DER and General Consultation, Second Draft Determination

Submission to Amendment of the Market Ancillary Service Specification

Reposit Power

18 November 2021

1 Executive Summary

Reposit Power (Reposit) welcomes the opportunity to provide feedback on AEMO's Second Draft Determination on the Amendment of the Market Ancillary Service Specification (MASS) - DER and General Consultation (MASS second draft determination).

Reposit continues to support AEMO's objectives of the MASS consultation and key areas of its first draft determination.[1] However, Reposit does not support AEMO's reversal of key positions in its MASS second draft determination which are based on the University of Melbourne's (UoM's) analysis (and evidence from other stakeholders[2]). AEMO's MASS second draft determination proposed a 200 ms minimum measurement time resolution requirement for Fast FCAS for aggregated connection points (only DER resources can aggregate connection points) compared to a 50 ms requirement remaining for all other connection points.

Reposit does not support AEMO's proposal to allow a 200 ms measurement time resolution for aggregated ancillary service facilities with no inertial response (aggregated sites) and a 5% discount applied to aggregations of less than 200 sites. This draft decision:

- Understates the risk to the power system associated with the measurement and verification of energy for Fast FCAS and is likely to negatively impact overall market operation and efficiency.
- Creates a clear and unnecessary distinction between the technical requirements for different registered participant categories based on the size of assets at the connection point.

AEMO has based its assessment on UoM's analysis of Fast FCAS performance verification and investigation of different integration rules. Reposit considers UoM's methodology is flawed which results in its analysis of verification error being skewed and understated with respect to the sampling measurement rates of 100 ms and 200 ms. These flaws include:

- The use of synthetic (not real-world) data. In calculating the verification risk associated with Fast FCAS, UoM's assessment is based on a fabricated dataset of 1000 sites based on a single Tesla Powerwall 2 (PW2). This PW2 is responding to a frequency injection test for a single contingency event

[1] AEMO stated the objectives are to: resolve a number of ambiguities and make the MASS consistent with the rule requirements for mandatory primary frequency response and determine whether any changes to the measurement arrangements in the MASS were appropriate to facilitate increased participation of DER in the contingency FCAS markets.

[2] It is unclear from AEMO's second draft determination what further evidence it used as the basis for reversing its position from its (first) draft determination.

under lab conditions and with a response measured by an instrument of unknown calibration, then ‘fuzzed’ 1,000 times with two random variables

- A case study approach being used, which is not able to generalised to an entire market for any future point in time, and in this case appears to reverse engineer outcomes. That is, the generated data set appears to have been contrived to deliver 0% (or minimal error) when down sampled to 200 ms, integrated with the trapezoidal method and RoCoF frequency detection time (FDT) method. This is inappropriate.

Given this, AEMO should not rely on UoM's analysis to identify potential errors of FCAS energy delivery measurement using different sampling rates. Any conclusions reliant on this analysis should also be reconsidered. For example, if a 50 ms sampling rate is required to reliably verify the delivery of FCAS then Reposit’s view is that there is no need to make any changes to the FCAS verification tool.

Reposit appreciates that AEMO and UoM did not have other data to base UoM’s analysis, this was identified by AEMO in the MASS stakeholder consultation forum on 8 November 2021 and in a subsequent email to stakeholders. In June 2021 AEMO requested Reposit provide a small number of high speed traces from inverters to examine their response profiles for power quality concerns, however, a short time later indicated to Reposit that it did not yet have the tools to use this information. As such, the requested data was not provided to AEMO.

To assist AEMO (and presumably UoM) reconsider the “additional” error created by a 200 ms sampling rate using actual site data, Reposit has provided actual data from 1,650+ NMIs in response to the frequency disturbance from two trip events including the Callide trip on the afternoon of 25 May 2021 and the 25 August trip.

While this actual data provides valuable insight, Reposit encourages AEMO to use any available data it has access to at the NMI-level or inverter-level (i.e. data window to include the period from 5 seconds before the frequency exceeded the Normal Operating Frequency Band (NOFB) to 65 seconds after) from the Callide trip event (or any recent trip event). Data from recent events can help to better understand the power response from aggregate ancillary service facilities and determine if the verification error is within the MASS’s 2% allowable error range.

Reposit has also conducted an identical analysis to that conducted by UoM on this actual data for both trips and provided the results in this submission. Reposit’s analysis demonstrates that for the 25 August 2021 trip and for a 200 ms sampling rate and 200 aggregated sites the AEMO proposed changes result in a minimum and maximum verification error of 9.6% % and -2.7%. A minimum and maximum verification error of -6.7 % and -4% is apparent for same analysis with 1000 aggregated sites.

All calculated aggregations result in error that is outside the 2% allowable error range specified in the MASS. This analysis demonstrates an error that is much greater than that obtained from the MASS’s current and accepted metering and verification standard. Effectively, the analysis demonstrates that AEMO’s proposed changes would significantly degrade the certainty of energy delivered to/withdrawn from a contingency event.

While this actual data provides valuable insight, Reposit encourages AEMO to review and test its analysis and would welcome the opportunity to discuss its methodology or results at a more detailed level with AEMO and UoM. Full details of the analysis and data are in Appendix A and B.

As AEMO is aware, it is important that it carefully considers its obligations under the National Electricity Law (NEL) and National Electricity Rules (NER) with respect to any consultation. In considering changes that lower existing technical requirements for distributed energy resources (DER) participation, AEMO's primary concern is in maintaining power system security and any relaxing of technical standards must ensure this is maintained and provide a positive long-term benefit to consumers consistent with the National Electricity Objective (NEO).

Reposit considers that the proposed changes with respect to measurement and verification will, in the long term, erode power system security and cost consumers more in managing any impacts. Reposit's analysis (using actual data) demonstrates that a 200 ms (and 100 ms) sampling rate does not accurately and reliably measure Fast FCAS delivery. In the long term, if the amount or quality of the service is not delivered, this will be more costly for consumers as greater amounts of Fast FCAS will need to be purchased to arrest remaining frequency deviation.

