AEMO NEM Virtual Power Plant Demonstrations

September 2021

Knowledge Sharing Report #4

Important notice

PURPOSE

The purpose of this document is to provide a fourth and final update to the Australian Renewable Energy Agency (ARENA) and the industry regarding the Virtual Power Plant (VPP) Demonstrations progress and lessons learnt.

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VERSION CONTROL

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ARENA summary

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Sub-contractors	Intelia Pty Ltd Customer Service Benchmarking Australia Pty Ltd
Ref	Knowledge Sharing Report #4
Applicable time period	24 months from trial commencement
AEMO contact	Matt Armitage

Executive summary

The Virtual Power Plant (VPP) Demonstrations project was an initial step in AEMO's broader Distributed Energy Resources (DER) Program, designed to provide early insights on how to integrate VPPs into market frameworks at scale, and develop empirical evidence to inform related changes to regulatory frameworks and operational processes.

This fourth Knowledge Sharing report outlines key insights from the VPP Demonstrations and recommendations for next steps to develop the necessary collective capabilities for a high DER future.

Participants in the VPP Demonstrations have included:

- Eight VPP portfolios across all mainland National Electricity Market (NEM) states.
- A total registered capacity of 31 MW (equivalent to a small scheduled hybrid solar farm plus battery). Although participation was open to any technology, all VPPs used batteries in their portfolios.
- Approximately 7,150 consumers who signed up in the VPP Demonstrations (almost 25% of residential customers with registered batteries in the NEM).

Over the last two years, the VPP Demonstrations project has helped the VPP sector develop its collective understanding and capabilities to participate in electricity markets. As a result, the trial has helped the VPP sector shift along the maturity curve from start-up to early growth phase. It has also helped AEMO develop its understanding of the future capabilities required to facilitate a secure and operable power system in the high DER future contemplated in the ISP.

When the concept of the VPP Demonstrations was being developed in 2018:

- AEMO's first *Integrated System Plan* (ISP)[1] had estimated that by 2040 there would be up to 21 gigawatts (GW) of distributed photovoltaics (PV) and almost 6 GW of distributed battery storage capacity in a Neutral scenario (and 56 GW/15 GW respectively in a High DER scenario) operating in the NEM.
- Various planned state-based incentives programs were collectively targeting up to 700 megawatts (MW) of VPP-capable residential battery storage by 2021-22.

The VPP Demonstrations began in July 2019 and are set to conclude following the final determination of the Market Ancillary Services Specification (MASS) consultation towards the end of 2021.

Although the targeted 700 MW of residential batteries by 2022 will not eventuate, the uptake has been fast, with the DER Register recording almost 168 MW of residential batteries (across about 31,000 connections) in the NEM in June 2021[2].

To prepare for the safe and efficient integration of these resources, AEMO acted prudently to trial VPPs' capability to:

- **Participate in markets and value stacking**, including through provision of contingency frequency control ancillary services (FCAS), responses to energy price signals, and interact with distribution networks.
- Provide **operational visibility**.
- **Improve the consumer experience**.
- Cater for **cyber security** threats.

Below are key insights and recommendations related to each of these capabilities.

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[1] At https://aemo.com.au/energy-systems/major-publications/integrated-system-plan-isp/2018-integrated-system-plan-isp.

[2] At https://aemo.com.au/energy-systems/electricity/der-register/data-der/data-downloads.

VPP market participation and value stacking

This trial has observed VPPs delivering FCAS, responding to energy price signals, and delivering local network services, at times delivering more than one service simultaneously.

Frequency control ancillary services

Small battery VPPs, like utility-scale batteries, have proven to be highly effective at providing contingency FCAS, through various response methods[3].

VPPs have supported the power system during numerous major contingency events over the last two years, including separation events between South Australia and Victoria as well as trips of major generating units.

VPPs in the trial have continued to increase market share of contingency FCAS, reaching 3% of market share in April 2021, up from 0.6% in April 2020.

VPPs have developed conservative bidding strategies and have been observed to allow up to 10% additional fleet capacity above the target they have been enabled for, to ensure they reliably deliver what is required and mitigate the risk of under-delivery and associated claw-back processes.

Cases of under-delivery have been observed during the trial, due to settings being erroneously changed during firmware upgrades or complications associated with delivering a required Lower FCAS response (that required batteries to charge) while simultaneously responding to a high energy spot price (that required batteries to discharge). Strategies implemented by VPPs to mitigate the risk of repeated under-deliveries include:

- Introducing daily checks on all systems to ensure they are responding according to the expected configuration requirements (so no unexpected changes due to firmware upgrades or other causes).
- Introducing a new method to value stacking, whereby responses to energy price signals are prohibited when frequency is detected to be outside of the normal operating frequency band.

Early learnings from the VPP Demonstrations led to the introduction of the *Interim arrangements for provision of FCAS from DER*[4]. This was a change in AEMO's approach, to recognise the bi-directionality of VPPs with load connection points by allowing net exports from those connection points (generation) to be recognised for Raise FCAS. Previously VPPs would have to register as two separate market participants for the load and generation capabilities. These bi-directional arrangements are to be embedded in the new MASS and in the Integrating Energy Storage Systems (IESS) rule change.

At the beginning of 2021, AEMO launched a MASS Consultation process, part of which is to determine the appropriate ongoing arrangements for verification of FCAS delivery from DER. This consultation is assessing whether to leave the current MASS unchanged, to adopt measures similar to those tested in the VPP Demonstrations, or to implement alternative measures. The draft determination proposed leaving the MASS unchanged, with reasoning outlined in the draft determination paper.[5]

The MASS Consultation will be completed towards the end of 2021 and will coincide with the end of the VPP Demonstrations. AEMO is considering the learnings from the VPP Demonstrations and feedback from stakeholders during the consultation process in making its final determination on the DER components of the MASS Consultation.

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[3] Responses characterised as either proportional, switched responses, and even dynamic switching controllers that deliver a proportional response.

[4] At https://www.aemo.com.au/-/media/Files/Electricity/NEM/Participant_Information/New-Participants/Interim-Arrangements-for-FCAS-from-DER.pdf.

[5] At https://aemo.com.au/en/consultations/current-and-closed-consultations/mass-consultation.

FCAS recommendations

It is necessary to establish an industry working group to agree and implement appropriate measures that will enable DER provision of FCAS to scale. Drawing on evidence from the VPP Demonstrations and other trials, the topics this working group could address include, but are not limited to:

- Agreement between aggregators and distribution network service providers (DNSPs) on the control hierarchy of participating DER inverters and the prioritisation of services such as volt/var service (reactive power) ahead of FCAS (active power).
- Exploration of mandating compliance with AS/NZS 4777.2.2020 for new (and potentially existing) DER providing FCAS to mitigate risk of disconnections when enabled for FCAS.
- Development of processes/guidelines on firmware upgrades, with responsibility for VPP operators to check the effectiveness and accuracy of firmware upgrades once they have been made. Large-scale resources are required to follow firmware upgrades processes set out in the Generator Performance Standards, which may be a useful reference point in this discussion.
- Exploration of implementation (over time) of tiered Dynamic Operating Envelopes (DOEs), sent from the DNSP to the VPP operator, in high DER areas. The tiers could represent one DOE for system normal operation and one for contingency events that would allow the system normal envelope to be exceeded temporarily when delivering contingency FCAS.
- Exploring how to streamline processes to register portfolio updates with AEMO.

Responses to energy price signals

VPPs are highly capable of responding to energy market prices in real time, and do so at times, however their behaviour is largely dominated by serving the household first and maximising the self-consumption of rooftop PV.

VPP responses to energy price signals are also inconsistent across different VPPs, and across price events. This is partly due to different drivers within different VPPs; for instance, customer contracts restrict the use of their systems in some VPPs but not in others. As a result, VPP behaviour has been shown to be inherently very difficult to forecast, which could lead to errors in AEMO's operational forecasting as VPPs scale.

The VPP Demonstrations project has provided an important source of data to test assumptions in the ISP. The following observations have been made to help to improve future ISP modelling around VPPs:

- The proportion of batteries in VPPs has been underestimated previously, most notably for South Australia. This has been reviewed, and the 2021 battery projections use VPP Demonstrations data as an input to better estimate the current proportion of batteries operating within VPPs.
- VPP Demonstrations data suggests the response of VPP batteries to both high and negative price events is smaller and less predictable than currently assumed in AEMO's models. However, a follow-up survey of VPP participants to investigate this observation indicated it is at least partly due to VPPs being in the early stages of their development. Several respondents indicated their intent to better consider wholesale prices in their dispatch algorithms in future. Based on this, AEMO will continue to monitor VPP behaviour to determine whether changes to the modelling approach are needed.

Data has also shown that VPPs have already improved their algorithms during the trial to consistently charge during the day and discharge during evening peaks that often coincide with higher energy prices.

If this behaviour was extrapolated out to a very large VPP sector, VPPs could help reduce the severity of peak demand and minimum system load (peak rooftop PV) conditions, either through coincidence with solar self-consumption algorithms or through automated responses to high or negative spot prices.

VPPs can provide most efficiency benefits to the power system, and to consumers overall, as more and more resources respond to energy spot prices, which are a proxy for the power system's need for energy. The next step for VPPs is to ensure that energy market rules and procedures cater for their full participation in the energy market. The IESS rule change and the Energy Security Board's (ESB's) Post 2025 NEM Market reform process will have direct bearing on the future participation arrangements for VPPs in the NEM.

Responses to energy price signals – recommendations

Data from VPPs will continue to be an important source of information for AEMO's planning studies such as the ISP. Given that the data received through the VPP Demonstrations will stop as the project ends, new low-cost sources of relevant/required data should be identified, potentially through collaborations with the VPP sector as it develops.

The VPP sector is encouraged to engage in the energy market rule changes and reforms such as the IESS and ESB Post 2025 reforms, so VPP sector perspectives contribute to the design and implementation of these reforms, particularly the Trader Services and participation models of the ESB reforms.

Distribution network collaboration opportunities

As VPPs scale, aggregators will need to develop systems, capabilities, and relationships to interact with DNSPs. Although the delivery of local network services or consideration of distribution network limits was not in scope for the VPP Demonstrations, AEMO engaged VPPs and with SA Power Networks (SAPN), which simultaneously delivered its Advanced VPP Grid Integration Project[6], to understand how the distribution network interacts, and potentially impacts, VPPs' capability to stack value streams.

In their VPP trials in South Australia, both AGL[7] and Simply Energy[8] identified that distribution network constraints, in particular local power quality issues in areas with high levels of rooftop PV, can limit VPP performance and capability to deliver market services.

VPPs with customers on flexible connection agreements can receive DOEs (or flexible export limits) from DNSPs to signal the available capacity of the local network. This enables the VPP to take local constraints into account when responding to energy prices or bidding into wholesale markets. This has been proven to be effective in SAPN's trial, in which customers in the Energy Locals/Tesla SA VPP were permitted to export up to 10 kilowatts (kW) when the network capacity was available (twice the standard export limit of 5 kW).[9]

Widespread adoption of DOEs could enable VPPs/DER to provide a greater contribution to peak demand or contingency FCAS events when network capacity can accommodate it, and equally to ensure VPPs do not breach local network limits when delivering services during times when the network is already congested.

This will lead to a greater overall utilisation of the local network, and a more efficient power system for all consumers. It will also enable consumers to continue installing bigger systems, and to export more to the grid over the course of the year, on the proviso that exports are reduced when the network is congested (currently during sunny Spring weekends when there is low demand on the local grid and high PV exports).

SAPN's trial also proved that VPPs can deliver local voltage support service simultaneously with contingency FCAS. Through agreeing with the SA VPP that the voltage support service should be prioritised over FCAS, the VPPs capacity to deliver the FCAS service was reduced. VPPs can mitigate the risk of FCAS under-delivery by bidding conservatively in the FCAS market to ensure a buffer of capacity is maintained above the amount that is bid into the market.

SAPN also received operational telemetry data through its trial that improved SAPN's understanding of the VPP's impact on the network, and assisted in tuning the hosting capacity model and assessing VPP site compliance to the flexible export limit. The trial also helped build a greater understanding of the underlying

[6] See https://www.sapowernetworks.com.au/future-energy/projects-and-trials/advanced-virtual-power-plant-grid-integration-trial/.

[7] AGL, *Virtual power plant in South Australia Stage 1 Milestone Report*, 31 July 2017, at .

[8] *Stage 2* Knowledge *Sharing Report, Simply Energy VPPx*, June 2020, at https://arena.gov.au/projects/simply-energy-virtual-power-plant-vpp/.

[9] Note that this was only implemented in a trial with one aggregator and is yet to be implemented permanently.

performance of the low voltage (LV) network more broadly, and helped identify issues unrelated to the VPP operations.

Distribution network collaboration opportunities – recommendations

AEMO, DNSPs, and VPPs must collaborate on a range of topics to plan for the efficient integration of VPPs (and DER more broadly) in a high DER future. These topics may include, but are not limited to:

- Agreeing and implementing various actions relating to potential power system security risks that could arise as DER provision of FCAS scales, as outlined above.
- The efficient adoption of flexible connection agreements for consumers, exchange of DOEs between aggregators and DNSPs, and exchange of operational visibility data (explored further below).
- The continued assessment of whether minimum device standards are appropriate for maintaining a secure and operable power system in a high DER future.

Operational visibility

AEMO's *Power System Requirements* reference paper[10] identified the capabilities required for AEMO to operate the power system securely and continually keep supply and demand balanced. The system must be:

- **Dispatchable**, so AEMO can coordinate resources and power system services to maintain system security and reliability.
- **Predictable**, so AEMO can:
  - Access appropriate data relating to network power flows and the activity of participating resources, across numerous timeframes, as key inputs into operational decision-making and planning.
  - Forecast upcoming power system conditions and have confidence in how the system will perform.

AEMO obtains operational visibility and keeps the power system in balance using the central dispatch process conducted every five minutes. As resources reach a material threshold of capacity, they are required to participate in the central dispatch process as scheduled resources. For large-scale batteries this threshold is 5 MW, but there are no requirements for aggregations of smaller batteries to be scheduled in the same way. The aggregated capacity of VPPs in this trial is 31 MW, 27 MW of which is in South Australia.

The operational visibility of VPPs obtained during the VPP Demonstrations[11] was instrumental to developing AEMO's understanding of VPP behaviour and the ongoing need for VPPs to contribute to the capabilities outlined above.

AEMO established a number of Application Programming Interfaces (APIs) to receive large amounts of continuous data, allowing deep, insightful analysis as shared in the various knowledge sharing reports.

AEMO's analysis of this data verified the ongoing need for operational visibility of VPPs as they reach material thresholds. This visibility could be delivered in progressive stages, such as:

- Visibility – VPPs providing near real-time actual performance data at a portfolio level.
- Forecastability – VPPs providing forecasts of their expected operation and available capacity, potentially at different price points, to AEMO and have a requirement to meet that forecast.
- Ability to be coordinated (or dispatched) – potentially through VPPs participating in wholesale dispatch by submitting bi-directional bids/offers.

AEMO would use this information to maintain efficient and accurate operational forecasting that is published to the market or as an input to short-term planning and central dispatch processes. For this purpose, AEMO

[10] At https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Power-system-requirements.pdf.

[11] Details of the data obtained can be found in the VPP Demonstrations Data Specification, at https://aemo.com.au/en/initiatives/major-programs/nem-distributed-energy-resources-der-program/der-demonstrations/virtual-power-plant-vpp-demonstrations.

requires visibility of actual performance that can be used to train forecasting models, and accurate forecasts of any 'active' shifting of distributed load or generation above a material threshold.

Data received in this trial has shown that VPPs are able to, and are best placed to, provide forecasts in the form of a schedule of discharge and charge activity over a variety of forecast horizons. Providing accurate forecasts has been difficult for most VPP operators, with actual charge and discharge profiles often varying materially from forecasts (when compared to large-scale solar farm forecasting accuracy). This difficulty emphasises the criticality of the approach taken, whereby the operator of the assets must create the forward forecast. The complex operating patterns of VPPs has made it clear that AEMO is not best placed to forecast the behaviour of these assets.

The current level of forecasting error indicates VPPs are not currently capable of being integrated into market systems as forecastable/dispatchable resources without changes to their operational behaviour, changes to their control methodology, uplift of their forecasting capability and/or incentives for following of forecast schedules. This is because diverging significantly from forecasts may result in significant variability in demand forecasts that are published to the market (as VPPs reach material thresholds).

If VPPs can consistently follow forecast schedules, then moving to the third stage of participating in central dispatch may be deferred until the capacity of VPPs reaches higher thresholds. To propose thresholds for the scheduling and participation of VPPs in central dispatch, AEMO sees benefit in leveraging the guidelines that have been prepared for Wholesale Demand Response (WDR)[12] mechanism.

The design of systems to obtain operational visibility should also consider that DER/VPPs, and the information architecture to provide data from DER, are fundamentally different to large-scale resources that are connected to dedicated communication networks with high levels of redundancy and security.[13] VPPs use home wi-fi, 3/4G and public internet to source data from devices that could then be aggregated and sent to Network Service Providers (NSPs) and AEMO.

At any one time during the trial, AEMO received 70-98% of the telemetry data from each of the participants, this largely reflects house-to-VPP cloud communication dropouts due to issues with wifi or 3G networks. Forecasting systems that AEMO or NSPs develop will have to cater for regular gaps in data received, and even for the event of a total communication dropout through loss of public internet.

This is all being considered in the design of the "scheduled lite" model[14] put forward by the ESB in the Post 2025 reforms. This concept proposes a visibility model, followed by a dispatchability model, and is intended to be voluntary for non-scheduled resources to engage in.

Operational visibility – recommendations

With VPP and price-responsive demand now at significant capacity in the NEM, AEMO is regularly seeing a degradation in forecast accuracy during periods of price volatility. Without visibility and understanding of the behaviour of these assets under control, AEMO's ability to coordinate resources on the power system, to ensure power system security and reliability, is being compromised. Visibility of this behaviour is becoming increasingly critical to ensure efficient power system operations, particularly at times of system stress, can be maintained.

Insights from the operational visibility obtained in the VPP Demonstrations has led to the following recommendations:

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[12] At https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2020/wdr-guidelines/final-stage/wholesale-demand-response-guidelines-mar-2021.pdf?la=en.

[13] Outlined in the Power System Data Communication Standard, at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Network_Connections/Transmission-and-Distribution/AEMO-Standard-for-Power-System-Data-Communications.pdf.

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

- To accelerate the design and implementation of the scheduled lite visibility model, and to consider implementing the model as mandatory for resources that exceed material thresholds, for example VPPs in South Australia. AEMO is planning to submit a rule change proposal to the Australian Energy Market Commission (AEMC) in due course.
- AEMO to review the data communication standard with reference to appropriate standards to facilitate the visibility model, and to consider new, more cost-effective ways for non-scheduled resources to provide operational data.
- AEMO to continue to engage with forecast service providers to help uplift forecasting capability in the sector.

Consumer experience

AEMO engaged Customer Service Benchmarking Australia (CSBA) to conduct social science research to identify how consumers' experiences of VPP participation can be improved in future. The research indicates consumers' ongoing satisfaction with, and advocacy of, VPPs will be further enhanced with improvements in initial and ongoing communications and transparency in the operation and earning potential of the VPP. In particular, consumers want to understand:

- The financial benefits to their household (how much energy they provided to the grid and what they were paid for this).
- The environmental impact (for example, how much CO_2 was saved and how many trees this is equivalent to planting).
- The community benefits (for example, how many minutes of power shortfalls in the consumer's state were saved by their household's power contribution).

With most consumers having access to smart phone applications (apps) providing data on the operation of their battery and VPP, this has been identified as a key means to deliver targeted communication and information. VPPs should consider how they can create apps that communicate and enhance consumer understanding and satisfaction, addressing the areas highlighted above.

The insights also highlight the consumer expectation to 'save money on energy bills' is the most prevalent factor in sign-up and retention. VPPs must consider the existing energy costs to individual sites and ensure realistic expectations of savings and other benefits are set.

The pathway to VPP 'membership' also influences overall satisfaction; those with previous experience with solar panels and generous feed in tariffs have high expectations of the value potential of VPP membership.

Consumers are aware that participation in a VPP involves handing over a level of asset control, making it important to positively reinforce the benefits for consumers to ensure they remain willing to participate.

Use of traditional media such as television and radio (for example, discussion programs such as 'The Drum' or topical programs such as 'War on Waste' or even 'The Checkout') has been identified as a productive way to enhance consumer awareness and understanding of VPPs.

Strategies will need to be developed to handle how VPPs are transitioned or how consumers switch in/out or between VPPs, together with programs for battery replacements as they deplete over time. As the majority of consumers participating in VPPs have been identified as 'early adopters', it is also important to consider how to attract other consumer segments as the VPP industry matures.

Consumer experience recommendations

The consumer experience is heavily influenced by the communication, transparency, and earning potential available to individual households. VPPs need to consider how they communicate to consumers to ensure information is relevant and increases engagement and retention, both in the onboarding phase and throughout the consumer's participation in the VPP.

The consumer obligations associated with operating a VPP are key to ensuring the consumer's protection. Careful consideration will be needed regarding the information provided to consumers who plan to participate in a VPP, and also about whether the current retail electricity process of "explicit informed consent" will be required to switch between VPP providers.

Cyber security

The expanding role of DER in Australia' energy system opens the door to new types of cyber security threats under the broad heading of demand side threats. These cyber security threats pose risk to power system security. Scenarios where the remote instruction capability is taken advantage of, impacting power system security, are those where either:

- DER device(s) in aggregate do not respond to remote instructions (or transmit telemetry) in a timely fashion, or
- DER device(s) in aggregate respond incorrectly, either in response to a required instruction or autonomously

It is imperative that DER devices and their interfaces are architected to be resilient to manipulation through their entire lifecycle, from the DER device manufacturer to the end user to the market operator, and every step in between.

On 3 September 2020, the Australian Government released the voluntary Code of Practice: Securing the Internet of Things for Consumers[15]. The Code of Practice is a first step towards lifting the security of Internet of Things devices in Australia; this is in conjunction with the Australian Energy Sector Cyber Security Framework (AESCSF) voluntary assessment of cyber security maturity.

The ESB is progressing work as part of its 2025 energy market reforms that includes cyber security considerations for communications and interoperability for demand side generation/load resources.

Cyber security recommendations

VPPs are encouraged to engage in AESCSF voluntary assessments and the ESB reforms that relate to cyber security, and to implement best practice cyber security frameworks in their system architectures.

Concluding remarks

Demonstrations are not suitable, or practical, to inform all reforms, but they can effectively test how to address a discrete challenge, or to increase understanding of a range of complex and interrelated issues associated with a particular theme. In this project, the theme was to provide early insights on how to integrate aggregated DER/VPPs into market frameworks at scale, and the project set out to address a range of interrelated issues identified in the project objectives.

Interviews with VPP Demonstrations participants showed strong support for the 'learning by doing' method applied in this project. Feedback supported this as the most effective approach for increasing knowledge across the VPP sector, largely because broad participation was encouraged throughout (in the trial itself but also in the monthly open-invite stakeholder forums), resulting in an uplift of organisational capability, accelerating VPP sector maturity and bringing stakeholders in the broader industry on the journey.

AEMO thanks all stakeholders who participated or showed an interest in this project. Industry collaboration has been instrumental in developing a common understanding of VPPs' current capabilities, and continued collaboration is a prerequisite as VPPs scale to agree and implement the future capabilities required that will facilitate a secure and operable power system in a high DER future.

[15] At https://www.homeaffairs.gov.au/reports-and-publications/submissions-and-discussion-papers/code-of-practice.

