AEMO Virtual Power Plant Demonstration

March 2020

Knowledge Sharing Report #1

Important notice

PURPOSE

The purpose of this document is to provide an update to ARENA and the industry regarding the Virtual Power Plant (VPP) Demonstration progress and lessons learnt.

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VERSION CONTROL

Version	Release date	Changes
#1	19/03/2020	
#2	17/07/2020	Revenue figures updated – Section 2.2 Value stream realisation

ARENA summary

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Sub-contractors	Intelia Pty Ltd The Customer Experience Specialists
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1. Introduction

1.1 Background

The Australian Energy Market Operator (AEMO)'s Virtual Power Plant (VPP) Demonstrations trial began in July 2019 and in September 2019 it gained its first participant when Energy Locals, in a consortium with Tesla (SA VPP), registered to participate in the VPP Demonstrations. In February 2020, AGL registered as the second participant; however, at the time of publication, AEMO has not had the opportunity to review any operational data from AGL. AEMO will continue to work with a pipeline of interested VPP participants and expects more participants to join over the coming months.

Over the past year, there were notable power system and market events that required large amounts of contingency Frequency Control Ancillary Services (FCAS) or energy only responses. Some of these events are analysed in this report to draw insights from the data on how the SA VPP is interacting with the power system. Note that Tesla has supplied data for this analysis.

Events requiring contingency FCAS were:

- 9 October 2019, Kogan Creek trip (Queensland generator).
- 16 November 2019, Victoria and South Australia regional separation.
- 10 December 2019, under frequency event.

Events requiring an energy response were:

- 30 April 2019, behaviour regarding a negative pricing event.
- 9-15 January 2020, behaviour over the course of a week.

1.2 Virtual power plant demonstration objectives

A VPP broadly refers to an aggregation of resources (such as decentralised generation, storage and controllable loads) coordinated to deliver services for power system operation and electricity markets.

In Australia, grid connected VPPs are focused on coordinating rooftop photovoltaic (PV) systems, battery storage, and controllable load devices, such as air-conditioners or pool pumps, through the market. This is heavily integrated with AEMO's uplift of distributed energy resources (DER) performance standards development.

The VPP Demonstrations explore the capability of aggregated DER to deliver contingency FCAS and develop AEMO's understanding of how VPPs respond to energy market price signals. It is anticipated that coordinating DER through VPPs can benefit both:

- Consumers owning VPP assets who earn value from delivering grid services, such as reliability and emergency reserve trader (RERT), FCAS, or energy. The value received by consumers depends on the business model offered to them by VPP operators.
- All other electricity consumers who benefit from a more efficient power system, as more resources respond to market price signals rather than operating independently.

The progress to date allows AEMO to begin exploring two of the research questions identified in the final design of the demonstration program[1] these are explored in Section 2:

[1] AEMO, Pilots and Trials - NEM Virtual Power Plant (VPP), final design, 2019: https://www.aemo.com.au/-/media/Files/Electricity/NEM/DER/2019/VPP-Demonstrations/NEM-VPP-Demonstrations_Final-Design.pdf

- Operational capability for market participation.
  - Can VPPs reliably deliver the contingency FCAS that they bid, and are enabled, for?
  - What is the typical extra fleet capacity that VPP operators dispatch, over and above the target that they have been enabled for, to reliably meet that target?
  - What are appropriate ongoing operational arrangements for DER to participate in the FCAS and energy markets?
- Market dynamics and planning.
  - To what extent do VPPs respond to energy market price signals?
  - If this behaviour is extrapolated to reflect the potential for very large VPPs in future, what impact could VPPs have on energy market dynamics?
  - How much reliance should be placed on VPPs responding to energy market price signals for integrated system planning studies?

AEMO will address the other research questions (local power quality, consumer insights, and cyber security) in future progress reports as participation ramps, more data is received, and the customer insights study gets underway.

One of the stated objectives of the VPP Demonstrations is to assess current regulatory arrangements affecting participation of VPPs in energy and FCAS markets and informing new or amended arrangements where appropriate. Early conversations with participants have indicated interest in further participation of FCAS markets from a DER and VPP perspective, this is discussed under Section 2.3.

1.3 Purpose of this paper

AEMO is committed to sharing the insights learned throughout the VPP Demonstrations by publishing knowledge-sharing reports to allow others to gain insights and value from the rich data set that VPP participants share with AEMO. This first knowledge sharing report will cover AEMO and participants' early lessons learnt and next steps.

2. AEMO's lessons learnt

AEMO has gained several insights from the VPP Demonstration project which are valuable for the industry to be aware of as the DER community matures. This section details various early lessons learnt regarding:

- Operational capability for market participation.
- Value stream realisation.
- Early assessment of regulatory arrangements.
- Technology development.

2.1 Operational capability for market participation

Understanding VPP's operational capability for market participation was a critical reason for establishing the VPP Demonstration. Please refer to Chapter 1 of the VPP Demonstrations Final Design document for further information on the VPP Demonstrations objectives and why this project is important.[2]

At this stage there is a small pool of data to draw on, however, the data received so far indicates that VPPs can effectively respond to power system events and price signals.

This includes responding to frequency excursions beyond the normal operating range (49.85-50.15 Hz) and pre-charging (or discharging) to cater for future high (or low) price events, respectively. See below for various SA VPP responses to contingency FCAS and energy events in South Australia.

