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21 June 2022

Violette Mouchaileh
AEMO

Dear Violette

AEMO MASS Issues Paper Consultation: May 2022 – Tesla response

Tesla Motors Australia, Pty Ltd (Tesla) welcomes the opportunity to provide AEMO with feedback on the Market Ancillary Services Specification (MASS) Issues Paper. Tesla continues to support the work that AEMO undertakes in ensuring the MASS is fit for purpose and updated to reflect latest market developments and in this case, as required to implement a new FCAS market for very fast market ancillary services (Very Fast FCAS).

The introduction of Very Fast FCAS reflects the technology advances that are being made in the market, the increasing penetration of renewables (and associated impacts on inertia), ongoing challenges with frequency stability, and the complementary enabling technologies that are providing valuable frequency control ancillary services (FCAS) in response.

As per the previous MASS consultation that concluded at the end of 2021, it will also be particularly important to recognise and ensure participation from the rapidly increasing fleet of controllable DER and virtual power plants (VPPs) in providing ancillary services, such as Fast and Very Fast FCAS. Tesla is pleased to see AEMO taking a data driven approach to the inclusion of VPPs, with many of the 2021 MASS review considerations in respect of distributed energy resources (DER) being taken into account.

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

- Given the criticality for delivery, AEMO should introduce minimum levels of contingency FCAS per region to ensure NEM wide provision

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

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-second response window (for very fast FCAS) compared to the 6 second 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%.

This is supported by the work done by the University of Melbourne (UoM) in their “Very Fast FCAS Sampling Rate Analysis in Support of the Market Ancillary Services Specification (MASS) consultation. 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 Tesla believes that 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.

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 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 are increasingly harder to forecast ahead of any formalised inertia arrangements. This is an optimal low-risk/ high-reward approach.

A detailed response to relevant Issue Paper questions is provided below. For more information on any of the content included in this submission, please contact Emma Fagan (efagan@tesla.com).

Kind regards

Emma Fagan - Head of Energy Policy and Regulation

MASS Issues Paper – Consultation Questions

#	AEMO Question	Tesla response
1	Are there any further issues for investigation by the Consultative Forum that are relevant to the specification of Very Fast FCAS?	N/A
2	Do you agree with the capabilities expressed in Table 3? If not, please advise which of these you do not agree with and provide evidence to support alternative capabilities	Yes, battery storage capabilities are accurately captured in Table 3. However, we would note that the time response of supercapacitors should also be limited by its inverter and therefore should be equivalent to battery capabilities.
3	Are there any technologies not mentioned in Table 3 that could potentially provide Very Fast FCAS? If so, what characteristics (including response time) could be expected of them? Please provide evidence to support their capabilities	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 the new market service, but rather the granularity of the data that is available from DER to verify compliance with the market service. To support both the capability of VPPs and aggregated inverter based DER in providing Very Fast FCAS services, Tesla has developed the attached Application Note looking at Measurement Error rates associated with aggregated systems providing a 1 second frequency response. This is provided to AEMO at **Attachment A.**
4	How could wind farm and solar farm operators be incentivised to participate in the Very Fast FCAS markets?	N/A
5	Are there any other issues relevant to the capability to provide Very Fast FCAS by different technologies that AEMO should consider?	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.
6	Are there any specific useful lessons to be learned from other FFR markets around the world?	N/A
7	Are there any issues with the concept of shifting Fast FCAS to accommodate a similar, but faster, Very Fast FCAS? Is there a better alternative that is compatible with the Amending Rule?	*"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, 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.
8	Are there any other issues relevant to market design that AEMO should consider?	Ideally AEMO could provide participants comfort by providing additional visibility on how it forecasts FCAS volumes will evolve going forward (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.

