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Ausgrid's Battery Virtual Power Plant

Final Report February 2023

Contents

1 Executive Summary

This final report covers the entire period of Ausgrid’s Virtual Power Plant (VPP) Trial, which commenced in 2019 and concluded in 2022. Ausgrid’s VPP trial started with 237 residential battery customers, increasing to approximately 750 residential battery customers with a total battery power of 3.4MW and storage capacity of 7.3MWh by the end of the trial.

Our partnerships with Reposit Power, Evergen and ShineHub have enabled Ausgrid to dispatch over 130 MWh of battery energy across more than 180 event days.

Key findings from the trial are outlined below:

- A sufficiently sized VPP can help address network constraints during peak demand periods and potentially defer or avoid network upgrade. However, a significant increase in residential battery uptake is required for this potential to be realised.
- While an orchestrated VPP dispatch can offer considerable additional power and demand reduction potential, residential batteries without VPP control (‘business as usual’ operation) can also reduce demand during peak periods, suggesting that a wider proliferation of residential battery will have a positive impact on demand management of the network.
- A VPP can be used by multiple parties for different purposes, which could impact its availability during peak periods. It is important to coordinate and implement appropriate customer incentives, contracts and systems to manage VPP availability.
- While pre-charging the batteries is important for maximising VPP energy output, the timing of the pre-charging needs to be managed so that it doesn’t add to the peak demand. For the customers, the benefits received from the dispatch need to sufficiently compensate for the cost of pre-charging.
- Sending updated command signals throughout a dispatch can help optimise VPP dispatches by adjusting VPP behaviour to respond to changing conditions (e.g. load, available stored energy) however this requires a reliable communication network.
- Both gross and net Feed-in-Management (FiM) can assist with lowering voltage during times of over voltage on the network however these options reduce customers’ solar output, leading to financial loss for the customers.
- Net FiM management is preferable to gross FiM as it allows the customer’s load to be supplied by solar while restricting export into the grid. However, net FiM is more complex to implement because the inverter output must be constantly adjusted to supply the load but must be limited to prevent export exceeding a set threshold.

- Participants' feedback for the trial was largely positive with the majority of the surveyed participants expressing that they're satisfied with their experiences with the trial and are likely to join a VPP again in the future.

2 Introduction

Ausgrid's VPP project explored whether VPPs can provide a viable source of demand reduction or voltage support services to avoid or defer network upgrades. As the energy industry transitions to a net zero future, there is a greater need for demand flexibility and integration of renewables. The battery VPP trial was part of Ausgrid's Demand Management Innovation Allowance (DMIA) program, one of the ways in which Ausgrid engages with market providers and customers to help integrate renewables, maximise grid efficiency and reduce costs for the customers.

Primary research objectives of the project include determining:

- whether VPPs can provide reliable short-term demand reductions (typically 2 – 4 hours) during hot summer and cold winter evenings when electricity demand peaks
- whether VPPs can provide reliable sources of voltage support in conditions of over-voltage (typically during sunny Spring and Autumn days) or under voltage
- the typical battery charge and dispatch profile, to assess BAU (Business-As-Usual) battery operation and to provide a baseline operating condition for the assessment of VPPs.

3 Background

3.1 Previous research

Ausgrid has been exploring the potential for behind the meter and grid-based batteries for peak demand reductions since 2012. A residential battery trial in 2012 involved the installation of zinc bromide RedFlow batteries for 60 residential premises (5kW / 10kWh batteries) at Scone and Newcastle in the Hunter region. Although RedFlow batteries were just emerging from the research and development phase, this trial highlighted the significant potential of batteries for grid support. The trial also identified several obstacles, such as with battery stability, reliability and costs.

The Newington Grid Battery trial in 2014 involved the connection of a 60kW / 120kWh lithium ion battery to the low voltage distribution network in the Sydney Olympic Park area. The trial again demonstrated the value of batteries for grid support, but highlighted issues related to battery management system reliability and the need for further reductions in battery storage costs before batteries could be considered a firm and cost competitive demand management resource.

Since these early trials, there have been significant technological and market improvements which have made the reassessment of behind the meter batteries for network support particularly relevant. These developments include the maturing of battery technologies in terms of size, capability and cost, the emergence of the VPP concept to meet multiple network and market needs, and the emergence of VPP market providers and aggregators.

3.2 Virtual Power Plant

A VPP links decentralised and independent energy resources (such as solar and batteries) into a network, forming a centrally managed virtual generating unit. VPPs can be coordinated to provide support to the electricity grid on days of very high demand, Frequency Control Ancillary Services (FCAS) or can be used to trade electricity at times of high wholesale electricity prices. By dispatching energy when of highest value, VPPs have the potential to offer greater flexibility of choice in optimising planning and operation of the grid, potentially leading to lower costs for all customers on the network.

Throughout Ausgrid VPP trial, dispatches and reports were managed via user-friendly platforms developed by the VPP providers, where dispatches and reports can be quickly generated by Ausgrid at anytime and anywhere with a login account. Participating customers were paid for use of their batteries, lowering their energy costs.

4 Year 1 Results

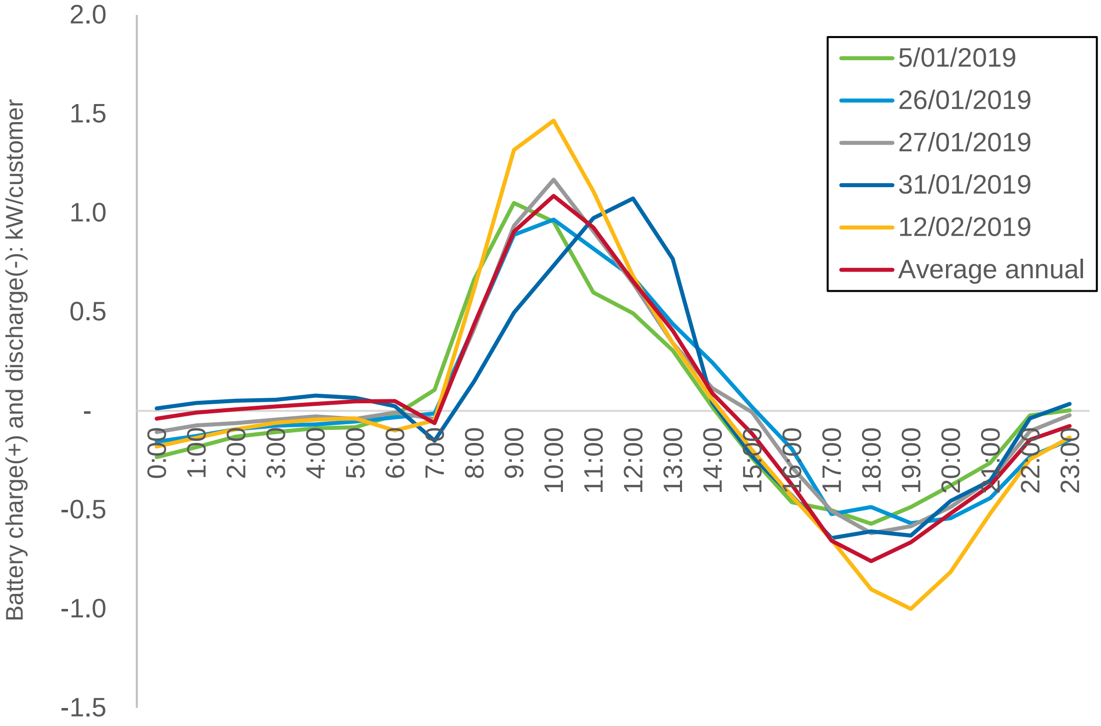
In 2019, Ausgrid VPP trial commenced with 237 Reposit Power customers representing an aggregated dispatch power capacity of 1MW and a storage capacity of 2.4MWh. There were over 10 event days with approximately 7MWh of battery energy dispatched in the first year. One of the key priorities in the first year was to understand battery's BAU behaviour and additional value that could be added by a coordinated dispatch.

4.1 'Business as usual' operation

Residential battery systems are typically managed to charge during the day from the excess energy generated from the customers' solar system. For customers on flat retail tariffs, the battery discharges to maximise self-consumption and therefore minimise grid import. While for customers on TOU retail tariff, the objective is to optimise costs by discharging the battery during shoulder and peak periods.

Figure 1 shows average battery profile on 5 hottest non-dispatch days in the summer of 2018/19 and annual average profile of the batteries in the VPP fleet. The chart shows that under BAU conditions (no dispatch) the battery discharging coincided with network peak, which was an encouraging sign that an increase in proliferation of batteries could help reduce network peaks even without the VPP dispatch.

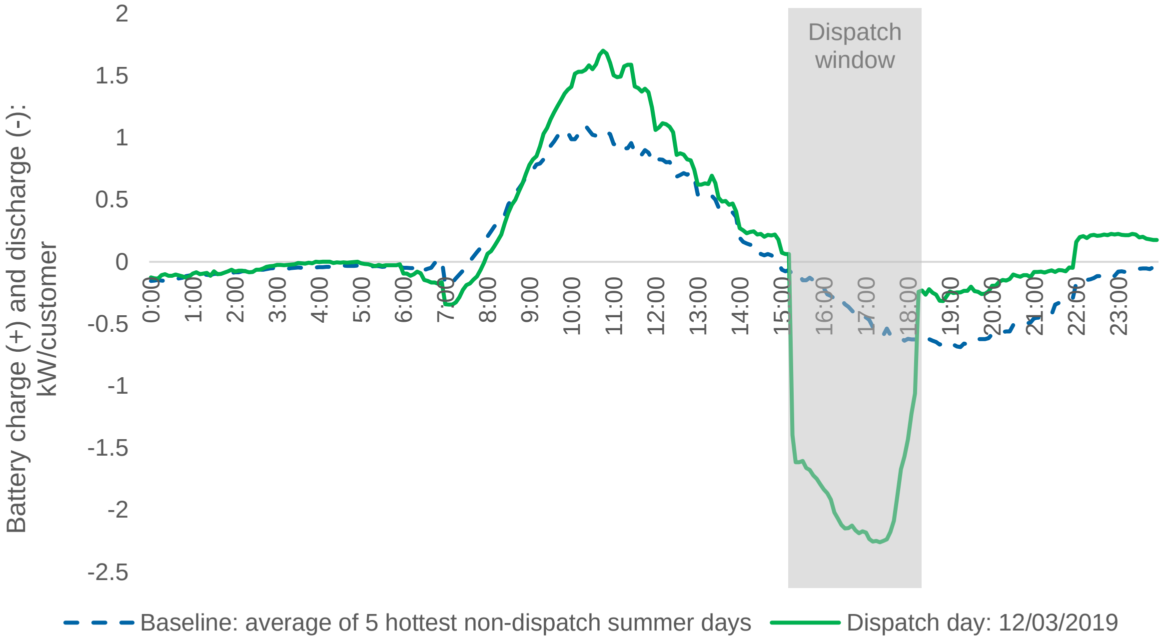
Figure 1 - the daily battery cycle for 'business as usual' and five extreme temperature days for 2018/19



