be undertaken by AEMO to demonstrate that there is a real and probable … before introducing a limit on switched response controllers in any FCAS markets… as has been foreshadowed in the Issues Paper.

Iberdrola Australia

For switched responses, we also query how AEMO will control the frequency threshold at which load trips depending on inertia conditions?

Enabling FCAS Providers with switched capabilities could lead to over-procurement of FCAS when these generators are not dispatched to provide Contingency FCAS during a given interval but still have the relevant control scheme activated.

…

[See also submission on Reference Frequency Levels in section 4.2.1] Iberdrola supports a lower droop coefficient of 0.7%.

Iberdrola supports incentives to start responding within the normal operating frequency band (NOFB) as opposed to from the NOFB.

Rheem & CET

… permitting the use of a combination controller is appropriate as it provides an opportunity for some existing Very Fast FCAS technologies to maximise their response without significant downsides.

sonnen

[23] Available at https://www.transpower.co.nz/sites/default/files/bulk-upload/documents/TASC%20035%20Report.pdf.

> sonnen's approach of dynamically allocating switched FCAS trigger frequencies across a sufficiently large aggregation of distributed resources to deliver an aggregate droop characteristic would seem plausible for delivery of Very Fast FCAS.

Tesla

> We can understand the rationale for limiting the response of large systems and to ensure spread of fast responding systems is evenly distributed in the NEM (and avoid sudden flow changes across interconnectors). However, one improvement could be for AEMO to include a MW 'upper limit' to the blanket 1.7% droop setting, below which the requirement could be relaxed (noting that switched controllers have 0 droop).
>
> AEMO must also clarify (or potentially codify) the calculations used in the MASS (as used by HPR to justify >57MW registration (with PFR) for R6 and R60).

4.4.2. AEMO's assessment

AEMO's proposed approach to allow combined FCAS controllers to participate in the Very Fast FCAS markets and be available to BESS facilities was largely supported. This would enable FCAS Providers to maximise their FCAS capacity while also assisting in the recovery of power system frequency. AEMO is interested in how hybrid facilities could ensure that the switched component of their response is limited to enablement, or where this is not feasible, how major over-delivery could be avoided.

At this time, AEMO does not propose to specify a limit on the percentage of enabled Very Fast FCAS from FCAS Facilities using switching controllers, but has observed that smaller frequency excursions outside the NOFB will not trigger many switching controllers. This can prolong the frequency recovery time if switching controllers were enabled for a significant percentage of the Very Fast FCAS markets. To evaluate this issue further, AEMO has initiated a review of the settings allocated to several switching controllers.

AEMO notes further suggestions from Consulted Persons to consider allowing more aggressive droop controls on a general basis. The current restrictions on significant assets in the NEM aligns with well-established experience in power system control based on droops in approximately the 2-5% range. Most grid codes AEMO is aware of require generators to maintain controls with a droop function in the approximate range of 3-5%. Therefore, proportional controls set in this range have been well proven in terms of their ability to work together in a large grid in a stable manner, and matters such as protection design and stabilizing controls have been based on these long-standing assumptions. AEMO is not aware of any examples of major grids allowing droop to be set much lower than this range at scale.

In setting a policy on allowed droop (as for other FCAS Facility requirements), AEMO strives to act in a consistent and technology-agnostic manner, where this is possible. This means that AEMO's droop policy, specified in the Battery Energy Storage System Guide for Contingency FCAS registration[24] should be suitable not for just one FCAS Facility, but for all similar ones that follow. That is, allowable settings, such as droop, set a precedent for an increasingly significant technology in the NEM. FCAS Providers are no doubt aware of the very large amount of battery resource potentially seeking to participate in the NEM.

The most significant power system security concerns AEMO has regarding very low droop (high gain) controls are:

- Dynamic stability. As gain is increased in any closed-loop control scenario, the probability of instability (in particular, oscillation) rises. This is true of isolated controllers but much more so where multiple, dispersed high gain controllers exist, such as would be the case

[24] Available at: https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Ancillary_Services/Battery-Energy-Storage-System-requirements-for-contingency-FCAS-registration.pdf.

with widespread adoption of very low droop frequency response across the NEM, each operating with slightly different frequency measurements and inherent delays. These concerns are further magnified where such controllers are separated by significant distance (e.g. at different ends of the NEM), where the long transfers of frequency response could exacerbate oscillation.

- Phase-angle shift. Rapid injection of large amounts of power can cause material shift in network voltage angle, which could conceivably cause stability problems with phase lock loops (PLLs) and synchronism, particularly in weaker parts of the grid.
- Undesirable interaction with protection schemes. Large rapid injections need to be carefully assessed as to how they interact with or cause misfire of various protection schemes that monitor many different kinds of conditions. These have generally been set up under an expectation of more 'typical' frequency response characteristics.

These concerns also exist for switching controllers (particularly the second and third), but are different in nature due to how those controllers operate.

Nowithstanding these concerns, AEMO recognises that a review of droop policy, supported by quantitative modelling, is desired by various Consulted Persons. AEMO proposes to engage with interested parties (likely via the Ancillary Services Technical Advisory Group, or ASTAG) to identify the highest priority work items.

4.4.3. AEMO's conclusion

A limit on the use of switching controllers is not anticipated prior to AEMO completing its review and undertaking further work focusing on the circumstances under which limits may be necessary.

4.5. Verification and measurement requirements

4.5.1. Issue summary and submissions

AEMO also noted in the Issues Paper[25] that the three most important factors in the delivery of FCAS from an FCAS Facility are:

- The FCAS is delivered within the relevant time parameters.
- The correct quantity of FCAS (in energy and capacity terms) is delivered.
- The scan rate or response rate is not slowed down to match the sampling rate

At the conclusion of the 2021 consultation, AEMO adopted a tiered measurement regime for Fast FCAS[26]. The MASS applies a discount factor to Fast FCAS delivered by Aggregated FCAS Facilities made up of DER that meet certain criteria.

In the Issues Paper, AEMO considered that the same approach could be applied to Very Fast FCAS. It also mentioned that the proposed Very Fast FCAS must respond six times faster than Fast FCAS, which means that measurement times with a resolution of 200 ms or 100 ms might not be adequate for measurement of its provision. Very Fast FCAS Providers would have the option of capturing data at a higher resolution to avoid the application of the

[25] See section 5.4.
[26] See section 5.4 of the MASS.

discount, or use their Fast FCAS metering installation knowing that a discount will apply to their delivered quantities.

A discounting regime is necessary to avoid the need to procure additional Very Fast FCAS to offset the potential verification errors arising from data captured at a lower measurement time resolution. AEMO acknowledged that the applicable discount must be reasonable.

In addition to the measurement sampling rate, the allowable error and accuracy must be sufficient for AEMO to assess whether Very Fast FCAS has been delivered in accordance with the MASS. In the Issues Paper, AEMO proposed to specify:

- For power measurements, an allowable margin of error at 2% and resolution of 0.2%, which means that all types of Contingency FCAS would have the same requirements in this area.
- For frequency measurements, AEMO considered that a balance needs to be reached between sufficient accuracy and the relative cost of compliance.

Submissions were made on several measurement and verification issues[27].

Sampling rate and discounting

Delta Electricity

> There are measurement rates relevant to the monitoring recorders and separate measurement rates for the controllers. Rates at the cycle of electricity are feasible for the recorders. Rates of detection systems depend on the system but range from instantaneous such as is the case with mechanical speed detection to slower systems (in the range of 1s) used to activate slower controllers. A faster measurement rate for the slower systems is not feasible presently and would require improved source instrument and upgraded control equipment.

Enel X

> Yes, measurement rates of < 100ms are feasible for load assets but at a significant cost, especially for smaller loads that are being aggregated together. We can measure across a variety of rates and currently do so across many sites.
>
> More sophisticated metering comes at a cost and we ask AEMO to set out any rationale for requiring increased measurement rates above those of other FCAS. Additionally, AEMO should be restrained when setting any measurement rate lower than 100ms, if it is justified, due to the increased costs for FCAS Providers, which may decrease competition in the market. This is because, given our previous experiences, some aggregators may not be able to justify the additional metering costs associated with the more sophisticated equipment across enough sites to build a meaningful portfolio.

Evergen

> [AEMO should investigate]
>
> Consideration and specification of an eligibility and discounting regime based on the number of DER within a DUID for the Very Fast FCAS market, similar in approach to the current arrangements for the Fast FCAS market.
>
> …
>
> Evergen supports the participation of small-scale battery-based aggregators participating in the Very Fast FCAS market at 200ms, through a discounting process. This discounting process could be based on the existing discounting process that aggregators can use to participate in the fast markets, using the number of devices under the dispatchable unit ID (DUID) as a factor when determining eligibility for the Very Fast FCAS market, and how FCAS contribution should be discounted.
>
> …

[27] Note that submissions quoted in this document are in this font; a footnote in this font indicates that the footnote is copied from the submission. In the interests of saving space, AEMO has replaced descriptions in the submissions with acronyms that are defined in the Glossary.

Evergen is able to accommodate high sample rate (e.g., 100ms or less) data on our platform. However, our approach to VPP orchestration for small-scale DER is to reduce costs and achieve monitoring and control via a cloud-to-cloud API-based integration with hardware vendors. This means FCAS capability via Evergen is based on the capabilities of our hardware partners.

Evergen does not currently have any **residential** hardware partners who can deliver 100ms or finer resolution measurements to the Evergen platform via API, and only two as of June 2022 are able to deliver FCAS capability with 200ms sample rate.

…

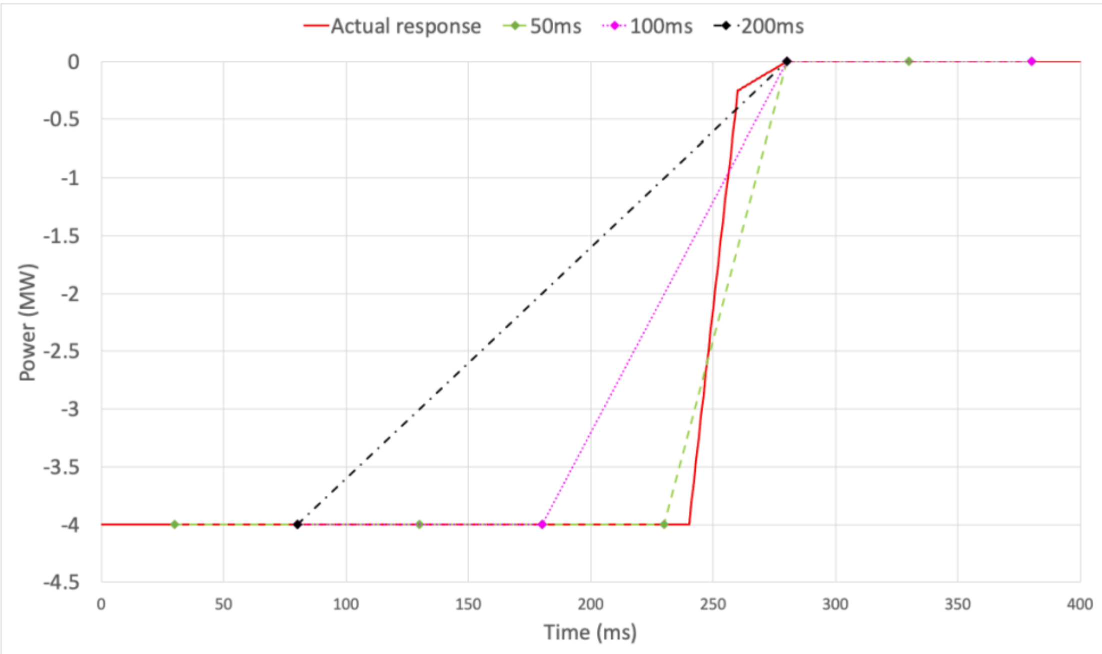
The University of Melbourne (UoM) study indicated a bias towards underestimation (almost all errors were negative values) when assessing Very Fast FCAS for switched response facilities (see Figs. 3.1-3.4 from the 1-s study, and Figs 4.1-4.3 from the 0.5 s study).

Evergen is concerned by this, as it suggests that this error may be mitigated with different analysis assumptions, perhaps resulting in smaller absolute errors if the average/median were closer to zero with positive and negative errors occurring across the family of generated profiles.

By considering Figs. 3.9 and 3.10, it appears that this bias towards underestimation is only evident in the 0ms delay case. Evergen wonders if this bias towards underestimation is an artifact of the way UoM determined a reference assessment window for the switched control cases (given the reality was that the delay in the real responses was so long their assessable Very Fast FCAS would have been zero, requiring an artificial method to determine the assessment window).

In practice, the locally measured FDT will be dependent on the sampling rate, and therefore the assessment window will also depend on sampling rate. By choosing the start of the 1s assessment window (for the no-delay case) as a point of maximum change in the response, and this point being universal across all profiles at all sample rates, perhaps this may have biased errors towards underestimations. We are interested in hearing from UoM as to why errors are biased in this way for the 0ms delay switched response profiles. Can UoM identify whether this is a result of their methodology for creating and assessing response windows for switched response loads, the FCAS verification approach in general, or the real-data profiles that formed the basis of the analysis?

Fig. 3.5 from the UoM study depicts how worst-case underestimation errors might occur based on the timing of samples. Evergen includes here a different sampling timing to indicate how close to worst-case over-estimation might occur for low sample rates:



It seems intuitive that a large over-estimation might occur in the worst case similar to the under-estimation worst case, especially for the 200ms sampling rate case. And yet the bias towards underestimation is apparent in UoM's results.

… the issues discussed here are especially relevant for consideration of FCAS Facilities comprising many DERs (such as a VPP of many residential BESSs). If verification error is unbiased with a fairly equal distribution of over- and under-estimation errors, then there is less risk in allowing VPPs of many small-scale DER to participate in the Very Fast FCAS market even with a coarser sampling rate, provided there are a sufficient number of DER in the FCAS Facility, perhaps with a discount based on the number of DER.

This is the approach AEMO determined for discounting of Fast FCAS market response over the 2021 MASS Review, and Evergen supports a similar approach being adopted to facilitate participation of small-scale DER in the Very Fast FCAS market.

Using samples outside the assessment window to improve coverage for low sampling rates

At the end of Section 4.1, UoM says: "These larger errors stem from the way samples are selected for the assessment. In the case of 200ms sampling rate, the 0.5s assessment window only enables capturing three samples, potentially leaving a fifth of the response unaccounted for. This uncaptured area naturally introduces another approximation in the area calculated as the Very Fast FCAS contribution, thereby increasing the assessment errors for 200ms sampling rate. Sampling rates of 50ms and 100ms are divisors of 500ms, which create samples that, in principle, can cover the full window of 0.5s. This issue was not experienced in the 1s assessment window, as all the sampling rates considered (50ms, 100ms and 200ms) are divisors of 1000ms "

Evergen does not understand why lower sampling rates would leave some of the response "unaccounted for", or why it should matter whether the sampling rate is a divisor of the assessment window duration. It seems mathematically principled and straightforward to use sample points on either side of the assessment window to determine additional trapezoidal areas, and then pro-rata a portion of these edge trapezoids when calculating area.

For example, if the assessment window is from 0-500ms, and 200ms samples occur at -120ms, 80ms, 280ms, 480ms and 680ms, then it seems principled and mathematically uncomplicated to calculate the verification area as consisting not just of the two trapeziums between 80-280 and between 280-480, but also include 40% of the trapezium between -120 and 80 and 10% the trapezium between 480 and 680ms. Doing this would reduce the verification error arising from lower sampling rates, and … there is some justification that this would be appropriate. This issue may not have been considered previously by AEMO, given that it only becomes extremely acute when considering lower sample rates and very short (0.5s) assessment timeframes.

Ready.Energy

The concern we have … is that the <u>changed</u> 200ms sampling rate for a "Aggregated Ancillary Service Facility" [VPP/s] <u>is unsuitable for the operations of VPP</u>, and that the significant delta, (of 150ms) to the "normal" large system Ancillary Service Facility ie 50ms, poses a real risk of unexpected outcomes and sawtoothing frequency response.

…

What is now apparent, confirmed with both AEMC and AEMO, is that the MASS is clearly ambiguous at best, and significantly misleading at worst when it comes to the requirements for CONTROL - as against METERING

The only discussion on sampling rates is in section 5 (specifically 5.3.2 Table 4) [of the MASS] - "*The equipment required to measure and record the delivery of FCAS, <u>including both the source transducer and data recorder</u>, must have the characteristics detailed in Table 4.*"

The issue is that this wording applies not JUST to measurement - <u>but all equipment</u>!

… it was "understood" that <u>control must be at <50ms</u> for any/all FCAS participation.

It should also be noted that the AS4777.2 2020 is very specific that ≤50ms was the sampling requirement and that nexus should be consistent.

What controls FCAS? The control of FCAS is simply the deviation away from 50Hz and any excursion ±0.150Hz (NOFB) - the control is RoCoF. Appendix 2 sets out a <u>simplistic description</u> of this. For more clarity though RoCoF is a "slope" [0.125Hz/s Mainland, and 0.4Hz/s Tasmania] - <u>however there is no mention of, let alone requirement specifying, the maximum sample rate allowed to calculate it</u>.