As such, Reposit requests that AEMO reconsiders its proposed position based on an analytical (rather than case study) approach. The current case study approach does not create results that can be generalised to the entire market. It is also prone to the manipulation of key parameters so as to derive a favourable outcome for aggregated ancillary service facilities with lower sampling rates for Fast FCAS.

2 Context

2.1 Purpose of Fast FCAS

Fast FCAS is provided to arrest a material change in system frequency following a contingency event that takes it outside the NOFB. It must be provided within the first 6 seconds of a frequency disturbance.

Currently, for Fast FCAS, a market participant providing this service must be capable of measuring power flow and local frequency at intervals of 50 ms or less at every site (as represented by a national metering identifier (NMI)).

2.2 AEMO's responsibilities

AEMO has two key responsibilities under the NEL that are relevant for this consultation, including:

- Promoting the development and improving the operational and administrative effectiveness of NEM
- Maintaining power system security.

In assessing changes to the MASS, AEMO must consider the NEO and power system security. AEMO must ensure FCAS providers have appropriate and accurate metering in place to ensure the service needed has been provided and participants are appropriately compensated for the service provided. The inherent risk is that insufficient FCAS is delivered to, or withdrawn from, the grid at times when this service is needed to arrest a frequency disturbance.

While there are other sources of risk to be managed, AEMO manages the energy delivery risk through the MASS' technical requirements. For Fast FCAS, AEMO specifies these technical requirements including specifying quantities and calculations. Through the MASS AEMO must specifically manage the delivery risk associated with energy delivered to, or withdrawn from, the power system when a contingency event occurs and a frequency disturbance follows. It is therefore critical there are appropriate measurement and verification arrangements to understand the service delivery risk and that error in that delivery risk is appropriately accounted for and managed.

2.3 DER Integration and participation

As noted in previous MASS submissions, Reposit has been successfully providing and operating contingency FCAS from DER (including as a virtual power plant (VPP) provider) under the existing MASS technical requirements since December 2018. This commercially operating VPP continues to grow and does not rely on any future relaxation of technical standards.

The VPP trial specified alternative measurement requirements to encourage more VPP providers to participate and test capabilities to deliver contingency FCAS. Since Reposit's VPP and DER meets the existing metering and verification requirements, Reposit saw little to no value in participating in these trials. Participating in these trials would have incurred unnecessary costs (e.g. developing APIs) which would be borne by customers.

Reposit continues to question why other participants are not focussed on meeting accepted power system requirements instead of diluting them to meet commercial imperatives – this values the short-term over the long-term benefits for customers. While the VPP trials may have identified some learnings, the trial has insufficiently tested the impact of relaxing verification and measurement requirements.

3 Response to proposed changes in AEMO's MASS second draft determination

3.1 Introduction

Reposit supports the two objectives of the MASS consultation as identified by AEMO "…to resolve a number of ambiguities and make the MASS consistent with the rule requirements for mandatory primary frequency response…" and "…determine whether any changes to the measurement arrangements in the MASS were appropriate to facilitate increased participation of DER in the contingency FCAS markets."[3]

This consultation has been controversial and complicated by divergent stakeholder views and interests which AEMO must balance to ensure that appropriate technical requirements are in place for all FCAS providers, including VPP providers. However, first and foremost, AEMO must adequately consider the requirements of the power system which it is responsible for operating.

Table 1 summarises Reposit's positions on AEMO's key positions on the appropriate arrangements for DER providing Fast FCAS in both draft determinations. It should be noted that AEMO's MASS second draft determination reverses several key policy positions from its MASS (first) draft determination based on further analysis from UoM, which Reposit considers is flawed.

Table 1 Summary of AEMO and Reposit draft determinations key positions

	MASS draft determination	**Reposit's position**	**MASS second draft determination**	**Reposit's position**
Minimum measurement time resolution for Fast FCAS (sampling rate)	All FCAS providers must meet a 50 ms measurement for Fast Raise Service and Fast Lower Service	Supported	• 200 ms for aggregated facilities with no inertial response (5% error applies if number of sites is less than 200) • 50 ms for all other facilities.	Unsupported
FCAS verification methodology changes	Not relevant	Not relevant	A combination of proposed changes to the FCAS verification methodology	Unsupported
Transitional arrangements	VPP trial participants will need to comply with MASS measurement requirements by 30 June 2023	Supported	Same as draft determination, noting that AEMO has proposed changes to minimum measurement requirements	Unsupported

[3] Amendment of the market ancillary service specification - DER and general consultation, second draft determination, 28 October 2018, p.2.

Discount arrangements	For VPP participants covered by the MASS transitional arrangements, a discount to be applied to the Fast FCAS quantities provided • 20% if data captured was between 200 ms and 1 s intervals • Less than 50 ms but higher than or equal to 200 ms, a discount of 20% applies	Unsupported	a 5% discount applied to reflect the verification error when less than 200 sites.	Unsupported
Oscillatory response	AEMO noted this as a power system security concern	Supported	AEMO ignored the possibility of any oscillations faster than once per second (1Hz)	Unsupported
Measurement at or close to the connection point	Measurement at or close to the connection point	Supported	No change	Supported

This section identifies Reposit's position and its rationale for not supporting AEMO's MASS second draft determination.

3.2 Measurement time resolution for FCAS provided by DER

3.2.1 UoM analysis

Underpinning AEMO's decision to reverse its approach on the minimum measurement time resolution for Fast FCAS provided by DER are the results of UoM's analysis and further information from consulted persons. AEMO states:

> "At this stage, based on the additional evidence submitted by Consulted Persons and further analysis from the University of Melbourne, AEMO proposes to vary its draft determination to:
> - Require a minimum measurement time resolution for Fast FCAS providers of: – 200 ms for aggregated facilities with no inertial response (5% error applies if number of sites is less than 200); and – 50 ms for all other facilities.
> - Leave the measurement location 'at or close to' the connection point."[4]

And:

> "AEMO's assessment, supported by UoM analysis, is that a 50 ms sampling rate is not required to reliably verify the delivery of Fast FCAS unless it is necessary to identify how an inertial response impacts the FCAS delivery."[5]

[4] AEMO, Amendment of the Market Ancillary Service Specification – DER and General Consultation, Second Draft Determination, 28 October 2021, p. 2.
[5] Ibid., p. 149.