		As a related priority step, Tesla supports AEMO implementing regional based minimum quantities for contingency FCAS procurement, as previously explored in the Frequency frameworks review.
9	Are there any other issues relevant to the impact of inertia that AEMO should consider?	Tesla does not agree that inertial response should be excluded from the proposed FFR 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 FFR this will also allow alignment with the parallel focus on Primary Frequency Control 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 FFR. 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 VPP – with services procured on a technology agnostic basis.
10	Are there any other issues relevant to the interaction between Very Fast FCAS and PFR that AEMO should consider?	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.
11	Does a 1-second response time specification automatically exclude certain technologies from being able to participate in the Very Fast FCAS markets? Which ones and why?	N/A
12	Is there anything else AEMO should consider in maximising the pool of potential Very Fast FCAS?	As noted above, 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)
13	Will some technology types be locked out of the Very Fast FCAS markets if the maximum response time is	The issue 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.

	specified as 0.5 seconds rather than 1 second?	This will result in either more expensive equipment being required or more systems locked out of providing FFR 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 second 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 providers being able to technically provide a service. As AEMO notes on page 31 of the Issues Paper "a Very Fast FCAS response of either 0.5 or 1 second response is adequate to contain frequency within the applicable containment band…" Based on this the 1 second 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 second 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.
14	Are there benefits to setting the response time for Very Fast FCAS faster than 1 second that AEMO should consider?	AEMO has captured the power system security benefits and trade-offs well
15	Are there any other issues relevant to the proposed response time and timeframe that AEMO should consider?	Tesla supports the justifications outlined for 1-sec response and 6 second sustain time for Very Fast FCAS.
16	Are there any other issues relevant to the proposed market ancillary service offer requirements that AEMO should consider?	N/A
17	Are there any other issues or concerns relevant to AEMO's proposal to apply the current definitions of 'Raise Reference Frequency' and	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. 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 above, it would be helpful if any shift to the frequency reference bands was also accompanied by greater transparency regarding the overall FCAS procurement

	'Lower Reference Frequency' to Very Fast FCAS?	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.
18	Are there any other issues relevant to RoCoF that AEMO should consider?	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.
19	Is AEMO's proposal to permit the use of a 'combination' controller, namely, a hybrid of proportional and switched controls for Very Fast FCAS appropriate? Please provide reasons for your response.	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).
20	Are there any other issues relevant to the proposed control system requirements for a combined FCAS controller that AEMO should consider?	n/a
21	Are there other FCAS delivery methods that AEMO should consider allowing for Very Fast FCAS?	See response to Q19
22	What is the error margin and resolution for frequency measurements by high-speed metering installed by Fast FCAS Providers that could be retrofitted to existing Ancillary Service Facilities for participation in Very Fast FCAS markets?	As noted above, 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.