2.1.1 Contingency FCAS response

During the trial period to date, three significant contingency FCAS events which demonstrated different responses from the SA VPP occurred and have been analysed:

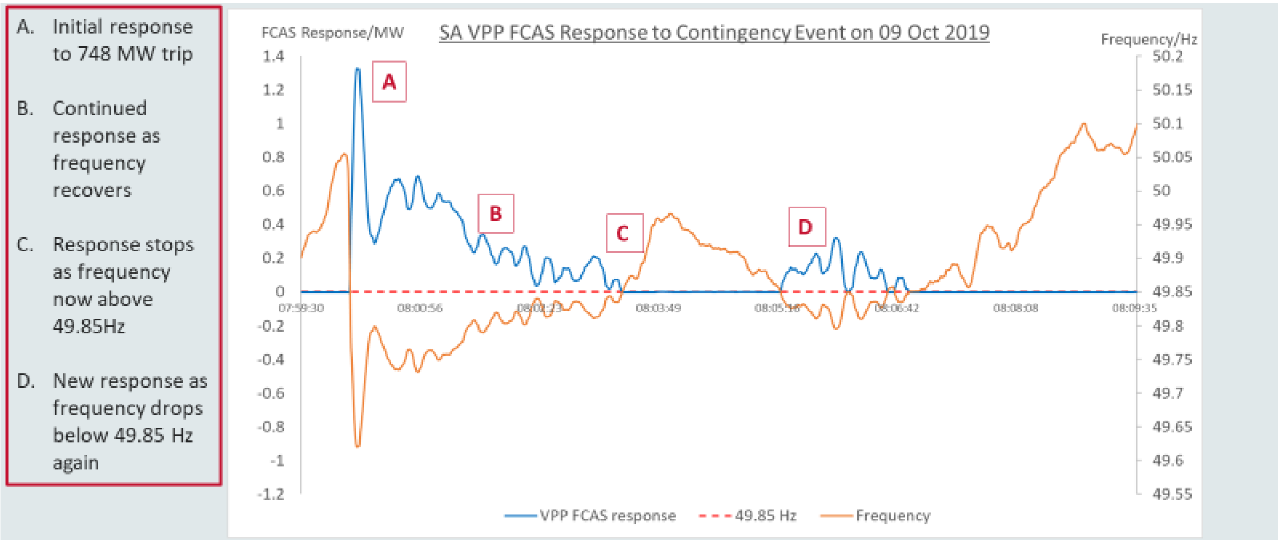
- The 9 October 2019 Kogan Creek trip (Queensland generator).
- The 16 November 2019 Victoria and South Australian regional separation.
- The 10 December 2019 under frequency event.

It should be noted that when Queensland and New South Wales were separated on 4 January 2020, the SA VPP was not enabled for contingency FCAS.

9 October 2019, response to Kogan Creek trip

During this event, the largest generating unit (at Kogan Creek in Queensland) in the National Electricity Market (NEM) tripped off unexpectedly from 748 MW and power system frequency immediately dropped to 49.61 Hz, which is below the normal operating range. The SA VPP detected this frequency excursion and responded immediately to inject power into the system and aid frequency recovery, shown below in Figure 1.

Figure 1 FCAS response for SA VPP – 9 October 2019, Kogan Creek trip (Queensland generator)



Source: Tesla data, verified by AEMO

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[2] AEMO, 2019. *VPP Demonstrations Final Design document*. Available: https://aemo.com.au/initiatives/major-programs/nem-distributed-energy-resources-der-program/pilots-and-trials/virtual-power-plant-vpp-demonstrations.

16 November 2019, response to Victoria and South Australia regional separation

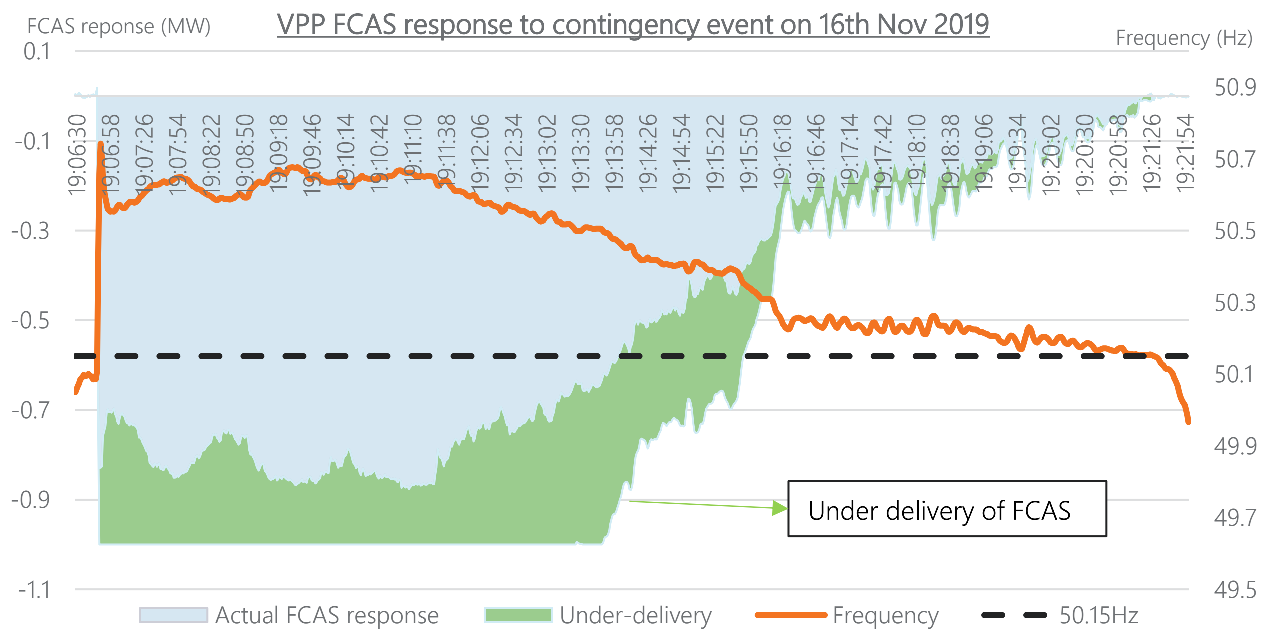
At just after 6pm, a non-credible contingency event resulted in the electrical disconnection of the South Australian region from the rest of the NEM power system for nearly five hours. The initial separation resulted in the power system's frequency reaching 50.85 Hz[3], which meant the SA VPP was required to deliver its full amount enabled, 1 MW lower contingency FCAS. In this example, the SA VPP under-delivered FCAS.

Energy Locals and Tesla provided the below insights regarding the SA VPP's response to this contingency event.