To date, for FCAS and for PFR (by thermal generators), RoCoF is based on sampling data <50ms. The expectation is that big batteries with sophisticated systems will have even faster response - this is why the Amending Rule was made.

…

Returning the main/first issue.

It reasonable then to suggest, if not require, that all FCAS should have sampling and control at the highest sampling rates.

I have discussed this sampling issue with people designing/building VPPs (esp control equipment) and there appears to a common misunderstanding that the 200ms is across the board measurement for control and metering (and appears to driven by a misunderstanding of what is meant by "measurement").

This misunderstanding needs to be corrected as a matter of urgency.

SUMMARY

So we have two major consumer issues - firstly that it appears that systems provided, or being designed, may not meet the requirements (and therefore will be barred from participation) and, secondly, that without clear focus and understanding of market segmentation (and associated costs) the opportunities for VPPs may be limited ... and reducing over time.

Lastly, without going into a dissertation on the mathematics, the system security risks of mismatched sampling, on latency and jitter, and consequential financial impacts and/or rewards, cannot be overstated.

This is not an immediate risk (the VPP volumes are small and thermal PFR is currently dominant) but it's a fatal flaw for people building VPPs and for more so for consumers that are being enticed into buying batteries on promises of VPP revenues (through all sorts of schemes).

We hope to see detailed discussion of controls versus metering, and clearer requirements for control...

Reposit

… UoM's insistence on case study based analysis[28] of metrology error continues to understate the uncertainty that slow sampling rates introduce. There are rigorous numerical approaches that can be applied and demonstrated by Reposit, but they have been actively disregarded by the UoM and AEMO. Reposit has stated on many occasions that a case study analysis measures only the error in the case study data, and this error is not rigorously generalisable to other datasets. This is recognised by the UoM in their analysis:

> *"It should be appreciated that a lot more profiles should be analysed to reach statistically significant conclusions"*

This understatement of error will give AEMO a false sense of security in the performance of the Very Fast FCAS. This service will be increasingly important as inertia leaves the NEM and the economy is electrified. The correct metrology for this service is a matter of national interest and should be attended to by the National Measurement Institute for the same reasons the M6 electricity metering standard was developed by them[29].

Reposit considers it essential for AEMO to facilitate National Measurement Institute involvement in formulating the metrology for the Very Fast FCAS to at least the extent that UoM has been involved in FCAS metrology to date. Reposit will contribute to this involvement by providing strong support to National Measurement Institute in becoming familiar with the FCAS family of services.

Rheem & CET

- In our view, analysis of a few battery samples, whether in the lab or in real life deployments, are not representative of the extent of performance variations that we have observed across many thousands of real-life deployments, and … any extrapolated results from a test on a few batteries (The report notes there were three) are in no way an indicator of field-based performance (response times etc) of any particular battery brand or battery technology across a wider aggregation of devices.

- Rheem and CET have thousands of BESS across our fleet of deployed BTM HEMs[30] orchestrated sites on which to base our conclusion. All of our sites have 50ms (per previous MASS) meter sampling rates. Our consistent observations and empirical data gathered from the field is that performance (response times etc) of any particular battery brand or battery technology is affected by many factors which are constantly changing. We see variation in response times and ramp rates (up and down) of BESS technology in the field as a result of, but not limited to, battery/ambient temperature, battery charge state, line voltage, local disturbances (ripple etc), battery operational status etc. These factors all affect the response times of every individual battery and are constantly changing.

[28] https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nemconsultations/2022/amendment-of-the-mass/very-fast-fcas-verification---final-report.pdf.

[29] https://www.industry.gov.au/sites/default/files/2019-05/nmi_m_6-1.pdf.

[30] Behind the meter home energy management systems.

- In contrast, we would contend that particular switched loads, such as Rheem's variable power grid interactive water heater Powerstore, have extremely predictable and repeatable response times as they are not affected by any of the aforementioned performance modifiers that affect batteries. Hence in our experience, any analysis that is based on a normal distribution assumption may be applicable for certain switched loads as identified above but in our opinion should not be used as a basis of analysis for batteries in the determination of assessment errors.

- Given these issues, … there is a need for further analysis by AEMO of large aggregations of field derived data across a variety of battery models / vendors. This should include a review of the analysis methodology used, and supports a case for regular high speed post event sampling verification at a 50ms sampling rate resolution. Any relaxation of the sampling rate to be greater than 50ms in a new Very Fast FCAS market of 0.5 or 1 s in duration may risk grid security of supply. In any case, given that cost effective, open access metering at a 50ms sampling rate is available (from ourselves and others) a 50ms sampling rate requirement is a no risk cost effective risk mitigating solution that can be adopted by AEMO, whilst at a minimum preserving the fidelity of the Very Fast FCAS market.

Due to the significance of the decision being made, we would suggest that AEMO give due consideration to commissioning a secondary study with the National Metering Institute. As the Government's independent body that tests and certifies measurement instruments, including revenue meters currently used within the NEM and WEM, it would be the logical choice to carry out a parallel independent assessment.

…

We support retention of 50ms sampling at an NMI level for the proposed Very Fast FCAS.

…

Having analysed the UoM Report, we had observations and questions relevant to the data set used, the calculation of error, determination of error across aggregated DER and hence the determination of a metrology sampling rate and any discount rates that may apply. We thank AEMO for the Friday 17th June 2022 technical discussion which has clarified many of our questions.

Our further comments and observations are based on the empirical data we have derived, and our continued observations from our field deployments of DER. We still contend that lab or field-based analysis of a few battery samples, whether in the lab or in real life deployments, are not representative of the extent of performance variations that we have found across many thousands of real-life deployments. … any extrapolated results from a test on a few batteries (the report notes that there were three) are in no way an indicator of field-based performance (response times etc) of any particular battery brand or battery technology across a wider aggregation of devices.

Questions and observations that come to mind and have been left open within the report include:

1) Do the batteries respond identically? Given that we know that batteries do not respond identically, what are the required level of proof, sample size, and under what conditions should testing and analysis be completed to ensure accurate representation of an aggregated fleet of batteries?

2) Given the above, what level of non-identical response is acceptable to AEMO when contemplating using an 'assumed identical response and average' type scheme and why?

3) Does AEMO have any independent analysis of average assumed identical response vs real response?

4) What 'identical' fleet averaging methodologies would AEMO accept and why (e.g. pure statistical distributions, determined from real data, derating, number of devices, evidence, etc.)?

5) What are acceptable frequency triggering mechanisms for response? Do they have to conform to the same accuracy requirements as measurement?

6) Can AEMO offer any insight into the methodology used for their sampling (e.g. reading of an instantaneous voltage from the raw waveform)? What sample rate was the waveform sampled at, what window was used, etc? This is very relevant to the report conclusions as it drastically changes the meaning of a 200ms sample (for example) depending on how the data is processed.

7) Was there any consideration given to sample offset to determine most favourable and least favourable metering (i.e. generation of f and P value) offsets? Again, relevant because it may drastically change the analysis.

8) Was there any consideration given for harmonics and real-world noise beyond the three-battery sample size? This would need to be considered / analysed for both triggering and metering. This is again relevant because it can drastically change the analysis, especially with different metering offsets or sampling and averaging methodologies

Supporting our views and questions above, we have evidence from thousands of BESS across our fleet of deployed BTM, HEMS orchestrated sites on which to base our statements. All of our sites have 50ms … metering sampling rates. Our consistent observation from empirical data gathered from the field is that performance (response times etc) of any particular battery brand or battery technology is affected by many factors which are constantly changing. We see variation in response times and ramp rates (up and down) of BESS technology in the field as a result of, but not limited to, battery/ambient temperature, battery charge state, line voltage, local disturbances (ripple etc), battery operational status etc. These factors all have an effect on the response times of every individual battery and these responses constantly change as the factors change. In contrast, we would contend that particular switched loads, such as Rheem's variable power, grid interactive PowerStore water heater have extremely predictable and repeatable response times as they are not affected by any of the aforementioned performance modifiers that affect batteries. **Hence in our experience, any analysis that is based on a normal distribution assumption may be applicable for certain switched loads as identified above but should not be used as a basis of analysis for batteries in the determination of assessment errors.**

These modifiers to battery operation … support the need for analysis of large aggregations of field derived data across a variety of battery models / vendors. This should include a review of the analysis methodology used and **supports a case for regular high speed post event sampling verification at a 50ms sampling rate resolution, which at the very minimum will preserve fidelity in any 0.5 or 1 s Very Fast FCAS market.**

Concluding remarks:

Any relaxation of the sampling rate to be greater than 50ms in a new Very Fast FCAS market of 0.5 or 1 s in duration in our view **may risk grid security of supply**. In any case, given that cost effective metering at a 50ms sampling rate is available (from ourselves and others), a 50ms sampling rate requirement is a no risk, cost effective, risk mitigating solution that can be adopted by AEMO whilst at a minimum preserving the fidelity of the Very Fast FCAS market.

…

YES, our metering technology (with no changes required) as deployed on many thousands of BTM DER (generation and flexible load) orchestrated sites across the NEM and WEM supports <100ms measurement rates and meets 50ms settling time requirements. We do not need to make any changes.

Please see the CET-HD-PM2-1 Product Brief V1[31] included in our response.

Further our metering technology supports open control interfaces and protocols (Modbus over Ethernet or PLC) and can be utilised with any technology participating in FCAS / Very Fast FCAS markets. We provide an extremely cost-effective product that can be easily integrated into an existing FCAS installation for 50ms metering.

Shell Energy

The UoM's supplementary report on Very Fast FCAS sampling rates appears to indicate that a sampling rate of 50ms or 100ms should be sufficient to minimise both measurement errors and costs for providers. To the extent that costs for potential Very Fast FCAS Providers can be reduced this should remove a barrier to participation, thereby increasing competition in the market. Increased competition should lead to lower overall costs to consumers.

Tesla

Related to DER, Tesla has undertaken detailed statistical analysis looking at the error rates associated with different measurement resolutions depending on the total number of sites aggregated (provided as Attachment A). This analysis mirrors the equivalent analysis completed and provided to AEMO to support the 2021 MASS review, with updates made to reflect a 1-s response window (for Very Fast FCAS) compared to the 6 s response window for Fast FCAS. This analysis has been attached to this response, with findings summarized as per the below:

- The observed error rate is more closely aligned with the number of sites aggregated than with the measurement resolution. VPPs and aggregated DER with a larger number of sites experience lower error percentages.
- For VPPs with 200 or more sites the maximum absolute assessment error with 100ms metering is below 1% (and well below the 2% MASS requirement) – or in other words due to the diversity, 200 sites at 100ms performs better than a single site at 20ms (which can have up to 2% error in power meter readings). The average observed error rate for 100ms resolution with 200 sites aggregated is ~0.2%.

[31] Attached to Rheem & CET's submission.

This is supported by the work done by the UoM ... This analysis showed that verification error trends towards less than 2%, with an outer limit of 4% for single sites. The Tesla analysis provides further consideration of the implications of the aggregation of multiple sites.

Based on this assessment … the discount applied for aggregated systems operating at 100ms resolution should be nominal for sites with ~200 systems aggregated, and this should reduce further where additional sites are aggregated.

…

Tesla recommends resolution of frequency measurements at sites allows for aggregated response (>200 sites) with 100ms metering without discount – which is more than sufficient as shown by UoM analysis where verification error trends towards less than 2%, with an outer limit of 4% for single sites.

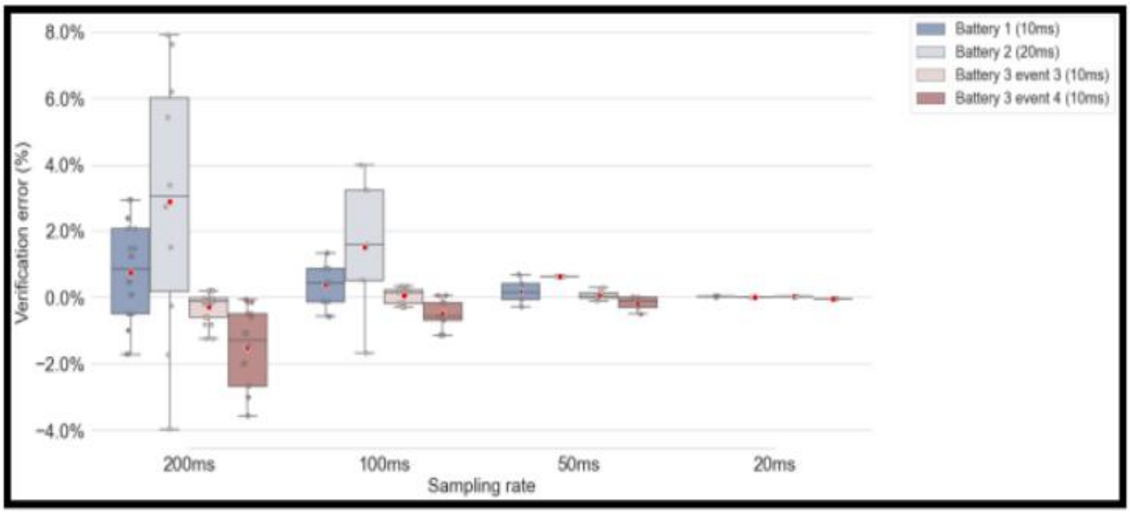
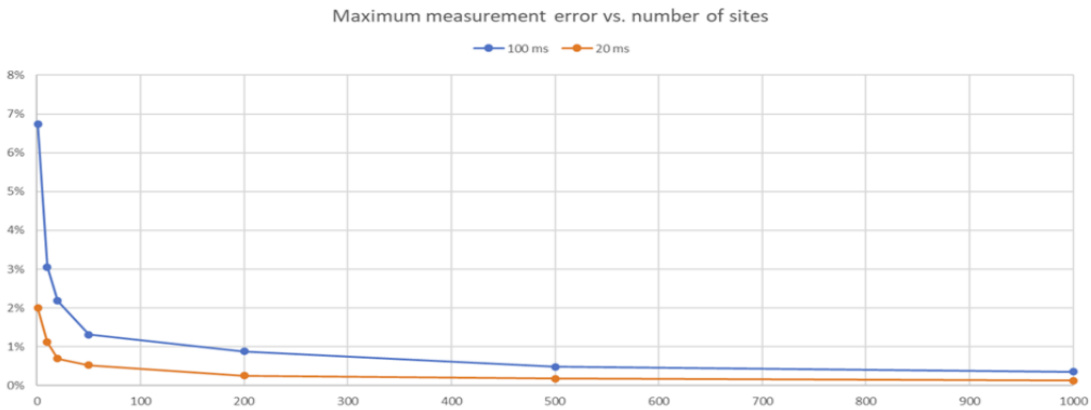


Figure 3.12. Error distribution of lower sampling rates for batteries in the assessment case based on FDT

This is supported by the Application Note[32] which provides further context on the error rates for different numbers of aggregated assets at different measurement resolutions. Similar to the previous VPP MASS review for Fast FCAS, our analysis also demonstrated that for VPPs with 200 or more sites the maximum absolute assessment error with 100ms metering is below 1% (and well below the 2% MASS requirement) – or in other words due to the diversity, 200 sites at 100ms performs better than a single site at 20ms (which can have up to 2% error in power meter readings):



…

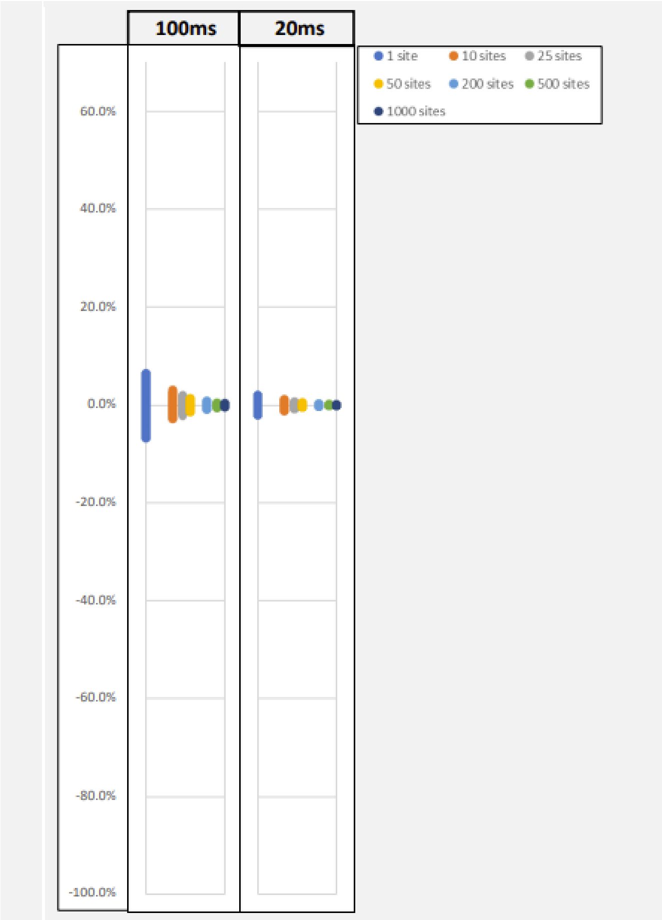
We support AEMO investigating this issue, but … the majority of FCAS Providers use Elspec meters and it would be highly inefficient and unnecessary to force them to install another type of meter.

