MASS Consultation Paper Submission

Reposit Power

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1 Executive Summary

Reposit Power thanks AEMO for the opportunity to contribute to the January 2021 Market Ancillary Service Specification (MASS) consultation. This submission is primarily concerned with Section 2 of this consultation. Section 3 of the consultation is addressed in brief.

Reposit is a small, Australian company based in Canberra that was founded in 2012. It has been built with less than $10M in equity spent to date and has controllers on more than 6000 DER assets in the NEM providing energy, FCAS and various DNSP services.

Reposit commercially operates and is actively growing a 7MW VPP (DUID: ASNAES1) in all contingency FCAS markets under the full obligations of the MASS v6. This FCAS facility operates in the open contingency FCAS markets. That is, it is not part of AEMO's VPP Demonstrations project and does not require the relaxations afforded to trial VPP providers to participate in FCAS provision.

The health and growth of this facility is strong evidence that no alterations are required to the MASS or the NER to allow DER to participate in all contingency FCAS markets. This submission presents detailed regulatory and electrical arguments for Reposit's position drawing upon Reposit's eight years of experience in operating VPPs in the NEM and one year of operating a non-trial, multi-MW, multi-vendor, multi-market contingency FCAS facility in the NEM.

1.1 Key Arguments

Consistent metering requirements for all Fast FCAS market participants
Reposit is opposed to any optionality in the measurement and verification of FCAS services. Reposit believes that the measurement and verification processes in the MASS should be consistent for all NMIs regardless of capacity, technology type, market participation status or other differentiating factors. This approach promotes the achievement of the NEO and is consistent with the market design principles currently described in the National Electricity Rules.

MASS v6 compliant metering has a marginal cost of no more than $120/NMI
MASS compliant metering is cost-effective for all scales of generation and load (**Section 2**).

DER responses from units of the same "type" are not the same
Many factors influence the speed, volume and stability of energy delivery from, or absorption to, a DER device. These factors are different for each particular device, and change in an unsynchronised way over time. This makes an assumption of response homogeneity invalid. As such responses cannot be "deemed" as a result of type testing (**Sections 3.3.3.3, 3.3.4.3**).

Option 2 metering will damage system security
Only precise metering of Fast FCAS response at the *Connection Point* can be relied upon if a high certainty of arresting high-speed frequency deviations is required for system security. Option 2's deeming approach introduces between 16-22% new uncertainty to a DER unit's contribution to arresting a frequency deviation. System security will be materially damaged where a significant proportion of Fast FCAS is provided by Option 2 metered DER (**Section 3.4**).

More Fast FCAS will need to be procured at the expense of Consumers
AEMO will not compromise system security for the benefit of some VPP providers. AEMO will be required to purchase additional Fast FCAS MW to increase the certainty of arresting a frequency deviation. This additional cost is inefficient and degrades the NEO. This additional FCAS will come at the additional cost to consumers of approximately $1M for every 20,000 Option 2 DER units (**Section 4.2**).

Option 2 is a wealth transfer from Consumers to Option 2 metered participants
Consumers will unnecessarily pay Option 2 metering providers at least $60/DER device/year if Option 2 is adopted. This wealth transfer does not occur under Option 1 metering (**Section 4.2.4**).

Option 2 metering will be replaced by Option 1 metering within 5 years
The availability of very fast new system services and DER's participation in them will drive the refitting of Option 2 metering in the NEM. This represents an inefficiency of $60,000/MW in refitting cost (**Section 4.3.2**).

Option 2 damages investment efficiency across all AEMO markets
The adoption of Option 2 penalises early market entrants and hence discourages technology innovation in the NEM. Likewise it heralds a new source of regulatory uncertainty and will necessarily increase investment discounting. Both create new investment inefficiency and are contrary to the NEO (**Section 4.4**)

Option 2 violates the Market Design Principles stated in the NER
The National Electricity Rules clearly specify:

- 3.1.4(a)(3) - avoidance of any special treatment in respect of different technologies used by Market Participants
- 3.1.4(a)(5) - equal access to the market for existing and prospective Market Participants

Metering optionality, particularly a technology-specific relaxation such as Option 2 is in clear violation of these principles (**Section 5.1**).

1.2 Responses to AEMO's questions

Reposit's submission to this issues paper is substantial. It analyses Option 2 in depth from various perspectives. The answers to AEMO's questions are embedded in the analysis. Points significant to the question are raised here and further detail is available in the referenced section and its supporting sections.

1.2.1 Question 1

Which option for the ongoing measurement requirements for DER described in Section 2.3 do you want AEMO to implement and why? Should any other options be considered?

Reposit asserts that AEMO should require all Fast Contingency FCAS market participants to implement Option 1 metering.

Option 1 metering is cost-effective and accessible to all participants (**Section 2**).

Fast FCAS relies on a low-error delivery or withdrawal of energy from the grid to arrest a frequency deviation. Uncertainty caused by increased error in energy delivered or withdrawn will result in diminished system security. Option 2 metering introduces between 16%-22% (**Section 3.4**) additional error into Fast FCAS when compared to Option 1. This will result in a material reduction in system security and should be avoided (**Section 3**).

Option 1 metering results in a more efficient procurement of Fast FCAS. The additional error created by Option 2 metering must be accommodated with discounting. This is inefficient at a cost of $48/DER unit/year (**Section 4.2.3**).

Option 1 metering is the only equitable option presented. Option 2 metering results in up to $60/DER unit/year being unnecessarily transferred from consumers to Option 2 metered participants. This wealth transfer does not occur with Option 1 metering (**Section 4.2.4**).

Option 1 metering is more efficient when the long term interests of consumers are considered. Option 2 metering results in a long-term loss of at least $60,000/MW as a result of meter replacement due to the definition of future services (**Section 4.3**).

Option 1 metering promotes innovation, investment and technology development in NEM FCAS markets. The implementation of Option 2 metering irrevocably damages future investment across all current and future AEMO operated services (**Section 4.4**).

Option 1 FCAS response is measured and managed with provably low-error energy computations. Option 2 FCAS response is estimated using unvalidated and ungeneralisable assumptions, uncharacterised error and uncontrolled future states (**Sections 3.3.6 and 4.5**).

Option 1 metering is aligned with the market design principles described in the National Electricity Rules. Option 2 metering clearly violates these principles (**Section 5.1**).

1.2.2 Question 2

Which option do you think is more consistent with the NEO, and why?

Option 1 metering is more consistent with the NEO. Option 2 metering is inefficient (**Section 4.2.3**), does not consider the long term interests of consumers (**Section 4.3.2**), discourages efficient investment (**Section 4.4**) and diminishes system security (**Section 3.4**).

1.2.3 Question 3

Should AEMO consider any principles other than those described in Section 2.4 to guide its assessment?

AEMO is legislated in the National Electricity Law to have regard to the National Electricity Objective when carrying out its statutory functions (**Section 4.1**). AEMO is also obligated to obey the National Electricity Rules and the market design principles held within (**Section 5.2**).

Reposit asserts that any other principles are either encapsulated in the NEL, NEO or NER already, or are irrelevant (**Section 4.1**).

1.2.4 Question 4

What is the difference in implementation costs, such as updating the communication links or installing additional equipment, for capturing data at a resolution of either 50 ms or 1 second for every NMI for different VPP facility types? Do you consider the cost difference to be prohibitive for participating in the Contingency FCAS markets? Please provide examples or analysis if possible.

In 2016 Reposit was delivering fully MASS v6 compliant metering at $97/phase. This is not the marginal cost of MASS compliance, but the cost of the entire meter/phase. In 2021 Reposit delivers better than MASS v6 compliant metering at a marginal cost of $25/phase. That is, the marginal cost of MASS v6 compliant metering over 1 second, low accuracy/precision metering is $25/phase. Reposit has demonstrated technology to bring this marginal cost down to $15/phase (**Section 2.1**).

It is extremely conservative to state that fully MASS v6 compliant metering can be delivered to any residential connection point in the NEM for a lifetime marginal cost of less than $120 (**Section 2**).

1.2.5 Question 5

Do you think that either of the options presented will result in more or less competition in the Contingency FCAS markets?

Option 2 will result in more Participants in Fast FCAS markets but less competition. Option 2's assumption of homogenous response across a DER "type" removes the key objects of competition between VPP providers in FCAS. They are:

1. Stable and reliable control of distributed energy storage sufficient to deliver a fast, sustained and linear response
2. Time synchronised response across large numbers of DER units
3. Efficient forecasting of energy available to a service a contingency event given DER unit current and future state
4. Efficient forecasting of energy available to a service a contingency event given uncontrolled loads at the connection point

All of the competitive objects above are made irrelevant by Option 2. Option 2 removes this competition to the detriment of system security and the efficiency of Fast FCAS. DER unit response is not homogeneous within a type (**Sections 3.3.3.3 and 3.3.4.3**). Homogeneous response is the ideal, it is far from a given. Stronger competitors will be able to provide a more homogeneous response than weaker competitors.

FCAS measurement and verification processes reward fast, sustained and stable responses from VPPs with the ability to submit higher bidding volumes. Because Option 2 assumes a homogeneous response, and introduces device-level metering, all VPP providers will simply offer the sum of their nameplates into Fast FCAS. This will be regardless of whether the whole summed nameplate capacity will act to support a fast contingency event when one arises.

Option 2 providers are also advantaged during customer acquisition as a result of a lower initial cost of metering. Likewise they are advantaged through the avoidance of having to manage and process per NMI 20Hz data to inform AEMO measurement and verification, as well as system security improvement processes. Additionally they do not need to find cost-reductions on advanced metering as they are largely exempted from it.

Option 2 also heavily advantages VPP providers that are connected with a vertically integrated controller+battery+inverter manufacturer. This is because the Option 2 requirements to type test and install "5MW meters" are much more onerous for a commercial entity that has many "types" of DER. This penalises the aggregation of different "types" of DER within a single commercial entity. This will act as a strong barrier against customers switching from a VPP provider which is discrete from the manufacturer of their DER hardware.

Option 1 has none of these competitive issues and has no substantial barriers to entry (**Section 2**) or customer switching.

1.2.6 Question 6

Are there any technical risks that you envisage if the Option 2 measurement requirements are allowed? How material do you consider those risks and how could they be efficiently mitigated?

Option 2 metering will increasingly diminish the security of the NEM (**Section 3.4**). Materiality will increase to critical levels as more Option 2 DER is introduced into Fast FCAS markets. AEMO (**Section 3.4.1**), ENA and CSIRO (**Section 4.5.1**) reports suggest that this will occur within 5 years.

1.2.7 Question 7

Does the sampling rate of one second rather than 50 ms for Fast Contingency FCAS under Option 2 and the determination of the FCAS delivery at the inverter/controllable device level create market distortion or negatively impact the FCAS markets?

The 1Hz sampling rate and the device level metering create unacceptable error bounds of 16-22% in Fast FCAS response (**Section 3.4**). AEMO will not diminish system security and will procure upwards of 4% additional Fast FCAS for every 120,000 Option 2 DER units enabled for Fast FCAS. This will result in an unnecessary wealth transfer from consumers of at least $9600/MW/year to Fast FCAS providers (**Section 4.2.3**).

Additionally, consumers will subsidise only Option 2 metered DER VPPs at the rate of $12/year/Option 2 DER unit in the form of reduced metering costs. This results in a total wealth transfer of at least $60/year/Option 2 metered DER unit (**Section 4.2.4**).

By assuming unit response homogeneity, AEMO will also be removing the incentive for VPP providers to produce a stable and homogenous response across their VPPs. This will reward poor VPP control and penalise investment in strong VPP control. This is clearly not desirable and represents a significant market distortion (**Sections 3.3.3.3, 3.3.4.3 and 3.4.1**).

1.2.8 Question 8

If Option 2 was adopted, should the changes to the measurement requirements of the MASS be limited to small-scale DER (under 1 MW per NMI), or should a different threshold apply, such as 5 MW? For example, what do you see as the risks and benefits of expanding these measurement requirements to other FCAS providers and in what circumstances might that be appropriate?

Option 2 metering requires the assumption that a FCAS providing unit responds identically to units of the same “type” for each frequency deviation and for all time. This assumption is known by Reposit to be incorrect and has been shown to be so by the limited information provided by the VPP Demonstrations project. (**Sections 3.3.3.3, 3.3.4.3)**

Increasing MW of Option 2 metered plant increasingly damages system security and NEM efficiency (**Section 3.4**). Allowing larger units to be Option 2 metered simply reduces the amount of time that AEMO has to address this new threat to system security.

Additionally, Option 2 metering limits towards becoming Option 1 metering (disregarding the device-level metering) as the number of units of a “type” approaches 1. This means that it is irrelevant unless there is a large number of identical units deployed as would be the case if a single vendor were to become dominant in the market. This would indicate a market failure and would be addressed by market bodies and participants via the NEM’s regulatory mechanisms.

2 Metering Cost Analysis

MASS-compliant metering is cost-effective for deployment on residential connection points today. This has been the case for at least five years. It is the result of cost-reductions in electrical quantity measurement facilitated by low-cost, high-speed analogue to digital converters (ADCs) and embedded computing. All of Reposit's installations have included MASS-compliant metering since 2016.

Reposit operates the largest in-market FCAS participating Virtual Power Plant (not under trial or demonstration conditions). This is a result of investments made into research and development in 2013-2015 in the area of MASS-compliant metering. The Fast FCAS metering requirements of the MASS have not changed since at least 2012 and this has provided ample time for VPP aggregators to make the required investments.

Reposit is able to meter up to 3 grid phases at the 20Hz metering requirement, as well as additional metering for subcircuits or legacy AC solar with lesser requirements, on a single RS485 bus. The fact that Reposit has been able to do this sustainably for over 5 years makes it very clear that such metering is technologically possible, commercially viable and cost effective.

Given that MASS-compliant metering is already proven to be commercially viable, Reposit asserts that it is a key enabler of DER and the wider transition to renewables. Furthermore it would seem that the metering time-resolution change proposed in Option 2 would penalise the metering innovations of Reposit and others made up to this point.

2.1 Marginal cost of high-speed metering is small

Reposit's first generation, MASS-compliant metering cost $97/phase. This metering was designed in 2015. Reposit has continued to invest in MASS-compliant metering and now has a cost of not more than $25/phase. This cost includes all metering ICs, supporting components, PCB, manufacturing, high-accuracy CTs and calibration. The cost-down design work was done by 1.5 FTE hardware/electronic engineers and 1 FTE firmware engineer. The total metering development costs at Reposit over the last 8 years are approximately $340,000, or $43,000/year.