Contents

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ABBREVIATIONS

Abbreviation	Term
AEMO	Australian Energy Market Operator
AEMC	Australian Energy Market Commissioner
ARENA	Australian Renewable Energy Agency
DEIP	Distributed Energy Integration Program
DER	distributed energy resources
DNSP	distribution network service provider
DOE	Dynamic Operating Envelope
DRSP	Demand Response Service Provider
ESB	Energy Security Board
FCAS	frequency control ancillary services
FRMP	financially responsible market participant
GW/GWh	gigawatts/gigawatt hours
IESS	Integrating Energy Storage Systems
IRP	Integrated Resource Provider
ISP	*Integrated System Plan*
kV	kilovolt
kWh	kilowatt hours
MASS	Market Ancillary Service Specification
ms	milliseconds
MW/MWh	megawatts/ megawatt hours
NEM	National Electricity Market
NER	National Electricity Rules
NMI	National Metering Identifier
PASA	Projected Assessment of System Adequacy
PV	photovoltaic
RERT	Reliability and Emergency Reserve Trader
SCADA	Supervisory Control and Data Acquisition
SGA	Small Generation Aggregator
VPP	Virtual Power Plant
WDR	Wholesale Demand Response
WDRUs	Wholesale Demand Response units

1. Introduction

The Virtual Power Plant (VPP) Demonstrations – developed by the Australian Energy Market Operator (AEMO), in collaboration with the Australian Energy Market Commission (AEMC), the Australian Energy Regulator (AER), and members of the Distributed Energy Integration Program (DEIP) – aim to understand how VPPs can integrate into the future energy landscape.

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 (see Figure 1). The VPP Demonstrations concluded with 31 megawatts (MW) of VPPs operating in the National Electricity Market (NEM), with approximately 7,150 consumers signed up across eight separate portfolios spanning all mainland states in the NEM.

1.1 Origins of the VPP Demonstrations

During 2018, a number of VPP projects and government subsidies to support VPP capable systems were announced, with targets equating to up to 700 MW of VPPs operating in the NEM by 2022.

At that time there were no residential battery VPPs delivering contingency frequency control ancillary services (FCAS), and AEMO had no visibility of how VPPs operated in response to energy price signals. Given the potential scale of VPP-capable residential battery uptake, and the potential responsiveness of those batteries to energy price signals, AEMO took a prudent approach to consult on establishing a framework (the VPP Demonstrations) that would allow VPPs to demonstrate their capability to deliver services in energy and FCAS markets, while also providing AEMO with visibility of those resources.

1.2 Industry consultation

AEMO consulted on the proposed VPP Demonstrations framework in November 2018[16], with the aim to inform subsequent changes to the regulatory frameworks, operational systems, and processes required to facilitate the smooth integration of VPPs as they ramp up in size.

The Consultation Paper highlighted that effective integration of DER will involve enabling:

- Aggregated DER to respond to wholesale energy and FCAS market price signals.
- System operators to have sufficient operational visibility of DER.
- Distribution network limits to be considered when dispatching DER.

The VPP Demonstrations sought to address the first two elements. The third element has been and is being addressed through AEMO's collaboration with Energy Networks Australia (ENA) on the Open Energy Networks, the broader DEIP Dynamic Operating Envelopes process, and AEMO's latest trial Project EDGE[17].

AEMO held two stakeholder webinars to facilitate further discussion on the Consultation Paper prior to a deadline for written submission. The details for these webinars, and over 25 non-confidential written submissions received, are on AEMO's website[18].

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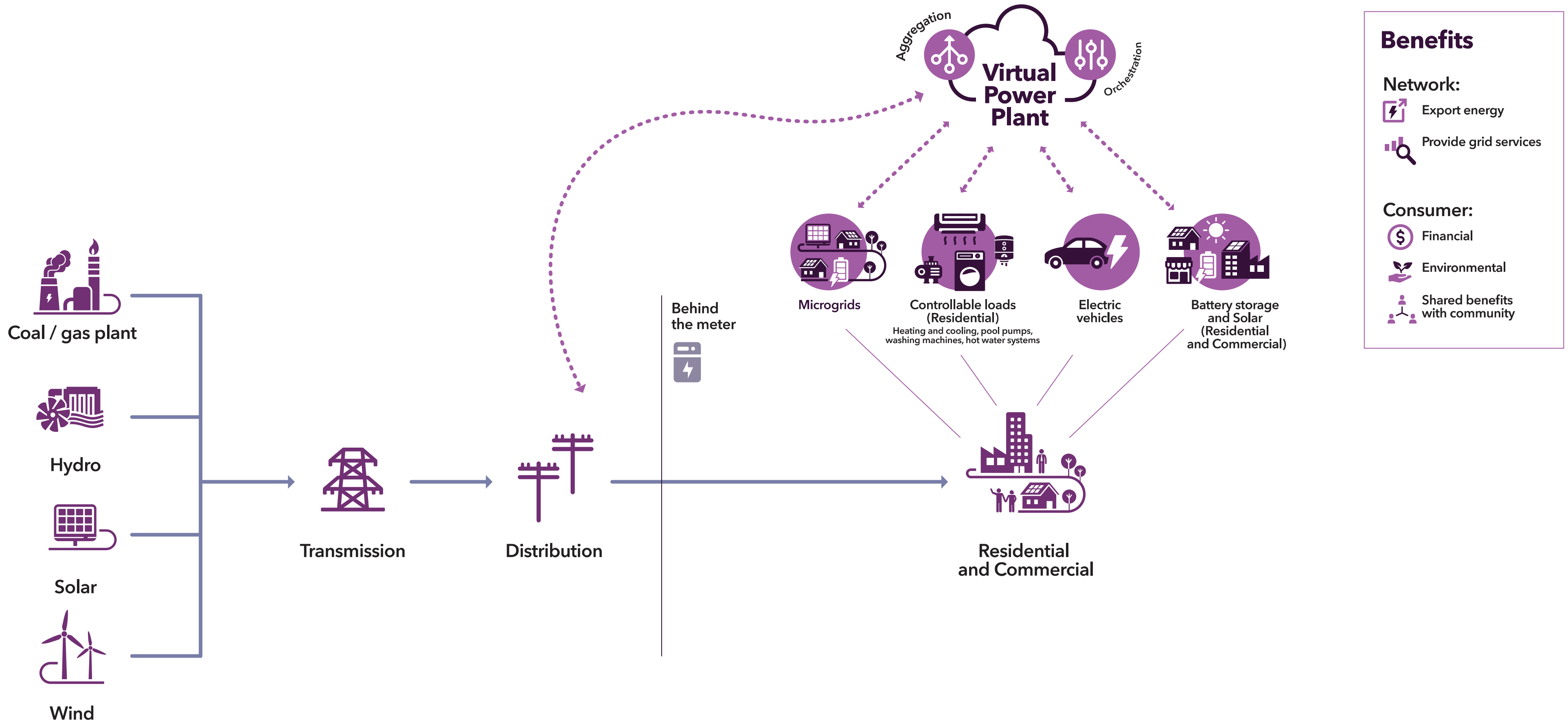
[16] At https://aemo.com.au/en/initiatives/major-programs/nem-distributed-energy-resources-der-program/der-demonstrations/virtual-power-plant-vpp-demonstrations/vpp-demonstrations-reference-information.

[17] At https://aemo.com.au/en/initiatives/major-programs/nem-distributed-energy-resources-der-program/der-demonstrations/project-edge.

[18] At https://aemo.com.au/initiatives/major-programs/nem-distributed-energy-resources-der-program/der-demonstrations/virtual-power-plant-vpp-demonstrations/vpp-demonstrations-reference-information.

Figure 1 Virtual Power Plants schematic overview



1.3 Final design and project objectives

In July 2019, AEMO published the Final Design Document[19] and participation terms and conditions captured in the VPP Demonstration Enrolment Form[20], and launched the VPP Demonstrations with the following objectives:

1. Understand whether VPPs can reliably control and coordinate a portfolio of resources to stack value streams relating to FCAS, energy, and possible network support services.
   - AEMO will test a new FCAS specification for the VPP Demonstrations, consistent with section 7.3 of the Market Ancillary Services Specification (MASS)[21], and will observe VPPs responding to energy market price signals as non-scheduled resources. AEMO also aims to learn the extent to which VPPs can deliver local network support services to distribution network service providers (DNSPs) while participating in the VPP Demonstrations.
2. Develop systems that provide AEMO with operational visibility of VPPs to understand their impact on power system security, local power quality, and how they interact with the market.
   - As VPP participants will operate unscheduled in the energy market, AEMO will establish a series of application programming interfaces (APIs) that will enable participants to submit operational forecasts and actual performance data from their VPPs to AEMO.
   - Observing VPP operations is expected to help AEMO determine what systems and capabilities are needed to support VPP market participation at a large scale (potentially gigawatt-scale) in future, while maintaining system security.
3. Assess current regulatory and operational arrangements affecting market participation of VPPs and inform new or amended arrangements where appropriate
   - The VPP Demonstrations will operate under the current regulatory framework, noting that AEMO is testing a new FCAS specification for distributed energy resources (DER). The VPP Demonstrations aim to assess the suitability of these approaches, and inform consideration of any required changes to regulatory frameworks and operational processes to ensure VPPs are better integrated into the NEM.
4. Provide insights on how to improve consumers' experience of VPPs in future.
   - AEMO intends to engage a social science specialist to conduct a study with willing VPP consumers to evaluate their experience of being part of a VPP, encapsulating the initial sales and marketing process, installation of equipment, operation of a VPP, perceived/realised value delivered, and whether consumers have experienced any changes to their electricity consumption after joining a VPP.
5. Understand what cyber security measures VPPs currently implement, and whether they should be augmented in future.
   - AEMO is including cyber security as a specific area of research in the VPP Demonstrations, recognising the importance of collaborative action to address cyber security risks. Gaining a thorough understanding of DER-related cyber security risks and taking appropriate action in the near term will set the foundation for reliable and secure large-scale integration of DER in the medium to long term.

To support the delivery of these objectives, a number of research questions were outlined in the Final Design Document that have provided a framework for the analysis conducted during the project. These are examined further in Chapter 3.

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

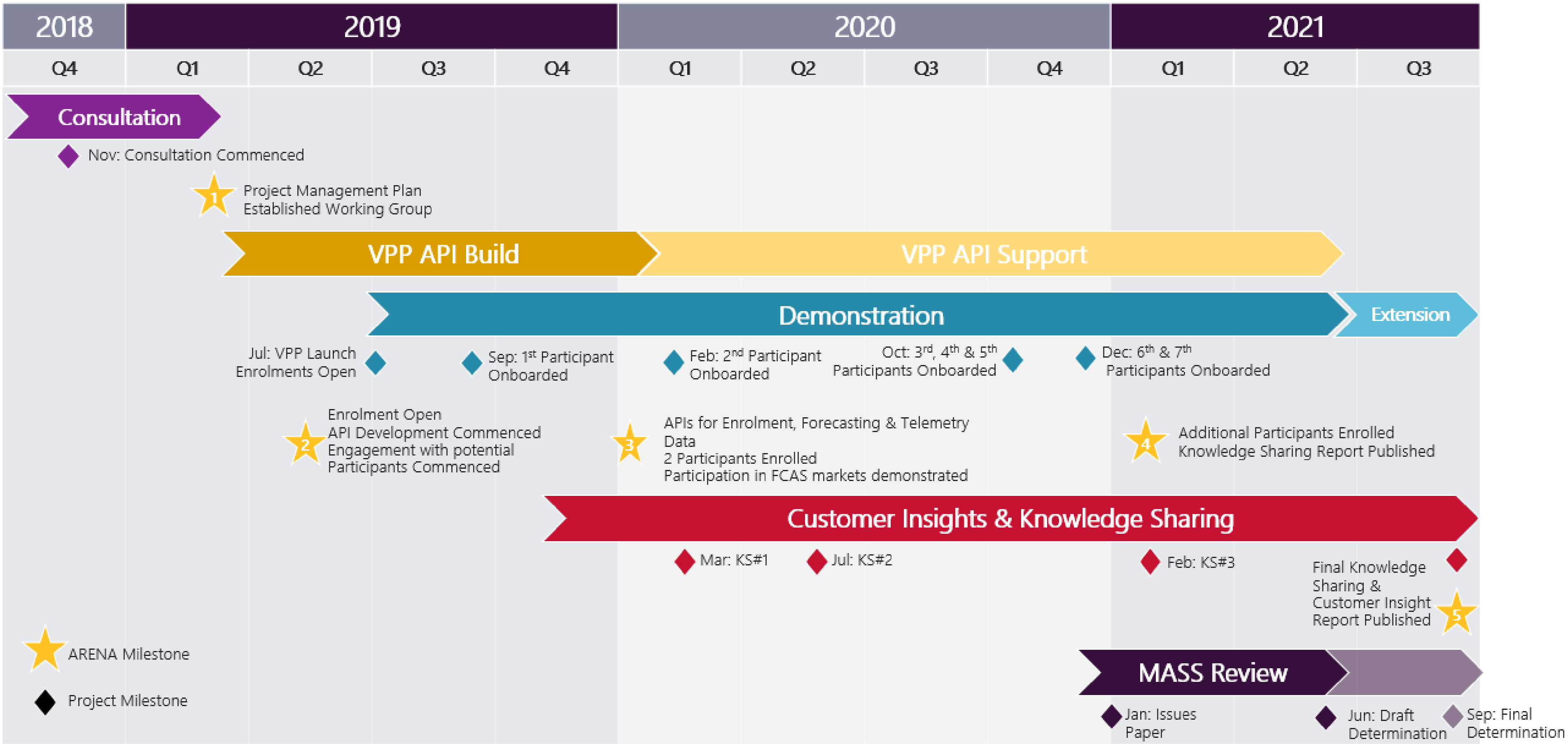
[20] At https://aemo.com.au/-/media/files/electricity/der/2020/vpp-demonstration-enrolment-form.docx?la=en.

[21] At https://www.aemo.com.au/energy-systems/electricity/national-electricity-market-nem/system-operations/ancillary-services/market-ancillary-services-specification-and-fcas-verification-tool.

1.4 Project timeline and key milestones

The figure below outlines the project timeline and key milestones delivered.

Figure 2 VPP Demonstrations timeline and key milestones



1.5 Participation

Initially participant sign up was slower than expected, largely due to COVID-19 causing delays to stock arrivals/installations and re-prioritisation of work to focus on responding to the impact of COVID-19. The decision was made to extend the VPP Demonstrations by a further year to 30 June 2021, and the original target of five participants was exceeded in the second year with seven participants (and a total of 8 portfolios across all mainland regions of the NEM) joining the Demonstrations, as described in Figure 3 and Table 1.

AEMO's VPP Demonstrations took a technology-neutral approach that was open to all resources; however, due to the Demonstrations' timing and the relatively small scale of other technologies (smart hot water and pool pump systems) only photovoltaics (PV) and battery capability has been tested in participating VPPs.

Figure 3 VPP Demonstration participants, 31 MW capacity, across all mainland NEM jurisdictions

Table 1 VPP Demonstrations participants

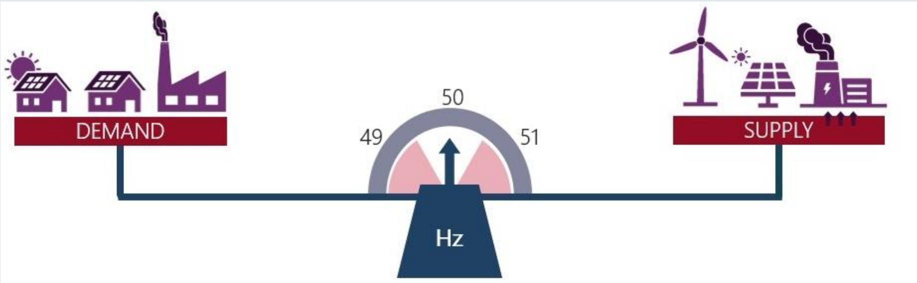
	Energy Locals (Tesla SA VPP)	AGL	Simply Energy	sonnen	ShineHub	Energy Locals (Members Energy)	Hydro Tasmania
DUID	VSSEL1V1	VSSAE1V1	VSSSE1V1	VSNSN1V1	VSSSH1S1	VSVEL2S1, VSNEL2S1	VSQHT1V1
Jurisdiction	SA	SA	SA	NSW	SA	VIC and NSW	QLD
Registration *	MC	MC	MC	MASP	MASP	MC	MASP
Battery technology	Tesla PowerWalls	Tesla PowerWalls	Tesla PowerWalls	sonnen	AlphaESS	Alpha ESS Saj/Everready	Tesla PowerPack
FCAS delivery	Proportional	Proportional	Proportional	Proportional	Switched	Switched	Proportional
Registered capacity (Aug 2021)	16 MW All cont FCAS	6 MW All cont. FCAS	4 MW All cont FCAS	1 MW All cont FCAS	1 MW All 6 cont FCAS	1 MW (x2) All 6 cont FCAS, except L6	1 MW All 6 cont FCAS

*Registration types are MC = Market Customer, MASP = Market Ancillary Services Provider

FCAS explainer – what is contingency FCAS and how is it procured by AEMO? [22]

Frequency describes how many times voltage cycles occur every second. In the Australian power system, this is designed to cycle 50 times per second, meaning the system's frequency is 50 hertz (Hz). When the frequency is equal to 50 Hz, supply and demand is in balance, but this is very rare. The frequency will exceed 50 Hz when supply exceeds demand and will drop below 50 Hz when demand exceeds supply. Maintaining this balance can be challenging because the power system cannot generally store electricity, so everything that goes into the power system must always equal what goes out.

Figure 4 Frequency, maintaining the supply and demand balance



As the wholesale energy market is settled on a 5-minute basis, additional services are required to ensure supply and demand are in balance on an intra-5-minute basis. There are two types of FCAS, and eight markets facilitating them:

- Regulation FCAS caters for the natural deviations within the nominal operating frequency band (NOFB) of 49.85 Hz and 50.15 Hz, and is facilitated by generators connected to Automatic Generator Control (AGC) via supervisory control and data acquisition (SCADA) and centrally dispatched.
  - There is a raise regulation FCAS market and a lower regulation FCAS market.
- Contingency FCAS caters for larger deviations, beyond the NOFB, such as a large generator or load tripping off. It is locally detected by devices, such as inverters, and they respond depending on how much they have been enabled for. Payment is made on availability, rather than (as in regulation FCAS and wholesale energy markets) energy delivered. The six markets for contingency FCAS are:
  - Six-second 'fast' raise and lower markets.
  - 60-second 'slow' raise and lower markets.
  - 5-minute 'delayed' raise and lower markets.

Currently, VPPs in the NEM can only actively bid in contingency FCAS markets. For more on FCAS offers, bids and settlement in the NEM see the Guide to Ancillary Services in the National Electricity Market[23].

For contingency FCAS, AEMO must be able to characterise each portfolio as providing either a proportional/variable or switched style of response:

- Proportional controlled portfolios provide a response that is proportional to the size of the frequency deviation, for instance using a droop controller.
- Switch controlled portfolios involve an on/off switch so the response is not variable in nature, for instance by switching a pool pump on or off.

It is important to note that portfolios of switch-controlled devices can be characterised as proportional if a smart control system is able to stagger the switching of each device in the portfolio to deliver an overall proportional response.

[22] Image and more information at https://aemo.com.au/en/learn/energy-explained/energy-101/energy-explained-frequency.

[23] At https://www.aemo.com.au/-/media/Files/PDF/Guide-to-Ancillary-Services-in-the-National-Electricity-Market.pdf.

1.6 Learning phase and knowledge sharing

AEMO has conducted the VPP Demonstrations openly and transparently throughout, seeking to share information and insights that can help accelerate the VPP sector's understanding of market participation in the NEM.

The VPP Demonstrations webpage[24] hosts information from inception to completion, including the four knowledge sharing reports (including this one) published at six-month intervals.

A monthly open invite VPP Frequency Asked Questions forum was also established during the project, with 40-50 stakeholders typically attending each month. At the start of 2021, this forum evolved into the DER Market Integration Consultative Forum[25], with a purpose to enable:

- AEMO to better understand aggregator perspectives on design options for market participation of VPPs or Aggregators, which can inform AEMO's development and prioritisation of activities.
- Aggregators to better understand the market operations and practicalities of market participation, facilitating a smoother integration into market frameworks.
- Timely updates on the progress of trials facilitating DER integration into market operations and related works.[26]

1.7 Structure of this report

The remainder of this paper is structured as follows:

- Chapter 2 – describes the methodology, materials, and technology developed to facilitate the VPP Demonstrations.
- Chapter 3 – summarises the key insights from the trial, with reference to the research questions highlighted in the Final Design document.
- Chapter 4 – considers opportunities for further work beyond the VPP Demonstrations, building on the learnings from this project.

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[24] At https://aemo.com.au/initiatives/major-programs/nem-distributed-energy-resources-der-program/der-demonstrations/virtual-power-plant-vpp-demonstrations.

[25] At https://aemo.com.au/en/consultations/industry-forums-and-working-groups/list-of-industry-forums-and-working-groups/der-micf.

[26] At: https://aemo.com.au/-/media/files/stakeholder_consultation/working_groups/der-program/der-micf/der-market-integration-consultative-forum-terms-of-reference.pdf?la=en.

2. Actions to facilitate the VPP Demonstrations

To deliver on the stated objectives highlighted in Section 1.3, AEMO established numerous materials, specifications, and technology solutions to facilitate the project. These are outlined below in relation to the project objectives.

2.1 Objective 1: Understand whether VPPs can stack value streams, including FCAS participation

At time of the VPP Demonstrations consultation (November 2018), there were no residential-scale VPPs participating in FCAS markets in the NEM. Some possible reasons for this include:

- The residential-scale VPP sector was in an early stage of development at this time.
- FCAS markets are complex and difficult for new participants to understand.
- The MASS, which determines the capabilities required to deliver and verify FCAS, was seen by industry as a barrier to new residential-scale entrants, in two particular areas:
  - As only one behind-the-meter device (battery inverter) was responding to frequency excursions and delivering FCAS, the FCAS response measurement point of "at or close to the connection point" would have added potential complexity for residential VPPs. The DER FCAS provider would have been required to factor changes in load behaviour and PV output into the FCAS response.
  - Fast FCAS (the 6-second service) required 50 millisecond (ms) metering at each site in the portfolio to verify delivery and most residential battery systems capture data at a lower resolution. Slow and Delayed FCAS services only require 4-second metering at each site, which is not a barrier to entry in those markets.

Following consultation, AEMO developed the VPP Demonstrations FCAS Specification[27] to enable VPPs taking part in the project to also participate in the NEM contingency FCAS markets under a slightly different specification to the existing MASS.

The VPP Demonstration FCAS Specification applied in accordance with the MASS, the National Electricity Rules (Rules), and the National Electricity Law. The provisions in the MASS continued to apply to the VPP Participant and the performance of ancillary services except as expressly provided in the VPP Demonstration Specification. The exceptions related to two areas in particular:

- Measurement points – AEMO sought to test whether verification of FCAS delivery at the device level could be appropriate and what the advantages/disadvantages of this approach would be. Although the amount of FCAS delivered during the trial would refer to the device level measurement, AEMO still required measurements of non-controlled load, either directly metered or calculated using net connection point flow measurements, to review whether the FCAS response is negated at times on purpose by the non-controlled load.
- Measurement sampling rate – AEMO allowed VPP Demonstrations participants to choose one of two options with regards to the measurement sampling rate of active power and local frequency to verify delivery of Fast FCAS:

[27] At https://aemo.com.au/-/media/Files/Electricity/NEM/DER/2019/VPP-Demonstrations/VPP-Demonstrations-FCAS-Specification.

- Samples on a time base less than or equal to 100 ms at every National Metering Identifier (NMI) enabled.
- Samples on a time base less than or equal to 1 second at every NMI enabled, plus samples from one high speed meter (sampling frequency on a time base less than or equal to 50 ms) per region. All eight portfolios that participated in the VPP Demonstrations chose this option.

These options were inspired by approaches in Europe, including:

- In the United Kingdom, Firm Frequency Response[28] is a service that requires an initial response within 2 seconds and a full response within 10 seconds. All providers are required to capture 100-ms data in pre-qualification testing[29] and then 1-second data for ongoing performance monitoring.
- In the Netherlands, Frequency Containment Reserve[30] (FCR) is a service that requires an initial response within 2 seconds and a full response within 30 seconds. All providers are required to capture 100-ms data in pre-qualification testing and 1-4-second data for ongoing performance monitoring. TenneT completed a pilot in 2018 of aggregated resources delivering FCR[31].

VPPs taking part in the Demonstrations were actively participating in the contingency FCAS markets, and they had to follow specific registration and on-boarding processes to access these markets. As the trial participants were allowed to participate in the FCAS markets under alternative measurement arrangements, participants were required to assist AEMO in meeting the objectives of the Demonstrations. These requirements are outlined in relation to each objective.