4.2 Battery dispatch vs BAU

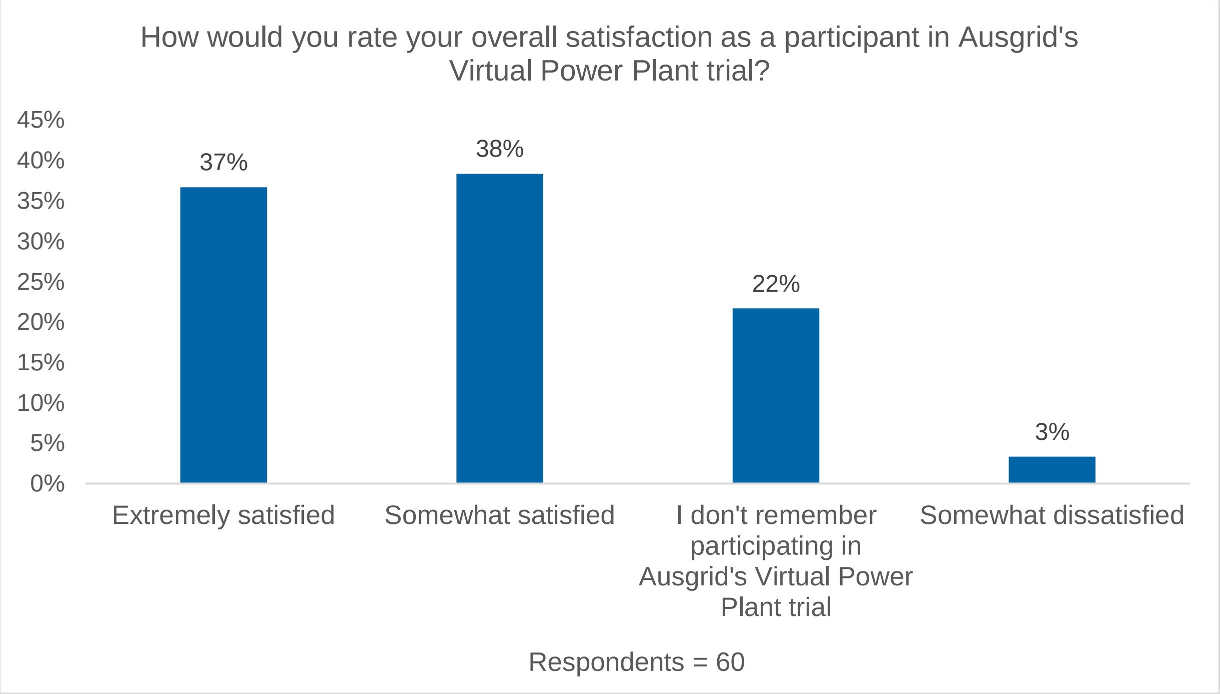
One of the key findings from the first year was that a targeted VPP dispatch can deliver considerable additional power during evening peak periods in comparison to a 'business as usual' non-dispatch battery profile. This was demonstrated in a dispatch on 12 March 2019, in which additional 1.5kW/customer was discharge from the battery when compared to average BAU profile of 5 hottest non-dispatch days in the summer of 2018/19 (see Figure 2).

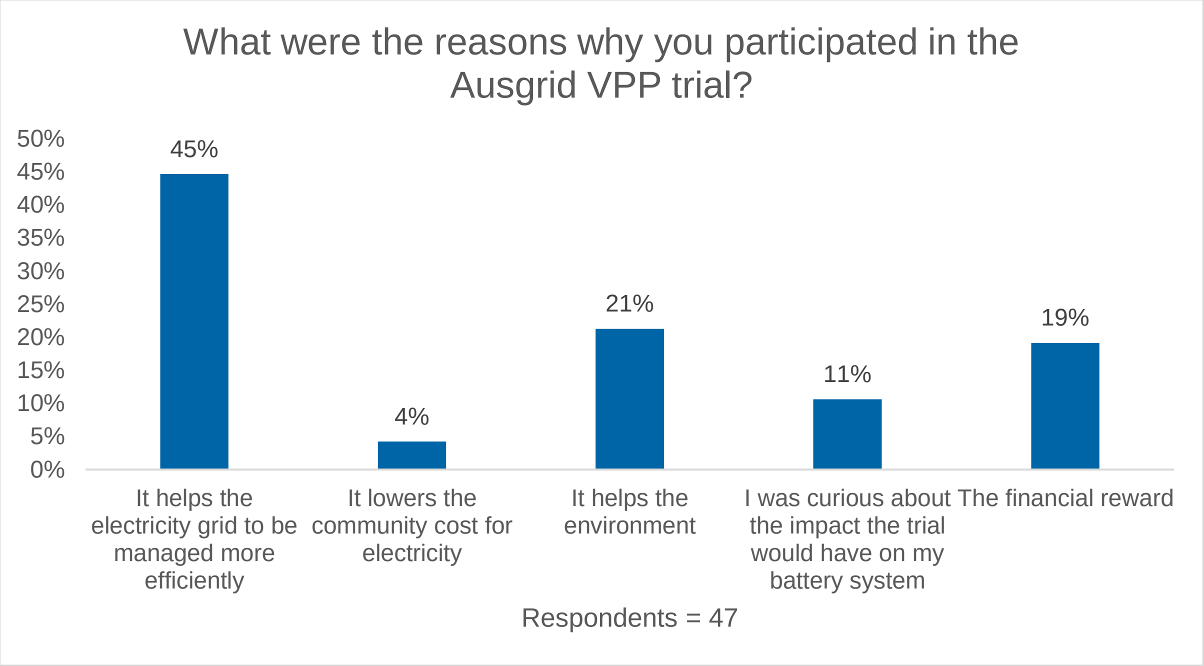
Figure 2: VPP dispatch profile on 12 March 2019

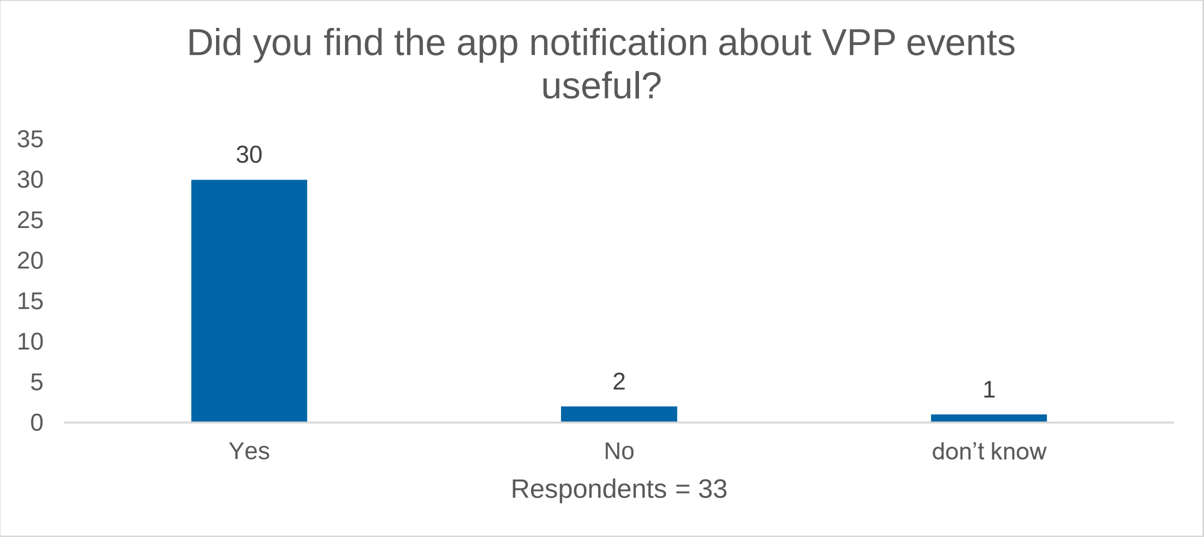


4.3 Customer survey results

In November 2019, some months after the first series of dispatches in year 1, the participants were invited to provide their feedback about their trial experience. Key results are presented below:





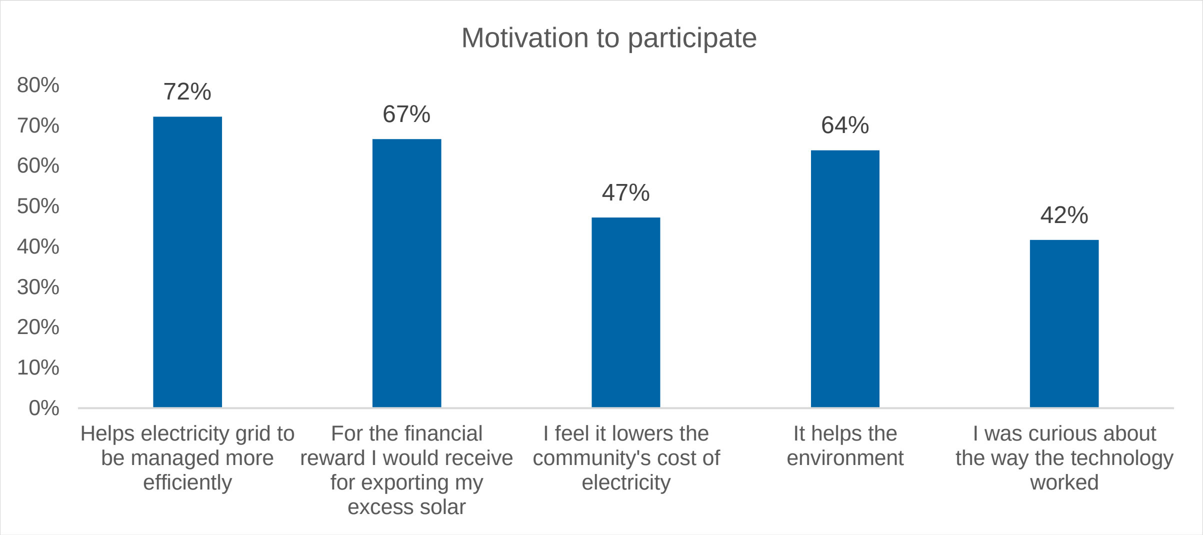


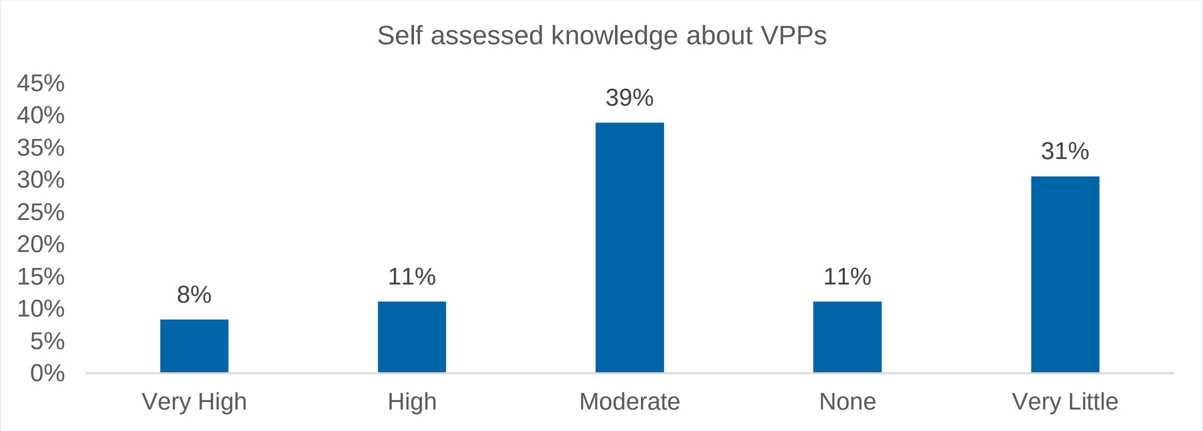
5 Year 2 Results

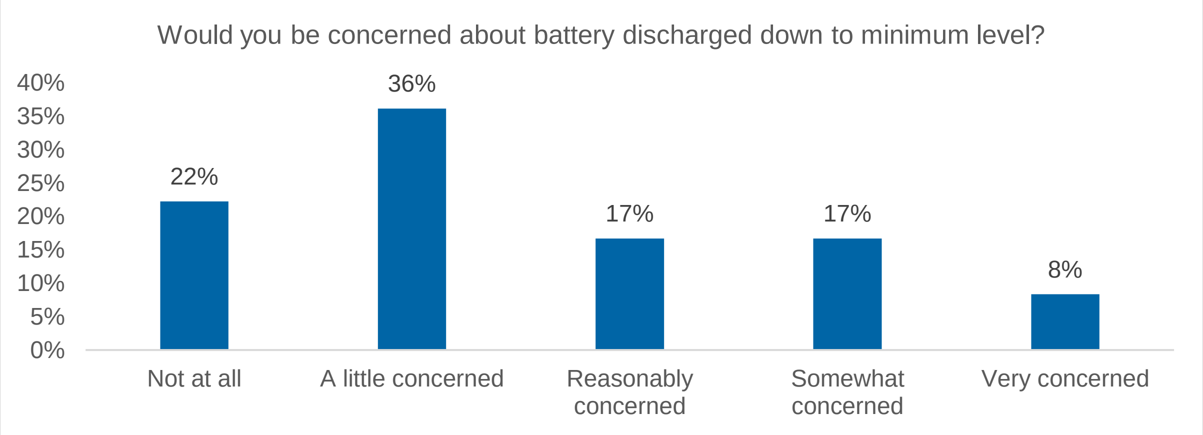
After being selected as part of an open tender process, Evergen and ShineHub joined the trial in 2020. By the end of the second year, the VPP power capacity had increased to 1.4MW with a storage capacity of 3.5MWh across approximately 350 residential battery customers. There were over 35 VPP event days with approximately 12 MWh of energy dispatched in the second year. With additional VPP providers joining the trial, Ausgrid was able to test and compare various features across the fleet.