> 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

Figure 2 shows the aggregated response to the event where the green shading indicates the amount that was not delivered by the SA VPP.

Figure 2 FCAS response for SA VPP – 16 November 2019, Victoria and South Australia regional separation



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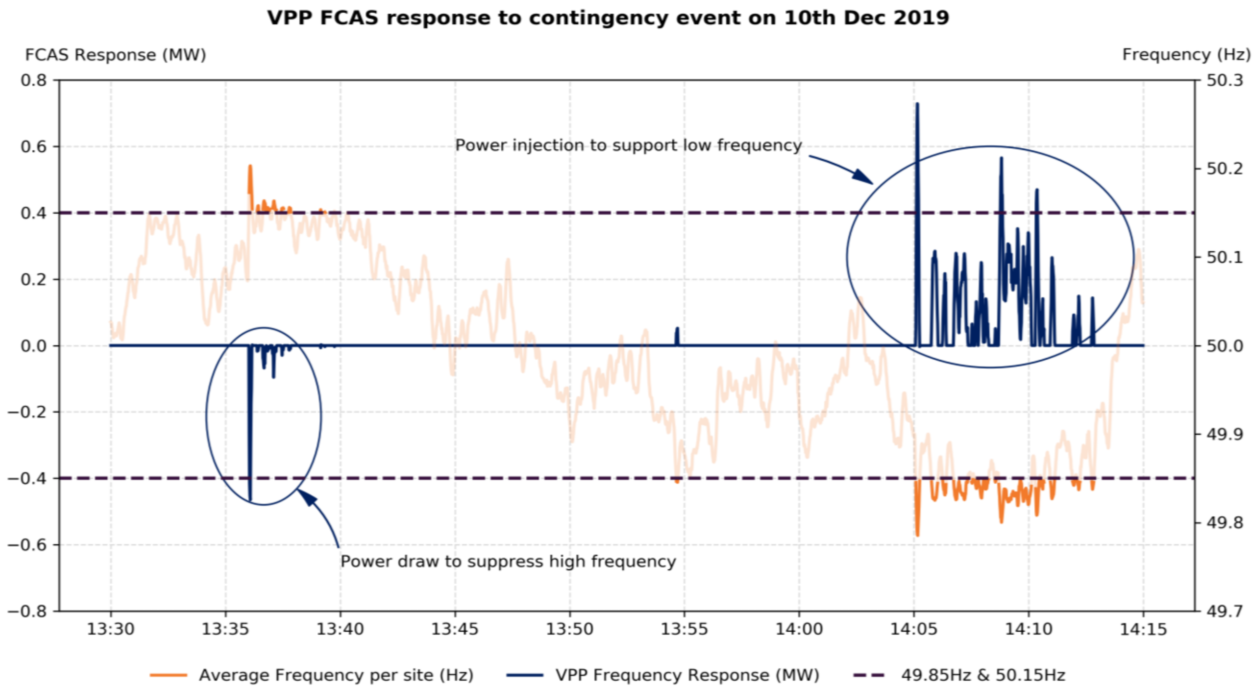
[3] AEMO. *Preliminary report non-credible separation event South Australia – Victoria on 16 November 2019*. Available: https://www.aemo.com.au/-/media/Files/Electricity/NEM/Market_Notices_and_Events/Power_System_Incident_Reports/2019/Preliminary-Incident-Report---16-November-2019---SA---VIC-separation.pdf.

10 December 2019, response to under frequency event

During this event, the NEM experienced both high (>50.15Hz) and then low (<49.85Hz) frequency events within 45 minutes of each other. The SA VPP responded immediately in both cases to first charge the batteries to lower system frequency, and then discharge the batteries to raise system frequency, shown in Figure 3 below.

Figure 3 FCAS response for SA VPP – 10 December 2019, Victoria and South Australia regional separation



2.1.2 Energy market response

Two energy price events over the course of 2019 have been chosen to assist in demonstrating the SA VPP's ability to cater for various scenarios.

Of interest is the pre-charging and discharging behaviour the batteries undertake in preparation for forecast high and low events, respectively. There are two scenarios that highlight this:

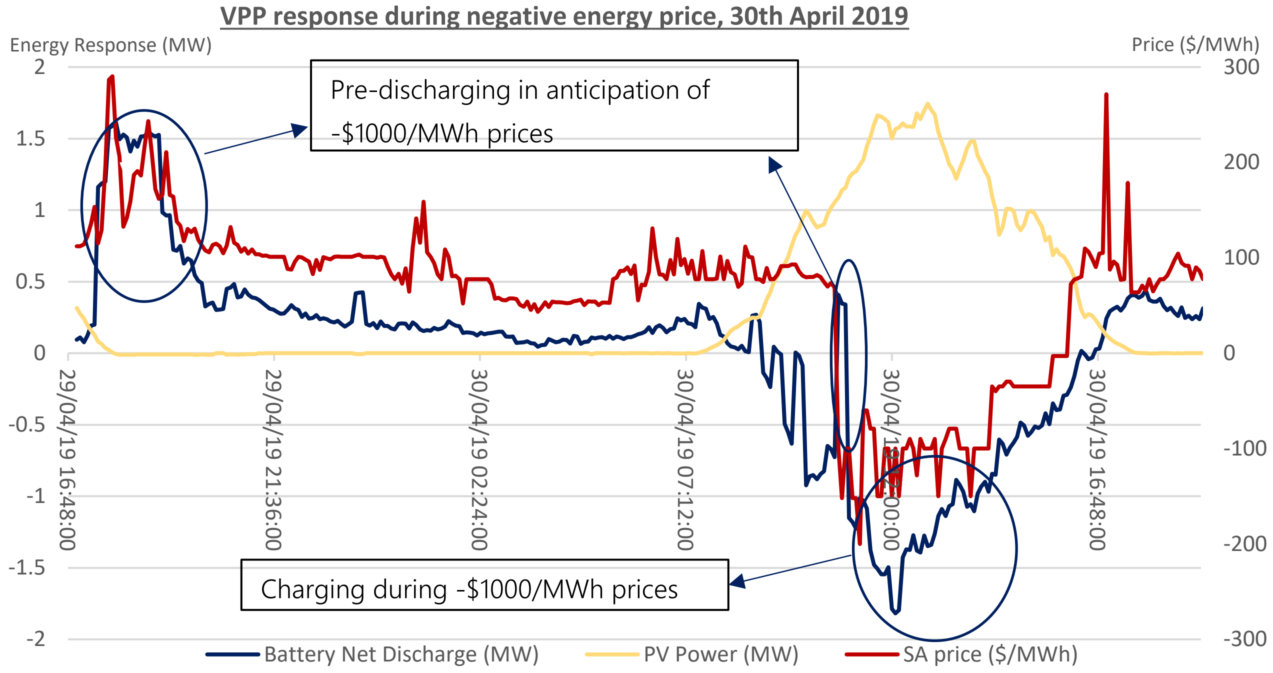
- 30 April 2019, behaviour regarding a negative pricing event.
- 9-15 January 2020, behaviour over the course of a week.