To a consumer, $25 per phase adds no more than $75 to a solar and battery system which typically costs between $5,640 - $19,440 or 1.3% - 0.39% as of February 2021[1]. There are no additional installation requirements given that both Option 1 and Option 2 require connection point metering, and MASS-compliant metering is virtually physically identical to non-MASS-compliant metering.

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[1] https://www.solarchoice.net.au/blog/battery-storage-price

Reposit cannot comment on the cost of competitor metering and so for additional conservatism has assumed that it is zero cost. This is clearly inaccurate, but it is the best possible case for the combined cost of the required Option 2 grid metering and the Option 2 device-level (device internal) FCAS metering.

In the interests of conservatism, Reposit assumes that all NMIs attract a $120 lifetime additional cost for Option 1 (MASS-compliant) metering over Option 2 metering. This includes all hardware and data costs. This is an overestimation of between 4.8x and 1.6x depending on the proportion of three-phase residences in the NEM.

2.1.1 Fast frequency measurement costs are low and falling

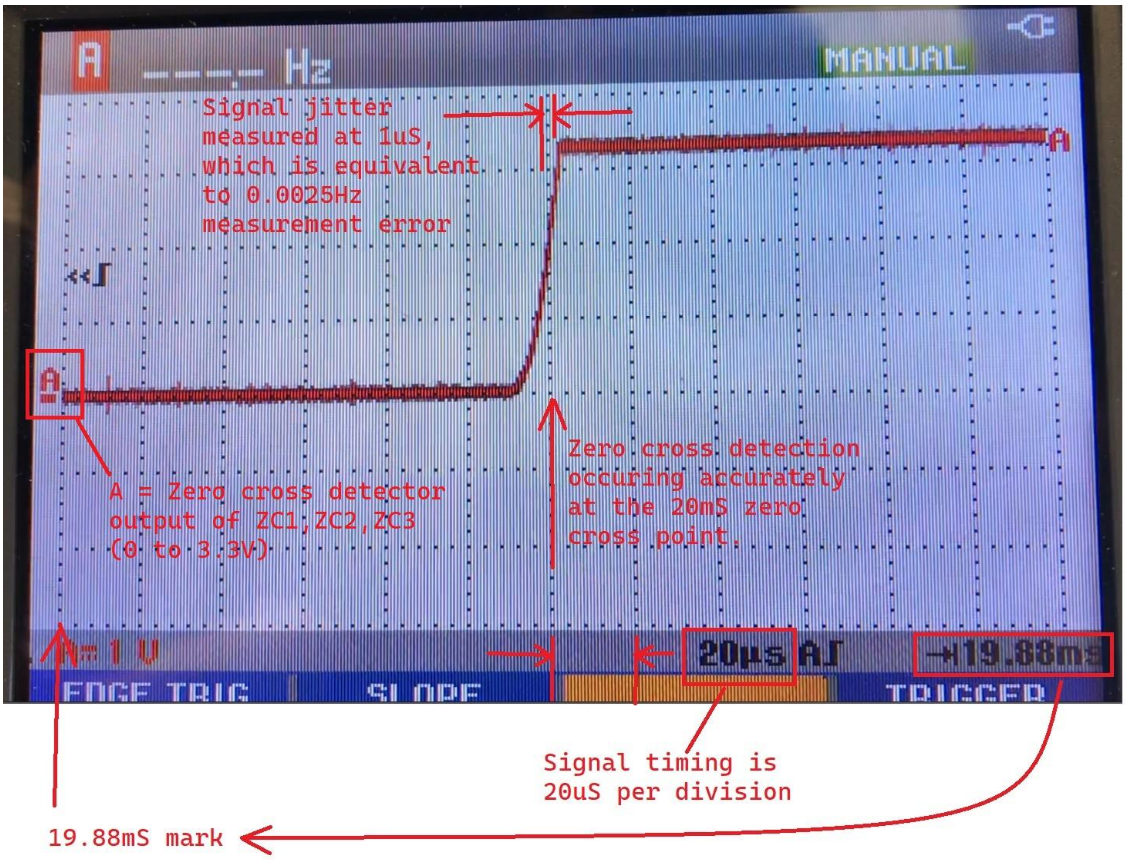
Reposit continues to seek lower-cost MASS-compliant metering. Development efforts have identified the use of a "Zero Cross Detect" (ZCD) mechanism as being able to deliver MASS-compliant frequency measurement. This approach implements a circuit that simply emits a signal every time the sine wave of the reference signal crosses zero. In the case of grid metering this refers to the AC sine wave. Many off-the-shelf, low cost metering integrated circuits (ICs) already contain such functionality and can emit the signal to a low cost PIC Microcontroller for further processing. These ICs and PICs are both readily available from IC manufacturers such as Microchip and Analog Devices.

Reposit experimented with designing and implementing a native Zero Cross Detect circuit. This simple circuit was designed with nothing but capacitors, resistors, op amps and an oscillator. The total component cost of this circuit was $2.31. The bill of materials for this circuit is below:

Name	**Value**	**Quantity**	**Cost (AUD)**
Capacitor	100nF	15	0.00312 at 10k
Capacitor	10nF	5	0.01039 at 4k
Capacitor	4.7uF	10	0.00971 at 4K
Resistors	1M	3	0.00331 at 10k
Resistors	47k	6	0.03682 at 5k
Oscilator	10MHz	1	1.60426 at 1k
MCU	16 Bit MCU	1	4 /unit
Isolator	ISO7730FDW	1	1.57248 at 2k
op amps	LM321LV	3	0.09260 at 3k

Reposit projects that further development of this approach would result in MASS-compliant metering at no more than $15/phase.

This circuit has been verified under lab conditions with a reference frequency of 50Hz and the output observed using an oscilloscope. The results of this test can be seen in the annotated oscilloscope output below.



Of note in this oscilloscope output is that this circuit delivers :

- Reliable zero cross detection at 20mS (the interval of zero crossings you would expect at 50 Hz - 1s / 50 Hz)
- Signal jitter at 1uS for 0.0025 Hz error - in line with the requirements of the MASS.

Similar circuits are well documented in electronics engineering literature, and are easily found via simple Google searches.

2.1.2 Fast energy measurement costs are low and falling

Whilst the MASS imposes tight requirements in terms of accuracy and precision of frequency measurements - “error of less than or equal to 0.01 Hz, and resolution of less than or equal to 0.0025 Hz”[2] - power requirements are notably less stringent and allow “error of less than or equal to 2% of the measurement range, and resolution of less than or equal to 0.2% of the measurement range”. Power measurements that greatly exceed these requirements (even when coupled with

[2] AEMO MASS v6 - item 3.6.vi, Available: https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2020/primary-freq-resp-norm-op-conditions/market-ancillary-services-specification---v60.pdf

low cost CTs) are available via a wide range of metering ICs including the low cost Microchip ATM90E36A[3] 3-phase SOC available for under $5[4].

Open source development kits or breakout boards can be found for a range of suitable ICs including the ATM90E36[5], MCP39F511[6] and ADE7816[7] at costs of less than $65 for a full development kit. It is worth noting that these development kits have not been developed for commercial deployment and that the economies of scale, cost engineering and design for manufacture would all contribute to dramatically lowering this cost.

Low-cost, MASS-compliant power measurement is a trivial problem. Full MASS compliance for power and frequency can be delivered at not more than $15/phase in 2021.

2.2 High speed metering data costs are negligible

Reposit asserts that the data costs for high-speed metering are negligible. Reposit does not dispute that the transfer and storage of 20Hz data 24/7 is costly. However there is no requirement under the MASS to stream 20Hz data 24/7. The data requirement is that the six seconds prior and sixty seconds after an FCAS fast event are captured and stored. As such it is entirely feasible to discard any high-speed data that does not meet this criteria and only transfer the high-speed data as required. All DER aggregators must have software to detect a contingency event in order to respond to it. This same process is easily leveraged to gather the required high-speed data for a contingency event, and discard all other data.

By way of comparison, Reposit uses five second data as the standard operational data collection, transfer and storage interval. This equates to approximately 17,280 data points per device per day or 518,400 per month. 66 seconds at 20Hz for three phases is 3,960 samples per FCAS fast event per device. Since the introduction of the Primary Frequency Response[8] Rule Change Reposit is observing approximately two Fast FCAS events per month or a total of 7,920 samples per month. This means that the overhead of 20Hz FCAS data adds 0.02% to our overall data transfer and storage.

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[3] https://www.microchip.com/wwwproducts/en/atm90e36a

[4] https://www.digikey.com.au/products/en/integrated-circuits-ics/pmic-energy-metering/765?k=ATM90E36A

[5] https://www.tindie.com/products/whatnick/three-phase-energy-monitor-atm90e36-featherwing/

[6] https://www.tindie.com/products/whatnick/mcp39f511-breakout/

[7] https://www.tindie.com/products/whatnick/ade7816-breakout/

[8] https://www.aemc.gov.au/rule-changes/mandatory-primary-frequency-response

A naive (capture and transfer everything 24/7) approach to handling 1Hz data creates approximately 2,592,000 data points per month. This is over 300 times higher than the simple approach to high-speed data described above. Reposit suggests that it is not the frequency of the data that creates cost, but a lack of sophistication in data management. Strong data management is a key competitive advantage for a VPP aggregator.

3 Option 2 Metering Analysis

Section 2.3 of the AEMO consultation paper proposes two options for the inclusion of VPP Demonstrations capacity in FCAS markets. Option 1 is to require all VPP Demonstrations capacity to meet the full requirements of MASS v6. Option 2 is to include the VPP Demonstrations measurement requirements into the MASS. Reposit considers Option 2 to be inconsistent with the NEO. The rationale for this statement is presented below.

3.1 Option 2 formulation

Option 2 modulates only two parts of the MASS v6 measurement requirements. NMIs with less than 1MW of capacity* can choose between the following metering requirements[9]:

	MASS v6	**Option 2**	**AEMO rationale for Option 2 relaxation**
Time resolution of power flow and local frequency measurement	50ms	<1000ms	AEMO states it has been able to identify under-delivery of FCAS using 1Hz data[10]
Frequency injection test required for every controller + inverter + battery combination	Required (see Feb 2021 Reposit registration)	Required	(Not provided) Reposit posits that AEMO is characterising DER “type” and is assuming homogeneity of response across type.
50Hz meter at full MASS precision and accuracy requirements	Required on all *Connection Points*	Required at one device for every 5MW of capacity* per region	(Not provided) Reposit posits that AEMO is characterising DER “type” and is assuming homogeneity of response across type.
Power measurement location for the verification of FCAS delivery	*Connection Point*	Inverter or Controllable device	(Not provided) Reposit posits that AEMO is satisfied to disregard the error introduced into FCAS response by site loads.

[9] MASS Consultation Paper - January 2021 - Section 2.3.2
[10] MASS Consultation Paper - January 2021 - Section 2.2.1

*AEMO does not specify how this capacity is to be measured or specified.

AEMO has not provided a complete engineering argument for these relaxations of MASS v6 requirements. These relaxations were formulated during the design of the VPP Demonstrations project as part of hypothesis building. The VPP Demonstrations project must have rationale and supporting data to show that these relaxations have no material effect on the effectiveness or efficiency of FCAS delivery. Other than AEMO's assertion that under-delivery could be identified, these rationales and data have not been presented in the Knowledge Sharing Reports, nor in this MASS Consultation Paper.

AEMO states that the VPP Demonstrations have informed the new or amended arrangements[11]. It is appropriate that AEMO present formal engineering arguments and raw supporting data that support the relaxations provided in Option 2. Without this data stakeholders are forced to propose AEMO's arguments for these relaxations. This is not conservative. AEMO are presenting a material change to the operation of Fast FCAS informed by AEMO's VPP Demonstrations project, and it is AEMO's responsibility to justify these changes with engineering rigour and supporting data.

3.2 Purpose of Contingency FCAS

MASS v6 states that Contingency FCAS Services are enabled to ensure the power system can arrest and recover from material frequency deviations that might arise from larger supply-demand imbalances[12]. Contingency FCAS provides this role by providing a fast injection of energy, or fast reduction of energy, to manage supply and demand[13].

It is the total injection of energy into, or withdrawal (reduction) of energy from, a *Connection Point* that makes an FCAS response effective. Because energy = (power x time), this can be redefined as the sustained modulation of power in response to a frequency deviation, for the total time that the power modulation is sustained.

This means that a strong FCAS response will guarantee a larger amount of energy delivered into/withdrawn from a contingency event, than a weak FCAS response. This can be calculated simply enough as (MW of FCAS offered x required duration of delivery). For a 5kW machine offering into the Fast FCAS market, the best possible delivery of FCAS will see (5 x 1/60) = 0.083 kWh delivered into/withdrawn from to the *Connection Point*. Any factor that causes less than this amount of energy to be delivered into/withdrawn from the contingency event lowers the quality of the FCAS response.

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[11] MASS Consultation Paper - January 2021 - Section 1.1
[12] MASS v6 - Section 2.1
[13] https://arena.gov.au/blog/what-is-frequency-control-ancillary-services/- accessed 22/2/21

A low-energy Fast FCAS response will make it more difficult for AEMO to arrest a material frequency deviation. A UFLS or system black will occur where a sufficiently large proportion of the Fast FCAS capacity provides a low-energy response. Fast FCAS is the last line of defence against large frequency deviations causing unscheduled load shedding and so the quality of the Fast FCAS response is material to the achievement of the NEO. As a result AEMO has historically treated Fast FCAS services with the utmost seriousness.

3.2.1 Low-energy FCAS responses

Low-energy responses are any that cause the *Connection Point* to receive less **energy** than the amount implicit in the **power** offer made by a Participant.

Examples of response characteristics that reduce energy delivered are:

1. A slow response - that is, one that only delivers the full power offer at the very last moment (e.g. at 5.9 seconds for Fast FCAS), resulting in reduced energy delivered to the *Connection Point*
2. A non-linear response - that is, one that achieves the required power modulation but then does not sustain required power during the entire response period, resulting in reduced energy delivered to the *Connection Point*
3. An absorbed response - that is, one that is diminished by changes in load or generation behind the grid connection point, resulting in reduced energy delivered to the *Connection Poin*t.