5.1 Survey of customer expectations

Some of the participants that joined the trial in 2020 were surveyed prior to the start of the trial. Key results from 36 respondents are presented below:







5.2 Remote monitoring and control

Amongst Ausgrid's VPP partners, there were two processes used to communicate dispatch signals to the customer's inverter. It should be noted that the following descriptions only apply to processes encountered in the trial. It is possible in some cases to adjust the processes to have a different set of characteristics. Figure 3 illustrates a process where the dispatch commands are received by the inverter via inverter company's gateway/cloud infrastructure. The advantage here is that it avoids the need for installation and maintenance of additional control hardware at the customer's premise. Further, if the customer decides to leave the VPP program there won't be a need to decommission the hardware or potentially have a stranded hardware at the customer's premise. This arrangement is dependent on the inverter manufacturer facilitating a gateway/cloud solution to control and monitor their inverters.

Figure 3 – High level communication process for VPP dispatch via inverter manufacturer's gateway

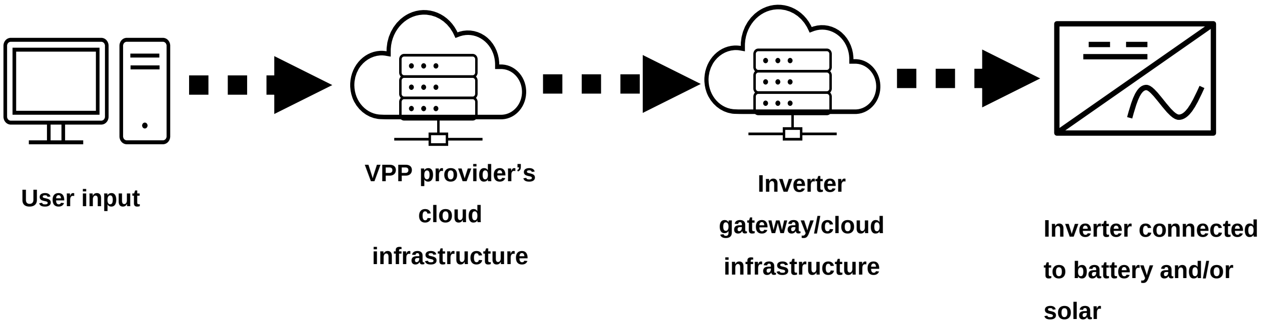
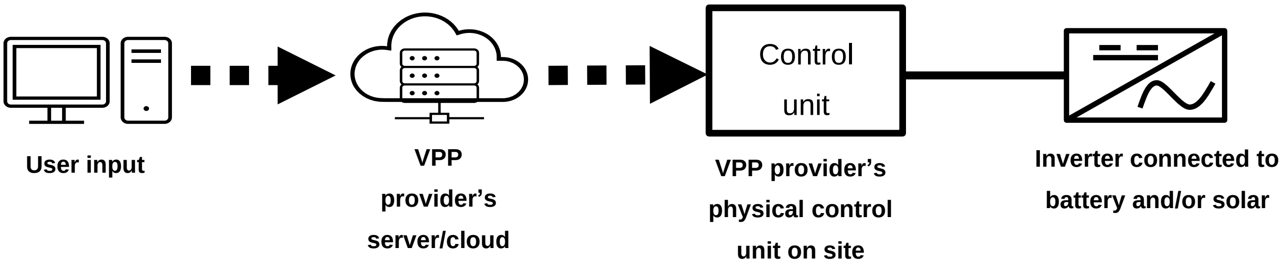


Figure 4 illustrates another process encountered in the trial where the dispatch signals are sent via VPP provider's physical control unit that's directly connected to the inverter at customer's premise. The advantage of this approach is that it allows the VPP provider to customise certain aspects such as data refresh rates and metering configuration more readily without negotiating with the inverter manufacturer. In addition, the VPP provider can send and store a set of dispatch signals in the control unit prior to a dispatch so that if internet connectivity is unavailable before or during a dispatch, the inverter continues to receive command signals from the control unit that's connected at the site. This arrangement is dependent on the control unit being compatible with the inverter at customer's premise.

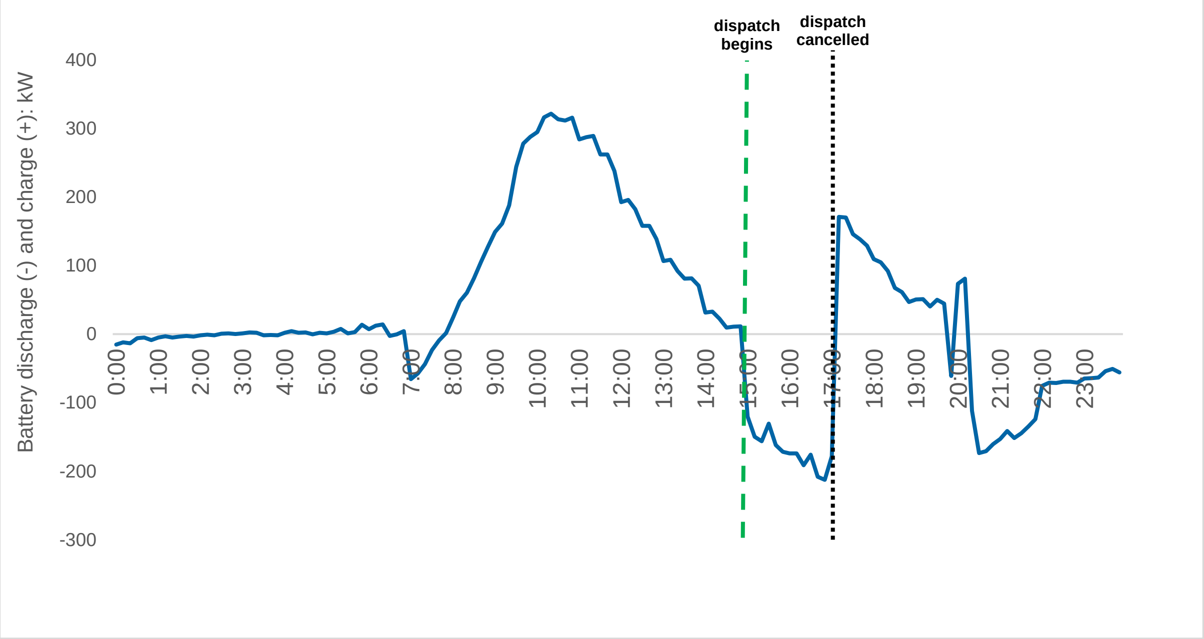
Figure 4 – High level communication process for a VPP dispatch with a control unit



5.3 VPP availability

On 23 and 31 January 2020, Ausgrid scheduled dispatches had to be shifted or cancelled due to the VPP being pre-activated as part of RERT[1] (Reliability and Emergency Reserve Trader) response to LOR2[2] (Lack of Reserve) condition in NSW (see Figure 5). The pre-activations did not result in a dispatch of the batteries.

Figure 5 - Cancelled dispatch on 31 January 2020



VPPs can be used for multiple purposes including providing broader network stability for the market operator, addressing network constraints for network service providers and managing cost of wholesale electricity prices for the retailers. There may also be limited battery availability due to customer's self-consumption. It's important for stakeholders to co-ordinate and implement appropriate customer incentives, contracts and systems to manage the availability of VPPs.

5.4 Dispatch profiles

The dispatches scheduled during year 2 were static dispatches, where the aim is to deliver a constant power output that aligns with a fixed target value set at the start of the dispatch. One of the challenges that we encountered during year 2 was to achieve and maintain constant dispatch output for the entire dispatch period. The following section presents various dispatch profiles that Ausgrid encountered during year 2 of the trial. Figure 6 and

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[1] RERT is a mechanism that allows AEMO to contract for emergency supply reserves typically during high demand or short supply periods.

[2] LOR is a market notice issued by AEMO to communicate tightening of supply reserves.

Figure 7 show dispatch profiles where the VPP batteries did not reach their maximum output until the second half of the dispatch window. Figure 8 and Figure 9 show dispatch profiles that had a relatively consistent output for the majority of the dispatch window with a significant decline in output near the end. Figure 10 and Figure 11 show relatively consistent dispatch profiles that generally achieved the target power output throughout the dispatch window (see section 7.2 Optimising for more information).