Various documents were published to support participant's onboarding journey, such as:

- An enrolment guide and enrolment form.
- An onboarding guide, checklist and timeline (see Figure 5 below).
- VPP Demonstrations FCAS Specification.
- FCAS verification data template.
- VPP Demonstrations Data Specification.
- Guide to AEMO VPP Demonstration APIs.
- VPP Demonstrations Cyber Security Questionnaire.

These can all be found on AEMO's VPP Demonstration website[32].

Objective 1 also sought to understand whether VPPs could deliver local network services as part of the value stack. As AEMO is not involved in these DNSP-VPP interactions, AEMO has sought input from SA Power Networks (SAPN) to its knowledge sharing reports for this topic, since SAPN was simultaneously delivering its award-winning Advanced VPP Grid Integration Project[33].

[28] National Grid ESO Firm Frequency Response Interactive Guidance, at https://www.nationalgrideso.com/sites/eso/files/documents/Firm%20Frequency%20Response%20%28FFR%29%20Interactive%20Guidance%20v1%200_0.pdf.

[29] National Grid ESO Firm Frequency Response Testing Guidance, at https://www.nationalgrideso.com/document/148811/download.

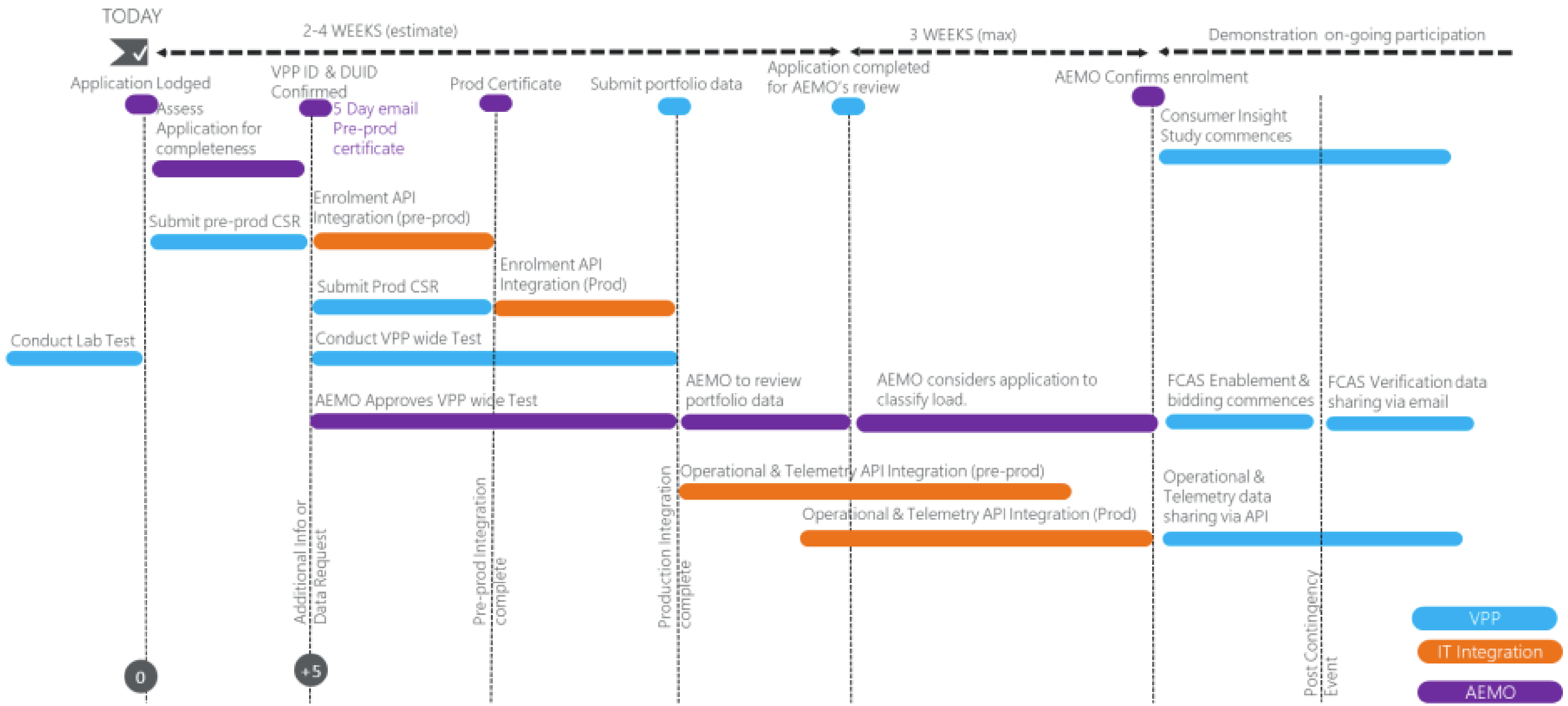
[30] TenneT Frequency Containment Reserve Handbook, at https://www.tennet.eu/fileadmin/user_upload/SO_NL/Handboek_FCR_voor_BSPs_-_EN_version.pdf.

[31] TenneT, Just a matter of balance pilot. At: FCR_Final_report_FCR_pilot__alleen_in_Engels_.pdf (tennet.eu).

[32] At https://aemo.com.au/en/initiatives/major-programs/nem-distributed-energy-resources-der-program/der-demonstrations/virtual-power-plant-vpp-demonstrations.

[33] At https://arena.gov.au/projects/advanced-vpp-grid-integration/.

Figure 5 VPP Demonstrations onboarding timeline



2.2 Objective 2: Develop systems that provide AEMO with operational visibility of VPPs

The data exchange obligations on VPP Demonstrations participants were enacted through the enrolment form terms and conditions and outlined in the VPP Demonstrations Data Specification[34].

The operational data section of this specification provided AEMO with operational visibility of VPPs and comprised:

- Aggregated data, at VPP/portfolio level:
  - Forecasts, both operational forecasts of generation/load under control, and availability forecasts of capacity.
  - Performance data, actual delivered generation/load under control received near real time – 5-minute resolution, received 5 minutes after the fact.
  - Standing data, actual generation/load capacity if the VPP discharged/charged at the maximum rate, updated every 30 minutes.
- Device level data, 5-minute resolution for each DER device within a VPP portfolio (shown in Table 2), refreshed/uploaded to AEMO on a daily or weekly basis.

Table 2 Device level telemetry data specification

Installation type	Parameter	Units	Basis
All	Timestamp	Timestamp	Instantaneous
All	Customer gross load	kW, kVAr	Max, min, mean
All	Voltage	V	Max, min, mean, instantaneous
All	Frequency	Hz	Max, min, mean, instantaneous
All	Export power	kW, kVAr	Max, min, mean
DC battery	Inverter power output	kW, kVAr	Max, min, mean
DC battery	Battery DC power output	kW	Max, min, mean
AC battery	PV inverter power output	kW, kVAr	Max, min, mean
AC battery	Battery inverter power output	kW, kVAr	Max, min, mean
Any battery	Battery state of charge (usable)	Wh	Mean, instantaneous
No battery	Device net power output. Power consumption is negative	kW, kVAr	Max, min, mean

AEMO developed various systems and APIs to facilitate the exchange of these datasets. The details of these APIs can be found in the Guide to AEMO VPP Demonstrations APIs[35], but the conceptual architecture and message patterns for these systems are shown in the figures below.

[34] At https://www.aemo.com.au/-/media/files/electricity/nem/der/2019/vpp-demonstrations/vpp-demonstrations-data-specification.pdf?la=en.

[35] At https://www.aemo.com.au/-/media/files/electricity/der/2020/guide-to-aemo-vpp-demonstration-apis.pdf?la=en.

Figure 6 Conceptual architecture diagram

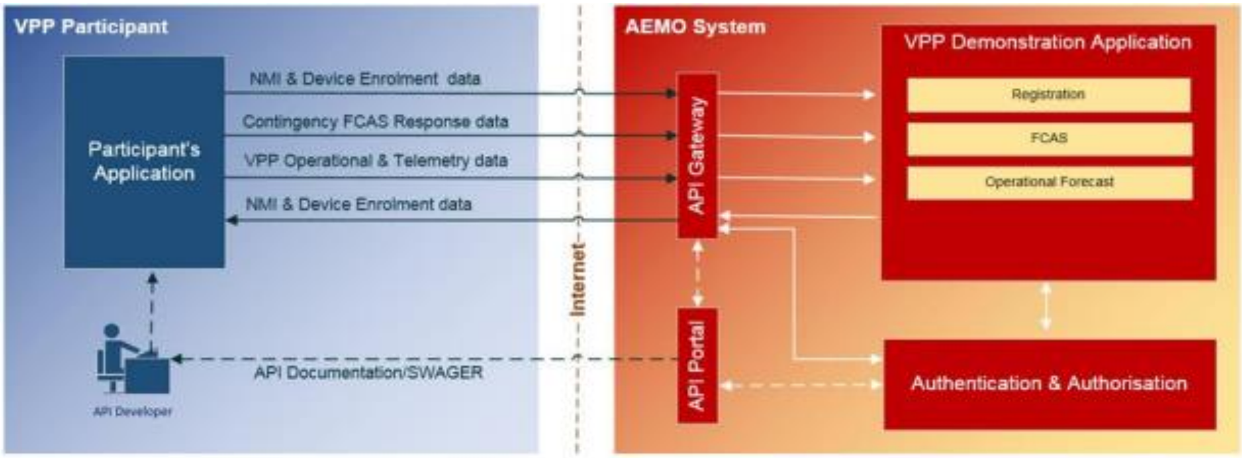
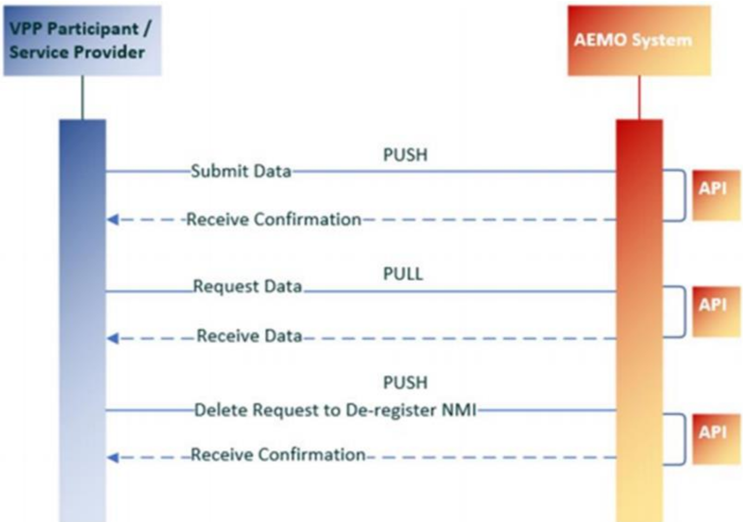


Figure 7 Message pattern



2.3 Objective 3: Assess current regulatory and operational arrangements affecting VPPs

AEMO did not publish any materials in relation to this objective when the project launched, but the project involved continued assessment of the regulatory and operational arrangements affecting VPPs and aligning with other regulatory processes or launching new processes as and when appropriate.

Current relevant regulatory and operational arrangements for VPPs

With respect to wholesale market participation of VPPs, there are already allowances for retailers to include consumers into VPP aggregations (for both wholesale market and FCAS); however, the only way for VPP operators to have direct exposure to the wholesale market is as a Small Generation Aggregator (SGA).

The SGA category only allows for the aggregation of generation resources (not load connection point), and SGA rules currently require that each generating system have a separate connection point. These arrangements create barriers to the effective participation of VPPs in wholesale markets.

With respect to operational arrangements, AEMO currently requires batteries >5 MW and generating systems >30 MW to be scheduled in the central dispatch process, but there are no provisions for aggregations of smaller resources that combine to capacities above these thresholds. There are now multiple residential battery VPPs exceeding 5 MW in the NEM, with some aggregators aiming to have portfolios of hundreds of megawatts in the next few years.

Assessment of current arrangements

The first assessment of regulatory arrangements came early in the project. Prior to the VPP Demonstrations, AEMO's general approach to ancillary services classifications had been to treat an ancillary services load with respect to the import side of the connection point only, and similarly to only allow Market Generators to provide ancillary services through export to the grid. This meant that a participant registered as a Market Customer or Market Ancillary Services Provider could not have net exports from its connection points recognised for raise FCAS services.

AEMO allowed this to occur under the VPP Demonstrations, and in December 2019 published the Interim Arrangements for FCAS provision from DER[36] to allow load connection points to deliver FCAS bi-directionally outside of the trial as well.

AEMO always envisaged that the VPP Demonstrations trial would lead to a Rules-based consultation process on the MASS to determined what the ongoing arrangements for DER provision of FCAS should be. This consultation process was launched in January 2021, before the end of the VPP Demonstrations.

AEMO has also fed insights and learnings throughout the VPP Demonstrations into various existing regulatory processes, including:

- Energy Security Board (ESB) Post 2025 reforms relating to demand side participation[37].
- Wholesale Demand Response[38].
- Integrating energy storage systems into the NEM[39].
- AEMC Generation Registrations and Connections rule change[40].
- Western Australia's DER Roadmap[41].

Chapter 4 outlines the next steps on these processes to change the current regulatory arrangements

2.4 Objective 4: Understand how to improve consumers' experience of VPPs in future

To meet this objective, AEMO ran a competitive procurement process that engaged a consumer insights specialist to conduct social science research on three key questions:

- What are consumers' experiences of participating in Australia's early stage VPPs?
- Is VPP participation attractive enough for consumers to let VPP operators utilise their assets?
- How can consumers' experience of VPP participation be improved to make it more attractive for consumers to sign up in future?

AEMO engaged Customer Service Benchmarking Australia (CSBA) to conduct this study. CSBA developed a multi-staged market research approach, using specific methodologies to tackle the introduction of VPPs to the market and capture insights into consumers' evolving behaviours and attitudes.

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36 At https://www.aemo.com.au/-/media/Files/Electricity/NEM/Participant_Information/New-Participants/Interim-Arrangements-for-FCAS-from-DER.pdf.

37 At https://esb-post2025-market-design.aemc.gov.au/.

38 At https://aemo.com.au/initiatives/trials-and-initiatives/wholesale-demand-response-mechanism.

39 At https://www.aemc.gov.au/rule-changes/integrating-energy-storage-systems-nem.

40 At https://www.aemc.gov.au/rule-changes/generator-registrations-and-connections.

41 At https://aemo.com.au/initiatives/major-programs/wa-der-program.

CSBA published an interim report in February 2021, and a final report alongside this report, both on AEMO's website[42]. A summary of the key findings is in Section 3.5.

To facilitate the study AEMO placed obligations in the terms and conditions of participation that VPPs must contact at least 75% of their VPP consumers with information about participating in the study. Consumers themselves were not obliged to take part, but over 2,400 consumer surveys were completed voluntarily, with an average response rate of 25% showing a high level of engagement from VPP consumers.

The key insights from this research are outlined in Section 3.5 and in the CSBA final report.

2.5 Objective 5: Understand suitability of cyber security measures VPPs currently implement

To meet this objective AEMO required each participating VPP to complete a cyber security questionnaire during the registration process.

The questionnaire was a VPP-focused version of the Australian Energy Sector Cyber Security Framework[43] questionnaire that large market participants had completed. It was designed to determine the high-level security maturity of VPP organisations and assist AEMO in developing a risk profile of the VPP platforms.

MITRE[44] in the United States also approached AEMO, seeking to use the VPP Demonstrations to examine the VPP model/use case from a cyber security risk perspective. AEMO's cyber security team engaged with MITRE during the VPP Demonstrations, and the insights from this collaboration are outlined in Section 3.6.

[42] At https://www.aemo.com.au/initiatives/major-programs/nem-distributed-energy-resources-der-program/der-demonstrations/virtual-power-plant-vpp-demonstrations.

[43] At https://aemo.com.au/en/initiatives/major-programs/cyber-security/aescsf-framework-and-resources.

[44] At https://www.mitre.org/capabilities/cybersecurity/overview?category=all.

3. Insights

To guide the analysis performed during the VPP Demonstration, the final design document considered various 'research questions', which covered market participation, operational insights, market dynamics and planning, local power quality, consumer insights, and cyber security.

Various subject matter experts from across AEMO helped analyse the data received during the VPP Demonstrations and develop insights to address each of these research questions. This chapter outlines these insights.

3.1 VPP capability for market participation

Insights in this section broadly relate to the first objective regarding VPPs' capability to stack value streams.

3.1.1 Can VPPs reliably deliver the contingency FCAS that they bid, and are enabled for?

Throughout the VPP Demonstrations, AEMO provided numerous examples in knowledge sharing reports of VPPs reliably and effectively providing contingency FCAS when enabled.

Participating VPPs have responded effectively to some major power system events over the last two years, including:

- Kogan Creek trip on 9 October 2019 (748 MW), shown in Knowledge Sharing #1, Figure 1[45].
- South Australia separation events:
  - 16 November 2019, shown in Knowledge Sharing #1, Figure 2[50].
  - 31 January 2020, shown in Knowledge Sharing #2, Section 3.1[46].
- Callide C3 and C4 trips on 13 January 201 (826 MW combined), shown in Knowledge Sharing #3, Figure 3[47].
- VPPs assisted in elevating the South Australian operational demand by approximately 5 megawatts (MW) during the record minimum demand period on 11 October 2020, reducing the severity of the event. This is shown in Knowledge Sharing #3, Figure 4[52].

The VPP Demonstrations also observed various types of FCAS responses, for instance:

- VPPs using Tesla Powerwalls or Powerpacks (Energy Locals SA VPP, Simply VPP, AGL VPP, and Hydro Tasmania) deliver a variable/proportional response using a 0.7% droop setting.
- VPPs using AlphaESS equipment deliver a standard switched response.
- sonnen's use of more sophisticated dynamic switching controllers to deliver a proportional response.

In addition to the many examples of successful contingency FCAS delivery, there have also been examples of under-delivery that the whole industry can learn from, as outlined in Table 3 below.

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

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

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

Table 3 Examples of under-delivery and industry insight

VPP	Date/event	Reason for under-delivery	Description	Remediation / action to avoid a repeat
Energy Locals (Tesla) SA VPP	South Australia separation event, 16 November 2019*	Firmware upgrade	Fewer systems than expected had the appropriate frequency support settings enabled.	Introduced daily checks on all systems to ensure they are responding according to the expected configuration requirements.
Energy Locals (Tesla) SA VPP	South Australia separation event, 28 January 2020**	Error in approach to value stacking to respond to energy spot prices and deliver FCAS	Under-delivery occurred during a high frequency event that coincided with a high energy spot price. Batteries that should have been charging to deliver an FCAS lower service were discharging in response to the high energy price.	New method to value stacking implemented. When the frequency is within the NOFB, the VPP may respond to energy price signals. However, the VPP will prioritise the delivery of contingency FCAS when the frequency is outside the NOFB and it will not respond to energy price signals.
Anonymous	Loy Yang A2 trip, 31 March 2021	Error when setting the droop to 0.7%	The droop was set to 7% rather than 0.7% droop, which caused the VPP to under-deliver FCAS when responding to a frequency disturbance.	The participant updated its processes to prevent a similar incident from occurring by developing the ability to directly monitor and control the assets and configure the droop setting. Additional safety measures have been implemented to ensure that the droop setting is not changed without AEMO's prior approval.

* See Knowledge Sharing #1.
** See Knowledge Sharing #2.

There have also been significant learnings in relation to value stacking network services with market services. The SA VPP, through simultaneously participating in the VPP Demonstrations and SAPN's Advanced VPP Grid Integration project, considered how VPPs prioritise regulated grid services, standards, and market participation. Tesla has provided the following input to share its work and learnings with the industry.

VPP – market integration and system security

A key consideration for operators of virtual power plants (VPPs) is ensuring that all the distributed energy resources (DER) participating in a VPP are appropriately prioritising market services and regulated grid services necessary for the protection of the network. While VPPs can play an important role in providing contingency FCAS services (as has been demonstrated through the AEMO VPP Demonstrations trial), it is critical that the provision of these services does not have an adverse impact on local distribution network security.

Prioritising distribution network services over market services is an important starting point and forms the basis both of market participation in current FCAS markets and will increasingly play a role in providing future system security services as fast frequency response (FFR) and potentially inertia markets evolve.

Current DER regulated requirements

AS4777.2:2015 and the latest version of AS4777.2:2020 underpin inverter-based technology registered with AEMO under the VPP demonstrations trial. VPP systems operating in South Australia are also compliant with the AEMO short-duration undervoltage disturbance ride-through requirements[48] which provides additional network protection.

Current DER regulatory settings are largely complimentary to the AEMO VPP market settings outlined in the AEMO FCAS Specification and provide very clear operating windows for which DER should operate within.

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

VPP enabled inverters can comply with all requirements by simply prioritising services in the right order. Inverters which prioritise voltage support (volt-var and volt-watt) behaviour ahead of freq-watt response support network requirements ahead of frequency market participation.

As an additional back-stop, inverter-based systems will be constrained off, if voltage is maintained over 258V under the requirements of AS/NZS4777.2:2015 and AS/NZS4777.2:2020. This back-stop ensures that DER is always incentivised to maintain network voltage and serve the networks first. If an FCAS enabled system is constrained down to zero due to over-voltage at the site, then the VPP aggregator runs the risk of under-delivering on their FCAS bids.

How this translates to market behaviour

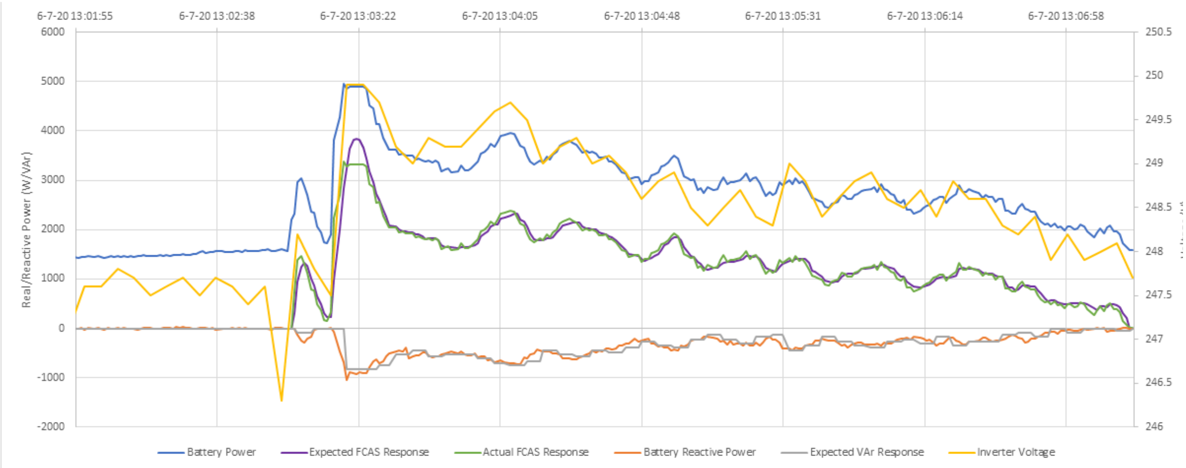
In practice what this means is that network requirements should always be prioritised over market participation. Figure 8 below shows a Tesla SAVPP site that is enabled for FCAS market participation. This site has a 5kW solar PV system and a Tesla Powerwall installed and operates in the contingency FCAS markets under the VSSEL1V1 DUID with a 0.7% droop curve.

Stepping through the three dot highlighted points in Figure 1 above:

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

What is clearly demonstrated in Figure 1 is that as soon as 250V limit is reached, the Powerwall immediately reduces the real power FCAS response in order to instead provide reactive power support and reduce the VPP impact on local voltage. The reduction in FCAS response is demonstrated by the green "Actual FCAS" response being lower than the blue "Expected FCAS response". The prevention of additional voltage rise is evidenced by the plateau of the inverter voltage readings at ~250V.

Figure 8 Coincident volt-var and contingency FCAS response from an FCAS-enabled VPP site



VPP operators will need to account for this potential derating of output by ensuring that there is enough contingency capacity available across the entire fleet to deliver on the total bid amount provided.

Importance of VPPs

There are other major benefits associated with operating systems under VPP type arrangements – as opposed to having all systems operate as passive DER. As demonstrated through the AEMO VPP Demonstration trial, having VPP operators provide asset and fleet level datasets is incredibly valuable in providing distribution level visibility that otherwise does not exist to AEMO. Some NSPs are looking at also working with VPP operators to access this data to gain further insights into faults and potential risks across their distribution network.