Low-energy FCAS responses are clearly undesirable. It is AEMO's role to discourage and detect low-energy FCAS responses so as to maintain system security during material frequency deviations. Likewise, it is inefficient for AEMO to purchase FCAS with a higher likelihood of a low-energy response, when FCAS with a lower likelihood of a low-energy response is available at a similar or same price.

The key question that AEMO must answer when considering alternative Fast FCAS metering arrangements is: "are AEMO enabling, incentivising or accepting low-energy Fast FCAS responses with the alternative metering arrangements?".

Reposit argues that Option 2 clearly enables, incentivises and validates low-energy FCAS responses to the detriment of system security and the NEO.

3.3 Engineering analysis of Option 2

AEMO's statements in the VPP Demonstrations design documentation, Knowledge Sharing Reports, and this MASS consultation paper can be parsed to synthesise AEMO's engineering argument for Option 2 metering. This argument is as follows:

Premise 1	MASS v6 accuracy and precision is required for the measurement and verification of Fast FCAS
Premise 2	At least 50ms time resolution is required to measure the energy delivery response of each "type" of DER resource
Premise 3	AEMO assumes every unit of a DER resource type has the same energy delivery/withdrawal response to a frequency deviation
Premise 4	AEMO assumes every unit of a DER resource type has a frequency response identical to the "type" test result, over its entire life.
Inference 1	Every unit of a DER resource type delivers energy in exactly the same way every time it delivers energy, over its entire life.
Premise 5	Under-delivery of energy delivered into/withdrawn from a fast contingency event can be detected using 1Hz data
Conclusion	Therefore 1Hz metering is sufficient to measure energy delivered into/withdrawn from a contingency event, from every unit of a DER resource type, for any point into the future.

Reposit has examined this argument as follows.

3.3.1 MASS v6 accuracy and precision

3.3.1.1 AEMO premise 1:

MASS v6 accuracy and precision is required for the measurement and verification of Fast FCAS.

3.3.1.2 Inferred from:

AEMO does not modulate the accuracy and precision requirements for any metering in Option 2. High-speed and 1Hz metering all must meet MASS accuracy and precision requirements. The only modulation is in time resolution for device-level meters.

3.3.1.3 Reposit's position:

Reposit believes that the accuracy and precision requirements of MASS v6 are appropriate for a long-lived DER asset. The requirements are perhaps too restrictive for a 5-15kW DER unit in a 6-second response market. But the cost of delivering this functionality is low and it is likely that it will be required for future energy services in the NEM.

3.3.2 High-speed metering required to measure energy delivery

3.3.2.1 AEMO premise 2:

At least 50ms time resolution is required to measure the energy delivery response of each “type” of DER resource.

3.3.2.2 Inferred from:

AEMO requires a frequency injection test on every different type of controllable device that responds to an excursion. This must be measured at a time resolution of 50ms or less[14].

3.3.2.3 Reposit’s position:

AEMO agrees that 20Hz metering is sufficiently high-resolution to determine energy delivered/withdrawn with acceptable error. It is likely that this rate has been selected by past power engineering staff at AEMO in response to the error associated with measuring a continuous quantity (energy under the curve) with a discrete measurement device (a digital electricity meter/SCADA RTU). This error is described in detail in section 3.3.6.3.1 of this document.

3.3.3 Homogeneity in energy delivery over DER “type”

3.3.3.1 AEMO premise 3:

AEMO assumes every unit of a DER resource type has the same energy delivery/withdrawal response to a frequency deviation - that is, a homogenous energy delivery/withdrawal response.

3.3.3.2 Inferred from:

AEMO will allow DER to meet the measurement requirements by capturing power flow and local frequency with a resolution of less than or equal to 1 second.

That is, AEMO does not require high-speed energy delivery data from each unit of DER. The only information AEMO has about energy delivery from the DER unit comes from the “type” frequency injection test.

The “type” frequency injection test was used on the VPP Demonstrations to characterise the response of a every different type of battery system in a VPP[15]. AEMO describes a battery system as being a unique combination of inverter model, battery model and control system.

[14] MASS Consultation Paper - January 2021 - Section 2.3.2
[15] MASS Consultation Paper - January 2021 - Section 2.3.2

3.3.3.3 Reposit's position:

AEMO's premise is that a particular type of battery system in a VPP will respond identically to the same frequency deviation. Reposit asserts that AEMO's premise is incorrect.

Reposit asserts that there is no validity in assuming that the energy delivery/withdrawal response of a DER unit of a particular "type" will be the same as that of the type tested unit for that "type", for any given frequency deviation. Reposit cannot find any evidence for this premise as an outcome of the VPP Demonstrations. Instead AEMO has shown that the response of battery systems in its VPP Demonstrations were not homogenous.

In Knowledge Sharing Report #1, AEMO reported on the cause of an under-delivery of FCAS capacity as being related to a difference in configuration settings on different units of the same type[16].

> Energy Locals and Tesla realised that fewer systems than expected had the appropriate frequency support settings enabled. This led to fewer individual units responding as part of the VPP to deliver a reduced fast lower FCAS aggregate response; this equated to 83% of the expected response, or 828 kilowatts (kW) rather than 1 MW bid.
>
> The correct frequency settings were configured and activated upon enrolling additional systems into the SA VPP. These settings were later modified for some systems when a test was manually scheduled for the purpose of gathering data for the VPP-wide test, as described in the VPP Demonstration FCAS Specification.
>
> A benefit of VPPs is that once identified, this issue was fixed immediately by remotely reconfiguring the non-compliant systems. Since this event, Tesla informs AEMO that it has introduced daily checks on all systems to ensure they are responding according to the expected configuration requirements. It is expected that this approach will mitigate the risk of any future under-delivery.
>
> Energy Locals and Tesla

The vendor committed to "daily checks on all systems" to "ensure they are responding according to the expected configuration requirements". This is a very simple and clear demonstration that "type" homogeneity is fragile at best, and non-existent at worst. This type of configuration difference between the unit used for the type test and the actual units in the VPP resulted in a low-energy FCAS response. In this case, it was able to be rectified remotely as it was a software inconsistency, but this will not be true of a hardware inconsistency.

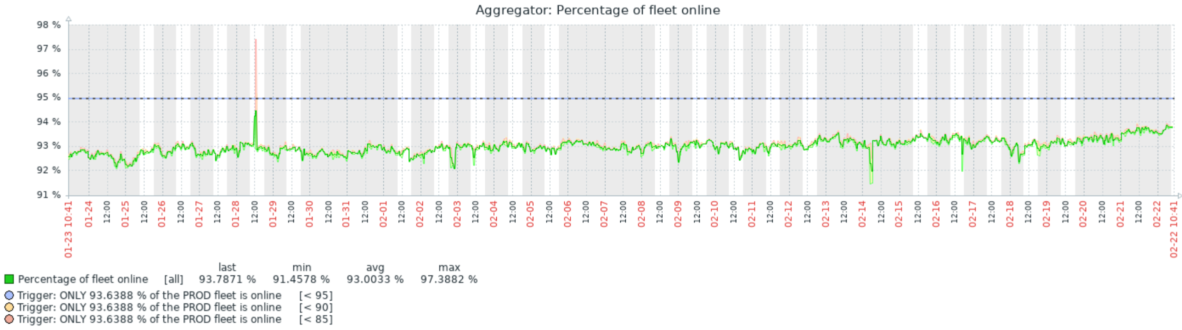
In fact, AEMO has demonstrated that even where it is a software configuration problem there can be up to 8% of units experiencing communication problems[17].

Data quality insights

- Evidence indicates that VPPs experience communications drop-outs that result in around 5-8% of required data from their fleet missing at any given time.

[16] VPP Demonstrations Knowledge Sharing Report #1 - Section 2.1.1
[17] VPP Demonstrations Knowledge Sharing Report #2 - Executive Summary

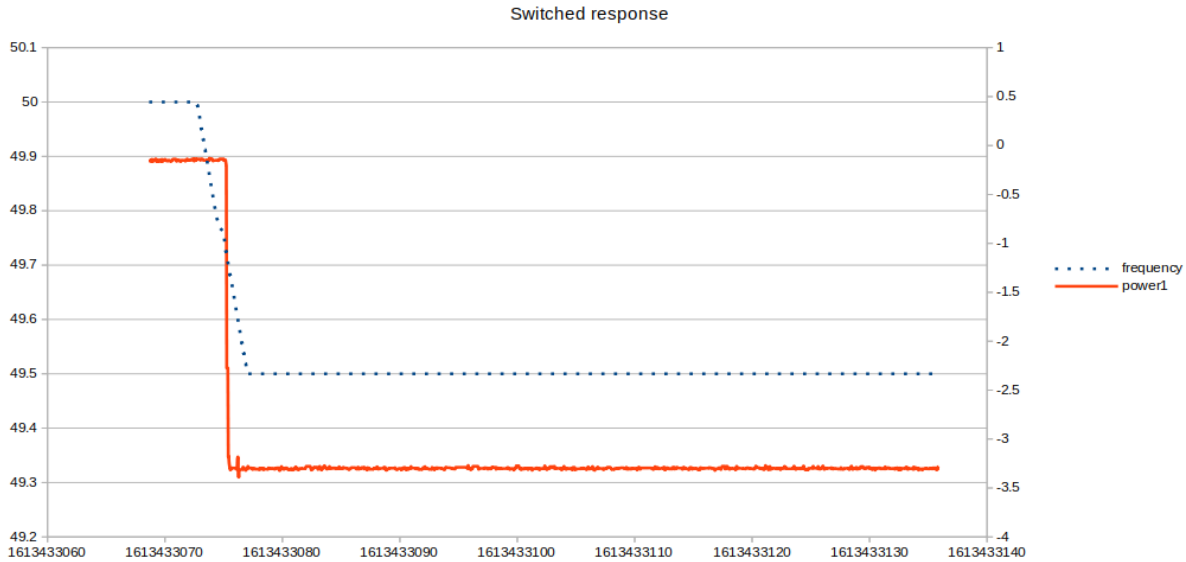
These communications problems may be chronic or intermittent. In either case, they present an opportunity for configuration, firmware and other software to be different on the same "type" of battery system. Data on these communications problems has not been made available by AEMO, however this metric is consistent with Reposit's experience of residential Internet connectivity.



Reposit aggregate fleet connectivity over time - household Internet connections

Compounding the argument against homogeneity, AEMO published the responses of a switching controller-based VPPs in Knowledge Sharing Report #3. It is notable that neither of these switching controller-based VPPs demonstrated the hallmarks of a homogenous, switched response.

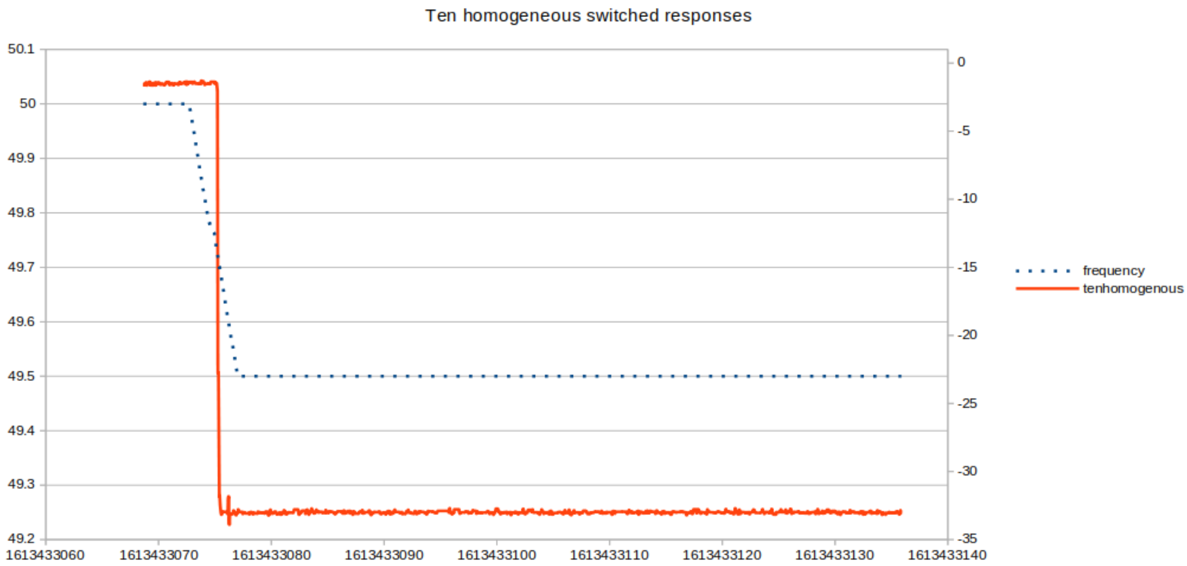
AEMO provides switching controller-based VPPs with Raise and Lower frequency deviation trigger settings[18]. A homogeneously responding, switched controller-based VPP should show a very sharp response to reaching a frequency deviation. This is because a switching controller's response is binary. It is either delivering/withdrawing power, or it is not. As a result, something like the following response is expected from a single switching controller:



[18] MASS Consultation Paper - January 2021 - Section 2.3.2

This is a 20Hz data capture from an actual inverter under continuous Reposit control. Reposit is a switching controller. There is a clear step change in power at 49.75Hz. In this case the inverter went from idle power to delivering almost 3.5kW in under 1 second. This is close to ideal control for a switching controller battery response and is characterised by two sharp discontinuities (or “elbows”) in the power curve.