…

32 See Appendix C.

… for Tesla's utility scale battery systems measurements sub 100ms are feasible using an Elspec meter. However, as outlined above this is not idea for controllable DER or VPPs. Tesla's household battery systems have demonstrated they can do measurements down to 100ms (as set up following the recent VPP focused 2021 MASS review).

To reconfigure to below 100ms would involve additional cost and data requirements, and provide diminishing returns with respect to measurement errors. Tesla analysis highlights that as soon as the number of sites is above 50, measurement error is better at 100ms than a single site with 20ms measurement rate (assuming 2% error in power meter readings) and can leverage the diversity of measurements across the multiple sites to effectively 'cancel-out' the differences in measurement windows. In other words, to enforce faster measurement rates is unnecessarily for aggregated fleets, and similarly to apply discounts to VPPs with sufficient sites would be unfairly harsh as it would also need to be applied to single site large-scale systems that have equivalent (or higher) measurement errors.



…

Following the extensive process that was undertaken for the VPP MASS review through 2021, Tesla recommends AEMO follows the same principles of allowing aggregated response to participate under the same 'discount' methodology – i.e. provided there are sufficient sites (our analysis indicates a threshold of ~50 sites would be sufficient to meet under 2% measurement error, 100 sites enable around 1%, and 200 sites under 1%) then VPPs can provide Very Fast FCAS with one high-speed meter per jurisdiction, and with proportionate discounts depending on the number of sites being aggregated.

Power measurements

Rheem & CET

As Australian based manufacturers we have made a large R&D investment in bringing to market cost effective metering compliant with 50ms FCAS metering and have a desire to ensure technology neutrality in the design of new market services, commercial fairness, and adherence to the principles of the NEO.

In summary we:

• Support 50ms metrology as a sampling rate for any 0.5 or 1.0 s Very Fast FCAS Market, and;

• Though not highlighted as an open consultation issue, support retention of NMI level metering for Very Fast FCAS.

Further, we have provided within our response cost estimates[33] for our MASS compliant DER power meter offering (with 50ms sampling rate), which has better than a 0.01Hz accuracy / 0.001Hz frequency resolution. This cost-effective power metering product is designed and engineered in Australia and is deployed on many thousands of our BTM mixed DER sites across the NEM and WEM. Our power meter includes a local, open, industry standard Modbus interface accessed via either Ethernet or PLC, for use with any DER seeking to participate in the Contingency FCAS market.

In preparing this response …, we have focussed on the findings of the UoM study. Having analysed their report, we have provided detailed comments on their findings, particularly how they compare to our own field observations from high-speed (50ms sampling rate) metering across many thousands of BTM DER sites where our metering is deployed. Our comments and observations are relevant to the data set used, the calculation of error, determination of error across aggregated DER, and hence the determination of a final metrology sampling rate along with any discount rates that AEMO may apply. We wish to thank AEMO for affording us the opportunity to explore many of these questions in our meeting of Friday June 17th, 2022.

Frequency measurements

Delta Electricity

The accuracy of high-speed metering is typically ±0.01Hz. Resolution can depend on how wide a range of frequency is being catered for in cheaper instruments i.e. wider range of measurement can reduce the resolution of the resultant signal. In the recorders Delta Electricity currently uses, the accuracy and resolution depends on the AtoD[34] conversion rate of the source signal (commonly a voltage input to the recorder) and whether any time-smoothing over consecutive zero-crossing is taking place. 12bit in older systems and 16bit in newer systems. A 16bit system seems to have a resolution <0.0001Hz. A 12bit system seems to have a resolution of 0.0012Hz.

…

[High-speed metering that is not currently in use in the NEM has] resolutions better than the above, which is technology available several years ago, are probably available in the latest technology.

Enel X

Schneider PowerLogic PM8000 provides high accuracy of standard speed (1s) and high-speed (1/2 cycle) measurements, including true RMS per phase and total for voltage, current, active power (kW), reactive power (kvar), apparent power (kVA), power factor, frequency, voltage and current unbalance, and phase reversal.

Frequency measurement accuracy of Class 0.2 as per IEC 61557-12.

…

… high-end power quality monitoring devices like the Schneider PowerLogic PM8000 series meters provide highly accurate high-speed data capture and control around frequency excursions.

…

Please see https://www.se.com/ww/en/download/document/ PLSED310058EN_Web/ for specification.

Iberdrola Australia

Currently, MASS Requirement accuracy is 0.01Hz or 0.02% of 50Hz and resolution of 0.0025Hz or 2.5mHz

Lake Bonney BESS uses an Acuvim meter (Acuvim IIR-D-5A) for control. Accuracy 0.02% frequency, resolution of 1mHz. Lake monitors with an Elspec 4430 with 10mHz resolution and an accuracy of ±10mHz.

Iberdrola Australia now specifies Elspec G5 meters at the point of connection for all projects. This model has a 1mHz resolution and an accuracy of ±1mHz.

Rheem & CET

[33] See the submission quoted under the Cost of Compliant Metering sub-heading on page 33.
[34] Analogue to digital.

The current CET metering solution that is deployed on many thousands of BTM DER (generation and flexible load) orchestrated sites across the NEM and WEM has a 0.01Hz accuracy, with better than 0.001Hz resolution.

sonnen

sonnen has yet to identify a suitable (both technical and cost effective) solution that can be retrofitted to our residential BESS for participation in Very Fast FCAS markets.

…

sonnen has yet to identify a suitable (technical and cost effective) solution that can be included in our residential BESS for participation in Very Fast FCAS markets. Global metering solution providers for residential battery systems are not familiar with high-speed (<1 s update rate) requirements.

…

sonnen is currently investigating the potential development road map implications of support for updated rates of <100ms, however we are unable to provide feedback at this point in time.

Cost of compliant metering

Delta Electricity

The cost of recorders is in the order of $250k installed but cheaper varieties are available.

Enel X

Typically in the thousands of dollar range depending on volume and model selection.

Iberdrola Australia

For a utility scale battery, solar farm or wind farm, this is not significant.

Rheem & CET

The following wholesale pricing is for the current CET metering solution that is deployed on many thousands of BTM DER (generation and flexible load) orchestrated sites across the NEM and WEM. Full specifications can be found in the included CET-HD-PM2-1 Product Brief V1[35] which confirms accuracy and resolution (i.e., margin of error lower than < 0.1Hz):

The CET-HD-PM2-1 is a 6 Channel Power Meter that comes in an IP66 enclosure. An open Modbus interface is supported with access via Ethernet or PLC. Unit pricing and options pricing are as follows:

Unit Pricing:

CET-HD-PM2-1 6 channel IP66 power meter to minimum 50ms FCAS specification.

$A 318.00 Ex GST Ex Works Sydney Australia

CT harness to support 2 bundles of 3 CTs

$A 35.00 Ex GST Ex Works Sydney Australia

CT Bundle – 3 by 60A CTs

$A 48.00 Ex GST Ex Works Sydney Australia

CT Bundle – 3 by 120A CTs

$A 72.00 Ex GST Ex Works Sydney Australia

Note 1: Bespoke CT bundles supported – pricing on request.

[35] Attached to Rheem & CET’s submission.

Note 2: Volume pricing available on request.

Note 3: All prices are supply only

sonnen

Costs associated with higher resolution metering (hardware, data transfers and storage) to support a 0.5 s response time disproportionally disadvantage aggregated distributed resources such as residential BESS.

…

sonnen suggests this question is incomplete [Question 24 of Issues Paper – cost of high-speed metering that captures frequency measurements with a margin of error <0.1 Hz] and could generate potentially misleading interpretations of consultation responses.

Given that frequency estimation algorithm errors are typically sensitive to RoCoF and waveform distortions (transients, harmonics, DC offsets and other noise sources) sonnen suggests that responses to this question be categorised between those able to provide details on performance under a 1Hz/s RoCoF and acceptable rejection of typical waveform distortions that occur during contingency events, and those that do not explicitly state performance under the dynamic conditions expected during a contingency event in a low inertia power system.

… higher performance algorithms typically require high internal sample rates and high-performance computational resources.

Other issues AEMO should consider

Delta Electricity

Rapid detection of frequency and initiation of service is even more critical for Very Fast FCAS than for Fast FCAS. There is no point having a very fast service and monitor of that service if its frequency detection and control activation processes are slow except that, at least the fast monitor should record and display and confirm that the overall detection/initiation was slow. A slow detection and response system coupled with an equally slow or slower recorder should be cause for rejection of any such proposed Very Fast FCAS.

Rheem & CET

50ms metering is appropriate to ensure the greatest confidence in the deployment of the widest technology pool for participation in Very Fast FCAS.

sonnen

Practically achievable control system response and verification error budgets including but not limited to frequency estimation errors under dynamic and ‘real world network’ conditions.

Tesla

We would also welcome additional detail – particularly in relation to metering and verification - and are keen to work closely with AEMO to ensure DER and VPPs can actively participate in the Very Fast FCAS market and are best utilised. … AEMO should take a principles based (‘technology neutral’ and ‘scale agnostic’) view that reflects the optimised provision of services over the long-term.

4.5.2. AEMO’s assessment

Sampling rate and discounting

The measurement requirements for Very Fast FCAS are important to ensure that an FCAS Provider has complied with the FCAS enablement received from AEMO’s market systems. AEMO proposes a similar approach to that reached at the conclusion of the 2021 consultation. AEMO commissioned a new study from the UoM and the datasets used in the analysis were actual measurements captured following frequency excursions, as provided by FCAS Providers.

While most submissions were focused on the measurement sampling rate for Very Fast FCAS, it was brought to AEMO's attention that some Consulted Persons may have assumed that the scan rate of an FCAS Facility's control system may match the measurement sampling rate. This is concerning, particularly if these devices are intended to participate in the Very Fast FCAS and Fast FCAS markets.

AEMO requested high-speed data from Fast FCAS Providers with a measurement sampling rate greater than 50 ms for the purpose of the UoM analysis.

The results show that any delay to initiate the FCAS response will result in an increase in the assessment error. UoM has defined the assessment error as an indication of the relative difference of the Very Fast FCAS contribution (in MW.s) when changing the sampling rate.

The assessment errors for switching controllers and variable/proportional controllers when different sampling rates are used to verify the delivery of Very Fast FCAS are summarised in Table 2 and Table 3, which are taken from the UoM report.

Table 2 Largest absolute value of percentage assessment errors (relative to a 20 ms sampling reference) for the switched controllers analysed

Sampling rate/ms	0.5s service				1s service			
	Delay – 0 ms	Delay - 200 ms	Delay - 300 ms	Delay - 400 ms	Delay – 0 ms	Delay - 200 ms	Delay - 500 ms	Delay - 800 ms
50	1.57	2.46	3.87	9.07	0.79	0.92	1.37	3.71
100	7.62	12.54	18.99	39.47	3.78	4.67	7.38	17.63
200	37.9	63.17	82.77	95.05	8.61	11.21	17.83	45.32

Table 3 Largest absolute value of percentage assessment errors (relative to a 20 ms/10 ms sampling reference) for the variable controllers analysed

Sampling rate/ms	0.5s service	1s service
20	0.18	0.04
50	1.89	0.69
100	7.90	3.98
200	33.28	7.88

The results shown in Table 2 highlight that it is important to consider the delay before a switching controller initiates the FCAS response. Regardless of whether the response time for Very Fast FCAS is 0.5 s or 1 s, the assessment error increases significantly if the initiation delay exceeds 500 ms.

Based on the data considered, the results of the analysis for a response time of 1 s show that a measurement sampling rate of 100 ms will introduce an error close to 8% for a switching controller with an initiation delay of 500 ms and an error close to 4% for a variable controller.

AEMO considers that a 200 ms sampling rate is inadequate to verify a Very Fast FCAS response for the following reasons:

- A large discount will need to apply to offset the assessment errors from the slower sampling rate. For example, a discount close to 20% will be required for a switching controller with a 500 ms initiation delay.
- A 200 ms sampling rate could fail to capture the start of the FCAS response due to the delay before any change in active power is observed after Local Frequency has exceeded a controller's deadband or trigger setting.
- Considering that there is an additional delay between the frequency disturbance time (FDT) and when Local Frequency exceeds the trigger setting assigned to a switching controller, for example, if it takes more than 200 ms for frequency to ramp down from 49.85 Hz to 49.75 Hz, only two or three samples might be available to verify the Very Fast FCAS response within the first second of a disturbance.

Evergen submitted that the UoM study indicated a bias towards underestimation. AEMO notes that measurements captured at a slower sampling rate could fail to capture the stepped response from a switching controller. Subsequently, in the examples considered where the response delay is 0 ms, a linear approximation of the change in active power results in an underestimation of the area of the curve for slower sampling rates and negative values for the assessment error. The integrity of the applied methodology i.e. the rolling assessment window is demonstrated in Figure 3.9 and Figure 3.10 of the UoM report, which show both over- and under-estimation of the assessment error based on the different switched response profiles and delays considered, and no bias towards under-estimation.

Evergen also proposed a new FCAS verification methodology that would reduce the verification error arising from lower sampling rates, and questioned why this was not considered by UoM. UoM has applied the same methodology implemented in the FCAS Verification Tool, which had been reviewed as part of the last MASS consultation. Evergen suggested the inclusion of 40% of the FCAS trapezium between -120 ms and 80 ms and 10% of the trapezium between 480 ms and 680 ms for an assessment window of 500 ms. This, however, would not work in practice because timestamps are captured, not the time difference in ms from the initiation of the FCAS response. Furthermore, AEMO considers that Evergen's proposed approach could result in an over-estimation of the FCAS capacity delivered if the FCAS response was only initiated right before a new sample was captured.

For the purposes of last year's MASS consultation, studies were completed by UoM to confirm whether the verification error as a result of measuring the FCAS reponse at a slower sampling rate would decrease as the size of the aggregation increases. The measurement requirements for Fast FCAS were subsequenlty updated after consideration of the results from UoM's study. In line with last year's amendments to the MASS, Evergen and Tesla proposed similar arrangements for Very Fast FCAS based on the size of the aggregation, and Tesla's analysis to support its submission can be found in Appendix C. In principle, AEMO agrees that a lower discount could be adequate for a large aggregation of assets participating in the Very Fast FCAS markets, but considers it prudent to adopt a cautious approach at this stage. AEMO may review the discount if it appears justified with the benefit of operational experience with the Very Fast FCAS markets.

Measurements and metering cost

The proposed arrangements mean that most existing Fast FCAS Providers will not be required to retrofit additional equipment or incur additional cost to comply with the measurement requirements for Very Fast FCAS.

AEMO does not consider that there was any new information presented in the submissions to trigger a review of the sampling rate for Fast FCAS.

AEMO understands that Rheem & CET have the ability to measure at 50 ms intervals and they consider that specifying a slower sampling rate for Very Fast FCAS could risk grid security of supply. AEMO has not identified any technical justification for this conclusion. In contrast, the proposed specification for Very Fast FCAS would require the application of a discount greater than the verification errors from UoM's analysis, which would ensure that FCAS providers are delivering at least up to the capacity enabled. If the allowable sampling rate is no more than 50 ms for Very Fast FCAS, it will only allow a small number of aggregators, including Rheem & CET, to participate. Allowing FCAS Providers with a slower sampling rate to register in the Very Fast FCAS markets, with appropriate safeguards through the discount mechanism, is expected to increase competition, which AEMO considers to be in the best interest of consumers.

Rheem & CET also considered that a number of questions and observations had been left open. The UoM report specifies that the input data for the analysis consisted of a number of real-life response profiles. The most aggressive droop setting allowable for grid-scale battery systems is 1.7% and a significant percentage of FCAS from batteries is delivered by variable controllers with a droop of 1.7%. In response to Rheem & CET's other questions and comments on the need for further analysis, it is true that the accuracy of the analysis completed by UoM could be improved further if data from a larger variety of battery models and vendors was available. As Rheem & CET are aware, AEMO requested high-speed data from FCAS Providers for the purpose of this analysis but there are only a small number of FCAS Facilities currently capturing data at intervals less than 50 ms.

Reposit and Rheem & CET strongly support an independent analysis by the National Measurement Institute on the measurement arrangements for Very Fast FCAS. AEMO has consulted with an independent metering expert, Michael Guy, to determine adequate testing requirements for FCAS meters, whose key recommendation is that the equipment measuring the FCAS response should be type tested and certified to the IEC61557-12 standard. AEMO accepts this recommendation and as part of the FCAS registration process, AEMO will verify whether the type of FCAS meter selected by the proposed FCAS Provider complies with this standard. While the MASS does not specify the methodology to be followed to sample measurements, AEMO considers that certification to the IEC61557-12 standard will ensure that the control systems to deliver FCAS are measuring frequency appropriately and that the meters capturing the FCAS response are sampling both frequency and power adequately.