30 April 2019, response leading up to and during a negative energy pricing event

There was a negative pricing event before the VPP Demonstration began which shows the typical behaviour of the SA VPP when anticipating negative prices in the energy market.

Figure 4 shows the batteries pre-discharging, prior to the forecast negative prices on 29 April 2019, to ensure there would be capacity to charge during this event. It also shows the batteries charging during the excess of supply causing negative prices in the middle of the day on 30 April 2019.

Figure 4 Energy response for SA VPP – 30 April 2019, negative price event

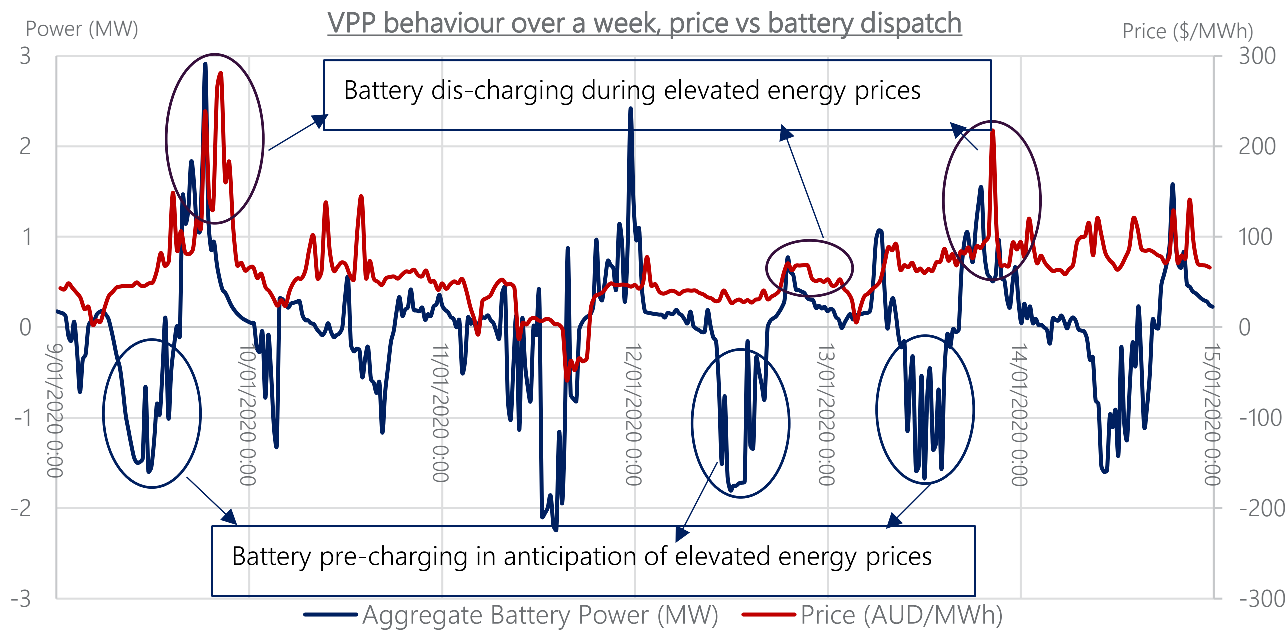


9-15 January 2020, response to energy spot prices over the course of a week

Observing the VPPs' response over the course of a week provides evidence that VPPs do respond to energy market signals. This is shown in Figure 5 by batteries pre-charging in anticipation of elevated prices and discharging during the elevated price event.

As a result, the power system is supported by the provision of additional power when needed.

Figure 5 Energy response for SA VPP – 9-15 January 2020, behaviour over a week



These events show that VPPs can benefit:

- Participating consumers by sharing the value earned through the VPP participating in FCAS or responding to energy market prices; and
- All other consumers by creating more competition in these markets to reduce prices and, if VPPs scale up enough, potentially deferring/displacing the need for large-scale generation assets.

2.2 Value stream realisation

Energy Locals, as the market participant for the SA VPP, has been able to earn revenues by participating in the six contingency FCAS markets. Total revenue over the first four months of their involvement (from 13 September 2019 to 12 January 2020) is $225,000. Note that the SA VPP increased its registered capacity from 1 MW to 2 MW on 19 November 2019.

To gain a deeper understanding of how this revenue was earned, Table 1 presents different metrics. It highlights that most of the revenue was from five large contingency FCAS events ($132,047 or 59% of total earnings) and from lower contingency FCAS ($102,471 or 78% of the amount earned during these events). The larger portion from lower FCAS was driven by several very high, contingency FCAS lower prices during big power system events. Energy Locals had its VPP enabled for contingency FCAS approximately 70% of the time during this period.