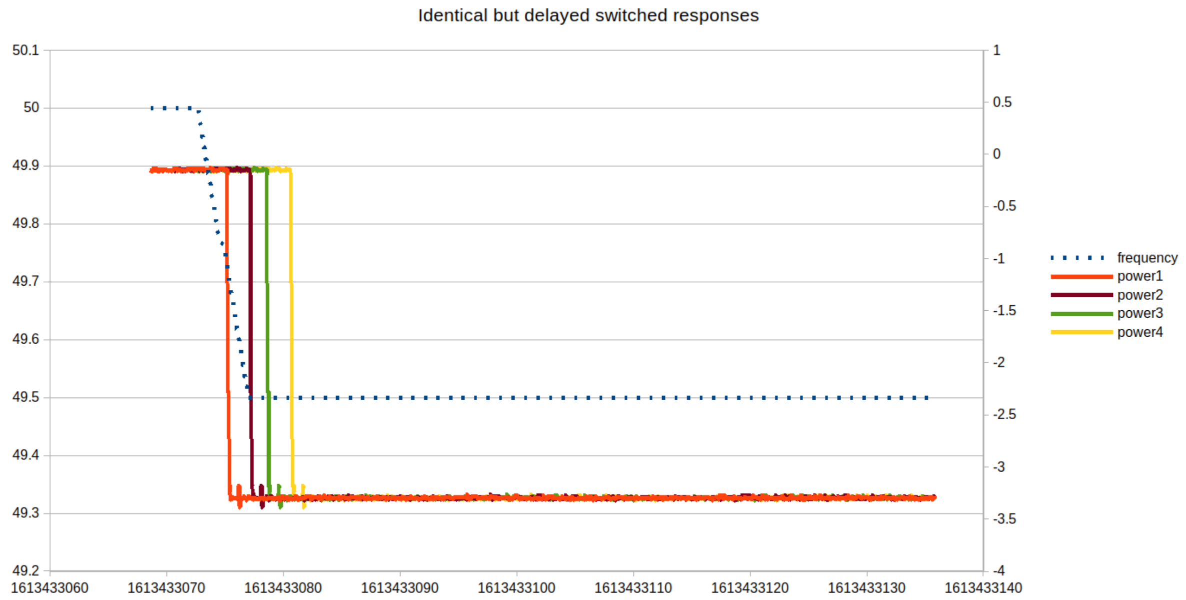
Frequency is system global on FCAS timescales so a homogenous response from ten of these inverters of the same “type” would show the same curve, but with a 10x greater magnitude of response.



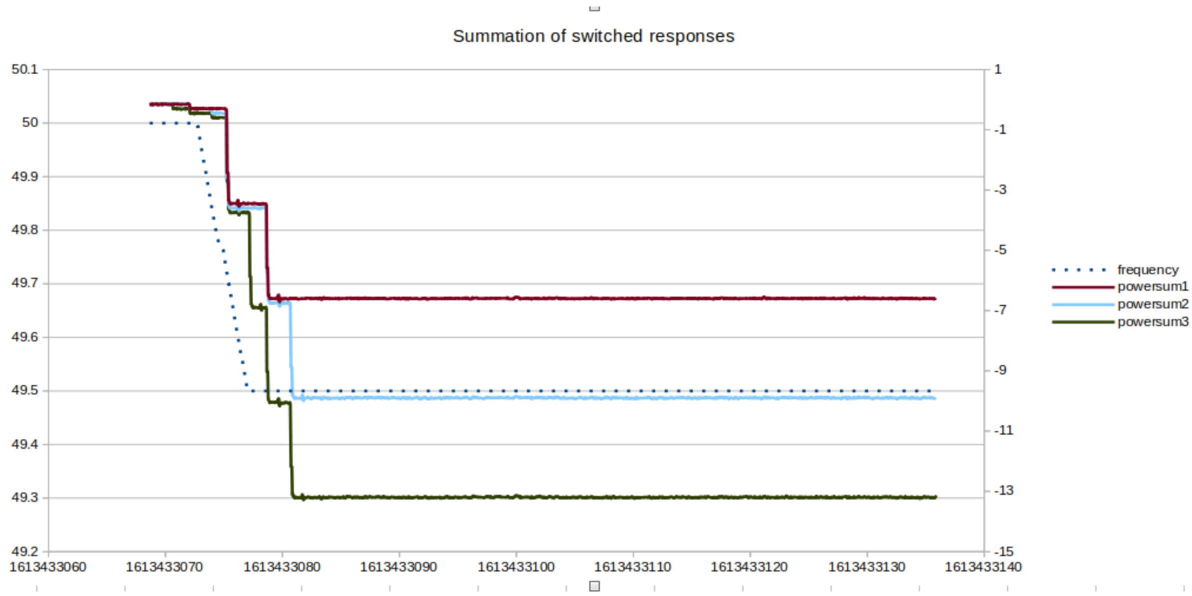
The aggregated response is the result of a linear time-series convolution of the responses from each of the providing storage systems. Convolution is a basic operation in digital signal processing and is the correct mathematical treatment for combining a collection of time series signals such as energy metering data. Note the clear step changes (the elbows) in the power graph. It is very clear that the aggregate response retains the discontinuous nature of switched control.

A non-homogeneous response will lose this characteristic discontinuity and instead become continuous. This is because the difference in the responses creates error which smooths the discontinuity. It is notable that this smoothing is clearly evident in the switching controller responses published in AEMO’s Knowledge Sharing Report #3.

Below is the same response but replicated four times, with each replica given a small time delay.



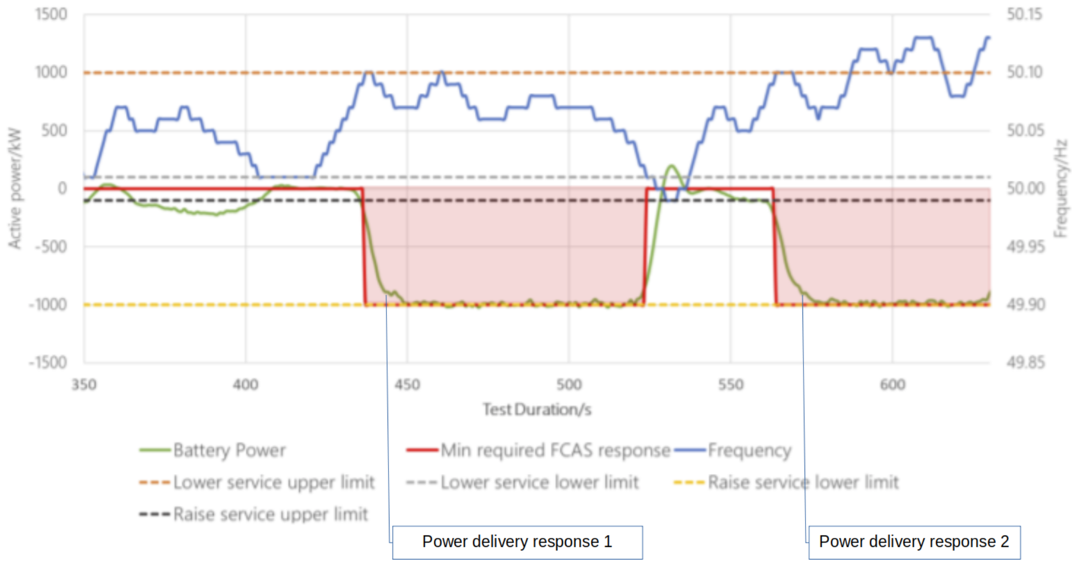
Below are three linear time series convolutions of this data. Powersum1 adds power1 to power2. Powersum2 adds power3 to powersum1, and powersum3 adds power4 to powersum2.



It is clear that the discontinuity (elbows) that are characteristic of a homogenous switched response are being smoothed as more power curves are added. This is the non-homogeneity of the responses working together. The only difference in the power responses is a non-uniform delay in response initiation. The discontinuity will be smoothed further where other differences are apparent in the power responses, and as more non-homogenous power responses are added to the convolution.

Any smoothing of a discontinuity means that the FCAS response of the units in the aggregated response are not homogenous.

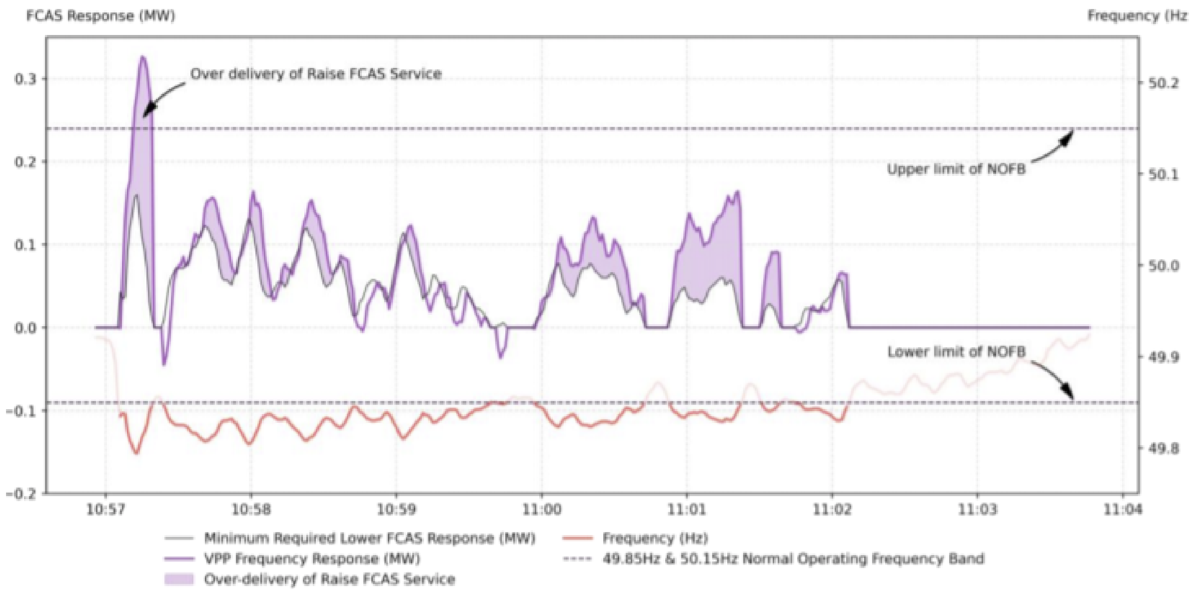
The graph below[19] shows a non-linear, but somewhat stepped response. It is not indicative of a homogenous response on power delivery. This is clear from the "curvy" shape of the power delivery initiation. A linear time-series convolution of homogeneous switched controlled systems does not display the discontinuity smoothing evident here.



Further to this, the initiations of power delivery response 1 and 2 in the above graph are different. The energy absorption of this switched controller VPP was materially different where nothing was changed except for a small passage of time and a previous small charging event. It is impossible for AEMO to claim that this VPP responds homogeneously when its power response is materially less after only a small increase in charge state. It should be noted that the energy absorbed by this VPP during ramping was substantially less in the second response than in the first. This is visible at 1Hz resolution and Reposit suggests that the 20Hz data would show an even greater discrepancy.

This is even more evident in the second switched controller VPP response provided[20].

[19] VPP Demonstrations Knowledge Sharing Report #3 - Section 2.1.1
[20] VPP Demonstrations Knowledge Sharing Report #3 - Section 2.1.2



There is no evidence of the characteristic discontinuity of a homogeneous, switched controller response. AEMO state that this VPP implements some sort of hybrid response[21]:

> The frequency deviation trigger setting of each battery system can be dynamically adjusted so the aggregated response from the VPP is proportional to the frequency excursion, even though each system essentially makes a step change in active power.

This in itself suggests that each battery in the VPP does not deliver a homogenous response. The only way the response from the VPP can be proportional to frequency, with each battery making a switched response, is if different batteries are doing different things. This is by definition not a homogeneous response across the VPP and makes the "type" test of this DER type completely irrelevant. If Option 2 were to be made available by AEMO, this VPP could not adopt it.

In short, the Knowledge Sharing Reports contain enough information to demonstrate that every unit of a DER resource type does not have the same energy delivery/withdrawal response to a frequency deviation. AEMO's own data demonstrates AEMO's premise 3 as being invalid.

This result agrees with Reposit's 8 years of experience in controlling energy storage systems from multiple vendors. Reposit has large amounts of data that demonstrates that DER units composed of the same inverter, battery and control system combination do not natively behave homogeneously. This is a result of many differences, which can and do occur in the same model of equipment, including:

1. Inverter and battery firmware version

[21] VPP Demonstrations Knowledge Sharing Report #3 - Section 2.1.2

2. Inverter hardware revisions
3. Battery cell chemistry
4. Battery cell manufacturer
5. Battery form factor (e.g 18650, 2170, prismatic)
6. Battery string configuration
7. Controller hardware revision (CPU, RAM, storage)
8. Controller/inverter/BMS configuration settings

These differences in a single “type” of DER cause significant deviations in energy delivery/withdrawal. Overcoming them requires closed, local and high-frequency control. Oftentimes, particular DER units will need to have their power contribution heavily discounted to account for the effects of differences within a “type”.

Further to this AS4777 prescribes that individual units modulate their power delivery to meet local conditions. And DER operating envelopes currently being explored by AEMO’s Project EDGE, ARENA’s Evolve, and several DNSPs will do the same. Homogeneity of response within a “type” cannot exist under the technical constraints imposed by these alone.

Managing this lack of homogeneity is a key value add of a DER aggregator. It consumes large amounts of research and development resources, and is essential to the deterministic delivery of energy. It is in AEMO’s interests to incentivise homogeneity of response as it is a strong indicator of a high-energy FCAS response. A VPP aggregator can do many things to improve the homogeneity of response if they have the incentive to do so. Option 2 assumes homogeneity of response and so removes this incentive.

Reposit has learned over time that a conservative and reliable delivery/withdrawal of energy can only be achieved where each DER unit is managed, offered and controlled as an individual unit. That is, any assumption of homogeneity introduces unbounded error/uncertainty into energy delivery/withdrawal. This has not been acceptable to Reposit’s DNSP customers in the past, and we expect it is not acceptable to AEMO. It has only been through the visibility afforded by in-field, high-frequency metering that these issues have been detected, characterised and resolved.

3.3.4 Homogeneity in frequency response over DER “type”

3.3.4.1 AEMO premise 4:

AEMO assumes every unit of a DER resource type has a frequency response identical to the “type” test result, over its entire life.

3.3.4.2 Inferred from:

AEMO requires a single 50ms or better meter for every 5MW of capacity in a region. This is to confirm whether the response from the controllable system was initiated at the right time and in the case of switching controllers, whether the local frequency went below or above the assigned Raise and Lower frequency deviation settings[22].

That is, AEMO does not require high-speed frequency response data from each unit of DER. This means the only reliable information AEMO has about frequency response comes from the "type" frequency injection test.

3.3.4.3 Reposit's position:

AEMO requires "5MW meters" as part of the requirements for the adoption of Option 2. AEMO does not make it clear what the intent of this meter is, only stating that the 5MW meter is used to determine response initiation characteristics for one DER unit in every one thousand DER units (in a residential DER context).