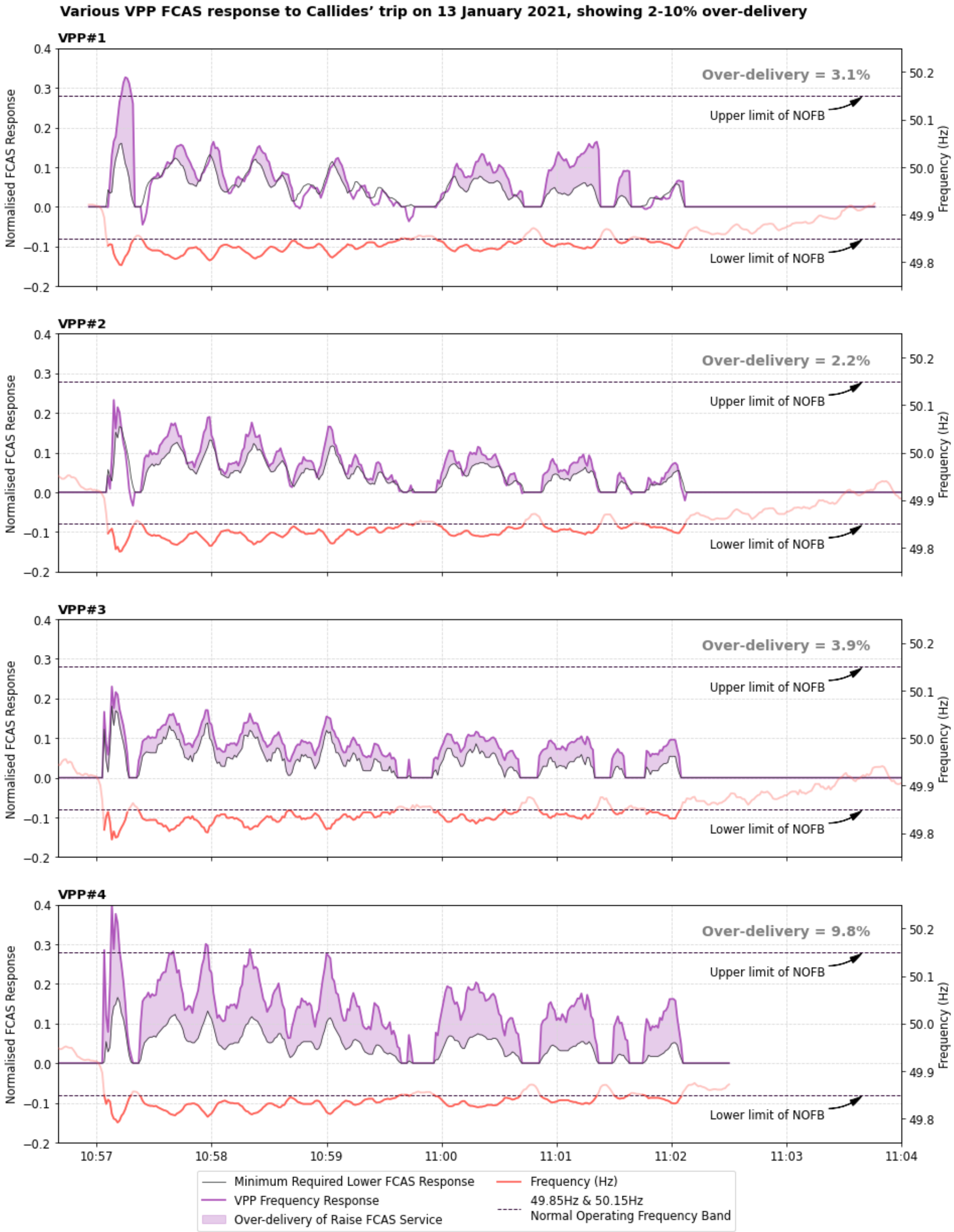
In addition, operating systems under a VPP arrangement provides a centralized point of control that is valuable for AEMO and the networks. This provides scope to include additional market services and for aggregators to remotely respond to emerging network and system security requirements, as well as incentivising charging and discharging behaviour to manage negative load issues in the middle of the day.

In the absence of appropriate market access, there does not appear to be any incentives for customers to participate under VPP arrangements and provide additional system control.

3.1.2 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?

As there is no penalty for over-delivery of FCAS, AEMO has observed VPPs typically have an over-delivery buffer. This means they continuously monitor their fleet to calculate their portfolio capacity to deliver FCAS, then bid this capacity conservatively to ensure that they always have more capacity that what they are enabled for. In the example of Callide's trip on 13 January 2021[49] (shown in Figure 9 below), the additional fleet capacity is 2-10% above the target they have been enabled for.

Figure 9 VPP responses to Callide trip – 13 January 2021



[49]Over delivery is calculated: $Over - delivery\ (\%) = \frac{average\ overdelivery\ (MW)}{enabled\ (MW)}$

VPPs are still learning how to refine their monitoring, forecasting and automated bidding systems to make this process as efficient as possible. Additional factors to consider in this process include:

- Communication dropouts due to public internet use have been observed in the VPP Demonstrations to impact up to 30% of the VPPs' fleets at any one time. These dropouts can impact monitoring and forecasting systems and need to be catered for in bidding strategies.
- If VPPs are also delivering and prioritising network services, a further buffer may be required to cater for the delivery of a volt/var service reducing the portfolios capacity to deliver an FCAS response.

3.1.3 What are appropriate ongoing operational arrangements for DER to participate in the FCAS and energy markets?

Ongoing operational arrangements for DER to participate in market frameworks will differ between FCAS and energy.

FCAS markets

The immediate ongoing arrangements for DER to participate in contingency FCAS markets are being determined in the MASS Consultation[50] process, but some arrangements may continue to evolve as DER provision of FCAS scales. The MASS Consultation process is still ongoing and the Draft Determination[51] proposed not to change the existing MASS, so that:

- The 50 ms metering requirement at every site for Fast FCAS remains.
- The measurement point for FCAS verification remains at or close to the connection point.

AEMO will consider the wealth of stakeholder feedback before making its final determination.

In the Draft Determination AEMO also identified a number of power system security concerns (see Table 4 below) relating to DER provision of FCAS at large-scale, and possible actions to address them. A number of these concerns, relating to all residential-scale inverters, were outlined in a report published in May 2021 on DER behaviour during power system disturbances[52].

AEMO is committed to working with industry to explore solutions to address these concerns as DER participation in energy and FCAS markets scales.

With regard to recognising the bi-directional capabilities of DER to provide FCAS, the updated MASS will incorporate provisions to embed the Interim Arrangements for DER Provision of FCAS into the ongoing arrangements.

Another relevant Rule change, that has reached a draft determination stage in the AEMC process, is the Integrating Energy Storage Systems (IESS) Rule change.[53] The draft determination is discussed in more detail in Section 4.2.2. This is proposing to introduce a new bi-directional Ancillary Services Unit that will effectively allow for raise and lower contingency FCAS to be provided by VPPs (as well as Grid-scale Integrated Resource Units) under the Rules once the Final Determination of the IESS rule change is published.

With regard to DER provision of regulation FCAS, technical barriers currently prevent residential VPPs from participating in this market, such as the need to respond AEMO's Automated Generation Control (AGC) signal that is sent out by AEMO through the SCADA network to participating resources.

[50] At https://aemo.com.au/en/consultations/current-and-closed-consultations/mass-consultation.

[51] At https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2021/mass/second-stage/mass-draft-determination-2021.pdf?la=en.

[52] At https://aemo.com.au/en/initiatives/major-programs/nem-distributed-energy-resources-der-program/operations/der-behaviour-during-disturbances.

[53] At https://www.aemc.gov.au/rule-changes/integrating-energy-storage-systems-nem.

Table 4 Power system security concerns and possible actions as DER provision of FCAS scales

Risk	Description	Possible action to explore further
Unexpected disconnection due to a local network fault	Potential power system security risks in frequency recovery if the unexpected inverter disconnections are not properly accounted for, resulting in a DER FCAS Provider not being able to respond to a frequency disturbance	Requiring compliance with AS/NZS 4777.2:2020 for all systems upon registration for FCAS. The updated AS/NZS 4777.2:2020 standard is intended to address some issues suspected to be influencing DER inverter disconnection rates, including better measurement and sampling, immunity to a broader range of plausible disturbances, and grid support capability, however, the behaviour of legacy inverters is a significant concern, as well as compliance of assets tested and certified to the updated requirements. Note that there have been no examples of FCAS under-delivery resulting from inverter disconnections during the VPP Demonstrations.
Behaviour during local distribution network and global power system disturbances	Potential risk of under-delivery of FCAS due to inverter requirements, e.g. autonomous reactive power (Volt-Var response) support assisting voltage management in the distribution network prioritised over active power (FCAS response)	Reaching industry agreement on the control hierarchy of participating DER inverters, to ensure security and reliability functions are prioritised appropriately and for this to be accounted for within aggregators' bidding. This was successfully tested in SAPN's Advanced VPP Grid Integration Trial, and described in detail in Tesla's extract in section 3.1.1. If adopted more broadly, VPP operators' bids into the FCAS markets would better reflect potential restrictions on FCAS enablement amount.
Rapid active power injection from FCAS delivery exceeding secure limits of the local network	Risks associated with large-scale, rapid active power injection or withdrawal from deeply embedded assets (aggregated to provide FCAS) exceeding the limits of secure distribution network operation limits	Coordination between DNSPs and aggregators to ensure distribution network limits are appropriately specified and prioritised within the control hierarchy of participating DER inverters. This could be through static rules or DNSPs issuing limits to aggregators on a dynamic basis. Several projects have tested flexible connection agreements and communicating dynamic operating envelopes to DER operators, such as SAPN's Advanced VPP Grid Integration trial, the evolve[54] trial and Project EDGE[55]. SAPN's final report includes a section on 'Operating Envelopes during contingency scenarios' outlines capabilities and aggregator interactions with DNSPs that might be required as more DER participates in the FCAS markets. Another potential action is to work with DER FCAS Providers and DNSPs on how distribution network limits are accounted for in the registration process. The Wholesale Demand Response Guideline[56] includes a DNSP endorsement process to augment the assessment of the security impacts of aggregation, which recognises that DNSPs are best placed to assess the security risks that arise from aggregation in their distribution networks.
Unexpected responses from inverters that cannot be identified using low granularity measurement	For example, if inverters deliver an oscillatory response within 1s intervals due to a voltage or frequency disturbance	AEMO's Draft Determination for the MASS proposed to maintain the 50 ms measurement resolution requirement.

[54] At https://arena.gov.au/projects/evolve-der-project/.

[55] At https://aemo.com.au/en/initiatives/major-programs/nem-distributed-energy-resources-derprogram/der-demonstrations/project-edge.

[56] At https://aemo.com.au/en/consultations/current-and-closed-consultations/wdr-guidelines.

Energy market

VPPs can already respond to energy spot market price signals as they please, potentially capturing financial benefits if they are the financially responsible market participant (FRMP) at the connection point, which is typically the retailer, or if they are a VPP operator that has a commercial arrangement with the FRMP.

Under current regulatory arrangements, VPPs are exempt from participating in the energy market dispatch process, even if the portfolio reached > 100 MW in size. As a result, AEMO has no operational visibility of VPPs, which could pose a risk to the efficient operation of the power system as VPPs scale.

AEMO's *Power System Requirements* reference paper[57] identified the capabilities required for AEMO to operate the power system securely and continually keep supply and demand balanced. The system must be:

- Dispatchable, so AEMO can co-ordinate resources and power system services to maintain system security and reliability.
- Predictable, so AEMO can:
  - Access appropriate data relating to network power flows and the activity of participating resources, across numerous time frames, as key inputs into operational decision-making and planning.
  - Forecast upcoming power system conditions and have confidence in how the system will perform.

AEMO obtains operational visibility and keeps the power system in balance using the central dispatch process conducted every five minutes. Semi-scheduled and scheduled participants submit bids/offers into AEMO, and receive dispatch instruction from AEMO such that supply meets demand with cheapest possible combination of resources while maintaining the system within security and reliability parameters.

The VPP Demonstrations provided visibility of participating VPPs, but the systems to receive this data have been shut down as the project closes. The following section outlines the value of this data and provides insights on what data may be required from VPPs as they scale.

It is logical that as VPPs grow in size, and in materiality in the context of the broader supply demand balance, their collective capabilities must also contribute (over time) towards the operability of the power system.

That said, it is not expected that VPPs will be required to be scheduled participants in the central dispatch process in the short term. The likely progression of the capabilities required of VPPs over time is:

- Provide operational visibility to networks and AEMO.
- Provide information to enable accurate forecasting of behaviour.
- Participate in central dispatch when these portfolios reach a material capacity in a region.

This is consistent with ESB and AEMC thinking on the concept of "scheduled lite", which is outlined in the *ESB Post 2025 market design options – part B*[58]. The scheduled lite concept is exploring a visibility model and subsequent dispatchability model that could apply to VPPs in future.

The Post 2025 reforms also provide a pathway for VPP operators (that are not retailers) to become FRMPs in their own right, with direct exposure to the energy spot price, through Flexible Trading Arrangements. This would enable VPP operators to engage directly with consumers regarding their energy use, which should create more competition and innovative offerings for consumers.

The IESS rule change is the first step on the journey that will enable bi-directional resource providers in the NEM to be able to participate bi-directionally in the energy market. For small-scale resources, the market small generator aggregator category will be transferred to the Integrated Resource Provider category, with a label of Small Resource Aggregator, and will now also be able to provide FCAS.

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[57] At https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Power-system-requirements.pdf.

[58] At https://esb-post2025-market-design.aemc.gov.au/options-paper.

3.2 Operational visibility insights

For AEMO to maintain power system security and reliability, three key aspects of new energy resources such as VPPs are considered: visibility, forecastability and coordination. Once an energy resource is of a material size in a region, these three aspects must be considered to ensure appropriate scope of control and ability to accurately forecast grid conditions.

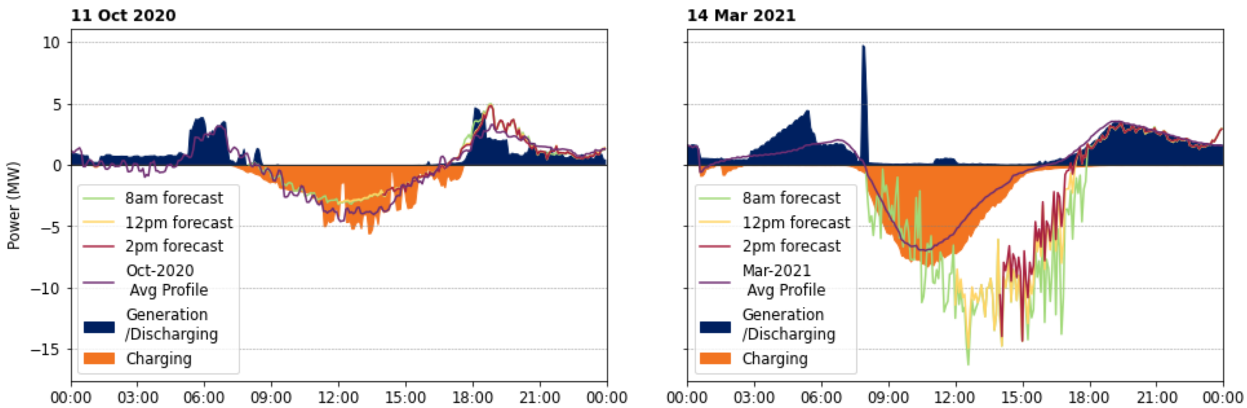
3.2.1 To what extent are VPPs able to accurately forecast their operational capability over various timeframes?

VPP's have shown they are able to provide forecasts in the form of a schedule of discharge and charge activity over a variety of forecast horizons. The accuracy of these forecasts is a function of the quality of the forecast and how closely the VPP follows the forecast schedule.

Providing accurate forecasts has been difficult for most VPP operators, with actual charge and discharge profiles often varying from forecasts. An example of this was provided in the third knowledge sharing report[59] that highlighted the large forecast errors on 11 October 2020 when a new record minimum operational demand was set in South Australia.

Another case study on forecast accuracy is provided in Figure 10 from 14 March 2021, where there was a transmission line outage that required minimum scheduled demand to remain above 400 MW for power system security in South Australia. Forecasts on this day over-estimated the capability of VPPs to charge in the mid to late afternoon, and it was during this time that scheduled demand fell below 400 MW. Charging at this time would have assisted keeping demand above this threshold. As VPPs scale in capacity, this type of deviation from the forecast provided has the potential to lead to increasingly challenging conditions for AEMO to maintain power system security.

Figure 10 Aggregated South Australian VPP profiles on two minimum demand days



VPP forecasting accuracy does not appear to improve with decreased lead time, with significant forecast errors relative to other large-scale forecastable resources (see Table 5). As VPPs scale up to several hundred megawatts, significant divergence from forecasts may result in significant variability in demand forecasts that are published to the market, even at very short lead times, significantly impacting AEMO's forecast accuracy.

This level of forecasting error indicates VPPs are not currently capable of being integrated into market systems as forecastable resources without:

- Changes to their behaviour, to more strictly adhere to the forecast schedule of charge and discharge. Material change in circumstances in the shorter term would need to be reflected in the forecasts.

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

- Uplift of their forecasting capability, such that forecasts at shorter lead times better capture the dynamic nature of VPPs. Providing forecasts that adapt to the constantly changing state of charge and other conditions will be pivotal in reducing forecasts errors as VPPs scale up.
- Incentives or disincentives for following of forecast schedules, that ensure VPPs are able to operate in the market without resulting in poorer market outcomes.

Table 5 Forecasting (normalised mean absolute error) accuracy of South Australian VPPs compared to large-scale solar

	5 minutes ahead	1 hour ahead	4 hours ahead	24 hours ahead
South Australian large-scale solar (three in total)	2%	4%	5%	5%
South Australian VPPs (four in total)	12%	12%	12%	13%

This reduces AEMO's scope of control, but also AEMO's ability to accurately forecast expected demands, which in turn can impact system adequacy assessment, unit commitment, and outage planning decisions.

The following sections propose thresholds for which VPPs should be considered to follow forward schedules or to participate in central dispatch.

3.2.2 What VPP operational data does AEMO require to facilitate very large VPPs operating without negative impacts on power system reliability and security?

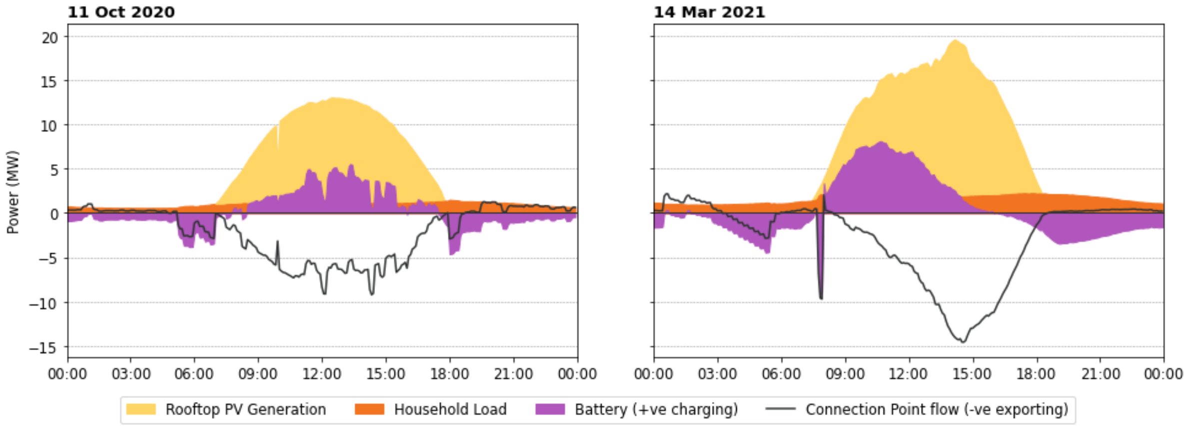
From an operational perspective, AEMO requires visibility of the controllable resources in a VPP portfolio. AEMO sees this as being any DER that can be actively controlled by an aggregator, VPP, or relevant agent. This is not limited to demand side DER (such as batteries), with the potential for rooftop PV generation to be actively controlled via smart meter functionality or other elements such as pool pumps.

AEMO requires accurate forecasts of any 'active' shifting of distributed load or generation so it can be reflected in load forecasts that are published to the market or generation scheduling. A similar process is currently in place to account for Reliability and Emergency Reserve Trader (RERT) in the load forecasts that are published to the market.

For the purpose of operational visibility, AEMO prefers to receive live operational telemetry about VPP activity as gross data, as occurred during the VPP Demonstrations. When live data is provided as net (net connection point flows), the information of activity behind the meter is lost. This is illustrated in Figure 11, where battery charging can masquerade as low rooftop PV generation in the morning (compare black connection point flow line to the charge and generation profiles on 14 March below).

The 14 March 2021 example provides a good case study for why gross data of the VPP, including the controllable resources, is more valuable than net data. On this day, rooftop PV was required to be curtailed to maintain grid demands at 400 MW. If visibility and control of elements within the VPP – such as batteries and/or rooftop PV – is enabled, this can avoid any curtailment of consumer loads, providing efficient outcomes for the consumer.

Figure 11 Aggregated SA VPPs on two minimum demand days vs the net connection point flow



During the demonstrations, the following operational data categories were sought from VPP participants[60]:

- Operational forecasts.
- Availability forecasts.
- Actual performance data.
- Standing data.

The operational and availability forecast categories aimed to provide deterministic forecasts of the VPP's controlled load and generation, as well as the forecast availability for system adequacy forecasting purposes. The actual performance data and standing data aimed to provide load/generation production and the actual availability of the VPPs.

This report focuses on the accuracy of the operational forecasts compared to the actual performance data. However, AEMO believes availability forecasts and standing data will also be required as VPPs scale. This information is analogous to the available capacity bids in Projected Assessment of System Adequacy (PASA) systems for scheduled generation. It is expected that 'live' capacity of VPPs will change often (for example, as more batteries are installed) so regular updates to installed capacities (standing data) are required.

The exact specification of operational data required from VPPs in the long term will ultimately depend on the forecast and control methodology (for example, if wholesale price-responsive or not) of the systems, the forecast accuracy, and how they interface with AEMO's dispatch and PASA processes.

Considerations of different levels of integration with AEMO's systems include:

- A non-scheduled, visibility-only model would require VPPs to only provide real-time telemetry. This may require very minimal integration into AEMO's market systems, and is unlikely VPPs would be considered in PASA and pre-dispatch. Real-time telemetry is currently provided by semi-scheduled and scheduled resources through the SCADA system. A recent report commissioned by the AEMC[61] estimated that the costs of connecting to SCADA at a basic level would be $0.7-1 million, and $2-2.5 million for more advanced connections associated with scheduling. These costs are why AEMO explored using APIs to exchange this data in the VPP Demonstrations and AEMO continues to explore new options to keep these costs down for participants.
- A type of 'scheduled' model where VPPs are incentivised to submit their own forward schedules and ensure a level of adherence to the schedule would require less sophistication than a full dispatch

[60] See https://aemo.com.au/-/media/files/electricity/nem/der/2019/vpp-demonstrations/vpp-demonstrations-data-specification.pdf?la=en.

[61] At https://www.aemc.gov.au/sites/default/files/documents/ghd_report_-_assessment_of_scheduling_costs_-_final.pdf.

approach. This may require only limited integration into AEMO's market systems and VPPs may be included in PASA and pre-dispatch via the demand forecasts produced by AEMO.

- Participation in central dispatch would require VPPs to effectively be 'self-forecast' with bid-offer pairs submitted, 5-minute dispatch targets followed, and availability submitted at all times. This would require full integration into AEMO's market systems with VPPs represented in PASA and pre-dispatch as both demand and generation.

The next section discusses thresholds for which VPPs may be considered material for forecast scheduling or participation in central dispatch. Once a VPP reaches material aggregation thresholds or regional thresholds, SCADA (or potential SCADA-like alternatives) will be required from VPPs, as well as some level of forecasting of both actual output and availability. This visibility is not necessarily required for every end point, but for appropriate level of aggregation within the VPP.

AEMO notes that the operational data required from VPPs may depend on the behaviour and classification of that VPP. Where a VPP is remotely controlled and actively managed in the market, driven by factors such as price forecasts, it is critical that operational control mechanisms are carefully considered and imposed. Where a VPP is 'passive' – that is, it does not change behaviour day-to-day and is not remotely controlled – this may not be considered a VPP and is likely to require fewer degrees of visibility, forecastability, and coordination.