UoM used the following to explore the impact of different sampling rates lower than 50 ms:

- A case study approach with six case studies
- The Trapezoidal rule to calculate the contribution of FCAS response, UoM stated this "...rule is far superior to simpler integration methods such as Riemann methods..."[6]
- The "RoCoF-based" method instead of the "first recorded point" frequency detection time (FDT) method which UoM considered is "...superior to other "relative window" methods proposed by different stakeholders when determining frequency disturbance time."[7]

Of relevance to the verification error, UoM concluded that:

- Using NMI-level data instead of aggregated response from aggregated ancillary service facilities reduces the verification error for lower sampling rates, e.g. 100 ms and 200 ms.
- Adjustments need to be made to the FCAS verification tool to capture the different approaches for DER and synchronous generators
- a 50 ms sampling rate should be maintained for synchronous generator responses for FCAS verification purposes.

Based on UoM's analysis AEMO concluded that "...to remove inefficient costs incurred by market participants to delivery of FCAS, the specifications in the MASS should be at a level needed for AEMO to reliably verify that the enabled amounts of FCAS are delivered, and no more onerous than required."

3.2.2 Issues with verification error analysis

UoM's analysis seeks to identify "additional" verification error by exploring a range of factors affecting verification error and establish a methodology to identify potential oscillatory response.[8] Verification error has at least the following components:

- Power measurement error
- Sampling rate
- Determination of frequency disturbance time
- Quantity of response that is inertial
- Compensation factor
- Site aggregation method
- Integration rule used.

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[6] Fast FCAS Sampling Verification in Support of Market Ancillary Services Specification (MASS) consultation, p. 1.
[7] AEMO, Amendment of the Market Ancillary Service Specification – DER and General Consultation, Second Draft Determination, 28 October 2021, p. 2
[8] The UoM, Fast FCAS Sampling Verification in Support of Market Ancillary Services Specification (MASS) consultation – Phase 2, October 2021

Any change in verification error (the “additional” error) is important to understand because this represents the modelled risk of any relaxing of technical standards. If AEMO modifies quantities and calculations in the MASS and this increases verification error by X%, then AEMO and consulted persons must accept that either:

1. The affected FCAS is now X% less effective
2. AEMO must procure X% more of the affected FCAS to ensure that service provision does not reduce below pre-modification levels.

Reposit believes that UoM’s, and therefore AEMO’s, analysis of “additional” error is incorrect for the following reasons:

- The dataset provided by AEMO to UoM is not based on actual operational data. The 1,000 sites data provided to UoM is a fabricated dataset based on a single Tesla Powerwall 2 (PW2). This PW2 is responding to a frequency injection test for a single contingency event under lab conditions and with a response measured by an instrument of unknown calibration, then ‘fuzzed’ 1,000 times with two random variables - measurement error and poll time
- The analysis is based on a fabricated dataset provided by Tesla, who has a vested interest in the MASS requiring a lower sampling rate.
- The only error quantity that is relevant to the measurement and verification of contingency FCAS is worst-case error. This is because contingency FCAS must deliver under a worst-case scenario to prevent a cascading failure in the power system. The case study presents the error inherent in the dataset the case study was built on. This is not worst-case error - it is just “this-case” error.
- The use of case studies to determine whole-of-market requirements is not valid. The results obtained from an error analysis from a particular case study are not able to be generalised across all cases with any validity. The measured error in each case study is highly dependent on the nature of the contingency event and the composition and specific responses of the DUID units at the time. None of these things are able to be generalised to the entire market at any future point in time. A case-study calculates a “this-case” error, not a “worst-case” error
- The error identified in the case studies is unlikely to be the worst-case error. The Monte Carlo sampling used in the methodology is not guaranteed to identify worse-case error for a given case study. The UoM analysis only includes 500 Monte Carlo simulations – this creates an artificially low worst-case error as the likelihood of a worst-case scenario being analysed is smaller than if a reasonable number of Monte Carlo simulations were undertaken.

- The “error reduction” displayed in these case studies due to “site aggregation” is error cancellation. The lower sampling rate creates additional interpolation error above that created by 50 ms sampling. This error both overestimates and underestimates energy delivered to a contingency event. UoM and AEMO have considered that aggregation of FCAS contingency response over many sites will result in the errors cancelling and therefore create a high accuracy aggregate measurement. This would work where the negative and positive errors were aligned in time and so would cancel each other out. However, this depends on the constituent site responses being:

    - Symmetrical - the sampling happens at the same time offsets on the left and right side of the “middle” sample time. More precisely, the sampling offsetting on one side of the median response is the same as the sampling offsetting on the other side of the median response

    - Homogenous - all of the DER units do exactly the same thing at the same time. More precisely, a there are as many MWh delivered before the median constituent response, as there are after the median constituent response.

- The data UoM relied on (provided by AEMO using Tesla’s data) has strong symmetrical and homogenous characteristics because:

    - The sampling poll time error was manufactured using a normal distribution i.e., it is perfectly symmetrical

    - It is a single power response, statistically fuzzed but otherwise simply repeated 1,000 times i.e., it is homogeneous.

Given this, UoM calculated the “additional” verification error using a dataset that demonstrated an unrealistic level of error cancellation. This degree of error cancellation would not occur in the real world (or using actual data) because:

- At best sampling offset is random (uniformly distributed) – there is nothing that suggests any symmetrical distribution or that it is the same at different points in time.