Figure 6 - Dispatch profile 1

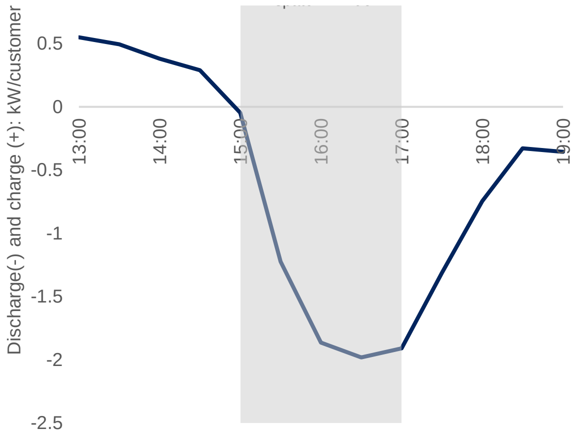


Figure 7 - Dispatch profile 2

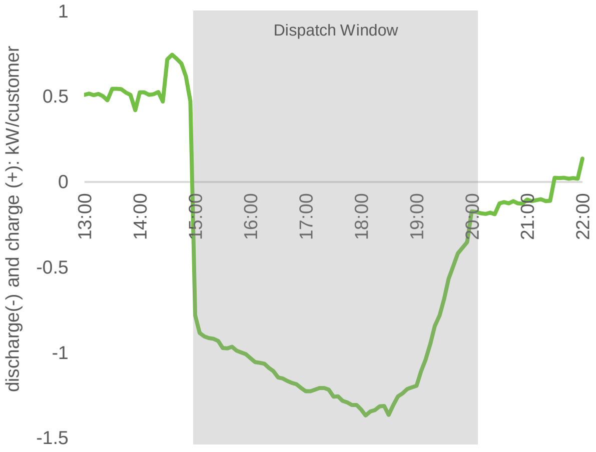


Figure 8 - Dispatch profile 3

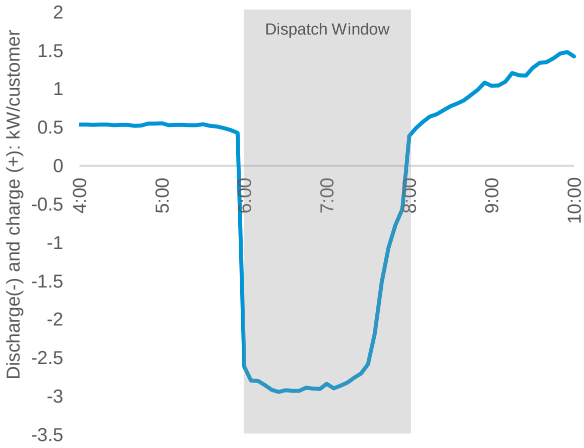


Figure 9 - Dispatch profile 4

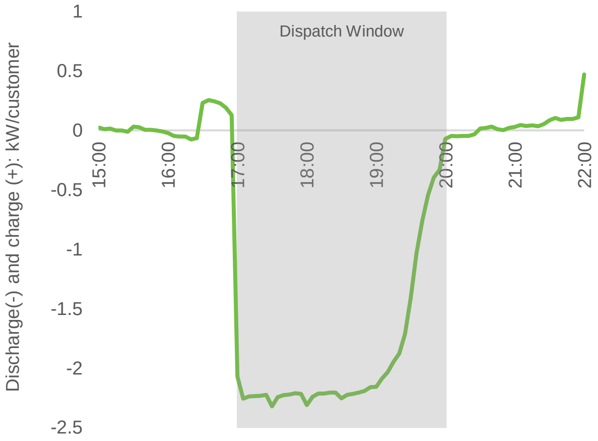


Figure 10 - Dispatch profile 5

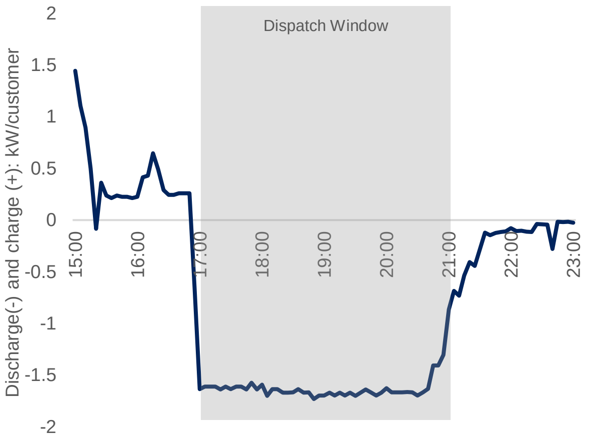
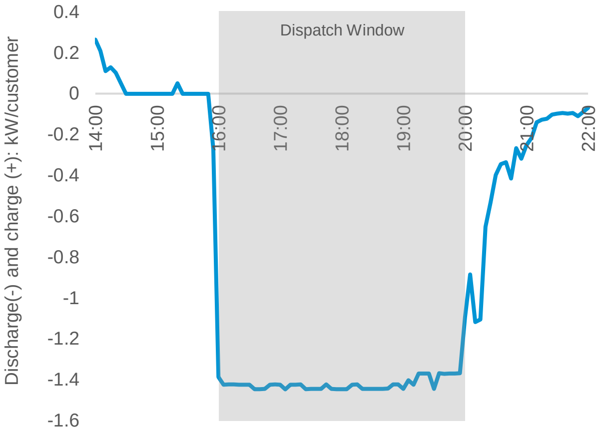


Figure 11 - Dispatch profile 6



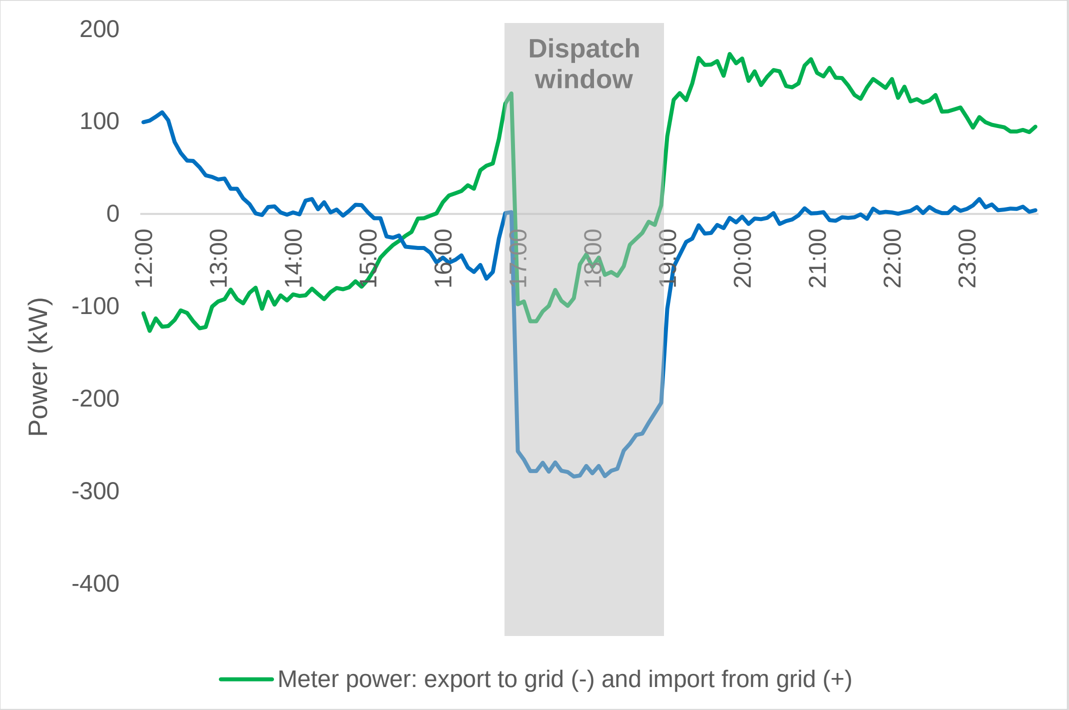
6 Year 3 Results

During year 3, the VPP fleet increased to 750 residential batteries with a total battery power of 3.4MW and storage capacity of 7.3MWh. There were over 70 dispatch days with approximately 60MWh of energy dispatched. A number of new functions were tested in year 3 including dynamic dispatches and FiM (Feed in Management).

6.1 Dynamic dispatch

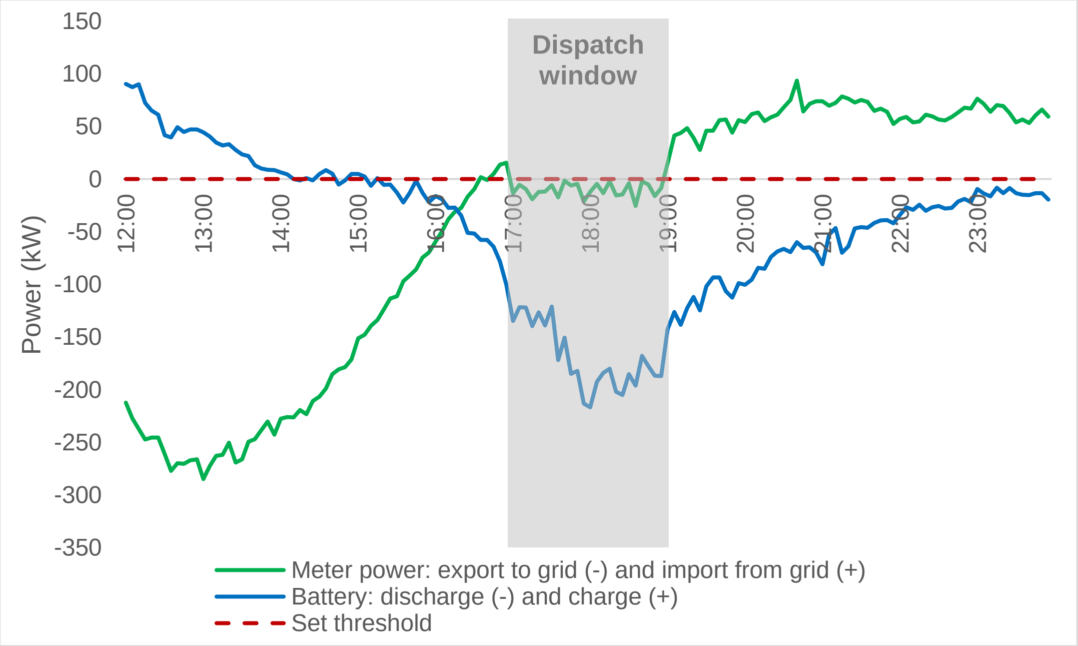
The majority of dispatches scheduled in the first a couple of years were static dispatches, where the aim was to discharge at a fixed level of power throughout the dispatch window without any consideration for customer's usage. Figure 12 demonstrates an example of a static dispatch between 17:00 – 19:00 where the VPP output was relatively consistent and meter power varies throughout the dispatch window due to changes in the customer's energy usage.

Figure 12 - Typical static dispatch on 26 July2021



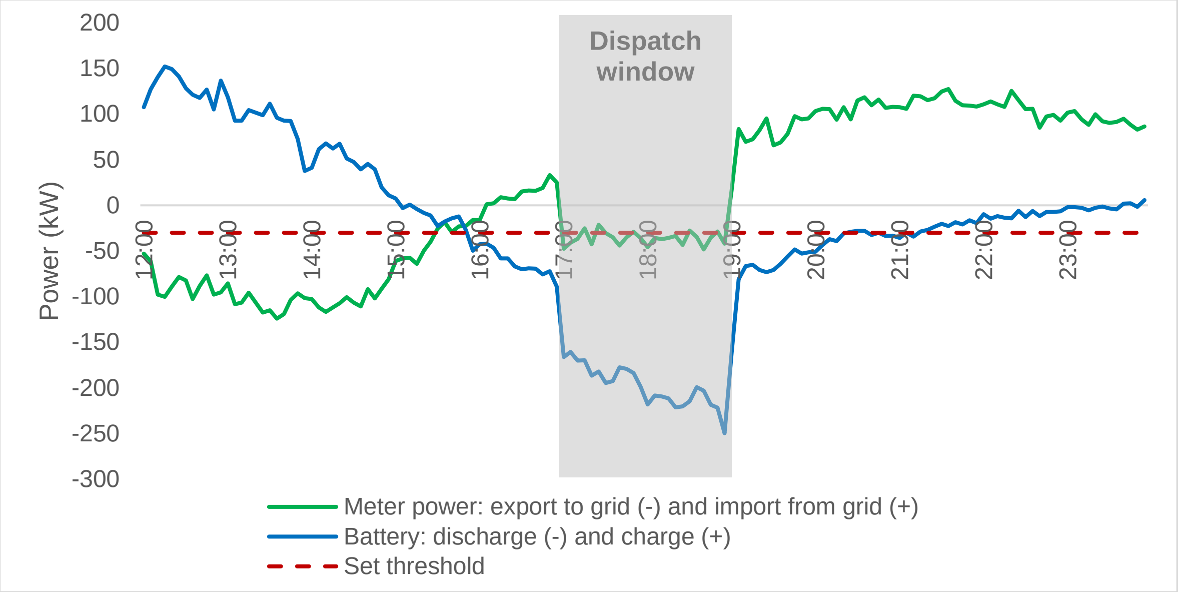
In year 3, Ausgrid tested dynamic dispatch, where the battery VPP output was automatically adjusted to maintain meter power below a certain threshold. Figure 13 shows an example of dynamic dispatch where the consumption threshold was set to zero (no load consumption) and the battery discharge was automatically adjusted to keep the load below the threshold.