3.2.3 Is it appropriate for large-scale VPPs to become scheduled resources in the energy market and, if so, at what threshold?

While VPPs have provided a forecast schedule during the VPP Demonstrations, they are not bound by it, and (as mentioned in Section 3.2.1) VPPs frequently diverge from this forecast schedule. If VPPs can consistently follow forecast schedules, an approach for market participation similar to the two proposed in the ESB's options paper ('scheduled lite')[62] may provide sufficient visibility and forecastability for the market, network businesses, and AEMO.

This scenario would mean that VPPs would not have to necessarily participate in central dispatch, although incentives and requirements to follow their forecast schedule would be required to assist in the management of power system security. However, as VPPs scale up in size, it may be necessary to enforce higher standards for visibility and coordination to ensure reliability and security of supply.

If VPPs can consistently follow forecast schedules, scheduling in central dispatch may be deferred until the capacity of VPPs reaches certain thresholds. To consider thresholds for the scheduling and participation of VPPs in central dispatch, AEMO sees benefit in leveraging the guidelines that have been prepared for the Wholesale Demand Response (WDR)[63] mechanism.

The guidelines for WDR impose requirements on both individual and aggregated units to provide telemetry and communications after certain thresholds (currently 5 MW for individual units, and for cumulative capacity behind an individual transmission node) are met or exceeded. The WDR guidelines also outline a regional threshold that sets a maximum total quantity of demand response that may be dispatched at one time for which no telemetry is provided (see Table 6).

Table 6 Initial regional thresholds for non-telemetered WDR

Region	NSW	QLD	SA	TAS	VIC
Initial threshold (MW)	140	100	32	17	95

[62] At https://esb-post2025-market-design.aemc.gov.au/32572/1619564199-part-a-p2025-march-paper-esb-final-for-publication-30-april-2021.pdf.

[63] At https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2020/wdr-guidelines/final-stage/wholesale-demand-response-guidelines-mar-2021.pdf?la=en.

AEMO is aware that the size of VPPs currently participating in the Demonstrations exceeds the 5 MW threshold for telemetry and is quickly approaching the regional thresholds imposed by WDR in South Australia (VPP registered for FCAS in South Australia = 27 MW, but other VPPs are operating and may be responding to energy prices).

In consideration of the size of current VPPs and some operating examples throughout the Demonstrations which show the flexibility of these resources, particularly those responding to wholesale price, it is imperative that the visibility, forecastability, and coordination of VPPs is developed further.

It is recommended that rule changes are pursued to integrate VPPs into the wholesale market to provide operational visibility, forecasts for the resources, and indicative bids. Changes should be made such that VPPs are able to be considered and relied upon as a resource in the system from a system adequacy perspective given their relative and potential size in the market, as well as able to be forecast accurately to ensure efficient dispatch and market outcomes.

AEMO is developing a Rule change proposal for the scheduled lite visibility model as a first step on this process, which aligns with the ESB DER Implementation Plan.

3.2.4 Data transfer learnings

AEMO asked VPP Demonstration participants to share near real-time data via four APIs, in lieu of scheduled obligations.

This section explores the challenges that were overcome to obtain this data in a timely manner from multiple participants.

The four APIs were:

- Standing data, via the enrolment API.
- FCAS verification data, via the FCAS API.
- Actual performance and operational forecasts on at an aggregated level on a 5-minute basis, via the Operational API.
- Household level actuals on a 5-minute basis, capturing (but not limited to) grid frequency, voltage, battery state of charge, and PV output, via the telemetry API.

Further details can be found in the Data Specification document[64].

These APIs allowed AEMO to test the technology and receive large amounts of continuous data allowing deep, insightful analysis as shared in the various knowledge sharing reports. On reflection, AEMO and the VPP participants spent a large, material amount of time:

- Setting up sending/receival of the required data within defined data packet sizes.
- Checking the data quality.
- Correcting the data coming through (such as incorrect date formats, fields [Alternating Current (AC) or Direct Current (DC) coupled], units, calculations, positive/negative reference points).
- Conducting various 'back-filling' tasks, noting that historical forecasts were largely unavailable.
- Weeding through error messages and trying to figure out the origination of the error.
- Updating passwords and figuring out who the 'password administrator' was for each entity.
- Identifying that some fields are not captured by the vendor or software platform.

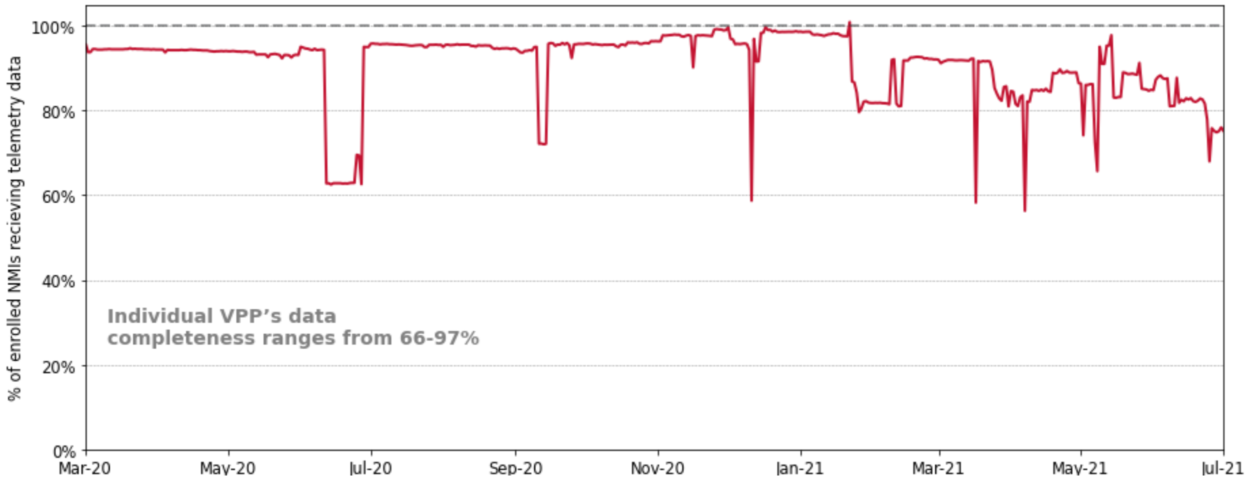
AEMO thanks the VPP participants that worked closely with their vendor(s) to ensure the various data fields can be captured now and/or into the future.

[64] At https://aemo.com.au/-/media/files/electricity/nem/der/2019/vpp-demonstrations/vpp-demonstrations-data-specification.pdf?la=en.

At any one time, AEMO received 66-97% of the telemetry data from each of the participants. This largely reflects house-to-VPP cloud communication dropouts due to the 3G network being down, or relying on wifi rather than a physical connection to the devices.

As a result, VPP participants are encouraged to consider the percentage of online, usable resources at any one time to ensure compliance when enabling themselves to provide contingency FCAS.

Figure 12 NMIs enrolled vs NMIs sending telemetry data, across all VPPs



As the VPP Demonstrations closes, all four APIs have been decommissioned and not deemed to be the enduring solution for transferring real-time visibility, forecasts, or participation in central dispatch. On a per API basis, the following decommissioning reasons are provided:

- Enrolment API.
  - Enrolment/Registration to be supported through the Portfolio Management System being developed for Wholesale Demand Response.
- FCAS API.
  - The effort & expense for participants to develop this API is noted as a barrier to entry for future VPP participants.
  - This feature may be required as VPPs scale, however at the current stage of maturity this is an unnecessary expense to impose on AEMO and the VPP industry.
- Operational API.
  - Currently there is no NER requirement to collect operational forecasting-related data outside of VPP Demonstrations for the purposes of providing contingency FCAS.
- Telemetry API.
  - Transfer of device level telemetry data is not required outside of the VPP Demonstrations.

3.3 Market dynamics and planning insights

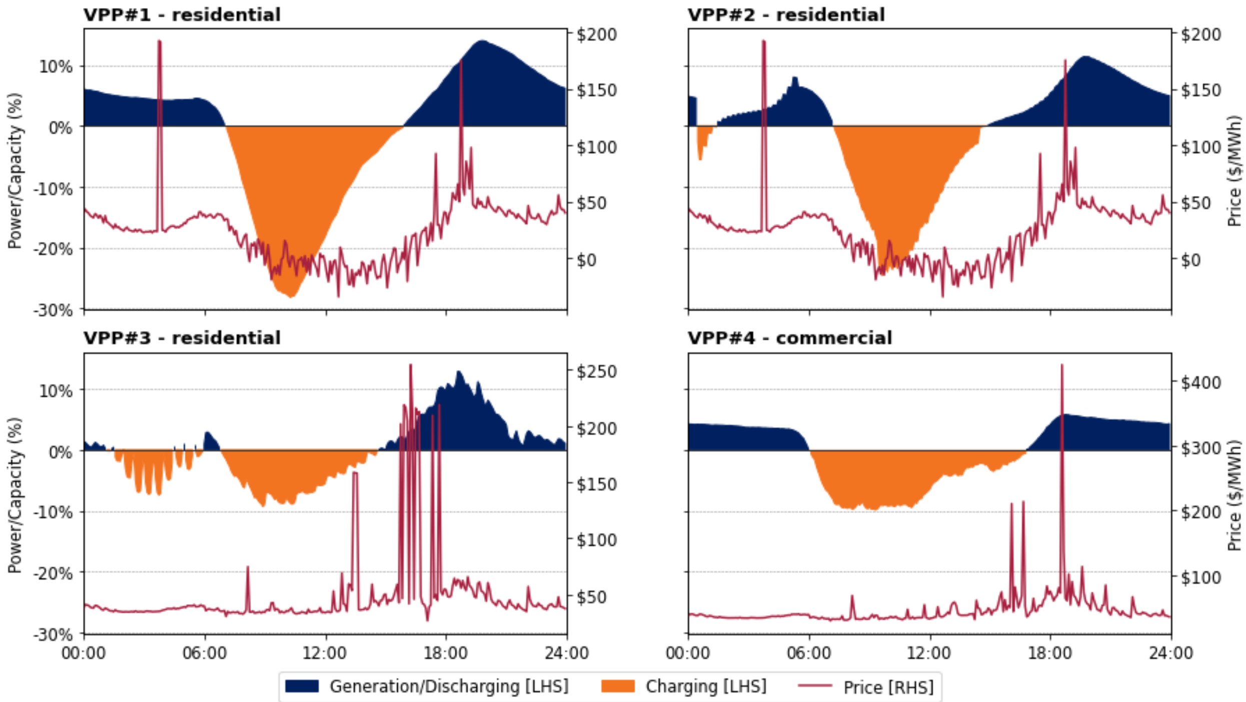
3.3.1 To what extent do VPPs respond to energy market price signals?

To further understand whether VPPs respond to energy and FCAS market price signals, AEMO examined data received from eight VPPs.

Energy

All eight VPPs showed similar charging and discharging behaviour during the study period, largely focusing on optimising household self-consumption[65], rather than responding to energy market price signals (see Figure 13).

Figure 13 VPP average normalised daily operational profile and average daily price per region (1 December 2020 to 28 February 2021)



Note: Power/capacity ratio refers to average VPP power in MW divided by total VPP capacity.

While VPPs have not exhibited large changes in generation during typical energy prices ($0-$300/megawatt hour [MWh]), findings from their response to volatile spot prices were mixed.

AEMO analysed VPPs' behaviour when prices were greater than $10,000/MWh (extremely high prices) and less than -$500/MWh (extremely negative price). Analysis indicated that some VPPs were more responsive than others, although findings also showed that there was no consistent pattern in their strategy towards such extreme price signals:

- **Extreme high price** – only three out of seven VPPs[66] responded at times, and even so, the most reactive VPP only responded to high prices around 39% of the time. With limited storage capacity, the VPP was not able to capture longer duration price spikes without recharging.
- **Extreme negative price** – VPPs charging at extremely negative prices was observed in some instances, noting that negative prices often coincide with the typical charging cycle (middle of the day). In addition, response during negative price periods out of the charging cycle was limited. Follow-up interviews revealed that participants are less likely to charge at low prices due to customer contracts in place.

The lack of a strong correlation between VPP behaviour and energy price signals suggests that generation patterns are still highly dependent on other factors including an operator's specific agreements with customers, market position, and algorithms used to manage VPP charging and discharging.

[65] A load-following mode where the battery will charge when there is excess solar generation during the day, and discharge to offset excess loads in the evenings.

[66] During the study period between 1 December 2020 and 31 March 2021, there was no dispatch interval that exceeded $10,000/MWh in Victoria.

As indicated, VPPs predominantly focus on household self-consumption. Analysis to date also suggests the type of consumer and battery storage size influences their charging and discharging patterns:

- **Consumer type** – participants with *residential load (VPP #1, #2, #3)* exhibited high evening peak generation, consistent with residential load patterns. This contrasts with participants with *Commercial & Industrial (C&I) load (VPP #4)*, where evening generation was much lower than VPPs with residential load. Furthermore, charging patterns showed that *VPP#4* maintained a consistent level of low charge during daytime hours as solar output was prioritised for demand[67].
- **Battery storage size** – participants with *smaller battery storage (VPP #3)* re-charged in the early hours (0110 to 0555hrs) prior to morning peak demand, due to energy storage levels declining to very low levels following high levels of generation to meet peak evening demand. Average daytime charge for smaller batteries was also comparatively lower than other participants (*VPP# 1 and VPP #2*).

FCAS

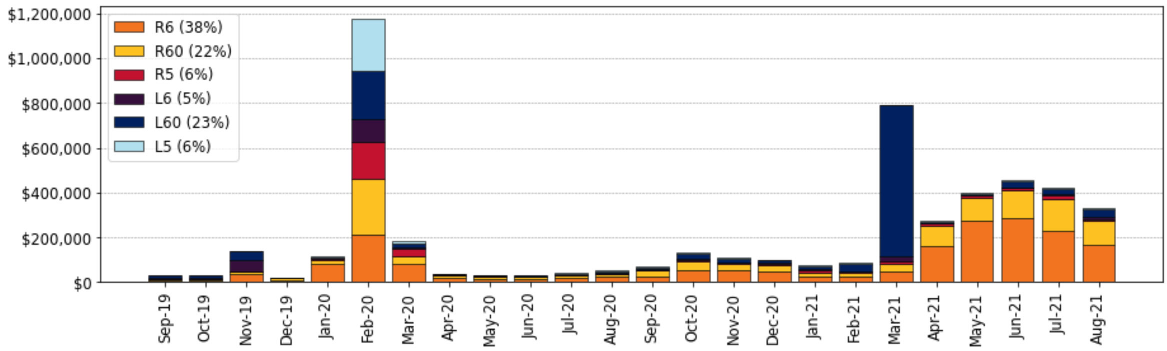
In addition to the energy markets, FCAS is another key market in which participating VPPs operate, with all eight VPPs registered in the six contingency FCAS markets (but not in the two regulation FCAS markets).

Figure 14 illustrates the monthly FCAS revenue stream for participating VPPs since September 2019. The vast majority (99%) of FCAS revenue to date was from South Australian participants, driven by higher registered capacity, as well as periods of extreme FCAS price volatility in the region.

Of note since the last knowledge sharing report was significant price volatility in the South Australian lower 60-second FCAS market during 12-17 March 2021, which resulted in $685,000 of FCAS revenue received by South Australian VPPs, accounting for 86% of total March 2021 revenue. High lower 60-second prices during this period was a function of a planned outage of Moorabool-Mortlake 500 kilovolt (kV) line which necessitated local South Australian contingency lower requirements, limited lower 60-second supply from Torrens Island Power Station following a 12 March transformer issue, and periods of high local requirements to cover for the loss of the Heywood to Tarrone to Haunted Gully to Moorabool 500 kV lines.

VPP FCAS revenue from raise 6-second and raise 60-second services increased from April 2021 due to elevated FCAS prices in South Australia and increased capacity (see Figure 18).

Figure 14 VPP FCAS monthly revenue by market (September 2019 to July 2021)



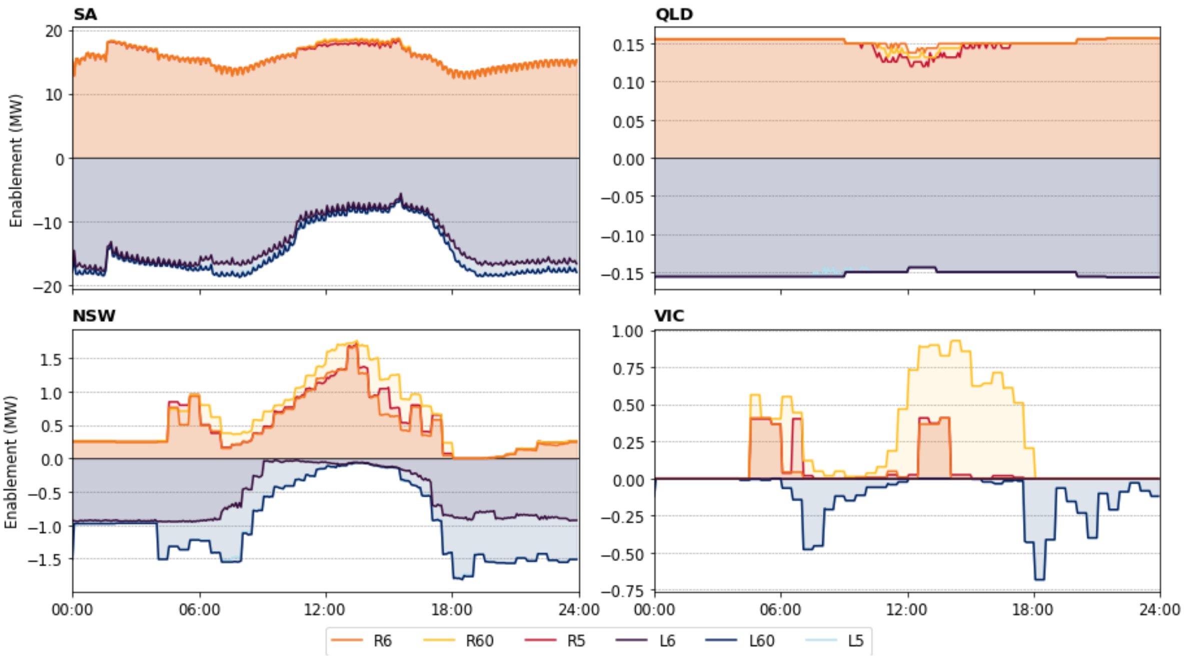
Average enablement[68] for VPPs in the FCAS market was largely driven by charging profile and size rather than response to price signals. As Figure 15 shows, VPPs that charged heavily during daytime hours had less contingency lower capacity available. In addition, VPPs with larger storage capacities (Queensland and South Australia) had higher levels of stored energy, so were able to provide contingency raise services throughout

[67] Less excess solar generator was available for batteries to charge, as C&I consumers have higher demand during daytime hours.

[68] When a VPP is enabled for raise FCAS services (that is, responding to low frequency), VPPs are required to increase output/discharge or reduce load/charge. In contrast, when a VPP is enabled for lower FCAS services (that is, responding to high frequency), VPPs are required to reduce output/discharge or increase load/charge.

the day. This is a contrast to VPPs with smaller storage capacities (Victoria and New South Wales), where average raise enablement was confined to daytime hours when batteries were highly charged.

Figure 15 VPP average daily contingency FCAS enablement profile (18 March 2021to1 September 2021)

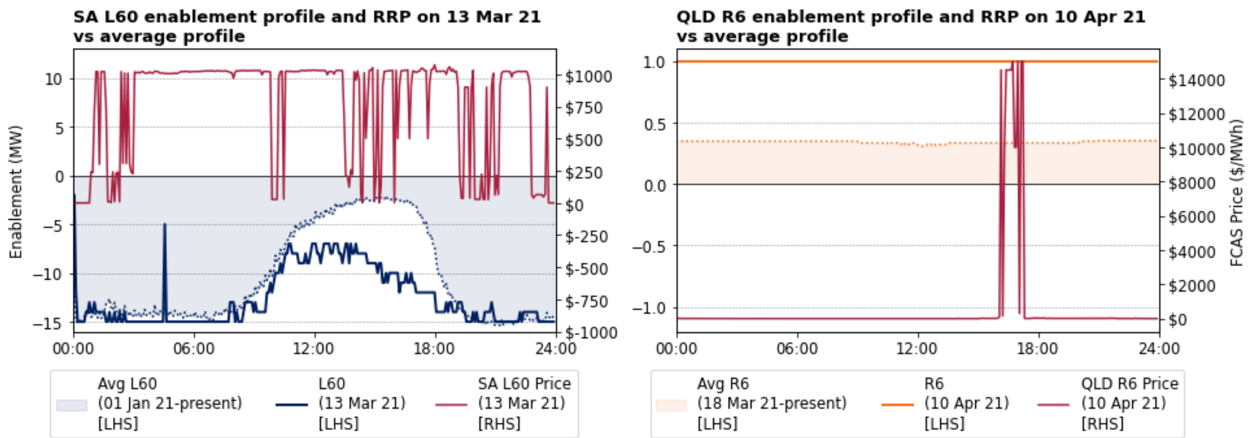


Note: VPP participants in all regions started bidding on 18 March 2021.

In addition to examining VPPs' average enablement in the FCAS market, AEMO also examined VPPs' responsiveness towards price volatility, particularly in 2021.

Analysis to date suggests that VPPs' responsiveness was limited to its registered capacity. For example, participants with only 1 MW of registered capacity (Queensland, Figure 16), were not responsive to extreme high prices, as they were already enabled to maximum capacity. However, higher than average enablement for larger VPPs during periods of elevated FCAS market prices highlighted an opportunity for VPPs to be more responsive as they continue to build capability and understanding of the FCAS markets. Figure 16 shows that South Australian VPPs were responsive to high lower 60-second market prices (>$1,000/MWh) on 13 March 2021, providing higher than average lower 60-second services during middle of the day. As capacity increases over time, AEMO expects to see VPPs' behaviour in the FCAS market continue to evolve.

Figure 16 VPP FCAS response to volatile FCAS prices (VPPs aggregated by state)



3.3.2 If this behaviour is extrapolated to reflect the potential for very large VPPs in future, what impact could VPPs have on energy market dynamics?

As VPPs continue to grow, it is important to understand their potential impact in both energy and FCAS markets. Compared to January 2020, the number of VPP participants has grown from two to eight, with total registered capacity across six contingency FCAS markets increasing to 184 MW.

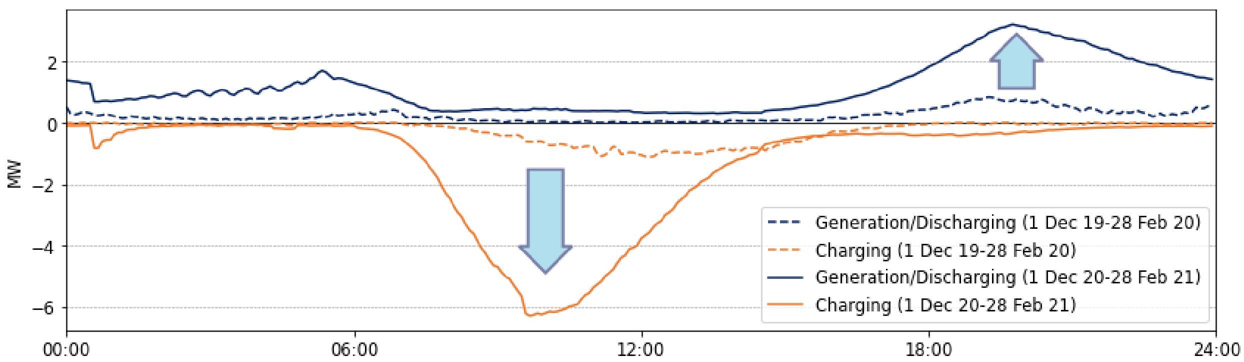
Table 7 VPP registered capacity in each contingency FCAS market

Market	Raise 6-sec	Raise 60-sec	Raise 5-min	Lower 6-sec	Lower 60-sec	Lower 5-min
Registered capacity (MW)	31	31	31	29	31	31

Energy

VPPs' impact on the energy market remains limited due to size. However, as indicated in previous knowledge sharing reports, if capacity was extrapolated out to a very large VPP sector, it could assist with the management of peak demand and lessen duration of negative spot prices. This is shown in Figure 17, where daytime charge and evening generation have increased substantially since last year as capacity increased.