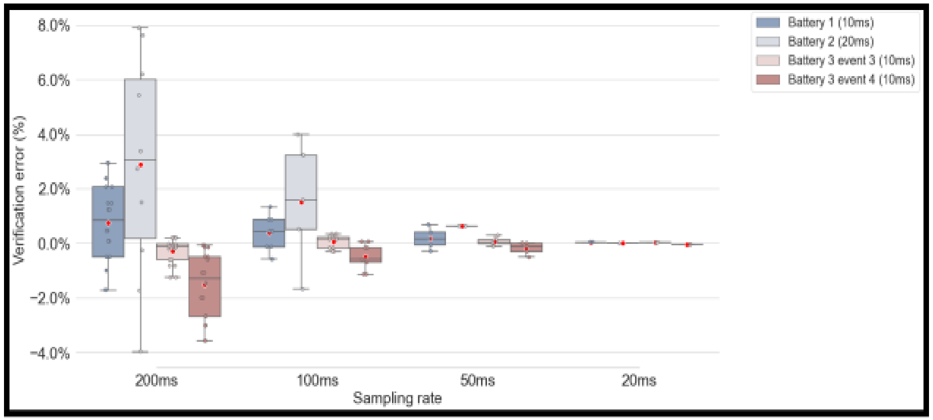
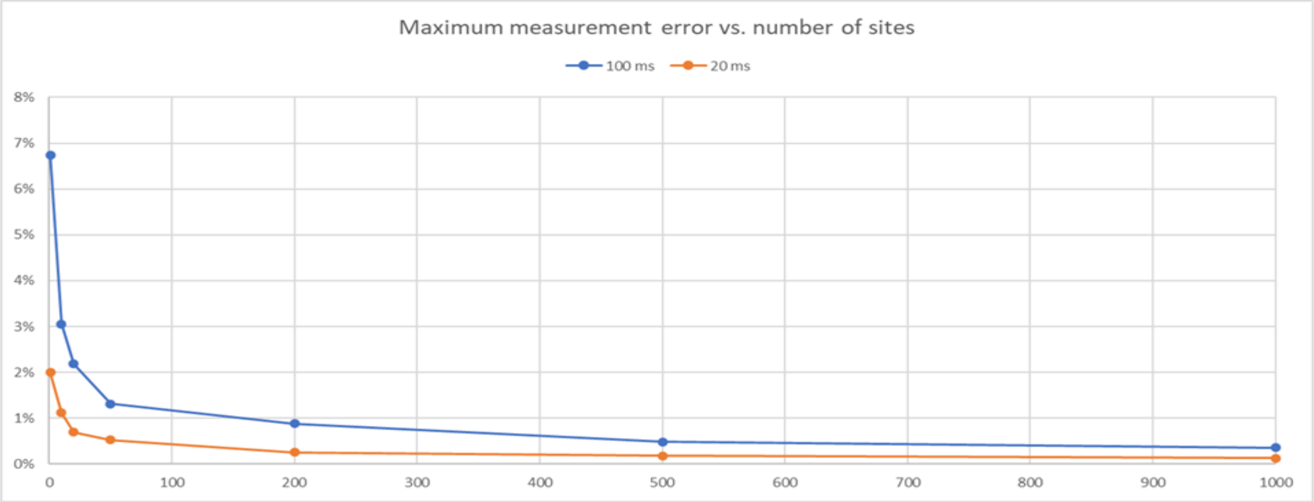
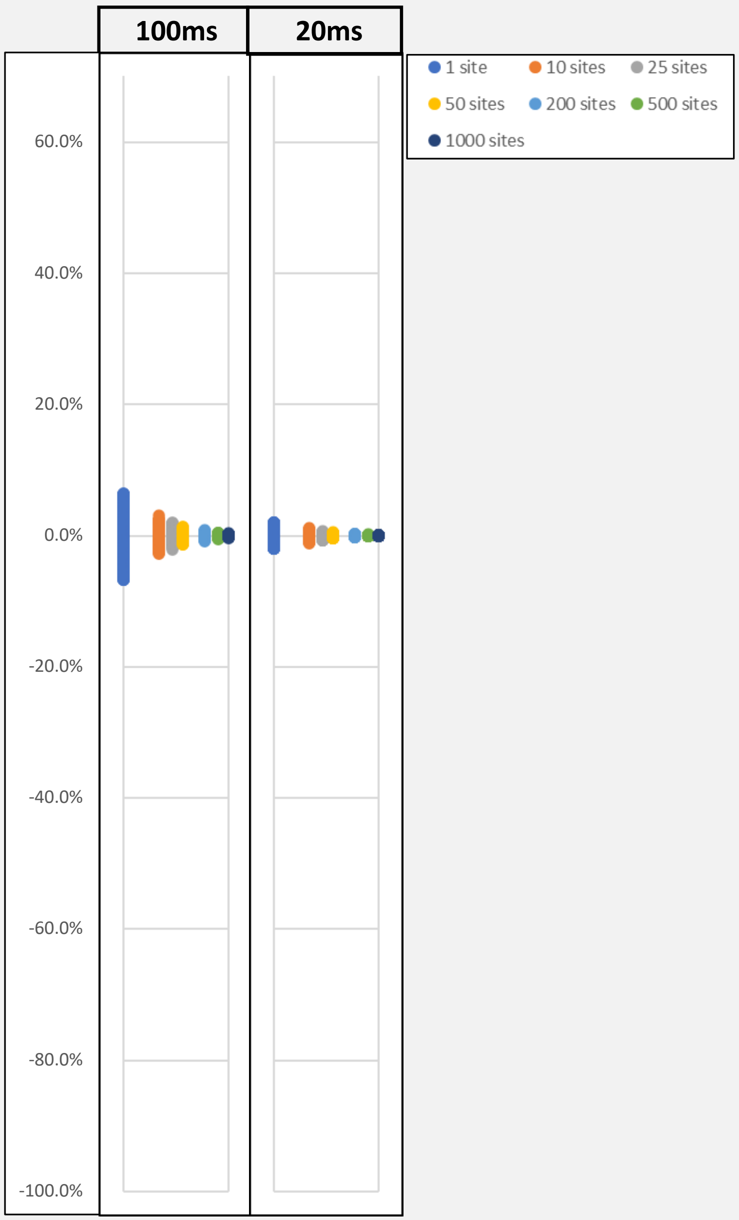