Reposit presumes that AEMO is assuming that the response initiation characteristics of the 20Hz-metered unit are identical to those of the 1Hz-metered units in the 5MW aggregation. That assumption requires that the frequency response of the entire unit (controller, inverter and battery) is identical on the 20Hz-metered site and the 1Hz-metered sites. This is because it is the response characteristics of all three (not just the controller) that determines when a response-related energy transfer reaches the metering point.

It should be noted that AEMO is assuming here that all DER responds homogeneously, not just of a DER type. This is because a 5MW aggregation may (and most likely will) have different "types" of DER in it, all proportional or switched controlled, but only have a single "5MW meter". In this case, it is impossible for the "5MW meter" to be measuring the response initiation characteristics of all of the types of DER in the 5MW aggregation.

Data that validates the assumption that all DER has homogenous response initiation characteristics has not been presented by the VPP Demonstrations project. Nor has data been presented that shows that even a single "type" of DER has homogenous response initiation characteristics.

Reposit asserts that this assumption is invalid for many of the same reasons described in section 3.3.3. Response homogeneity in a VPP fleet, even for systems composed of the same controller, inverter and battery, does not exist. There are too many variables that must be taken into account, and hence individual response initiations and deliveries are heterogeneous and must be measured. This has been shown by the VPP Demonstrations project and it is well known to Reposit.

Reposit suggests that fleets of a single "type" of DER with more than 10MW of capacity will come to demonstrate this point. It is extremely unlikely that the

[22] MASS Consultation Paper - January 2021 - Section 2.3.2

response characteristics of the DER units at the “5MW meter” sites will display perfectly homogeneous response initiation and energy delivery for all future frequency deviations. This likelihood will fall as more capacity, and hence more “5MW meters” are added. At this point, AEMO will be presented with data that proves that units of a DER “type” do not respond homogeneously. Reposit suggests that the homogeneity assumption underlying Option 2 will be shown to be invalid and that Option 2 will no longer be able to be supported by AEMO. This will not be in the interests of Option 2 VPP providers.

For this reason Reposit suggests that a requirement of Option 2 should be the right for non-market, third-party metering of any “5MW meter” site, by any interested party at their own expense. This will:

1. Provide AEMO with multiple, non-VPP aligned metering streams of single events at a single site
2. Ensure that “5MW meter” sites are able to be verified as being representative of the unmetered sites
3. Provide an additional incentive to the owner of the “5MW meter” site to host additional metering equipment.

As with section 3.3.3, homogeneity in any part of the VPP aggregation cannot be assumed. It is the role of the VPP aggregator to deliver high-quality responses to AEMO when responding to contingency events. There is investment that must be made by VPP aggregators to deliver the kind of homogeneity that results in high-energy Fast FCAS responses. To assume this homogeneity removes incentive from a VPP-provider to work towards high-quality responses, ultimately damaging system security.

3.3.5 Homogeneity over time for each DER “type”

3.3.5.1 AEMO inference 1:

Every unit of a DER resource type delivers energy in exactly the same way every time it delivers energy, over its entire life.

3.3.5.2 Inferred from:

AEMO does not specify the gathering of any post-frequency injection test high-speed data for energy delivery or frequency response - for the entire life of the DER asset.

3.3.5.3 Reposit’s position:

AEMO infers the statement from Premises 3 and 4. Option 2 requires this inference because there is at best a 0.1% likelihood under Option 2 that any high-speed data will ever be gathered from a particular DER unit. This means that only the point-in-time “type” test data can be relied upon to determine energy delivery accurately.

Reposit does not see any data to support AEMO's assumption that any kind of response homogeneity exists for DER units. This includes response homogeneity over time. Reposit's experience is that there is no consistent response, identical to that of any "type" tested unit, for every frequency deviation until unit decommissioning. There are simply too many variables that affect response.

The variables listed in section 3.3.3 are essentially characteristics of equipment models and their evolutions. The following incomplete list of variables are much more point-in-time and have an at least equal effect on the energy delivery/withdrawal that a storage system will make into a contingency event:

1. Battery temperature
2. Battery state of charge
3. Inverter temperature
4. Inverter AC terminal/connection point voltage
5. Controller background processing load
6. Controller temperature

Homogeneity of response between a "type" tested unit and any other unit of the same "type" cannot be assumed. It cannot be assumed between units of the same type, and it cannot be assumed to be consistent over any time period. The assumption of homogeneity is not correct.

It is the role of the VPP aggregator to deliver high-quality responses to AEMO when responding to contingency events. There is investment that must be made by VPP aggregators to deliver the kind of homogeneity that results in high-energy Fast FCAS responses. To assume this homogeneity removes incentive from a VPP-provider to work towards high-quality responses, ultimately damaging system security.

3.3.6 Under-delivery of energy can be detected with 1Hz metering

3.3.6.1 AEMO premise 5:

Under-delivery of energy delivered into/withdrawn from a fast contingency event can be detected using 1Hz metering data

3.3.6.2 Inferred from:

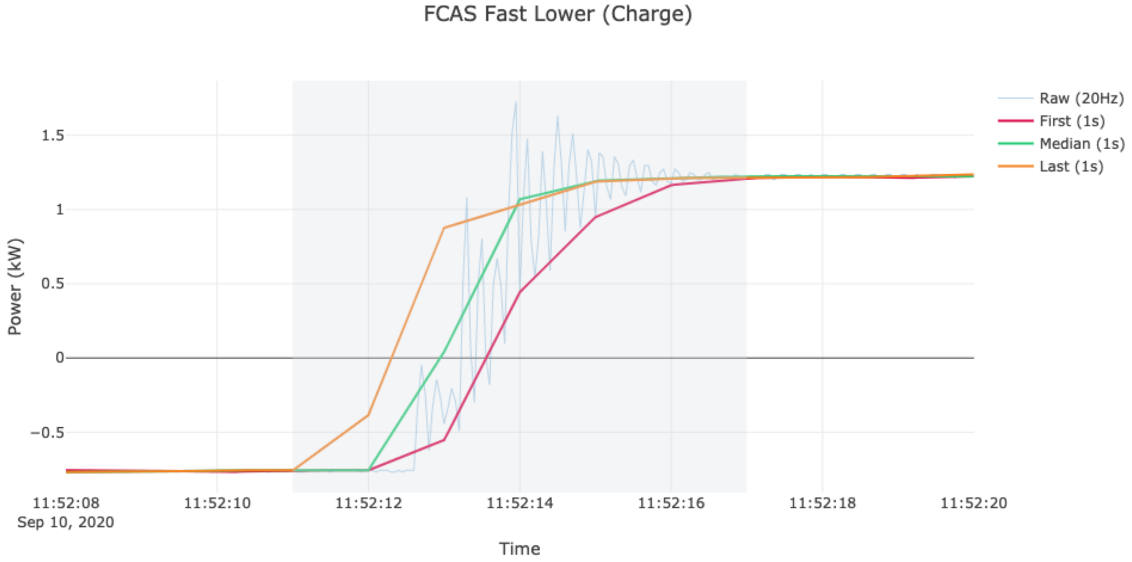
AEMO states that an under-delivery could be identified whenever the calculated minimum required FCAS response was more than the actual amount of FCAS delivered[23].

[23] MASS Consultation Paper - January 2021 - Section 2.2.1

3.3.6.3 Reposit's position:

Reposit does not understand how AEMO is sure it has been able to detect under-delivery of FCAS using 1Hz data. It is statistically very unlikely that AEMO has correctly measured the energy delivery/withdrawal made into a contingency event by a VPP, by using 1Hz data.

The following is a measurement of an actual Fast raise response from a "VPP-enabled" storage system.



This response shows the sub-second power oscillations so frequently displayed by electricity storage systems examined by Reposit. These oscillations are not able to be detected with 1Hz metering, but are clear at 20Hz. Each of these oscillations results in less energy being delivered to the Fast raise response.

Note that the 1-second metering, done in three different ways makes this response look like a valid and reliable Fast FCAS response. The 20Hz metering however shows this response to be unstable, low-energy and dangerously oscillatory.

(Reposit has chosen to not include this hardware in its supported products list. However it is an attractive integration target under Option 2 metering as it sells well and there are many thousand of these storage inverters deployed in the NEM today.)

It is clear that low time-resolution data contains less information about a continuous property like energy, than high time-resolution data. An assumption must be made where data is missing. That is, AEMO does not know what energy was delivered during the period between measurements. To compute a quantity it must make some assumption as to what happened between measurements.

This assumption carries with it highly material consequences. With this assumption comes a quantity of "assumed energy". Assumed energy is the quantity of energy that was not measured, but is assumed to be contributing to the arrest of a frequency deviation. A fall in frequency will not be arrested where assumed energy delivered is materially greater than actual energy delivered. Likewise, a rise in frequency will not be arrested where assumed energy withdrawn is greater than actual energy withdrawn. The assumption that is made when computing assumed energy, has a real and material effect on system security at precisely the moment when system security is at greatest threat.

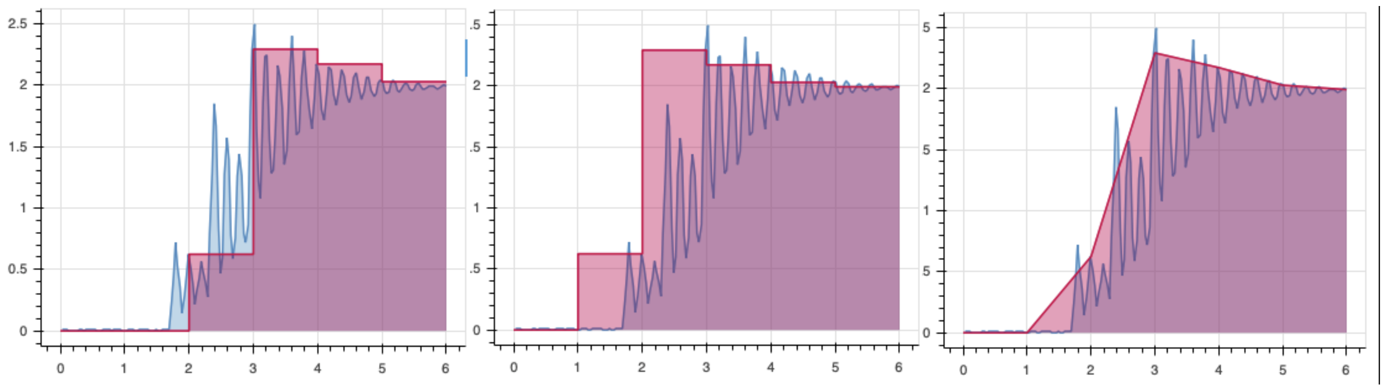
There are three workable (non-polynomial) options for the assumption, that can be used to compute assumed energy. They are the:

1. Left Riemann sum
2. Right Riemann sum
3. Trapezoidal sum

Each method assumes that power (energy/time) is some value during the time period between actual measurements. If t_n is the measurement at time n, then t_{n-1} is the previous measurement.

The left Riemann sum assumes that the power at t_n is equal to t_{n-1}.The right Riemann sum assumes that the power at t_{n-1} is equal to the power at t_n. The trapezoidal sum attempts to implement a more moderate right Riemann sum by somewhat splitting the difference.

The following three graphs show the same 20Hz measurement of the Fast raise response discussed above.



Different summations of energy delivered - 1. Left Riemann. 2. Right Riemann. 3. Trapezoidal

The S-shaped nature of a Fast FCAS response, and the proclivity for poorly-controlled residential electricity storage systems to deliver oscillatory power means that all three methodologies overestimate the amount of energy delivered.

Methodology	Computation (Wh)	Error
Left Riemann	71.16	-3.97%
Right Riemann	91.08	-33.08%
Trapezoidal	81.12	-18.53%
Actual	68.44	0.00%

In particular the right Riemann sum heavily overestimates energy delivered. The use of the right Riemann or trapezoidal summation methods is highly likely to result in AEMO receiving low-energy Fast FCAS responses from Option 2 meters.

However, given the discontinuous nature of electricity metering, the trapezoidal rule is the best choice for calculating the energy sum. The error for the trapezoidal rule is characterised by the following inequality[24]:

$$|R(f, I_n)| \leq \frac{1}{2}\nu(h)\bigvee_a^b(f).$$

This says that the error that you get from the trapezoidal sum is linearly related to step size for bounded functions. Or in metering terms, error in energy delivery increases linearly with increased step size. Option 2 metering has 20x the step size of Option 1 metering and so has 20x the energy sum error.

Option 2 does not modulate the 2% energy metering error requirement of MASS v6, and so energy sum error is 20x greater in Option 2 when compared to Option 1. Just to reinforce this point, the only way for energy sum error to remain constant between Option 1 and Option 2 would be to specify a 0.1% energy metering error, and then increase time-resolution error by 20x. Option 2 does not do this.

3.3.6.3.1 Energy sum error bounds calculation

The error in the energy sum can be precisely calculated using the following inequality[25]:

$$E_n^T(f) \leq \frac{|I|}{2n} \inf_r \|f_r\|_{BV,I},$$

- $|I|$ is 6 for Fast FCAS because the response is required over 6 seconds

[24] https://journals.tubitak.gov.tr/math/issues/mat-00-24-2/mat-24-2-3-9911-3.pdf - Inequality 1.4

[25] https://www.emis.de/journals/JIPAM/images/031_02_JIPAM/031_02.pdf - Inequality 1.10

- n is the number of measurement that are taken during the 6 second response - 6 at 1Hz, 120 at 20Hz
- $inf_r||f_r||BV, I'$ becomes 1-(-1) because we are interested in percentage error and so can operate on unit quantities, and so is 2

For Option 1 metering our maximum error is (6 / 240 * 2 = 0.05). We will have maximum error after all the measurements are done, which is after 6 seconds. In percentage terms this is 0.05/6 = 0.83% error.

For Option 2 metering our maximum error is (6 / 12 * 2 = 1). We will have maximum error after all the measurements are done, which is after 6 seconds. In percentage terms this is 1/6 = 16.67% error.

You can see that the first inequality holds. Option 2 metering has 16.67/0.83 = 20 times more energy summation error than Option 1 metering.