Figure 13 - Dynamic dispatch with threshold = 0 (no load consumption) on 16/08/2021



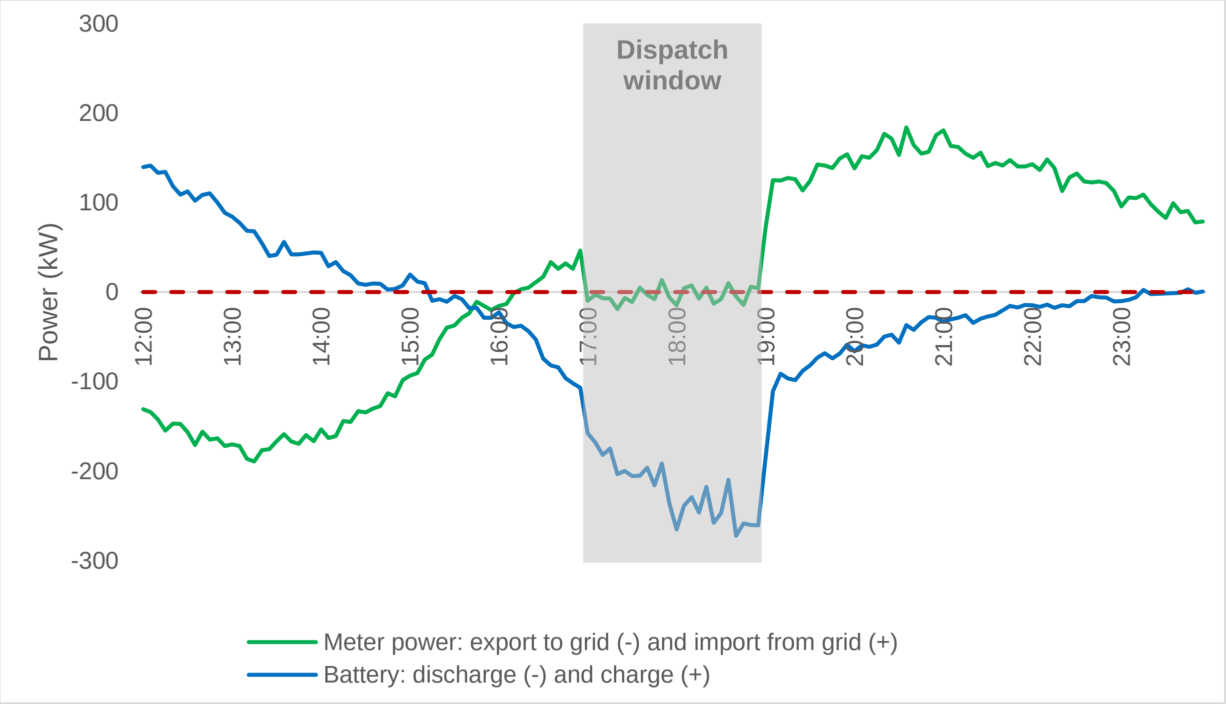
The threshold was set to a negative number (export) for some events, which means the Battery Management System (BMS) adjusted VPP output to achieve a minimum level of export at the meter point to assist the grid during peak periods. Figure 14 shows a dynamic dispatch where the threshold was set so that there is a minimum export of 30kW.

Figure 14 - Dynamic dispatch with threshold = -30kW (export) on 31/07/2021



Dynamic dispatch feature does require a reliable communication network as it involves regular communication (multiple times per minute) between the battery inverter and the BMS. Occasional threshold exceedances can be seen in Figure 14 and Figure 15, which can be explained by connectivity issues.

Figure 15 - Dynamic dispatch with threshold = 0 on 22/07/2021



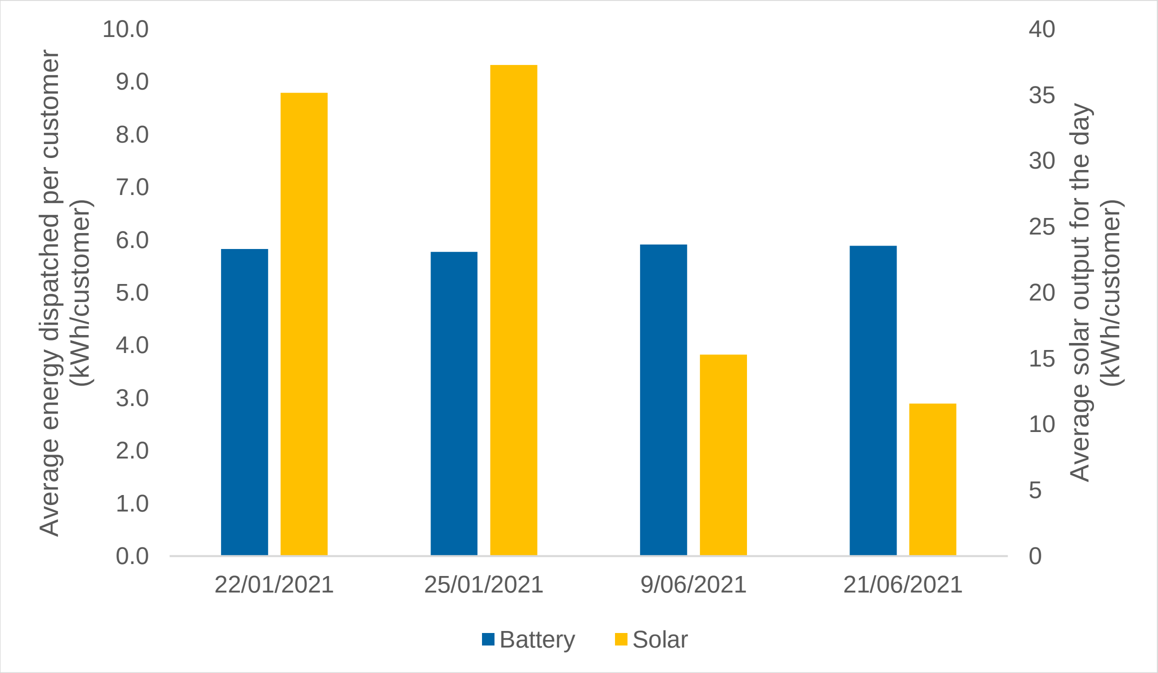
Advantages of dynamic dispatch include:

- Ability to meet a set threshold that is appropriate to the network constraint
- Discharging of batteries only when required
- A more consistent load at the metering point

6.2 Pre-charging to maximise dispatched energy

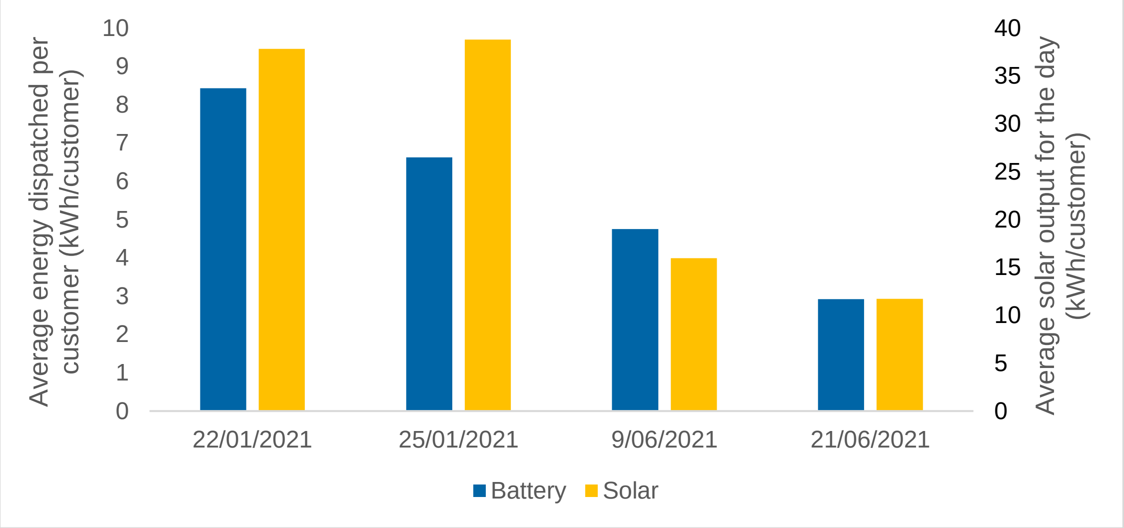
One of the main methods of maximising dispatched energy from a VPP is to pre-charge the VPP fleet before a dispatch. Approximately half of the batteries in Ausgrid's VPP fleet had an automatic pre-charge function, where the BMS monitored the battery state of charge and automatically charged the batteries prior to a dispatch with the aim of maximising available energy. Figure 16 shows that for batteries with the automatic pre-charge function, the dispatched energy was consistent throughout summer and winter event days, despite variations from solar output.

Figure 16 - Dispatched energy for a group of batteries with an automatic pre-charge function



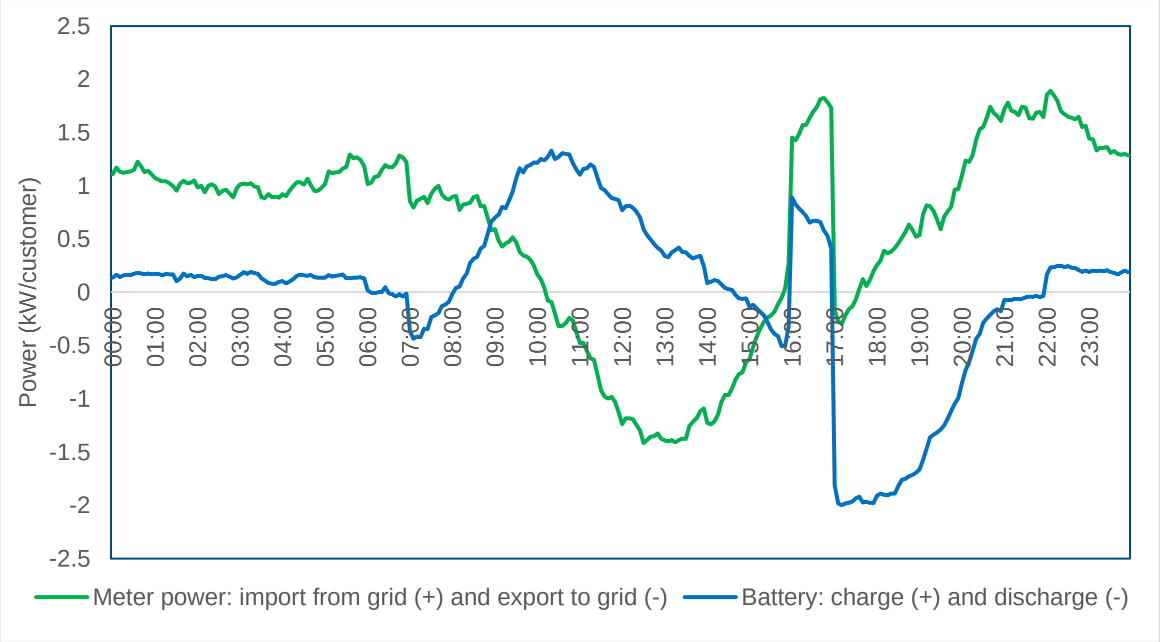
For batteries without an automatic pre-charge function, the dispatched energy is dependent on solar output and customer usage leading up to and during the dispatch. Figure 17 highlights the fluctuations in dispatched energy for batteries without an automatic pre-charge function. While a manual pre-charge can be scheduled for these batteries, it is not as efficient as an automatic pre-charge function where the BMS monitors the batteries and charges the batteries as required.

Figure 17 - Dispatched energy for a group of batteries without an automatic pre-charge function



While an automatic pre-charge function is useful for maximising energy dispatched, the pre-charging could potentially increase peak demand if it occurs prior to a peak demand dispatch. Figure 18 shows a dispatch that was called one hour prior to the dispatch window (17:00-21:00) which resulted in a pre-charge that increased the customer's load consumption between 16:00-17:00.

Figure 18 - Dispatch for a fleet of batteries with automatic pre-charge function on 29 July 2021



These results highlight the usefulness of automatic pre-charging but also the importance of managing the timing of the pre-charge. Ideally pre-charging should occur during an off-peak period however this may not always be possible especially if the dispatch is scheduled with a short notice prior to the dispatch window.

It’s important to note that pre-charging adds costs to the customer’s electricity bill and financial incentives need to compensate for the cost of pre-charging and the use of their battery. This cost/benefit to the customer must always be considered when pre-charging to maximise VPP output.

6.3 Feed in Management

High voltage scenarios on local low voltage distributors are increasing as networks continue to experience high growth in new solar connections. Higher voltages typically arise at times when there is a low demand for grid power and high volumes of local solar generation. A customer’s solar power system may be interrupted or reduced in output during these times of local higher voltages as solar inverters are programmed to disconnect or ramp down generation when the local voltage rises above certain limits.

There are a range of network upgrade options which can alleviate these issues and avoid instances where solar power systems are interrupted or restricted due to high volts. But to explore potentially better ways to regulate local voltage, a Feed in Management (FiM) functionality available with some VPP participants was tested to explore efficacy and reliability.

In November 2020 and November 2021, Ausgrid tested solar Feed in Management (FiM). The FiM participants had either AC coupled, DC coupled or AC/DC configuration at their house. In many of the sites, compatibility with legacy solar inverter prevented the FiM technology from working as planned. Both gross FiM and net FiM were tested during the trial. Net FiM restricts solar generation to supply customer load and limits the net export to a set threshold. For example, net zero FiM event would restrict solar generation to supply only the load and limit net export to zero. Gross FiM simply limit solar generation to a set amount without any consideration for customer’s load.