Figure 3.12. Error distribution of lower sampling rates for batteries in the assessment case based on FDT

This is supported by the Application Note provided at **Attachment A** 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 6-sec 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):

		
23	What is the error margin and resolution for frequency measurements by high-speed metering that is not currently in use in the NEM, but is available for use in the Very Fast FCAS markets?	We support AEMO investigating this issue, but would note that the majority of participants use Elspec meters and it would be highly inefficient and unnecessary to force all NEM participants to install another type of meter
24	What is the cost of high-speed metering that captures frequency measurements with a margin of error lower than 0.1Hz	N/A
25	Can metering providers submit the specifications of their high-speed metering currently available, or in use by Fast FCAS providers?	N/A
26	Are measurement rates of <100ms feasible for your technology? What is the nature and extent of changes that	Yes, 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).

	would need to be made to support rates of <100ms?	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.


100ms
20ms
1 site
10 sites
25 sites
50 sites
200 sites
500 sites
1000 sites
60.0%
40.0%
20.0%
0.0%
-20.0%
-40.0%
-60.0%
-80.0%
-100.0%

27	Are there any other issues relevant to the proposed verification and measurement requirements that AEMO should consider?	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.
28	How long can overload capacity be sustained?	We note 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).
29	What percentage of a generating unit's nameplate rating is equivalent to the overload capacity?	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.
30	How often can overload capacity be triggered in a 5-minute trading interval?	N/A
31	Can overload capacity be delivered proportionally to the frequency deviation, or can it only be delivered by a step change in active power?	N/A
32	Is there an energy payback after overload capacity is delivered?	N/A
33	What technologies other than BESS have overload capacity that be sustained for at least 6 seconds?	N/A
34	Are there any other issues relevant to the potential use of overload capacity	N/A

	for Very Fast FCAS that AEMO should consider?	
35	Can Consulted Persons identify any case where a decrease in Fast FCAS capability could be observed?	N/A
36	Are there any other issues relevant to the interaction between Very Fast FCAS and Fast FCAS that AEMO should consider?	N/A

ATTACHMENT A - APPLICATION NOTE: MEASUREMENTS ERROR

Methodology

Overview

To support the AEMO's Issue Paper on the amendment to the Market Ancillary Services Specification (MASS) for very fast frequency control ancillary services (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 second measurement window considered as opposed to the 6 second fast 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.

