TESLA

AEMO MASS Review – Draft Determination: Tesla Response

Executive summary

Overview of response

Tesla Motors Australia, Pty Ltd (Tesla) welcomes the opportunity to provide the Australian Energy Market Operator (AEMO) with our views on the MASS Draft Determination.

Tesla believe the AEMO MASS Review is a critical process in developing a market framework that encourages the optimal integration of rapidly growing distributed energy resources (DER) into the National Electricity Market (NEM). The latest AEMO Integrated System Plan (ISP) Inputs and Assumptions workbook assumes between 30 and 39 GW of installed distributed PV generation in Australia by 2030 – this equates to ~150% of the total installed coal capacity that we currently have operating in the NEM. Similarly, AEMO are projecting up to 12GW of behind the meter embedded storage, with up to 5GW aggregated to support market needs. Four out of five of the scenarios considered by AEMO consider moderate to high growth in respect of virtual power plants (VPPs). Further, AEMO is anticipating up to 4.7m EVs on the roads. This adds a potential additional 33 GW of controllable home EV charging infrastructure that can either be integrated into market and controlled or contribute to peak demand.

AEMO is at a point where increased focus needs to be given on how to best integrate DER as a critical part of Australia's energy mix. We cannot plan for 100% renewable energy by 2025 if DER is not considered. And planning for DER cannot occur without considering how to best integrate DER into existing and emerging markets Tesla believes that the best pathway for AEMO is achieved by moving DER from being predominantly passive (as is the case today) to actively controlled and participating in markets. The MASS Review can provide a tangible investment signal to accelerate the development of technology that benefits consumers whilst enhancing AEMO's obligations under the NER.

The alternative scenario, which will largely be driven by the lack of available market incentives and clear pathways for market integration of DER, is that in 2030 AEMO has >50GW of uncontrollable, passive, invisible DER serving the needs of individual customers, and creating system security concerns for the rest of the national electricity market (NEM).

From a first principles perspective the outcomes of the MASS Draft Determination do not appear to support an active DER future – rather it may set the basis for the alternative scenario where the NEM is dominated by passive, customer serving DER. Tesla is concerned that the approach proposed in the MASS Draft Determination will significantly limit the development of innovative VPPs in Australia and as a result will remove a number of the incentives that currently exist for consumers to invest in behind the meter storage that positively contributes to the electricity market.. It will also reduce the incentives for OEMs to invest in the development of fast, price-responsive EV charging infrastructure capable of providing FCAS response.

Tesla is committed to working with AEMO to establish a scalable, sustainable market framework for VPPs participating in all markets. We recognise that this is a structural shift from how all market frameworks and infrastructure was set up. While this will take time and concerted effort, Tesla believes that this is critical for the future of the NEM to best manage the growth of DER including Electric Vehicles.

In addressing the content provided by AEMO in the MASS Draft Determination, Tesla has considered the key aspects put forward by AEMO, specifically:

- Measurement resolution
- Measurement location
- Power system security concerns

Tesla's response is provided in more detail below, but all content has been developed to support our recommendations on these three areas. Further, the full context of our position can be supported by Tesla's views on core principles for DER Market Integration – also articulated below.

Summary of concerns

Tesla is concerned that the recommended approach put forward will unnecessarily increase the costs for aggregators looking to register VPPs in the fast contingency FCAS markets. This is of particular concern given that that there are lower cost alternatives that should be considered as achieving the same technical outcomes for AEMO. As it currently stands, Tesla can support 100ms measurement resolution for individual Powerwall sites, but cannot meet the 50ms measurement resolution. As such, to maintain participation in the fast FCAS markets, and subsequently create the most compelling VPP offer for our customers, Tesla would need to install additional metering hardware, capable of 50ms resolution on every VPP enabled site.

In addition, verifying FCAS performance using site level data, rather than device level data, will result in a less accurate representation of performance, and a more conservative approach to bidding to account for both site load and uncontrollable generation externalities.

This creates both cost and efficacy concerns for Tesla:

- Requiring 50ms metering for all VPP sites wanting to participate in fast FCAS markets would add ~$20m in additional metering costs to a 100MW VPP (assuming a mid-range estimate of $1000 per site based on the cost estimates provided by AEMO).
- Measuring at the site connection point rather than at the device level will result in inefficient bidding behaviour and will result in a 5 – 10% reduced revenues across the slow and delayed markets.

In the absence of a cost-effective metering solution the most likely outcome is that many VPPs will not participate in fast FCAS markets. Organisations delivering VPPs to customers to lower energy prices, increase renewables and stabilise the grid may see a reduction of 30 – 50% revenue per site. Due to lack of access to fast FCAS markets the following impacts may be placed on retailers developing VPPs as well as Tesla VPP market goals:

- Considering which jurisdictions are technically viable to introduce a competitive VPP offer.
- Increasing or reconsidering the customer retail rate that may be offered.
- Reconsidering the overall customer incentives that can be offered:

This in turn will reduce the customer uptake of VPP offers, and the stymy the transition from passive to active DER that should be a strategic imperative for AEMO in order to work towards being able to periods of 100% renewable energy by 2025.

TESLA

Distributed energy resources in Australia – Tesla principles

A core principle that Tesla applies to all of the DER development work that we undertake, both locally and globally, is that the market benefits more from active DER than it does from passive DER. Making the transition from passive to active DER is a necessary and key element in achieving AEMO's stated goals of preparing the grid for periods of 100% renewable energy penetration by 2025.

Currently we have >15GW of passive distributed solar in the Australian electricity mix. This compares with ~400MW of behind the meter storage. Importantly, only ~40MW of this the total DER currently installed in Australia are registered with AEMO and would be considered active – less than 0.3% of the total installed DER capacity – consequently AEMO and Governments more generally are faced with significant social and technical challenges of managing minimum and potentially negative day time demand.

Tesla believes that AEMO can feasibly create a target of 5 – 10GW of dispatchable DER by 2025. This will take dedicated effort and resources to bridge the gap from where we currently are, but the technology exists and both industry and consumers are ready to support this shift. Central to accelerating this transition are the following elements relevant to the MASS Draft Determination:

1. The insights from the VPP Demonstrations Trial have largely being ignored when they should form the basis of AEMO's ongoing DER roadmap; and
2. Broader DER power system security concerns should not be conflated with the MASS and need to be addressed separately.

VPP Demonstrations Trial

One of the key concerns that Tesla has with the position put forward in the MASS Draft Determination was the lack of insights that appear to be drawn from the AEMO VPP Demonstrations Trial. Tesla is confident that AEMO undertook the VPP Demonstrations Trial in good faith, and that current AEMO priorities such as Project Edge support future market integration of DER. However the recommendations included in the MASS Draft Determination appear to be driven primarily by potential or perceived risks associated with broader integration of high penetrations of DER into the markets, rather than considering both the learnings of the VPP Demonstrations trial and steering the future of DER in Australia towards using markets as opposed to regulations to drive consumer and industry investment.

The VPP Demonstrations Trial provided two years of in-market, technical demonstration of VPP performance, and in-depth collaboration between AEMO and industry. From Tesla's perspective this work was leading both from a domestic and an international perspective. Providing a detailed practical demonstration of services is critical when considering major market shifts, and the insights gained by both AEMO and industry during the trial are far more valuable than those gained during an equivalent desktop consultation process.

At the conclusion of the two-year demonstration, none of these changes have flowed through to the MASS Draft Determination. AEMO has provided no industry guidance on whether the VPP registration approach used during the trial will be maintained, and there is limited guidance as to how the visibility and forecasting approaches used by AEMO during the VPP Demonstrations Trial will flow through to future market changes.

While there should be further consideration given to the appropriateness of the settings tested during the VPP Demonstrations trial, Tesla believes that the work done should form the basis of AEMO DER market settings. In our response below, Tesla has provided our own views as to how AEMO should progress with the approach and learnings gained during the VPP Demonstrations trial to benefit both AEMO and the industry more broadly.

Power system security concerns will not be resolved by maintaining the MASS

Tesla accepts the power system security concerns highlighted by AEMO, however these are largely separate to the MASS requirements and appear to be driven by broader AEMO concerns on the market participation of DER and/or related to the high penetrations of DER more generally. Importantly, these issues will not be resolved by maintaining the MASS in its current form, and Tesla is disappointed to see the MASS review process conflated with these broader DER concerns.

In fact, Tesla expects that these risks will be exacerbated by increasing market barriers for DER because removing market access also removes incentives for customers to invest in smarter, more active DER. This in turn results in less DER providing system security services, and it also results in less visibility of DER performance for AEMO. Tesla believes that these issues are critical for AEMO to address, but this needs to be done through a separate forum to the MASS review process.

Tesla recommendations on MASS Determination

Following on from the general points above and supported by the detailed analysis undertaken by Tesla and included in the body of our response, Tesla puts the following recommendations forward to AEMO.

Measurement resolution:

- AEMO should allow for fast FCAS measurement resolution of 100ms as an alternative to the 50ms resolution currently required and included in the Draft Determination. This should be done on a conditional logging basis, with 1 second measurement resolution maintained outside of frequency deviations (before a frequency deviation, and after the 60 second following a frequency deviation).
- AEMO should update the MASS FCAS verification tool to use the trapezoid measurement resolution approach.
- The combination of these two recommendations creates a near zero error risk for AEMO – well under the 2% allowable error range for fast FCAS currently allowed within the MASS.
- Tesla's analysis also highlights that for fleets of >200 systems, the error risk associated with 1 second measurement resolution is also less than 2%. Tesla recommends that AEMO further consider options for larger fleets to operate with a less granular measurement resolution (see detailed analysis in Attachment B).

Measurement location:

- Tesla understands AEMO's concerns about measurements at the site level, however Tesla believes that the FCAS measurement location should be the same as where the FCAS response is implemented. Some VPPs implement a closed loop response at the site level while others, like Tesla, implement an open loop response at the asset level. For simplicity, Tesla recommends that AEMO:
    - Where FCAS is provided by a site level, closed loop device the performance of that site should be verified at the site level (with the VPP operator required to provide data at the device level for FCAS enabled devices, as well as site level data).

    - Where FCAS is provided using open loop device level controls, or closed loop controls at the device level, the performance should be verified at the device level (with the VPP operator required to provide both site and device level data)
- If AEMO maintains site level measurements resolution for all sites, then Tesla suggests that in the event of AEMO assessing under-delivery of FCAS, market participants are able to demonstrate compliance using device level data, to show that the perceived under-delivery was caused by uncontrollable load or solar.
- Tesla believes that AEMO should not disregard asset level measurement for the following reasons:
    - Measurement at the site level creates risks for VPP aggregators in accounting for uncontrollable loads and changes in solar PV output. Based on these externalities, measurement at the device level provides a more accurate method of verification of FCAS performance.
    - Where there are multiple FCAS enabled devices at a single site, then the aggregator must demonstrate suitable metering for each asset and must demonstrate that the performance of the multiple devices is complementary.

Other MASS related recommendations

DER

- AEMO should reinstate the API set up for the VPP Demonstrations trial and make API integration a specific requirement of VPP registration within the MASS.
- This API provided clear benefits to AEMO in terms of increased visibility of DER in real-time, as well as setting the framework for forecasting.
- Tesla supports providing AEMO with ongoing DER visibility. Maintaining the API would result in AEMO receiving 100ms data during frequency deviations (for compliance purposes), and 1 second data provided at all other times.
- VPP operators could either be required to provide this data as a MASS condition of registration or provide it on an opt-in basis.
- This breadth of data will help enormously with the power system security concerns raised by AEMO as it will provide real-time data to help identify a range of different inverter responses to different fault level conditions.
- Conversely, maintaining the MASS as it currently stands will provide AEMO with 50ms data only during a contingency event. This doesn't help with any other system disturbance, or to more broadly analyse how inverters behave in response to distribution level fault issues. The API does support that.
- Tesla also believes that the transitional arrangements proposed for existing registered VPP Demonstrations trial capacity should be extended from 30 June 2023 to 30 June 2031. This 10-year transitionary period is more aligned with investment timeframes and ensures that private investment is not placed at risk.

General

In respect of the General Mass discussion included in the MASS Draft Determination, Tesla has only one recommendation in respect of the proposed s 3.5 "New Regulation FCAS requirements – minimum 2MW regulation FCAS bid size.

- Tesla believes that the 2MW limit is arbitrary and inconsistent with "no less than half the bid size" (i.e. 1MW/2 = 500kW).
- We recommend that AEMO removes these thresholds, and/or recognise technology differences - it is much easier to observe a clean 1MW regulation response on a battery than it might be to observe a 5MW on a thermal plant.

Power system security:

- Tesla does not believe that the power system security risks articulated by AEMO in the MASS Determination are relevant to the outcomes of the MASS Review– they need to be managed regardless of whether the MASS is updated or maintained in its current form.
- Tesla proposes that these issues need to be addressed through strong industry collaboration – and through a bespoke forum specifically focused on DER Power System Security concerns. Alternatively, an existing forum, such as the Energy Security Board (ESB) "Maturity Plan" or the Distributed Energy Integration Program (DEIP) could be used to address these concerns.
- Alternatively, Tesla is supportive of the proposed "Consultative Forum" proposed by AEMO and would be happy to support this as a forum to addressing the broader system security concerns flagged.
- Further, it seems as though the lack of DER visibility is central to all DER power system security concerns raised by AEMO. This can be managed through maintaining the API that was developed for the VPP Demonstrations trial and making this an ongoing requirement for all VPP market participants.
- Complying with the ongoing data provisions and providing AEMO with real time fleet and asset visibility via API, should first be included in the MASS and then adopted into the rules through the 'Scheduled Lite' rule change and the implementation of the Visibility Model explored by the ESB.

BAU settings for VPP:

- Tesla recommends AEMO establish a strong framework setting out the business as usual (BAU) expectations for VPPs registering with AEMO.
- The work done during the VPP Demonstrations trial provides the basis for what the future market integration can and should look like.
- Tesla has developed a set of guiding principles – based on both the AEMO VPP Demonstrations trial key findings, as well as our response to the points raised in the Draft Determination.
- This is provided to AEMO as Attachment A of this response.

For more information on any of the content included in this submission please contact the Tesla Policy Team (Energypolicyau@tesla.com)

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AEMO MASS Draft Determination – Tesla detailed submission and supporting evidence

1 Introduction

1.1 About Tesla

Tesla Motors Australia, Pty Ltd (Tesla) is a global leader in manufacturing electric vehicles and clean energy products. Tesla produces a unique set of energy solutions such as Powerwall and Megapack, enabling homeowners, businesses, and utilities to manage renewable energy generation, storage, and consumption. Our mission is to accelerate the world's transition to sustainable energy and globally Tesla has deployed more than 6.2 GWh of residential and utility scale energy storage systems across 40 countries. In 2020 alone, Tesla deployed more than 3GWh of energy storage systems around the world and installed its 200,000th Powerwall.

Tesla is also a leader in delivering high quality virtual power plants (VPPs). The South Australia VPP (SAVPP), delivered by Tesla and Energy Locals with support from the Government of South Australia and the Australian Renewable Energy Agency (ARENA) currently has 16 MW registered to provide all six contingency frequency services – and has been providing high quality frequency response services for more than two years.

Tesla currently employs more than 140 people in Australia to undertake the full range of the development and deployment of utility scale energy storage and VPP work. Our permanent employees provide end-to-end development of all Tesla's local energy projects including Business Development, Engineering, Project Management, Project Deployment, Software Development, Market Integration, Service & Operations.

1.2 Tesla VPP experience

In Australia, Tesla has been actively deploying VPPs since 2018. In 2018, in partnership with the South Australian Government, Tesla launched the SAVPP[1] which targets up to 50,000 South Australian residents. Importantly this VPP has been launched on SA Housing Authority properties – enabling customer demographics who have previously been locked out of DER ownership to benefit from renewable energy installed on their property. The SAVPP is being deployed in three phases:

- Phase 1 (2018): Proof of concept phase. This first phase saw 100 systems installed to demonstrate the ability of smart storage technologies to be aggregated.
- Phase 2 (2018 – 2019): Aggregation phase. This second phase saw an additional 1000 systems installed. During this phase, Tesla engaged Energy Locals as the market customer/retailer for sites and successfully registered with AEMO to provide FCAS services – first registering as ancillary services load under the existing rules (slow and delayed markets) and then transitioning to the VPP Demonstrations trial (all markets)

[1] https://www.tesla.com/en_au/sa-virtual-power-plant

- Phase 3A (2021 – present): Scale phase. This phase is currently in the process of being deployed. To support Phase 3A, Tesla successfully attracted bank finance from the Clean Energy Finance Corporation (CEFC), as well as grant funding from ARENA. Separately Tesla has contracted with the SA Government through the grid scale storage fund (GSSF) to provide a number of new market services in SA – notably fast frequency response (FFR) , inertia and localised voltage support (working with SA Power Networks).

The South Australia VPP is the largest VPP operating in Australia and the first VPP to use Tesla market integration and bidding software globally. It is also the only centrally owned Australian VPP, with bank finance from the CEFC, and was the first VPP registered in the AEMO VPP Demonstrations trial.

In 2019, Tesla also launched our Tesla Energy Plan (TEP) in South Australia. The TEP allows private customers to use their own Powerwalls to participate in the Tesla VPP. All SAHA sites and TEP sites are aggregated together under a single DUID for the purpose of current FCAS market participation.

Throughout the deployment of our VPP, Tesla has focused on knowledge sharing, collaboration with all relevant stakeholders, and industry development. We are committed to the future of VPPs in the Australian market. It is also clear that state governments, ARENA and the CEFC are equally invested in the future market development of VPPs in Australia.

1.3 Tesla Principles for DER Market Integration

Tesla has been very active in all Australian DER work over the last five years. Tesla Powerwall allows customers to install storage for self-consumption purposes as well as to participate in VPPs. Our smart software is used for market integration of DER, and increasingly our global team is looking at the role of smart EV charging infrastructure.

Given the breadth of experience, Tesla applies the following principles to all the DER market reform work that we support.

The NEM benefits from active DER over passive DER

The starting position from Tesla is that the NEM benefits more from distributed energy resources (DER) that are actively providing services, and responding to market signals, than from passive DER.

Active DER provides more market competition in both NEM and network services, ensures direct pass through of market benefits to customers, and most importantly encourages aggregation of DER.

With increased aggregation comes increased visibility of system and fleet performance, and increased ability to forecast solar, customer load and battery outputs. Early market integration of DER is critical to laying the groundwork for a more complete shift to active DER which will benefit AEMO and the network service providers (NSPs).

Importantly, the shift from passive to active DER also means that customer owned, behind-the-meter DER can be used to their full potential. These systems will not sit their idle during key system security events at the NEM level or for providing non-network solutions to NSPs.

If the same technical outcome can be provided at lower cost, this change needs to be made

A core tenet of AEMO's obligations in respect of the National Electricity Objective (NEO) is to reduce costs. If the same technical outcome can be achieved through a lower cost, more readily available technologies, then AEMO needs to consider these changes.

The 50ms measurement resolution requirement for fast FCAS has existed since the MASS was first introduced in a market context where services were provided by a small number of larger generators , and has not been amended despite the significant shift in the make-up of the generation mix in the national electricity market (NEM). This current MASS review provides AEMO with an opportunity to consider whether updates to the measurement resolution and/or the FCAS verification tool, can satisfy AEMO needs whilst also reducing barriers to entry for new technology types – notably aggregated DER.

Tesla's response below demonstrates the technical compliance of 100ms and 200ms data and we strongly believe that AEMO can move forward with reducing costs for new participants whilst being comfortable with receiving the same level of service. From Tesla's perspective we can achieve a 100ms (or 200ms) granularity in measurement resolution with our additional hardware. Alternatively maintaining a 50ms resolution would require the installation of additional hardware for each participating VPP site. Looking at a mid-range cost of $1000 based on the cost estimates put forward by AEMO in the MASS Draft Determination, this would equate to a cost of $20m in additional metering for a 100MW VPP.

AEMO's obligations under the NEO (which are explored in more detail in section 3 below) must drive a consideration of a lower cost outcome if it achieves the same technical outcome – in this case an appropriate measurement resolution that is within the allowable error bands considered by the MASS.

Customer engagement is critical

From an economic perspective, better integration of DER into the markets provides the most efficient investment because it utilizes customer investments. As such, it is critical that customers are adequately engaged and rewarded for their system being used for market purposes. Where DER is used to provide a value-add service, customers should be compensated for that service.

A major benefit of the VPP Demonstrations trial is that it showed how willing customers are for their systems to be market integrated where the trade-off is an appropriate incentive package. With more than 30MW of capacity registered under the VPP Demonstrations trial, this equates to 5000 – 7000 customers who have actively chosen to be a part of a VPP. This can grow at scale, but Australian industry needs certainty of market settings to make investments in building out this capability.

2 Benefits of active DER in Australian market

As noted above, the starting view held by Tesla is that a move from passive to active DER provides an overarching benefit to the market and is necessary to address a number of higher order risk factors arising from uncontrolled daytime solar exports, as well as supporting the wider transition to higher levels of renewable energy.

This position seems to be supported by the wealth of information that has been released by AEMO, the Australian Energy Regulator (AER), the Australian Energy Market Commission (AEMC) and the Energy Security Board (ESB) in recent years.

There also seems to be broad acceptance that integrating VPPs into the existing market frameworks is a necessary starting point for accessing these benefits. For instance, the “ESB P2025 Market Design Options Paper[2]” notes the following:

> *“By unlocking the value of aggregated DER, this can provide a competitive alternative to large scale generation to deliver low-cost energy and system services, as well as reducing the need for investments in networks. This results in benefits to all customers (not just those with DER).”*

Tesla’s view is that now is the critical time for industry, AEMO and distribution network service providers (DNSPs) to be collaborating on how to best create the future market settings and regulatory requirements to start treating active DER (and VPPs in particular) as a critical piece of Australia’s electricity mix. Ignoring detailed trial findings and the time and investment made by industry in collaborating with AEMO since 2018 does not support these outcomes.

2.1 Market outlooks for DER/ VPPs

AEMO clearly views VPPs as being a critical part of Australia’s energy mix in the future. This position is reinforced by AEMO’s latest Integrated System Plan Draft 2021 Inputs, Assumptions and Scenarios report which assumes somewhere in the magnitude of >25 GW of VPPs operating in Australia by the late 2040s, and up to 5GW in 2030 (as shown in **Figure** 1**)**.