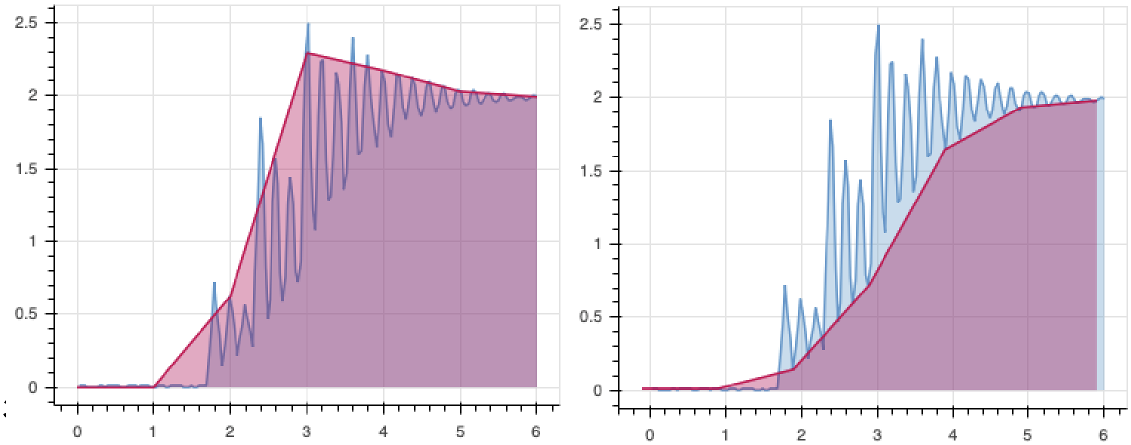
For Option 2 metering, the energy sum error is 0.83%, which is below the 2% meter energy measurement error allowed by the MASS. This means that the leading error term for the total energy computation is the meter energy measurement.

For Option 1 metering, the energy sum error is 16.67%. This dwarfs the 2% meter energy measurement error allowed by the MASS and now becomes the leading error term for the computation. This is an increase in summation error of 15.84%. This means that the increase in energy sum error with the adoption of Option 2 metering is workably 16%. This number is material to the certainty of delivery of a Fast FCAS response.

AEMO has not described the computation that was applied during the VPP Demonstrations project. Reposit requests that the AEMO describe the computation methodology that was used in the VPP Demonstration project, and detail the computation method that will be used in Option 2 during the treatment of 1 second data.

3.3.6.3.2 Sub-second time alignment effects

Compounding this problem is the time alignment of 1 second response initiation to actual clock-tick (physical system) trigger time. Sub-second errors in alignment result in vastly different computations of FCAS response as shown below.



Trapezoidal summation. Left: 0.0 second offset; Right: -0.1 second offset

Time offset from initiation (seconds)	Energy (Wh)	Error
-0.5	46.98	-31.36%
-0.45	63.84	-6.72%
-0.4	70.86	3.54%
-0.35	58.38	-14.70%
-0.3	50.88	-25.66%
-0.25	68.46	0.03%
-0.2	74.94	9.50%
-0.15	61.02	-10.84%
-0.1	54.48	-20.40%
-0.05	69.66	1.78%
0	81.12	18.53%
0.05	67.92	-0.76%
0.1	59.64	-12.86%
0.15	72.36	5.73%
0.2	79.8	16.60%
0.25	68.16	-0.41%
0.3	63.96	-6.55%
0.35	78.72	15.02%
0.4	90.12	31.68%
0.45	83.7	22.30%
0.5	66.6	-2.69%

The nature of the error results from different time offsets suggest that very small errors in time alignment will have very large impacts on assumed energy.

The VPP Demonstrations project has not described the time alignment methodology that was used to generate the trial's results. Reposit requests that the AEMO describe in detail the time alignment mechanism that was used in the VPP Demonstrations project, and detail the time alignment method that will be used in Option 2 during the treatment of 1 second data.

Given the problems with 1 second metering, Reposit suggests that AEMO should explain in mathematical terms the full Option 2 process for the conversion of multiple, 1 second power flow and local frequency data captures into an FCAS response calculation. This process should characterise the assumed energy component of the FCAS response under various response profiles, and the error bounds associated with Option 2 response.

3.3.7 1Hz metering is sufficient

3.3.7.1 AEMO conclusion:

Therefore 1Hz metering is sufficient to measure energy delivered into/withdrawn from a contingency event, from every unit of a DER resource type, for any point into the future.

3.3.7.2 Inferred from:

AEMO's presentation of Option 2 as a valid metering option for Fast FCAS.

3.3.7.3 Reposit's position:

Option 2 is not a valid measurement solution for Fast FCAS.

None of AEMO's assumptions of DER "type" homogeneity have been validated by AEMO. They have been shown to be false by the VPP Demonstrations project and they are known to be false by Reposit. Without the assumption of homogeneity in place, DER "type" testing is redundant in the consideration of FCAS response. Reposit asserts AEMO cannot assume to know anything about the performance of a particular DER unit of a particular "type" by looking at the performance of a "type" tested DER unit.

Reposit does not agree that AEMO can detect under-delivery from 1Hz data. Reposit has shown that any workable summation method for 1Hz data will deliver substantial error. AEMO has not characterised the error of computed energy delivered/withdrawn using trial data, nor via mathematical proof. Reposit has shown that it is mathematically impossible to accurately calculate energy delivery/withdrawal using 1 second data. Reposit suspects this is why Fast FCAS response has always been measured using 20Hz data.

This means that the only way to understand the performance of a particular DER unit in energy delivery/withdrawal, for a particular frequency deviation, is to measure its response at high-speed. As a corollary, the only way to understand a particular VPP's response to a particular frequency deviation is to perform a linear, time-series convolution on the high-speed energy metering data across each of its contributing units. To do anything else is to introduce vast amounts of uncharacterised error into the computation of energy delivered to/withdrawn from the grid as a result of a frequency deviation. To introduce this kind of error into this energy quantity is a mistake, and will increasingly damage system security with higher DER penetration into FCAS markets.

Hence, Reposit asserts that only Option 1 is workable.

3.4 Option 2 will damage system security

Reposit asserts that use of Option 2 for verification of FCAS response will result in reduced system security if no additional FCAS is procured. This is because Option 2 diminishes the energy available to a contingency event in at least two ways:

1. Energy summation error - 16%
2. Device-level metering (energy absorbed) error - 6%

Reposit estimates that an Option 2 Fast FCAS VPP will deliver with confidence 0.78MWh for every 1MWh delivered with confidence by an Option 1 VPP.

A contingency event requires energy to be delivered to or be withdrawn from the grid to arrest a frequency deviation. AEMO determines the FCAS MW required to cater for the size of the contingency in a region. It then asks Participants to offer a magnitude of power modulation that can be sustained for a fixed period of time. Should the contingency arise then Participants are required to deliver energy in the form of a time-sustained power modulation. That is, Participants offer in power but deliver with energy. It is the quantity of actual energy reaching the grid that is important, not the quantity that is reported to AEMO. Ideally these quantities are the same.

3.4.1 Overestimation of energy delivered/withdrawn

Error in energy delivered into or withdrawn from a frequency deviation will affect the efficacy of an FCAS response. An overestimation of expected response from a VPP provider's offer will damage the ability of the Fast FCAS service to arrest a frequency deviation. As discussed throughout section 3 of this document, Option 2 introduces significant error into the delivery of Fast FCAS. This comes from an incorrect assumption of homogeneity across DER "type" and is compounded by the assumptions that must be made if 1Hz data is to be used for measurement.

Using this analysis Reposit estimates that Option 2 will decrease the certainty of energy delivered from a VPP to a Fast contingency event by 16%. That is AEMO would need at least 16% more Option 2 Fast FCAS MW than Option 1 Fast FCAS MW to arrest the same frequency deviation. Or in other words, Option 2 FCAS is likely to be no greater than 84% effective when compared to traditional FCAS.

Additionally, Option 2 removes the majority of the incentive for VPP providers to deliver a well-controlled, homogeneous response. This is because it assumes a well-controlled homogeneous response as part of its verification processes. As a result VPP providers will make little to no effort to deliver high-energy FCAS responses but instead will focus on putting as much capacity into the market as possible. This is akin to the effect that solar feed-in-tariffs have had on the wholesale energy market. That is, well-controlled, reliably metered generation will be replaced by poorly controlled, poorly metered generation creating a double effect in the decrease of system security during frequency contingency events.

Even a VPP provider that is committed to enhancing system security is foiled by Option 2. A VPP provider (and AEMO) cannot detect energy under-delivery/withdrawal with 1Hz metering (see 3.3.6.3) and so has no chance of being able to rectify it. Likewise, Option 2 blinds AEMO to the actual response being delivered to a contingency event when a material proportion of a region's Fast FCAS capability is being provided by DER fitted with Option 2 metering.

Reposit asserts that should AEMO proceed with Option 2 but does not discount Option 2 FCAS, then system security will be diminished. Reposit suggests that this discount needs to be 16% (section 3.3.6.3.1) . FCAS providing DER accounts for 30MW of Fast FCAS response today - 22MW of using Option 2 metering. This is a small percentage and a 16% error in this quantity is immaterial. However AEMO's own RIS has predicted up to 2.5 GW of aggregated, behind-the-meter storage within 5 years[26], most of it eligible for Option 2. This would be more than sufficient to saturate the FCAS markets with Option 2 DER. In this circumstance AEMO would be forced to address this error or be faced with a continuous and material risk to system security.

3.4.2 Device-level metering

Independent of the energy delivered/withdrawn error discussed above is Option 2's requirement that power flow be measured at the device rather than the connection point. This is a departure from the *Connection Point* measurement of response that has been used throughout the NEM from market start.
The effect of this change in measurement is that error from absorbed energy (section 3.2.1) will increase by some unknown and changing amount over time.

This absorbed energy will not contribute to the arrest of the frequency deviation, but will be assumed to be delivered to the grid. That is because AEMO procures energy in the form of FCAS offers to feed the contingency and assumes that it all reaches the grid. This is a valid assumption where FCAS measurement is conducted at the *Connection Point*, but it is not a valid assumption where FCAS measurement occurs behind the connection point. This is because another device behind the connection point could absorb some of that energy.

AEMO recognise that this could occur intentionally[27] and requires connection point metering (of unspecified properties) as a result. Clearly AEMO is concerned about absorbed energy, but incongruously Option 2 allows Participants to bid nameplate capacity anyway. Intention is not important to a frequency deviation, in all cases absorbed energy will damage the ability of Fast FCAS to arrest a frequency deviation.

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[26] AEMO RIS FAQ - https://aemo.com.au/-/media/files/major-publications/ris/2020/ris-faq.pdf - page 3
[27] MASS Consultation Paper - January 2021 - Section 2.3.2

Allowing absorbed energy to be considered part of the FCAS response is damaging to system security unless it is compensated for by AEMO. Much like in the error in quantity of energy delivered/withdrawn introduced by 1Hz metering, AEMO is blinded to what this compensation amount might need to be. Option 2 provides no high-speed metering that can be processed to determine the compensation factor. Instead AEMO will need to rely on the effect that absorbed energy has on Option 1 FCAS (DER and otherwise) to estimate how much more FCAS requires procuring. Reposit offers an error estimate of at least 6% informed by fleet operational data but has no data to suggest a future state.

4 NEO Impact Analysis

It is Reposit's opinion that AEMO's proposal to amend the Market Ancillary Service Specification (MASS) to include alternative metering arrangements (Option 2) for some NMIs does not promote the achievement of the National Electricity Objective (NEO). Reposit asserts that this proposal is detrimental to the achievement of the NEO as it runs counter to concepts explicitly referenced by the objective. It is also not clear that AEMO has described how the proposed alternative metering arrangements promote the NEO.

4.1 No NEO promoting argument

The National Electricity Law states that AEMO must have regard to the national electricity objective when carrying out its statutory functions[28]. This means that AEMO is legislated to provide NEO-based justifications for decisions made. As quoted in section 2.4 of the consultation paper, the NEO's primary concern is efficiency. Specifically the NEO is concerned with efficient investment, operation and use of electricity services. NEO supporting arguments are ones that describe how a feature of the NEM improves productive, allocative or dynamic efficiency. These arguments discuss electricity services rather than assets. And they describe how the long term interests of consumers are promoted even if there are short term costs.

AEMO states in section 2.4 of the issues paper that the key issues of non-compliance, gaming, unnecessary costs and competition will guide the assessment of Option 2's adherence to the NEO. The NEO does not directly consider any of these issues. Perhaps AEMO has some rationale for how the stated key issues relate to the NEO, but this has not been made clear to the market. Reposit also asserts that AEMO cannot claim to be guided by the NEO where decision making is focussed on alternative key concepts to those in the NEO.

Reposit suggests that there must be a clear NEO-based justification of Option 2 if it is to be adopted. This is especially necessary when market participants such as Reposit believe that the proposal is detrimental to the NEO. Ultimately AEMO is legislated to execute its statutory functions with regard to the NEO. It is difficult to see how the proposal can be successfully implemented into the NEM when there is no NEO-promoting argument offered, and only NEO-diminishing arguments are offered by its detractors.

[28] NEL - Part 5, Division 1, 49(3)

4.2 Does not promote more efficient decisions

When assessing a change to the NEM for promotion of the NEO, the key question that should be answered is "does this change promote more efficient decision making in the investment, operation and use of electricity services in the long term interests of consumers?"[29]. The NEO is not promoted where the answer to this question is no, and the change cannot be implemented in the NEM.

4.2.1 Some additional metering cost

Reposit asserts that AEMO's proposed Option 2 does not improve decision making consistent with the NEO. Reposit argues that Option 2 actively degrades decision making with regard to FCAS services. This is because the proposal introduces unnecessary uncertainty into FCAS Measurement and Verification (M&V), procurement and investment processes. Uncertainty results in discounting which is a source of productive inefficiency in the investment and use of FCAS services.

AEMO's states in the consultation paper that its key consideration of efficient operation and use of FCAS is based on the perceived additional cost of metering under Option 1 as compared to Option 2. Reposit agrees that there is no more than a $40-$120 (depending on phase count) additional cost per NMI for Option 1 metering over Option 2. This number is conservatively estimated. Reposit incurs a $25/phase metering cost in doing Option 1 metering in 2021. This is described in detail in Section 2.1 of this document.