The two large contingency FCAS events mentioned in Table 1 took place in November 2019 and a brief explanation of these events is provided below. It is the responsibility of the VPP to decide how this revenue is shared with its customers:

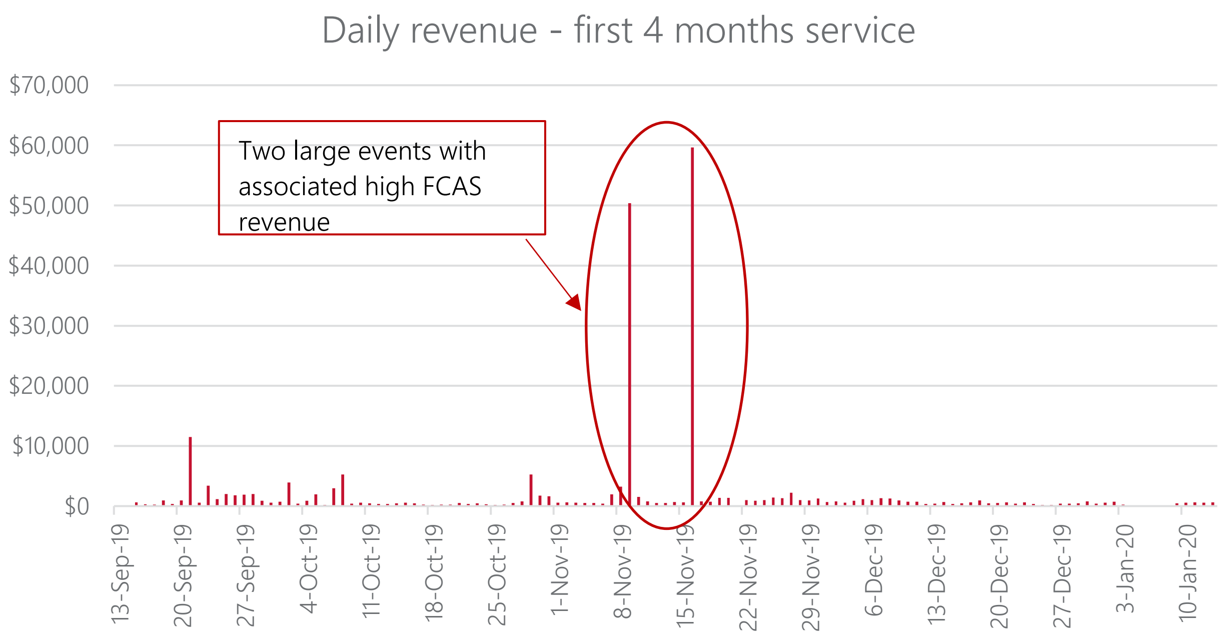
- On 9 November 2019, AEMO invoked local contingency FCAS requirements for South Australia due to the heightened risk of electrically islanding the state. During this event, a shortage of supply in the lower 6-second and lower 60-second markets resulted in prices hitting the price cap ($14,700/MWh) in the wholesale market for 85 minutes. This event resulted in daily revenue of $50,396 for the SA VPP.
- On 16 November 2019, a trip of the Heywood Interconnector resulted in South Australia islanding from the rest of the NEM for around five hours. During the islanding, AEMO invoked local FCAS requirements for South Australia, with scarcity of supply in three FCAS markets resulting in very high FCAS prices. A shortage of lower 6-second and raise 6-second supply led to these markets hitting the price cap for 100 minutes and 65 minutes, respectively, which resulted in daily revenue of $59,645 for the SA VPP.

Table 1 Revenue and enablement analysis

Revenue and enablement analysis for the period 13 Sep 2019 – 12 Jan 2020 (inclusive)						
	Lower contingency FCAS			Raise contingency FCAS		
Revenue	LOWER5MIN	LOWER60SEC	LOWER6SEC	RAISE5MIN	RAISE60SEC	RAISE6SEC
Total	$224,926					
Total across the 6 contingency FCAS markets	$4,226	$59,886	$62,080	$4,057	$30,359	$64,319
Sum of Lower/Raise services	$126,191			$98,735		
Lower/Raise portion of total	56%			44%		
Two large (>$50,000) contingency events, lasting 1-2 hours	Two events, earning $110,041 which equates to 49% of all revenue					
Five medium (>$5,000) contingency events	Five events, earning $132,047 which equates to 59% of all revenue and an additional ~$22,000 above the two large events					
Daily average, including the medium-large contingency events	$1,844					
Daily average, excluding the medium-large contingency events	$761					
Amount of time the VPP was enabled per contingency FCAS market	73%	73%	73%	70%	71%	71%
Average amount of energy enabled per contingency FCAS market (MW)	1.1	1.1	1.1	1.2	1.3	1.3
Monthly NMI revenue	September 2019	October 2019	November 2019	December 2019	January 2019	Average
Monthly NMI revenue ($/NMI/month)	$57.67	$64.85	$238.79	$26.17	$5.13	$78.52

Figure 6 provides some perspective between regular FCAS earnings in the NEM, compared to the event driven revenues. Note the 9 and 16 November large events are clearly visible.

Figure 6 Daily SA VPP revenue for the first four months of service



In comparison to the first four months of commercial operation, the SA VPP earnt $1,033,303 between 31 January – 12 February 2020. This revenue was generated during the South Australian islanding event that started on 31 January 2020 ran until 17 February 2020. Figure 7 shows the revenue earnt over the first five months (13 September 2019 to 12 February 2020) of commercial operation. This further highlights that contingency FCAS revenue is tightly associated with some power system events.