AEMO is concerned about Ready.Energy's submission that some organisations involved in designing and building the control equipment for VPPs have assumed that the measurement sampling rate specified in the MASS refers to both measurement for control and metering. AEMO wishes to make it clear that this is not the case. The previous MASS consultation focussed solely on the appropriate FCAS measurement requirements, and did not examine how sampling rate may affect the FCAS controls of an FCAS Facility.

Finally, AEMO agrees with Delta Electricity that it is important that the detection of frequency must be rapid and accurate so that control activation processes quickly respond to a frequency excursion. Therefore, AEMO is proposing the measurement specifications for control and metering in separate sections of the MASS to avoid any confusion between the two requirements. The specification of controller scan rate requirements will also ensure that the control systems do not respond slowly to deviations in frequency.

4.5.3. AEMO's conclusion

AEMO proposes to amend the MASS by:

- Specifying the measurement sampling rate for Very Fast FCAS providers as follows:
  - ≤100 ms for Aggregated FCAS Facilities comprised of ≥25 FCAS Facilities with no Inertial Response and with an initiation delay of ≤500 ms.
  - ≤50 ms for all other FCAS Facilities.
- Specifying the applicable discount on the quantity of very Fast FCAS delivered by an Aggregated FCAS Facility with a sampling rate >50 ms but ≤100 ms as follows:
  - 5% to the combined quantity of Very Fast FCAS measured at or close to the *connection points* of the Aggregated FCAS Facility if the *control system* is a Variable Controller; or
  - 10% if the *control system* is a Switching Controller or a discrete combination of both.
- Including scan rate requirements for FCAS controls, separately from the current measurement sampling rate requirements.
- Introducing type testing requirements for FCAS measurement equipment as follows:
  - Certification by an accredited testing facility to the sections of the IEC61557-12 standard as specified in Table 4:

Table 4 Application of IEC 61557-12 type tests

Measurement Parameters	Requirements section	Description	Type Test section	Comment
Power and Frequency			6.2.1 6.2.2 6.2.3 6.2.4	General test and acceptance requirements and temperature influence.
Power only	4.8.2	Specifies the limits of uncertainty, over the rated measuring range, under reference conditions and influence quantities, environmental and electromagnetic. Sample rate, measurement range and uncertainty as specified in Table 5 of the MASS	6.2.5 6.2.16	Specific tests for active power measurement and EMC test.
Frequency only	4.8.5	Specifies the limits of uncertainty, over the rated measuring range, under reference conditions and influence quantities, environmental and electromagnetic. Sample rate, measurement range and uncertainty as specified in Table 5 of the MASS	6.2.9	Specific test for frequency measurement.

  - Completion of tests by a facility accredited by either:
    a) The Australian National Association of Testing Authorities (NATA), or
    b) The International Accreditation New Zealand (IANZ); or
    c) By accreditation bodies that are signatories to the International Laboratory Accreditation Cooperation Mutual Recognition Arrangements (ILAC MRA).

- Where the meter is embedded in another device (e.g. an inverter or a protection relay), the respective clause in Annex H of the IEC61557-12 standard applies.

4.6. Overload capacity

4.6.1. Issue summary and submissions

In the Issues Paper[36], AEMO sought information to assist its consideration of whether the overload capacity of an FCAS Facility should be counted as Very Fast FCAS. To meet the proposed specification for Very Fast FCAS, the overload capacity would need to be able to be maintained for at least 6 s. AEMO posed questions for consideration by Consulted Persons.

Submissions were received on several issues around this[37].

Sustain time

Akaysha Energy

> Akaysha are working with an inverter supplier with a product capable of P/Q of 2.0pu for 2 s, 1.7pu for 30 s and 1.2pu for 5 min. Very few products are capable of providing such overload capability and unfortunately despite this having a high potential for support of the power system, the MASS currently does not enable use of this capacity.
>
> Overload capability is also extremely valuable for a VSM BESS to provide system strength and virtual inertia to enable the connection of additional renewables. Any FCAS market opportunity to support the business case of an overload capable BESS must be explored by AEMO to support the use of these assets in the NEM and reduce the costs by providing multiple services at the same time from the same generator e.g. VSM.
>
> Many other inverters can provide sustained overloads of 1.1 to 1.2pu however … it is more economic to install a single set of inverters with 2pu overload capability than two sets of 1pu inverters that are output limited to be able to provide a more beneficial overload capability.
>
> Akaysha would be happy to work with AEMO on how this overload capability can be best utilised for all stakeholders in the NEM.
>
> …
>
> … possibly flywheels and supercapacitors, possibly also solar PV with high DC/AC overbuild [have overload capacity that can be sustained for >6 s]. However, … these technologies will not be economic or have sufficient availability to provide these services at the times they are needed.

Delta Electricity

> The answer to this question depends on the system. However, in considering Very Fast FCAS, why does it matter as long as overload can be sustained for period the service demands (0-6s)? In any case, the capacity available to Delta Electricity, which depends on many factors including atmospheric, time of year, fuel quality and plant conditions, is in the order of minutes. Delta Electricity will probably not provide overload capacity for use in FCAS as its overload capability is delivered with caveats that require care to ensure a Unit remains secure and this generally means Raise FCAS is not available during overload operations.
>
> …
>
> Conventional Steam boiler and turbogenerator sets would have [overload] capacity, either switched or proportional, but it is not presently expected that many are designed for this use for FCAS [sustained for at least 6 s].

Iberdrola Australia

[36] See section 5.5.

[37] Note that submissions quoted in this document are in this font; a footnote in this font indicates that the footnote is copied from the submission. In the interests of saving space, AEMO has replaced descriptions in the submissions with acronyms that are defined in the Glossary.

Question for OEMs as responses will vary.

Our understanding is that this work on an I^2t relationship (current overload, not power overload). If because of voltage disturbance the system switches to Q priority, there would be no guarantee of the inverter being able to provide active power.

Tesla

… for our utility-scale systems we already need to comply with testing requirements to run at maximum and minimum MW for at least one dispatch interval (plus ramp up and ramp down).

Repeatability during Trading Interval

Akaysha Energy

This depends on the magnitude of overload capability delivered. The capability is based around the amount of heating the additional current creates within the silicone and copper of the inverter. For partial overloads, multiple triggers can occur in a 5-min interval.

Delta Electricity

Delta Electricity would not be proposing to use overload capacity for any type of Raise FCAS.

Iberdrola Australia

Question for OEMs as responses will vary.

Our understanding is that it would depend on how big the overload is (thermal recovery issue).

Delivery of overload capacity

Akaysha Energy

This is likely control system dependent. The inverter Akaysha Energy are working with can deliver overload either proportional to frequency deviation or as a step change.

Delta Electricity

It is considered conceivable that overload capacity could be delivered as proportional FCAS if a unit was so designed but is such a design is not presently under consideration for use in any FCAS.

EnergyAustralia

EA supports further investigation into overload capacity and the use of combination controllers. We also support the proposal that FCAS is initiated no later than halfway through the relevant ramp-up period. All would seem to offer the potential for improved frequency outcomes, from both technical and economic perspectives.

Percentage of nameplate rating equivalent to overload capacity

Delta Electricity

The overload is unit dependent but estimated to be in the range 2-5% of MCR for many plants.

Iberdrola Australia

Question for OEMs as responses will vary.

Our understanding is that for inverter units this usually is limited to maximum ~20%. Synchronous generators are limited by the protection system.

…

Tesla

It would be beneficial for AEMO to provide some further commentary on how stable operation will be demonstrated at overload. It will be particularly important to ensure that any approach to overload does not interfere with hold point testing, and that the AEMO connections team have a process in place to manage.

Energy payback after delivery of overload capacity

Akaysha Energy

Inverter overload should be separated into reactive power overload versus active power overload. Reactive power overload is mainly used to provide system strength where active power overload relates to inertia and Very Fast FCAS. Reactive power overload does not require additional battery capacity whereas real power overload will require a larger battery or one with a boosting capability.

Battery cell types each have different discharge and charge rate limit. Most cells used in utility storage applications are 0.25c, 0.5c or 1c. 0.25c means the cell takes 4 hours to discharge at its nominal output. For a 100MW BESS to have overload capability up to 150MW, it needs to have at least 150MWh of 1C cells, or 300MWh of 0.5C cells. This means for any real power overload capability an inverter has, this must be matched by sufficient DC power in the cells, often making project economics more challenging.

AEMO should work to enable BESS to provide overload capability in all FCAS markets to enable better utilisation. This would allow to use for instance two different type of batteries with a single inverter grid connection (DC coupled) to provide an energy power service and a high-power service.

Iberdrola Australia

Question for OEMs as responses will vary.

Our understanding is there isn’t subject to state of charge. For synchronous generation, there is the effect of the inertial response.

Other issues AEMO should consider

Akaysha Energy

AEMO should further investigate the potential registration of inverter overload capability with regards to FCAS registration amounts and acceptable testing of new units during the connection process. Many inverters are capable of sustained overload for periods of up to 5 min which is highly beneficial for bringing more FCAS capability to market however may not be acceptable as registered energy capability or allowed to be tested by the AEMO connections team.

…

AEMO’s FCAS team must work with the Connections team to determine how overload capacity will be functionally tested during commissioning noting that Connection will typically only allow a generator to run at its 5-min maximum rating. Akaysha sees large project risks that AEMO FCAS team may allow the use of overload capability that we would consider in our financial models, however AEMO Connections may now allow the utilisation of this capability.

Delta Electricity

Designs may be possible for existing steam generators but the estimated expected utilisation of overload capacity for this service does not yet justify the expense in designing and testing such a system. The overload capacity and the need to use it for FCAS will depend on considerations as to what regularity of operation a unit is at maximum output and the Contingency FCAS prices as to whether the deployment would be feasible. Units can provide FCAS raising services up to the PMAX but unless, by virtue of energy market dynamics, units are generally operated at PMAX, there may be no incentive to provide FCAS that utilises overload capacity unless also required whilst raise Contingency FCAS markets are also regularly at very high prices due to lack of supply. Such conditions could occur and may prompt considerations for such systems.

Iberdrola Australia

In our view this can only work if Very Fast FCAS is allowed to have a higher cap than the other Contingency FCAS (assuming voltage stays at or greater than 1p.u)

Utilising the overload capability to provide active power may result in generator performance standard (GPS) non-compliance in relation to reactive power capability and voltage control.

How will AEMO manage the registered FCAS trapeziums for overload capabilities to prevent stranding of the assets (outside the FCAS trapeziums)? Will the Enablement Max reflect the overload capability of the system or the registered maximum capacity?

…

[Whether overload capacity be delivered proportionally to the frequency deviation, or can it only be delivered by a step change in active power]

Question for OEMs.

Our understanding is that it should be proportional.

4.6.2. AEMO's assessment

The submissions suggest that the use of overload capacity will introduce complexities to the connection process and even lead to a GPS non-compliance if sustained during the provision of FCAS in accordance with the MASS.

While the overload capacity will enable some technology types to maximise their FCAS capacity, AEMO considers that further investigation is needed to understand the risks in allowing the overload capacity to be used by an FCAS Provider to comply with the MASS.

4.6.3. AEMO's conclusion

AEMO appreciates the careful consideration given to the topic of overload capability. Owing to the range of complexities involved, AEMO will defer further consideration of overload capability to a future review.

4.7. Impact on other FCAS

4.7.1. Issue summary and submissions

In the Issues Paper[38], AEMO considered the impact of Very Fast FCAS on other types of FCAS:

- The need to change the timeframe for delivery of Fast FCAS has the potential to impact the maximum ancillary service capacity of Fast FCAS Providers. Recognising that this could effectively require them to re-register their Fast FCAS. AEMO calculated a small increase in the Fast FCAS quantity using the current time average methodology and concluded that a re-assessment of FCAS Facilities delivering Fast FCAS should not be needed unless Fast FCAS Providers wish to use the same FCAS Facilities to deliver Very Fast FCAS.
- AEMO considered potential interactions between Very Fast FCAS and Slow and Delayed FCAS and did not identify any issues that require consideration.
- AEMO also considered potential interactions between Very Fast FCAS and Regulation FCAS and did not identify any issues that require consideration.

Submissions were received on several issues around this[39].

[38] See section 5.6.1, 5.6.2 and 5.6.3.

[39] Note that submissions quoted in this document are in this font; a footnote in this font indicates that the footnote is copied from the submission. In the interests of saving space, AEMO has replaced descriptions in the submissions with acronyms that are defined in the Glossary.

Impact on Contingency FCAS

Akaysha Energy

AEMO should ensure adequate resources are allocated to support the registration of new assets and re-registration of existing assets to provide these services to avoid delays in having a sufficient level of the capability available in the market.

…

No. [Cannot identify any case where a decrease in Fast FCAS capability could be observed]

…

AEMO have mentioned in Figure 8 that R1 and L1 may increase above R6/L6 and other Contingency FCAS depending on inertia levels in the power system. Logically it is ideal to procure more R1/L1 to enable operation at lower levels of inertia, but how is this implemented functionally? Any generator with capability to provide Very Fast FCAS or any other Contingency FCAS will likely do so via a single droop controller, meaning if enabled for more MW in R1/L1, it will also provide more MW in R6/L6. Would this then mean that generators provide more than they have been enabled for without renumeration?

Delta Electricity

There is no technical rationale to reducing Fast FCAS from 0 to 6s to 1 to 6s. It actually makes better sense in frequency control to focus on the faster responses instead of the slower responses and it is suggested that AEMO consider revising Fast FCAS into a 1 to 7s service and the Slow FCAS a 7 to 60s (or 61s if it would also benefit) instead of the proposed reduction in Fast FCAS. 1s removed from the Fast FCAS reaction is a greater proportion of its assignment than 1s removed from the Slow FCAS. Registration issues may be affected by the expected change to cap the performance to peak active power change so there appears to be scope to revise all services in designing the Very Fast FCAS.

…

If all existing frequency reactions that provide existing FCAS are, as determined from arithmetic that will calculate the very fast frequency response, already providing a very fast frequency reaction, it is questionable that the service will demonstrably prove its worth. i.e. why develop a market to pay Very Fast FCAS Providers for a service already being provided unless, for whatever reason, the quantity expected to be required in the Very Fast FCAS is quite distinct from the quantity expected from Fast FCAS. How will the new system demonstrably deliver better overall frequency control for contingency events? If a distinct system is required, it may be preferable to have a distinct measurement in time that does not overlap Very Fast FCAS into Fast FCAS. A similar problem exists with the Fast and Slow (and maybe Delayed FCAS) with regards to the distinction between a proportional reaction and a switched reaction. A proportional reaction is really delivered in a single response and is quite simply directly proportional and opposite to the frequency deviation. Whether the delivery is fast or slow actually depends on the overall system response, and the subsequent period of time the overall system recovery takes which is outside the control of any one machine. e.g. as a result of PFR, fast/slow delivery on any one machine is very different to what it was prior to PFR and this is not surprising but the MASS and assessing responses for it remain a strange arithmetic where a unit's existing readiness and capability to provide a singular proportional reaction to any one frequency deviation can actually be an applicable service in two separate markets let alone now proposed to be additionally paid for by a new third market.

…

The overall system response appears to have a large bearing on the performance of individual machines. This is not surprising. Fast FCAS performance of individual machines alongside Mandatory PFR is improved upon what it was for events prior. However, the prevalence of regular 50mHz peak-to-peak variations, and subsequent reactionary PFR, mean that sometimes calculations will start from either a supporting or counteracting position and it is therefore hard to predict cases which might yet demonstrate a reduction in Fast FCAS capability. Theoretically, having Fast FCAS calculated only over 5s instead of 6s, it is expected will occasionally result in less overall response in Fast FCAS. Therefore, it is recommended that AEMO consider making the Fast FCAS a 1 to 7s service recovering over 7 to 60s (or 61s) and subsequently adjusting slow FCAS to suit.

…

Very Fast FCAS response will occur through the transition from mechanical-hydraulic governing to DCS/Boiler supporting FCAS and this is not easy to coordinate to improve precision in the delivered response.

Enel X

We query whether the effectiveness of the current Contingency FCAS markets – particularly the R6 market – would be reduced at times when no R1 is being procured (during high inertial levels with strong interconnection, as is suggested by the Issues Paper) due to the reduction of the R6 ramp window back to 1 to 6s, from 0 to 6s. Notionally, during periods of zero R1 procurement, there will be no Contingency FCAS between 0 to 1s.

As such, AEMO should consider always procuring sufficient R1 to cover any reduction in R6 from shifting the ramp window back by 1s.

EnergyAustralia

We also agree with and support the changes proposed to the Fast FCAS market, provided modelling shows it will not result in a significant reduction in system inertia. Combined with the above, we consider these settings will strike an appropriate balance between:

- secure system outcomes,
- adherence to the FOS,
- minimising the risk of service over procurement, and
- the cannibalisation of revenues from other existing FCAS markets.