- DER response is not homogeneous – a homogeneity assumption is invalid and unrealistic. The UoM analysis assumes homogenous responses from the same type of units. Several factors affect DER response and can be different for different devices and can change in an unsynchronised way. For further information on homogeneity refer to sections 3.3.3 to 3.3.5 in Reposit’s submission to the MASS consultation issues paper

3.2.3 Reposit’s analysis

Reposit replicated UoM’s analysis from its second report. This analysis uses:

- Actual operational data from 1,000 NMIs in a single region. This includes datasets from two recent Fast FCAS trip events, including the Callide trip on 25 May 2021 and the second on 25 August 2021. The NMIs were all responding existing NMIs in Reposit's DUID.[9] As mentioned, UoM has used a fabricated dataset based on one Tesla PW2
- 10,000 Monte Carlo simulations as conducting 500 simulations is 200 times less likely to miss the worst-case error combinations, and hence under-estimate worst-case verification errors.

Reposit's analysis is set out in Appendix A and B.

To demonstrate the verification error results using 'real-world' data Table 2 sets out the minimum and maximum verification error results for different levels of aggregation using a 200 ms sampling rate (as proposed by AEMO). This demonstrates some more specific observations that AEMO should consider, including:

- Using actual operational data for the 25 May 2021 and 25 August 2021, the verification error (for any number of sites) is more than the accepted MASS 2% verification error
- It is more appropriate to consider the verification errors identified from 25 August because this is a more typical trip event
- The RoCoF based methodology:
    - For 25 May 2021, the results demonstrate that the methodology does not work primarily due to the frequency recovering within the NOFB within 2.6 seconds. This is a more extreme event and demonstrates how inappropriate UoM's methodology is when using actual operational data
  - For 25 August 2021, the verification errors calculated once a significant number of NMIs have been aggregated appear to be directly proportional to the sampling period, i.e. 200 ms has twice the error of 100 ms (refer to Appendix A and B).

[9] The 25 May 2021 Callide data set is from 1,669 NMI responses and the 25 August 2021 trip is from 1,671 NMI responses.

Table 2 Minimum and maximum verification errors for different aggregation levels and a 200 ms sampling rate

No of sites	**UoM (table 7.6) (%)**		**Reposit – 25 May 2021 (Callide) trip (%)**		**Reposit -25 August 2021 trip (%)**	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
1	-4.7	2.8	-14546.5	24559.6	-8448.3	11379.8
10	-2.4	0.6	-18840.0	358348.5	-319.6	14.0
25	-2.0	-0.2	-46884.3	94542.2	-25.8	3.9
50	-1.7	-0.4	-628411.5	35471.2	-16.3	-0.1
200	**-1.3**	**-0.7**	-10587.4	9056.8	-9.6	-2.7
500	**-1.2**	**-0.9**	-2272.6	28517.0	-8.0	-3.6
1,000	**-1.0**	**-1.0**	-33.5	9621.5	-6.7	-4.0

For comparison purposes, using the same methodology, Table 3 shows the minimum and maximum verification error results for different levels of aggregation using a 100 ms sampling rate (as proposed by AEMO).

Table 3 Minimum and maximum verification errors for different aggregation levels and a 100 ms sampling rate

No of sites	**UoM (table 7.6) (%)**		**Reposit – 25 May 2021 (Callide) trip (%)**		**Reposit -25 August 2021 trip (%)**	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
1	-4.4	2.9	-4377.7	23048.5	-7036.7	7128.3
10	-2.3	1.0	-190734.0	5522.5	-302.7	9.5
25	-1.9	0.1	-58505.3	79302.7	-13.1	2.2
50	-1.6	-0.3	-776830.7	22931.8	-9.8	0.9
200	**-1.2**	**-0.6**	-3873.4	3439.8	-5.4	-0.7
500	**-1.1**	**-0.7**	-1137.0	3573.4	-3.8	-1.3
1,000	**-0.9**	**-0.9**	-53.1	14272.6	-3.8	-1.8

3.2.4 Reposit's position

Reposit disagrees with UoM's methodology and conclusions in its second report and considers the analysis to be fundamentally flawed as demonstrated in section 3.2.3.

The high-level observations from this analysis include:

- The fabricated input data is the source of the low verification errors identified in UoM's analysis
- 'Real-world' data (actual operational data) does not show the same level of error cancellation
- The site aggregation method behaves nominally on "normal" deviations but ceases to function under 'real-world' extreme circumstances. The Callide 25 May trip event shows some absurd results
- Error characterisation using a case study approach does not generalise.

Since AEMO based its MASS second draft determination on UoM's conclusions, it stands to reason that AEMO's proposed position on relaxing minimum metering and verification requirements for aggregated ancillary service facilities is also flawed. Reposit does not consider AEMO should rely on analysis that is based on a fabricated dataset provided by a market participant with a vested interest in the outcomes of this consultation. It is surprising that due diligence was not undertaken before AEMO or UoM sought to rely on this data.

That said, Reposit appreciates that AEMO and UoM did not have other data to base UoM's analysis on which AEMO identified in the MASS stakeholder consultation forum on 8 November 2021. To make transparent the circumstances of AEMO's request to Reposit regarding the data request – AEMO requested Reposit provide high speed traces from inverters to examine the response profiles for power quality concerns, however then indicated to Reposit that it did not yet have the tools to use this information[10]. As such, there was no point in Reposit providing the requested data to AEMO.

Reposit notes that AEMO recently published a statement in the MASS Consultation – Third stage consultation forum summary indicating that Reposit ("another stakeholder") "…had been unable to provide the data to AEMO…".[11] For the reason explained above, this was not the case. Reposit would appreciate AEMO clarifying this miscommunication in its upcoming final determination.

3.3 Other issues with UoM analysis and AEMO's approach

There are several UoM recommendations included in AEMO's MASS second draft determination that appear to be included to ensure the 200 ms sampling results are more favourable and can be accepted. This section identifies these and Reposit requests AEMO reconsider whether they are appropriate in light of any new analysis based on the actual data provided by Reposit or any other participant.