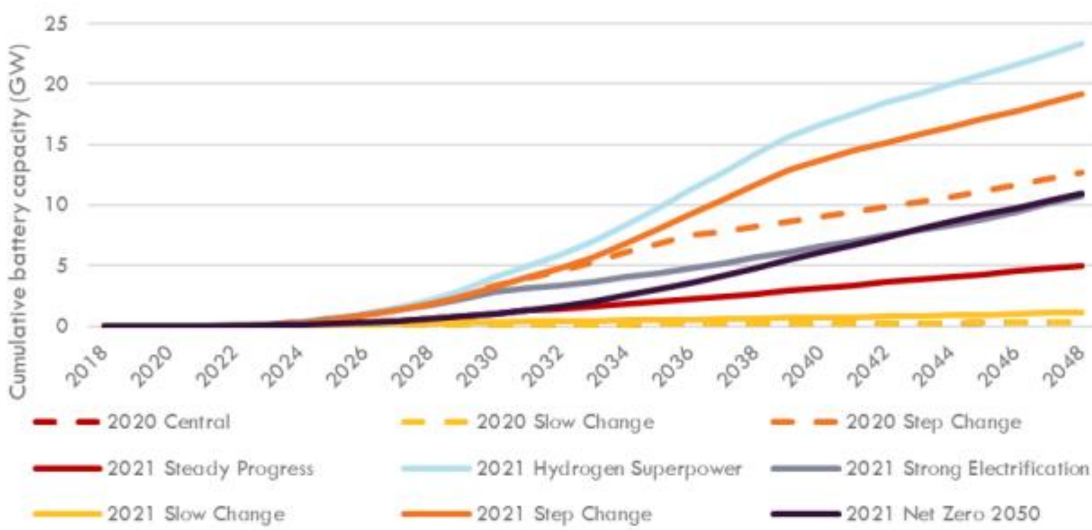

Figure 1: AEMO, "2021 Inputs, Assumptions and Scenarios Report"

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[2] https://aemo.com.au/-/media/files/major-publications/isp/2021/2021-inputs-assumptions-and-scenarios-report.pdf?la=en

It would appear, therefore, that it is critical to get the market access arrangements right to ensure optimal use of VPP systems as they are integrated into the market.

While AEMO's assumptions on the number of aggregated batteries that will providing DER is ambitious, they are also dwarfed by the total passive DER that will be installed and operational by 2040. In total, aggregated batteries are anticipated by AEMO to make up 40% of the installed behind the meter battery fleet by 2030, and 50% by 2040.

In the absence of the MASS Final Determination enabling VPP market access in full, Tesla considers these ratios to be unachievable. With full market integration, and a dedicated plan to growing market access arrangements for VPP, Tesla believes that this ratio could be much higher, and will also start to bring the gap between the level of installed smart VPP integrated DER and uncontrolled solar (with VPP storage expected to be installed at a ratio of 1:6 by 2030 – see **Figure *2***)

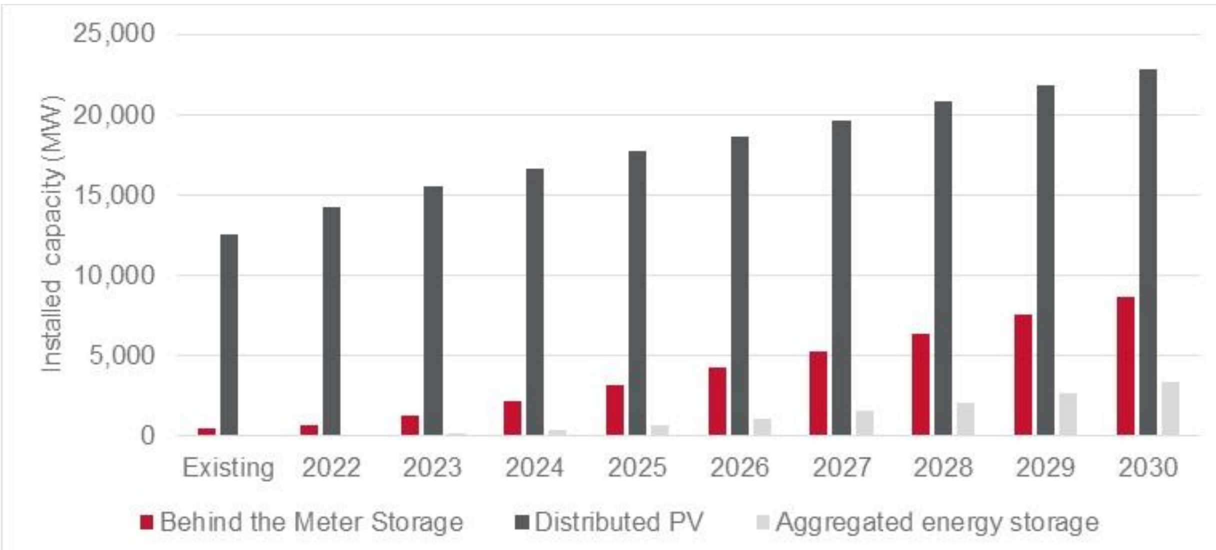

Figure 2: Anticipated solar, battery and aggregated battery uptake[3]

2.2 Benefits of active DER

Tesla also believes that better market integration of DER is a starting point to resolving the key DER issues that AEMO is currently concerned about in particular the concerns around minimum demand. These are best resolved through increased market integration of DER, removing disincentives for increased storage, and creating frameworks for AEMO to have more real-time visibility and forecasting of DER performance.

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[3] Data based on AEMO High DER scenario data with some notes. Note 1. Behind the meter storage and aggregated energy storage figures are drawn from the Draft 2021-22 Inputs and Assumptions sheet. Note 2: Distributed PV numbers are based on the 2020 ISP Generation Outlook for High DER. We consider these numbers to be extremely low given the current installed distributed PV capacity is already more than 15GW. As such the ratio of passive DER to active DER – now and projected, is much, much greater. In addition, we were unable to use the most recent ISP input data (and new scenarios) as there are errors in the AEMO workbook released as there were errors in the released version.

There are substantial benefits associated with better market integration of DER, these include:

1. Managing the impacts of minimum demand
2. Additional capacity to respond to disturbances
3. Better real-time DER visibility and forecasting

Benefit 1: Managing minimum demand

A major current concern of AEMO and the ESB is minimum demand, and the associated power system security risks that are arising because of it. This is the number one priority for the ESB's DER workstream, and the first topic considered in the DER Maturity Plan work-program.

The installation of battery storage, particularly larger residential battery storage systems right sized for the accompanying solar installation, will play a key role in reducing daytime solar exports and reducing the risk of minimum demand and impacts on the network. Tesla analysis across a fleet of 244 NMIs participating in the SAVPP shows a noticeable reduction in daytime solar exports when battery storage is added to VPP properties (**Figure *3***).

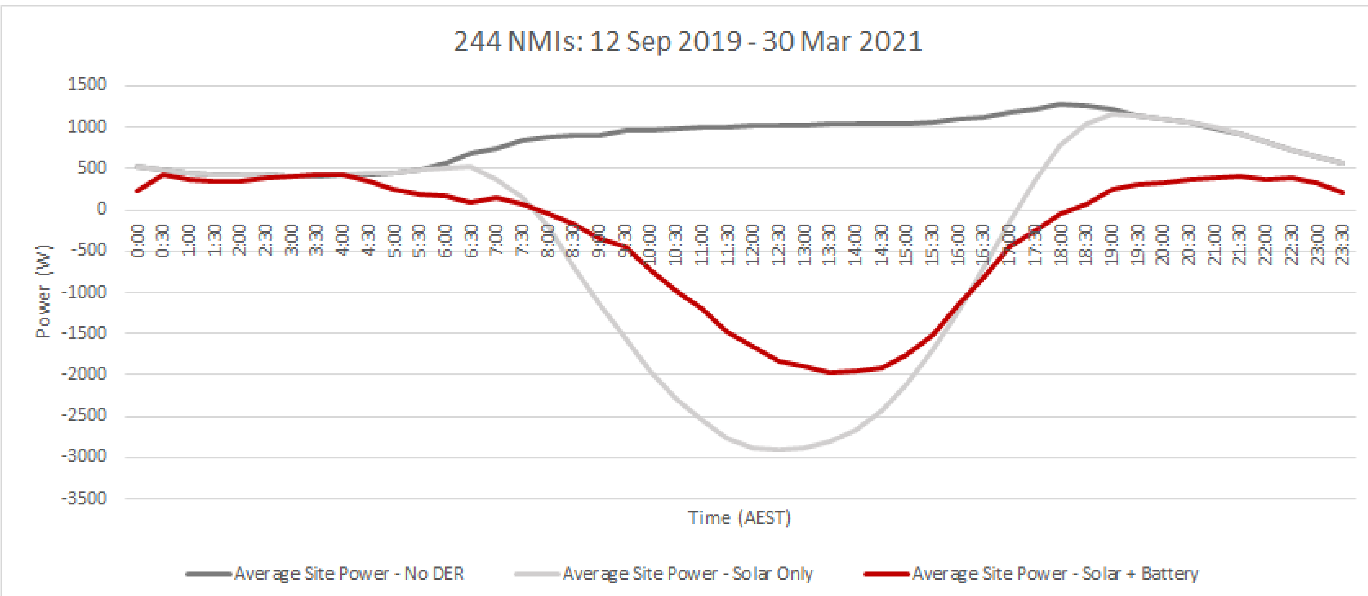

Figure 3: Tesla analysis of VPP fleet in reducing daytime exports

This is even more noticeable when a larger battery or multiple batteries are paired with solar – see **Figure 4** below.

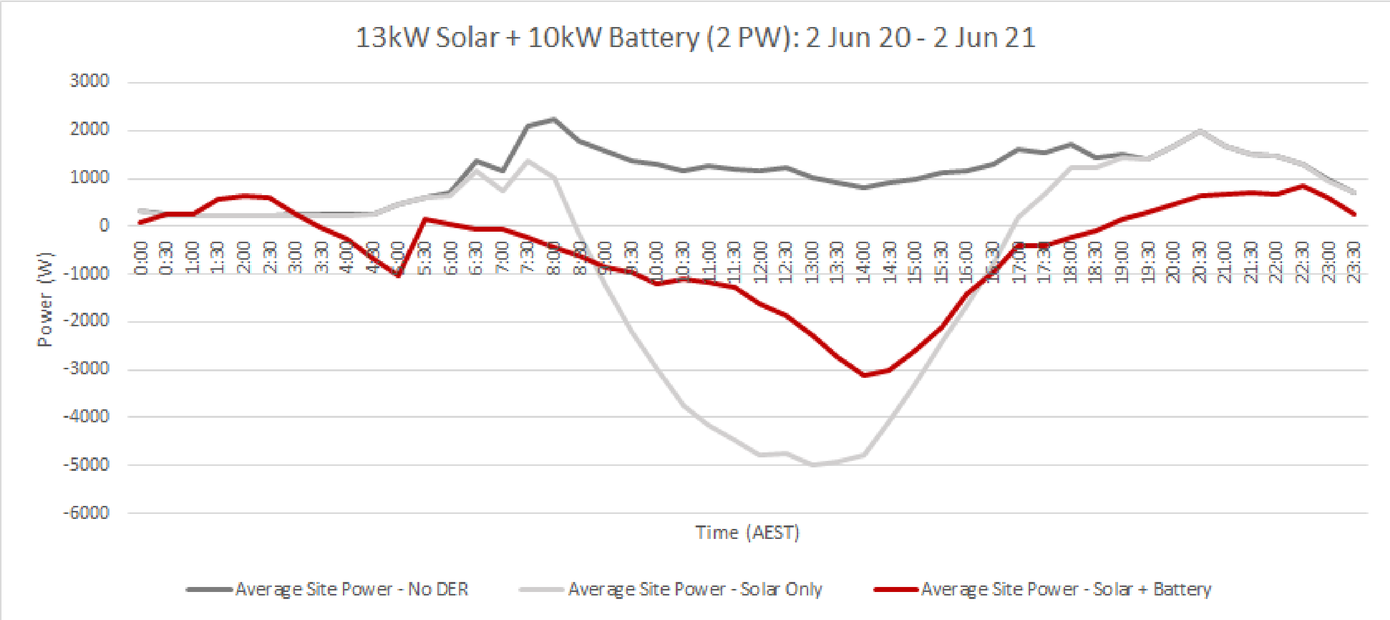

Figure 4: Tesla analysis of larger batteries reducing daytime solar exports

A key driver for customers purchasing battery storage at the moment is the competitive VPP retail offers and associated customer benefits that come from participating in a VPP – up-front hardware discounts, ongoing grid-credits, competitive electricity tariff rates etc. Limiting access to, or creating additional cost impositions for, participating in fast FCAS markets will negate most of these benefits that can be offered to customers and reduce the entire VPP value proposition for customers. As such we anticipate less customers opting into VPPs and less dispatchable DER entering the market.

Given the focus on minimum demand, AEMO should not be looking to create disincentives or remove market access for additional storage as this will ultimately lead to less customers installing residential storage and the concerns associated with rooftop solar exports and negative demand will be exacerbated.

Benefit 2: DER responds to disturbances

A second major benefit of creating appropriate market frameworks and incentive structures to incentivise DER to actively participate in all FCAS markets is that systems are not sitting idle during an event. During the Callide C event on 25 May 2021, Tesla had thousands of available systems in NSW and Queensland that sat there idle, rather than responding to the rapid frequency drop that occurred.

This is due to the fact that there are no current VPP offers in NSW or Queensland that use the Powerwall. In the event that these systems were part of one or more VPP, they would have provided an immediate frequency injection to help restore the grid and ride-through the Callide event.

More market access for DER results in more VPP offers which results in more systems being visible and useful to the market.

Benefit 3: Data and forecasting

A key benefit that AEMO has gotten out of the AEMO VPP Demonstrations trial is access to real-time asset and fleet wide data, via an API specifically stood up for the trial. Tesla understands that this data has been valuable to AEMO both in analysing DER response during system disturbances, and in assisting the operations team in forecasting.

Tesla was supportive of the development of the API during the trial, and we continue to be supportive of providing real-time fleet and individual asset level data. A key recommendation Tesla makes as part of our response to the MASS Draft Determination, is to maintain the API and have all VPP providers continue to provide data to AEMO. We believe this could be implemented within the MASS as a starting point, and then reinforced through the Scheduled Lite rule change and implementation of the visibility model considered in the ESB P2025 Options Paper.

Tesla believes that the provision of ongoing 1 second data – both asset and fleet level – should be a minimum requirement for all VPP providers in the market. In addition, Tesla is supportive of continuing work with AEMO on future DER forecasting needs.

Figure 11 Average VPP forecast vs actual over a range of forecast time horizons, 1-7 May 2020

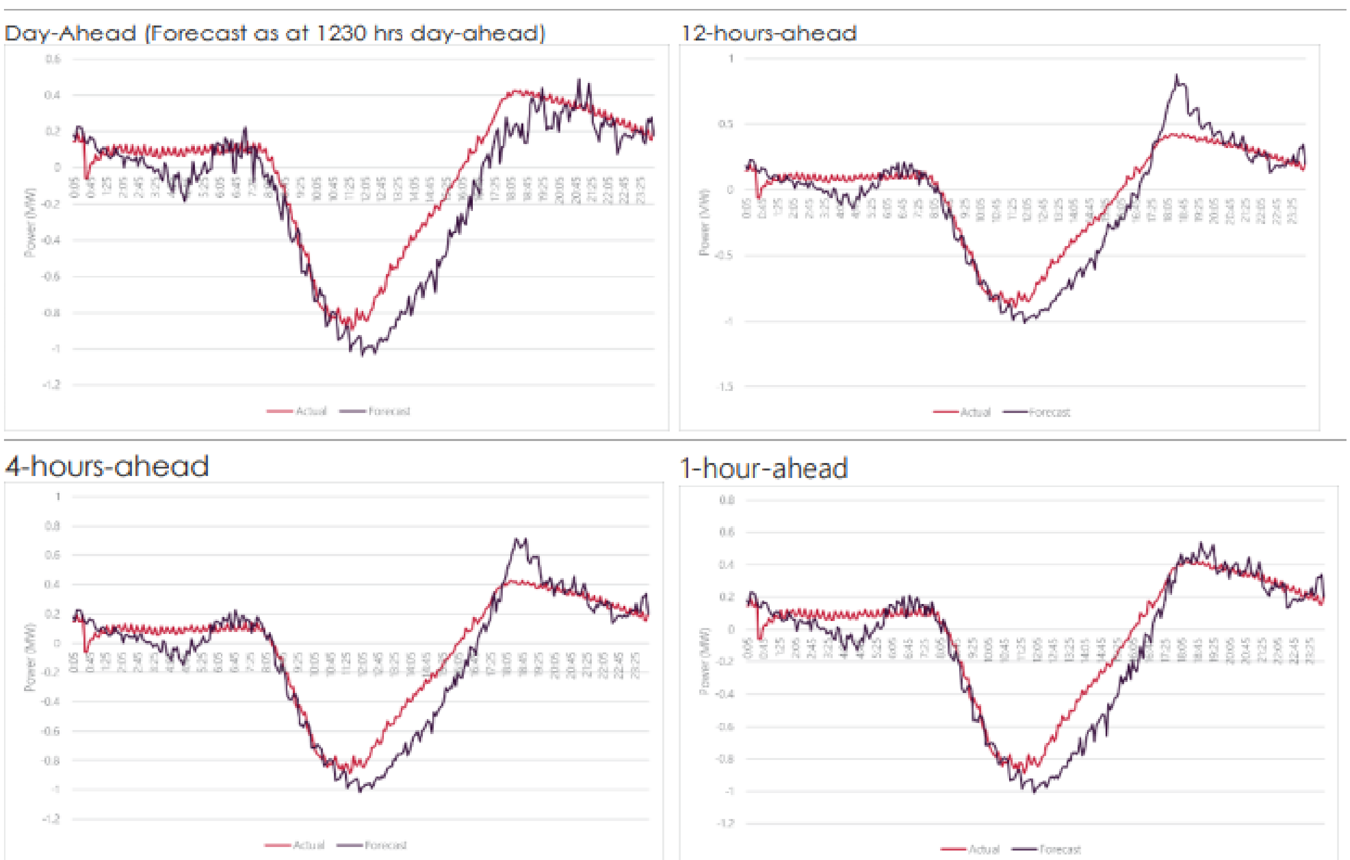

Figure 5: VPP Demonstrations Knowledge Sharing Report 2 - forecasting

As demonstrated in **Figure 5**, the AEMO VPP Demonstrations trial set up a mode of forecasting that was successful to an extent. Given the Scheduled Lite rule change will also, likely include some form of scheduling, Tesla is supportive of continuing to work with AEMO on this approach to determine the best future approach for forecasting.

The key take-away from both points is that AEMO and industry have already collectively begun working on market approaches for VPP/ DER visibility and forecasting. These insights should not be ignored and should form part of the long-term VPP workplan that AEMO needs to lead.

3 AEMO obligations under the National Electricity Objective

As AEMO points out in the MASS Draft Determination the National Electricity Objective (NEO) exists 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"*

AEMO specifically must carry out its functions, including updates to the MASS with regards to the NEO.

Tesla does not believe that the outcomes put forward by AEMO in the MASS Draft Determination are aligned with either the NEO, nor AEMO's obligations under the NEO.

Where AEMO has an opportunity to reduce costs to entry to increase competition – both in respect of total FCAS market competition and regarding retail competition, with VPP offers increasingly driven by FCAS market access.

Tesla believes that maintaining the 50ms measurement resolution in favour of further consideration of 100ms and 200ms options, or an update to the MASS verification tool is not well aligned to the National Electricity Objective. The core focus of the NEO is to promote efficient investment in, and efficient operation and use of electricity services. In the Draft Determination, AEMO has considered (for the first time) the options of 100ms and 200ms data resolution. These options have been independently verified by a third-party University of Melbourne.

Tesla recognises that more work needs to be done in considering these alternative measurement resolutions, however we feel that this is valuable in supporting the most efficient approach for market integration of DER. We also believe that this work should be undertaken through this current MASS review.

Tesla is concerned that ruling out potential options that would increase competition – both in FCAS markets and in customer retail offerings – when these options have been independently verified by the University of Melbourne as creating error band that is well within the 2% allowable error included the MASS, is not well aligned with the NEO. Our recommended changes are below, and we would ask AEMO to conduct further investigation on the options presented during consultation on the Draft Determination, ahead of releasing the Final Determination.

4 International market settings

4.1 International frequency market settings

An important consideration for AEMO in determining the final MASS requirements for DER is looking at the measurement resolutions required for existing, comparable frequency or ancillary services markets in international jurisdictions.

The 50ms measurement resolution for fast FCAS services has existed as a requirement since the MASS was first introduced and has not subsequently been revisited. Industry has accepted this requirement without considering whether 50ms provides more valuable information than 100ms or 200ms, whether there are lower cost options available and without looking to guidance from international markets. Given that the fast FCAS measurement resolution is now the topic of the current AEMO MASS Review, this position needs to change.

Better alignment with international requirements is particularly critical when AEMO is considering the future of aggregated fleets of assets providing frequency services as it influences asset level design and build-out.

- **Primary Frequency Regulation** (maintain frequency stability for continuous changes). Assets operate within a standard frequency droop curve (+-200 mHz). **Full activation time 10 - 30 seconds**.
  - **UK:** Firm Frequency Response (FFR). Sampling rate: 1 second
  - **Ireland:** Primary Operating Reserve (POR). Sampling rate: 1 second
  - **Nordics:** Frequency Containment Reserve (FCR). Sampling rate: 1 second
  - **EU:** Frequency Containment Reserve (FCR). Sampling rate: 1 second
  - **Taiwan:** 100ms power and frequency measurement, with performance assessed using 1 second data.
  - **ERCOT:** responsive reserve service – sampling rate 2 seconds
  - **CAISO:** distributed energy resource provider, ancillary services requirements – sampling rate 4 seconds.

Considering international markets is important for two reasons. 1. It provides a secondary reference point as to whether the measurement resolution that has always been included in the MASS remains fit for purpose in the changing Australian energy mix. European markets in particular have been progressing rapidly over the last five years, so the market settings and measurement resolutions have been introduced more recently. 2. If there is no drive internationally for 50ms measurement resolution then updates to hardware to comply with Australian specific requirements is a more challenging ask for international OEMs.

4.2 Summary recommendations – international experience

There is no international market evidence to support the roll-out of 50ms data resolution for fast FCAS markets. As such, for OEMs that operate on an international basis, it is difficult to justify product development to accommodate a 50ms measurement resolution for a single jurisdiction.

5 AEMO VPP Demonstrations Program

5.1 Overview

As noted in our opening comments, Tesla is particularly concerned with the fact that the MASS Draft Determination appears to ignore all work done, and insights gained, from the two-year VPP Demonstrations Trial.

The VPP Demonstrations trial was first launched by AEMO in December 2018 with an initial consultation paper suggesting the trial to test the technical capability of aggregated DER to provide FCAS.