This cost is incurred as a result of more costly meter componentry and some additional meter installation cost. It represents at most a 0.8% increase[30] in the most popular battery system in the market[31]. It also represents an amortised annual cost of not more than $12/year for the life of a DER asset given that a 10-year warranty period as standard in the market. It should be noted that a connection point meter with at least 1Hz time resolution will be required on all NMIs under Option 2. This is the only way to satisfy the "not being negated on purpose" requirement stated in section 2.3.2 of the consultation paper.

4.2.2 Option 2 metering encourages error in energy delivery from DER

The vast decrease in metering time-resolution, and the accompanying assumptions that must be made to compute energy delivery create the conditions for VPP aggregators and hardware manufacturers to disinvest in sub-second control stability and response homogeneity. The result is vastly increased, and almost

[29] AEMC - Applying the Energy Market Objectives - https://www.aemc.gov.au/sites/default/files/2019-07/Applying%20the%20energy%20market%20objectives_4.pdf - section 1.2
[30] https://www.solarquotes.com.au/blog/another-powerwall-price-rise/ - February 2021
[31] Formbay - Solar Cutters Community Update - January 2021

completely uncharacterised error on Fast FCAS energy delivery. This error is described in section 3.4 of this document.

This error will need to be managed by AEMO's system management team proportional to the amount of Option 2 metered FCAS enabled in a period. In effect, Option 2 metering creates a second, high-error, identical-cost Fast FCAS product in the NEM. This product will need to be co-optimised with Option 1 metered FCAS such that error is acceptable. Inevitably the energy error associated with slow-metering (described in section 3.3.6.3) means that AEMO will need to discount energy delivered from Option 2 metering.

4.2.3 Option 2 metering will cause additional FCAS procurement

In return for at most a $12/NMI/year annual saving, the NEM will incur significant additional costs. AEMO will need to discount the FCAS provided by Option 2 DER and hence procure more FCAS in response to the energy measurement error of Option 2 metering. Fast FCAS was a $144M[32] market in 2020. Assuming FCAS bidstack homogeneity (which is extremely conservative), every 1% error in FCAS response energy delivered into Fast FCAS will result in AEMO spending an additional $1.44M on Fast FCAS annually. This assumes that there are no additional costs associated with managing the possibility of over-delivery as a result of this error.

Option 2 is more efficient than Option 1 only where 120,000 Option 2 DER units increase total FCAS response error by less than 1% ($1.44M/$12 = 120000 units). Option 2 becomes inefficient if 120,000 Option 2 DER units increases error by more than 1%. The reality is that 120,000 Option 2 DER units would contribute 360MW to the Fast FCAS bid stack assuming a very conservative unit size of 3kW.

This is conservatively in the order of 25% of total NEM Fast FCAS MW. If a very conservative 16% energy delivery error as a result of Option 2 metering eventuates (section 3.4 puts this at 22%), the NEM would need to procure an additional 4% Fast FCAS. This comes at a cost of $5.8M to market participants, and inevitably consumers.

That is, if Option 2 is adopted, the NEM will spend annually an additional $5.8M in Fast FCAS procurement to save at most $1.44M in metering costs for Option 2 DER. This relationship is linear and so for *every* $1.44M in metering costs saved by Option 2, the NEM will spend an additional $5.8M in Fast FCAS procurement. This is the same as the NEM spending an additional $48/year/Option 2 metered DER unit on FCAS to save $12/year/Option 2 metered DER in metering costs for some participants only.

[32] http://www.nemweb.com.au/REPORTS/CURRENT/Ancillary_Services_Payments/AS_PAYMENTS_SUMMARY_2020.CSV

4.2.4 Option 2 creates an inequitable wealth transfer

Option 2 metering will result in additional Fast FCAS to be procured by AEMO. Because the additional FCAS revenue will at least partially go to VPP aggregators, there is the potential for up to $60/year/Option 2 metered DER unit ($48 + $12) to be inequitably transferred from all energy consumers to only Option 2 metered Participants.

It should be noted that there is already 22MW of Option 2 metered DER systems providing Fast FCAS services in the NEM today. Using the same calculation, this represents an annual wealth transfer of $264,000/year ($60 x 4400) from all energy consumers to Option 2 (VPP Demonstrations) FCAS providers.

The calculations above make it clear that Option 1 is not only more efficient, it is also the only equitable option.

4.3 Faster power modulation required in the near future

The AEMC is currently considering several new market ancillary services. These services are Fast Frequency Response (FFR), Inertia and System Strength. There is no doubt that DER will be able to provide FFR, and DER will demonstrate Inertia and System Strength capabilities in due course. It is important to note that correctly instrumented and controlled DER is often able to deliver additional system security services at zero marginal cost. Additional services are typically enabled in software, and software is zero marginal cost. When coupled with the AEMC's principle of least demanding assumptions[33] it is likely that these new services will be able to be delivered by DER.

The nature of these services is such that their measurement and verification will require high-speed, high-resolution data for M&V. At least System Strength requires connection point metering, and Reposit is unconvinced that device-level verification is consistent with the NER as it stands.

4.3.1 Option 2 metering is a false economy

A DER asset may not require new power conversion hardware should it want to participate in these new services, but it will require advanced metering equipment. As described in section 2.1 of this document the additional hardware cost of this metering is at most $120/NMI for a competitive participant in 2021. The cost of labour to refit metering at a DER site is at least $200 and rising, as labour shortages lift prices as a result of solar PV uptake.

This means that Option 2 metering conflicts with the NEO in two additional ways.

[33] AEMC - Applying the Energy Market Objectives - https://www.aemc.gov.au/sites/default/files/2019-07/Applying%20the%20energy%20market%20objectives_4.pdf - section 1.2.3 - page 6

Option 2 metering creates a productive inefficiency of at least $250/NMI or approximately $60,000/MW. This is easily calculated as (refit labour cost + redundant slow metering cost) x number of DER systems/MW. This inefficiency exists assuming that the AEMC will introduce new market ancillary services during the warranty period of a DER asset. It relates to the “long term interests of consumers” test contained within the NEO.

The warranty period is typically how consumers measure the economic life of DER. The warranty period of a DER asset is typically 10 years. This defines the “long term interests” component of the NEO for this matter. Consumers consider the end of the warranty period as being the end of the economic value of a DER asset. They take their cue from the manufacturer in this regard. A consumer assumes they will need to replace the asset soon after the warranty period is over. It is hence when the capital or fixed components used in the provision of energy services can be changed[34]. That is, decisions made at the installation time of a DER asset have NEO-relevant efficiency consequences for 10 years.

4.3.2 Option 2 metering will be replaced with Option 1 metering in a competitive market

Option 2 metering also creates an allocative inefficiency of $hundreds of thousands/MW. Option 2 DER will not have advanced metering available without a refit and so will be unable to participate in these new services. Instead these new services will need to be provided by new capacity of the sort which typically costs $millions/MW. It is assumed that this new capacity will be co-optimised, and so it is not unreasonable for the order of magnitude of allocative inefficiency to be in the $hundreds of thousands/MW range.

It is clear that Option 2 DER at a NMI will be refitted with advanced metering where competition is not stifled. It is clearly more efficient to equip existing electricity storage and conversion hardware with appropriate M&V to deliver new services, than it is to duplicate that storage and conversion hardware. This is clear when the productive inefficiency of $60,000/MW for a metering refit is compared to the allocative inefficiency of $hundreds of thousands/MW. A competitive market will pursue the least cost option, which is a replacement of Option 2 metering on DER that is able to participate in new market ancillary services. This consequence of Option 2 metering alone makes it grossly inefficient in regard to the NEO.

4.4 Option 2 metering damages investment efficiency

Investment signals are a key part of the governance framework of the NEM. Decentralised decision making on the right investments to make is facilitated by the publishing of price signals, service definitions and market reviews. Investors allocate capital on the certainty that these instruments provide.

[34] AEMC - Applying the Energy Market Objectives - https://www.aemc.gov.au/sites/default/files/2019-07/Applying%20the%20energy%20market%20objectives_4.pdf - section 1.2.3 - page 5

Some of this investment is in research and development to create new technology able to deliver existing electricity services at a lower cost. Other investment is in new physical machinery that implements research and development outcomes to provide existing electricity services at a lower cost. Both of these forms of investment are important to the dynamic efficiency of the NEM. Decisions that discourage these kinds of investments create dynamic inefficiency and so are detrimental to the NEO.

Option 2 erodes both forms of investment. It is Reposit's opinion that it does this directly for FCAS, but also anywhere else where AEMO decision making is relevant to any investment that attempts to improve the efficiency of electricity services.

4.4.1 Option 2 discourages innovation

Innovation in electricity often takes time. This means that successful innovators in the space need to be able to predict well in advance what will happen to the markets that they operate in. Predictions are always discounted for uncertainty. More uncertain markets attract more discounting. At some point a market is too uncertain to predict, regardless of the value in the market and so no innovation occurs in that market. This type of market has low dynamic efficiency and does not work in the interests of consumers. It is the opposite of that encouraged by the NEO.

Stable regulation and market operator adherence to that regulation make it easier for innovators to get their predictions right. This results in less discounting and more innovation. The NEM has seen strong innovation since 2014 because investors have judged its transformation to be relatively predictable. That is, the NEM is moving towards renewables and high-speed electronics, and away from fossil fuels and electromechanical control. Regulations that are consistent with more renewables and high-speed electronics are considered to be low-risk to the transition.

The metering requirements for contingency FCAS have been the same since at least MASS v4 dating back to at least 2012. Innovators such as EnelX and Reposit invested in R&D on metering equipment that met those requirements as part of an effort to bring DER to FCAS services. This metering is operating in the NEM today. Other innovators have also invested in MASS-compliant metering, but have yet to bring it to market for various reasons.

AEMO's adoption of Option 2 will diminish the investment returns that these innovators have made in R&D. This will not go unnoticed in the NEM and innovators will be forced by their governance regimes to heavily discount NEM-centric R&D as a result.

It is Reposit's opinion that the adoption of Option 2 by AEMO communicates the following to innovators:

1. Technical requirements of plant will change even if those changes are contrary to the NEO, the interests of existing (non-trial) participants and trends in technology
2. Early entry to a NEM market is disadvantageous. The market operator will remove short-term, technology-based competitive advantage in the interests of promoting competition
3. Investments in regulatory change activities are more likely to deliver returns than R&D where your existing technology does not meet NEM requirements.

The adoption of Option 2 creates a strong barrier to innovation and discourages the uptake of new technology. Both of these are characteristics of dynamically inefficient markets[35] and so Option 2 does not promote the achievement of the NEO.

4.4.2 Option 2 creates unnecessary investment uncertainty

Investment in physical assets is essential to the correct functioning of the NEM. This is especially true during the current transition to renewable energy. Investment must be made into new plant to deliver electricity services to consumers. The mechanisms that drive investment in the NEM are price signals, market information and regulatory certainty. Any action by a market body that diminishes the functioning of these mechanisms creates investment inefficiency in the NEM. This action is considered deleterious to the achievement of the NEO.

Option 2 creates unnecessary regulatory uncertainty in much the same way as it discourages innovation. It signals to the market that long-standing technical requirements of electricity service delivering assets are subject to change contrary to general trends in the market and the NEO. This has likely not been taken into account by investors and so represents a new source of uncertainty, and hence discounting. This discounting contributes to investment inefficiency in the NEM and does not promote the achievement of the NEO.

This mechanism affects investors in plant, not investors in R&D. There are circumstances in which they are the same party, but often this is not the case. Where DER is concerned, these investors are most often the Consumers referenced in the NEO. These investments are made by Reposit's customers to reduce the effective "price" of electricity services via the return of economic value through their DER participating in the use of electricity services. More uncertainty translates to a lower return on their DER investment for these Consumers. This can be argued as increasing the price of their electricity services.

[35] AEMC - Applying the Energy Market Objectives - https://www.aemc.gov.au/sites/default/files/2019-07/Applying%20the%20energy%20market%20objectives_4.pdf - section 1.4 - page 12

In this way Option 2 is doubly damaging to the NEO. Not only does it create investment inefficiency, but it also acts to effectively increase the price of electricity services for some Consumers.

4.5 Does not make the least demanding assumptions

Key to the long term interests of consumers are regulatory arrangements that are both flexible and resilient enough to respond and evolve whatever the future may bring. Flexible and resilient regulatory arrangements are those that rely on the least demanding assumptions[36]. Option 2 makes assumptions that Reposit does not consider to be the least demanding and so considers the adoption of Option 2 to degrade the MASS's flexibility and resilience.

4.5.1 Large amounts of DER in FCAS are likely

Option 2's introduction of large amounts of error into Fast FCAS response could be argued as acceptable where small amounts of DER were expected to participate in FCAS. Instead it is probable that the combined capacity of Virtual Power Plants operating in the FCAS market will exceed the capacity of traditional large scale generating units currently in market at some point in the future.

The ENA and CSIRO have predicted that the combined capacity of DER will exceed 40GWh by 2030[37]. It is therefore safe to assume the percentage of FCAS provision in Australia that comes from 'small-scale' generators will rapidly grow over time. Allowing vastly increased metering error for a generator type that will represent a rapidly increasing and future dominant proportion of the overall generation mix in the NEM, will have direct and negative implications with regard to the ongoing security of the grid.

4.5.2 Future generators may not be fixed in capacity or location

The penetration of Electric Vehicles (EV's) in Australia is steadily increasing. These assets when connected to the grid can contribute to the FCAS market. The nature of these assets however mean they are transient. They will not always be connected to the grid, or not always connect to the grid at the same point. In fact, they will likely change the location upon which they connect to the grid frequently.

Given this, there may be fixed locations which act as single "generating units" with respect to the FCAS market, that will not have a fixed capacity, charge stations or car parks for example. It is possible that the transient nature of the capacity connected to these generating units means that they will have an FCAS biddable

[36] AEMC - Applying the Energy Market Objectives - https://www.aemc.gov.au/sites/default/files/2019-07/Applying%20the%20energy%20market%20objectives_4.pdf - section 1.2.3 - page 6

[37] https://www.energynetworks.com.au/resources/reports/electricity-network-transformation-roadmap-final-report/

capacity that at times sits above 1MW of capacity and at others sits below 1MW of capacity.

It is unclear with the introduction of this threshold how these locations will be treated, and what metering requirements will be applied. Further, the situation in which a single registered 'generating unit' (location) could both sit above and below this threshold depending upon the time of day or year further exemplifies the arbitrary nature of having a threshold at all.