3.3.1 Oscillatory behaviours

AEMO's MASS draft determination and MASS second draft determination identifies the importance of being able to identify an under-damped oscillatory response particularly when the power system is under stress, e.g. a frequency disturbance requiring FCAS. As identified by AEMO "…measurement time resolution is directly linked to the identification of under-damped oscillatory behaviour."[12]

An oscillatory response of faster than 1.25 Hz being measured with a 200 ms sampling rate will result in energy delivery or withdrawal being over-estimated for

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[10] AEMO requested inverter traces to review DER unit responses. Reposit did not receive a request from AEMO to provide operational data on large numbers of sites (20+ sites).
[11] AEMO, MASS Consultation – Third stage consultation forum, 15 November 2021, p. 3.
[12] AEMO, Amendment of the Market Ancillary Service Specification – DER and General Consultation, Second Draft Determination, 28 October 2021, p. 71.

a contingency event because a material amount of energy will assumed (not measured). This will occur because the interaction between the dips and the slower sampling time means that energy delivered/withdrawn is not identified and potentially over counted. This could have material consequences for the power system, e.g. the frequency deviation will not be addressed adequately and a UFLS event occurs.

UoM concluded that “the measurement time resolution needs to be at least one-fourth of the oscillation period to capture the maximum magnitude of the oscillation…” and “The under-damped oscillatory behaviour was able to be identified using measurements of power flow at 100 ms and 200 ms intervals.”[13] The identification of an oscillatory response does not mean that it is being appropriately measured. Reposit considers that AEMO needs to reconsider any approach that does not adequately measure oscillatory responses, particularly as DER increases its future FCAS contribution. Reposit provides the following comments:

- The detection of an oscillatory response is entirely different to the measurement of an oscillatory response. Only the measurement of an oscillatory response is relevant when considering additional measurement error from lower sampling rates

- A 200ms sampling rate will not be able to reliably measure energy delivered/withdrawn where the response contains oscillations faster than 1.25Hz. Oscillation “detection” is dependent on sampling rate in accordance with Shannon-Nyquist theory. That is, sampling rate must be 4 times faster than the fastest oscillation – as observed by UoM.

- Measurement of a 6Hz oscillatory response should and can be tested before AEMO makes its final decision. Reposit is aware there are thousands of battery inverters behind the meter that display the 6Hz oscillatory response. An analysis of the measurement (not detection) of this oscillatory response can be found in section 3.3.6.3 of its submission to the MASS consultation paper. It is noted that AEMO provided UoM with oscillatory responses of between 1Hz and 0.3Hz for testing in its case study analysis. There is no reason for oscillations to be limited to this range and is risky for AEMO to suggest otherwise.

- It is not valid for AEMO to ignore high-frequency oscillations. Reposit has determined that high-frequency oscillatory responses deliver less energy to a contingency event. The point is to accurately measure the energy delivered or withdrawn and this is impossible the sampling rate is not at least 4 times faster than the fastest oscillation (refer to Shannon-Nyquist theory)

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[13] Ibid.

- Reposit requests AEMO test a 6Hz oscillatory response for slower sampling rates (100ms and slower), however this would be unimportant if AEMO determines that aggregated ancillary service facilities must have a 50 ms sampling rate.

3.3.2 Use of trapezoidal integration rule and RoCoF based method

Reposit's analysis demonstrates that a 200 ms sampling rate is unworkable and would compromise power system security. If AEMO has identified other reasons for changing from the "first recorded point" to the "RoCoF based" method or adopting the Trapezoidal integration method instead of the right-Riemann, it should consider the benefits and costs to participants in doing so. Reposit does not see the benefit of changing these if 50 ms sampling is retained and encourages AEMO to explore the costs of making these changes with participants.

3.4 NEO Analysis

AEMO's assessment of how its proposed changes meet the NEO is set out in section 4.5.2 of its MASS second draft determination. AEMO used the AEMC's *Applying the Energy Market Objectives* to guide its application of the NEO. In doing so, AEMO (supported by UoM's analysis) identified how it considers specific NEO variables apply to its determination, including price, quality, reliable supply, system security and safety. Additionally, AEMO identified various other NEO components that apply, including consumers, services not assets, long-term changes that may undermine incentives to make investment and operational decisions, and technology.

AEMO noted that "the specifications in the MASS should be at a level needed for AEMO to reliably verify that the enabled amounts of FCAS are delivered, and no more onerous than required."[14] Table 4 summarises AEMO's position on measurement time resolution for Fast FCAS by DER and specified by the NEO variables and components identified by AEMO. The table also includes Reposit's response and assessment taking into account it has undertaken using UoM's methodology and actual data from 1,650+ NMIs for two recent contingency events.

Table 4 Summary of AEMO's assessment against NEO variables and components and Reposit's response

Specific NEO variables	**Summary of AEMO's NEO position on measurement time resolution for Fast FCAS by DER**	**Reposit's response**
Price	*Lower barriers to entry lead to lower consumer prices:* - Lowering the Fast FCAS measurement resolution for aggregated ancillary service	• Inefficient costs involved in participating in Fast FCAS have not been demonstrated. Noting that cost has not been a barrier to entry for many DER participants (evidenced by growing levels of

[14] Ibid., p.148.