After consultation, and with support from the majority of respondents, the trial was officially launched in July 2019 with the following goals[4]:

- Understand whether VPPs can reliably control and coordinate a portfolio of resources to stack value streams relating to FCAS, energy and possibly network support services.
- Develop systems that provide AEMO with operational visibility of VPPs to understand their impact on power system security, local power quality and how they interact with the market.
- Assess current regulatory arrangements affecting participation.
- Provide insights on how to improve consumers experience of VPPs in future.
- Understand what cyber security measures VPPs currently implement and whether VPP cyber security capabilities should be augmented in future.

The VPP Demonstrations Program now has 2 years of in-market demonstration of the technical capability of VPPs to participate in all FCAS markets. Importantly, all VPP Demonstrations Program participants joined the trial in good faith, and with the assumption that if the stated goals of the program were met then the trial settings would flow through to business as usual settings to improve market access for VPPs.

On 19 January 2021 AEMO released an initial consultation paper which put two options to industry – Option 1 (make no changes to the MASS); and Option 2 (update the MASS to include those provisions included in the VPP Demonstrations program).

Of the 31 submissions received relevant to DER, 18 of those explicitly supported Option 2. Nine submissions supported a hybrid approach or further consideration – but these overwhelmingly supported AEMO making updates to better include DER in the market. Four submissions supported Option 1.

Tesla does not believe that the lack of changes presented in the MASS Draft Determination are an adequate representation of the work done in the VPP Demonstrations Trial and does not capture the success of that program and the key lessons learnt. We also believe that over the course of the two-year trial there was sufficient time to stress-test some of the new information that has been put to industry in the Draft Determination.

The MASS Draft Determination appears to provide a lot more weight to the analytical responses provided to the first MASS consultation, from those not participating in the trial, than to the 2 years' worth of demonstrated, technical experience and findings that came from the trial, and resulted in three (soon to be four) detailed knowledge sharing reports.

[4] https://aemo.com.au/-/media/files/electricity/der/2021/nem-vpp-demonstrations_final-design.pdf?la=en

Industry and AEMO collectively invested millions of dollars, and years of effort, in order to “learn by doing” and create optimal market settings for DER and at the end of the process, we have not progressed settings for DER or implemented any findings. This could result in industry being less inclined to invest time and resources into future trials that AEMO run, for fear that this investment won’t result in moving the industry forward.

While we understand the concerns raised by AEMO in the MASS Draft Determination – and address these in more detail in sections 6 and 7 of this response, we also believe that the lessons learned and outcomes of the VPP Demonstrations Trial are sufficient to support more changes being made to the VPP market arrangements, than have been considered in the MASS Draft Determination. Tesla’s assessment of the success of the AEMO VPP Demonstrations trial in achieving their stated goals of the program is outlined below.

5.2 Technical performance

As noted above, the primary goal of the VPP Demonstrations trial was to assess technical capability of controllable DER to participate in all FCAS markets, and thus better stack market revenues.

Under the VPP Demonstrations Trial AEMO established a new approach to registering VPP systems for the purposes of providing FCAS. Specifically, AEMO introduced a two-step approach:

1. Asset level frequency injection test which effectively required a lab test of FCAS-enabled VPP systems to verify individual asset level performance; and
2. VPP fleet-wide test which was required to confirm the ancillary service capacity of the fleet as a whole.

This approach provides two points of verification for AEMO. The first ensures that all types of individual plant registered within a fleet are technically capable of providing all FCAS market services that the plant is registered for. **Figure 6** below shows the “raise” frequency injection test provided to AEMO for a 5kW Powerwall for instance.

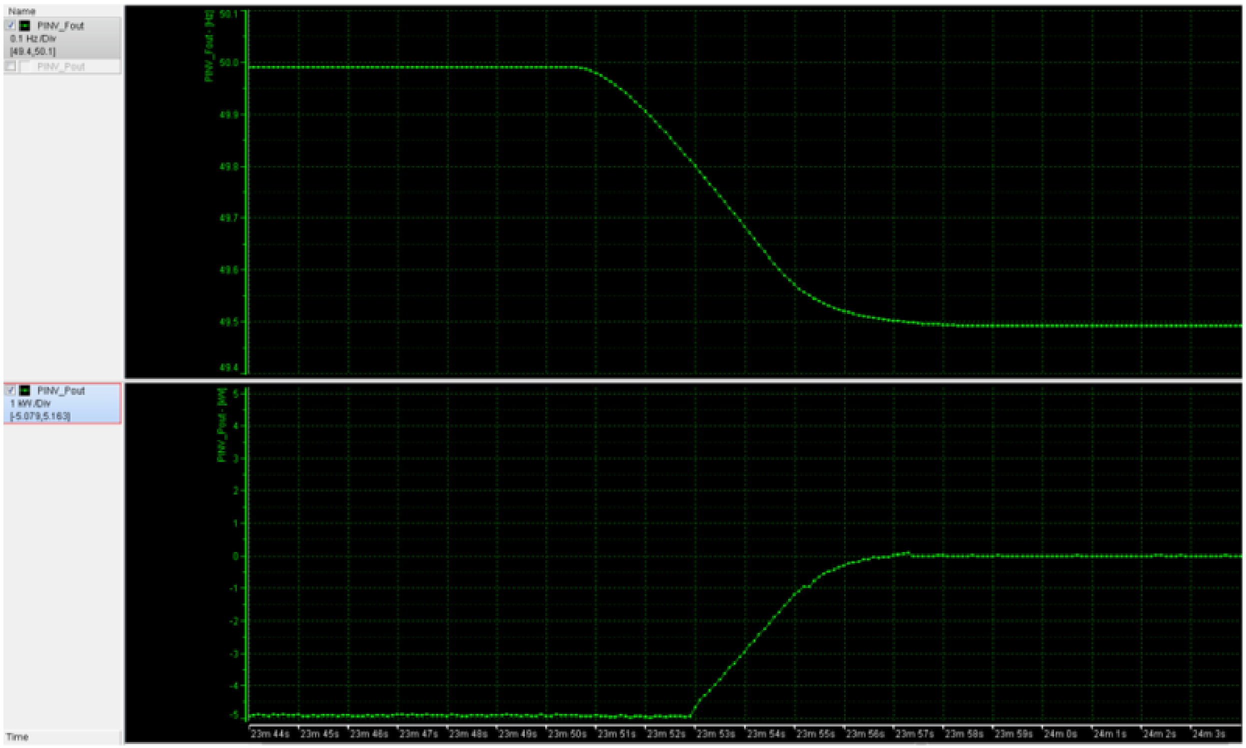

Figure 6 - Tesla Powerwall 2 Frequency Injection Test Results: 5kW Raise Response

The fleet-wide test ensures that fleet is technically capable of delivering the registered capacity. Importantly for the second point, this is a field test. AEMO needs to have confidence that a fleet is capable of delivering 1MW before approving that 1MW registration. This two-step process ensures that the FCAS service delivered meets the registered capacity and provides AEMO with confidence that individual assets can meet the AEMO minimum performance requirements.

AEMO positioning on technical performance

AEMO's confidence in VPPs demonstrating a technical capability to provide all FCAS services, including fast FCAS appears to have been verified through the three knowledge sharing reports released by AEMO over the course of the Demonstrations Trial, which made comments such as:

- In response to the 9 October 2019, Kogan Creek trip "*The SA VPP detected this frequency excursion and responded immediately to inject power into the system and aid frequency recovery*"[5]
- In response to 10 December 2019 under frequency event, "*The SA VPP responded immediately in both cases to first charge the batteries to lower system frequency, and then discharge the batteries to raise system frequency*"[6]

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[5] https://aemo.com.au/-/media/files/electricity/der/2020/aemo-knowledge-sharing-stage-1-report.pdf?la=en

[6] Ibid

- In response to the January 2020 South Australian separation event, "*To help suppress the high frequency, the VPP very quickly increased its power drawn to beyond the enabled minimum response. Of note is the speed of the response: from zero to approximately 1.9 MW output in under 10 seconds, with a peak rate of change in this period of over 1.1 MW/s.*"[7]
- In response to s trip of Callide C3 and C4, *"The minimum mainland frequency observed was 49.786 Hz, and the data provided in Figure 3 shows that the VPP met its FCAS requirement for a 1 MW enablement."*[8]

There were no significant concerns raised by AEMO as to the ability of VPPs to technically deliver FCAS services in any of the contingency markets – including the fast FCAS markets. As such, it appears as though a core goal and stated outcome of the trial has been met by AEMO. In the most recent VPP Demonstrations Knowledge Sharing Report, AEMO released the following traffic light indicators in respect of how well VPP technical performance. Most noticeable is AEMO's "green" ranking of the technical capability of VPPs to "reliably deliver" all contingency services that they bid and are enabled for – including fast FCAS services.

Figure 7: AEMO assessment of VPP technical performance - VPP Knowledge Sharing Report #3[9]

Verification of performance

Over the duration of the VPP Demonstrations trial, the verification of performance under the trial conditions was considered. The second Knowledge Sharing report speaks specifically to the approach taken to verifying technical performance, without raising concerns as to the 1 second measurement resolution that was in place for the duration of the trial, including providing a specific example of the verification of a particular event. In the Knowledge Sharing Report, AEMO notes that the Energy Locals / Tesla VPP over-delivers on the committed response. – see **Figure 8** below.

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[7] https://aemo.com.au/-/media/files/electricity/der/2020/vpp-knowledge-sharing-stage-2.pdf

[8] https://aemo.com.au/-/media/files/initiatives/der/2021/vpp-demonstrations-knowledge-sharing-report-3.pdf?la=en

[9] Ibid

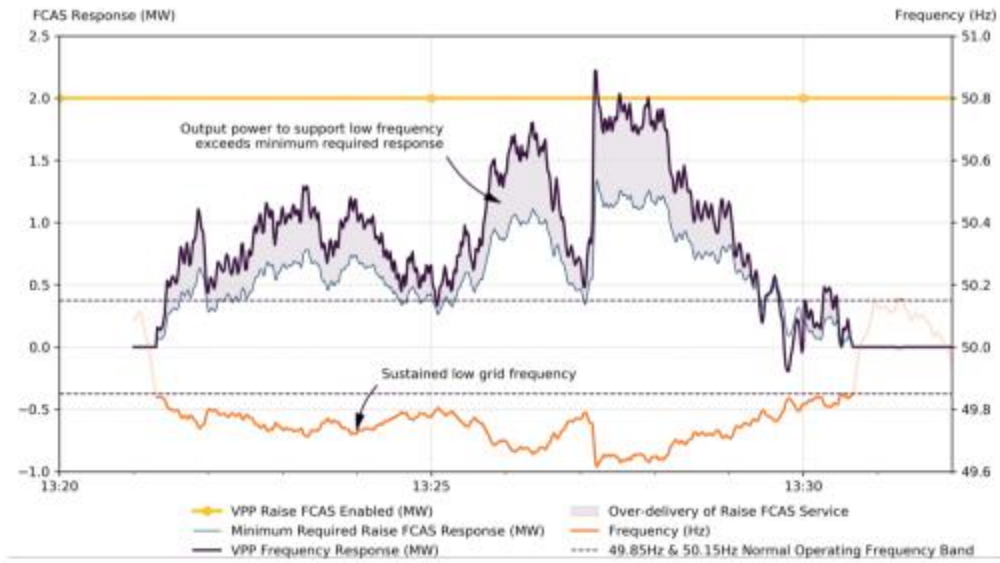

Figure 8: AEMO VPP Demonstrations - Knowledge Sharing #2

Concerns raised in MASS Draft Determination

Between the first consultation on the MASS review and the release of the MASS Draft Determination, AEMO has considered some concerns that were not addressed during VPP Demonstrations Trial in respect of the verification approach undertaken. Specifically, AEMO are concerned that the 1 second measurement resolution that was deployed during the trial is not sufficient to properly verify performance, and this creates a risk of overpayment for FCAS services delivered.

This appears to conflate the issue of technical performance with the approach taken to verifying technical performance. As far as Tesla is aware, the approach implemented by AEMO during the VPP Demonstrations trial to establish both system and fleet wide technical performance has been sufficient in establishing confidence in the technical performance of VPPs to provide fast FCAS services.

In section 5 below, Tesla provides additional context on this point, Based on this analysis, plus the two-step technical verification approach that was implemented by AEMO during the VPP Demonstrations Trial, as well as the overwhelmingly positive content provided by AEMO in the knowledge sharing reports in respect of the technical capabilities of VPPs to deliver fast FCAS services, we believe that AEMO has been more than satisfied of the technical capability of VPPs to deliver fast FCAS.

5.3 Assess current regulatory barriers affecting participation

As of June 2021, the trial has gained the following level of participation:

- 7 registered participants.
- 30MW of FCAS registered.

- 5 different DER technology types.
- A mix of switched and proportional controls; and
- Operation in all NEM states with the exception of Tasmania.

Importantly it has resulted in competitive new market retail offers being made available to 5,000 – 7,000 customers. Since launching the program AEMO has run two years' worth of dedicated consultation with more than 30 different stakeholders representing all parts of the DER industry – this consultation should have resulted in a detailed understanding of the barriers to entry and how the AEMO VPP Demonstrations trial has helped resolve these.

Importantly the VPP Demonstrations Trial also considered alternative measurement and metering requirements designed to increase market participation. Tesla's consideration of how the VPP Demonstrations Trial met the stated goals of the program is articulated below.

We note that as a direct result of the VPP Demonstrations trial, AEMO has seen 30MW of additional FCAS capacity registered, and seven additional market participants. This compares to only a single DER aggregator registered under the existing rules, providing strong evidence that the VPP Demonstrations trial did in fact demonstrate that there are barriers to entry that exist within the existing MASS settings, and that the trial settings implemented removed these barriers to entry and increased competition.

5.4 Improve operational visibility

In addition to not updating the measurement resolution and the measurement location (the two key areas that the trial was focused on), industry is also left with no further clarity on how AEMO intends to use other insights gained during the trial, including the following:

- Approach to provision of data in real time (both for individual sites and for the fleet as a whole)
- Fleet forecasting requirements
- Registration approach.

Access to live data at both an individual asset level, and from a fleet perspective, gave AEMO distribution level data access beyond what currently exists under any standard frameworks. This information is important both from a market planning perspective and to detect faults (see section above where we discuss the benefits associated with increased visibility in more detail).

Disappointingly AEMO has made the decision to decommission the API that was set up for the purposes of the AEMO VPP Demonstrations trial. These insights will not, however, be wasted as the approach that AEMO has taken to improving operational visibility will feed directly into the development of the Schedule Lite rule change – particularly the "visibility model" proposed in the ESB P2025 Options Paper – Part B[10]. As such we consider that this stated program goal can also be considered to be relatively successful. AEMO also rated the ability of VPPs to provide accurate forecasting information as green in their third knowledge sharing report.

[10] https://esb-post2025-market-design.aemc.gov.au/32572/1619564172-part-b-p2025-march-paper-appendices-esb-final-for-publication-30-april-2021.pdf

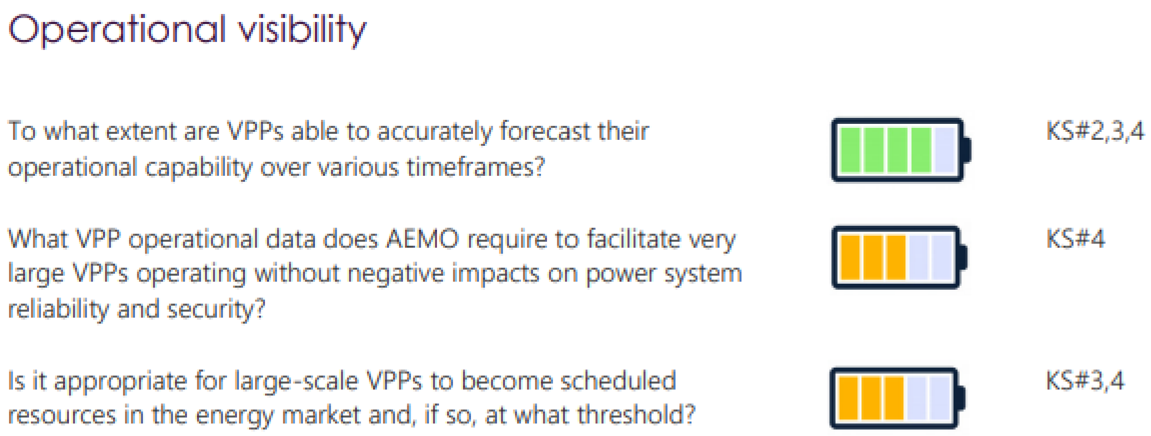

Figure 9*:* **AEMO assessment of VPP operational visibility - VPP Knowledge Sharing Report #3**[11]

As with AEMO's assessment of technical performance, the third VPP Knowledge sharing report also highly rates the work done in VPPs providing operational visibility. This raises more questions as to why the API has been decommissioned at the end of the VPP Demonstrations trial. Tesla recognises that there is ongoing work required to address the broader power system security concerns associated with VPPs participating in the market, and we have addressed these points separately in section 7 of this response.

5.5 Provide insights into consumer experiences

In addition to demonstrating the technical performance of VPPs to participate in all FCAS markets, AEMO also undertook detailed surveys with customers who were a part of a VPP and published a separate report on consumer insights with their third knowledge sharing report. The third knowledge sharing report provided an amber rating to the work done to date in respect of consumer insights. This is understandable as the work will necessarily need to extend far beyond the remit of AEMO's work plan and will require 5 – 10 years of constant work and industry development to deliver optimal settings for customers.

[11] https://aemo.com.au/-/media/files/initiatives/der/2021/vpp-demonstrations-knowledge-sharing-report-3.pdf?la=en

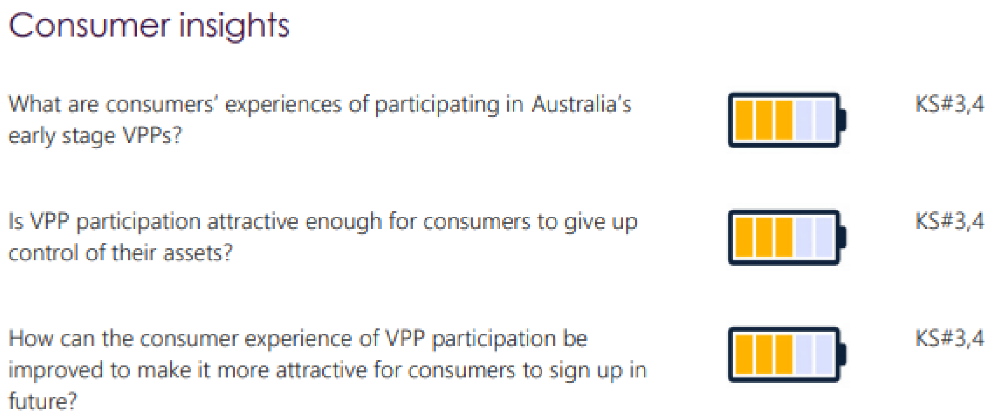

Figure 10: AEMO assessment of VPP operational visibility - VPP Knowledge Sharing Report #3[12]

5.6 Cyber security

The final stated goal was to provide more insights into cyber security risks associated with market participation from DER. To enable this, AEMO established a questionnaire for all VPP market participants to complete which outlined cyber security protection procedures that VPP participants needed to comply with. This cyber security questionnaire has since been adopted by the Victorian Government through their recent "Aggregated battery EOI" process.

This was one of the few areas that AEMO still rates as a "red" traffic light. Tesla is supportive of more work being done in this space (either directly by AEMO, or as planned through the Maturity Plan process), but it appears to be a topic that applies to DER more broadly, than just to VPPs. As such further development of cyber security protocols has not been considered in the MASS Draft Determination at all, and should not be a barrier to the finalization of the MASS.

5.7 Summary

The take-away of all the above is that all the stated goals of the VPP Demonstrations program have been met, yet no findings or work done have been included in the publication of the MASS Draft Determination. Noting the general success of the VPP Demonstrations trial, and the significant number of additional customers that have benefited from innovative VPP offerings over the last two years, Tesla believes it is in the best interests of both consumers and the DER industry to ensure that the learnings of the trial are implemented.

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[12] https://aemo.com.au/-/media/files/initiatives/der/2021/vpp-demonstrations-knowledge-sharing-report-3.pdf?la=en

In Attachment A, Tesla provides an overview as to how we think our recommendations on both the points raised in respect of the MASS Draft Determination, as well as the lessons from the VPP Demonstrations trial, should flow through to the VPP FCAS settings that AEMO adopts in the long-term.

6 MASS Draft Determination Response - DER

6.1 Summary

The Draft Determination focuses on AEMO's position in respect of two key areas that were the focus of the AEMO VPP Demonstrations Trial, and ultimately not accepted by AEMO:

- Measurement resolution
- Measurement location

In Tesla's response below, we consider both the learnings gained from the VPP Demonstrations trial, as well as our analysis of the new information put forward in the MASS Draft Determination. This section should be read as our recommendations on the appropriate pathways forward that AEMO should consider in the Final MASS Determination.

In providing our response, Tesla has considered the business impact of complying with the requirements put forward in MASS Draft Determination. While we note that these requirements are consistent with the MASS as it currently stands, Tesla has invested resourcing and development efforts over the last two years into the VPP Demonstrations Trial based on the fact that the trial settings were designed to create a more fit for purpose environment for DER/ VPPs to participate. No development work has been done on complying with the 50ms measurement resolution and given that there are no international drivers for 50ms compliance, this is not development work that Tesla will undertake.

Table 1 below summarises our concerns and the Tesla business impacts associated with complying with the MASS Draft Determination requirements, as well as our suggested alternative. This is followed with an in-depth analysis as to why we think the proposed alternative should be considered as suitable by AEMO.

Table 1: Impacts of compliance with MASS Draft Determination

MASS Requirement category	MASS sub-category	Tesla concerns	Impact on Tesla	Proposed alternative
Measurement resolution	50ms requirement during contingency events	Tesla Powerwall cannot currently comply with 50ms data resolution, and there are no internal drivers for hardware/ firmware updates to achieve this compliance – given the lack of international drivers and the existence of reasonable alternatives. As such, to participate in fast FCAS markets, Tesla would need to install an off-the-shelf metering solution for each participating VPP site. There are two options for this: • **Option 1:** working with a low-cost commercial option, which would see a different aggregator take on Tesla Powerwall systems • **Option 2:** install a genuine plug and play off the shelf high speed meter to capture 50ms resolution.	**Economics of compliance:** Option 1 - is based on the low-cost commercial options (<$200) that AEMO outlined in the Draft Determination. Tesla is yet to confirm a technology solution that exists in the <$200 range and is freely available for use by all VPP aggregators and retailers. Option 2 – Tesla has considered both the mid and high range of technology costs presented in the AEMO Draft Determination to consider the economic impost of compliance using off-the-shelf metering. A mid-range cost of $1000 per site (no ongoing fees) has been considered, as well as a high cost of $10,000 (no ongoing fees). These costs are then applied to Tesla's stated goal of achieving a 50,000 home VPP, with cost impacts as follows: • Medium - $50m (payback per site ~6 years[13]) • High - $500m (payback per site - ~60 years)	Reduce granularity to 100ms data resolution on a conditional logging basis. This aligns with AS4777.2:2020 and is technically sufficient for the purpose of verification (see Application Note). AEMO also needs to do further work considering whether less granular resolutions are appropriate on a fleet basis – such as 1 second. Consideration needs to be given to whether the error rate is reduced with increased fleet sizes.