Figure 17 VPPs (all) average daily operational profile – Summer 2019-20 vs Summer 2020-21



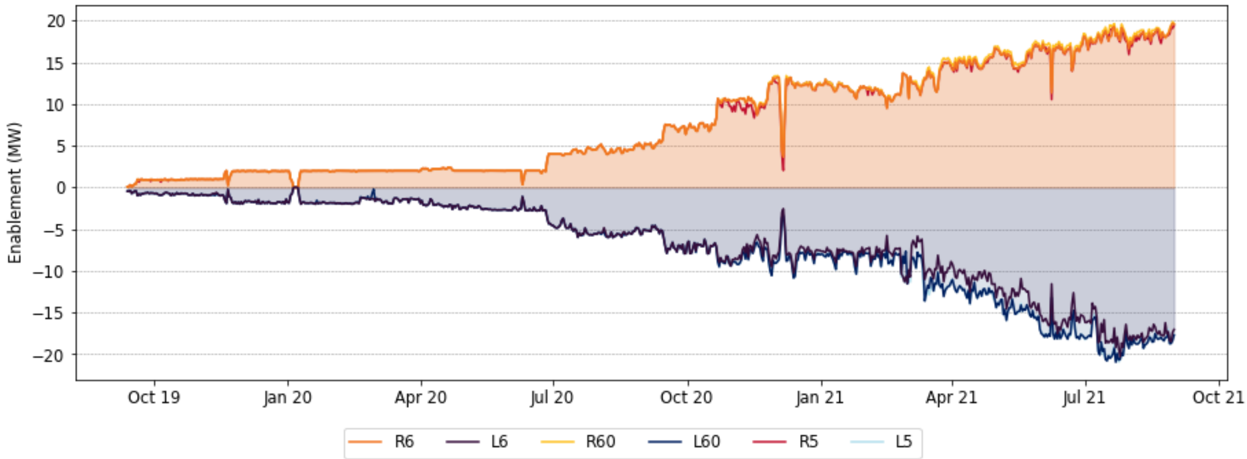
FCAS

In the contingency FCAS markets, VPPs continued to increase market share, reaching 3% in April 2021, up from 0.6% in April 2020. Between April 2020 and April 2021, VPPs' average FCAS enablement increased from 2 MW to 14 MW (Figure 18), in line with growth in registered capacity.

Analysis showed that VPPs often bid in at very low-price bands in FCAS markets, and have displaced traditional providers such as coal-fired generation. If VPPs continue to grow and bid large amount of capacity at low prices, they could contribute to lower FCAS prices and costs[69].

[69] Impact on FCAS prices and costs will be subject to offers from other supply and how they are bidding.

Figure 18 Averaged VPP (all) FCAS enablement growth, per market (1 September 2019 – July 2021)



3.3.3 How much reliance should be placed on VPPs responding to energy market price signals for integrated system planning studies?

As VPPs incorporate an increasing proportion of distributed solar and battery systems into the future it becomes increasingly important to understand their behaviour, including how they are likely to respond to high and low demand events, for system planning purposes. AEMO produces a key set of documents for this purpose in the *Integrated System Plan* (ISP)[70].

Previous ISPs applied the following assumptions for modelling VPPs:

- A proportion of batteries are associated with VPPs (referred to as Aggregated Batteries), with this proportion projected to grow into the future, at different rates depending on the forecast scenario[71].
- Aggregated batteries are included in the market models and are optimised with perfect foresight to maximise their benefit to the system, such as discharging to the maximum extent during peak demand periods and charging during periods of low demand.
- All rooftop PV is modelled as uncurtailed, so does not consider the possibility of VPP solar generation being augmented during negative pricing events (or other forms of curtailment).

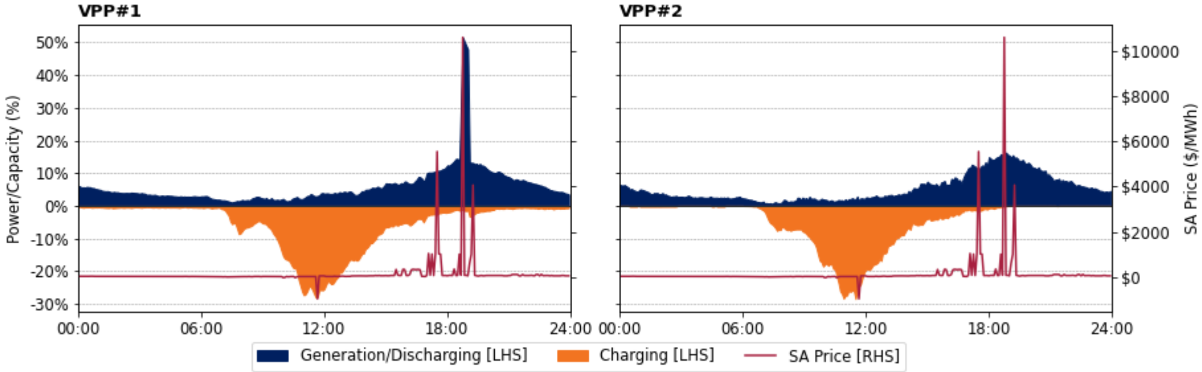
The VPP Demonstrations project has provided an important source of data to test these ISP assumptions. To date, the following observations have been made which will help improve future ISP modelling around VPPs:

- The proportion of batteries in VPPs has been underestimated previously, most notably for South Australia. This has been reviewed and the 2021 battery projections use VPP Demonstrations data as an input to better estimate the current proportion of batteries operating within VPPs.
- Current data from the VPP Demonstrations suggests the response of VPP batteries to both high and negative price events is smaller and less predictable than currently assumed in AEMO's models. This is illustrated in the charts below, where one VPP responds to the price signal, but only up to 50% of capacity, and the other does not appear to respond at all. However, a follow-up survey of VPP participants to investigate this observation further indicated that this is at least partly due to VPPs being in the early stages of their development. Several respondents indicated their intent to better consider wholesale prices in their dispatch algorithms in the future. Based on this, AEMO will continue to monitor VPP behaviour to determine whether changes to the modelling approach are needed.

[70] At https://aemo.com.au/energy-systems/major-publications/integrated-system-plan-isp.

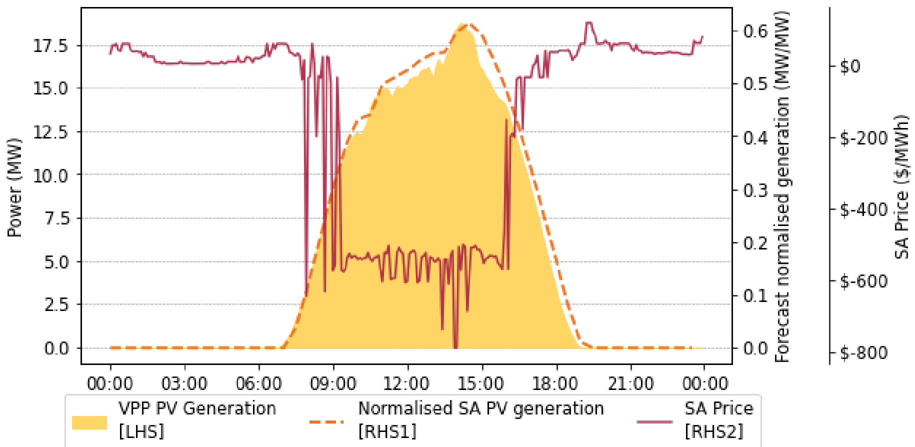
[71] See https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/inputs-assumptions-methodologies/2020/2020-inputs-and-assumptions-workbook-dec20.xlsx?la=en for further information on the ISP inputs including aggregated batteries.

Figure 19 Two SA VPPs' response to elevated prices (24 January 2021)



- Curtailment of rooftop PV during periods of negative pricing was also observed to be minimal, as illustrated in the example in Figure 20 below, suggesting AEMOs current assumption is justified for now. However, as with the battery response above, several respondents to the VPP survey also indicated that this is an area they are considering in the future. The introduction of flexible export connection agreements by SAPN for new PV connections in 2022 may lead to a reduction in PV output at times when SAPN's network is reaching its PV hosting capacity limits. AEMO will monitor how this develops and consider adjusting its modelling methodologies accordingly in future.

Figure 20 Aggregated SA VPPs' rooftop PV generation (14 March 2021)



Current evidence suggests that relatively low reliance should be placed on current VPPs responding to wholesale price signals, but based on responses from VPP trial participants, this may change in the future as VPP dispatch algorithms evolve to become more sophisticated. For this reason, and the diversity of responses to prices signals across different VPPs, operational visibility VPPs will continue to be an important source of information that AEMO will monitor into the future to improve system planning assumptions.

3.4 Local power quality insights

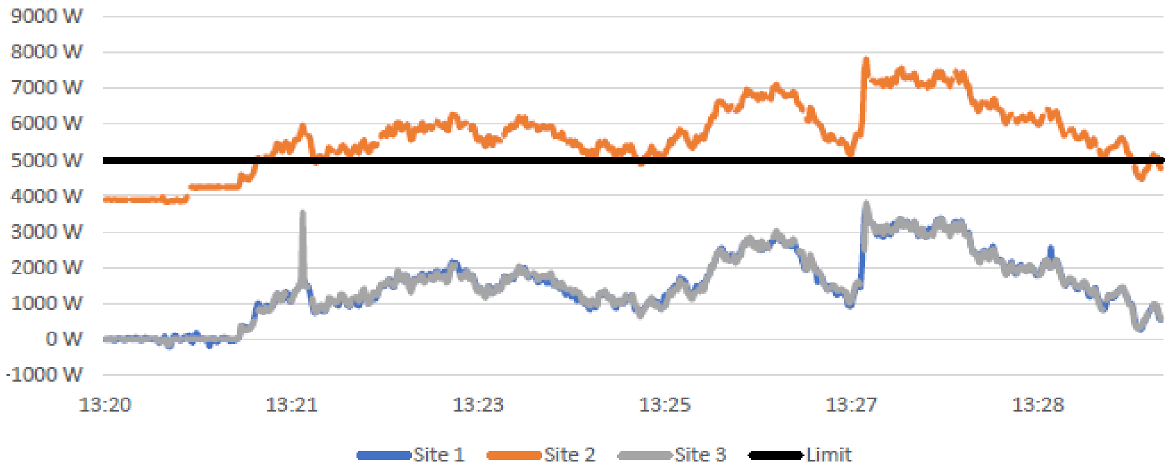
SA Power Networks (SAPN) was approached because of its experience and knowledge gained throughout their Advanced VPP Grid Integration trial[72] with Tesla, with support from the Australian Renewable Energy

[72] See https://www.sapowernetworks.com.au/future-energy/projects-and-trials/advanced-virtual-power-plant-grid-integration-trial/

Agency (ARENA). The following input has been taken from SAPN's final knowledge sharing report[73] and includes charts provided by Tesla.

3.4.1 To what extent do local power quality or fleet communication issues impact VPPs' capability to meet their operational objectives?

SAPN has provided the following insights regarding local power quality and fleet communication issues.

> Distribution network constraints, in particular local power quality issues in areas with high levels of rooftop PV, have been identified as a factor limiting VPP performance by both AGL[74] and Simply Energy[75] in their VPP trials in South Australia. If local voltage is high due to high solar output, the capacity of the VPP in that area can be reduced due to AS4777 Volt/VAr and Volt/Watt response being active in the VPP's battery inverters and reducing the available real power output. In some cases it can be the act of dispatching the VPP to discharge that pushes local voltage up to levels where local solar and battery inverters self-curtail or trip, resulting in a lower level of net power injection from the dispatch than expected.
>
> These issues arise because the VPP has no awareness of available local network capacity[76]. SA Power Networks has been examining this issue in our Advanced VPP Grid Integration trial with Tesla's South Australian VPP. The following text and figures are drawn from the final knowledge sharing report for that project[77].
>
> A key goal of this trial has been to explore the use of dynamic operating envelopes, or flexible export limits, to signal to the VPP the available capacity of the local network on a dynamic, locational basis, as a rolling 24-hour forecast. This enables the VPP to take local constraints into account when bidding energy exports into the market. As well as ensuring that the VPP performs as expected in areas that are constrained, it also allows the VPP to dispatch at levels higher than the standard 5kW per site export limit at times and in locations where there is sufficient local network capacity.
>
> An example of local export limits impacting a VPP's capability to deliver FCAS is illustrated below. Figure 21 shows the individual response at three VPP sites. It can be seen that, prior to the event, sites 1 and 3 are operating in zero-export mode, as is common when the battery is charging from PV or entirely supplying the site load. For these sites, the total FCAS response reached a peak of 3.8 kW export power per site during the event. Site 2 illustrates an alternative behaviour, with PV exports in progress prior to the event in the order of 4 kW, presumably due to the battery already being full at this site. As the frequency drops and the battery responds, a protracted export above the 5 kW published limit can be observed, peaking at 7.8 kW. All three sites produce an almost identical response profile.
>
> **Figure 21 Site level FCAS raise response 2 March 2020**
>
> 
>
>
> This illustrates the benefit from the additional export capacity allowed. Under a standard connection agreement all exports would be capped at 5 kW, meaning that sites like site 2 would not be able to participate in the

[73] At https://arena.gov.au/assets/2021/05/advanced-vpp-grid-integration-final-report.pdf

[74] *Virtual power plant in South Australia Stage 1 Milestone Report*, AGL, 31 July 2017, accessed at https://arena.gov.au/knowledge-bank/virtual-power-plant-south-australia/

[75] *Stage 2 Knowledge Sharing Report, Simply Energy VPPx*, June 2020, accessed at https://arena.gov.au/knowledge-bank/?keywords=Simply+Energy+Virtual+Power+Plant+%28VPP%29

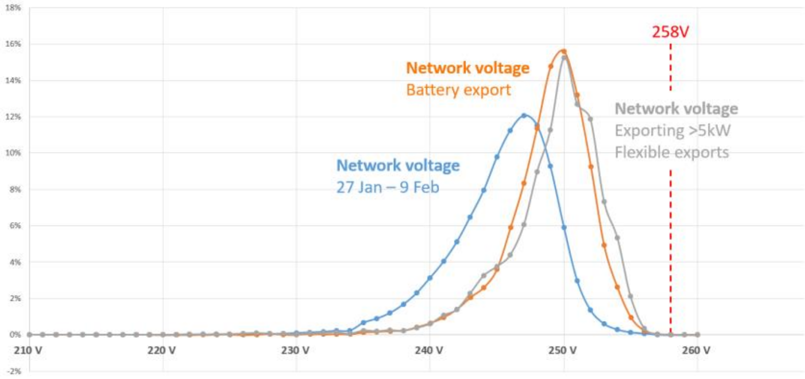
[76] Noting that, while networks, including SAPN, are making progress in reducing issues of local voltage rise due to solar PV – for example, SAPN's' $10 million Enhanced Voltage Management program () – an efficient network will always have capacity constraints at certain times and locations.

[77] SAPN, Advanced VPP-Grid Integration Project Knowledge Sharing Report v1.0, May 2021, at .

contingency frequency response. In practice, the VPP operator would need to reduce available contingency FCAS raise services during solar hours.

The figure below illustrates the effectiveness of the system in maintaining voltage within bounds during this trial during high-solar periods. It shows the distribution of average voltage measured at the battery for active VPP sites during the period from 27 January 2020 to 9 February 2020. The blue line shows the distribution of network voltage measurements averaged over all 5-minute intervals. The orange line shows the distribution of voltages over only those time intervals when batteries were exporting energy; site voltage is, on average, higher at these times, as expected. The grey line shows the same histogram for those times when site exports were greater than 5 kW, i.e. at times when the flexible export limit allowed for exports above the normal static limit. It can be seen that the voltage remains within bounds at these times, indicating that the system is only providing for higher limits at times when there is sufficient capacity to enable this, and has not caused any negative impact on overall LV voltage levels through this period. Further details of this trial can be found in the trial Knowledge Sharing Report[78].

Figure 22 Voltage performance at minimum vs maximum limits

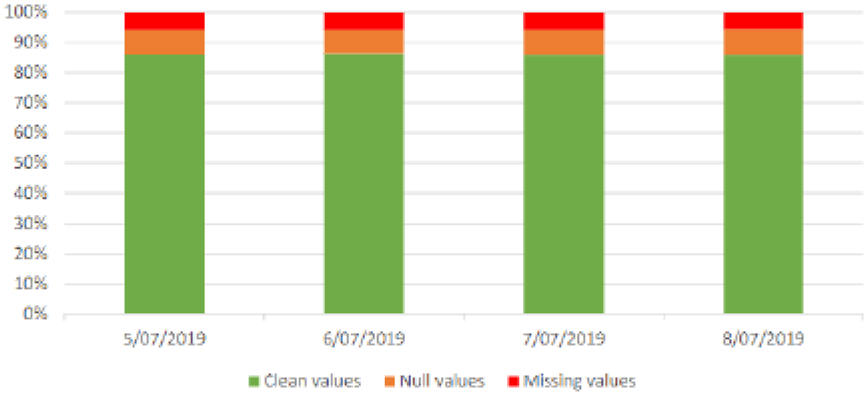


Communication

During the initial telemetry test, around 90% of data was received correctly on each day of testing. The cause of missing data was confirmed as being occasional dropouts in the communications links between consumer batteries and the Tesla cloud. This amount of data loss was in line with expectations, as Tesla's VPP relies on the consumer's internet connection for communication, which is not always reliable. This phase of testing also identified some specific software and configuration issues that affected data quality, which were resolved.

Figure 23 Proportion of data received

In the event that the VPP system is unable to communicate with the API, sites will revert to a default export limit. In this trial the default is 5 kW, commensurate with normal static limit.



Tesla's Autobidder is used to co-optimise VPP behaviour in response to markets and individual site conditions and is used to manage most communications out to VPP resources. Importantly, Tesla also does not use strict central control for the operation of their VPP, as is the case for many other VPP operators. Instead, individual Powerwalls have been designed to operate semi-autonomously with reference to price forecasts and other data provided by Autobidder. This approach is well suited to an environment that relies on consumer internet for site communications, which is not always reliable.

[78] SAPS, Advanced VPP-Grid Integration Project Knowledge Sharing Report v1.0, May 2021, at .

3.4.2 Can the VPP operational data provide useful insights to DNSPs about the real time status of low voltage networks?

SAPN has explored this question in its Advanced VPP Grid Integration trial with Tesla's South Australian VPP. The following text and figures are drawn from the final knowledge sharing report for that project[79].

> In this trial SA Power Networks receives 5-minute telemetry data from 1,000 VPP sites via SA Power Networks' VPP integration API. The following data streams were sampled for each participating VPP site.

Table 8 Data streams sampled for each participating VPP site.

Measurement	Calculation	Interval Length	Latency
Voltage (V)	Minimum	5 minutes	24 hours
Voltage (V)	Maximum	5 minutes	24 hours
Voltage (V)	Average	5 minutes	24 hours
Active Power (W)	Minimum	5 minutes	24 hours
Active Power (W)	Maximum	5 minutes	24 hours
Active Power (W)	Average	5 minutes	24 hours
State of Charge (Wh)	Instantaneous	5 minutes	24 hours

> In this trial, this data was intended to be used primarily to improve understanding of the VPP's impacts on the network, tune SA Power Networks' hosting capacity model, and confirm VPP site compliance to published limits. However, it became evident that the telemetry provided through the API could also help in building a greater understanding of the underlying performance of the LV network more broadly, and identify issues unrelated to the VPP operations. Analysis of this data revealed around 20 VPP sites where VPP equipment had been installed or commissioned incorrectly at the site, and SA Power Networks was also able to use data analytics on this data set to detect faulty neutrals at some consumers' premises, which is a potential shock hazard.
>
> One learning from this trial was that the impedance of the consumers' on-site wiring must be taken into account in interpreting the data, because the voltage measurements received via the API were obtained at the battery inverter, which can be some electrical distance away from the connection point to the network. This means that under high export conditions, the battery may raise the voltage within the consumer's premises while the local LV network, and neighbouring consumers' supplies, remain compliant.
>
> Further details of this trial can be found in the trial Knowledge Sharing Report[80].

AEMO thanks SAPN for sharing its insights as a DNSP with firsthand experience of integrating VPPs into the distribution network.

3.5 Consumer insights

As outlined in Section 2.4, in July 2019 AEMO commissioned CSBA to investigate and provide specific insights on how to improve the consumer experience. The VPP consumer study aimed to answer three critical questions:

- What are consumers' experiences of participating in Australia's early stage VPPs?
- How can consumers' experience of VPP participation be improved to make it more attractive for consumers to sign up in the future?
- Is VPP participation attractive enough for consumers to let VPP operators utilise their resources?

[79] SAPN, Advanced VPP-Grid Integration Project Knowledge Sharing Report v1.0, May 2021, at .

[80] SAPN, Advanced VPP-Grid Integration Project Knowledge Sharing Report v1.0, May 2021, at .

CSBA's full report and interim report on this study can be found on the AEMO website[81]. Outcomes of these findings in response to the three research questions above indicate:

- Consumers' experiences in participating in Australia's early stage VPPs are largely positive, particularly when consumers could see value (monetary, community, environmental) from participation.
- The experience of consumers can be improved by considering the existing knowledge they may have about DER, the way the grid operates and how DER operate, how they are kept informed regarding their asset's contributions (for example, apps, regular updates, easy to understand information and statistics), and translating how being part of a VPP has contributed to reducing their daily electricity costs.
- Consumers are willing to give up some control of their resources if tangible outcomes can be seen. The lower the positive impact the VPP appears to be having on the consumer, the more consumers question the level of control they are providing to an external company, and how they can regain control.

These findings and recommendations are further explored below.

3.5.1 CSBA key findings

VPPs can help consumers realise value from their rooftop solar and battery investments and also help stabilise the power system. Attracting consumers to such initiatives and retaining them over the longer-term will largely depend on the quality of their experience with their VPP provider. This report details the experience of 1966 individual respondents and draws upon their feedback to provide recommendations for how it can be optimised to improve the success of future VPP projects.

Overall satisfaction with the VPP system remained constant over time

Consumer satisfaction with VPPs was high and the majority of consumers indicated that they would be willing to promote participation in a VPP to others.

- Consumers' ongoing satisfaction with, and advocacy of, VPPs will be further enhanced with improvements in ongoing communications and transparency. In particular, consumers want to understand:
  - The financial benefits to their household (e.g., how much energy they provided to the grid and what they were paid for this).
  - The environmental benefits (e.g., how much CO_2 was saved and how many trees this is equivalent to planting).
  - The community benefits (e.g., how many minutes of power shortfalls in their state were saved by their household's power contribution).
- Strategies will need to be developed to handle how VPPs are transitioned to new tenants/owners, together with programs for battery replacements as they deplete over time.

The expectation that the consumer would be able to save money on energy bills was the most prevalent factor in sign-up and retention

Attraction to the VPP can be driven by marketing initiatives and focusing on the potential for cost savings. Retention is driven by the realisation of savings by the consumer. Those consumers who did not clearly identify cost savings in their bills after joining and those who were unclear if the VPP would reduce their energy costs became dissatisfied.

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[81] At https://aemo.com.au/initiatives/major-programs/nem-distributed-energy-resources-der-program/der-demonstrations/virtual-power-plant-vpp-demonstrations.

- Target suitable consumers with a strong and clear marketing strategy.
- Review energy bills for each site/consumer to ensure realistic expectations of savings and other benefits.
- Align reporting metrics with expectations to ensure the actual experience matches or outperforms the promised experience.

The pathway to VPP 'membership' influences overall satisfaction

The journey to participation in the VPP shaped consumers' levels of satisfaction. Previous experience with solar panels and generous revenues led to higher expectations of the value potential. Those who acquired a battery at the same time as joining the VPP tended to see them as intrinsically related.

- The marketing strategy and onboarding process for future VPPs need to reflect the pathway to VPP membership for the consumer.
- People with existing infrastructure will have different needs for re-education and previous arrangements such as high ongoing financial earnings from solar panels and existing discounts need to be considered.
- The marketing should provide positive reinforcement to the consumer that they are helping the community/environment by supporting grid stability.
- Actively marketing to those who do not already have solar and/or a battery will improve the future success of VPPs.. For example, Pathway Four candidates who are offered a package (panels, battery, VPP) are more likely to be highly satisfied and loyal.
- Linking with government rebate programs can improve attraction and retention as consumers benefit from both the government program and cost savings from participating in the VPP.