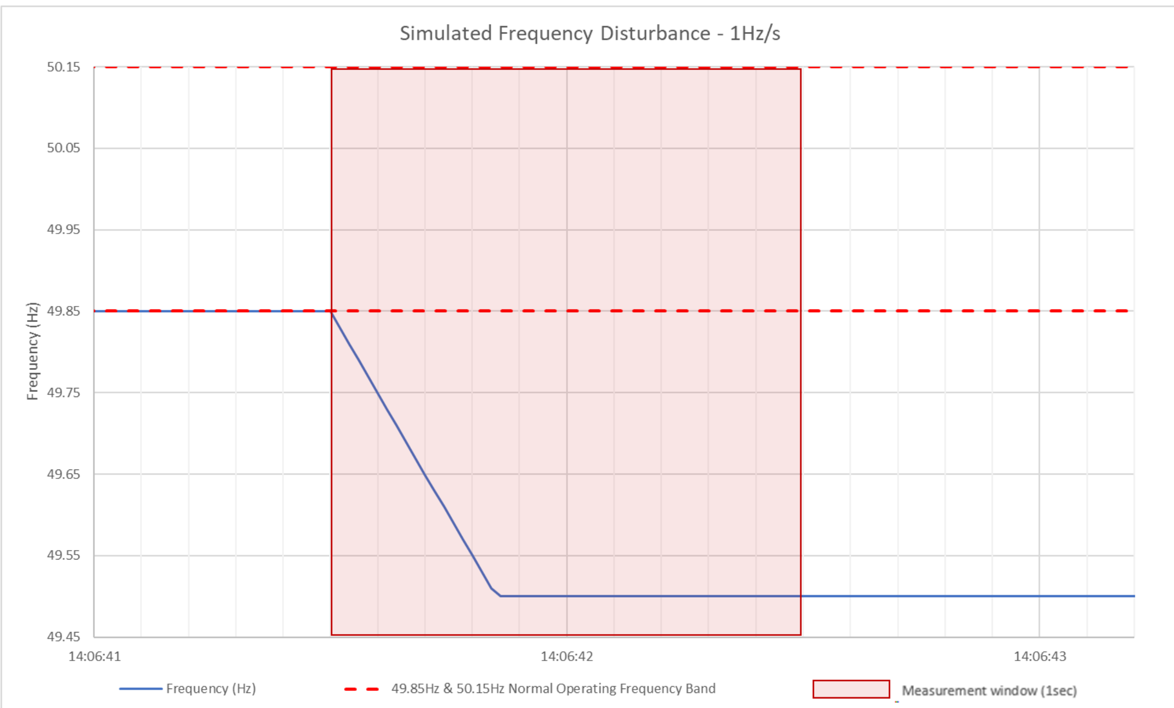


Figure 1 – Simulated frequency disturbance of 1Hz/s RoCoF (20ms sampling rate)

Power Response (20ms)

The response from a 5kW Tesla Powerwall 2 ("Powerwall") registered under Dispatchable Unit IDs (DUID) 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 Normal Operating Frequency Band (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.

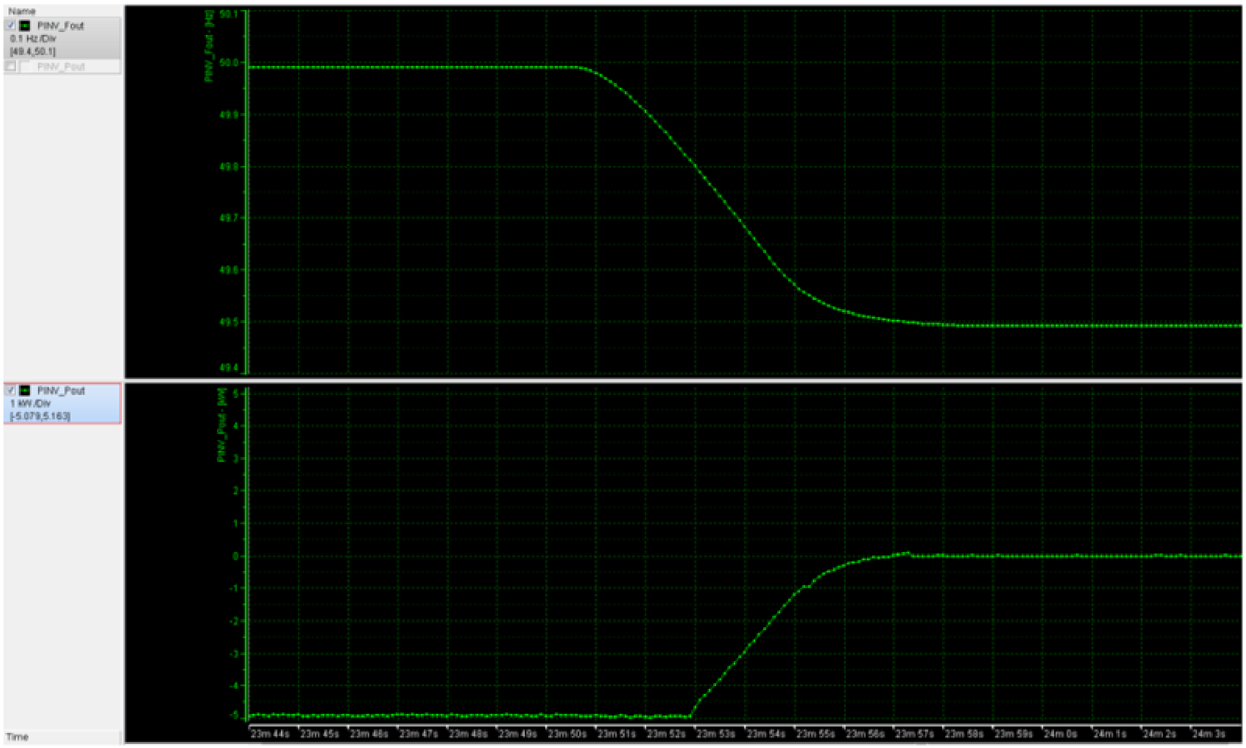


Figure 2 - Tesla Powerwall 2 Frequency Injection Test Results: 5kW Raise Response