Iberdrola Australia

This approach [shifting Fast FCAS to accommodate a similar, but faster, Very Fast FCAS] seems reasonable.

…

No. [Cannot identify any case where a decrease in Fast FCAS capability could be observed]

Rheem & CET

We have no issues with either alternative [shifting Fast FCAS to accommodate Very Fast FCAS]. Our technology capabilities support participation in current and proposed markets with cost effective 50ms sampling accuracy.

…

YES. [can identify case where a decrease in Fast FCAS capability could be observed][40]

sonnen

Existing Fast FCAS resources capable of responding in less than 1s (such as distributed batteries) but not capable of meeting all the requirements to participate in Very Fast FCAS may see an adverse impact on the measured quantity of Fast FCAS.

Tesla

> *"AEMO proposes that Very Fast FCAS be specified a manner that reflects the existing relationship between Fast and Slow FCAS. That is, the 'ramp up time' of Very Fast FCAS would coincide with the commencement of Fast FCAS, mirroring how Fast FCAS peaks at the time Slow FCAS commences (i.e. the 6-second mark). An implication of this is that the Fast FCAS measurement window must be shifted to accommodate Very Fast FCAS. Assuming a Very Fast FCAS designed with a 1- second ramp up time, this leads to the design shown"*

This links to our comments made above in Q5[41], where difficulties in the connection process resulting in a centrally dispatched control will lead to inefficient (slower) response that will include a comms delay. This unnecessarily presents additional challenges for inverter-based response– whereby technical limits are introduced due to inflexibility of considering off-site testing and/or accommodating for the frequency-watt response MW characteristics.

Impact on Regulation FCAS

Akaysha Energy

40 See also submission quoted in sections 4.3.1 and 4.5.1.

41 See submission quoted in section 4.3.1 under the Other Issues AEMO should Consider sub-heading.

None that we are aware of. [Issues relevant to the interaction with Regulation FCAS]

Delta Electricity

No issues with Regulation FCAS but the issues with the unchecked large regular 50mHz frequency variations on a 20-30s period and the PFR reactions to these variations are expected to affect the calculations of Very Fast FCAS as they already would be affecting Fast FCAS and Slow FCAS caclulations.

4.7.2. AEMO's assessment

Impact on Contingency FCAS

The submissions on this issue sought clarification on aspects of Contingency FCAS and suggested various interactions that AEMO ought to consider.

Akaysha Energy noted that it is likely that all Contingency FCAS would be provided via a single droop controller, and asked whether this would mean that if a higher enablement for R1/L1 was given to an FCAS Facility, whether it would also provide more MW in R6/L6. AEMO agrees that it is likely that such a controller would contribute similar amounts in the R6/L6 timeframe to the R1/L1 timeframe, subject to energy availability and so on. This is an outcome of the way the Contingency FCAS markets have been designed, where for many FCAS controllers, one continuous response is split into multiple time windows. This design provides FCAS Facilities with different capabilities the opportunity to participate in some FCAS markets even if they are incapable of participating in all of them. The introduction of a Very Fast FCAS market does not change this characteristic. Since FCAS Providers are free to bid as they please in the FCAS markets, AEMO considers they are best placed to factor these elements of the FCAS framework into their market offerings including pricing and offered availability.

Delta Electricity was concerned about the timing of Fast FCAS, and whether it would be better to retain Fast FCAS' timing as is, or consider making it a 1-s to 7-s service. Shell Energy also considered the option of extending the timing of Fast FCAS. EnelX queried whether making Fast FCAS start from 1 s (rather than 0 s) would result in a lack of FCAS during the first second. Discussion of proposals to extend the timeframe of Fast FCAS are addressed in section 4.2.1.

On the matter of retaining the commencement of Fast FCAS from the 0-second mark, AEMO notes the following:

- Fully 'overlapping' the timing of Fast FCAS and Very Fast FCAS would present new problems in deciding how to allocate a response between Fast FCAS and Very Fast FCAS.
- Fully 'overlapping' the timing of Fast FCAS and Very Fast FCAS also necessitates co-optimisation between procurement of Fast FCAS and Very Fast FCAS, which complicates the registration and dispatch process significantly, placing the delivery timetable at risk. Co-optimisation is not a trivial task, especially when not all Fast FCAS is interchangeable, or fungible[42].
- AEMO considers that few Fast FCAS Providers would deliberately withdraw any response after the first second. AEMO suggests that this 1-s delay in which AEMO will measure the Fast FCAS is of benefit to the Fast FCAS Providers; instead of their Fast FCAS being the

[42] Consider, for example, where some Fast FCAS is delivered within 1 s or 2 s, but other FCAS Providers take, say 3-4 seconds to respond. Co-optimising these dissimilar Fast FCAS response profiles with Very Fast FCAS presents a difficult problem, as the FCAS framework requires that all FCAS of a particular market be treated interchangeably.

time average of the full 6 s, it will be the time average of the last 5 s, where an FCAS Facility's response is likely to be greater. This, potentially, will yield a greater Fast FCAS response. Regardless, AEMO notes EnelX's submission that some amount of Very Fast FCAS should always be procured, to cover for any potential shortfall in response owing to the changed timing parameters of Fast FCAS. This will certainly be considered in AEMO's approach to Very Fast FCAS procurement.

AEMO notes Tesla's comments on how connection and FCAS requirements interact to drive a preference for centralised facility FCAS controls rather than distributed (e.g. inverter-based) controls, and will continue to work on this, striving for the best compromise.

Impact on Regulation FCAS

Consulted Persons did not identify any issues around the interaction between Very Fast FCAS and Regulation FCAS.

4.7.3. AEMO's conclusion

There are no changes proposed to the MASS as a result of the issues raised in section 4.7.1.

4.8. Revision to FCAS measurement

4.8.1. Issue summary and submissions

In the Issues Paper, AEMO discussed an aspect of the measurement methodology, referred to as the 'multiplier effect'[43], that stems from the long-standing FCAS measurement approach. This multiplier effect means that some FCAS Facilities can be registered for participation in the Contingency FCAS markets at levels that are significantly higher than 100% of their capacity.

AEMO proposed to address the issue with the legacy FCAS measurement approach based solely on a time average of energy by:

- Capping the maximum registered ancillary service capacity for all FCAS markets based on the peak active power change.
- Introducing a new requirement on Contingency FCAS to be initiated no later than half-way through the relevant ramp-up period.
- Requiring existing Contingency FCAS Providers seeking to participate in the Very Fast FCAS markets to seek a revision of their registration in the Fast, Slow and Delayed FCAS markets.

Submissions were received on several issues around this[44].

Capping maximum capacity

Akaysha Energy

> We also approve of the planned change to measurement of registered capability being capped at the maximum MW level achieved.

[43] See section 5.6.4 of the Issues Paper.

[44] Note that submissions quoted in this document are in this font; a footnote in this font indicates that the footnote is copied from the submission. In the interests of saving space, AEMO has replaced descriptions in the submissions with acronyms that are defined in the Glossary.

AEMO should ensure adequate resources are allocated to support the registration of new assets and re-registration of existing assets to provide these services to avoid delays in having a sufficient level of the capability available in the market.

…

We feel that based on the new proposed measurement methodology capping the time weighted average to the peak value, a BESS will provide the same level of Contingency FCAS across all services (excluding energy availability limits). How then would AEMO procure additional Very Fast FCAS without then making all BESS provide additional 6s, 60s, 5min FCAS? BESS owners may consider implementing controllers to limit the droop output after Very Fast FCAS which is probably non-ideal from a power system perspective.

…

Akaysha are supportive of the proposed measurement cap to peak MW value.

Enel X

Enel X is concerned with the following elements of the proposal that we consider will adversely affect the incentives of the Contingency FCAS markets and decrease Fast FCAS capability:

- cap on registration at maximum active power change
- requirement of response to be initiated within half the ramp period.

We consider limiting offers to the maximum active power change will reduce the appropriate incentive for the FCAS Provider to respond as fast as possible. This coupled with the half ramp period response requirement could see most responders only providing services all at the same time and providing a significant blocked response rather than a smoother, stratified response.

We can see the concerns that led AEMO to conclude these restrictions but we consider that they are mistaken and heavy-handed responses. The current active power limit applies collectively across all Contingency FCAS markets rather than on each market's offers in isolation. This better appreciates how all the Contingency FCAS markets operate together to return the frequency to normal levels and not a singular market. The changes proposed ignore this interrelation between the markets and how they work together to provide a singular response to a frequency event. Additionally, the proposal disallows slower responders and disincentivises faster responses unnecessarily for an issue that is already considered and appropriately dealt with by the current MASS and NER. As such, we consider the proposal seems an oversimplification and overcorrection of the current MASS arrangements, which are suitable for use in all Contingency FCAS...

Also … there is a concern of materially reduced R6 being provided when no R1 is being procured if FCAS Providers update their settings to start responding from 1s rather than 0s in line with the new ramp windows.

…

AEMO's modelling and Issues Paper discusses the faster the response the more benefit to the grid. So, principally the MASS shouldn't be discouraging quicker response and rather encouraging and rewarding it, especially for the Very Fast FCAS where the benefits of faster responses are more material. As such, the alternate is a proportional calculation based on rewarding those that can respond quicker, as is currently used in Contingency FCAS markets.

Enel X considers the proposed changes to be an overcorrection to a minor issue that has not been clearly articulated to date. … there needs to be consideration of the relationship (and overlap) of the different markets. In the example provided, where a switched load of 30MW is valued at 50MW in R6, they would only be able to offer R60 at 10MW, thus the total valued/dispatched FCAS across the two markets is equal to the actual active power capacity provided, whilst still valuing the speed of response. We propose that instead a holistic approach to all FCAS markets should be taken, which we note is how the NER already require all FCAS offers to be made.

EnergyAustralia

EA acknowledges the theoretical arguments underlying the proposal to cap the maximum registered FCAS capacity. We also strongly agree that FCAS Providers should not be paid for services not actually delivered to keep customer costs as low and as transparent as possible. However, we question the significance and frequency of this outcome in practice.

Under current arrangements, FCAS Providers must deliver services in line with their offered FCAS volumes. To the extent any under-delivery occurs, there are mechanisms to ensure payments are recouped and future performance is compliant with market obligations.

…

As outlined in the most recent Frequently Asked Questions (FAQ), the cap is intended to apply across all markets and to all FCAS Providers. This makes sense for new FCAS Providers, but we strongly question its application to existing FCAS Providers. Forcing an existing plant to re-register when it has already demonstrated market compliance seems to be introducing additional regulatory burden and costs for no benefit. In particular, when any changes to the FCAS assessment methodology can be simply handled by adjusting bids in line with the incentives described above or via a Schedule 3.1 form if any unintended over-offering occurs. Further clarity on, and justification for, the proposed change as it relates to existing providers is, therefore, sought.

Iberdrola Australia

Should AEMO proceed with the capping of registered FCAS based on the actual response, this would have to occur at the same time as the introduction of the Very Fast FCAS. Otherwise, we see the following problems:

- Unfair discrepancy in treatment of Fast FCAS between FCAS Providers having opted to register for Very Fast FCAS compared to the one not having opted to provide Very Fast FCAS
- A reduction in Fast FCAS capacity if not enforced for all will slow down the FCAS Providers in registering for Very Fast FCAS and taking a wait a see approach. It will take time to weigh the economic benefits of making the registration change.

As previously mentioned, faster responses should be seen as a positive contribution and should be incentivised. After the introduction of Very Fast FCAS, Iberdrola Australia supports the capping of the Fast FCAS, Slow FCAS and Delayed FCAS, but recommends a multiplier effect incentive for the Very Fast FCAS.

…

Iberdrola supports an incentive for providers to deliver a faster response.

… a cap, if any, should also consider the impact of the proportional / switched hybrid model that would provide an additional response once frequency exceeds the switched response threshold.

sonnen

Capping the capability to the actual peak active power change is not required as the overlaps between the Contingency FCAS transition from fast energy injections to arrest the frequency disturbance through to a sustained capacity response for the Delayed FCAS.

Initiating service half-way through ramp-up period

EnergyAustralia

… We also support the proposal that FCAS response is initiated no later than halfway through the relevant ramp-up period. All would seem to offer the potential for improved frequency outcomes, from both technical and economic perspectives.

Enel X

[see immediately preceding section on Capping Maximum Capacity]

4.8.2. AEMO’s assessment

Capping maximum capacity

AEMO acknowledges that the current FCAS measurement methodology incentivises FCAS Providers to respond faster to a frequency excursion by allowing the registration of more capacity in the FCAS markets. With the current fastest FCAS market being a 6-s service, some have argued that the multiplier effect is an appropriate way to reward FCAS that is provided significantly faster than 6 s, however, the Amending Rule was made by the AEMC to create an efficient and appropriate way to value responses significantly faster than Fast FCAS.

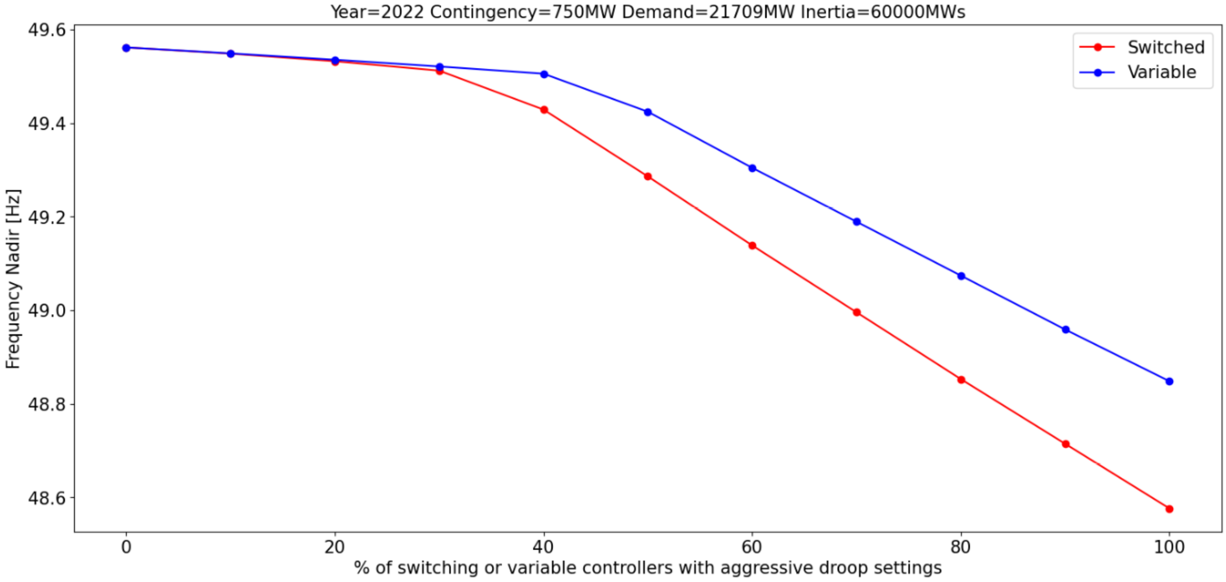
In the modelling shown in the Issues Paper, each scenario assumed the amount of active power in the FCAS delivered was equal to the FCAS enablement, which means that these studies did not demonstrate the potential impact of the multiplier effect very well. AEMO completed further studies that show how significant the impact of this effect could be.

Key assumptions of study

- Variable controllers were modelled with a deadband of ±15 mHz to align with the PFR requirement and with a droop setting of 1.7% to align with the maximum allowable droop setting for a grid-scale battery system.
- Switching controllers were modelled with an initiation delay of 150 ms and a step change in active power to reflect how loads respond once a controller is triggered.
- The multiplication factor implemented was 1.5 for variable controllers with aggressive droop settings and 1.7 for switching controllers. These values were derived as follows:
  - A 17.6 MW battery system with a droop of 1.7% and a deadband of ±15 mHz delivers a 10 MW response following a -0.5 Hz deviation. Due to the multiplier effect, the equivalent Very Fast FCAS capacity of the battery system would be 15 MW, which is 1.5 times more than the active power change.
  - Similarly, a 10 MW load that trips 150 ms after a switching controller is triggered, will also deliver a 10 MW response. Due to the multiplier effect, the equivalent Very Fast FCAS capacity of the load is 17 MW, which is 1.7 times more than the active power change.
  - The impact PFR and under-frequency load shedding (UFLS) was not considered as no particular amount of PFR was guaranteed, and in any case, FCAS is expected to ensure frequency is held within the acceptable bounds for credible events. UFLS is an emergency scheme intended to be used only in circumstances more severe than a mere frequency excursion triggering an FCAS response.
- When the multiplier effect is not included, the change in active power is equal to the amount of FCAS enabled and is proportional to the frequency deviation. For example:
  - If the total amount of FCAS enabled is 750 MW and 50% of the enabled FCAS comes from variable controllers with aggressive droop settings, the total active power change for a 0.5 Hz deviation is 625 MW, which represents 375 MW from variable controllers not impacted by the multiplier effect and 250 MW from the variable controllers with aggressive droop settings. Due to the multiplier effect, these controllers only need to deliver a 250 MW change in active power when enabled for 375 MW in the Very Fast FCAS markets.
  - If the total amount of FCAS enabled is 750 MW and 50% of the enabled FCAS comes from switching controllers with an initiation delay of 150 ms, the total active power change for a 0.5 Hz deviation is 595 MW, which represents 375 MW from variable controllers not impacted by the multiplier effect and 220 MW from the switching controllers. Due to the multiplier effect, these controllers only need to deliver a 220 MW change in active power when enabled for 375 MW in the Very Fast FCAS markets.