[13] Based on Tesla's experience and third-party revenue curves on achievable fast FCAS revenues per site. Assuming no ongoing fees and assuming no degradation of FCAS market value over the 6 years (note that this latter point assumes high end revenues as all third-party cost curves show a steep decline in expected FCAS revenues after years 2 – 3).

MASS Requirement category	MASS sub-category	Tesla concerns	Impact on Tesla	Proposed alternative
			Technical outcome: High speed, high quality FCAS services like those provided by open loop controls from devices such as Powerwalls do not require a meter to provide FCAS. Instead, the FCAS response is implemented directly at the inverter, which constantly monitors the voltage waveform and initiates a near instantaneous real power response. Meters are only used for verification purposes, which means that higher speed measurements won't translate into higher speed response or improve the quality of the FCAS service provided. As such, the cost and time associated with installing meters capable of 50ms measurements at every site does not benefit the grid at all. **Business outcomes:** Considering the overall cost vs benefit of installing a high-speed meter, and an assumed minimum payback of ~6 years, and the fact that customer retail contracts are in place for 12 months, the outcome of the additional cost impost is that Tesla would not register for fast FCAS markets. We would still provide AEMO with a high quality, FCAS response service from open loop controls (as identified through all of the VPP Knowledge Sharing reports) however we would comply with the minimum requirements of the slow and delayed services: start of response 6sec after frequency deviation, and 4sec measurements provided for FCAS verification.	

MASS Requirement category	MASS sub-category	Tesla concerns	Impact on Tesla	Proposed alternative
			The loss of around 50% FCAS revenue per site, due to lack of access to fast FCAS markets will also have some or all the following impacts on broader VPP market goals: • Considering which jurisdictions are technically viable to introduce a competitive VPP offer. • Increasing or reconsidering the customer retail rate that may be offered. • Reconsidering the overall customer incentives that can be offered. This in turn will reduce the customer uptake of VPP offers, and the stymy the transition from passive to active DER. Tesla is happy to work with AEMO to further expand on these scenarios.	
	High speed data logging	AEMO notes a single measurement resolution that needs to be recorded for 5 seconds before an event and 60 seconds after an event. In practice this would always mean maintaining a high-speed data log at each VPP site to ensure that the 5 seconds before an event is logged. This is because contingency events are unpredictable, which means that it is the 5sec period preceding an event cannot be known until the event happens.	Even with 100ms measurements speed, it will always be extremely difficult for VPP operators to maintain this data resolution. 100ms data resolution for the existing SA VPP fleet of 3500 sites would equate to > 1 trillion data points per signal per year, that is >3 trillion for frequency, asset power and site power. The amount of telemetry data required to be logged and stored is simply not scalable and would come at a significant engineering and data storage cost. The alternative approach of logging at 100ms during a contingency event and for 60 seconds after, and maintaining a 1 second at all other times would significantly reduce this data and engineering obligation. To meet the 5 seconds before Tesla suggests	Require 100ms resolution during frequency deviations and for the 60 seconds after, and 1 second data for all other times. Allow for interpolation of 1sec data for the 5 seconds before a contingency event. AEMO may also require that the FCAS providers use conditional logging

MASS Requirement category	MASS sub-category	Tesla concerns	Impact on Tesla	Proposed alternative
			using 1 second measurement resolution and interpolating between these measurements for the sake of providing 100ms data. We understand that AEMO requires this data to calculate a power baseline which is used to determine the amount of FCAS provided during the frequency deviation. This baseline is an average over this 5sec period, and as such 100ms resolution is not justified and 1sec is sufficient, especially when considering a fleet-wide response of no fewer than 200 assets.	with settings that are narrower than the NOFB, allowing to increase measurement speed to 100ms measurements when frequency is outside a +/- 140mHz or a +/- 130mHz dead band for instance. In addition, one high speed meter (50ms) per region and per technology should be required – see attachment A for more details.
Measurement location	Measurement at the connection point	Tesla measures VPP sites at both the connection point and at the individual device level (measuring grid flow, solar and battery performance at each site that a Powerwall is installed). Our preference is to verify performance at the device level as it provides a more accurate assessment of the performance of the device in providing FCAS.	In the event that measurement is maintained at the site connection point, rather than the device level, then Tesla will have to take a more conservative approach to bidding to account for the variability in *uncontrollable* load and generation on a site by site basis. This would require more contingency capacity available for each 1MW of FCAS registered. Tesla estimates that this would result in a 10% haircut on all bids placed (or conversely 10% more sites required to maintain the same bid). Besides the fact that this is an unfair treatment of asset-level procurement of FCAS due to the nature of DER	Allow for optionality in measuring at the site/ device level and/or allow for device level data to be used in the event that AEMO considers a VPP to have under-delivered during an event (driven by the impact of external load/ generation on site)

MASS Requirement category	MASS sub-category	Tesla concerns	Impact on Tesla	Proposed alternative
			(uncontrollable load and solar generation will vary independently of the FCAS-enabled asset behaviour, and this asset should not be penalized for this variation, nor should site-level VPP operators be allowed to claim procurement of FCAS from uncontrolled variations in load and solar generation), only a 100% bidding haircut can protect asset-level procurement of FCAS from apparent under-delivery if the response is assessed at the site level. Fig 20 illustrates a real-world impact of solar inverters tripping during a contingency event due to no fault of the Powerwalls behaviour, and for reasons outside of Tesla's control and scope.	
Firmware	N/A	AEMO expressed concerns with firmware updates well as occasional modification of inverter settings which may impact ability of devices to deliver FCAS,	N/A	FCAS providers should provide firmware version along with NMI and Device list and notify AEMO of firmware version updates within [10] business days, highlighting the potential impact on ability to deliver FCAS. In addition, FCAS providers shall be required to check their fleet's inverter settings on a [weekly] basis. If AEMO considers a VPP to have

MASS Requirement category	MASS sub-category	Tesla concerns	Impact on Tesla	Proposed alternative
				under-delivered during FCAS verification process, AEMO may request the FCAS provider to provide a report of the fleet's relevant inverter settings since the last successful FCAS delivery. Failure to provide such a report will be considered as a breach of the MASS.

6.2 Measurement resolution

Statement of concerns

Tesla understands that AEMO is concerned about the error introduced when 50ms and 1s samples are compared using the right Reimann sum method which is the approach currently used in the FCAS verification tool. Tesla specifically understands that AEMO has two key concerns in this respect:

1. The current error rates with 1 second measurement resolution can lead to AEMO overpaying for FCAS services delivered; and
2. 1 second measurement resolution does not adequately capture potential oscillation risks that exist.

The primary issue that should be considered as relevant for the purpose of the MASS Draft Determination is whether 50ms resolution is necessary for appropriate verification of fast FCAS services, or whether a less granular resolution is acceptable by AEMO. For the purposes of the VPP Demonstrations Trial, 1 second resolution was used with a single high-speed meter per jurisdiction. The MASS Draft Determination has since considered the 1 second resolution to create additional errors in respect of verification of performance.

The risk of inverter oscillations should be considered as a broader issue for AEMO, as it will also impact on the delivery of slow and delayed services. While verification should be the only topic considered within the scope of the MASS review, AEMO has also flagged broader DER power system security concerns as a driver for maintaining the 50ms measurement resolution. These issues exist for all DER and should not be resolved as part of the MASS review process. For completeness, however, Tesla has addressed these concerns as well as the specific performance verification concerns covered. The below section covers:

- Tesla's position on performance verification concerns raised by AEMO and justification for our recommendations.
- Analysis of technical concerns raised by AEMO – specifically oscillation risks used to justify 50ms measurement resolution.

Fast FCAS performance verification

Tesla summary position

The primary concern raised by AEMO in the MASS Draft Determination is that the 1 second measurement resolution does not provide suitable granularity for verification of performance and can lead to overpayment for fast FCAS services delivered.

As highlighted in section 4 above, it is important that AEMO understands that these concerns on measurement resolution only relate to the **verification** of performance and not the technical delivery of performance. We understand that AEMO needs a means of checking compliance data that is provided and verifying the delivery of performance. But the two-step approach introduced during the VPP demonstrations trial of frequency injection test plus fleet wide test should provide AEMO with full confidence of the technical capability of FCAS registered DER to provide the services they are registered to provide.

Tesla believes that based on what AEMO has presented, the concerns can be managed with the following approach:

1. For the provision of fast FCAS, AEMO should require **conditional logging of data at 100ms [or 200ms]** resolution during an FCAS event. These aggregated VPP sites should be measured at **1 second resolution** for the rest of the year – with data provided to AEMO via the existing VPP API, or equivalent.
2. In parallel, update the FCAS verification tool to use the **trapezoid rule** instead of the right Riemann sum.
3. Finally, Tesla believes that the overall energy band risk associated a fleet of hundreds of smaller assets providing FCAS is much lower than a single asset due to the larger overall number of samples. Tesla has undertaken a detailed statistical analysis to support this position.

This solution brings the error risk to effectively zero, and thus minimizes AEMO's concerns about overpayment. Importantly, as noted by AEMO in the Draft Determination, 100ms is a technical solution that can more readily be provided by more DER, which increases competition in both the FCAS and customer retail markets and aligns with AEMO's obligations under the NEO (explored in more detail in section 3).

Justification for proposed verification approach

Tesla's justification for the recommendations put forward are based on several factors:

- Tesla's own analysis of the different measurement resolutions, as well as detailed statistical analysis on fleet error rates.
- The independent University of Melbourne analysis undertaken; and
- Alignment with AS4777.2:2020

More detail on the justification for each of the recommendations made by Tesla as we discuss each of the recommendations made above in more detail.

1. Allow 100ms resolution for fast FCAS verification on a conditional logging basis

To support this position, Tesla has undertaken a detailed statistical analysis of the application of different measurement resolutions across a fleet of Powerwall assets. This analysis was undertaken based on 20ms data provided by AEMO and looking at the verification of performance at different measurement resolutions. Tesla has also undertaken Monte Carlo simulations across these measurement resolutions to further assess the error bands. This analysis modelled fleet response to the Callide C frequency event on May 25 across both NSW and Queensland – noting that the duration of the frequency deviations in these jurisdictions differed significantly.

This analysis is attached in full for AEMO in Attachment A. Tesla has also provided the full excel based model with all assumptions to AEMO for further consideration.

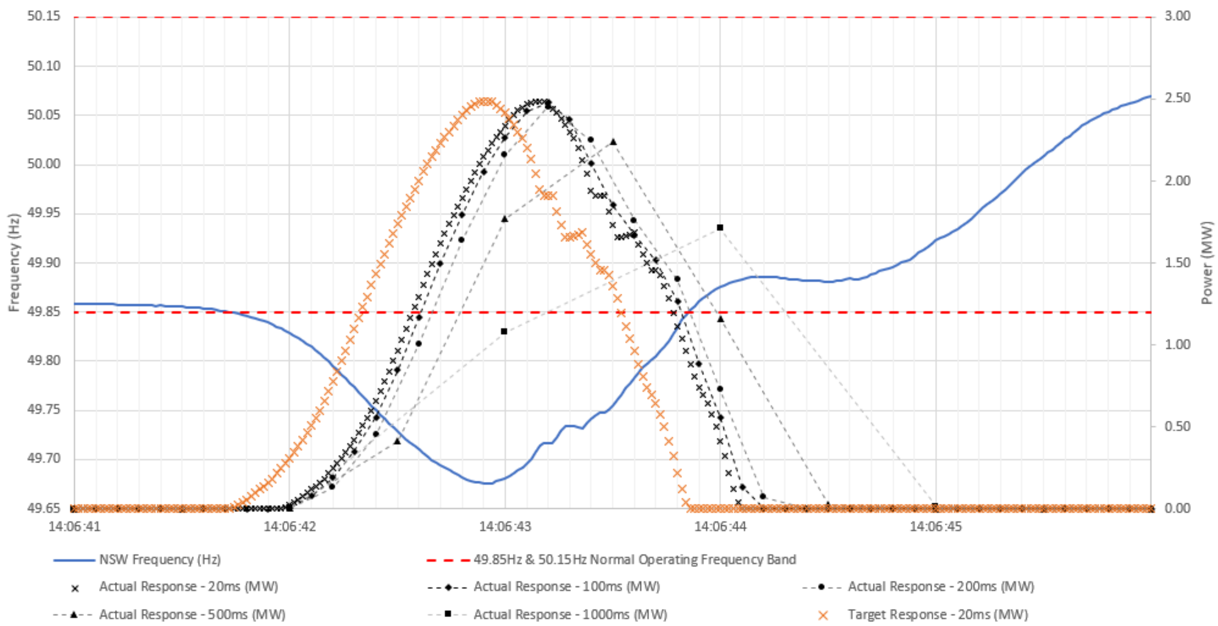

Figure 11: Measurement resolution at different levels – NSW frequency during Callide C event

As shown in **Figure *11*** above, the verification of response when undertaken at all measurement resolutions will be slightly behind the target response due to a ~250ms response observed during frequency injection test. Tesla demonstrates that there is no noticeable difference when the 100ms resolution or 200ms resolution is compared with a 20ms measurement resolution.

These findings are further backed up by the detailed Monte Carlo simulations undertaken by Tesla to support this position. This simulation considers whether the verification error rates decrease as the fleet numbers increase. **Figure *12*** below provides an overview of the findings of this analysis in respect of total energy provided in response to an FCAS event. This analysis has been undertaken using the right Riemann verification approach (with further discussion on this in the following section).

In considering the outcomes of the Monte Carlo analysis, Tesla has made the following assumptions:

- Tesla considers the minimum fleet size that should be considered by AEMO as relevant to this statistical analysis as 200. This will be the minimum number of systems needed to support a 1MW bid on an aggregated basis given the 5kW nameplate capacity of a Powerwall.
- Secondly, Tesla has considered a <2% error to be appropriate – in line with the current MASS requirements which allow “an error of less than or equal to 2% of the measurement range” (refer 3.6)(a)(v) of the MASS for allowable error rates for fast FCAS delivery). While this is currently applied on an individual asset basis, it makes sense for AEMO to apply the same error band to a VPP fleet operating as a single asset.

Based on the assumptions above, Tesla has drawn the following outcomes:

- When considering a fleet of 200 systems, the energy error bands assessed in both NSW and Queensland is <0.5% for all measurement resolutions 100ms – 1s.This is well under the 2% allowable error band.

- This error band continues to decrease as the total fleet size increases. For a fleet of 1000 systems the error band is <0.15% for all measurement resolutions in Queensland and NSW, for both the truncated and the rounded methods.

Energy Error (%)

		Queensland – Sampling rate (ms)						New South Wales – Sampling rate (ms)					
	Nb of sites	20	50	100	200	500	1000	20	50	100	200	500	1000
Truncated	1	1.01%	1.02%	1.01%	0.99%	1.03%	1.13%	1.04%	0.98%	0.98%	1.03%	2.11%	5.04%
	10	0.29%	0.31%	0.29%	0.29%	0.30%	0.35%	0.29%	0.29%	0.30%	0.29%	0.62%	1.43%
	25	0.18%	0.19%	0.20%	0.19%	0.19%	0.21%	0.18%	0.18%	0.18%	0.19%	0.39%	0.88%
	50	0.13%	0.14%	0.12%	0.13%	0.14%	0.15%	0.13%	0.13%	0.13%	0.14%	0.28%	0.66%
	200	0.07%	0.06%	0.07%	0.07%	0.07%	0.08%	0.06%	0.07%	0.07%	0.07%	0.14%	0.31%
	500	0.04%	0.04%	0.04%	0.04%	0.04%	0.05%	0.04%	0.05%	0.04%	0.04%	0.09%	0.20%
	1000	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.07%	0.14%
Rounded	1	0.99%	0.98%	1.00%	1.01%	0.97%	1.17%	1.01%	0.99%	0.98%	1.00%	2.14%	4.99%
	10	0.31%	0.29%	0.27%	0.29%	0.30%	0.34%	0.29%	0.30%	0.30%	0.30%	0.63%	1.39%
	25	0.19%	0.19%	0.18%	0.17%	0.20%	0.22%	0.19%	0.18%	0.18%	0.20%	0.42%	0.87%
	50	0.12%	0.13%	0.13%	0.13%	0.13%	0.14%	0.13%	0.13%	0.13%	0.13%	0.29%	0.61%
	200	0.07%	0.07%	0.06%	0.06%	0.07%	0.08%	0.07%	0.07%	0.07%	0.07%	0.14%	0.32%
	500	0.04%	0.04%	0.04%	0.04%	0.04%	0.05%	0.04%	0.05%	0.04%	0.04%	0.09%	0.19%
	1000	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.06%	0.14%

Figure 7 - Monte Carlo simulation results for absolute value of energy error (500 simulations)

Figure 12: Tesla analysis - energy error bands for different fleet sizes

Tesla believes that the error associated with total energy provided during an event is more important than the error associated with max power provided because the MASS v6 defines the amount of Fast Raise and Fast Lower services for dispatch purposes, in section 3.3 and 3.4 respectively, in terms of energy provided over the 60 seconds following the frequency disturbance time.

In addition, devices using open loop controls to provide FCAS services like Tesla's Powerwall don't use frequency or power measurements to provide that response. Instead, these measurements are used for verification purposes only, and the lower aggregate power measured is due to the measurement method as opposed to the actual FCAS response. However Tesla has also done additional Monte Carlo simulations looking at the error rates associated with different measurement resolutions in respect of power – see **Figure *13*** below.

Power Error (%)

		Queensland						New South Wales					
		Sampling rate (ms)						Sampling rate (ms)					
	Nb of sites	20	50	100	200	500	1000	20	50	100	200	500	1000
Truncated	1	1.00%	0.99%	1.00%	1.06%	1.04%	1.04%	0.96%	1.01%	0.99%	1.51%	5.89%	16.83%
	10	0.30%	0.30%	0.27%	0.30%	0.27%	0.30%	0.29%	0.30%	0.34%	1.23%	9.30%	30.22%
	25	0.18%	0.18%	0.19%	0.18%	0.18%	0.19%	0.18%	0.19%	0.24%	1.25%	9.21%	30.62%
	50	0.14%	0.13%	0.13%	0.13%	0.13%	0.13%	0.13%	0.13%	0.19%	1.26%	9.33%	30.64%
	200	0.07%	0.06%	0.06%	0.06%	0.06%	0.06%	0.07%	0.07%	0.16%	1.26%	9.35%	30.82%
	500	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%	0.16%	1.25%	9.35%	30.96%
	1000	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.16%	1.25%	9.37%	30.86%
		Sampling rate (ms)						Sampling rate (ms)					
	Nb of sites	20	50	100	200	500	1000	20	50	100	200	500	1000
Rounded	1	0.99%	0.98%	0.99%	1.01%	1.02%	0.99%	0.99%	1.00%	1.07%	1.42%	5.69%	16.44%
	10	0.30%	0.30%	0.28%	0.29%	0.30%	0.31%	0.29%	0.30%	0.70%	1.51%	8.89%	20.50%
	25	0.19%	0.20%	0.19%	0.17%	0.19%	0.18%	0.19%	0.19%	0.75%	1.50%	9.07%	20.10%
	50	0.13%	0.13%	0.13%	0.13%	0.13%	0.14%	0.14%	0.13%	0.78%	1.54%	8.96%	20.04%
	200	0.06%	0.07%	0.06%	0.06%	0.07%	0.07%	0.06%	0.07%	0.81%	1.55%	8.98%	20.12%
	500	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%	0.81%	1.54%	9.02%	20.03%
	1000	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.81%	1.54%	8.98%	20.03%

Figure 8 - Monte Carlo simulation results for absolute value of power error (500 simulations)

Figure 13: Tesla analysis - power error bands for different fleet numbers

Applying the same assumptions as those outlined above, the following additional conclusions can be drawn from the assessment of power error bands:

- For fleets of 200 systems or more, for both Queensland and NSW – a measurement resolution of 100ms or 200ms still falls well under the 2% allowable error band.
- The shorter duration of the NSW event leads to higher power error for NSW at a lower granularity – 500ms or 1s. However, the 100ms and 200ms error bands at the power level also fall well under the acceptable 2% error band. The increase in error from one site to multiple sites is addressed in the application note.

If AEMO was to look purely at the error bands associated with total energy delivered over a fleet of >200 assets it is clear that the overall error rate is well within the acceptable bands for fleets providing verification data to AEMO at all resolutions – including 1 second. Even if AEMO were to change the overall MASS methodology to also consider the power error bands, 100ms and 200ms fall well within the error bands acceptable and allowable by AEMO.

Conditional logging

Tesla also notes that logging of 100ms on a conditional basis only is critical to the scalability of VPPs. Under this approach, Tesla proposes to commence logging at 100ms as soon as frequency exits the normal operating frequency band (NOFB) and for 60sec thereafter. Data will be logged on a 1 second basis for all other times of the year.

This approach significantly reduces the data housing costs for an aggregated fleet. (for context a fleet of 3500 systems would log and store 1.1 trillion datapoints per year per signal if logging occurs at 100ms resolution on a permanent basis). Noting that most of this data does not provide value to AEMO for the purpose of verifying FCAS delivery, and that it does not improve performance at all, this approach will reduce the overall costs of entry for aggregated fleets of DER, whilst maintaining data integrity requirements. It is a critical step in enabling the scalability of VPPs.

Alignment with AS4777.2:2020

This point was also considered by AEMO in the MASS Draft Determination. Several responses to the earlier MASS consultation noted that 100ms is aligned with the measurement requirements included in AS4777.2:2020. In response AEMO noted in the Draft Determination that:

> *"The newly updated AS/NZS 4777.2:2020 (effective in December 2021) specifies a DER inverter standard of measurement time, which is aimed at ensuring stable input data for utilisation in protection and control functions, rather than any data logging or measurement time resolution requirements."*

This may be true; however, it is also a fit-for-purpose DER standard that most inverter OEMs will be basing their development work on. Transitioning from 100ms input data, to logging at 100ms requires less work and cost than transitioning to a 50ms data resolution. The current 50ms requirement is a legacy requirement first developed for single utility scale; transmission connected assets. AEMO can now consider whether a better starting point for DER is to align with an existing DER inverter standard.