Figure 7 Daily SA VPP revenue for five months of service

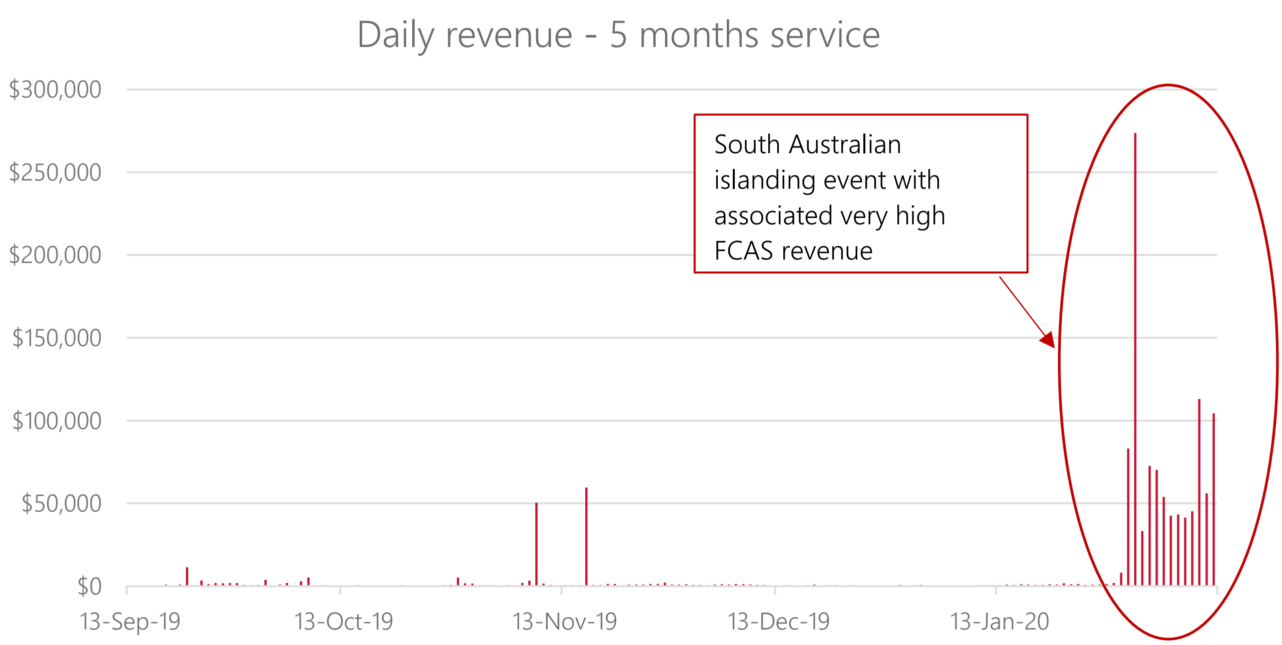
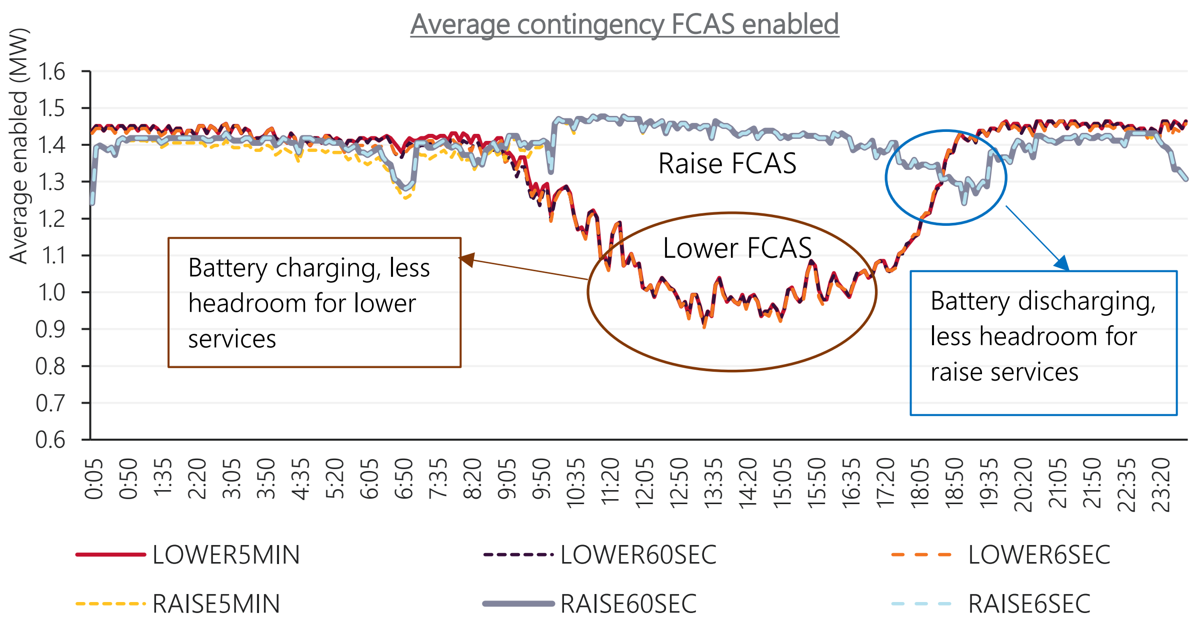


Figure 8 shows the average enablement over 24 hours for the full five months of service for all contingency FCAS. During the day, raise services are typically enabled at higher levels with a steady decline of lower services. This pattern is related to the charging and discharging behaviour of the aggregated batteries with in a VPP.

Figure 8 Average FCAS enablement over 24 hours



2.3 Early assessment of regulatory arrangements

The VPP Demonstrations has identified a number of regulatory arrangements to be considered for amendment. This section discusses what has been put in place to date and arrangements under consideration.

2.3.1 Arrangements made to date

One key regulatory restriction that the VPP Demonstrations has sought to address relates to the classification of a load which has DER behind the connection point as an ancillary services load under the current National Electricity Rules (NER) and Market Ancillary Services Specifications (MASS).

AEMO's general approach (before the VPP Demonstrations) has been to treat an application for approval to classify a load as an ancillary services load with respect to the import side of the connection point only. Where a Registered Participant wishes to provide ancillary services through export from the connection point, AEMO has required that the Registered Participant apply to classify the ancillary services generating unit to provide these FCAS services. As a result of this approach, only Market Generators have been eligible to provide ancillary services through export to the grid.

Interim arrangements for FCAS from DER

AEMO has considered the initial results of the VPP Demonstrations, stakeholder feedback, and the regulatory and technical requirements of the MASS and the NER in developing Interim Arrangements for FCAS from DER that were published in December 2019[4]. These arrangements recognise the provision of FCAS by exporting from a load connection point in AEMO's classification process, effectively allowing load connection points to operate bi-directionally to deliver FCAS.