The results of this study are shown in Figure 2, which plots the calculated frequency nadir as the proportion of FCAS provided by FCAS Facilities benefiting from the multiplier effect is increased.

Figure 2 Impact on frequency nadir in the Mainland due to multiplier effect



As demonstrated by the results of this study, the impact of the multiplier effect on the frequency nadir is concerning, as quantities greater than 30%-40% mean that the frequency is no longer held within 49.5 Hz. AEMO is already regularly seeing dispatch outcomes with >50% of Contingency FCAS assigned to BESS and switching controllers. This simple model demonstrates how critical it is that the FCAS delivered be equal to the FCAS dispatched by AEMO. Therefore, a cap is required to maintain power system security following a credible contingency event, particularly as it is expected that the number of FCAS Providers using switching controllers and aggressive droop settings will continue to increase. While this study was completed for the mainland only, it is expected that the frequency nadir will be impacted to a greater extent for an island system.

For the reasons outlined above, the maximum registered ancillary service capacity for all FCAS markets will be capped to the peak active power change, including for existing registered FCAS providers and new FCAS Providers.

AEMO notes concerns raised by EnergyAustralia around the regulatory burden and potential cost of FCAS re-registration, and will consider these impacts further.

Initiating service half-way through ramp-up period

AEMO notes the submissions on this proposal, that it could be difficult for some FCAS Facilities to achieve, and that they are, in effect, already penalised by responding late by way of this reducing their FCAS capability.

AEMO proposes that this requirement not be introduced, as the existing measures combined with capping FCAS capability to the maximum change in active power is likely to be sufficient to encourage FCAS Providers to respond adequately. AEMO expects to reconsider this in a future consultation when the Very Fast FCAS markets are in place and AEMO can consider the operational experience gained.

4.8.3. AEMO's conclusion

AEMO proposes to amend the MASS to include a requirement that the maximum registered ancillary service capacity for all FCAS Facilities be capped by reference to the peak active power change they are capable of delivering within the relevant FCAS timeframes and at the reference frequency levels. This change is planned to take effect coincident with the commencement of the Very Fast FCAS markets, scheduled for 9 October 2023.

4.9. Contingency event time

4.9.1. Issue summary and submissions

In the Issues Paper[45], AEMO discussed the introduction of Contingency Event Time[46] and its impact on FCAS assessment. With the benefit of experience and a marked change in power system frequency performance, it appears that using the Contingency Event Time complicates the assessment of FCAS delivery, especially for FCAS Providers who cannot easily determine the Contingency Event Time independently of AEMO.

AEMO proposed to discontinue this and revert to using the FDT as the starting point for FCAS measurement. To adjust for FCAS Facilities being significantly away from their true baseline due to PFR action, AEMO is proposing to adopt an approach that adjusts the pre-disturbance baseline by the FCAS Facility's known frequency response function. Recent power system frequency performance suggests the necessity for adjustment would be relatively rare.

Several submissions were made on this issue[47].

Contingency event time vs frequency disturbance time

EnergyAustralia

> We strongly disagree with the proposal to move back to FDT as the starting point for FCAS measurement from Contingency Event Time (CET). In the original Primary Frequency Control (PFR) rule change, AEMO committed to ensuring that PFR counted toward a unit's Contingency FCAS enablement during a frequency disturbance. Unfortunately, the proposed compensatory offset-band mechanism will effectively undermine this commitment. This is a result of the mechanism not factoring in the response provided between the PFR deadband and the edge of the Normal Operating Frequency Band (NOFB). For example, if the frequency during the initial MW measurement is 50Hz, there will be no offset band at all.
>
> Such a change will have critical market ramifications. Beyond seeing a substantial quantity of FCAS ignored in the response assessment, this will also inevitably result in a significant reduction in offered FCAS volumes. This is due to the effective loss of operational tolerances which would otherwise be used to meet FCAS enablement requirements.
>
> Together, these factors raise the very real risk that inadequate FCAS will be available to ensure sufficient aggregate response to meet power system limits following contingency events. Thus, damaging both AEMO's ability and credibility as the system operator. Moreover, such scarcity of supply would inevitably see customers face markedly increased costs for the provision of system security services. EA considers these are highly undesirable outcomes when weighed against the benefits of a small number of generators being more easily able to determine CET. In particular, when there are several other simpler, less risky and economically benign solutions available. For example, simplifying the definition of CET or having AEMO publish the CET for each event. We, therefore, strongly urge reconsideration of any changes to CET.

Shell

[45] See section 5.7.
[46] Contingency Event Time refers to the time of the actual contingency event.
[47] Note that submissions quoted in this document are in this font; a footnote in this font indicates that the footnote is copied from the submission. In the interests of saving space, AEMO has replaced descriptions in the submissions with acronyms that are defined in the Glossary.

The Contingency Event Time was introduced to the MASS for the specific purpose of measuring the level of PFR already supplied by an FCAS Provider within the NOFB. We supported this change.

AEMO has proposed removing the Contingency Event Time offset and reverting to using the FDT as the starting point for FCAS measurement. In addition, AEMO proposes to implement an additional calculation to compensate for an FCAS Facility being significantly away from their true baseline due to PFR action. Based on the example set out in Figure 25, it is not clear that AEMO's proposal will adequately calculate an FCAS Facility's PFR contribution when it has moved away from its energy target to maintain power system frequency close to 50 Hz. An FCAS Facility may be significantly away from its energy target providing PFR, even though system frequency is close to 50 Hz.

The proposed methodology is based on a measurement of contribution for system frequency away from the 50 Hz reference frequency. The closer system frequency is to 50 Hz, the lower the level of compensation allocated. As such, this methodology fails to compensate for the amount of PFR already undertaken by the FCAS Facility to maintain system frequency close to 50 Hz. This would be the case when a contingency event occurs close to the issue of a new dispatch target during periods of energy output ramping. In our view, any proposal to replace the Contingency Event Time offset with an alternative compensation method must adequately identify and compensate all the PFR work done by the FCAS Facility to maintain system frequency close to 50 Hz.

Alternatives to the baseline adjustment approach proposed by AEMO

Akaysha Energy

Not that we can think of.

Delta Electricity

There remains a likelihood that reserves prepared for Contingency FCAS are being eroded by an unsteady (lowering or rising or both) "normal" frequency conditions prior to any defined contingency event that requires the reserves. Such conditions were occurring prior to PFR but, although triggers of FCAS recorders have lowered by the narrowing of overall frequency range, continued unsteadiness of frequency normal is large enough to be regularly utilising reserves for PFR. The use of energy dispatch trajectories (actual to target) to determine the PFR position at a frequency event time can display a real MW support (or retardation) already deployed that should be included with the very fast FCAS calculation but should also be considered as the initial MW position in FCAS calculations. The dispatch trajectory target point can be sizeably (a few MWs) different from the basepoint MWs as determined in the present arithmetic examining Actual MWs just prior to certain frequency deviations as measured. The base starting MWs from which to measure a response should really be worked out from the dispatch trajectory basepoint (actual to target) and not from the actual MWs as recorded just prior to a frequency transition.

Iberdrola Australia

Not that we have considered at this time.

Other issues AEMO should take into account

Akaysha Energy

None that we are aware of.

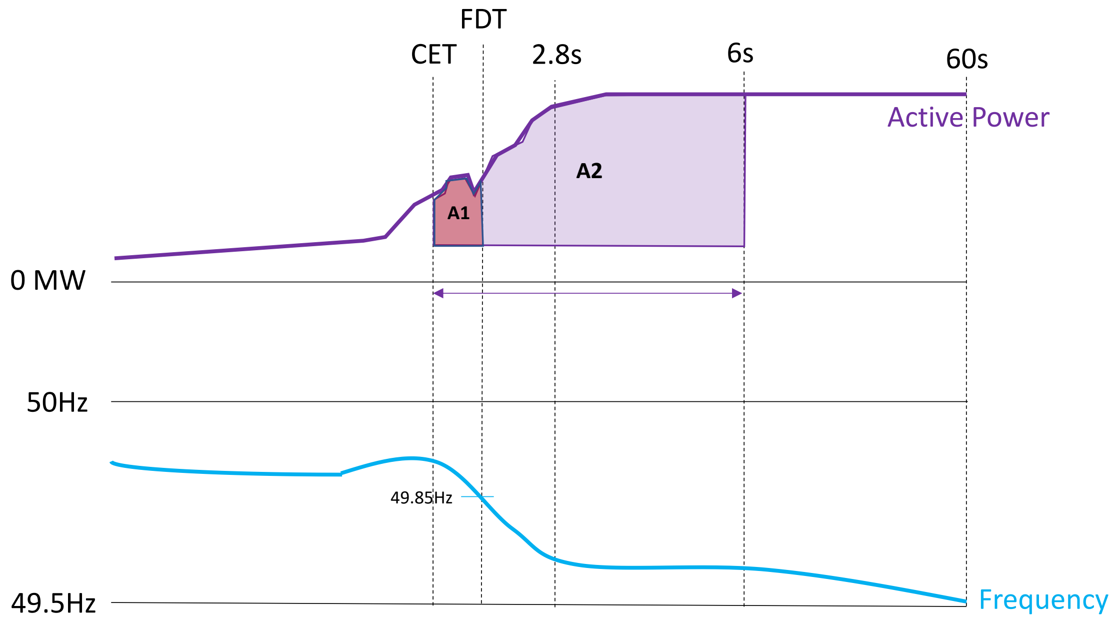
4.9.2. AEMO's assessment

Contingency event time vs frequency disturbance time

EnergyAustralia and Shell raised concerns that the proposal to measure FCAS from FDT rather than the Contingency Event Time could result in any frequency response provided within the NOFB (such as by PFR) being 'missed' during measurement, and this could present problems for FCAS compliance.

It is possible this concern may be based on a misunderstanding of the FCAS measurement process. FCAS measurement consists of a time average of a relevant period, not a calculation of area. All other things being equal, AEMO cannot identify a realistic scenario where the time average measured from FDT to 6 s after the FDT would result in a lower value than the time average measured from the Contingency Event Time to 6 s post FDT. An example is illustrated in Figure 3:

Figure 3 Comparison of total area and time average



While the total area of A1 (CET to FDT period) and A2 (FDT to the 6-s point) is greater than the area between FDT and the 6-s point, the time average of area A2 is greater than the time average of area (A1 + A2). It is the time average that is used in the FCAS calculations, not the area. So the FCAS measured by considering just the period FDT to 6 s later would be greater than if the CET to FDT period was also included.

Therefore, rather than CET vs FDT being important in recognising PFR action, what is especially important to the amount of FCAS measured is what the assumed base, or initial value is; that is, the value that all frequency response is measured against. The following section explores the implications of different approaches.

Alternatives to the baseline adjustment approach proposed by AEMO

Delta Electricity suggested that using a dispatch trajectory (based on actual-to-target, not target-to-target) could be preferable to establishing a base value. This is a reasonable suggestion, however, AEMO's experience in monitoring FCAS is that this would probably be a less robust approach overall because, for a variety of reasons, the dispatch trajectory is not strictly adhered to. The reasons include PFR action, slow FCAS Facility responses, and AGC control behaviour, especially for FCAS Facilities providing Regulation FCAS. Furthermore, for an increasing number of FCAS Providers (in particular, those with FCAS Facilities that are not comprised of scheduled or semi-scheduled plant) the concept of a dispatch trajectory is not relevant.

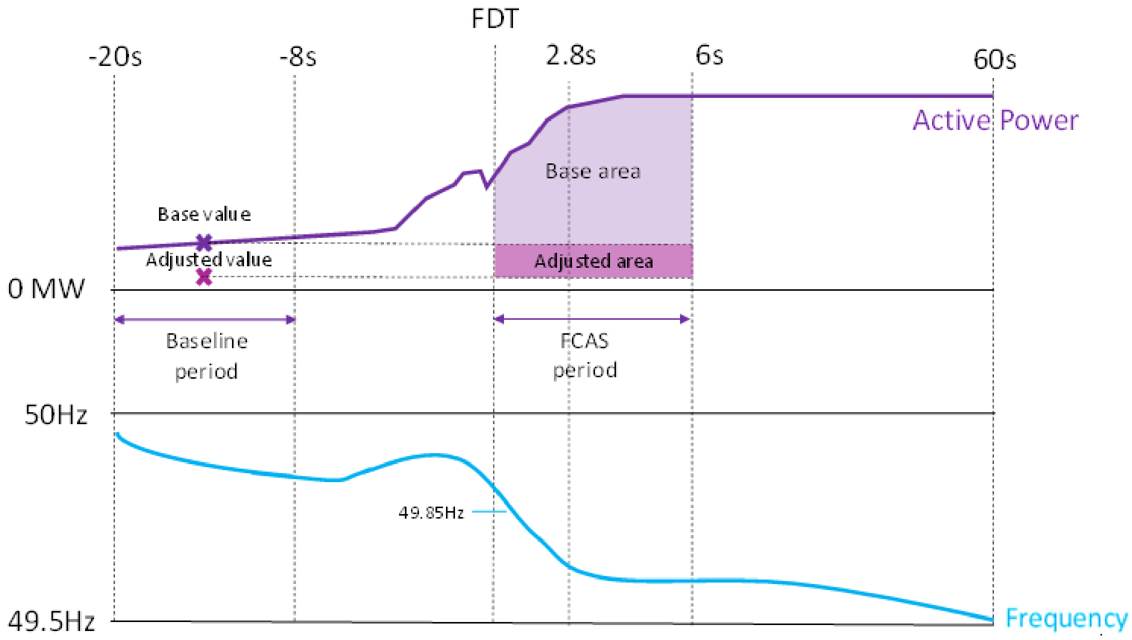
AEMO's existing methodology takes into account this trajectory as set out in section 2.1(a)(i) of the MASS Verification Tool User Guide version 4.1. However, this trajectory it is used to establish the **change** in output over the applicable period, rather than the absolute output. The absolute value is established as the average output between 8 and 20 s prior to FDT. AEMO suggests this averaging approach is more robust because, otherwise, all FCAS would essentially be calibrated against a single sample, being the 'actual' value at the start of the assessment. EnergyAustralia justifiably argued that setting the base value in line with a single point measurement (whether adjusted for frequency response or not) runs a significant risk of mis-identifying the true base value of the FCAS Facility especially when frequency and PFR action can be quite dynamic.

In light of these submissions, AEMO proposes to:

- Retain the base value as the average of the FCAS Facility's output between 8 and 20 s prior to FDT.
- Apply a narrow deadband adjustment (that is, the expected response based on known deadband and droop) for frequency response within the NOFB based on the average frequency over the same 8 to 20-s pre-FDT window.

Below is an example of how this would apply. Figure 4 shows the kind of frequency disturbance EnergyAustralia highlighted in its submission, where frequency returns close to nominal prior to contingeny event.

Figure 4 Example of Adjusted area



In evaluating various approaches and suggested methods against a range of hypothetical frequency disturbances, it appears that no single methodology works ideally in every conceivable circumstance. Therefore, AEMO's objective is to employ a robust methodology that works well for a significant majority of events, which is what AEMO has proposed.

4.9.3. AEMO's conclusion

AEMO proposes to amend the FCAS measurement process in the MASS to refer to the Frequency Disturbance Time, rather than Contingency Event Time, and introduce the baseline adjustment approach as described above.

AEMO proposes a new section 3.1.1 in the MASS that clarifies that AEMO considers demonstrable frequency response within the NOFB in response to a frequency disturbance to count towards any Contingency FCAS obligations. This should reassure FCAS Providers that there is no change in AEMO's policy of recognising PFR.

5. Matters outside of Consultation

5.1. Issues raised by AEMO

While not part of the scope of this Consultation, AEMO expects that Very Fast FCAS will also ultimately have these properties:

- Procurement will be inertia-aware: that is, the procurement volumes for Very Fast FCAS will take into account the level of system inertia.
- Procurement may need to take into account geographic limitations, for example, at a regional level.
- The level of proportional and pure-switched response comprising Very Fast FCAS will need to be managed.

Nevertheless, AEMO was interested to receive submissions on these matters. Submissions were received on the second issue, only[48].

5.1.1. Geographic diversity

Submissions

Akaysha Energy

> … within a few years geographic diversity of Very Fast FCAS capable BESS will not be an issue due to the large number of projects under development. Geographic diversity is logical from a system security perspective as distribution of the services helps protect against non-credible contingency events such as regional separation.

Evergen

> … aggregators of small-scale DER are well-positioned to deliver FCAS capability that is highly geographically diverse. To the extent that locational concentrations of Very Fast FCAS are to be avoided, this does not present a limitation for aggregator-based FCAS delivery.