6.3.1 AC coupled sites

For AC coupled sites (Figure 19) in the trial, Ausgrid discovered that the control function was only set up for the battery inverter and not the solar inverter, which resulted in FiM functionality not working as planned for these sites. Figure 20 and Figure 21 show a lack of response for the FiM events that were scheduled with AC coupled sites.

Figure 19 - AC coupled site

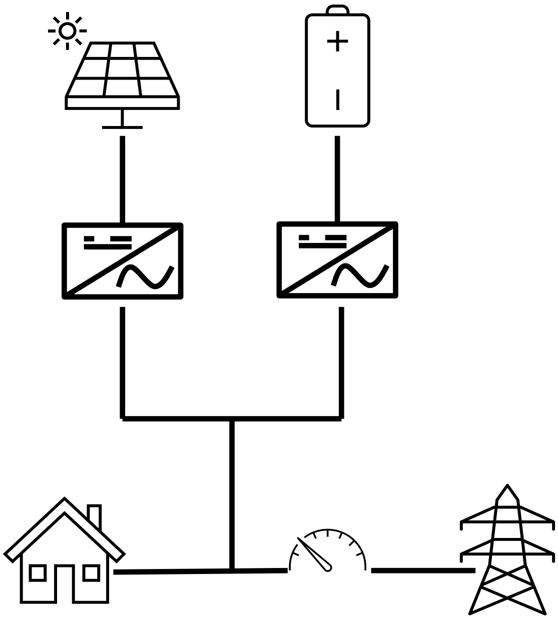


Figure 20 - Demand Profile of AC coupled sites that participated in gross zero FiM event between 13:00-14:00 on 18/11/202

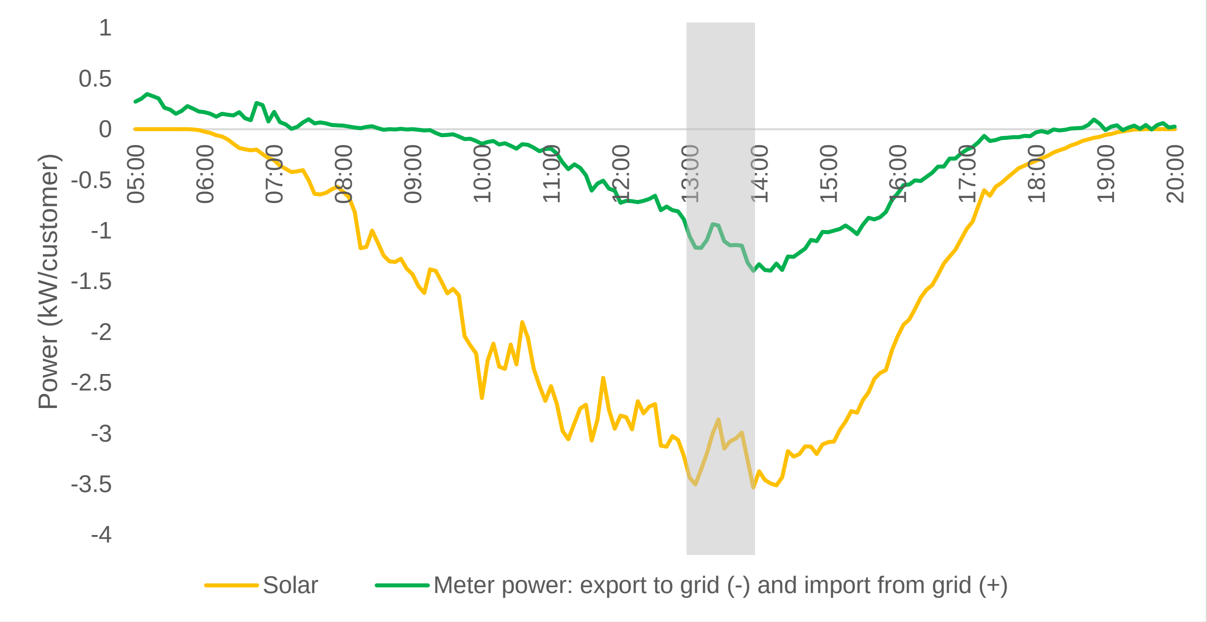
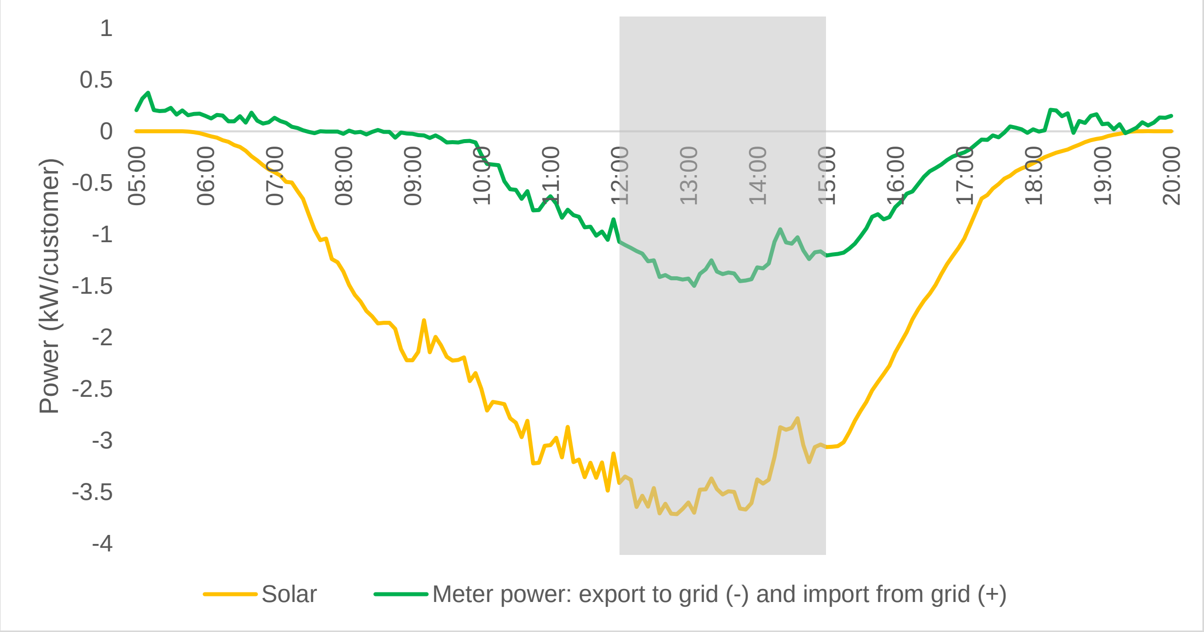


Figure 21 - Demand Profile of AC coupled sites that participated in net zero FiM event between 12:00-15:00 on 19/11/2021



6.3.2 AC/DC coupled sites

For an AC/DC sites in the trial (Figure 22) the control function was only set up for the hybrid inverter with the solar and battery, and not the standalone solar system. Therefore, FiM response was observed for the solar that was connected to the hybrid inverter and not the standalone solar system.

Figure 23 shows gross FiM event where all solar generation was scheduled to be turned off. The actual results show that only the output from one of the solar systems was turned off while the standalone solar system continued to operate normally. Similarly, only one of the two solar systems seems to have responded to the net zero FiM event on 19/11/2021 (see Figure 24).

Figure 22: AC/DC coupled site

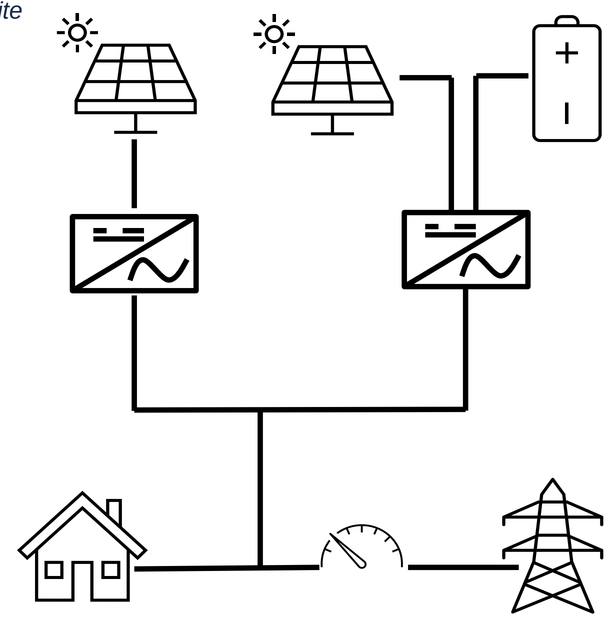


Figure 23 - Demand profile of sites with AC/DC coupled sites during gross zero FiM event on 18/11/2020

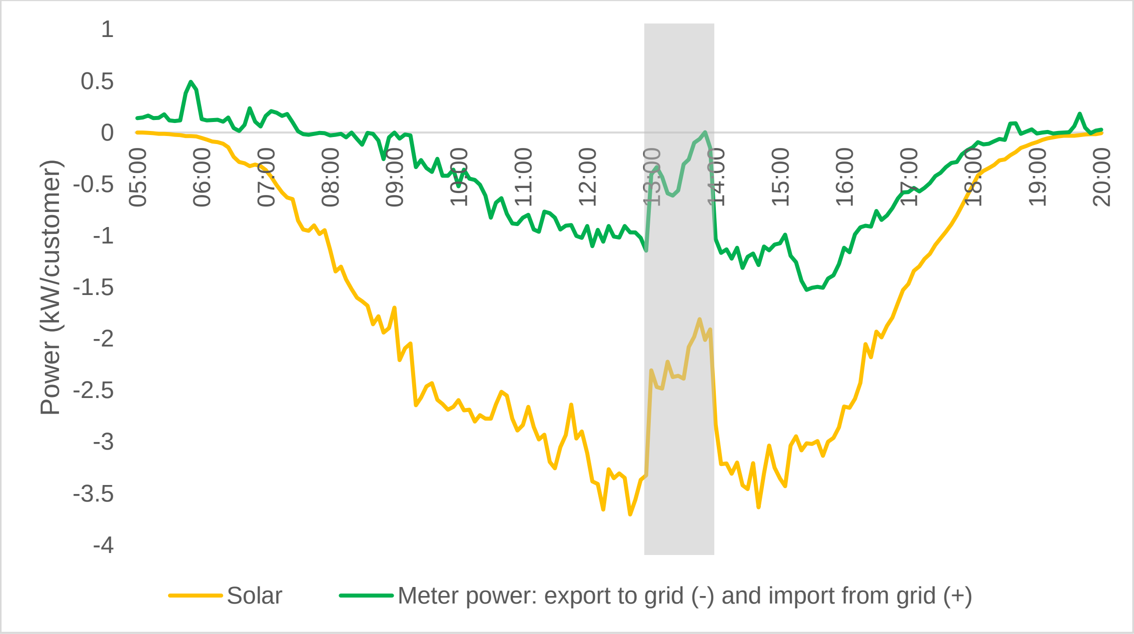
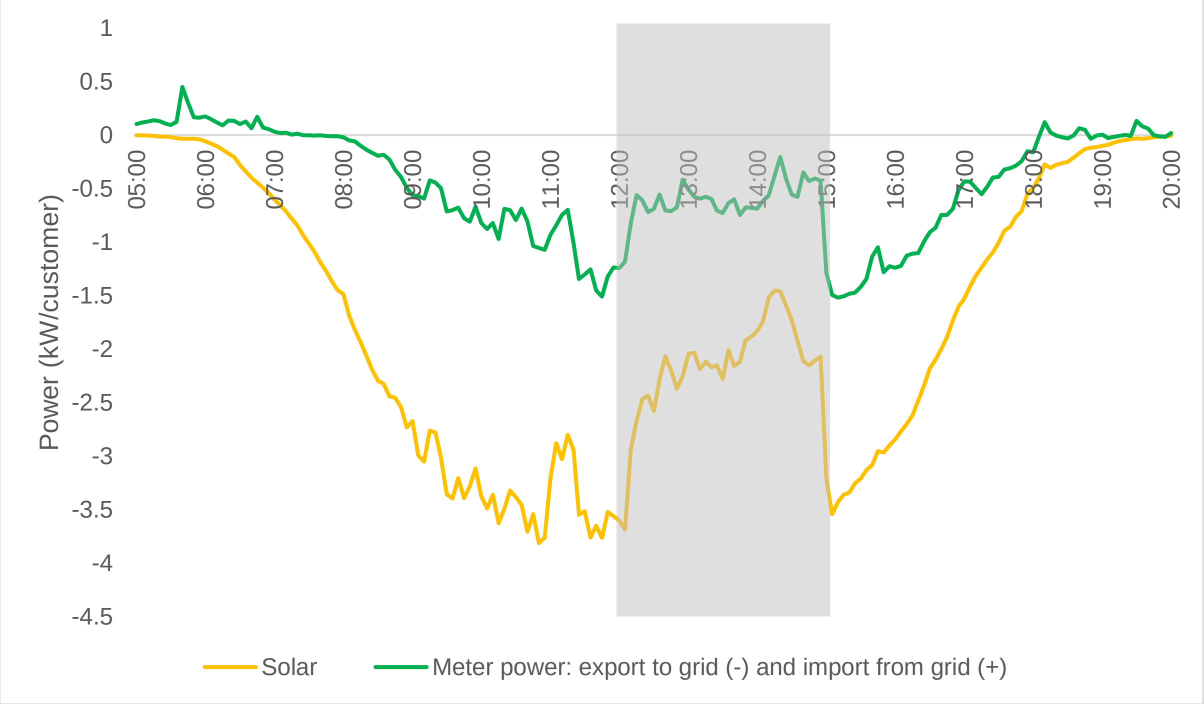