Consumers are aware they are giving up control of their asset when they join the VPP

Consumers understood that joining the VPP meant giving up some control over the hardware. For those whose expectations of benefits including mainly cost savings, but also community/environmental benefits, were met, this was not considered a problem as they appreciated the increased value potential by joining the hardware to the grid. Indeed, some consumers modified their behaviour, using electrical appliances at different times of day, to try to maximise the value they received from the VPP.

Inadequate compensation or a lack of understanding of the process were the key factors for dissatisfaction with losing control of the asset

For some consumers, especially those who had reached a 'set and forget' mentality, abdication of responsibility was seen as a positive.

- Consumers need clear information on how the VPP works, for instance why the battery discharges at certain times, to overcome any issues with giving up control of their assets.
- Positively reinforce the key message for handing over asset control: "The VPP extends the value of the asset to you and to the community."
- Better education on how VPPs operate is required up front.
- Communication channels should be targeted to the right audiences, and ongoing communications need to be tailored to the needs of consumers.

Uptake of VPP membership was primarily driven by 'early adopters'

CSBA undertook segmentation analysis to identify four consumer segments with common characteristics. The four groups were defined as Early Adopters, Going with the Flow, Personal Gain, and Caring Community.

Early Adopters were driven by a desire to be pioneers in new energy solutions and were highly motivated and engaged in the VPP Demonstration.

Going with the Flow consumers were pleased to be a part of the VPP, because they could see the benefits for the environment, the wider community and themselves, but there was a lack of engagement with the VPP.

Personal Gain consumers were primarily driven by the opportunity to make money from their asset, significant subsidies on batteries, and the expectation of being able to use more free solar power during the day or the evening.

Caring Community consumers were drawn to the VPP by the expectation of being able to use more green power and therefore help the environment, and also to share their excess solar energy with others in the community or not for profit organisations.

- In the early stages of VPP deployments, actively market to Early Adopters, key opinion leaders and influencers in the community.
- Develop a strategy to attract other segments over time. As uptake increases, less engaged consumers will be harder to reach and will continue to need validation.
- Use of traditional media such as TV and Radio (e.g., discussion programs such as 'The Drum' or topical programs such as 'War on Waste' or even 'The Checkout') has been identified as a way to reach consumers.
- Identify causes that resonate with the different segments and show how the VPP supports their specific motivations.

Consumers desire more information from their VPP Provider to boost engagement

Membership of a VPP means consumers have made an emotional investment in the VPP and they are eager to learn more about how to assess the financial impact of the VPP, how to manage their energy usage, VPP processes, and how the VPP community is progressing.

- There is a need to define the information needed at different points of the consumer's journey, for example, to provide consumers with clear worked examples of financial impacts during onboarding.
- Develop marketing strategies by segment and provide consumers with compelling information, either through a VPP app or through credible media.
- Provide clear information on how the battery is remotely managed.
- Enhance the onboarding experience by ensuring consumers are shown how to use the app and find the data they need.
- Upskill VPP provider call centre staff so they can address consumer questions about the VPP or provide direct access to knowledge experts for support to consumers.
- Provide in-app help and updates targeted to consumers' information needs.

An app is the manifestation of the VPP (virtual in their pocket)

The VPP demonstration did not require VPP providers to supply an app, but those consumers with access to an app found it to be a key benefit to their experience. As well as enabling them to check on the battery and see the energy flow between the battery, the panels and the grid, the app was a key means of communicating with consumers and reinforcing the benefits of participation, thereby leading to enhanced satisfaction and retention. There is an opportunity for VPP Providers to create apps to communicate with VPP members and enhance consumer understanding and satisfaction.

- Enhance design of apps to improve ease of understanding through relevant infographics and aligned reporting metrics.
- App development to consider the user experience (UX) and ensure apps deliver and convey the features and benefits of the VPP that are relevant to the consumer.
- Apps need to maintain functionality as phone operating systems evolve.
- Apps are a key means of increasing consumer engagement and retention and could be further enhanced through gamification, personalisation, push notifications (for example, number of households signed up), coverage maps and virtual rewards (such as gold stars, points).

The industry needs to develop clear guidelines for what consumers can expect from VPP membership

Various business models existed within the VPP Demonstrations, and consumer experience and satisfaction reflected those differences. Key processes need to be standardised across all providers so consumers know what to expect.

- Transparency in reporting.
- Consistency of language used.
- Contact channels and a clear complaints process.
- Messaging to focus on how consumers are financially better off by joining a VPP and contributing their assets.

3.5.2 VPP business model insights

In the VPP Demonstrations, aggregators orchestrate participating consumers' DER to deliver FCAS services and respond to wholesale energy price signals. When consumers participate in a VPP program, they allow a third party (the VPP operator) to utilise their DER asset(s) in exchange for some reward or value. This section explores this value exchange by analysing the marketing and contractual information provided (under the terms and conditions) to AEMO by the participants of the VPP Demonstrations.

Figure 24 VPP aggregator and consumer value exchange

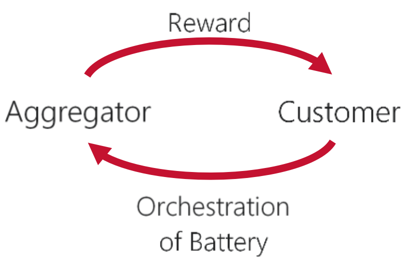


Table 9 captures a summary of the VPP consumer value exchange by considering rewards and orchestration of the batteries.

Table 9 Summary of VPP consumer value exchange

Rewards:	Orchestration of the battery:
• Rewards ranging from $280-$2,550 p.a. • Discounts on battery supply (capital expenditure) ranging from 11%-51% • Exclusive retail agreements ranging from 32% below to 16% above default offers • Non-financial benefits (promoting renewable energy, community benefits and grid support)	• How many times could the battery be managed under the VPP per annum? **30 – unlimited, unlimited most common** • How much of the battery capacity was reserved for household use? **0 – 30%, 20% most common**

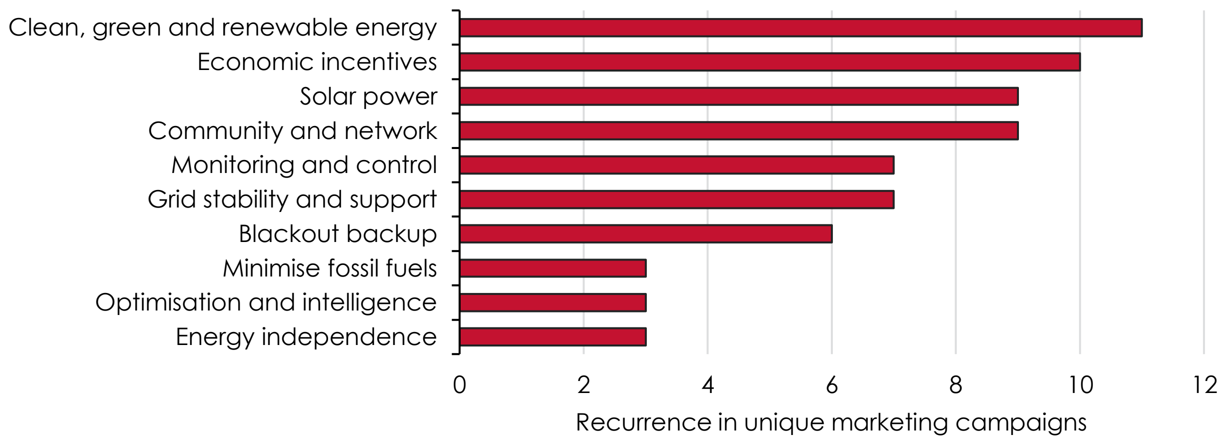
VPP offerings have diversified as the VPP market has become more established. Early VPP offerings were centred around the discounted supply of the battery and a locked-in retail deal. Later VPP offerings have become more sophisticated, offering sign-up credits and bonuses, bring your own battery options and no-lock in retailer options. VPP offerings have also diversified geographically.

A wide variety of VPP offers exist for consumers to consider, indicating this is a nascent part of the industry and no one strong business model exists (yet). These offers varied in location, reward structure and battery eligibility criteria.

It was found that when VPP programs offering discounted batteries were paired with the South Australian Government Home Battery Scheme subsidy, VPP consumers could access significant (up to 51%) discounts on batteries.

Common themes exist in the language used in VPP business to consumer (B2C) marketing campaigns (from a total of 11 examined). These themes are outlined in Figure 25 below, which draws attention to the non-financial, indirect benefits of VPP programs.

Figure 25 Common themes in B2C marketing campaigns



3.6 Cyber security

All participants of the VPP Demonstrations completed a cyber security survey[82] to increase AEMO's awareness and understanding of the measures taken by participants to protect DER from cyber threats and potential

[82] At https://aemo.com.au/-/media/files/electricity/nem/der/2019/vpp-demonstrations/vpp-demonstrations-cyber-security-questionnaire.xlsx?la=en

attacks. AEMO also engaged with MITRE to examine the VPP model/use case with respect to cyber security risk in more detail, which is reflected in the insights below.

3.6.1 To what extent do VPPs, and DER more generally, present cyber security risks that could pose a threat to power system security?

The expanding role of DER in Australia's energy system opens the door to new types of cyber security threats under the broad heading of demand side threats. These cyber security threats pose risk to power system security.

The VPP / DER high level cyber security risk statement

If…
a cyber security threat targeting DER devices in aggregate occurs

Then…
the power system could breach intended operating thresholds

Leading to...
impacts to power system security and reliability such as a localised loss of supply or islanding

The bulk energy system has historically operated as a closed environment – mature, technically capable actors, generation resources behind fenced or walled private property, systems connectivity using proprietary or niche protocols communicating over private networks.

This traditionally closed make-up has largely enjoyed a somewhat misdirected perception of inherent system security – security by obscurity. DER have almost entirely the opposite characteristics or attributes to the bulk energy system. DER are purchased (or leased) by members of the public, installed in a public, untrusted environment, use open protocols primarily communicating over an open network (Internet).

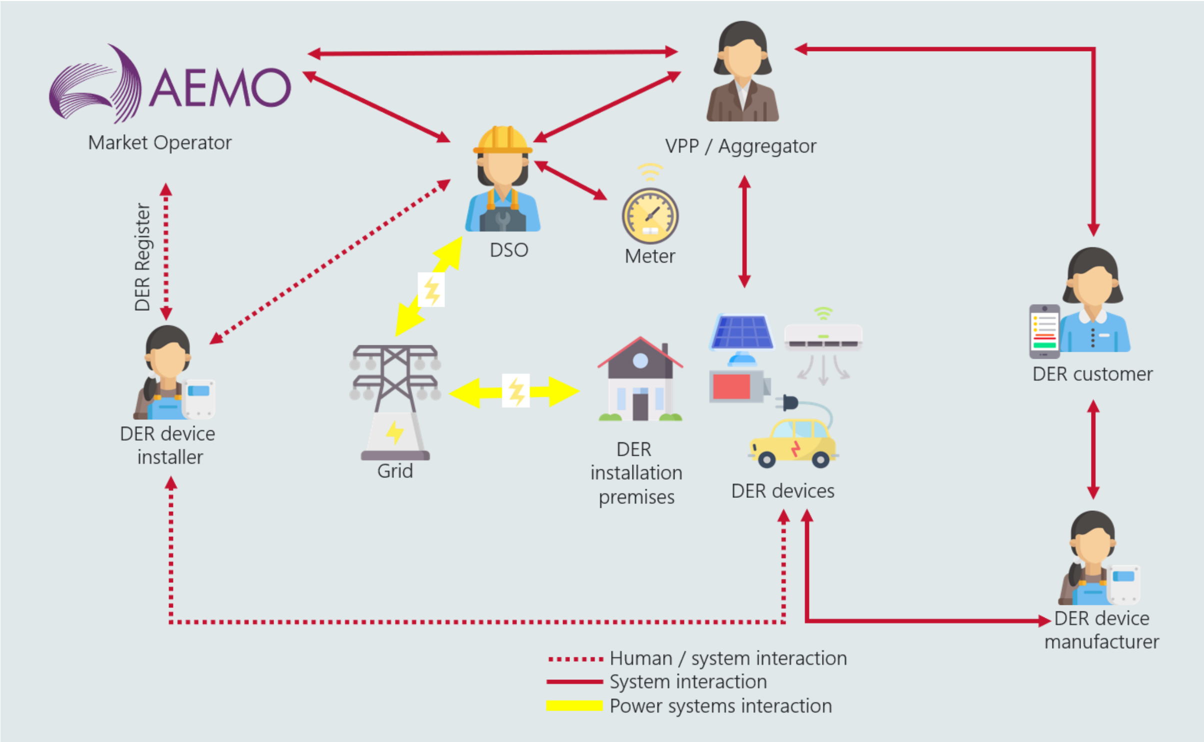
Securing remote instruction of the DER fleet

A power system with high penetration of DER needs to provide adequate granular control of system behaviour, particularly with new actors (as below in Figure 26) increasing the cyber security attack surface over and above that of the traditional power system. To be able to effectively participate in the power system, DER need to cater for remote systems access and must provide standardised interfaces enabling the remote modification of their software systems and operating parameters.

Example use cases for this remote access are:

- Responding to instruction from the aggregator e.g. to comply with dispatch instruction or changed operating envelope (potentially through a DER device manufacturer).
- Receiving software and firmware updates from the device manufacturer in response to feature updates or security patches.
- Churn of the device between aggregators or change of residential ownership.
- Consumers may configure additional interfaces to provide personal monitoring or management (e.g. via smart home devices).

Figure 26 A high level overview of the actors and interactions of the DER ecosystem



As in the risk statement above, scenarios where the remote instruction capability is taken advantage of, thereby impacting power system security, are those where either:

- DER device(s) in aggregate do not respond to remote instructions (or transmit telemetry) in a timely fashion, or
- DER device(s) behaviour in aggregate responding incorrectly either in response to a required instruction or autonomously.

DER device not responding to remote instructions in a timely fashion

The cyber security threats that could cause DER device(s) to fail to respond to instruction are summarised below.

Tampering

A tampering threat can impact the integrity of sensitive information. This information, in the context of the DER device ecosystem, includes configuration or settings of DER devices directly or other systems providing dependent services to the DER devices (for example, a 2030.5 utility server):

- DER device manipulation, (inadvertent or malicious) of device firmware, software, settings or configuration.
- Manipulation of communications pathways of the DER ecosystem to or from devices.
- Manipulation of dependent systems management infrastructure (such as name servers, time providers, authentication providers).

Denial of service

A denial of service threat can impact system availability by flooding a technology system with illegitimate requests such that it is unable to effectively respond to a legitimate request:

- Resource exhaustion of communications pathways of the DER ecosystem to or from devices:
  - Aggregator interfaces (particularly if internet-exposed).

- Manufacturer interfaces (particularly if internet-exposed).
- Resource exhaustion of dependent systems management infrastructure:
  - Name servers, time providers, authentication providers.

DER device responding or behaving incorrectly either in response to a required instruction or autonomously

Similar to the risk of failing to respond to instruction detailed above, tampering of DER devices directly, or their supply chain, is a threat scenario that could lead to incorrect or inappropriate DER device behaviour.

Reducing cyber security risk in the DER ecosystem

Pragmatic cyber security risk reduction generally involves the assessment and application of technology, people, and process controls to reduce the likelihood of a cyber security threat occurring, or the impact to the system if it does occur. It is imperative that DER devices and their interfaces are architected to be resilient to manipulation through their entire lifecycle, from the DER device manufacturer to the end user to the market operator, and every step in between. To date there has not been a coordinated assessment of the likely cyber security threats to a high penetration DER power system in Australia, nor an approach to mitigate these threats.

On 3 September 2020, the Australian Government released the voluntary Code of Practice: Securing the Internet of Things for Consumers[83]. The Code of Practice is a first step towards lifting the security of Internet of Things devices in Australia. The Code of Practice is intended for industry, but everyone has a role to play in improving cyber security in the Internet of Things.

Additionally, the Australian Energy Sector Cyber Security Framework[84] (AESCSF) contains useful cyber security controls that are relevant to any critical infrastructure organisation, including asset management, event detection and logging.

Realistically, the above threats would need to occur in tandem to DER devices en masse (hence the aggregate terminology in the high level risk statement above). However, given some of the attributes required for running high DER participation effectively such as remote device access and a homogeneous DER device environment, affecting a large number of devices is possible, particularly for threat scenarios where an aggregator or device manufacturer (or their supply chain) is compromised.

3.6.2 Are VPPs appropriately incentivised to independently address cyber security risks?

There are currently no formal regulations in Australia mandating the application of cyber security controls for entities participating in the power system. The AESCSF is a voluntary assessment of cyber security maturity aimed at helping to raise the bar across the energy industry. The Framework provides a foundation for energy market participants, including VPPs/aggregators, to assess their current state cyber security capability and maturity in a standardised manner and to make informed decisions regarding the steps that they need to take to become resilient in the face of a cyber-attack.

In line with the Australian Governments' Cyber Security Strategy 2020[85] it is expected the Critical Infrastructure – Systems of National Security (CI-SONS) legislation will be introduced (expected to be passed in Parliament in Q4 2021). It will provide a level of standardised cyber security controls for participants in the energy sector. At this stage, however, it is probable that aggregators (VPP operators) will be specifically excluded from these requirements unless they are of significant size (in aggregated nameplate capacity).

[83] At https://www.homeaffairs.gov.au/reports-and-publications/submissions-and-discussion-papers/code-of-practice.

[84] At https://aemo.com.au/en/initiatives/major-programs/cyber-security/aescsf-framework-and-resources.

[85] See https://www.homeaffairs.gov.au/about-us/our-portfolios/cyber-security/strategy.

In the interim, the onus of cyber security risk mitigation is up to Australian individuals and businesses. The decision to invest in cyber security controls can be considered analogous to a form of insurance. Purchasing insurance is inherently a risk management decision and the purchaser is making a contextual evaluation of their own exposure and loss potential. Through the dissemination of publicly accessible information sources such as this report, the cyber security risks should become better understood, thereby driving an improved appreciation for cyber security loss potential and the uptake of products and services that are differentiated by improved security outcomes.

3.7 Participant insights

AEMO interviewed the VPP Demonstrations participants to gain their insight on how effective the project was for them to learn and to meet their strategic development goals.

VPP Demonstrations participant feedback

The principle of 'learn by doing' applied in the VPP Demonstrations was largely seen as the most effective approach for increasing knowledge across the VPP industry. Specific benefits include:

- Open access – allowance of broad participation across the industry (not restricted in bilateral trials).
- Opportunities for organisations to uplift internal capability in preparation for future opportunities.
- Accelerating maturity of the VPP industry and allowing VPPs to scale in size in a learning environment.
- Bringing consumers on the journey through their participation, increasing their knowledge of VPP capability and deepening their understanding of how energy interacts with household devices.
- Participants had additional opportunities to leverage knowledge within AEMO and access to subject matter experts.

Overwhelmingly feedback has been positive from the VPP Demonstrations participants and the industry more broadly. That said, several areas for improvement were identified, that are outlined below.

Limited participation and technology

While seven VPP operators (across eight portfolios) were able to participate in the Demonstrations, the relative infancy of the industry and investment required to participate limited the opportunity for alternative technology types such as electric vehicles, hot water systems, or other controllable loads to be tested.

Suggestions around improving the demonstration to accommodate the infancy of the VPP industry and organisational capability included further reducing barriers to entry such as the 1 MW minimum portfolio size, API requirements, and the ability to have mixed control types (switching and proportional) within a VPP portfolio.

Further uplift of organisational knowledge through training, 1-1 meetings and easily accessible information would have accelerated participant enrolment progress in the trial and potentially broadened the technology types.

Compliance in the demonstration environment

As an on-market demonstration, it has been important that VPPs comply with the Rules and regulations applicable to all market participants. Participants (including VPP Demonstrations participants) are paid for FCAS upon enablement, however, if a Participant/VPP does not deliver what they have been enabled for, a financial clawback procedure may take place.

For this reason, many VPP participants expressed operating with caution while they tested and learned how to operate their VPP successfully in the market (for example, avoiding accidently enabling themselves). Although this built confidence in VPPs ability to participate within these market rules, the cautious approach may have restricted the level of 'learning by doing' that otherwise potentially could have been accomplished.

Cost of participation

Feedback from both participants in the Demonstrations, and those seeking to participate, was that APIs were costly both to develop and maintain, with suggestions that removing this requirement would have made the prospect of joining the demonstration more achievable and would improve the return on investment for those participants.

Furthermore, acquiring consumers, developing the operating platform, and ensuring technology was fit for purpose for the VPP were additional expenses which could have been reduced had the demonstration required less than 1 MW and had flexibility around technical requirements.

Registration/onboarding

AEMO and the VPP industry can take significant learnings from the registration and onboarding process used in the Demonstrations. Throughout the process, AEMO became aware of the variance in existing knowledge of market participation, integration with AEMO systems and platforms, and processes. The additional requirements for the VPP Demonstrations added another layer of complexity which saw all participants needing a level of 1-1 support to guide them through the process and ensure all requirements were met.

Of this, the key challenges were increasing portfolio sizes, completing the VPP wide test, and integrating APIs with the correct data specification with AEMO's systems. It is important to note that challenges were not only faced by the VPPs, but also AEMO.

With this learning in mind, AEMO has created an Account Management team to further support participants' onboarding journey into the future.

Despite these areas of improvement, feedback suggests that the 'learn by doing' model employed in demonstrations/trials should continue where appropriate. This model allows complex topics associated with the energy transition to be explored in a controlled environment where all stakeholders can develop and build durable working relationships with each other, and learnings/insights are recorded with diligence that will assist others in the Australian (and global) energy industry to tackle similar challenges.

4. Beyond the VPP Demonstrations

At the start of the VPP Demonstrations consultation process, there were no residential-scale VPPs participating in FCAS markets, and there was no understanding/visibility of how VPPs respond to energy market price signals or a detailed view on how and when VPPs should participate in the energy market in future.

On top of this, there were bullish targets for the uptake of residential 'VPP-capable' batteries, up to 700 MW by 2021-22, driven by planned state-based incentives.

As the VPP Demonstrations project closes, there are now nine VPP portfolios participating in contingency FCAS markets, of which eight have participated in the VPP Demonstrations, and the MASS Consultation is reviewing the ongoing arrangements for DER provision of FCAS.

Although the small-scale VPP sector is growing rapidly, the total capacity of the (residential VPP) sector in the NEM remains below 50 MW, albeit quicky reaching a threshold whereby the continued lack of operational visibility is untenable for system efficiency and security reasons outlined in Section 3.2.

The next steps required are to ensure that the Rules and procedures cater for the full participation of VPPs in Australia's electricity markets. The learnings from the VPP Demonstrations have fed into various processes outlined below that aim to deliver reforms that can achieve this goal.

4.1 FCAS

There are various next steps to plan for DER provision of FCAS at scale.

4.1.1 MASS Consultation

The MASS Consultation for the ongoing arrangements for DER provision of FCAS is reaching a conclusion, with the final determination due to be published and to be effective towards the end of 2021.

4.1.2 VPP Demonstrations transitional arrangements

To the extent that VPP Demonstrations participants cannot meet the ongoing MASS once the final determination is effective, AEMO proposes to permit them to continue participating in the FCAS markets for a specific period under Transitional Arrangements to be outlined in the Final MASS. Draft Transitional Arrangements can be found in the draft MASS, but may be updated in the final MASS based on AEMO's final determination.

4.1.3 Industry collaboration on power system security concerns

As indicated in the MASS Draft Determination, AEMO intends to establish a Consultative Forum to raise, prioritise, and progress issues relating to the MASS and address the concerns with DER inverter behaviour and provision of FCAS at scale (outlined in Section 3.1.3). The MASS Final Determination will set out the next steps towards establishing this working group.

4.1.4 Future MASS Consultations

Recent Rule changes call for MASS Consultations to define appropriate technical specifications relating to:

- Fast Frequency Response (FFR)[86].
- IESS in the NEM[87] – in draft determination stage.

Both of these consultation process will consider how DER may participate in FCAS under the new service (FFR) or the new participant categories under the IESS Rule change.