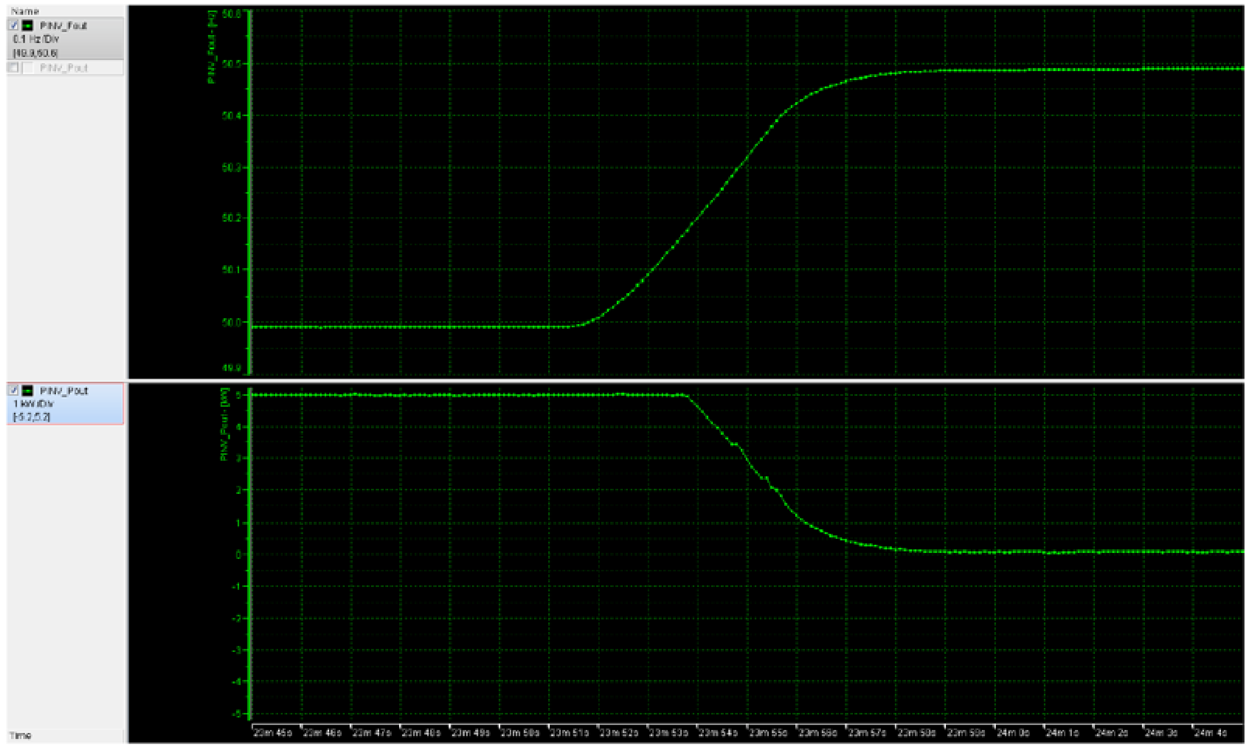


Figure 3 - Tesla Powerwall 2 Frequency Injection Test Results: 5kW Lower Response

The Powerwall uses open loop controls to provide contingency FCAS services, 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 Market Ancillary Service Specification (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 1sec)

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 1sec.

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 1sec scenarios.