2. **Update to the FCAS verification tool**

In addition to Tesla's analysis above, the independent analysis undertaken by the University of Melbourne presented to AEMO as part of the Draft Determination supports the potential adoption of 100ms and 200ms resolution. The final position put forward by the University of Melbourne noted a near zero error risk associated with 100ms and 200ms. Note that this analysis was based on the universal window method is used in this analysis and as such AEMO has determined that *"more conclusive information [and] significant further work [required to use of the universal window]*" would be needed.

Tesla believes that the same zero error risk outcome can be achieved through the adoption of the trapezoid verification approach while keeping the relative window. This would only be a minor adjustment to the FCAS verification tool and as such would not require the significant work that is flagged by AEMO.

As demonstrated in the figures below, adoption of the Trapezoid method, in combination with a 100ms resolution with a relative window provides a near zero error band. This near error risk finding is consistent with Tesla's analysis (demonstrated above) and reduces as the overall fleet size increases.

Tesla also notes that the MASS v6 allows "*AEMO to update the algorithms and its form from time to time*" (section 6.5) and the FCAS Verification Tool was updated to use the Trapezoidal rule to generate AEMO's average error calculation plot in in the draft report and determination (section 4.1.2), which demonstrated very low error (<2%) with 100ms measurements

Reg 1 Provider 1 Lower, 0-6s response				
MWs	50ms	100ms	200ms	1s
Left Riemann	-28.82	-28.60	-29.02	-30.64
Right Riemann	-29.25	-29.46	-30.74	-39.29
Trapezoid rule	-29.04	-29.03	-29.88	-34.97
Simpson's rule	-29.04	-29.03	-29.88	-35.15
Simpson's 3/8 rule	-29.04	-29.03	-29.88	-35.06
Boole's rule	-29.04	-29.03	-29.88	-35.15

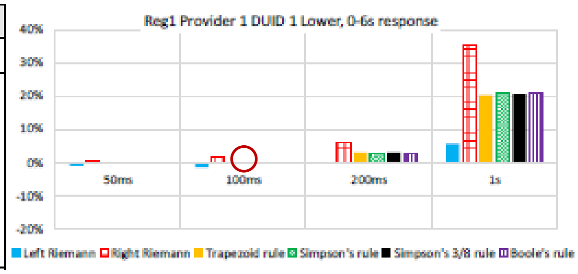

Figure 12. Comparison of different integration methods for registration event provider 1 lower FCAS response, with relative window.

Event 7 Provider 1, 0-6s response				
MWs	50ms	100ms	200ms	1s
Left Riemann	11.89	11.80	11.60	11.56
Right Riemann	12.10	12.20	12.40	15.63
Trapezoid rule	12.00	12.00	12.00	13.60
Simpson's rule	11.99	12.00	12.00	13.57
Simpson's 3/8 rule	11.99	12.00	12.00	13.51
Boole's rule	11.99	12.00	12.00	13.58

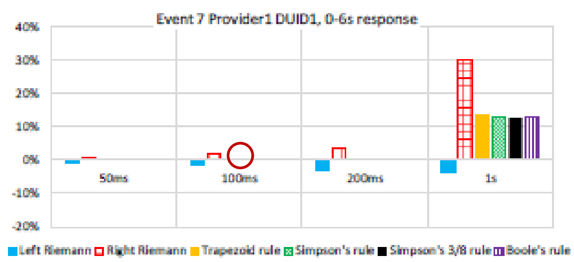

Figure 13. Comparison of different integration methods for event 7 provider 1 raise FCAS response, with relative window.

Figure 14: University of Melbourne analysis

Event 7 Provider 1 oscillation profile, 0-6s response				
MWs	50ms	100ms	200ms	1s
Left Riemann	11.76	11.67	11.51	11.82
Right Riemann	11.96	12.08	12.31	14.86
Trapezoid rule	11.86	11.88	11.91	13.34
Simpson's rule	11.86	11.86	11.84	12.93
Simpson's 3/8 rule	11.86	11.86	11.83	13.71
Boole's rule	11.86	11.87	11.86	12.84

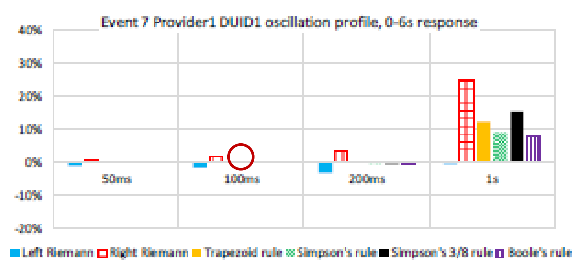

Figure 14. Comparison of different integration methods for event 7 provider 1 raise FCAS response with superimposed alternate signal, with relative window.

Event 1 Provider 2 DUID 1, 0-6s response				
MWs	50ms	100ms	200ms	1s
Left Riemann	80.00	78.66	85.52	99.40
Right Riemann	80.58	81.57	91.72	130.59
Trapezoid rule	80.29	80.11	88.62	114.99
Simpson's rule	80.31	79.96	87.75	115.91
Simpson's 3/8 rule	80.30	80.14	88.09	113.70
Boole's rule	80.32	79.89	87.51	115.93

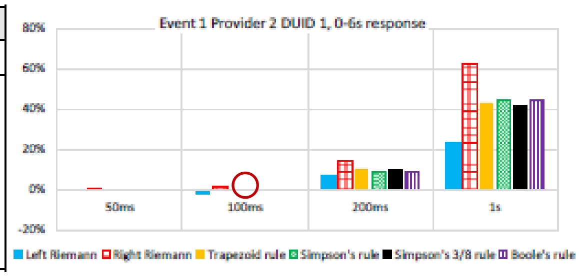

Figure 15. Comparison of different integration methods for event 1 provider 2 raise FCAS response, with relative window.

Figure 15: University of Melbourne analysis

Based on both Tesla's broad statistical analysis of the fleet level error risks, as well as the independent assessment from the University of Melbourne, Tesla believes that updating the verification tool to the trapezoid method is a low cost, low effort means of improving the error bands associated with verifying the quantum of fast FCAS service delivered. Furthermore, we understand that this change was already implemented by AEMO as part of the second stage consultation to allow AEMO to form its own view on measurement speed.

Summary findings and recommendations:

Based on the analysis above, Tesla has drawn the following conclusions:

- There is effectively zero risk for AEMO in immediately transitioning to 100ms or 200ms resolution as it provides the same resolution outcomes as 20ms .
- Updating the FCAS verification tool to the trapezoid method is low cost, low effort, and the mechanism to make this update already exists within the existing MASS framework.
- AEMO should also do further work to enable 1 second resolution at a fleet level.

As such, our recommendations are as follows:

- AEMO to enable 100ms or 200ms resolution for fast FCAS on a conditional logging basis.
- AEMO to update the FCAS verification tool to allow for trapezoid verification approach.
    - Note that given the combination of a 100ms or 200ms resolution with an update to the trapezoid approach provides a near zero error band, Tesla recommends that this approach is adopted for all fast FCAS providers, not just VPPs.
- Based on the statistical analysis above, AEMO should also seriously consider providing the option of 1 second measurement resolution for VPP fleets with more than 200 assets. This appears to be low risk and worthy of further consideration.

Technical delivery of service:

Oscillation risks

Tesla understands that AEMO has concerns around the oscillatory behaviour of inverters during power system disturbances. These concerns are outlined in the AEMO "Behaviour of distributed resources during power system disturbances" report[14]. These should be split into two broad categories. Expected inverter oscillations and unexpected inverter oscillations. The former can be broken down as:

- Concerns around inverter oscillations during voltage disturbances; and
- Concerns around inverter oscillations during frequency disturbances

Uncontrolled oscillations during a frequency event seem to be the particular concern of AEMO. In the Draft Determination AEMO notes one response to the earlier consultation which identified oscillation behaviour from a particular battery type (not currently being used within the respondees aggregation portfolio). This appears to be the primary basis for AEMO's concerns in respect of uncontrolled oscillations. Tesla agrees that this type of oscillatory

[14] https://aemo.com.au/-/media/files/initiatives/der/2021/capstone-report.pdf?la=en&hash=BF184AC51804652E268B3117EC12327A

behaviour is entirely unacceptable and devices that perform as such should not be enabled to provide FCAS regardless of the measurement resolution used for such a system type. In our >2 years of experience in providing FCAS, with more than 25MW of Powerwall capacity registered across three VPPs (equating to more than 5,000 systems) we have not observed a single instance of similar oscillatory behaviour. We also note that the fluctuations presented aren't oscillations but measurements of AC waveform at random voltage points.

Notwithstanding the above, it is quite clear that AEMO should be looking to prevent these systems from being registered for FCAS, rather than debating the granularity of measurement resolution necessary to observe this behaviour. This should be achieved through each registered piece of equipment through the FIT-D.

The following requirements that are already in place, or under development, should provide AEMO with sufficient confidence on the performance of a particular asset type:

- FIT-D required for each different system type registered with AEMO for the purpose of providing FCAS.
- Mandating compliance with AS4777.2:2020 and the AEMO Low Voltage Disturbance Ride Through (LVDRT) specification – the disturbance ride-through requirements will manage performance.
  - Note that Tesla also supports retrospectively requiring all inverter based DER registered for FCAS currently to demonstrate compliance with AS4777.2:2020
- Developing an iterative approach for the FIT-D which allows the test to be updated from time to time to include new requirements developed by AEMO under the broader DER technical performance standard.

Tesla expects this will solve for unexpected oscillations and ensure that systems that demonstrate the behaviour highlighted in the MASS Draft Determination are not registered for FCAS. This approach acknowledges that while there is no “generator performance standard” equivalent, there is an inverter standard which has been developed to provide the same network protections at the distribution level. In addition, the fact that AS4777.2:2020 and DER is now explicitly referenced with the National Electricity Rules (NER) provides AEMO with the framework to continue to manage DER technical requirements and make iterative changes

In respect of controlled or expected oscillations, during a credible contingency event DER inverters enabled for FCAS will oscillate proportionally to the frequency with the aim of bringing the frequency back within the NOFB. If inverters swing from charging or discharging to the other it's because they are just reacting to the frequency changes instantaneously.

Tesla has also been working closely with the AEMO DER standards team to provide more visibility as to how inverters behave during emergency events. As noted in our response, it appears that a key issue AEMO is facing at the moment is lack of accessible data – and visibility of performance.

Tesla believes that AEMO should maintain the API that was stood up for VPPs to access real-time DER data at both an asset and fleet level. This will provide AEMO with far more useful information on oscillatory behaviour that the compliance data provided by DER providers following a contingency event. This will enable AEMO to analyse inverter performance in real-time during a myriad of different power system security events. This also means that an increase in VPP registered capacity benefits AEMO because there will be a direct correlation in VPP capacity and DER visibility.

FIT-D requirements

As noted in section 4 above, the AEMO VPP Demonstrations Trial established a two-step means of verifying technical performance. Over the duration of the VPP Demonstrations Trial, AEMO was overwhelmingly positive as to the technical capabilities of DER in providing FCAS. Based on the subsequent content released in the AEMO MASS Draft Determination, there seems to be some conflation between the 50ms measurement resolution being linked to actual performance, versus being used to verify performance.

The Tesla 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. The measurement resolutions considered in the MASS Draft Determination are in no way linked to the actual system performance, they simply provide AEMO with a means of verifying the delivery of the total service.

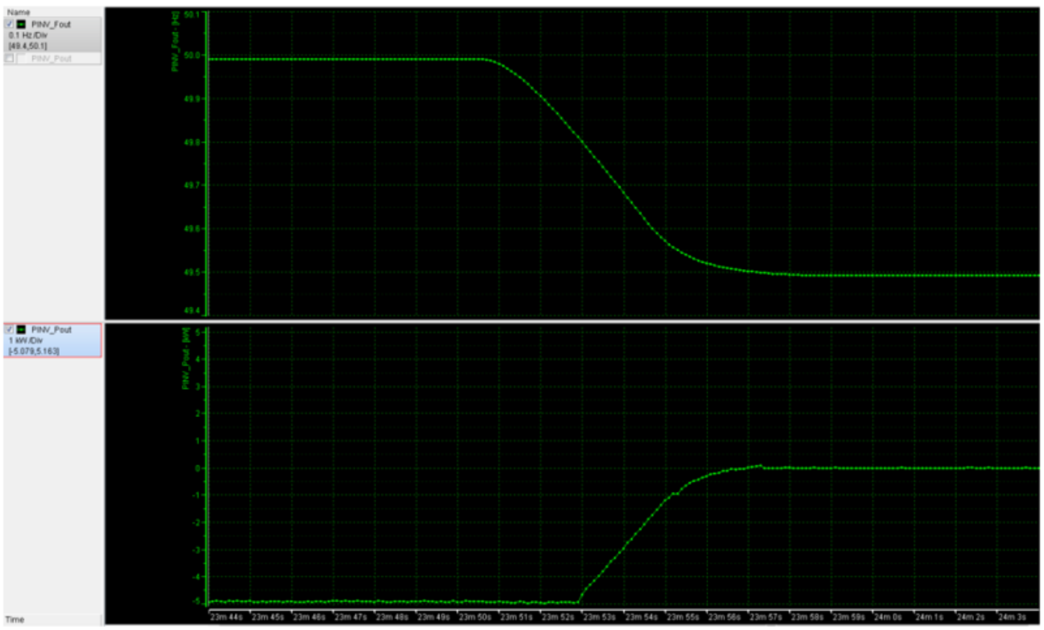

Figure 16 - Tesla Powerwall 2 Frequency Injection Test Results: 5kW Raise Response

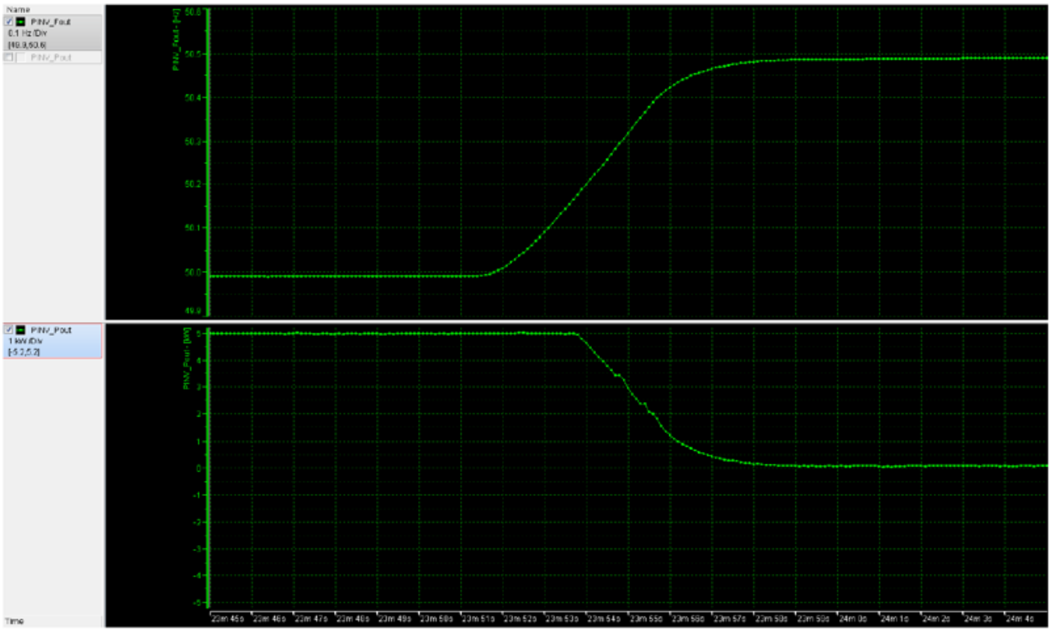

Figure 17 - Tesla Powerwall 2 Frequency Injection Test Results: 5kW Lower Response

The purpose of the Frequency Injection Test – Device (FIT-Device) required upon registration of a new technology in any VPP is to demonstrate the technical capability of the technology to respond to frequency deviations using the settings provided by AEMO, such as the 0.7% droop. The power response from a 5kW Tesla Powerwall 2 ("Powerwall") to frequency deviations simulated in a laboratory is shown in Figures 18 and 19. These tests and the associated ≤50ms power and frequency measurements were validated by AEMO as part of the registration process of DUID VSSEL1V1.

In addition to this test, a Frequency Injection Test – DUID (FIT-DUID) is also required upon registration of a new DUID. This allows AEMO to confirm that the response demonstrated by a device during the FIT-Device is delivered by a fleet of the same devices before that fleet can participate in the FCAS markets. The FIT-DUID test is meant to *verify the performance of the fleet*, not the technical capability of individual, identical devices. As such, a lower sampling rate than 50ms is sufficient to verify the performance of the fleet since, as per the MASS v6, Fast FCAS services are verified based on energy provided over the 60 seconds following the frequency disturbance time.

6.3 Measurement location

Statement of concerns

AEMO's position in the MASS Draft Determination is that "AEMO is not satisfied that the measurement of power at the asset level will accurately represent the amount of FCAS delivered to the grid. Especially in cases when more than one asset can be controlled". This position appears to be based on the following points made by AEMO:

- "*AEMO analysis of the FCAS response … indicates that changes in distributed PV and uncontrollable load during a frequency disturbance are smoothed out on an aggregate level*".

- "*Some consulted persons were also of the view that if measurements at the connection point are not used it could result in perverse incentives to game the FCAS verification and compliance approach…";* and
- "*Extra hardware would be required if there is more than one controllable asset behind a connection point".*

AEMO concludes that "*no supporting evidence was presented to confirm that measuring FCAS delivered by DER at the asset level would benefit the power system".*

Summary overview – Tesla position

Tesla does not agree with the analysis undertaken by AEMO nor with the approach proposed in respect of the measurement location. AEMO's final position seems to be primarily based on concerns around multiple assets providing FCAS at a single site. Tesla considers this to be a fringe issue which can easily dealt with.

Our recommendations to AEMO, which are dealt with in more detail below, are:

- All VPP providers provide AEMO with both site and asset level data to maintain a complete dataset.
- The point of verification (data used for verification) should be at the point at which the FCAS response is delivered:
    - If the FCAS response is provided by a single technology, using an open loop response, or a closed loop response using device level meter, FCAS performance should be verified using asset level data (with site level data provided as well).
    - If the FCAS response is provided by a site level controller (for one or more technology types sitting behind the meter) then FCAS performance should be verified at the site level (with data provided for individual assets as well)
- In the event that AEMO maintains the requirement to verify performance at the site level, rather than the asset level, then Tesla asks that aggregators are given the opportunity to use device level data in the event that AEMO considers a VPP to have under-delivered during an event (driven by the impact of non-controllable load/ generation on site).
- Tesla also believes that where a single NMI has more than one FCAS enabled technology then device level measurements should only be allowed where AEMO has sufficient confidence that the metering at the device level is sufficient and the two assets are compatible in response.

Our recommendations above are based on the following points:

- AEMO will benefit from having both site and asset level data whilst also providing optionality
- Tesla's analysis shows that there are risks of distributed PV and uncontrollable load impacting on the measured FCAS output of DER where the measurement is done at the site level. Even if FCAS providers reduced their bids to account for uncontrollable changes in solar and load, they would still unfairly be exposed to non-compliance given that the magnitude of these changes is unpredictable.
- The risks associated with multiple assets providing FCAS at a single site are largely fringe-case and/or theoretical and can be easily managed.
- AEMO's decision to lock in measurement location at the site, ignores the primary driver for the VPP Demonstration trial – which was to level the playing field for DER when compared with utility scale assets providing FCAS.

In respect of the concerns around multiple assets providing services at a single site, Tesla also thinks that there is a broader piece of work that needs to be done in respect of the customers' ability to select a single aggregator versus their ability to work with multiple aggregators for different systems behind the meter. This position is not yet settled and there needs to be further work done on both DER interoperability, and on customer protection frameworks – this needs collaboration from industry, AEMO, the Australian Energy Regulator (AER) and the Australian Competition and Consumer Commission (ACCC). It is important that AEMO does not use the MASS Draft Determination as a proxy for locking in one method ahead of this work being done.

Lastly, the concern raised by respondents around perverse incentives to game the FCAS verification and compliance approach seems to be based on a misunderstanding of the primary application of a battery which consists in increasing solar self-consumption. This is currently the default mode of operation of most residential batteries and consists in charging from solar production when it exceeds home usage and discharging to serve the home usage when it exceeds solar production. As a result, if an aggregator implements an FCAS response at the site level by which it increases loads for instance, a battery in self-consumption mode will compensate by almost instantaneously reducing its charge power or by discharging, in order to maintain 0kW imports and exports. And similarly, if the aggregator decreases load, the battery will reduce its discharge power or charge. Such behaviour should not be assimilated to gaming; instead it highlights the inappropriate configuration of the battery by the aggregator.

Besides, there are proven technical solutions currently available commercially that enable aggregators to control fleets of batteries such that they deviate from their self-consumption behaviour during frequency excursions and provide FCAS services either from an open loop proportional response, or from a closed loop step response.

More detail on each these points is provided below.

Justification of position:

AEMO benefits from both site and asset level data

A core principle backing our recommendations above is that it makes the most sense to verify performance at the point at which FCAS is delivered, and that AEMO will benefit from multiple data sources from all VPP aggregators. In practice we see this working as follows:

- **Aggregator A**: manages a fleet of batteries, uses open loop controls to manage the FCAS performance. Across the fleet there is also a combination of uncontrollable loads and solar system. The aggregator is required to provide battery data (FCAS device level data), as well as solar and load data. Performance is verified using the battery level data to ensure that the load and solar outputs do not impact on the verification.
- **Aggregator B**: manages a fleet of batteries using a close loop site level control system. Across the fleet there is also a combination of uncontrollable loads and solar system. The aggregator is required to provide battery data, as well as solar and load data, and total site data (FCAS level data). Performance is verified using the site level data.
- **Aggregator C**: manages a fleet of batteries and controllable air-conditioners using a close loop site level control system. Across the fleet there is also a combination of uncontrollable loads and solar system. The aggregator is required to provide battery data, air conditioner data, as well as solar and load data, and total site data (FCAS level data). Performance is verified using the site level data.

Having multiple data points is important for AEMO to ensure performance is compliant. Looking at the example of Aggregator B there is a risk of that aggregator taking credit for changes in load/solar production that they don't control. For instance, if during a lower event, a customer turns his/her kettle on, the aggregator may in response turn off one of the loads it controls (and if they don't, they can still claim the load increase as a legitimate FCAS response). Given that the customer would have turned on the kettle regardless of whether there is a contingency event or not, the aggregator should not be allowed to claim this additional load as a contribution towards its FCAS enablement. If AEMO asks for only site level data rather than also collecting data from FCAS enabled devices behind the meter.