4.5.3 VPP Demonstrations derived assumptions

The VPP demonstrations provides insights into the establishment and operations of VPPs in highly controlled 'sandboxed' environments with non-representative market and consumer samples. However, the insights presented in the Knowledge Sharing Reports fall short of providing a reliable evidence base to inform regulatory, compliance, or policy design outcomes.

In particular, the VPP trial cannot be considered to provide least demanding assumptions due to trial design limitations, and the low replicability of results and evidence.

4.5.3.1 Trial design limitations

Reposit asserts that there are material limitations in the trial design that unavoidably bias the trial. This means that insights from these VPP demonstrations should not be generalised and used to inform decision making. This assertion is based on the review of NEM Virtual Power Plant (VPP) Demonstrations Program Final Design[38] and the Knowledge Sharing Reports[39].

There seems to be no clear leading hypothesis for the VPP demonstration or articulation of trial assumptions expected key results, or controlled sampling techniques. Nor is there a clear 'business problem' articulated. At best, the trial objectives and research questions are open ended and exploratory. Additionally, there is limited description of the options analysis having been undertaken to ascertain trial scope and intent around verifying and validating the key assumptions of the trial. Which Reposit infers are:

1. MASS-compliant metering is not commercially viable
2. DER response is homogenous across units of a "type"
3. Energy exported from a non-generator Connection Point cannot contribute to an FCAS response under the existing NER.

Furthermore, the technologies used by the trial participants are not a representative sample of the real world deployments, nor are they representative

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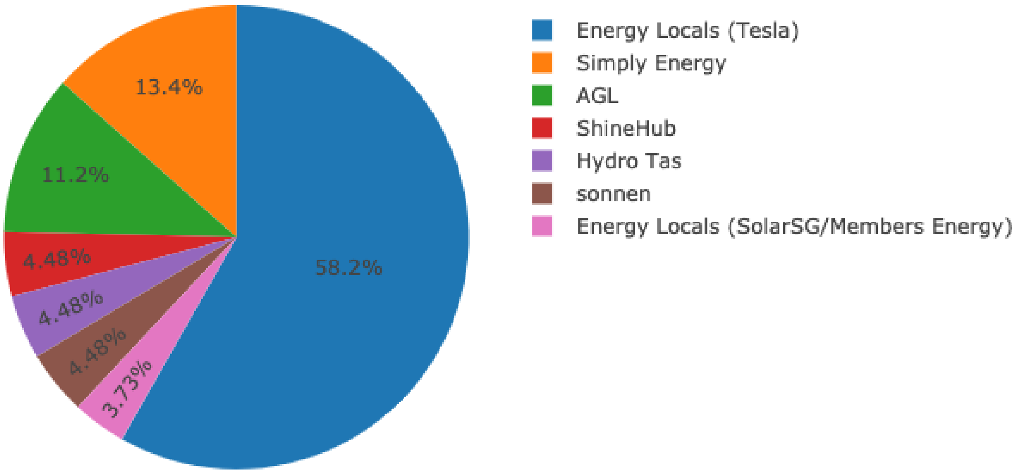
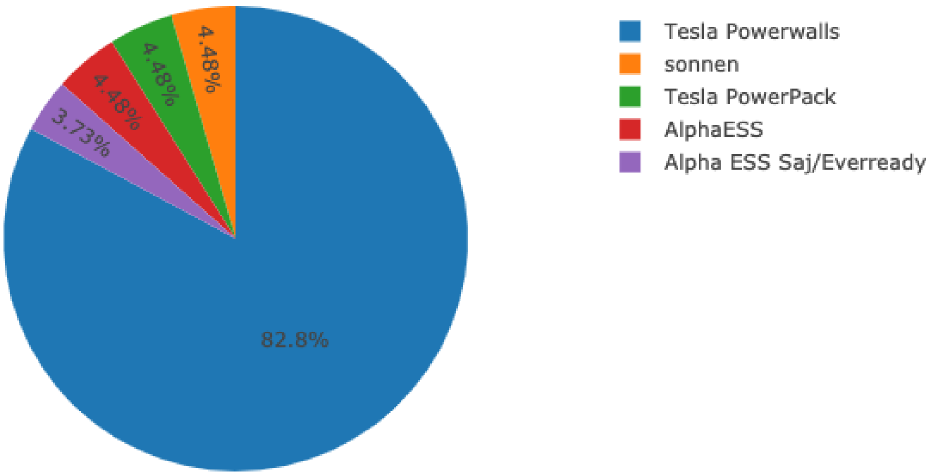
38 https://aemo.com.au/-/media/files/electricity/der/2021/nem-vpp-demonstrations_final-design.pdf
39 VPP Demonstrations Knowledge Sharing Report #3 - Table 1

of the market segmentation under real market conditions. It is evident that there is a clear bias towards certain vendors and technology solutions.



VPP Demonstration MW Registered by Participant



VPP Demonstration MW Registered by Technology Type

4.5.3.2 Replicability of results and evidence

The VPP Demonstrations project has not made any raw trial data publically available. This includes 1Hz data from FCAS responses, 20Hz "type" testing data, and the methods and calculations used to validate FCAS responses. As a result it is impossible for a third-party to examine the conclusions of the trial in respect to the data used to come to the trial's conclusions.

For example, based on the Knowledge Sharing Report #3[40], it appears that the ShineHub Alpha ESS response has NOFB set to very tight settings, in order to trigger a trip. Based on Reposit's operational experience in the market, this does not reflect actual frequency response in the market. This treatment was not mentioned in the Knowledge Sharing Report, nor was any raw data made available for examination.

Furthermore, the trial FCAS Verification Data template indicates a lower level of robustness in verification as compared to the MASS v6 FCASVT. No data on FCAS response verification has been provided at time resolutions other than 1Hz. Nor descriptions as to how the measurement of energy compares under different time resolutions, in particular in respect to error quantification.

Reposit accepts that the VPP Demonstrations project is largely complete and that in-depth criticism of the project is not constructive. Reposit asserts however that the trial lacked rigour and that it cannot be used to inform future policy or engineering decision making in the NEM. Reposit will contribute meaningfully to a review of the trial where the opportunity arises.

[40] VPP Demonstrations Knowledge Sharing Report #3 - Figure 1

5 Market Design Impact Analysis

5.1 Violation of NER Market Design Principles

Section 3.1.4(a) of version 156 of the National Electricity Rules provides the market design principles which govern the creation or modification of electricity markets. In particular, subsections (3) and (5) state the following principles when considering the introduction or alteration of electricity markets:

- 3.1.4(a)(3) - avoidance of any special treatment in respect of different technologies used by Market Participants
- 3.1.4(a)(5) - equal access to the market for existing and prospective Market Participants

Option 2 clearly does not avoid any special treatment in respect of different technologies used by Market Participants. It is trivial to show that Option 2 is clearly intended to relax the requirements of DER, while maintaining a strict metering regime for other types of generation and loads.

Likewise, the adoption of Option 2 provides lower-cost access to the Fast FCAS markets for new entrants. It is trivial to show that lower-cost access is not equal access, because there are existing participants in the Fast FCAS markets using technology of the same type as would benefit from Option 2.

These market design principles make it unlikely that Option 2 could be adopted in the NEM without a rule change. Reposit suggests that these market design principles in particular are central to what makes the NEM a market and that any rule change is unlikely to be successful. Additionally, Reposit considers it unlikely that the NEL can be interpreted such that these principles are not applicable to AEMO decision making.

5.2 Generator capacity and electrical materiality

Option 2 seeks to create different "classes" of MW. Those that are delivered from centralised (>1MW) units, and those that are created from aggregated (<1MW) units. This is not compatible with the design of the market.

The MASS review discussion paper states the following in its argument for relaxed metering requirements for individual generators below a 1MW generation threshold:

> "Larger facilities have more capability to impact the power system, and an ASL with a capacity of more than 1 MW at the NMI will have a significantly larger change in active power per hertz than residential battery systems. For these larger connections, high-speed measurements of power must be captured to verify compliance with the MASS."

This statement uses the capacity of individual generating units, and the materiality of that capacity to the grid, to compare a single residential generating unit to a large scale generating unit in arguing the case for relaxation of metering requirements.

What this argument fails to take into account, however, is that as part of a Virtual Power Plant, these individual residential units do not act individually. They will act in an orchestrated way with many other small scale generators to deliver their combined capacity to the grid at the same time. Electrically speaking, the materiality of outcome with respect to the electricity grid from generation delivered in this way is no different to the materiality of generation delivered from large-scale generation, as now the scale of generation between the two is comparable.

With respect to verification of delivery, AEMO's own FCAS Verification Tool also considers a VPP in aggregate only, requiring aggregated data to verify the delivery of service to market. This renders the application of relaxed metering requirements for small scale generators void, as their aggregated capacity, delivery and impact on the grid is not small-scale.

6 General MASS Issues

Reposit supports a substantive review of the MASS. The MASS is an increasingly important document in the NEM and suffers from well-identified shortcomings.

In 2020 the MASS regulated hundreds of millions of dollars of market value, and was instrumental in informing investment cases for many millions of dollars more. A substantial improvement in the MASS will immediately result in increased efficiency in investment, operation and use of FCAS and clearly promotes the achievement of the NEO. Delaying substantive improvements to the MASS for one reason or another imposes an efficiency cost on the NEM. It is important that any item delaying a substantive review of the MASS yields efficiency gains in excess of those delivered by a substantive MASS review.

It should be noted that despite the shortcomings of the MASS, it does not preclude the inclusion of DER in FCAS provision. AEMO states that a substantive review of the MASS is constrained by the end of the VPP Demonstrations on 30 June 2021. AEMO states that this is to achieve a clear path to continued participation of DER in FCAS markets[41].

This statement ignores that the ASNAES1 DUID is composed entirely of DER. It has been operating for over a year and is a multi-MW participant in all Contingency FCAS markets. This DUID operates without the relaxations provided by the VPP Demonstrations. The existence of this DUID makes it clear that there **is** a clear path for DER participation in FCAS under the current MASS.

This means that there is no urgent requirement to modify the MASS to allow a new, fast-growing and extremely efficient technology to provide FCAS. There is no time pressure and so a substantive review of the MASS can be completed. Reposit considers it inconsistent with the NEO for AEMO to perform an incremental review of the MASS. This is especially true if an incremental review is preferred to a substantive review so as to not delay MASS changes designed to accommodate participants that do not meet the current MASS.

6.1 Switching controller issues

Reposit understands AEMO's bifurcation of FCAS capability into frequency responsive and non-frequency responsive. Reposit agrees that it is largely a dispatch rather than MASS issue. As such it should be facilitated through a constraint (as it is in TAS1). The definition of the constraint, its trigger conditions and its calculation of key quantities should be made public to the market well before a similar constraint enabled in the Mainland NEM. This will allow Participants to determine the efficiency of migrating switched controlled MW to proportional controlled MW where that option exists.

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[41] MASS Consultation Paper - January 2021 - Section 3

Reposit supports the requirement for non-frequency responsive capacity to deliver only when enabled.

Reposit suggests that the restriction on switched controller over-delivery may result in a reduction in the certainty of FCAS delivery from some units. This is because under-delivery is managed by some Participants by constraining an FCAS offer to that part of a unit's response that is reliable. The remainder of any response is “gifted” to the system as it is not reliable enough to base an offer on.

Some existing units may offer capacity that is not reliable if over-delivery is to be restricted by some amount (50% is proposed by AEMO). This will increase the offers made by some units, but decrease the certainty of full delivery. Perversely, the restriction on over-delivery from some units will result in an increased likelihood of under-delivery from those same units. Reposit suggests that some of the most cost-effective, medium-scale FCAS in the market may be impacted by this restriction.

6.2 Delayed response

AEMO is correct that a proportional controller is unable to correctly deliver the Delayed service under the current MASS. The nature of the control means that frequency cannot be restored to 50Hz by a proportional controller. At first glance it would seem that proportional controllers should not be dispatched into Delayed. This would be technically correct, but would not contribute to the efficient restoration of 50Hz operation after a contingency event.

Many of the same issues that AEMO is attempting to address with the frequency responsive/non-frequency responsive bifurcation come into play here. Reposit asserts that AEMO is able to alleviate all of these issues with a considered application of frequency settings across units. These settings cannot be identical across units and so issues of equity arise. This is one of the reasons AEMO must work to demonstrate a fair and unbiased treatment of Participants in FCAS markets. A Participant that is trusting of AEMO is likely to carry an increased load for some time provided that they are sure that AEMO are not intentionally providing advantage to their competition.

6.3 Trial formulation

AEMO has substantially reworked the “Trials of New Technologies” section in its proposed new form of the MASS. In MASS v6, this section reads:

7.3. Trials of new technologies

AEMO, at its absolute discretion, may allow an Ancillary Service Facility to participate in a trial to test the performance of new technologies.

It is envisaged that any trial will:

- Be for a limited period,
- Be for a limited measurable quantity of the service, and
- Be subject to the conditions that the party conducting the trial:
  - Withdraw from the market if directed by *AEMO*.
  - Use best endeavours to meet the full requirements of the MASS.
  - Meet any other requirements AEMO, at its discretion, requests.

This is considered by Reposit to be generally correct for a trial of new technology. In particular the period and quantity limited nature of a trial under this formulation is important. Reposit suggests however that the period and quantity limits should be explicitly quantified and stated in the MASS.

An AEMO trial should not be interpreted by Participants to be a backdoor into AEMO markets. This interpretation would reduce investment certainty and discourage innovation, as Participants may inefficiently invest in the attainment and promotion of a trial of their non-compliant technology instead of in compliant technology. This is detrimental to the achievement of the NEO and may impact the trust other Participants feel towards the market operator.

Technology trials can be important, but only where there are no other efficient ways to gather the required information. Reposit asserts that AEMO should define the precise conditions under which a trial will be granted. Reposit suggests that the VPP Demonstrations has been useful in providing the NEM with lessons learned in this area, and that Participants are interested to work with AEMO to define these conditions.

AEMO has removed any and all specific restrictions on a trial in section 11 of the new proposed form of the MASS. For the reasons discussed above Reposit asserts that this is detrimental to the NEO, AEMO's position as the market operator, and Participants of new and existing market ancillary services.