Figure 24 - Demand profile of AC/DC coupled sites during net zero FiM event on 19/11/2020



6.3.3 DC coupled sites

For DC coupled sites (Figure 25) with only one inverter, the FiM functionality performed better than the other configurations as there was full control of the output. As shown in Figure 26, the gross FiM event switched off almost all solar generation, which resulted in the customer having to import electricity from the grid.

Figure 25: DC coupled sites in the FiM trial

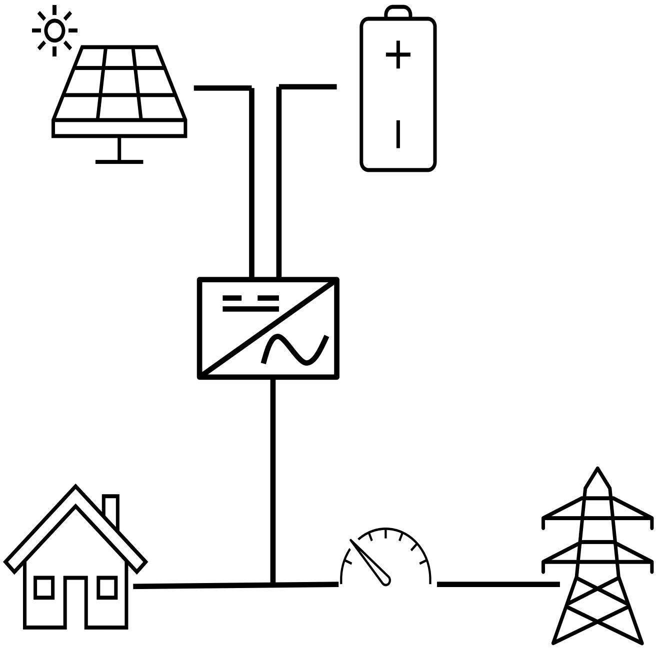
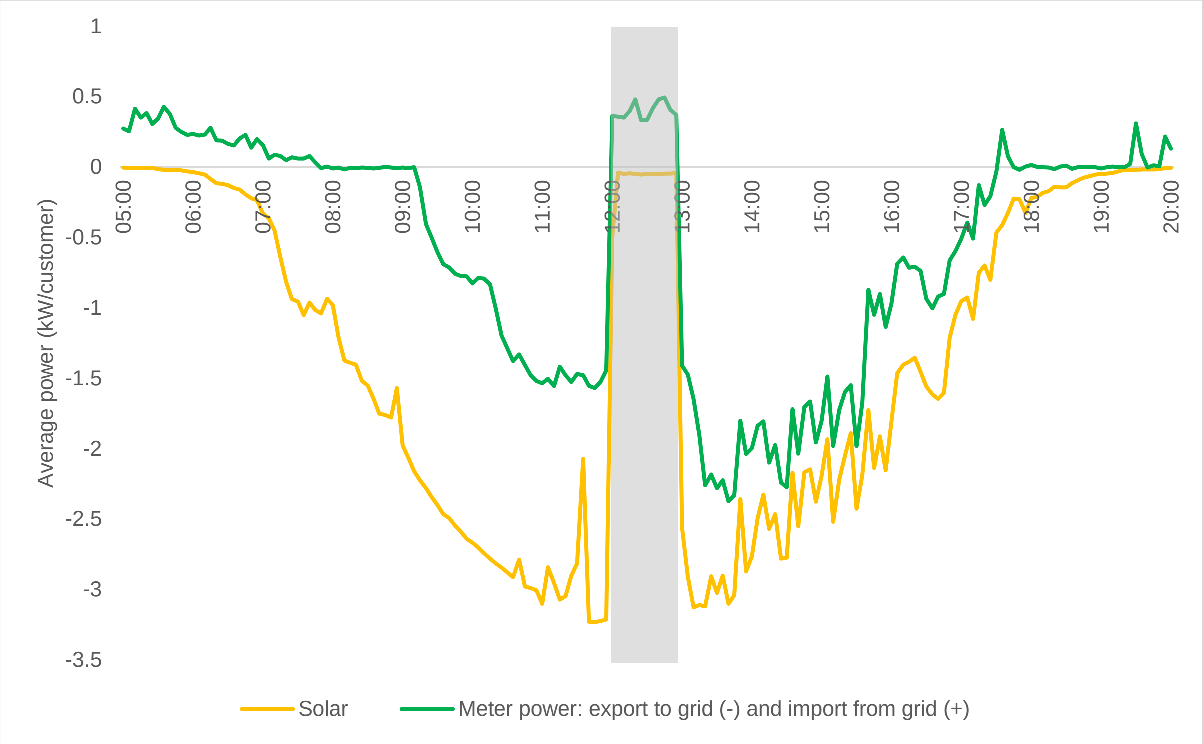


Figure 26: Demand profile of DC coupled sites during gross zero FiM event between 12:00-13:00 on 18/11/2021



The corresponding voltage chart for the gross FiM test is presented in Figure 27, which shows that there was a noticeable reduction in voltage during the gross FiM event.

Figure 27: Voltage profile of DC coupled sites during gross zero FiM event between 12:00-13:00 on 18/11/2021

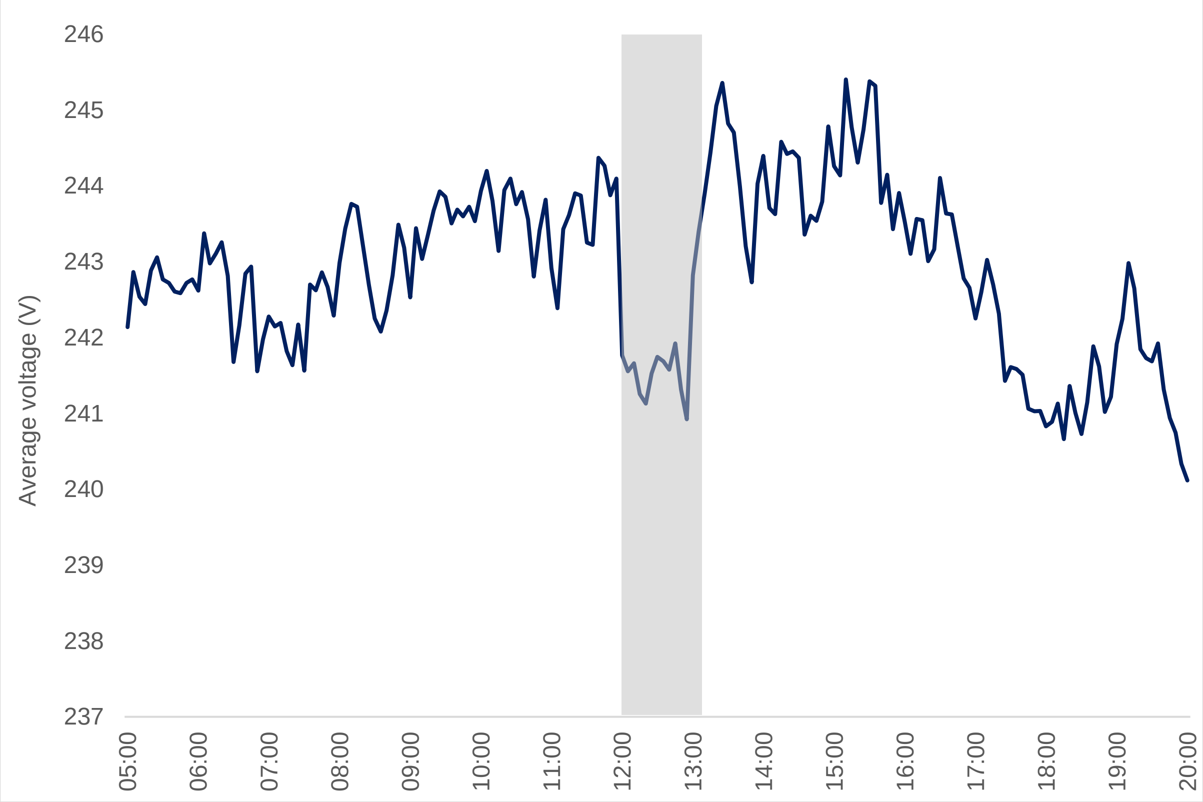


Figure 28 shows the results of a net FiM event where the export to the grid is set to zero. The corresponding voltage profile shows a reduction in voltage (see Figure 29).

Figure 28: Demand profile of DC coupled sites during net zero FiM event between 11:00-15:00 on 17/11/2021