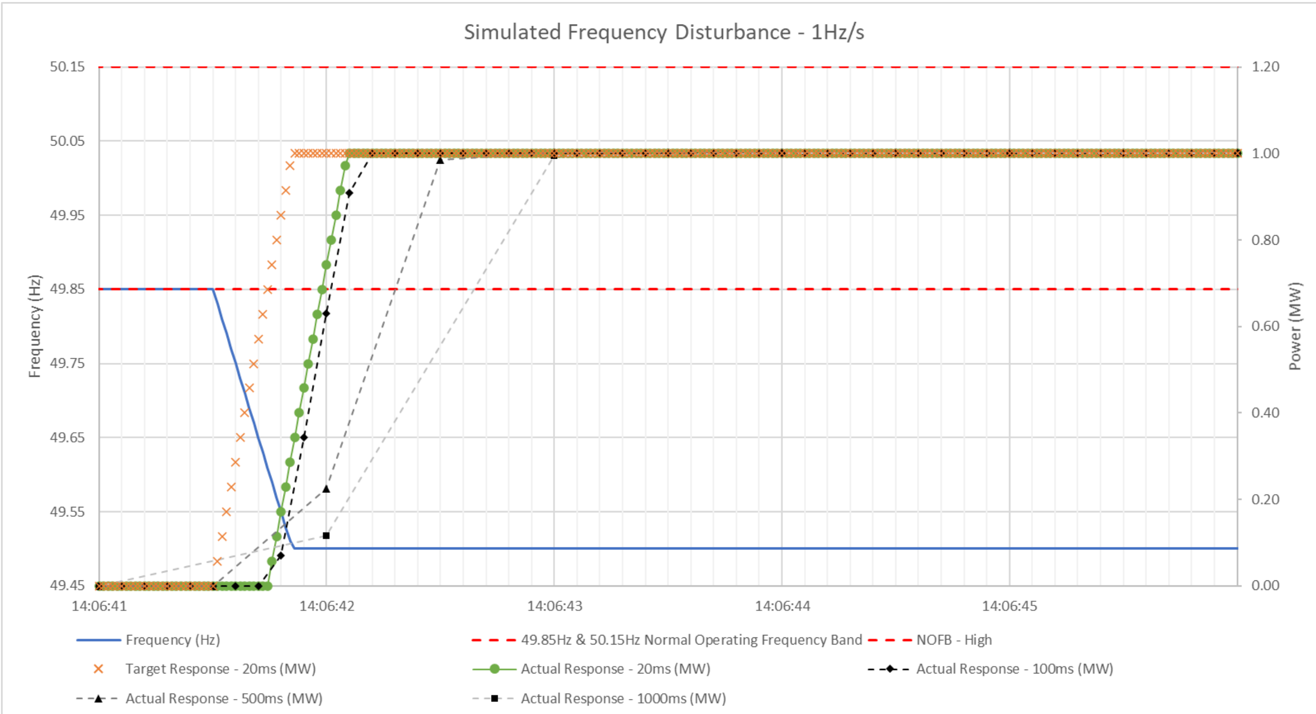


Figure 4 - Target and actual responses of 200 Powerwalls to a simulated frequency disturbance.

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:

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

where:

- n = number of Powerwalls (1, 10, 25, 50, 200, 500 or 1000)
- p = 750, which is the number of 20ms intervals over 15 seconds
- Sampling Rate = 20ms, 100ms, 500ms or 1000ms
- q = 750 / (Sampling Rate / 20ms), which is the number of intervals over 15 seconds 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.