[4] AEMO, Interim Arrangements for FCAS from DER on December 2019. Available: https://www.aemo.com.au/-/media/Files/Electricity/NEM/Participant_Information/New-Participants/Interim-Arrangements-for-FCAS-from-DER.pdf

2.3.2 Arrangements under consideration

AEMO has identified the various areas presented below for further consideration as a result of industry consultation and lessons learnt from the VPP Demonstrations:

- Streamlining data as a service for intending participants. AEMO is receiving increased interest from participants who would like to gain full access to AEMO's market data. This is particularly relevant to participants operating in consortium with a Market Customer, currently the process is lengthy and would benefit to being streamlined.
- Small Generator Aggregators (SGA) providing FCAS – AEMO has fielded numerous enquiries from organisations seeking to develop projects that would like to register as an SGA, but would also like to participate in FCAS markets.
- Faster contingency FCAS (e.g. sub two second service). The speed of VPP frequency response observed in the early stages of the VPP Demonstrations suggests that VPPs deliver Fast FCAS quicker than the required six second response. If a faster contingency FCAS market was deemed to be required (for instance a sub two second market), then VPPs may be eligible to participate in such a market. This would have to be considered in the context of the Mandatory Primary Frequency Response rule change process, and further analysis on potential changes to frequency control in the NEM.
- Could VPPs participate in regulation FCAS – AEMO is keen to collaborate with VPP Demonstrations participants to develop a test to explore whether VPPs would be capable of delivering a frequency regulation service.
- Future market services are designed to recognise that DER and VPPs could deliver those services, since early insights from the VPP Demonstrations suggest that VPPs are capable of delivering a range of services for the power system.

2.4 Technology development

2.4.1 Application programming interface integration

AEMO embarked on the establishment of a new application programming interface (API) management platform with the launch of the VPP Demonstrations. This required establishing patterns for the multi-cloud integration for the first time. All four APIs are published on the new platform[5] and are accessible via public internet.

In addition to the new API management platform, all VPP applications were developed using a modern toolset and technology. This process was more complicated and took longer than initially expected, largely as the VPP industry is still in the early stages of development in Australia.

Industry infancy

The following points are specifically noted regarding the early development phase of VPPs in Australia:

- The VPP communities are relatively new and growing, therefore capacity building is still underway.
- Supporting process documentation has been evolving over the VPP Demonstrations project lifetime.
- The maturity of cyber security frameworks, patterns, processes and practices have been developing over the VPP Demonstrations project lifetime.

Participants interested in joining the VPP Demonstration are encouraged to give consideration to:

- Developing API interfaces.
- Data sharing capabilities, governance, monitoring and quality assurance.

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[5] AEMO. Available: https://dev.preprod.aemo.com.au/.

- Regular settings checks.
- Default system settings.
- Cyber security.
- Continuous monitoring of capability and headroom to inform bidding strategies.
- Automated bidding capabilities.

AEMO is considering establishing a participant working group to discuss the capabilities, systems, and data elements required for VPP projects going forward.

Additionally, to further assist new participants who wish to join the VPP Demonstration trial, AEMO will be publishing an onboarding document in early 2020.

2.4.2 Scalable considerations

Platform development and enrolment processes are key considerations to scaling from the current demonstration environment to a production-ready one.

Platform development

The VPP Demonstration APIs are designed as synchronous APIs, which means they return a response from a request immediately. This involves performing a sequence of validation steps (such as API schema, data, and business rule), followed by writing the data to the backend database. On completion, a response (success or error) is sent to the participant. As observed in the VPP Demonstrations, a synchronous API design works very well when processing small amounts of data or with a small payload size. Additionally, it enables real-time processes, tracking of errors, and low latency.

As the payload size increases, the time taken to process the data also increases, resulting in longer API response times. This can lead to the degradation of services, unsatisfactory user experience and has the potential to cause timeouts and network errors. AEMO suggests using bundling and limiting the number of transactions within a request to achieve optimal response times. This will result in greater user experience, low latency and avoid the issues around timeouts. AEMO further recommends the use of streaming when participants need to submit a large volume of data.

Enrolment process

AEMO has developed a number of automated processes for VPP Demonstrations enrolment (such as National Metering Identifier (NMI)/ Financially Responsible Market Participant (FMRP) validation) but further work needs to be done to remove manual processes to enable the system to be more scalable. The pilot system was intentionally built as a proof of concept system to provide value for money and time to learn before AEMO implements a scalable, production-ready solution.

3. Participant lessons learnt/feedback

AEMO has sought feedback from Energy Locals and Tesla. Feedback is provided below as a quote directly from Tesla as the VPP operator (noting that the section on streamlining the registration process is given jointly by Energy Locals and Tesla).

3.1 Tesla feedback – general

> The AEMO VPP trial has provided significant opportunities to demonstrate the capability and revenue earning opportunities for aggregated DER and VPPs operating in the NEM; specifically, the capability of aggregated assets to rapidly respond to frequency deviations and provide critical system security services.
>
> This has also meant VPPs are able to access revenues from markets that aggregated assets, particularly smaller aggregated assets, have traditionally been excluded from. The VPP trial has enabled this by:
>
> - Allowing bi-directional, behind-the-meter aggregated DER assets (such as battery storage) to provide frequency services as both generation and load.
> - Requiring one high-speed (50 millisecond) meter per jurisdiction to cater for appropriate compliance data on a sampling basis when providing contingency FCAS.
>
> The VPP Demonstration has already delivered learnings that have enabled AEMO to release interim arrangements that allow the provision of frequency services as both generation and load, outside the VPP Demonstrations. This is the case if VPPs can meet the current Market Ancillary Services Specification (MASS)[6].
>
> Tesla

3.2 Tesla feedback – asset registration

> The draft 2020 AEMO Integrated System Plan (ISP)[7] projects a significant uptake of VPPs in the NEM between now and 2040. It assumes a large number of DER will be aggregated and market-facing.
>
> To achieve this projection, scalability of VPPs is vital. Tesla's experience over the first six months of the VPP is that there are areas for improvement to streamline the registration process and encourage greater coordination of DER assets.
>
> VPPs were a new asset class for AEMO. For the purposes of the AEMO VPP Demonstration Trial, AEMO has developed a VPP specific registration form which is fit for purpose and provides more clarity for market customers and VPP operators looking to participate as a VPP.