4.1.5 Regulation FCAS

AEMO will continue to work with the DER/VPP industry to explore how to overcome the technical barriers to DER participation in regulation FCAS markets. A possible pathway could be to explore new ways for aggregated resources to connect to the SCADA system to exchange data and receive the AGC signal.

4.2 Energy

There are numerous changes currently underway that will have direct bearing on the future participation arrangements for VPPs in the NEM, outlined below.

4.2.1 Wholesale Demand Response and 5-minute settlements

The AEMC determined the WDR Mechanism Rule on 11 June 2020 with a go live date of 24 October 2021. The WDR mechanism allows commercial and industrial qualifying loads (generally >100 MWh or >40 MWh per annum consumption in Victoria) with an ability to respond in dispatch timeframes to take part in the wholesale market. Like other scheduled plant, these sites will need to bid into the market and respond to dispatch instructions, in this case to reduce their load. It is anticipated that participation is most likely when prices and demand are high and these services will perform as a peak shaving service.

The qualifying loads will be classified as WDR units (WDRUs) and can take part individually or as an aggregation. Their dispatch performance and settlement will be measured against a baseline counterfactual (what they would have done had they not responded to an instruction to reduce load) which is determined and settled at the connection point level.

To reflect the nature of demand response units and bring the mechanism to market faster at lower cost, WDRUs are not subject to FCAS recovery settlement. WDRUs provide an energy only service. It is possible for a connection point to be classified as both a WDRU and as an Ancillary Service Load (ASL) (to take part in VPP aggregations). However, this can only be achieved if the same Demand Response Service Provider (DRSP) has sought the two classifications and this DRSP is required to manage the bids so that both FCAS and energy dispatch instructions can be met. There is no co-optimisation of DRSP WDR and ASL in the NEM Dispatch Engine (NEMDE).

Given the introduction of 5-minute settlement on 1 October 2021, the WDR mechanism will be dispatched and settled in the new 5-minute framework. Only connection points providing 5-minute meter data will be eligible for dispatch.

The WDR project is taking the learnings from the VPP Demonstration enrolment process to develop a long-term technical solution, known as the Portfolio Management System, for managing the classification, aggregation, and operation of WDRUs. It is intended that VPP data will be transitioned into this new system should planning processes allow.

4.2.2 Integrating Energy Storage Systems

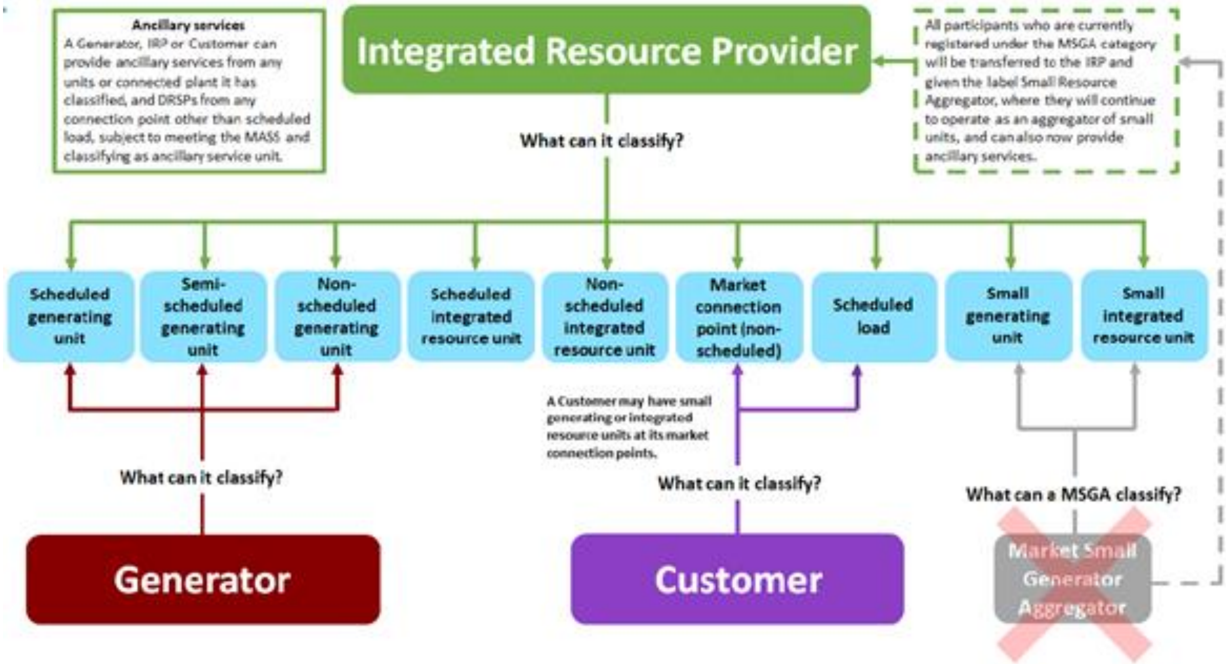
The IESS Draft Determination sets out the arrangements for the integration of storage into the NEM, both transmission- and distribution-connected. Its focus is the introduction of the Integrated Resource Provider

[86] At https://www.aemc.gov.au/rule-changes/fast-frequency-response-market-ancillary-service.

[87] At: https://www.aemc.gov.au/rule-changes/integrating-energy-storage-systems-nem

(IRP) which will be able to classify a number of existing and new technologies to provide services into the market. This is described below in Figure 27.

Figure 27 Overview of the Integrated Resource Provider classifications



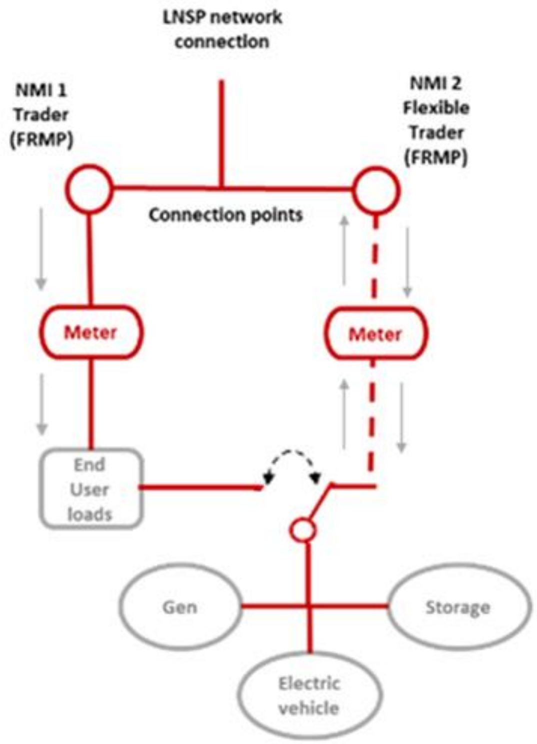
The introduction of the IRP also introduces a new approach to market registration, as the IRP will act as a universal category – the first step towards the Trader Services model outlined in the ESB's Post 2025 work.

A change that allows greater access to the market for VPPs is the ability of an IRP to classify Small Generation Aggregators (SGAs) and Integrated Resource Units. The IRP will effectively take over from the SGA category but add the ability to classify storage devices or other flexible bi-directional resources as Integrated Resource Units. These units will need to be connected at a separate connection point (to the load connection point) and can then be aggregated for wholesale market settlement.

These arrangements are really the introduction of what is described as the Flexible Trader model in the ESB's Post 2025 April 2021 Options paper – see Figure 28 below. Figure 28 also represents the ability of the consumer (or their representative) at either connection point to switch the resources from one connection point to the other (but never at the same time) to allow for the most flexible arrangements to benefit the consumer.

In addition, the IESS rule change will introduce the concept of an Ancillary Services Unit which will be a bi-directional unit classified for the provision of ancillary services. This will allow an IRP to classify storage devices or, load and Solar PV at a connection point for the provision of FCAS services – as long as the installation also complies with the MASS.

Figure 28 Flexible Trader model 1 – SGA framework



4.2.3 Energy Security Board Post 2025 NEM Market Re-design project

The ESB's Post 2025 reform process has been two years in the making and culminated in the advice sent to the Energy National Cabinet Reform Committee in July 2021[88].

Most of the initiatives outlined in the ESB Post 2025 papers will require further Rule changes to allow for a Rules consultation process and appropriate stakeholder consultation, but these initiatives do provide important directions for future changes across a wide range of market reforms.

The main area of import for VPPs is the Demand Side Participation stream, which includes several initiatives, discussed below.

Trader services model

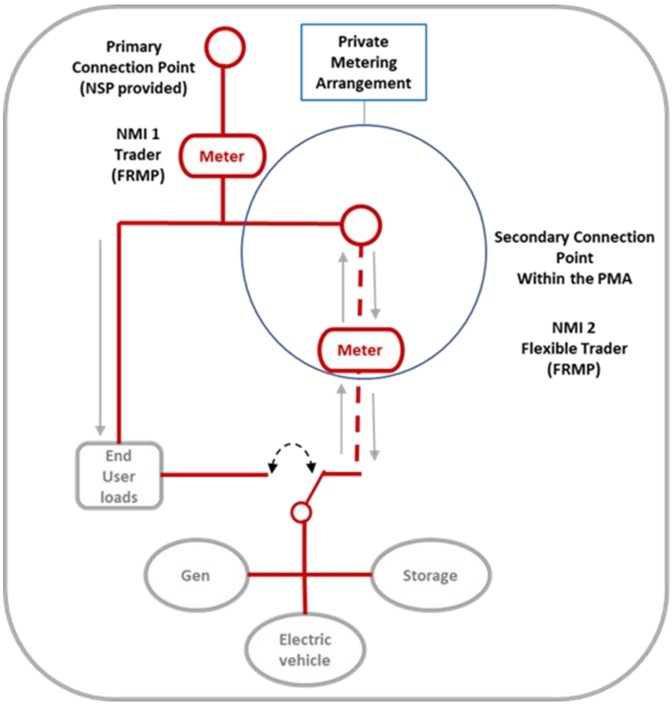
As outlined above, the introduction of the IRP is the first step towards the trader services model, which will allow registered IRPs or VPPs to classify for a range of services, and in the process streamline and improve the information provision processes for participants where possible and improve the ability of AEMO to manage new classifications and registrations more simply.

Flexible trader model

This model allows further flexible trading arrangements over and above those allowed under the IESS Draft Rule which will allow VPPs to access markets via Private Metering arrangements, similar to embedded network arrangements. This would allow the consumer to further minimise the cost and complexity associated with the need to add a separate connection point, but maintain the ability to provide services such as FCAS and be settled on the wholesale market.

[88] At https://esb-post2025-market-design.aemc.gov.au/.

Figure 29 Flexible trader model 2 – Private metering arrangement



Scheduled lite

Scheduled lite is a proposal to enable small- to medium-sized resources (including demand and generation) to actively participate in market processes or dispatch, as the current scheduling processes can be complex and onerous to interact with.

There are two main models, the visibility model and the dispatch model. A description of each is in Table 10 below. As the volume of aggregated portfolios increases, there will be a greater need from a system operation perspective to move VPPs to the dispatch model.

Table 10 Scheduled lite – visibility model (left) and dispatchability model (right)

Visibility model	Design element	Option	Change from non-scheduled
Market Access (static)	Participant type	non-scheduled load/demand aggregators/generators/VPP	Neutral
	Telemetry	Use 5-minute meter data	Neutral
	Metering	No change	Neutral
Market information (dynamic)	MT PASA	Provide no information	Neutral
	ST PASA	Provide no information	Neutral
Market intention	Pre-dispatch (energy bids)	Provide no bids	Neutral
	Forecasting generation /consumption	Provide forecast of generation/consumption	Increased
	Dispatch targets?	Not in dispatch	Neutral
Incentives	RERT costs?	RERT costs still apply	Neutral
	Civil penalties?	No change to civil penalties	Neutral
	Regulatory FCAS allocation?	Reduce regulatory FCAS causer pay allocation	Improved
	RRO obligations?	No change to RRO obligations	Neutral
	Interaction with OR	Reduce OR cost allocation	Improved

Dispatchability model	Design element	Option	Change from non-scheduled
Market Access (static)	Participant type	non-scheduled load/demand aggregators/generators/VPP	Neutral
	Telemetry	Light version of SCADA	Increased
	Metering	No change	Neutral
Market information (dynamic)	MT PASA	Not required	Neutral
	ST PASA	Provide some information	Increased
Market intention	Pre-dispatch (energy bids)	Provide standing bids	Increased
	Forecasting generation /consumption	Provided through bids, intermittent generators provide forecasts	Increased
	Following DI's	Follow DI (within limits of the resource)	Increased
Incentives	RERT costs?	Load avoids RERT	Improved
	Civil penalties?	Reduce civil penalties	Improved

Consumer obligations

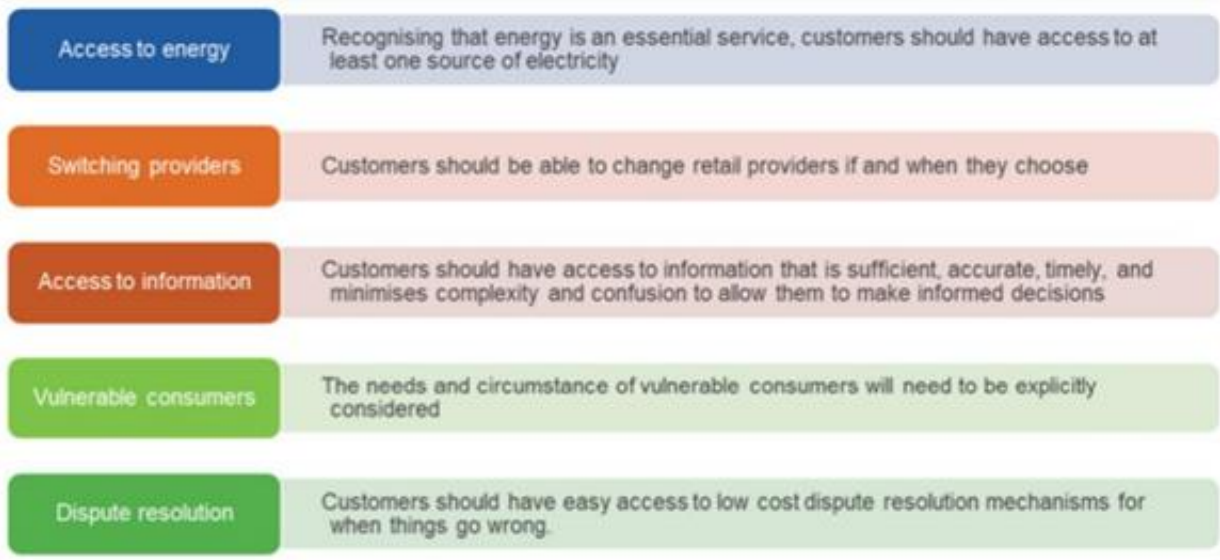
The consumer obligations associated with operating a VPP are key to ensuring consumer protection. The Demonstrations have shown that consumers will join a VPP if these offers are made available, but the value associated with joining is opaque and may in many cases be a non-financial benefit, such as greater grid or system resilience.

In addition, there are complexities predicting VPP value, as the revenue from contingency FCAS and future wholesale energy price spikes or dips are driven by power system events (such as a large generator, load, or transmission line trip). Careful consideration will be needed regarding the information provided to consumers who plan to participate in a VPP, and also about whether the current retail electricity process of "explicit informed consent" will be required to change between VPP providers.

The AEMC has recently explored the issue of consumer obligations and the ESB's NEM Post 2025 project has explored these issues as part of the Two-Sided Market design initiative.

To accompany all the changes outlined above, a review and changes to the consumer obligations, retailer exemption, or authorisation process are required. This is to ensure that the IESS and ESB Flexible Trader models afford consumers the appropriate protections based on the services they receive from market participants. The review will focus on five key areas outlined below.

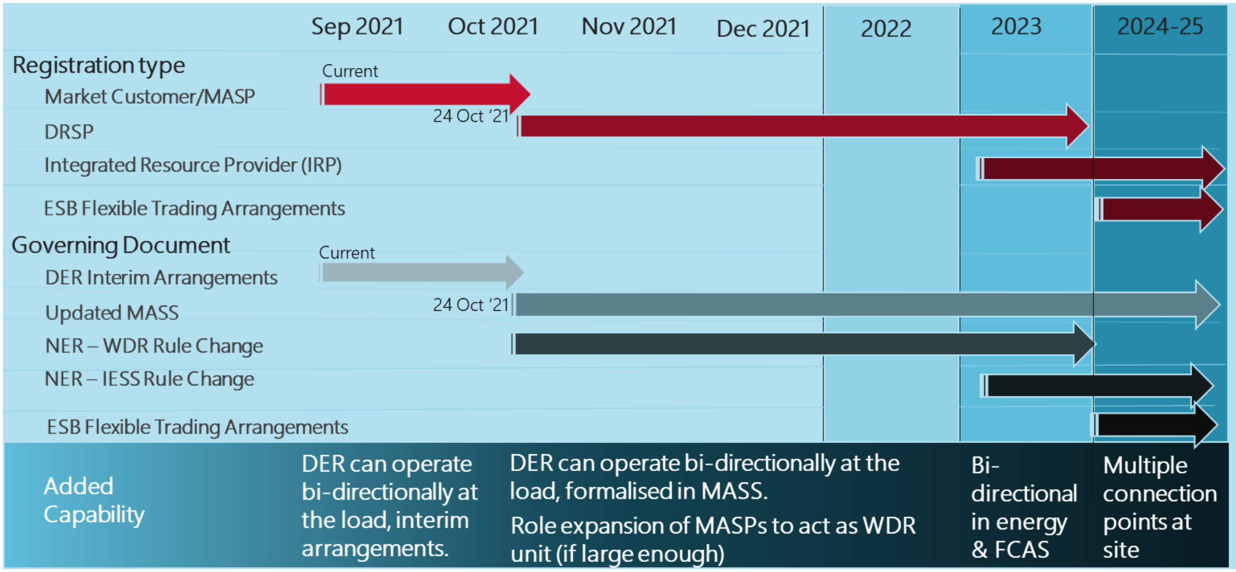
Figure 30 Consumer protections review, five key areas



4.2.4 DER/VPP capability roadmap

Figure 31 below plots the reforms outlined above on a timeline, together with the DER/VPP capability that each reform will unlock.

Figure 31 DER/VPP regulatory reform and capability roadmap



4.2.5 Flexible connection agreements

The VPP Demonstrations took a first step to obtain operational visibility of VPPs, and explicitly left out of scope any consideration of distribution network limits and participation in the central dispatch process since those complex issues should be examined in separate projects.

One of those projects was SAPN's Advanced VPP Grid Integration projects, in which SAPN sent distribution network limits to the SA VPP (operated by Tesla) to allow more exports onto the grid when the network capacity can accommodate it. Instead of applying the standard 5 kW export limit, these connection points could export up to 10 kW most of the time, and by the same token may be asked in future to reduce exports below 5 kW when the network is approaching its capacity. Over the course of the year, these flexible connection agreements would enable consumers to export more energy to the grid that before, and consequently enable consumer to install more/bigger systems.

Building on this, the South Australian Government recently introduced a Relevant Agent[89] requirements for all new solar PV to manage the remote connection and reconnection of inverters in emergency (such as minimum demand) circumstances, and SAPN is planning to roll out flexible export tariffs to new PV connections in 2022. Both are services which VPPs/aggregators have the opportunity to provide on a consumer's behalf.

4.2.6 Project EGDE

Project EDGE is a follow-up trial to the VPP Demonstrations, seeking to test an off-market, proof-of-concept DER Marketplace that efficiently coordinates DER to provide both wholesale and local network services within the constraints of the distribution network.

The project is a collaboration between AEMO, AusNet Services, and Mondo, with financial support from ARENA, and is focused in the Hume region of north-east Victoria.

Consumers participating in Project EDGE will test flexible connection agreements, with AusNet Services sending DOEs to their aggregator to ensure the operation of their DER maximises the use of the local network whilst always remaining within its secure limits.

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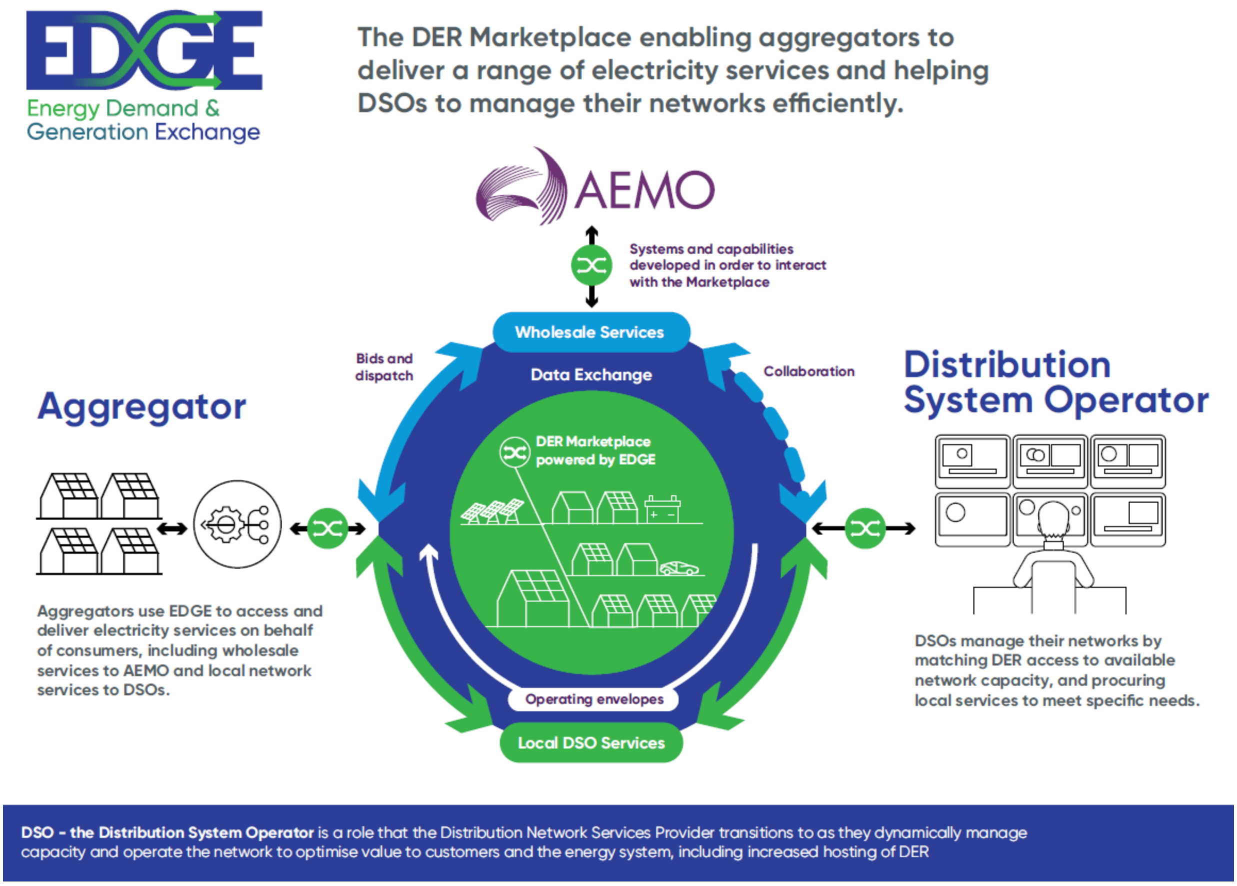
[89] More information on Relevant Agents is at https://www.energymining.sa.gov.au/__data/assets/pdf_file/0005/369266/Technical_Regulator_Guideline_-_Relevant_Agent_Roles_and_Responsibilities.pdf.

Project EDGE aims to create a robust evidence base that can inform the design and implementation of the various elements in the reforms outlined above, including:

- Scheduled lite visibility/dispatchability models and flexible trader models.
- Flexible connection agreements and DOEs.
- Bi-directional bidding processes with 20 bid bands, for the IESS Rule change.
- Information architecture models/standards for efficient data exchange.
- Interaction of the System Operator (AEMO) and Distribution System Operators (DNSPs).

Figure 32 Project EDGE overview of the DER Marketplace



Project EDGE will culminate with an independent cost benefit analysis that should help inform whether, how, and when the various elements tested in Project EDGE should be implemented.