Iberdrola Australia

> Diversity of response type, i.e. would it pose a significant issue if in some geographical areas Very Fast FCAS was only of a single type, e.g. loads?

Shell Energy

> … AEMO requests comments on the geographic diversity of very fast FCAS procurement. AEMO also indicates that a reasonable starting point could be to restrict FCAS from any region from being dispatched for more than 50% of the total requirement. Shell Energy considers that this limit maybe too high. In theory, it could allow for the entire Very Fast FCAS procurement to come from two regions. A limit of 40% of the total requirement would mean that Very Fast FCAS would have to be procured from at least three regions. … this would be a more prudent approach to ensure that there is sufficient diversity of supply. A limit of 30% could also apply, which would ensure that Very Fact FCAS must be supplied from at least four regions which in our view would provide a superior approach with regards to balancing the power system as a whole and improve overall system resilience. Regardless of what percentage is determined, for an interconnected mainland, the existing common (global) clearing approach should continue to apply. Only under infrequent islanding or prior network outages impacting interconnector flows where a local FCAS requirement is invoked, should a local FCAS price be implemented.

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[48] Note that submissions quoted in this document are in this font; a footnote in this font indicates that the footnote is copied from the submission. In the interests of saving space, AEMO has replaced descriptions in the submissions with acronyms that are defined in the Glossary.

Tesla

> Given the criticality for delivery, AEMO should introduce minimum levels of Contingency FCAS per region to ensure NEM wide provision
>
> …
>
> As a related priority step, Tesla supports AEMO implementing regional based minimum quantities for Contingency FCAS procurement.

Discussion

It is clear that Consulted Persons hold a range of views on the matter of geographical diversity, with some preferring no prescriptive distribution approach and others highly in favour of permanent geographical constraints. AEMO will ultimately be guided by power system security concerns.

As stated in the Issues Paper, this topic will be pursued further during AEMO's work on the procurement of Very Fast FCAS.

5.2. Drafting improvements

Consulted Persons will note that AEMO has taken the opportunity to redraft the following:

- Section 3.1 contains a general description of Contingency FCAS. The text was consolidated into a table for easier reference.
- Sections 8.1, 8.2, 9.1, 9.2, 10.1 and 10.2 in v7 of the MASS are, apart from the numbers, effectively identical. The introduction of similar requirements for Very Fast FCAS provides AEMO with an opportunity to consolidate all in a new section 6.3.
- Sections 8.3 and 9.3 in v7 of the MASS are identical. In the course of reviewing it for the purposes of this consultation, AEMO identified an inadvertent error in that there was no equivalent in section 10.3. Hence, all equivalent provisions were replaced by a new section 6.3, consolidating all references to the same requirement for all types of Contingency FCAS in the one place.
- Some of the content of Table 8 in v7 of the MASS was consolidated in the same way.
- The term "Ancillary Service Facility" has been shortened to "FCAS Facility", and the term "Aggregated Ancillary Service Facility" shortened to "Aggregated FCAS Facility".
- Some remaining references to '*dispatch interval*' were replaced with '*trading interval*' in line with five minute settlement rule changes.

AEMO invites submissions on whether Consulted Persons consider these changes improve readability and minimise misinterpretations.

5.3. Other changes to the MASS

AEMO proposes the following changes in addition to those related to Very Fast FCAS:

- A new section 5.8 to require an FCAS Provider to provide a monthly report to AEMO demonstrating compliance with any aspect of the MASS if requested.

- The removal of the requirement for settling time as recommended by the independent metering expert as the MASS already specifies the metering sampling rate and accuracy for measurements of power and frequency
- The removal of the term 'Trigger Rate' from the Glossary in section 1.2.1 as it is no longer used. FCAS equipment must trigger recording at least whenever Local Frequency changes exceeds the Trigger Range.
- The removal of the option for a switching controller to initiate delivery of FCAS based on a combination of both Frequency Deviation Setting and Frequency Rate of Change Multiplier. Due to the additional complexity in implementing this option, it is rarely selected by FCAS Providers and AEMO sees no benefit in retaining it.

6. Draft Determination

Having considered the matters raised in submissions, AEMO's draft determination is to amend the Market Ancillary Service Specification (MASS) in the form of Attachment 1, in accordance with clause 3.11.2 of the NER. Consistent with the Amending Rule, the amended MASS will take effect on 9 October 2023.

Appendix A. Glossary

Term or acronym	Meaning
[number] ms	millisecond
[number] s	second
Addendum	The Addendum to the Issues Paper – June 2022. Available at https://aemo.com.au/consultations/current-and-closed-consultations/amendment-of-the-mass-very-fast-fcas.
AEC	Australian Energy Council
AEMC	Australian Energy Market Commission
AGC	Automatic generation control system
Aggregated FCAS Facility	As defined in the MASS.
BESS	Battery energy storage system
BTM	Behind the meter
Contingency FCAS	Any of the following: • fast raise service; • fast lower service; • slow raise service; • slow lower service; • delayed raise service; and • delayed lower service
Delayed FCAS	Delayed raise service (also known as R5) and delayed lower service (also known as L5)
DER	Distributed energy resources
DI	dispatch interval
DUID	Dispatchable unit identifier
ESS	Energy storage system
Fast FCAS	Fast raise service (also known as R6) and fast lower service (also known as L6)
FCAS	Frequency control ancillary services, referred to as market ancillary services in the NER – effectively, Contingency FCAS and Regulation FCAS
FCAS Facility	As defined in the MASS
FCAS Provider	A Market Participant in one or more FCAS markets
FCAS Verification Tool	An Excel spreadsheet published by AEMO to assist market participants to calculate FCAS delivered by their plant
FFR	Fast frequency response
FOS	Frequency operating standard
Frequency Disturbance	An occasion when the power system frequency moves outside the NOFB
Frequency Disturbance Time (FDT)	As defined in the MASS
Frequency Settings	As defined in the MASS
GPS	Generator performance standard.
Hz	Hertz
IANZ	International Accreditation New Zealand
ILAC MRA	International Laboratory Accreditation Cooperation Mutual Recognition Arrangements
Issues Paper	AEMO's Issues Paper titled: Market Ancillary Service Specification Consultation – May 2022 Available at https://aemo.com.au/consultations/current-and-closed-consultations/amendment-of-the-mass-very-fast-fcas.

Term or acronym	Meaning
LCR	Largest credible risk.
Local Frequency	As defined in the MASS.
Lower FCAS	Any of the following (terms defined in the NER): • fast lower service; • slow lower service; and • delayed lower service.
Mainland	As defined in the MASS.
MASS	Market ancillary service specification
ms	millisecond
MW	megawatt
NATA	National Association of Testing Authorities
NEM	National Electricity Market
NEMDE	The NEM dispatch engine
NEO	The objective specified in section 7 of the National Electricity Law, which is to: ... promote efficient investment in, and efficient operation and use of, electricity services for the long term interests of consumers of electricity with respect to— (a) price, quality, safety, reliability and security of supply of electricity; and (b) the reliability, safety and security of the national electricity system.
NER	National Electricity Rules
NMI	National metering identifier.
NOFB	Normal operating frequency band
NSP	Network Service Provider
OEM	Original equipment manufacturer
PFR	Primary frequency response
Raise FCAS	Any of the following: • fast raise service; • slow raise service; and • delayed raise service
Regulation FCAS	Any of the following: • regulating raise service; and • regulating lower service
RoCoF	Rate of change of frequency
s	second
SA	South Australia
Slow FCAS	Slow raise service (also known as R60) and slow lower service (also known as L60)
Switching Controller	A control system that delivers a specific amount of FCAS by either switching generation or load on or off (as applicable) in response to parameters specified by AEMO
UoM	University of Melbourne
Very Fast FCAS	Very fast raise service (also known as R1) and very fast lower service (also known as L1)
VPP	Virtual power plant
VSM	Virtual synchronous machine

Appendix B. Summary of submissions and AEMO responses

No.	Consulted person	Issue	AEMO response
1	AEMO, Enel X, Iberdrola Australia, Rheem & CET, Tesla	Market Design See section 4.1.1.	See section 4.1.2 and 4.1.3.
2	AEMO, Akaysha Energy, Delta Electricity, Enel X, Iberdrola Australia, Rheem & CET, Shell Energy, sonnen, Tesla	Key Parameters for Very Fast FCAS See section 4.2.1.	See section 4.2.2 and 4.2.3.
3	AEMO, Akaysha Energy, Delta Electricity, Enel X, Evergen, Iberdrola Australia, Rheem & CET, sonnen, Tesla	Capability of different Technologies to deliver Very Fast FCAS See section 4.3.1.	See section 4.3.2 and 4.3.3.
4	AEMO, Akaysha Energy, Delta Electricity, Enel X, Iberdrola Australia, Rheem & CET, sonnen, Tesla	Control System Requirements See section 4.4.1.	See section 4.4.2 and 4.4.3.
5	AEMO, Delta Electricity, Enel X, Evergen, Iberdrola Australia, Ready.Energy, Reposit, Rheem & CET, Shell Energy, sonnen, Tesla	Verification and Measurement Requirements See section 4.5.1.	See section 4.5.2 and 4.5.3.
6	AEMO, Akaysha Energy, Delta Electricity, EnergyAustralia, Iberdrola Australia, Tesla	Overload Capacity See section 4.6.1.	See section 4.6.2 and 4.6.3.
7	AEMO, Akaysha Energy, Delta Electricity, Enel X, EnergyAustralia, Iberdrola Australia, Rheem & CET, sonnen, Tesla	Impact on other FCAS See section 4.7.1.	See section 4.7.2 and 4.7.3.
8	AEMO, Akaysha Energy, Enel X, EnergyAustralia, Iberdrola Australia, sonnen	Revision to FCAS Measurement See section 4.8.1.	See section 4.8.2 and 4.8.3.
9	AEMO, Akaysha Energy, Delta Electricity, EnergyAustralia, Iberdrola Australia, Shell Energy,	Contingency Event Time See section 4.9.1.	See section 4.9.2 and 4.9.3.
10	Delta Electricity	Interaction with Inertia Inertia has a more obvious impact on a Unit's reaction in the timeframes relevant to Very Fast FCAS sometimes negating the total response observed to a changing frequency especially if the	AEMO suggests this should be a factor carefully considered in processes exploring the case for inertia procurement.

No.	Consulted person	Issue	AEMO response
		frequency change is complex which is the case in the NEM as a result of regular 50mHz peak-to-peak variations occurring in the NOFB.	
	Iberdrola Australia	Agree that Very Fast FCAS and inertia (mechanical or synthetic) should be treated separately and exclusive. We note it may be challenging ex post to separate (synthetic) inertia and FFR responses when provided at small timescales and with an actual frequency trace (i.e. not a clean theoretical trace).	Noted.
11	Akaysha Energy	Interaction with PFR Figure 9 appears to be incorrect as the line 1.7% droop with 0.15Hz deadband shows no PFR response.	Noted.
	Delta Electricity	PFR and FCAS are delivered from an assortment of controllers. Sustained PFR as required by AEMOs Primary Frequency Response Requirements is not a simple system to evaluate because of the reaction time and coordination between initial reaction detected and delivered from the turbine reacting to a change in turbine speed, followed by the Unit DCS MW setpoint error detection and then the correction reaction followed/interlaced with (dependent on detection of frequency by separate frequency readings) DCS controller FCAS reaction that will typically override the MW correction action that may or may not commence before it, dependent on the size of initial frequency deviation. The FCAS assessment calculations run data from recorders through arithmetic which mathematically removes inertia but it is hard to distinguish between PFR and Fast FCAS and Slow FCAS because they are co-delivered. It is easier to distinguish between PFR/FCAS delivered initially by mechanical-hydraulic governor action then corrected by DCS MW setpoint correction action and the PFR/FCAS then delivered by governor setpoint change made by the DCS supported by Boiler/Turbine FCAS reactions.	Noted – developing robust methodologies to ensure PFR action is reliably captured in FCAS assessment is not straightforward therefore AEMO is ensuring the principle of counting PFR towards FCAS obligations is clearly stated in the MASS. See discussion in section 4.9.
	Enel X	We acknowledge AEMO's position on all FCAS responses being considered for Contingency responses but caution that this may confuse the purposes of the separate services. PFR relates to the quantity of Regulation FCAS required during normal operation and keeping frequency within NOFB. Whereas Contingency FCAS is about responding to a frequency deviation due to a continency event. Using one service procured for another purpose may erode the service from being able to meet its purpose – i.e. Contingency FCAS being used for Regulation FCAS may mean there is an insufficient response when an event occurs.	Section 3.2.1 of the MASS details how PFR is different from Regulation FCAS. The intersection between FCAS and PFR was addressed extensively during AEMO's consultation on the PFR Requirements.[49] AEMO continues to monitor PFR and Contingency FCAS performance and can readily adjust Contingency FCAS procurement settings if warranted.
	Iberdrola Australia	Agree with the approach outlined, and in particular the fact that all 'genuine' frequency response should count towards Contingency FCAS, regardless of whether it is delivered by a PFR mechanism, or whether it is inside or outside of the NOFB.	Noted.
	Tesla	Tesla continues to support the principle that all beneficial frequency response should count towards Contingency FCAS, regardless of whether it is delivered by a PFR mechanism, or whether it is inside or outside of the NOFB.	Noted.

[49] See https://aemo.com.au/consultations/current-and-closed-consultations/primary-frequency-response-requirements-document-consultation.

No.	Consulted person	Issue	AEMO response
12	Ergon Energy Retail	Ergon Energy Retail supports the proposed amendments to the MASS to implement a new FCAS market for Very Fast FCAS.	Noted, with thanks.
13	Tesla	Commencement We also strongly encourage AEMO to maintain timelines to introduce Very Fast FCAS in full, as quickly as possible (as proposed by the AEMC). Given the pace of the energy transition, it seems prudent to ensure a strong signal is sent to Very Fast FCAS Providers (existing and potential) to ensure credible contingencies can be adequately managed in the short-term, and to provide sufficient buffer for potential inertia shortfalls which are increasingly harder to forecast ahead of any formalised inertia arrangements. This is an optimal low-risk/ high-reward approach.	Noted.

Appendix C. Tesla's application note: measurements error

Methodology Overview

To support the AEMO's Issue Paper on the amendment to the MASS for Very Fast FCAS, Tesla has recreated similar modelling that was submitted to AEMO for the purposes of the 2021 MASS review focused on the integration of distributed energy resources (DER). Tesla has rerun the previous Monte Carlo analysis, as used in our previous submission with a 1Hz drop in frequency as defined by AEMO in the Issues Paper.

The methodology used in the 2021 analysis remains the same, however with a 1 s measurement window considered as opposed to the 6 sfast FCAS measurement window.

Frequency Measurements (20ms)

This study uses a simulated frequency disturbance of 1Hz/s as the assumed frequency ramp rate as per the Issues Paper. This disturbance is generated at 20ms.

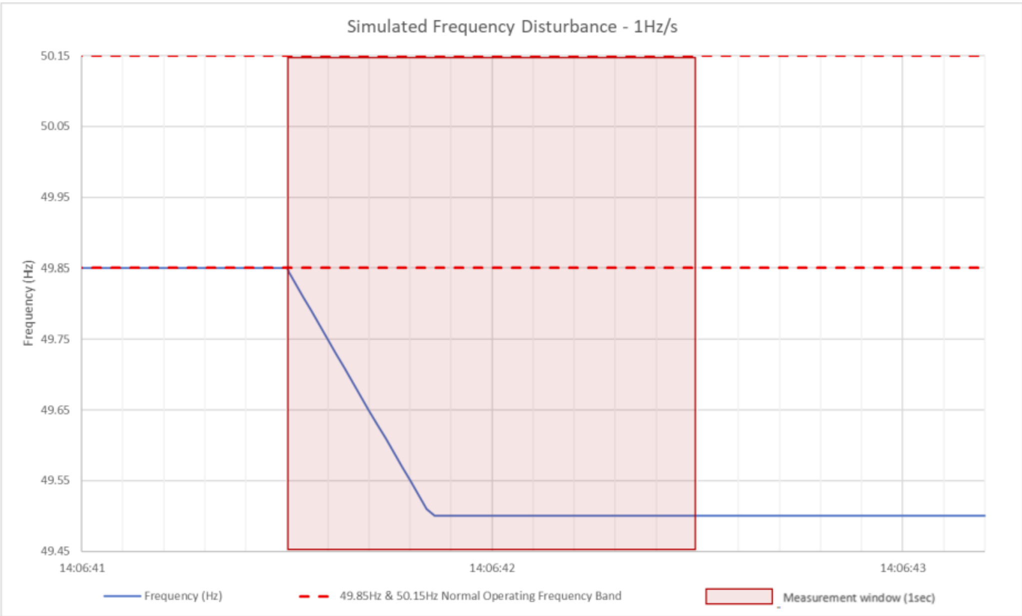

Figure 1 – Simulated frequency disturbance of 1Hz/s RoCoF (20ms sampling rate)

Power Response (20ms)

The response from a 5kW Tesla Powerwall 2 ("Powerwall") registered under DUIDs VSSEL1V1and ASSEL1V1is calculated using the 0.7% droop setting provided to this DUID by AEMO upon registration. The capability of the Powerwall to respond to a frequency deviation was demonstrated during a frequency injection test performed in a laboratory. Figure 2 shows that the Powerwall provides a proportional raise response of 5kW from 49.85Hz to 49.5Hz, and Figure 3 shows a proportional lower response of 5kW from 50.15Hz to 50.5Hz. Both responses start within less than 250ms of the frequency deviation outside of the 49.85Hz-50.15Hz NOFB. Therefore, a 240ms delay (multiple of 20ms) between the start of the frequency deviation and the start of the power response is introduced in this study.