[6] AEMO, Interim Arrangements for FCAS from DER, 2019, at https://wa.aemo.com.au/-/media/Files/Electricity/NEM/Participant_Information/New-Participants/Interim-Arrangements-for-FCAS-from-DER.pdf.

[7] At https://www.aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/isp/2019/draft-2020-integrated-system-plan.pdf?la=en.

There are, however, additional ways that AEMO can further improve the registration process and drive scale of uptake; recommendations are outlined in Table 2.

On a broader note, the current AEMO process requires unique Virtual Power Plant Identifiers (VPPIDs) and dispatchable unit identifiers (DUIDs) for all regions and technology types. Additionally, compliance data for frequency excursions and the VPP's response needs to be submitted manually.

AEMO should continue to work with VPP participants on options to streamline time spent on compliance requirements.

Table 2 Tesla's further improvement recommendations

Category	Current approach	Tesla recommendation
Registered capacity	Under the current approach, VPPs register the amount of capacity that they are able to demonstrate they can provide as per the results of the VPP wide test. This is managed in 1MW increments as per the National Electricity Rules (NER). This will not be directly equal to the nameplate capacity as available capacity will also be influenced by customer load and site factors.	Total registered capacity should be based on nameplate capacity of the aggregated assets. Bids should be submitted based on the available capacity during a dispatch period (based on state of charge and load profiles).
VPP Wide test	The current registration approach requires a VPP wide fleet test every time a VPP registration is updated. This is a requirement for all four registration scenarios[8], including scenario 4 which only includes updating the installed MW capacity without introducing new technology or new regions. This adds delays to registration updates and scalability as frequency excursions often do not last long enough to collect meaningful data and satisfy the requirements of the VPP wide test.	The preferred approach for updating a registration under scenario 4 is to provide AEMO with the following: 1. Updated NMI device list via API and corresponding aggregate capacity calculated. 2. Fleet wide configuration test that confirms all sites have proper frequency/power settings. 3. Ex post compliance data will still be provided to AEMO to ensure that all systems are delivering appropriate bid amounts. It is recognised that VPP wide tests will still be required for registration scenarios 1 and 3. scenario 2 may require further consideration as the trial progresses given the same technology use.
PRC approval process **(Energy Locals joint feedback with Tesla)**	AEMO Participant Registration Committee (PRC) approval process is currently required for all changes to registration, including scenario 4 which is a simple update to total registered capacity. This can add >10 business days to an update to installed capacity as PRC works to set timeframes.	For scenario 4, remove the need for PRC approval. Tesla suggests that as an alternative to PRC approval, the process should be as follows: 4. All new NMIs registered with AEMO via API integration. 5. VPP wide test alternative managed as per suggestion above. 6. AEMO updates capacity to reflect nameplate capacity of total aggregated systems registered.

Tesla

3.3 AEMO's response to participant feedback

AEMO appreciates and acknowledges the above feedback. These points will be given consideration, along with feedback from other participants as they join and operate within the VPP Demonstrations framework.

[8] AEMO, Pilots and Trials - Enrolment Guide, 2020, at https://www.aemo.com.au/-/media/Files/Electricity/NEM/DER/2019/VPP-Demonstrations/VPP-Demonstrations-Enrolment-Guide.pdf.

4. Next steps

The VPP Demonstrations will continue to gain learnings regarding the effectiveness of VPPs adding value to the power system, such as by charging up during negative pricing and discharging at peak demand times in the summer. The SA VPP's participation in the VPP Demonstrations so far is an example of close industry collaboration and implementing innovative solutions to challenges arising from the energy transformation.

AEMO will continue to monitor and analyse participants' responses to events on the power system. The addition of other participants will enrich the current data set and allow for more analysis to be carried out and a deeper understanding to be gained.

This analysis will be done with the following research questions in mind (not an exhaustive list):

- Operational visibility
  - To what extent are VPPs able to accurately forecast their operational capability over various timeframes?
  - What VPP operational data does AEMO require to facilitate very large VPPs operating without negative impacts on power system reliability and security?
  - Is it appropriate for large-scale VPPs to become scheduled resources in the energy market and, if so, at what threshold?
- Market dynamics and planning.
  - To what extent do VPPs respond to energy market price signals?
  - If this behaviour is extrapolated to reflect the potential for very large VPPs in future, what impact could VPPs have on energy market dynamics?
  - How much reliance should be placed on VPPs responding to energy market price signals for integrated system planning studies?
- Local power quality.
  - To what extent do local power quality or fleet communication issues impact VPPs' capability to meet their operational objectives?
  - Can the VPP operational data provide useful insights to distribution network service providers (DNSPs) about the real time status of low voltage networks?
- Consumer insights.
  - What are consumers' experiences of participating in Australia's early stage VPPs?
  - Is VPP participation attractive enough for consumers to give up control of their assets?
  - How can the consumer experience of VPP participation be improved to make it more attractive for consumers to sign up in future?
- Cyber security.
  - To what extent do VPPs, and DER more generally, present cyber security risks that could pose a threat to power system security?
  - Are VPPs appropriately incentivised to independently address cyber security risks?

Conclusions will then be drawn to inform the July 2020 knowledge sharing report, and future market reform recommendations.

During the course of the VPP Demonstration project, AEMO expects to receive further data which will assist with the following research questions:

- Device-level operation data:
  - What proportion of VPPs are under orchestration?
  - What factors drive orchestration?
  - What various charge/discharge profiles exist?
  - How available are VPPs at time of maximum demand?
  - What are the demographic drivers of charge state?
- Aggregate VPP operation data:
  - What generation and demand profiles exist?
  - What availability profiles have been created?
  - How accurate are the VPPs' forecast accuracy?

During the next few months AEMO will be conducting a comprehensive survey to better understand the aforementioned questions under 'customer insights', these will begin circulation in March 2020 to existing VPP Demonstration customers.