	facilities with no inertial response from 50 ms to 200 ms can remove inefficient costs and minimise barriers to entry, which could lead to lower prices for consumers through increased competition	participation outside of the VPP trials) and the metering required is not expensive and available from several suppliers • Lowering the technical requirement for aggregated ancillary service facilities (suggested by some stakeholders as a barrier to entry) will lead to increased prices (not lower prices) in the long-term for consumers because the increase in verification error (X% to Y%) will result in more FCAS being required to ensure a frequency disturbance is addressed • AEMO must quantify the cost and benefit to consumers before determining that a slower sampling rate meets the NEO. For example, project the amount of Fast FCAS that is expected from DER in the next 10 years, multiply this by the increased error and the average Fast FCAS price to determine an approximation of the long-term cost or benefit to consumers. • AEMO must also quantify the additional cost that 50ms metering adds over and above 200ms metering on a whole-of-market basis. Lowering barriers to entry in this circumstance leads to lower quality service which in turn leads to higher prices for consumers. AEMO also needs to consider that reducing the cost to participants at the expense of consumers is simply a transfer of wealth from consumers to participants.
Quality	*Reliable verification:* - 50 ms sampling rate is not required to reliably verify the delivery of Fast FCAS unless it is necessary to identify how an inertial response impacts the FCAS delivery - 200 ms sampling rate can adequately verify Fast FCAS delivery. *Verification assessment* - From aggregations of more than one site with changes proposed changes to the FCAS verification tool and the discount can minimise the error to a level that minimises the impact on the quality variable	• The increase in verification error does not mean the quality of FCAS diminishes, instead it is the quantity provided to the NEM that diminishes from a DER provider with a 200 ms sampling rate. • The need to make changes in the verification assessment (and tool) is deemed necessary because a slower sampling rate is proposed, which is of a lower quality than currently required by the current MASS. • The RoCoF method and other techniques are being proposed to compensate for the lower quality sampling rate and increased verification error. • It is inefficient for AEMO to make these changes to enable DER FCAS providers when there will be an increase in the verification error beyond the accepted 2% verification error in the current MASS. This is likely to result in the need for more Fast FCAS and hence greater cost to ensure the service level does not reduce.
Reliable supply	AEMO noted that the proposed 200 ms sampling rate allows FCAS markets to remain secure and reliable	• An increase in the verification error affects the amount of energy delivered or withdrawn into the power system. • An under-estimation or over-estimation will affect the expected response from a DER FCAS provider. This has the potential to impact supply at a

		time when power system security is already under significant distress
System security	As above	As above
Safety	AEMO noted that this is not a differentiating factor for the consultation	If insufficient Fast FCAS is provided to address a frequency disturbance following a contingency event and this leads to under-frequency load shedding and potentially, blackouts it may cause safety concerns affecting customers, e.g., traffic lights not working, CPAP machines not working.
Consumers	AEMO noted that the changes are in the long-term interest of consumers and argued that more competition leads to lower prices to the benefit of all consumers FCAS	• It is theoretically correct that competition leads to lower prices. • It is theoretically possible that in the race to lower prices services to customers diminishes as a result. • The increase in costs to consumers of more appropriate metering to ensure appropriate verification of Fast FCAS has been evidenced to be very low. • For existing assets to contribute to new services like FFR, the metering will need to be improved to allow this service to be provided. • If the quality of the service is diminished, then more service will need to be procured to meet the same power system security needs. Lowering the sampling rate and changing the verification methodology to ensure certain assets can participate in the short-term is a false economy and will result in consumers paying more in the long-term.
Services	AEMO noted that the approach allows the most cost-effective technologies to be utilised to provide services	• AEMO's proposed approach is to 'codify' the lower standards allowed, but not adequately tested, for in the VPP trials to apply for DER of the future. • If AEMO accepts a higher verification error (Reposit calculated between 4% to 7% for a 200 ms sampling rate using the 25 August trip, refer to Appendix B) then AEMO needs to consider the cost effectiveness of purchasing more service to mitigate the consequential risk to power system security. The most cost-effective technologies that meet the established standards are needed to ensure consumers do not pay more for services in the long-term
Long-term changes may not be appropriate where they undermine incentives to make efficient investment	AEMO did not make a direct comment, however noted that the proposed change is technology neutral and maintains a flexible framework that allows cost-effective technologies to be deployed.	• Based on its analysis, it is far from clear how increasing the risk to the power system and the likely increase in cost to procure services to mitigate that risk is in the long-term interest of consumers. • AEMO's proposed approach undermines the investment decisions made by DER providers that meet the MASS requirements. • AEMO's proposed approach may encourage investment in products that overall diminish power system security.

		• Customers are unlikely to be able to understand the implications of not having the technological capability to provide new services requiring higher speed metering prior to making this investment decision. • AEMO’s proposed approach may encourage more customers to invest in products without metering capable of providing new services like FFR and hence reduce competition for future services • AEMO’s proposal undermines the incentive to make efficient investment, demonstrating AEMO’s willingness to lower standards to encourage participation of DER and make de facto policy decisions ahead of the AEMC. A precedent for participants with slower metering who are likely to argue for slower metering requirements and other techniques to compensate should not be set. This will increase risks to the power system and result in the parties paying for these risks that are not best placed to manage them, i.e. at the expense of consumers.

Appendix A – Callide C Trip Analysis Results

Reposit conducted an analysis on the Callide C trip at 14:06 25 May 2021 using an identical methodology to that used by UoM in its second stage analysis.

The source data is 50 ms-sampled, grid connection point data from 1,669 actual residential electricity storage systems, manufactured by various vendors, in the ASNAES1 DUID in NSW1.

Table 5 Minimum and maximum verification errors for different aggregation level and sampling rates with "universal window"

Sampling (ms)	100	100	200	200	1000	1000
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
No. of sites						
1	4599.9	-4562.4	7487.3	-13582.4	72710.4	-51729.7
10	10349.6	-73691.6	282458.6	-24503.4	212954.1	-33176.7
25	9361.0	-15717.9	13539.1	-28138.4	212075.5	-336235.8
50	37757.6	-12663.3	23321.4	-522565.9	165115.5	-1231883.8
200	1553.2	-984.2	3198.1	-5535.0	25792.7	-1791.2
500	288.2	-1969.4	23652.5	-764.2	60794.2	-4961.8
1000	15.6	-1741.8	18.6	-4921.4	184.5	-1487.7

Table 6 Minimum and maximum verification errors for different aggregation level and sampling rates with "first recorded point"

Sampling (ms)	100	100	200	200	1000	1000
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
No. of sites						
1	23345.7	-3237.4	24900.2	-12224.7	102173.6	-43848.7
10	294265.0	-6402.4	191798.4	-22354.8	151007.0	-443052.1
25	22390.2	-44894.2	74527.4	-16985.5	1287457.3	-725.2
50	30184.0	-677207.9	251584.6	-3500.9	14933901.8	-130.9
200	11185.7	-189.3	41909.8	-465.0	148535.1	13.3
500	46971.3	-30.7	116197.8	-5.5	1210034.5	39.4
1000	32832.3	-1.7	62134.3	-0.7	1172277.7	67.4