In the example of Aggregator C, there is the potential that one FCAS device will over-perform and one will under-perform. If AEMO only asks for site level data for verification, they will have no visibility on this variance in performance and therefore will not be able to identify under-performing FCAS devices.

Interference from distributed PV and uncontrollable customer load

Related to the above, and the need to create a level playing field, Tesla does not agree with AEMO's position that "*changes in distributed PV and uncontrollable load are smoothed out on aggregate level".*

Tesla's analysis of data across individual sites shows that there are clear instances where a shift in solar output or a change to the uncontrollable load pattern has a demonstrable impact on the overall site profile.

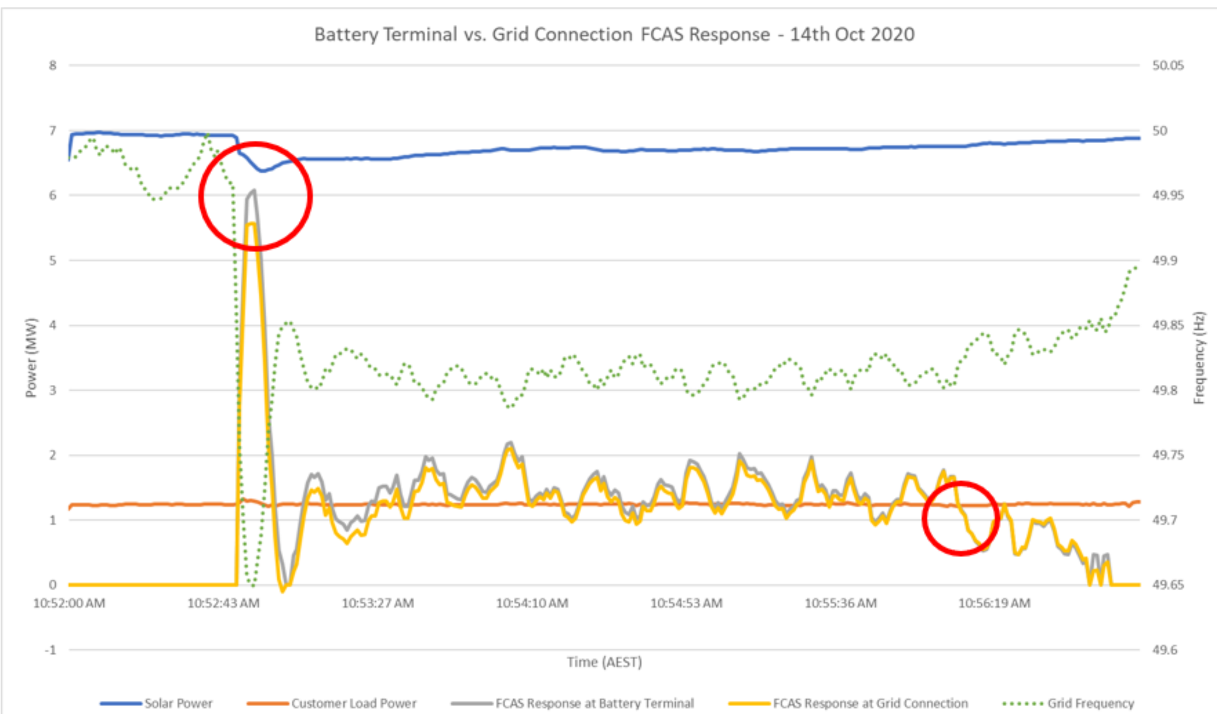

Figure 18: Impact of reduced solar output on site level output

As demonstrated in Figure 18 above, a decrease in solar output, which is not uncommon over an extended contingency frequency event, creates a noticeable difference between the measured battery output (actual provided FCAS response – yellow line) and the site level output (verified FCAS response if AEMO elects to maintain site connection level measurement requirements – blue line). In effect this will mean that aggregators will either need to bid conservatively, apply a haircut to their aggregated bids to manage the impacts of uncontrollable loads and/or changes in solar PV output, or risk facing action from AER and/or AEMO in respect of non-compliant bids.

During this particular event, SA VPP would not have been considered as under-delivering even if the site-level measurements had been used. However, this is only because at the time, Tesla used a conservative bidding approach with a large haircut as we were still gaining confidence in our ability to exceed required FCAS delivery for each and every 5-min enablement in all 6 markets. Tesla has since reduced its haircut while maintaining compliance and would most likely be considered as under-delivering during a similar event if only site-level data was used for FCAS assessment and non-controllable solar inverter behaviour was ignored. More importantly, in absence of battery and solar measurement, AEMO would have had no visibility whatsoever into the solar system trips, which is precisely one of the major challenges that AEMO has identified in *Behaviour of DER during power system disturbances* (June 2021): *"There remain areas where evidence is sparse, particularly around DPV behaviour during frequency disturbances."*

This reiterates the lack of level playing field between aggregated DER providing FCAS and utility scale assets providing FCAS. Utility scale assets do not have to adjust their bids to account for externalities such as other generation or load profiles.

In the event that AEMO maintains the requirement to verify performance at the site level, rather than the asset level, then Tesla asks that aggregators are given the opportunity to use device level data in the event that AEMO considers a VPP to have under-delivered during an event (driven by the impact of external load/ generation on site).

<u>Risk of multiple assets providing FCAS from the same site</u>

If more than one asset is providing FCAS at a connection point, then this creates concerns for AEMO. Tesla believes that this is likely to be a fringe issue and can simply be resolved through providing optionality to measure at site level vs asset device to start with – this means that if a MASP or market customer submits an ancillary services load registration form (single DUID) where there is more than one type of plant listed for a particular NMI then the aggregator is required to use site level measurements to verify performance unless the aggregator can demonstrate suitable asset level metering for each FCAS enabled plant. This position will be further enforced by the fact that only one MASP is able to register per NMI.

If an existing NMI has an FCAS enabled asset registered under a second DUID later, then this should create an immediate flag for AEMO.

<u>Need for an even playing field</u>

Building on Tesla's analysis above on the VPP Demonstrations Trial, it is again worth pointing out that the reason that AEMO considered measurement resolution at the asset level (rather than the site level) for the VPP Demonstrations Trial, was not to give undue advantage to VPPs, but to address the fact that the MASS was written with utility scale assets in mind, and as such the current settings can passively discriminate against how aggregated fleets of assets compete in the market.

For utility scale assets providing FCAS, the connection point and the device measurement point is one and the same. Taking utility scale batteries as an example, AEMO currently requires all utility scale battery storage systems to be registered as a scheduled generator and a scheduled load. Even when co-located with a wind or solar farm these are two separate assets.

For the purpose of providing FCAS, in a utility scale model it will be the battery that is registered as an FCAS generating unit. As such the "connection point" will always just measure the performance of a single asset.

Applying this logic to a fleet of aggregated assets installed behind the meter is misleading. Measuring at the "connection point" implies that everything behind that connection point is contributing to the FCAS response, rather than the single asset that is registered with AEMO to provide the FCAS response.

Tesla does not suggest that AEMO should provide preferential treatment for aggregated DER providing FCAS, just that they should be treated with some level of equivalence to utility scale assets. In that respect, it would make sense that for the purposes of verification, the measurement location is at the device level.

To ensure that AEMO has the most complete dataset available, it is not unreasonable for AEMO to expect VPP aggregators to provide both asset level and site level data, however in order to support a level playing field verification should be based on asset level data.

Tesla has also considered AEMO's conclusion that:

> *"no supporting evidence was presented to confirm that measuring FCAS delivered by DER at the asset level would benefit the power system"*

This should not be the threshold test applied to whether new technologies should have alternative settings and requirements applied to them. The threshold test should be whether the equivalent settings – developed for transmission connected utility scale assets – make sense when applied to DER. In this case they don't, and they actively disadvantage DER providing FCAS when compared with utility scale assets. Utility scale assets will never have to account for uncontrollable load or generation externalities in their bids and it is unreasonable to expect DER to do so.

6.4 Updates to MASS based on recommendations above and VPP Demonstrations Trial

Based on Tesla's assessment of both the outcomes of the VPP Demonstrations trial, and our recommendations on the positioning put forward by AEMO in the MASS Draft Determination, Tesla believes that AEMO should develop a guideline that articulates the registration and compliance obligations of VPPs on a BAU basis.

Tesla has articulated our views of this approach, as a general piece of industry guidance, in Attachment A. There has been significant work done to date by AEMO and industry in developing a scalable, sustainable model for VPP market integration, and it is critical that these insights are adopted by AEMO to maintain industry growth in line with AEMO projections.

Pending AEMO acceptance of our recommendations it is increasingly clear that there are a number of issues that need to be considered more fully ahead of AEMO releasing the MASS review, If AEMO does not accept the recommendations put forward by industry in the Final Determination, we believe that there needs to be an interim step where further analysis is done on the following:

- AEMO acceptance of error band risk at fleet level as well as for individual assets (which has been the only work done to date).
- Further consideration of measurement resolutions alternative to 50ms and 1 second and/or consideration of bidding discounts that could be introduced for 1 second resolution (this point would necessarily be linked to the first dot point above), and
- Updates to the verification tool to reduce risk.

7 Power system security risks

The AEMO MASS Draft Determination also considers a range of power system security risks associated with DER.

While Tesla acknowledges the existence of each of these risks, with the exception of the oscillation risks (covered in section 6.2 above), we do not consider the risks flagged in the MASS Draft Determination to be linked to MASS review process. These risks currently exist and will continue to exist regardless of whether the MASS is updated or not.

These risks should be addressed through concentrated efforts of AEMO, NSPs and industry. This also ties into the need for ongoing collaboration to create a scalable and sustainable market framework for VPPs that provides the optimal set of outcomes for all relevant stakeholders. If designed well, VPPs provide significant market and network benefits – rather than risks. However, to achieve this, there needs to be ongoing collaboration, and iterative work done to ensure suitable settings.

Below, Tesla provides an outline of the forums we think could be used to manage these concerns, as well as providing our own technical insights into the power system security risks flagged by AEMO in the MASS Draft Determination.

7.1 Plan for managing power system security risks

As noted above, Tesla believes that the best approach for managing these power system security risks, is through an ongoing, iterative work plan. These risks will not, and should not, be addressed through the MASS review process. Tesla recommends considering the range of forums that currently exist that can be used to bring together the expertise of AEMO, NSPs and industry.

In the long-term, Tesla believes that the DER Governance Committee approach proposed by the Energy Security Board in their DER Governance Rule Change[15] proposal. In the interim, Tesla believes that the following forums could be utilized to provide oversight on governance arrangements, and assist with the ongoing management of these power system security risks flagged in the MASS Draft Determination:

- ESB Maturity Plan,
- A new DEIP committee, or
- A fit for purpose industry and AEMO committee – Tesla supports the Consultative Forum idea and would be happy to work with AEMO on dealing with the bigger DER concerns that AEMO has flagged.

[15] https://www.aemc.gov.au/sites/default/files/2020-09/ERC0319%20RRC0040%20Rule%20change%20request%20pending.pdf

AEMO should be a key stakeholder in supporting reforms, education, and behavioural change to manage these power system security risks. However, we do not expect AEMO to be the lead organization. This should be a joint work program from all stakeholders that have interests in achieving sustainable VPP growth and supporting scalability of a VPP work program. Maintaining the MASS in its current forum will not resolve these issues.

7.2 Addressing the risks flagged in the MASS Draft Determination

Tesla has experience with assessing and managing the concerns directly raised by AEMO in the Draft Determination. While we do not think these concerns are at all relevant to the MASS review, we've provided some insights into each of the concerns raised by AEMO (with the exception of the oscillation risks covered above):

1. Unexpected disconnection due to a local network fault, and potential power system security risks in frequency recovery if the unexpected inverter disconnections are not properly accounted for, resulting in a DER FCAS Provider not being able to respond to a frequency disturbance.
2. Behaviour during local distribution network and global power system disturbances posing a risk of under-delivery of FCAS due to inverter requirements, e.g. autonomous reactive power (Volt-Var response) support assisting voltage management in the distribution network prioritised overactive power (FCAS response)
3. Risks associated with large-scale, rapid active power injection or withdrawal from deeply embedded assets (aggregated to provide FCAS) exceeding the limits of secure distribution network operation limits.

We also include our suggested plan for managing ongoing power system security risks – noting that this work will be iterative, and will need a sustained effort from AEMO, NSPs and industry in order to develop a sustainable and scalable future framework for VPPs in Australia.

7.3 Unexpected disconnection

As noted by AEMO in the MASS Draft Determination it appears that the risks associated with unexpected disconnection will likely be resolved through the introduction of the new AS4777.2:2020. As noted above, Tesla supports mandating compliance with AS4777.2:2020 for both new inverters based DER looking to provide FCAS services, and retrospectively requiring it for the existing fleet.

Tesla is working closely with the AEMO DER team to provide data from major disturbance events and consider any leading indicators that may lead to disconnect. We will continue to do so with the view that any learnings can be developed as new DER technical standards and mandated as part of the FIT-D requirements.

7.4 Behaviour during network disturbances

Tesla has been working closely with SA Power Networks throughout the deployment of our VPP in South Australia to ensure that network requirements are prioritised over market access, and that VPPs minimize network risks.

In practice what this means is that network requirements should always be prioritised over market participation. **Figure 19: Example of coincident volt-var and FCAS event** below shows a Tesla SAVPP site that is enabled for FCAS market participation. This site has a 5kW solar PV system and a Tesla Powerwall installed and operates in the contingency FCAS markets under the VSSEL1V1 DUID with a 0.7% droop curve.

Stepping through the three dot highlighted points in the Figure:

1. Contingency frequency event occurs – site enabled to provide FCAS response.
2. Volt-var requirements triggered. Actual FCAS response is tapered down from the expected FCAS response to enable the site inverter to instead provide volt-var response.
3. Once the Required FCAS response subsides below the max apparent power capacity of the inverter, both Freq-Watt and Volt-Var operate in parallel.

What is clearly demonstrated is that as soon as 250V limit is reached, the Powerwall immediately reduces the real power FCAS response to instead provide reactive power support and reduce the VPP impact on local voltage. The reduction in FCAS response is demonstrated by the green "Actual FCAS" response being lower than the blue "Expected FCAS response". The prevention of additional voltage rise is evidenced by the plateau of the inverter voltage readings at ~250V.

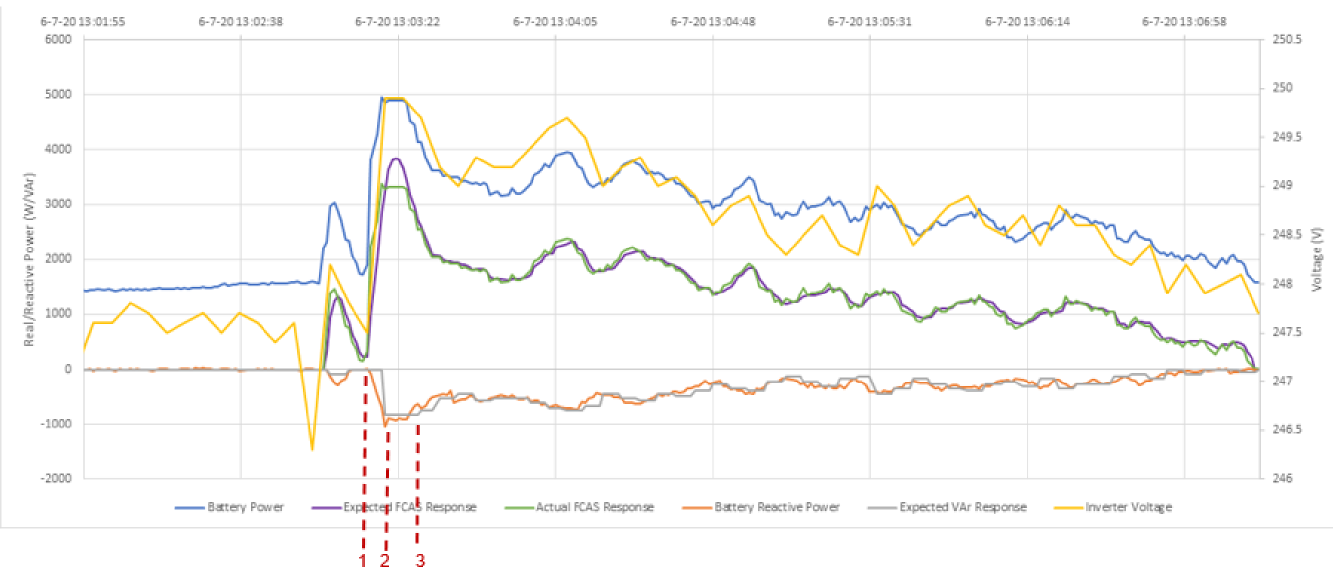

Figure 19: Example of coincident volt-var and FCAS event

7.5 Risks of exceeding network operating limits

The MASS Draft Determination also flags concerns associated with VPP systems exceeding site export limits set by DNSPs.

As a starting point, it is important to note that these site export limits were introduced primarily to manage the network risks associated with extended periods of electricity export during solar generating hours – not to manage short duration (sub-cycle, second and minute) level response to system security issues.

Breach of site export limits is also generally considered to be a fringe risk given breaches of site export limits only occur in very specific circumstances:

1. Battery must be fully charged so solar is exporting
2. The event must be a raise event.
3. The event must happen during solar generation hours.

Even then to create an actual network risk:

4. The contingency event must be large enough to cause the solar export + PW output to drive up site voltage
5. Voltage on the site must be on the high end prior to the FCAS event.

For the purposes of the SAPN Advanced VPP Integration Plan, Tesla analysed the VPP performance to look for examples of site export limits being breached and could only find the single example, **Figure 20** below.

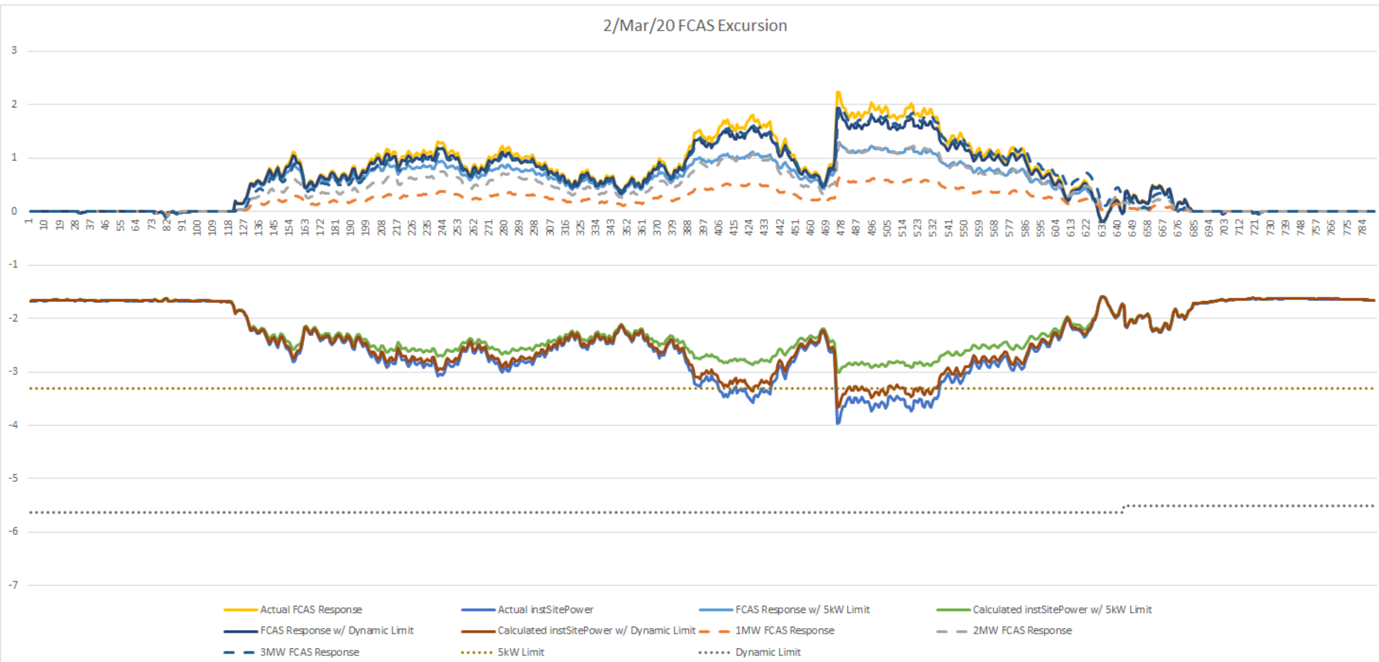

Figure 20: Example of site export limit breach

Tesla has been through the concerns regarding site export limits with SA Power Networks to ensure appropriate arrangements are in place for providing FCAS. We will continue to support both AEMO and NSPs in developing the most appropriate co-optimised approach to DER market participation.

8 Summary of recommendations

The full set of Tesla recommendations on the MASS Draft Determination is recapped below. As mentioned above, Tesla is committed to working closely with AEMO on the future development of appropriate VPP frameworks for Australia. As AEMO has acknowledged, this work will not be easy, so it's important to continue to make gains.

The power system security concerns identified in the MASS Draft Determination are a separate issue to the MASS reforms and need to be addressed through a different forum. Treating these as two separate tranches of work will be important and our recommendations below are based on this separation of work.

Tranche 1: MASS reforms – recommendations specific to VPPs providing FCAS/ participating in fast FCAS markets

Topic	Recommendation
Measurement resolution	▪ AEMO should allow for fast FCAS measurement resolution of 100ms as an alternative to the 50ms resolution currently required and included in the Draft Determination. This should be done on a conditional logging basis, with 1 second measurement resolution maintained outside of frequency deviations (before a frequency deviation, and after the 60 second following a frequency deviation). ▪ AEMO should update the MASS FCAS verification tool to use the trapezoid measurement resolution approach. ▪ The combination of these two recommendations creates a near zero error risk for AEMO – well under the 2% allowable error range for fast FCAS currently allowed within the MASS. ▪ Tesla's analysis also highlights that for fleets of >200 systems, the error risk associated with 1 second measurement resolution is also less than 2%. Tesla recommends that AEMO further consider options for larger fleets to operate with a less granular measurement resolution (see detailed analysis in Attachment B).
Measurement location	▪ Tesla understands AEMO's concerns about measurements at the site level, however Tesla believes that the FCAS measurement location should be the same as where the FCAS response is implemented. Some VPPs implement a closed loop response at the site level while others, like Tesla, implement an open loop response at the asset level. For simplicity, Tesla recommends that AEMO: ○ Where FCAS is provided by a site level, closed loop device the performance of that site should be verified at the site level (with the VPP operator required to provide data at the device level for FCAS enabled devices, as well as site level data). ○ Where FCAS is provided using open loop device level controls, or closed loop controls at the device level, the performance should be verified at the device level (with the VPP operator required to provide both site and device level data) ▪ If AEMO maintains site level measurements resolution for all sites, then Tesla suggests that in the event of AEMO assessing under-delivery of FCAS, market participants are able to demonstrate compliance using device level data, to show that the perceived under-delivery was caused by uncontrollable load or solar.