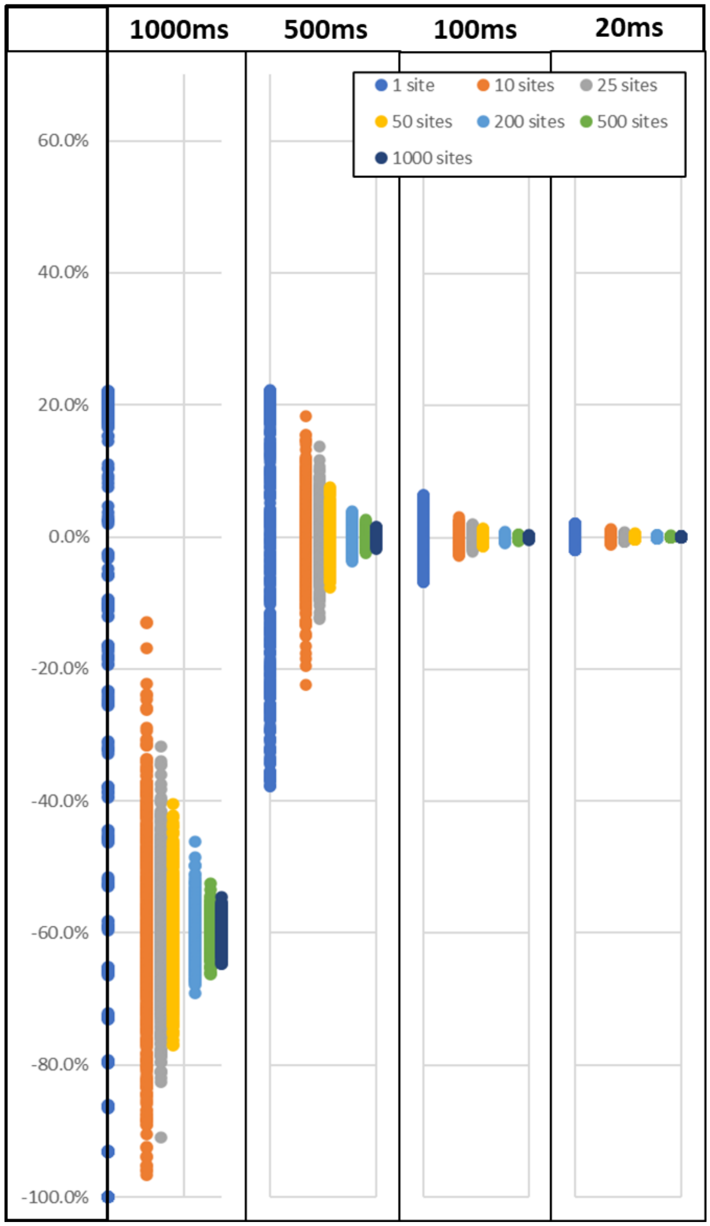


Figure 5: Span of energy error for each Monte Caro simulation

		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.** 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 second measurement window previously undertaken.

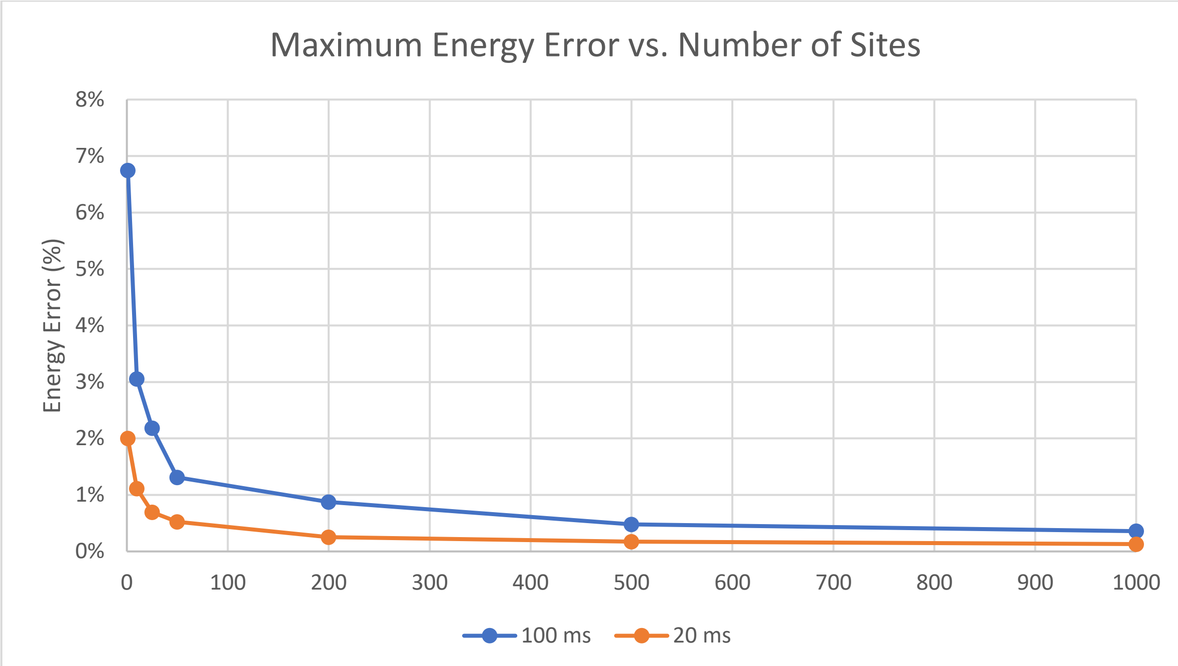


Figure 8: Maximum energy error vs. number of sites

Conclusion

For Aggregated Ancillary Service 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 <1%. Both of which meet current the allowable error and accuracy requirements for power measurements under the MASS.