Table 7 Minimum and maximum and minimum verification errors for different aggregation level and sampling rates with "RoCoF-based"

Sampling (ms)	100	100	200	200	1000	1000
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
No. of sites						
1	23048.5	-4377.7	24559.6	-14546.5	69373.3	-54165.2
10	5522.5	-190734.0	358348.5	-18840.0	178634.5	-639269.3
25	79302.7	-58505.3	94542.2	-46884.3	903041.3	-81799.5
50	22931.8	-776830.7	35471.2	-628411.5	3036364.6	-222280.9
200	3439.8	-3873.4	9056.8	-10587.4	29448.1	-29700.5
500	3573.4	-1137.0	28517.0	-2272.6	150456.7	-2767.3
1000	14272.6	-53.1	9621.5	-33.5	80906.5	-21.6

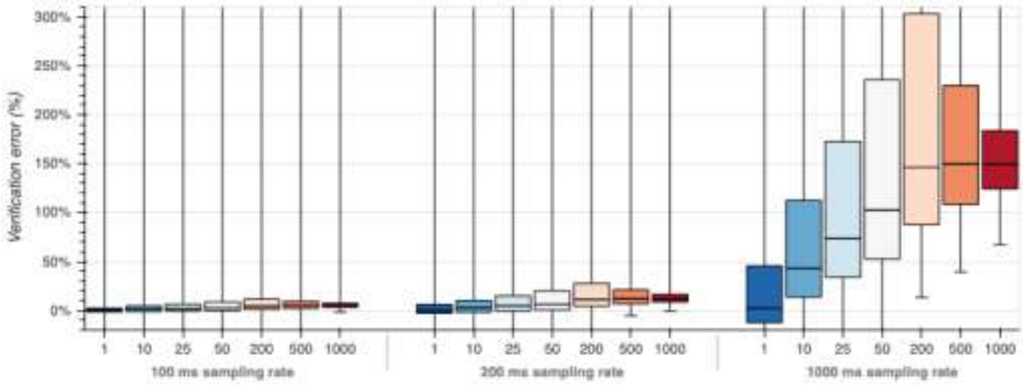

Figure 1 Verification error (without compensation response) of different aggregation levels under different sampling rates, using the "first-recorded-point" method and trapezoidal rule

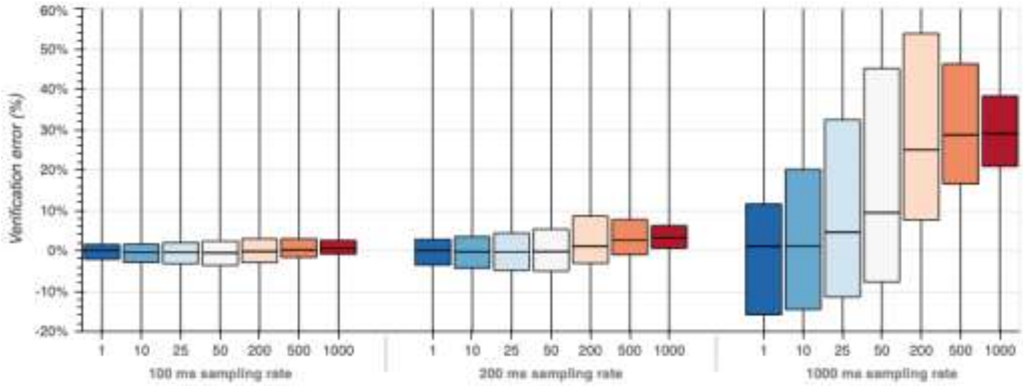

Figure 2 Verification error (without compensation response) of different aggregation levels under different sampling rates using the "RoCoF" method and trapezoidal rule

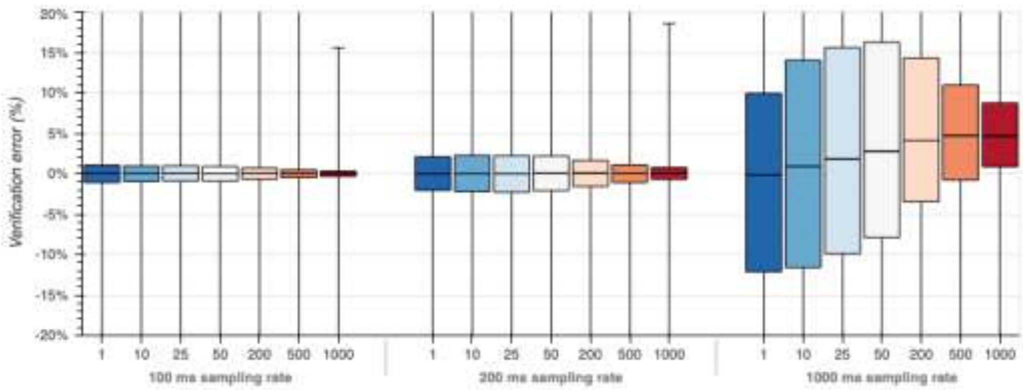

Figure 3 Verification error (without compensation response) of different aggregation levels under different sampling rates using the "universal window" method and trapezoidal rule

Appendix B – 25 August Trip Analysis Results

Reposit conducted an analysis on the contingency event recorded at 18:59 25 August 2021 using an identical methodology to that used by UoM in its second stage analysis.

The source data is 50 ms-sampled, grid connection point data from 1,671 actual residential electricity storage systems, manufactured by various vendors, in the ASNAES1 DUID in NSW1.