	▪ Tesla believes that AEMO should not disregard asset level measurement for the following reasons: ○ Measurement at the site level creates risks for VPP aggregators in accounting for uncontrollable loads and changes in solar PV output. Based on these externalities, measurement at the device level provides a more accurate method of verification of FCAS performance. ▪ Where there are multiple FCAS enabled devices at a single site, then the aggregator must demonstrate suitable metering for each asset and must demonstrate that the performance of the multiple devices is complementary.
Other MASS related reforms	<u>DER</u> ▪ AEMO should reinstate the API set up for the VPP Demonstrations trial and make API integration a specific requirement of VPP registration within the MASS. ▪ This API provided clear benefits to AEMO in terms of increased visibility of DER in real-time, as well as setting the framework for forecasting. ▪ Tesla supports providing AEMO with ongoing DER visibility. Maintaining the API would result in AEMO receiving 100ms data during frequency deviations (for compliance purposes), and 1 second data provided at all other times. ▪ VPP operators could either be required to provide this data as a MASS condition of registration or provide it on an opt-in basis. ▪ This breadth of data will help enormously with the power system security concerns raised by AEMO as it will provide real-time data to help identify a range of different inverter responses to different fault level conditions. ▪ Conversely, maintaining the MASS as it currently stands will provide AEMO with 50ms data only during a contingency event. This doesn't help with any other system disturbance, or to more broadly analyse how inverters behave in response to distribution level fault issues. The API does support that. ▪ Tesla also believes that the transitional arrangements proposed for existing registered VPP Demonstrations trial capacity should be extended from 30 June 2023 to 30 June 2031. This 10-year transitionary period is more aligned with investment timeframes and ensures that private investment is not placed at risk. <u>General</u> In respect of the General Mass discussion included in the MASS Draft Determination, Tesla has only one recommendation in respect of the proposed s 3.5 "New Regulation FCAS requirements – minimum 2MW regulation FCAS bid size. ▪ Tesla believes that the 2MW limit is arbitrary and inconsistent with "no less than half the bid size" (i.e. 1MW/2 = 500kW). ▪ We recommend that AEMO removes these thresholds, and/or recognise technology differences - it is much easier to observe a clean 1MW regulation response on a battery than it might be to observe a 5MW on a thermal plant.

Tranche 2: Addressing broader power system security concerns related to DER

Topic	Recommendation
System security – separate work program	▪ Tesla does not believe that the power system security risks articulated by AEMO in the MASS Determination are relevant to the outcomes of the MASS Review– they need to be managed regardless of whether the MASS is updated or maintained in its current form. ▪ Tesla proposes that these issues need to be addressed through strong industry collaboration – and through a bespoke forum specifically focused on DER Power System Security concerns. Alternatively, an existing forum, such as the Energy Security Board (ESB) "Maturity Plan" or the Distributed Energy Integration Program (DEIP) could be used to address these concerns. ▪ Alternatively, Tesla is supportive of the proposed "Consultative Forum" proposed by AEMO and would be happy to support this as a forum to addressing the broader system security concerns flagged. ▪ Further, it seems as though the lack of DER visibility is central to all DER power system security concerns raised by AEMO. This can be managed through maintaining the API that was developed for the VPP Demonstrations trial and making this an ongoing requirement for all VPP market participants. ▪ Complying with the ongoing data provisions and providing AEMO with real time fleet and asset visibility via API, should first be included in the MASS and then adopted into the rules through the 'Scheduled Lite' rule change and the implementation of the Visibility Model explored by the ESB.

Attachment A – Proposed AEMO VPP Registration and Compliance process

As noted in the body of our response above, Tesla believes there are several critical lessons from the VPP Demonstrations trial that should be applied to the BAU registration and operation approach for VPPs in the future.

Tesla has outlined a number of these process recommendations below:

Initial registration – new VPP DUID

VPP aggregators are responsible for completing:

- A frequency injection test (FITD-Device) for each individual technology that is enrolled in any VPP. This is required only once per technology.
- A fleet-wide test (FITD-DUID) – this is required for new DUIDs and to verify that the fleet is capable of delivering the total capacity that it says it is capable of delivering[16].
  - *Note 1: under the VPP Demonstrations trial AEMO required test data to be provided demonstrating both raise and lower response. For BAU purposes this should only be required to be provided for raise **or** lower response to enable the registration of additional capacity. This is based on experience over the trial, and the growing infrequency of contingency FCAS events (especially lower events) that last for sufficient time to provide the requisite data to demonstrate both raise and lower services.*
- During the demonstration trial Tesla was also supportive of having an additional high-speed

Specifications for these tests are outlined in Table 1 below.

Table 2: FITD-Device and FITD-DUID tests for VPPs

		Registration	Verification
Device Level	**Conditions**	**Per technology (lab)**	**Per technology, per region (field)**
	Speed	≤50ms – device level lab-test	≤100ms with option one additional high speed (50ms) meter per technology per region.
	Location	Asset	Asset

[16] This approach largely aligns with the AEMO VPP Demonstrations Enrolment Form. The exception being the lesser fleet wide test requirement outlined in Note 1.

	Signals	Frequency Asset Power	Frequency Asset Power
	Service Demonstrated	Raise AND Lower	As per frequency deviation
DUID Level	Conditions	Per DUID (field)	Per DUID (field)
	Speed	≤100ms or ≤200ms during freq deviations 1sec outside of frequency deviations	≤100ms or ≤200ms during freq deviations 1sec outside of frequency deviations
	Location	Asset or Site	Asset or Site
	Signals	Frequency Asset or Site Power	Frequency Asset or Site Power
	Service demonstrated	Raise OR lower	As per frequency deviation

System visibility

- AEMO to reinstate API used for VPP Demonstrations trial
- At registration (initial and all updates), VPP operators are required to ensure that all systems are integrated into the AEMO API.
- Requirement to provide both registration data and verification data via the API.
- VPP aggregators should be able to ensure that compliance data is provided at ≤100ms intervals during frequency excursions and data is provided in ≤1 second intervals at all other times.
- This will provide AEMO with increased DER visibility and enable better fault detection for a range of different events.

Updates to registration – additional MW, new region, or additional technology types

The following approach is based on the enrolment approach that was undertaken as part of the VPP Demonstrations trial, and which should be maintained for BAU arrangements for VPP enrolment.

The FITD-Device test approach should be updated periodically by AEMO (with industry consultation) to ensure that AEMO is satisfied with the technical capability of the technology to provide the services accounting for power system security concerns.

The FITD-Device requirements also appear to be the ideal place for AEMO to include additional DER requirements, such as inverter based technologies needing to be compliant with the AEMO Short Duration Undervoltage Ride Through Test requirements (VDRT test)[17] or to require compliance with AS4777.2:2020.

Table 3: VPP enrolment test requirements

	Same Region	New Region
Same Technology	FITD-Device: Not required FITD-DUID: Required (see Table 1) Outcome: Capacity added to existing DUID.	FITD-Device: Not required (if technology is already registered under another DUID, no new test is required, only the FITD-Device report). FITD-DUID Required (see Table 1). Outcome: new DUID is created for additional region with single technology.
New Technology	FITD-Device: Required[18] FITD-DUID: Required (see Table 1) Outcome: New technology capacity added to existing DUID.	FITD-Device: Required FITD-DUID: Required (see Table 1) Outcome: New DUID created in new region with multiple technologies.

Note 2: the approach to new technologies should enable both switched and proportional controllers to be registered under the same DUID provided the VPP aggregator can demonstrate that the two responses can be verified

Compliance and performance verification

Compliance data

- As per Table 1 verification process should mimic registration process, albeit with less stringent measurement speed requirements.
- Verification data should be provided at 100ms resolution for events.
- VPP aggregators should maintain 1 second live data for the fleet at all other times to help with fault identification.

[17] https://aemo.com.au/en/initiatives/major-programs/nem-distributed-energy-resources-der-program/standards-and-connections/vdrt-test-procedure

[18] Note that if an alternative aggregator is already using this technology then AEMO may accept the same FITD-Device test report already provided.

Verification of performance

- FCAS verification tool updated to trapezoid method as per University of Melbourne recommendation in *Fast FCAS Sampling Verification in Support of MASS Consultation*.

Site list management

- Required for every new DUID and every capacity update to an existing DUID. To be maintained on an ongoing basis:
    - AEMO to remove sites with different FRMP from FRMP listed in with AEMO
    - Aggregator to add sites every time an increase in the Maximum Ancillary Service Capacity is approved by AEMO.
    - Data: NMI, Device ID, **Device Firmware version**. Aggregator to notify AEMO within [10] business days after release of new Firmware version and provide release notes to AEMO. AEMO may require a new FITD-Device or FITD-DUID if Firmware version update may impact delivery of FCAS services. A change to the dead band within +/-150mHz does not warrant a new FITD-Device or FITD-DUID, however the Aggregator shall notify AEMO of such change within [10] business days.

Attachment B – Tesla application note on measurement resolution.

APPLICATION NOTE:
POWER MEASUREMENTS ERROR

Methodology

Frequency Measurements (20ms)

This study uses 20ms frequency measurements in Queensland and New South Wales during the frequency disturbance that happened at 14:06 on 25th May 2021 following the loss of Callide C coal plant. These measurements were provided by the Australian Energy Market Operator (AEMO). They show that the frequency disturbance lasted about 15 seconds in QLD and 2 seconds in NSW. Therefore, the 60sec period following the Frequency Disturbance Time considered for the verification of performance for Fast Services, as per section 3.7.1. (a) (i) of the Market Ancillary Service Specification (MASS), covers the entire duration of the frequency disturbances observed in QLD and NSW on 25th May 2021.

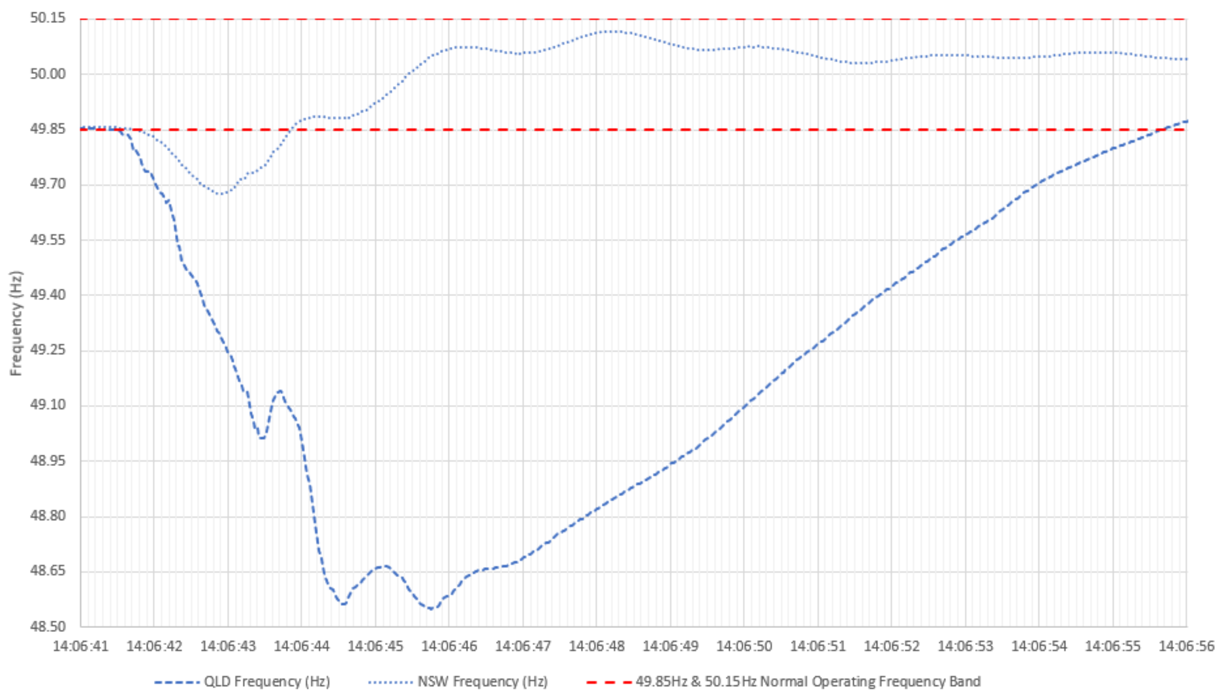

Figure 21 - AEMO's frequency measurements in QLD and NSW during the 25 May 2021 events (20ms sampling rate)

Power Response (20ms)

The response from a 5kW Tesla Powerwall 2 ("Powerwall") registered under Dispatchable Unit ID (DUID) VSSEL1V1 is 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.

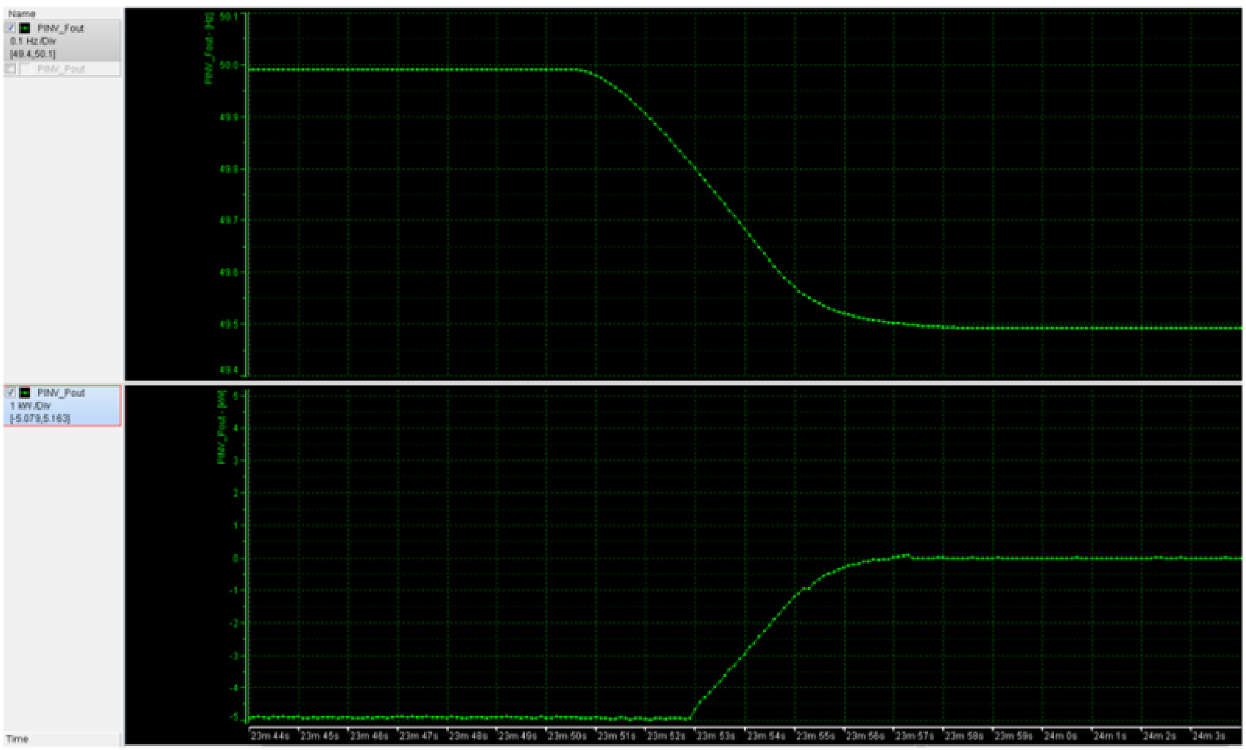

Figure 22 - Tesla Powerwall 2 Frequency Injection Test Results: 5kW Raise Response

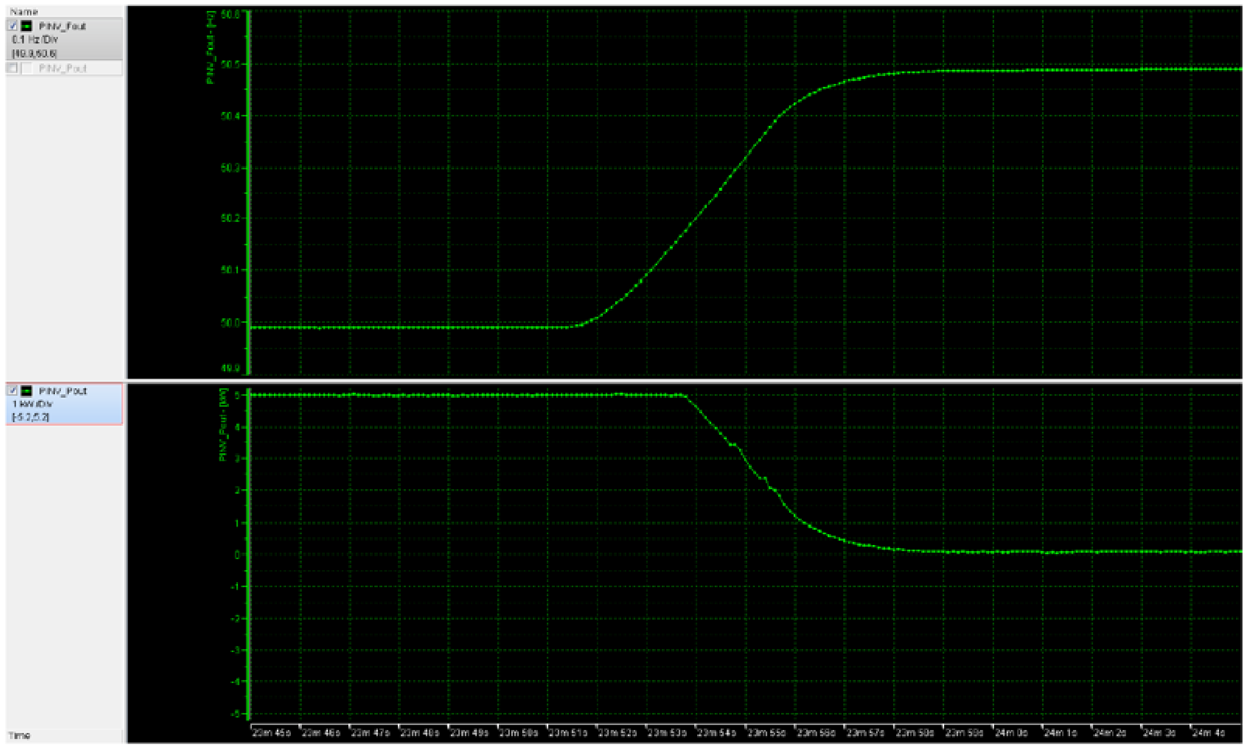

Figure 23 - Tesla Powerwall 2 Frequency Injection Test Results: 5kW Lower Response

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 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 1000 Powerwalls.

Sampling Rates (100ms, 200ms, 500ms and 1sec)

For each of the 1000 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 1000 Powerwalls is then aggregated using one of two aggregation methods:

- 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…

- The rounded method adds the responses with a time stamp of 60ms, 80ms, 100ms, 120ms or 140ms under time stamp 100ms, the responses with a time stamp of 160ms, 180ms, 200ms, 220ms or 240ms under time stamp 200ms, etc…

There are three other sampling rate scenarios, which all use the same method: 200ms, 500ms and 1sec. Figure 4 illustrates the 1 sec sampling rate scenario using the truncated method at three sites without introducing a 240ms delay and the error random variable, for clarity. Polling for each site happens at random and distinct 20ms intervals within a 1000ms interval. The 1 sec power response is then calculated as the *average* of the three distinct 20ms measurements for illustration purposes – as described above, to calculate the aggregate response, these values are summed.

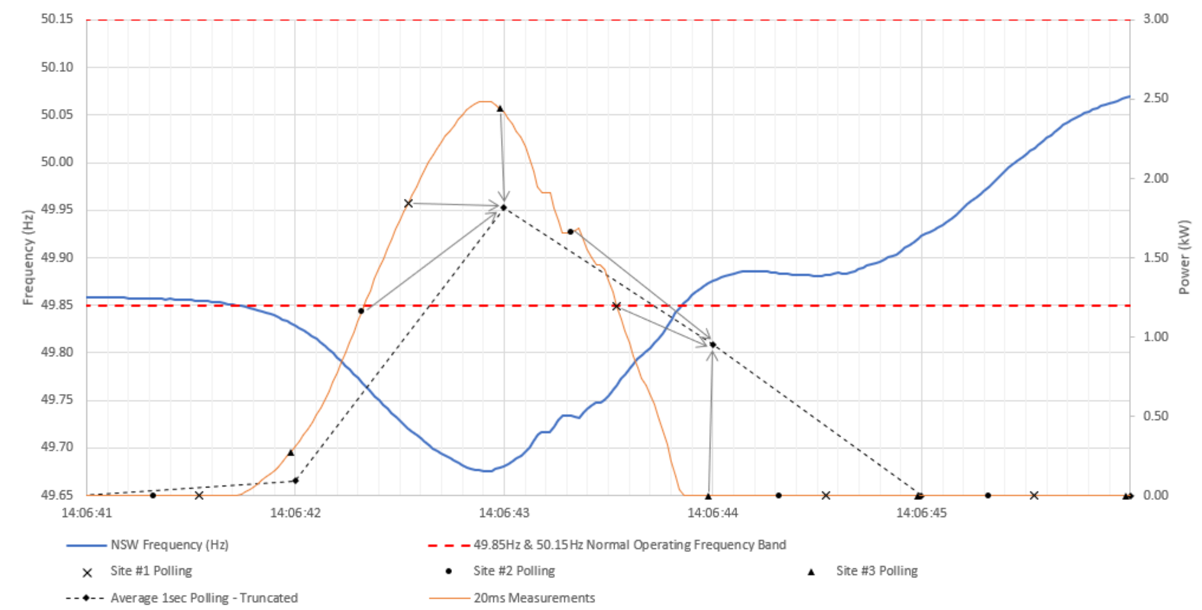

Figure 24 - Aggregation method for three sites (random 20ms polling, no delay, no error random variable, truncated method)

Figures 5 and 6 compare the *target* response – which has no 240ms delay, and no error and polling random variables – to the *actual* responses with varying sampling rates for 1000 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, 200ms, 500ms and 1sec scenarios.