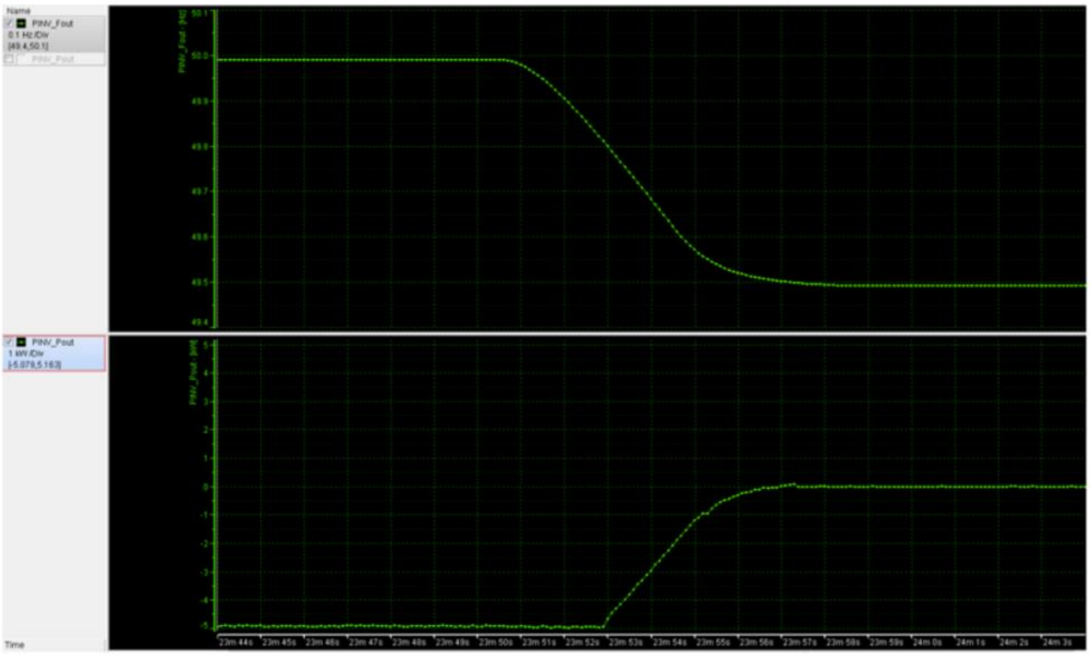

Figure 2 - Tesla Powerwall 2 Frequency Injection Test Results: 5kW Raise Response

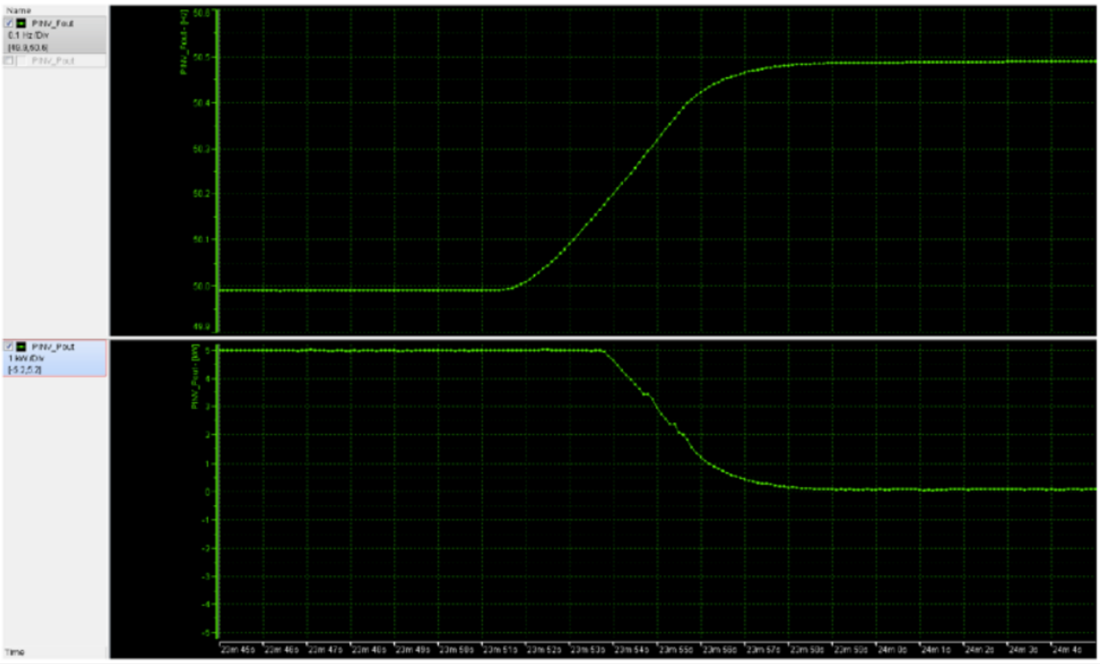

Figure 3 - Tesla Powerwall 2 Frequency Injection Test Results: 5kW Lower Response

The Powerwall uses open loop controls to provide Contingency FCAS, whereby the grid-tied Powerwall inverter initiates a power response as soon as it detects a frequency deviation. The Powerwall power response therefore does not depend on frequency measurements from a meter. As a result, no random variable is introduced to account for frequency measurement margin of error. However, a random variable is introduced for each site to account for a ≤2% of measurement range margin of error for power measurements ("error random variable") as per the MASS. For a 5kW Powerwall, a ≤2% of measurement range margin of error corresponds to a ≤100W margin of error. The 20ms resolution power response is then calculated for 200 Powerwalls.

Sampling Rates (20ms, 100ms, 500ms and 1s)

For each of the 200 power responses, another random variable is introduced to determine when power is polled ("polling random variable"). For a given Powerwall, in the 100ms sampling rate scenario, the first polling happens randomly during one of the first five 20ms intervals, and every 100ms after that. The response of all 200 Powerwalls is then aggregated using the truncated method:

- The truncated method adds the responses with a time stamp of 20ms, 40ms, 60ms, 80ms or 100ms under time stamp 100ms, the responses with a time stamp of 120ms, 140ms, 160ms, 180ms or 200ms under time stamp 200ms, etc…

There are three other sampling rate scenarios, which all use the same method: 200ms, 500ms and 1s.

Figures 4 compares the target response – which has no 240ms delay, and no error and polling random variables – to the actual responses with varying sampling rates for 200 Powerwalls using the truncated method. For avoidance of doubt, the 20ms actual response includes the 240ms delay and the error random variable, but it cannot include the polling random variable, contrary to the 100ms, 500ms and 1s scenarios.

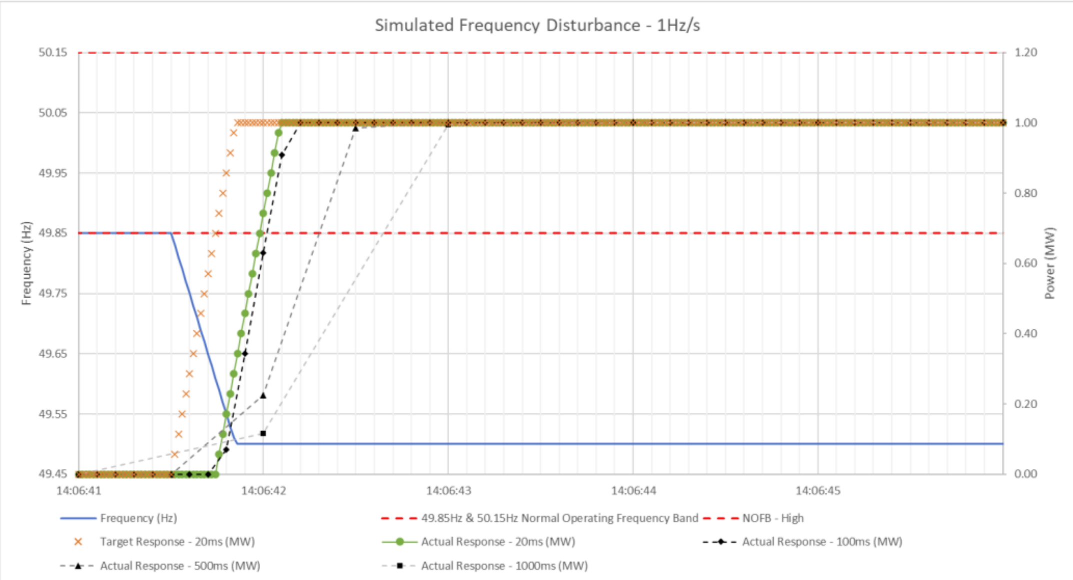

Figure 4 - Target and actual responses of 200 Powerwalls to a simulated frequency disturbance.

Evaluation Metrics

The evaluation metric used for the Monte Carlo simulation is outlined in detail below.

Metric used to estimate the measurement error between the actual response and the target 20ms response:

$$Energy\ Error_n = \frac{\left(\sum_{i=1}^{q} Actual\ Response_i\right) / \frac{1000\ ms}{Sampling\ Rate} - \left(\sum_{i=1}^{p} Target\ Response_i\right) / \frac{1000\ ms}{20\ ms}}{\left(\sum_{i=1}^{p} Target\ Response_i\right) / \frac{1000\ ms}{20\ ms}}$$

where:

- n = number of Powerwalls (1, 10, 25, 50, 200, 500 or 1000)
- p = 750, which is the number of 20ms intervals over 15 s
- Sampling Rate = 20ms, 100ms, 500ms or 1000ms
- q = 750 / (Sampling Rate / 20ms), which is the number of intervals over 15 s for a given Sampling Rate
- Target Response is the 20ms power response of n Powerwalls calculated using the 20ms frequency measurements and 0.7% droop settings. It does not include the 240ms delay or the error and polling random variables.

- Actual Response is the power response of n Powerwalls calculated using the sampling methodology described above. It includes the 240ms delay and the error and polling random variables, except for the 20ms scenario which cannot include the polling random variable.

The energy error formula uses the right Riemann sum method, similar to AEMO's FCAS Verification Tool

Monte Carlo Simulations

Monte Carlo simulations were run in order to assess the impact of the error and polling random variables on the energy error metric, for each of the four sampling rates and seven numbers of sites. The tables below show the average value of the absolute error in 500 different simulations.

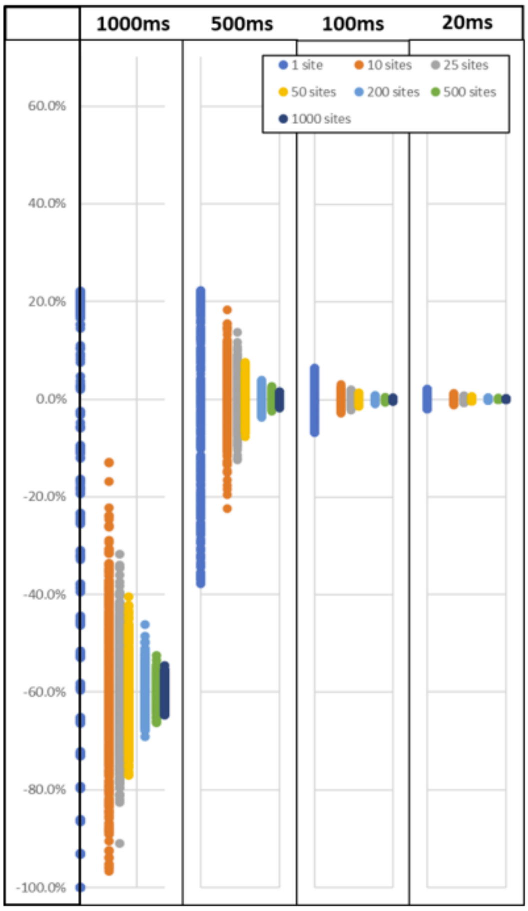

Figure 5: Span of energy error for each Monte Caro simulation

		Sampling Rate (ms)			
	Average Energy Error	20	100	500	1000
No of Sites	1	0.98%	2.78%	16.80%	66.82%
	10	0.30%	0.87%	5.03%	59.38%
	25	0.18%	0.55%	3.12%	59.68%
	50	0.13%	0.36%	2.04%	60.04%
	200	0.07%	0.20%	1.12%	60.08%
	500	0.04%	0.12%	0.74%	59.94%
	1000	0.03%	0.09%	0.50%	59.95%

Figure 6: Average energy error for each Monte Carlo simulation

		Sampling Rate (ms)			
	Maximum Energy Error	20	100	500	1000
No of Sites	1	2.00%	6.74%	37.83%	100.00%
	10	1.12%	3.05%	22.37%	96.59%
	25	0.69%	2.19%	13.66%	90.90%
	50	0.53%	1.31%	7.67%	77.06%
	200	0.25%	0.88%	3.89%	69.16%
	500	0.18%	0.48%	2.61%	66.33%
	1000	0.13%	0.36%	1.78%	64.71%

Figure 7: Maximum energy error for each Monte Carlo simulation

Based on our simulation we make the following observations.

- One second is simply not fast enough to capture an event of this speed, no matter how many sites are aggregated. One second metering converges to an average of around a 60% error.
- With 200 sites, sampling at 100ms provides a maximum error of 0.88%. This is well below the 2% allowable error.
- At 50 sites the average and maximum error rates for a 100ms resolution are both lower than a single site measuring at 20ms. This point is also demonstrated in Figure 8 below.
- For 200 sites – the minimum number of sites needed for a 1MW bid where 5kW Tesla Powerwalls are aggregated – the average error is 0.2% and the max error is<1%
- Error! Reference source not found.[50] shows that as number of sites and sampling rate increase, the maximum energy error reduces significantly. There are obvious challenges associated with undertaking a one second measurement verification for a one second market which is demonstrated in the high error of the results presented.
- As with our previous analysis presented to AEMO, Tesla has found for a one second measurement window the number of sites aggregated to provide a response has a larger impact on the error variance than the sampling rate does. These findings are consistent with the analysis of the 6 s measurement window previously undertaken.

[50] This is how the submission reads.

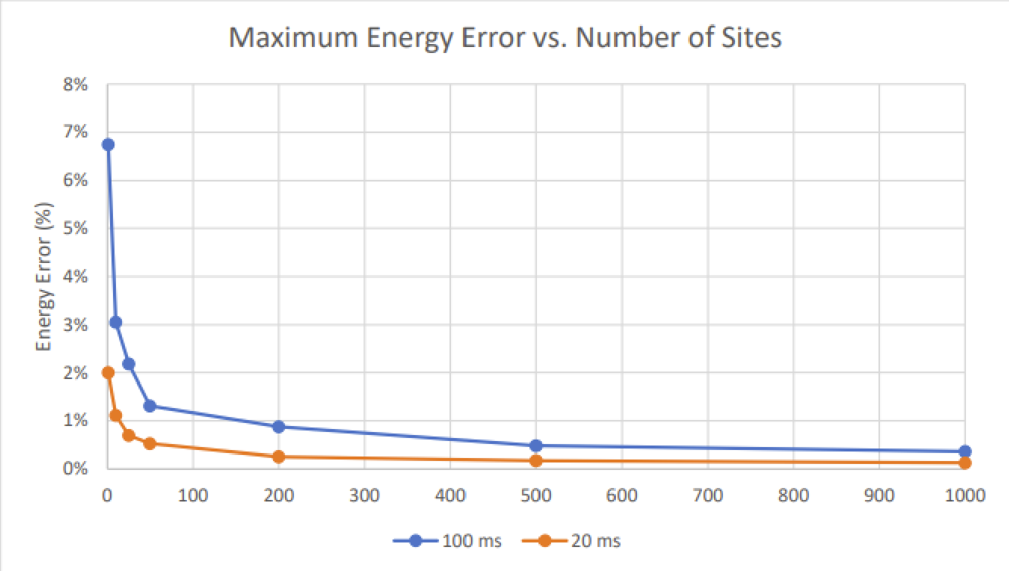

Figure 8: Maximum energy error vs. number of sites

Conclusion

For Aggregated FCAS Facilities, Tesla's modelling demonstrates that a maximum margin of error of 2% can be achieved by aggregating at least 50 sites at a measurement time resolution of 100ms.

Considering that the current minimum FCAS bid is 1MW, it would require at least two hundred (200) 5kW Powerwalls to be aggregated to meet the minimum bid. At this scale, the average energy error is 0.2% and the maximum energy error is