Table 8 Minimum and maximum verification errors for different aggregation level and sampling rates with "universal window"

Sampling (ms)	**100**	**100**	**200**	**200**	**1000**	**1000**
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
No. of sites						
1	-2274.7	2299.9	-8987.2	8299.8	-31346.6	32181.3
10	-7.8	15.2	-24.8	8.8	-141.3	113.9
25	-1.1	1.2	-3.0	3.0	-10.9	8.6
50	-0.6	0.5	-1.6	1.3	-3.9	3.8
200	-0.2	0.2	-0.5	0.5	-1.9	1.8
500	-0.1	0.1	-0.3	0.3	-1.2	1.1
1000	-0.1	0.1	-0.2	0.2	-0.9	0.8

Table 9 Minimum and maximum verification errors for different aggregation level and sampling rates with "first recorded point"

Sampling (ms)	**100**	**100**	**200**	**200**	**1000**	**1000**
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
No. of sites						
1	-8215.7	7699.7	-9938.6	12100.5	-225400.2	182097.1
10	-111.8	92.5	-334.5	6.8	-1037.1	52.1
25	-15.2	1.0	-25.7	-0.6	-46.3	12.5
50	-10.0	0.2	-18.5	-2.6	-28.7	3.0
200	-6.5	-1.9	-12.2	-4.9	-19.3	-4.6
500	-5.2	-2.5	-10.4	-6.1	-16.6	-6.8
1000	-4.7	-2.9	-9.4	-6.7	-14.6	-9.3

Table 10 Minimum and maximum verification errors for different aggregation level and sampling rates with "RoCoF-based"

Sampling (ms)	**100**	**100**	**200**	**200**	**1000**	**1000**
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
No. of sites						
1	-7036.7	7128.3	-8448.3	11379.8	-76900.1	43900.2
10	-302.7	9.5	-319.6	14.0	-535.7	81.0
25	-13.1	2.2	-25.8	3.9	-45.7	4.3
50	-9.8	0.9	-16.3	-0.1	-21.7	0.9
200	-5.4	-0.7	-9.6	-2.7	-14.0	-4.1
500	-3.8	-1.3	-8.0	-3.6	-12.8	-5.9
1000	-3.8	-1.8	-6.7	-4.0	-10.4	-6.7

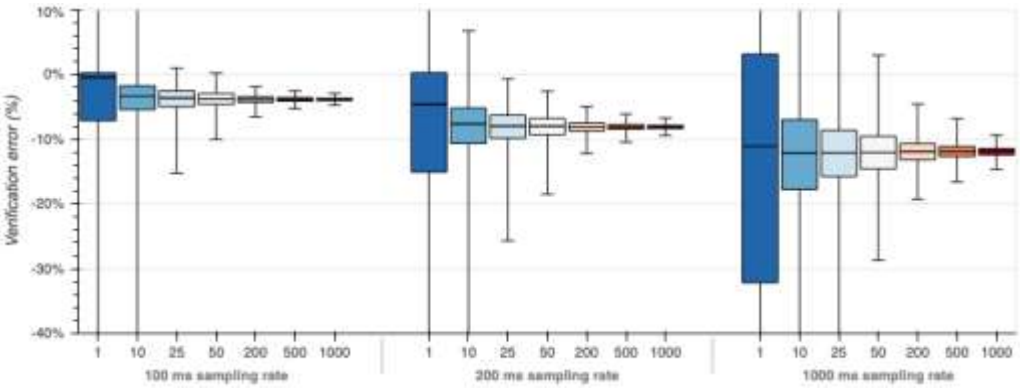

Figure 4 Verification error (without compensation response) of different aggregation levels under different sampling rates using the "first-recorded-point" method and trapezoidal rule

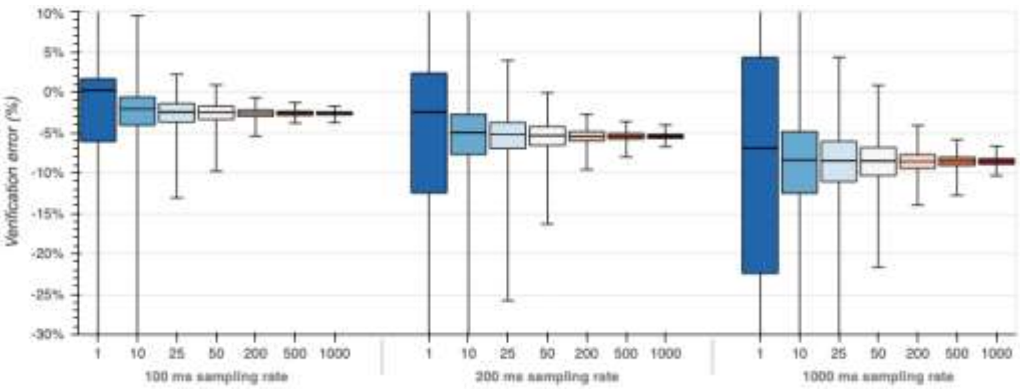

Figure 5 Verification error (without compensation response) of different aggregation levels under different sampling rates using the "RoCoF" method and trapezoidal rule

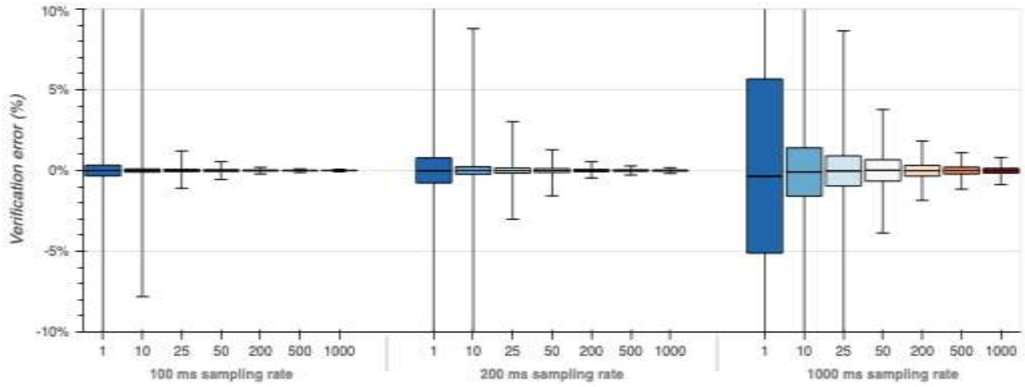

Figure 6 Verification error (without compensation response) of different aggregation levels under different sampling rates using the "universal window" method and trapezoidal rule