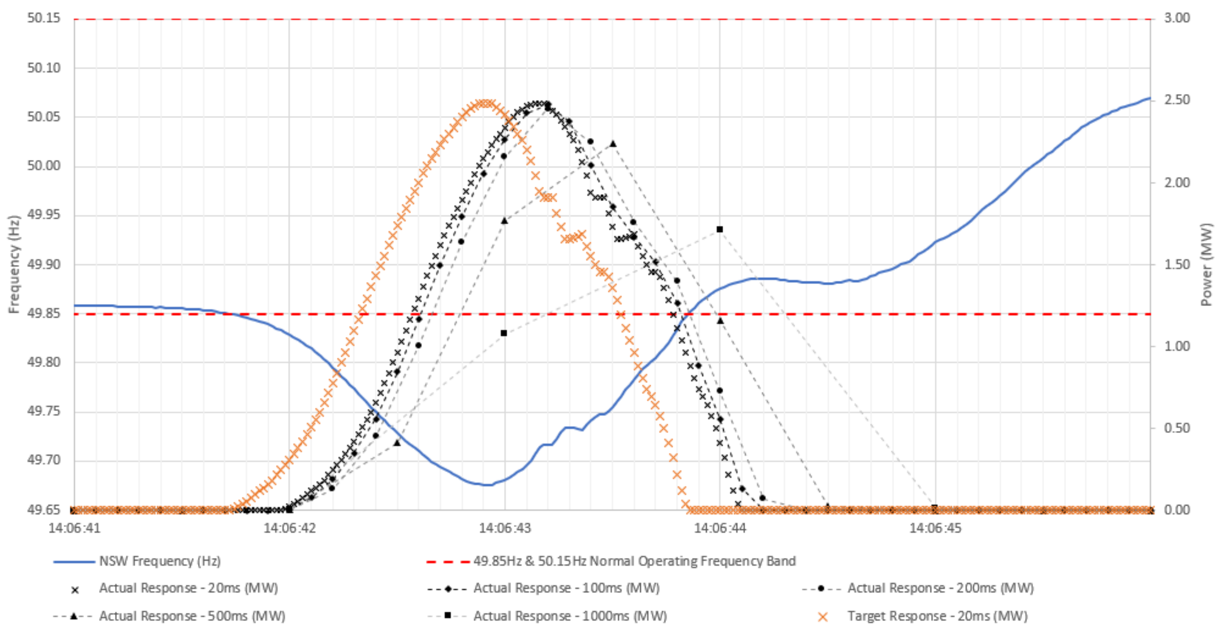

Figure 25 - Target and actual responses of 1000 Powerwalls in NSW to the 25 May 2021 events (varying sampling rates, truncated method)

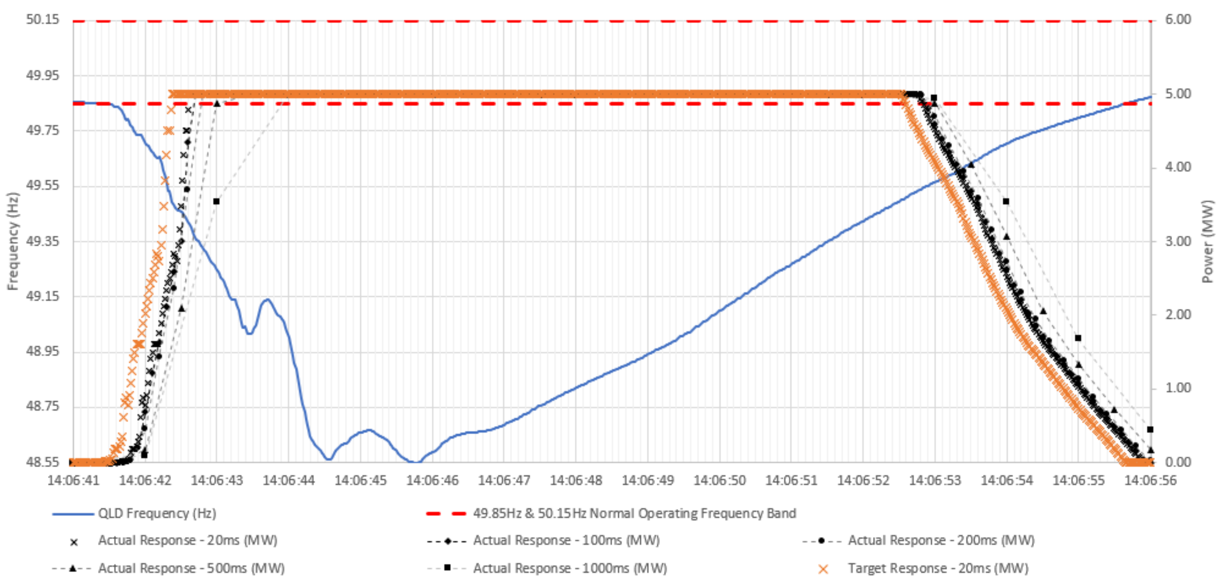

Figure 26 - Target and actual responses of 1000 Powerwalls in QLD to the 25 May 2021 event (varying sampling rates, truncated method)

For frequency deviations of short duration, the maximum power measured decreases as the sampling rate decreases due to the aggregation method, as illustrated in Figure 4. This is not the case for longer frequency deviations below 49.5Hz or above 50.5Hz lasting multiple sampling intervals. Indeed, QLD frequency deviation required a full 5kW response over 15 seconds, which means that there were multiple 1-second intervals during which the 5kW response of all 1000 sites could be measured.

Evaluation Metrics

Two metrics are used to estimate the measurement error between the actual response and the target 20ms response:

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

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, 200ms, 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.
- max(Target Response) is the maximum target power response over the 15 seconds interval
- max(Actual Response) is the maximum actual power response over the 15 seconds interval

The energy error formula uses the right Riemann sum method, similar to AEMO's FCAS Verification Tool, as AEMO mentions in section 4.1.2. of Amendment of the MASS – DER and General Consultation's Draft Report and Determination published on 14 June 2021.

A 50ms sampling rate scenario is also introduced since the MASS currently requires ≤50ms sampling rate to provide Fast FCAS services. For this scenario, the 20ms frequency data is first up-sampled to 10ms using linear interpolation. It is then down-sampled to 50ms by polling the 10ms frequency data every five intervals starting with time stamp ending in 0ms. A 250ms delay (multiple of 50ms) is then introduced, along with the error random variable, but no polling random variable was introduced since this methodology uses 50ms frequency data.

Monte Carlo Simulations

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

Energy Error (%)

Method	Nb of sites	Queensland 20	Queensland 50	Queensland 100	Queensland 200	Queensland 500	Queensland 1000	New South Wales 20	New South Wales 50	New South Wales 100	New South Wales 200	New South Wales 500	New South Wales 1000
		Sampling rate (ms)						Sampling rate (ms)					
Truncated	1	1.01%	1.02%	1.01%	0.99%	1.03%	1.13%	1.04%	0.98%	0.98%	1.03%	2.11%	5.04%
Truncated	10	0.29%	0.31%	0.29%	0.29%	0.30%	0.35%	0.29%	0.29%	0.30%	0.29%	0.62%	1.43%
Truncated	25	0.18%	0.19%	0.20%	0.19%	0.19%	0.21%	0.18%	0.18%	0.18%	0.19%	0.39%	0.88%
Truncated	50	0.13%	0.14%	0.12%	0.13%	0.14%	0.15%	0.13%	0.13%	0.13%	0.14%	0.28%	0.66%
Truncated	200	0.07%	0.06%	0.07%	0.07%	0.07%	0.08%	0.06%	0.07%	0.07%	0.07%	0.14%	0.31%
Truncated	500	0.04%	0.04%	0.04%	0.04%	0.04%	0.05%	0.04%	0.05%	0.04%	0.04%	0.09%	0.20%
Truncated	1000	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.07%	0.14%
Rounded	1	0.99%	0.98%	1.00%	1.01%	0.97%	1.17%	1.01%	0.99%	0.98%	1.00%	2.14%	4.99%
Rounded	10	0.31%	0.29%	0.27%	0.29%	0.30%	0.34%	0.29%	0.30%	0.30%	0.30%	0.63%	1.39%
Rounded	25	0.19%	0.19%	0.18%	0.17%	0.20%	0.22%	0.19%	0.18%	0.18%	0.20%	0.42%	0.87%
Rounded	50	0.12%	0.13%	0.13%	0.13%	0.13%	0.14%	0.13%	0.13%	0.13%	0.13%	0.29%	0.61%
Rounded	200	0.07%	0.07%	0.06%	0.06%	0.07%	0.08%	0.07%	0.07%	0.07%	0.07%	0.14%	0.32%
Rounded	500	0.04%	0.04%	0.04%	0.04%	0.04%	0.05%	0.04%	0.05%	0.04%	0.04%	0.09%	0.19%
Rounded	1000	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.06%	0.14%

Figure 27 - Monte Carlo simulation results for absolute value of energy error (500 simulations)

Power Error (%)

Method	Nb of sites	Queensland 20	Queensland 50	Queensland 100	Queensland 200	Queensland 500	Queensland 1000	New South Wales 20	New South Wales 50	New South Wales 100	New South Wales 200	New South Wales 500	New South Wales 1000
		Sampling rate (ms)						Sampling rate (ms)					
Truncated	1	1.00%	0.99%	1.00%	1.06%	1.04%	1.04%	0.96%	1.01%	0.99%	1.51%	5.89%	16.83%
Truncated	10	0.30%	0.30%	0.27%	0.30%	0.27%	0.30%	0.29%	0.30%	0.34%	1.23%	9.30%	30.22%
Truncated	25	0.18%	0.18%	0.19%	0.18%	0.18%	0.19%	0.18%	0.19%	0.24%	1.25%	9.21%	30.62%
Truncated	50	0.14%	0.13%	0.13%	0.13%	0.13%	0.13%	0.13%	0.13%	0.19%	1.26%	9.33%	30.64%
Truncated	200	0.07%	0.06%	0.06%	0.06%	0.06%	0.06%	0.07%	0.07%	0.16%	1.26%	9.35%	30.82%
Truncated	500	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%	0.16%	1.25%	9.35%	30.96%
Truncated	1000	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.16%	1.25%	9.37%	30.86%
Rounded	1	0.99%	0.98%	0.99%	1.01%	1.02%	0.99%	0.99%	1.00%	1.07%	1.42%	5.69%	16.44%
Rounded	10	0.30%	0.30%	0.28%	0.29%	0.30%	0.31%	0.29%	0.30%	0.70%	1.51%	8.89%	20.50%
Rounded	25	0.19%	0.20%	0.19%	0.17%	0.19%	0.18%	0.19%	0.19%	0.75%	1.50%	9.07%	20.10%
Rounded	50	0.13%	0.13%	0.13%	0.13%	0.13%	0.14%	0.14%	0.13%	0.78%	1.54%	8.96%	20.04%
Rounded	200	0.06%	0.07%	0.06%	0.06%	0.07%	0.07%	0.06%	0.07%	0.81%	1.55%	8.98%	20.12%
Rounded	500	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%	0.81%	1.54%	9.02%	20.03%
Rounded	1000	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.81%	1.54%	8.98%	20.03%

Figure 28 - Monte Carlo simulation results for absolute value of power error (500 simulations)

The energy error is less than the 2% allowable margin of error for power measurements for all scenarios except single sites in NSW with 500ms or 1000ms sampling rates. This means that a sampling rate of 200ms or less ensures that for any number of sites, both energy and power error remain less than 2% for the QLD and NSW frequency deviations, and for the truncated and the rounded methods. A minimum of 1MW is required to register a Virtual Power Plant in the FCAS markets, i.e. no fewer than 200 Powerwalls.

The power error is less than 2% except for 500ms and 1000ms sampling rates in NSW. The power error for 1000ms sampling rate in NSW is lower for single sites than for multiple sites because:

For single sites, the power error can range:

- from +2% if a) the 1sec polling happens during the 20ms interval when the power measurement is highest (2.48kW for a 5kW Powerwall), and b) the power measurement error is +2%
- to -41% if a) the 1sec polling happens during the two 20ms intervals when the maximum value across these two intervals is the lowest (1.50kW), and b) the power measurement error is -2%
- and given the NSW frequency measurements, it is slightly more likely that the 1sec polling of a single site yields a maximum power measurement closer to 2.48kW than to 1.50kW
- as a result, the average absolute value of the power error for a single site is around 17%.

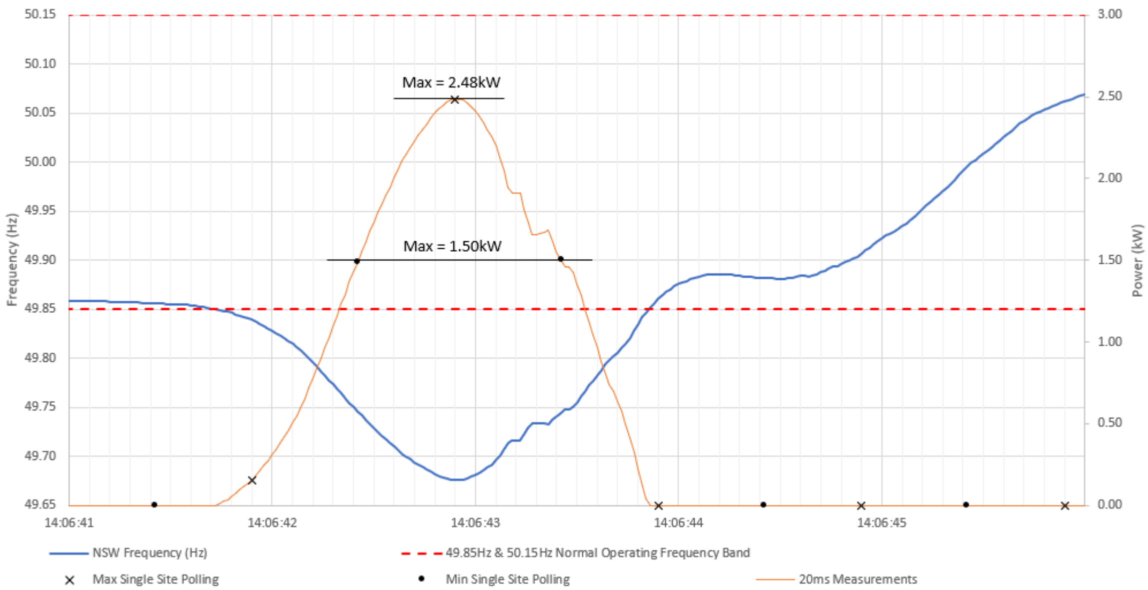

Figure 29 - Single site power error using NSW frequency measurements (no delay, no error random variable)

For multiple sites, the error depends on the average measurements across these sites, as shown in Figure 4, and varies based on the method (rounded or truncated) and the delay. With the truncated method, and a 240ms delay, given that the power response starts with time stamp ending in 20ms (i.e. beginning of a 1sec interval) and lasts for two seconds, the power error is a function of the max of:

- the average of the fifty 20ms power measurements over the first 1-sec interval (1.03kW), and
- the average of the fifty 20ms power measurements over the next 1-sec interval (1.75kW)
- as a result, the average absolute value of the power error for multiple sites is around 31%.

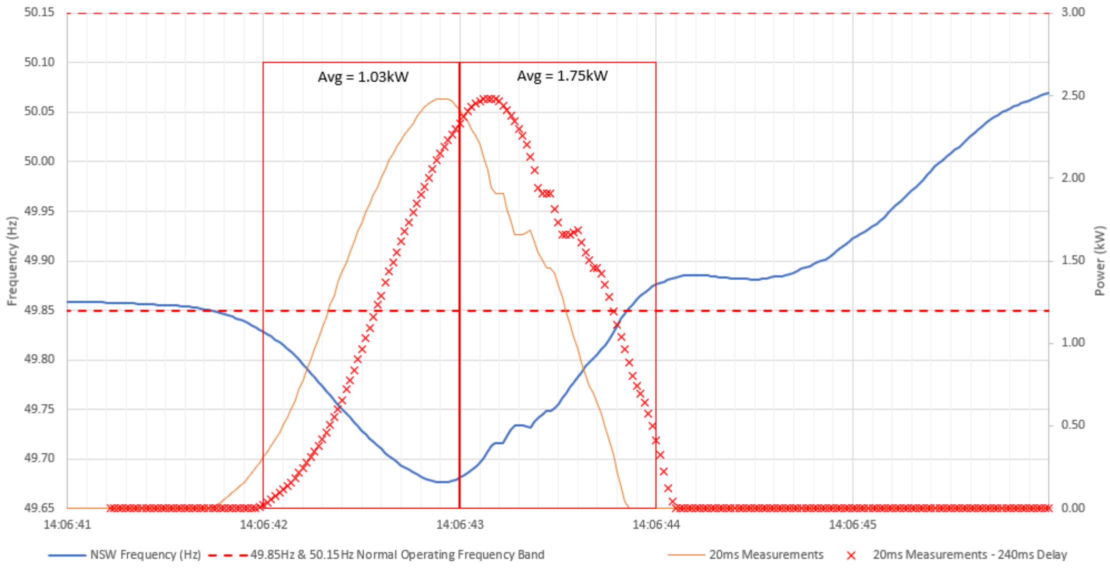

Figure 30 - Multiple sites power error using NSW frequency measurements (240ms delay, no error random variable, truncated)

Lastly, Figures 7 and 8 show that the difference between the truncated and rounded methods is negligible (<0.5%) except for power error with 1sec sampling rate scenario in NSW, as explained above.

The chart below shows the energy error results of the 100 different Monte Carlo simulations across different sampling rates using the rounded method.

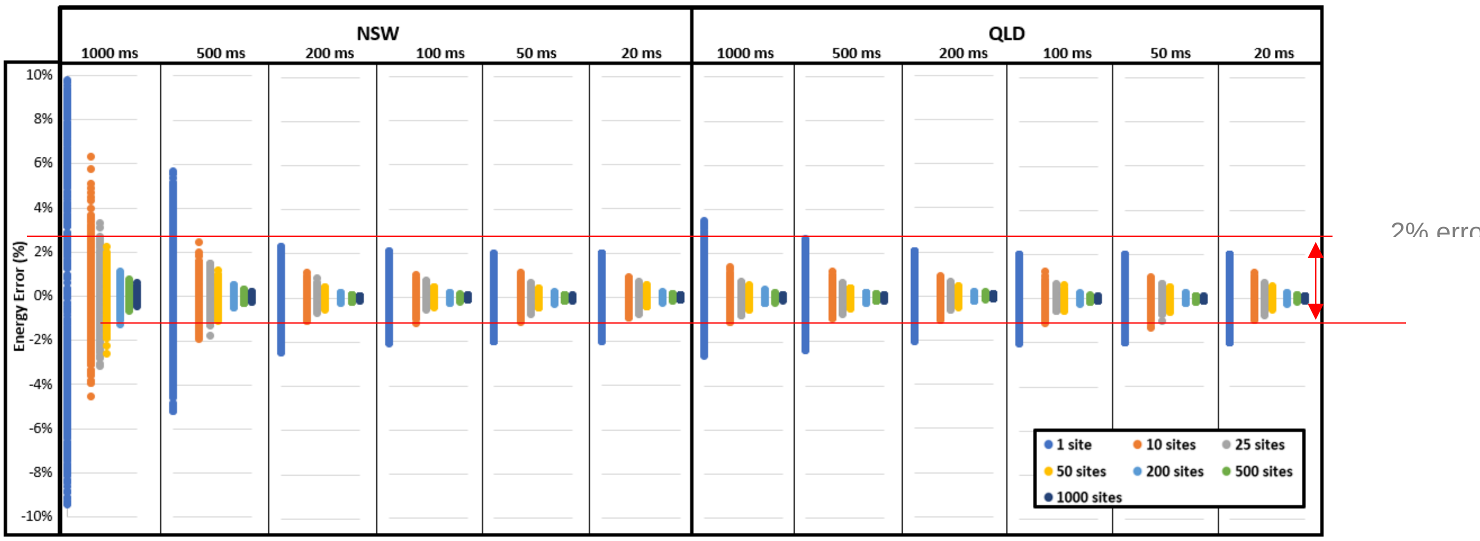

Figure 31 - Energy error distribution of Monte Carlo simulation using rounded method (500 simulations)

Figure 11 shows that as number of sites and sampling rate increase, the variance of the energy error reduces significantly. Interestingly, the number of sites has a larger impact on the energy error variance than the sampling rate. Indeed, with 1000 sites, the energy error calculated for each simulation stays well within +/-0.5% for any sampling rate, and with 200 sites (the minimum required to register in FCAS markets) it stays within +/-1% for any of the 500 simulations.

For comparison, in NSW, where the duration of the frequency deviation is short, the energy error for a single site is reduced from +/-10% with 1sec sampling rate to +/-2.5% with 100ms sampling rate; in QLD it is reduced from +/- 4% to +/-2%.

Conclusions

Errors of less than 0.5% are considered negligible. Errors between 0.5% and 1% are considered minimal. Errors between 1% and 2% are considered acceptable given the ≤2% of measurement range margin of error for power measurements allowed by the MASS.

- Energy error: For any sampling rate and both frequency deviations, the energy error is negligible for 200 sites and more. It exceeds 2% only for a single site, when sampling rate is 500ms or 1sec.
- Power error:
  - Maximum actual response is lower than maximum target response for multiple sites.
  - In QLD, where the frequency deviation exceeds +/-500mHz for multiple seconds, the power error is negligible for 10 sites or more and for any sampling rate.
  - In NSW, where the frequency deviation is only +/-350mHz for fewer than 3 seconds, the power error is minimal with 100ms measurements for 10 sites or more, and it is acceptable for 200ms measurements for any number of sites.

<table>
<tr><td>20ms...</td><td rowspan="4">...sampling rate keeps power and energy errors <0.5% for...</td><td>...10 sites and more...</td><td colspan="4" rowspan="2">...for both the QLD and NSW frequency deviations, and for both the truncated and the rounded methods.</td></tr>
<tr><td>50ms…</td><td>…10 sites or more…</td></tr>
<tr><td>100ms...</td><td>...10 sites and more...</td><td rowspan="2">...for both the QLD and NSW frequency deviations, and for both</td><td rowspan="2">...except for the power error for NSW frequency deviation</td><td>...0.5% and 1%...</td><td>...using the rounded method.</td></tr>
<tr><td>200ms...</td><td>...10 sites and more...</td><td>...1% and 1.6%...</td><td>...whether the truncated</td></tr>
</table>

500ms...		...25 sites and more...	the truncated and the rounded methods...	where it is between...	...9% and 10%...	method or the rounded method is used.
1000ms...		...200 sites and more...			...20% and 30%...	