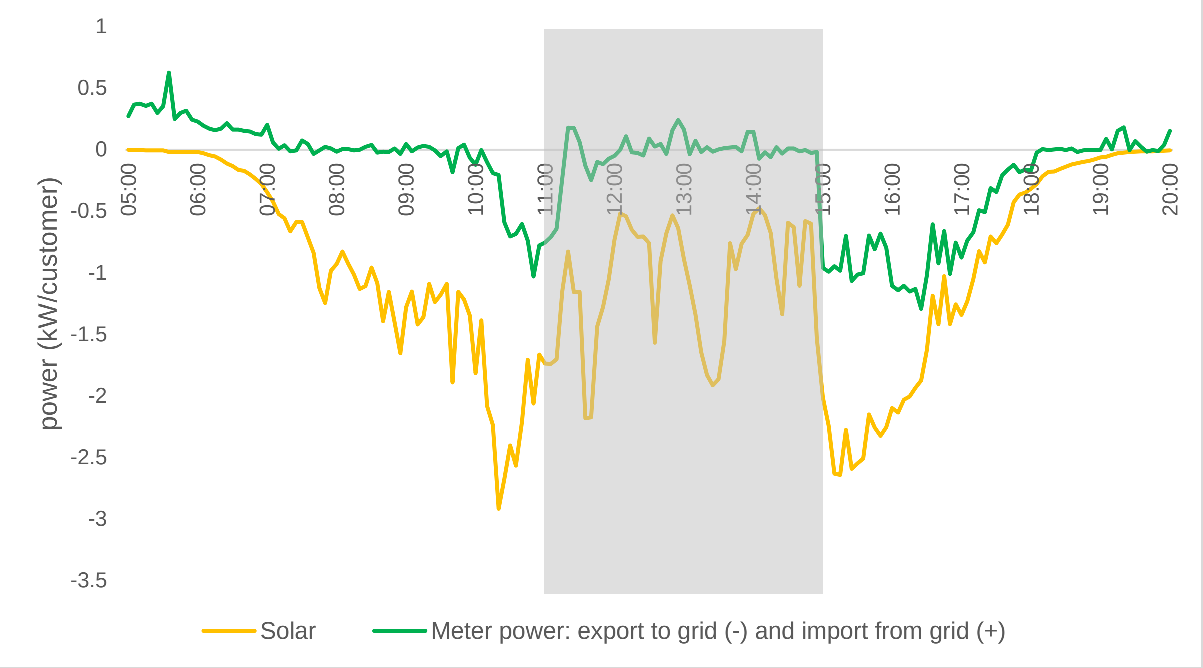
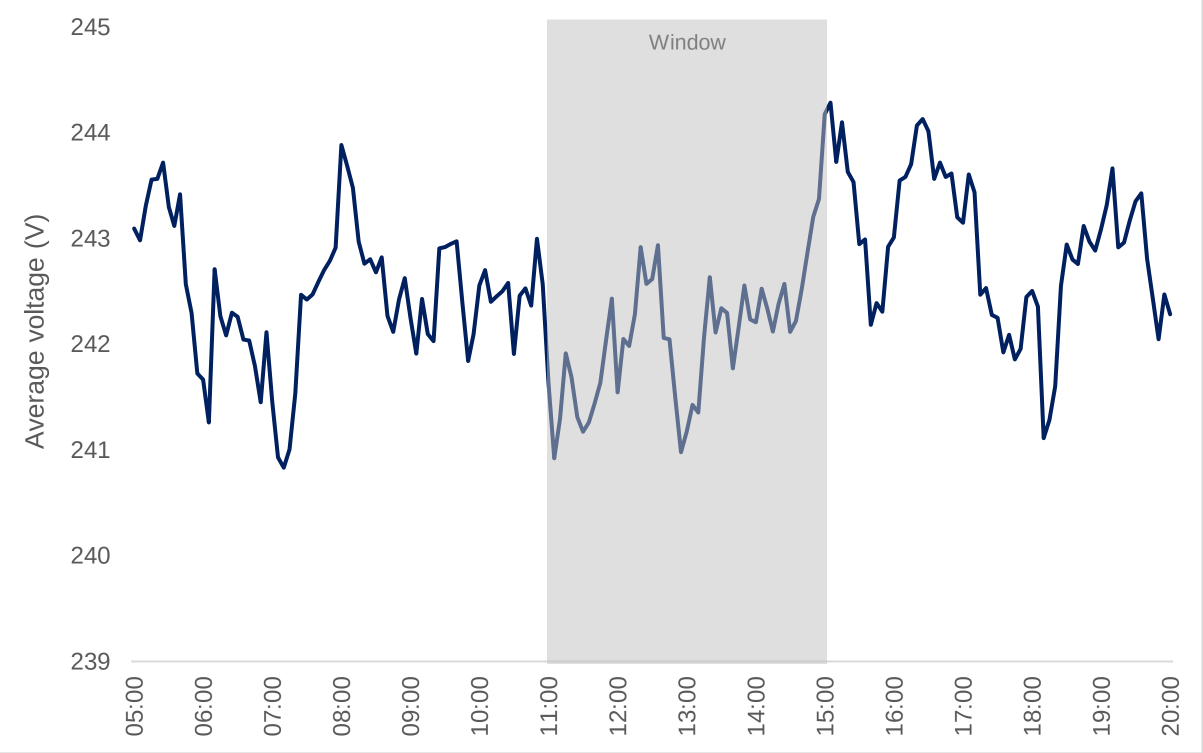
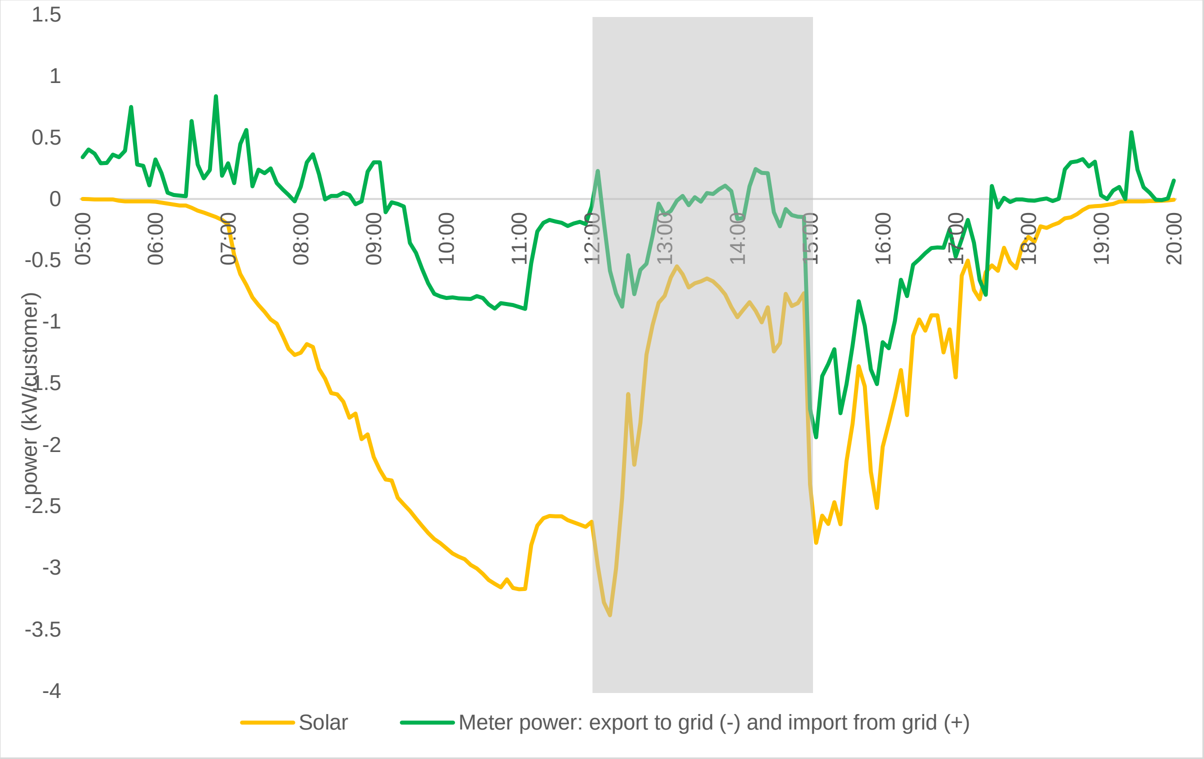


Figure 29: Demand profile of DC coupled sites during net zero export FiM event between 11:00-15:00 on 17/11/2021



Net FiM is more difficult to implement than gross FiM. While gross FiM simply limits solar to a set amount (e.g zero output), net FiM requires constant adjustment of solar output based on customer's load in order to meet a set export threshold. There were a number of net zero export FiM events where the solar output exceeded the load and resulted in export into the grid (see Figure 30 between 12:00-13:00). While gross FiM is easier to implement as it simply limits solar output to a set threshold, it can result in a larger reduction of solar output and the customer having to import energy from the grid to supply their house loads, which adds costs to their electricity bill and would require compensation.

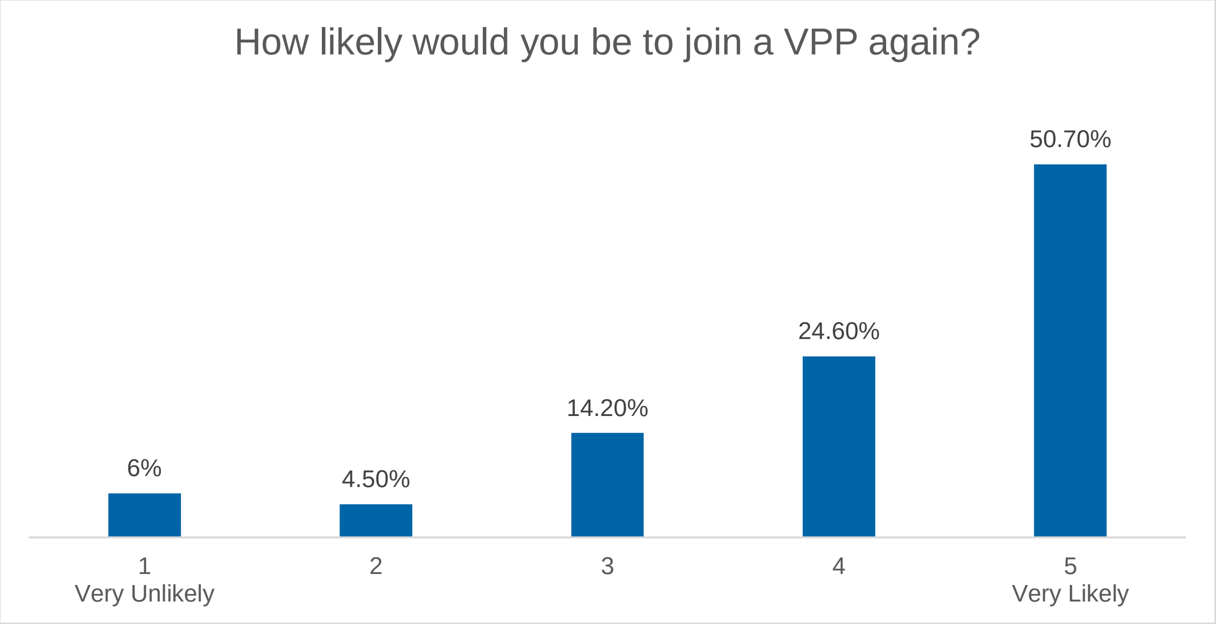
Figure 30: Demand profile of DC coupled sites during net zero export FiM event between 12:00-15:00 on 15/11/2021

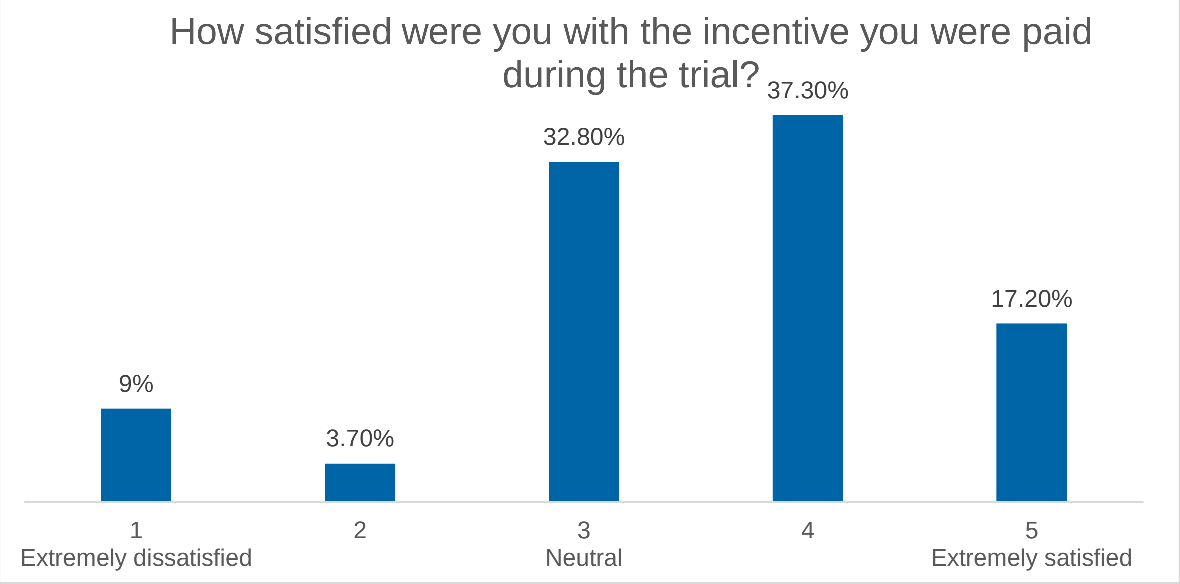


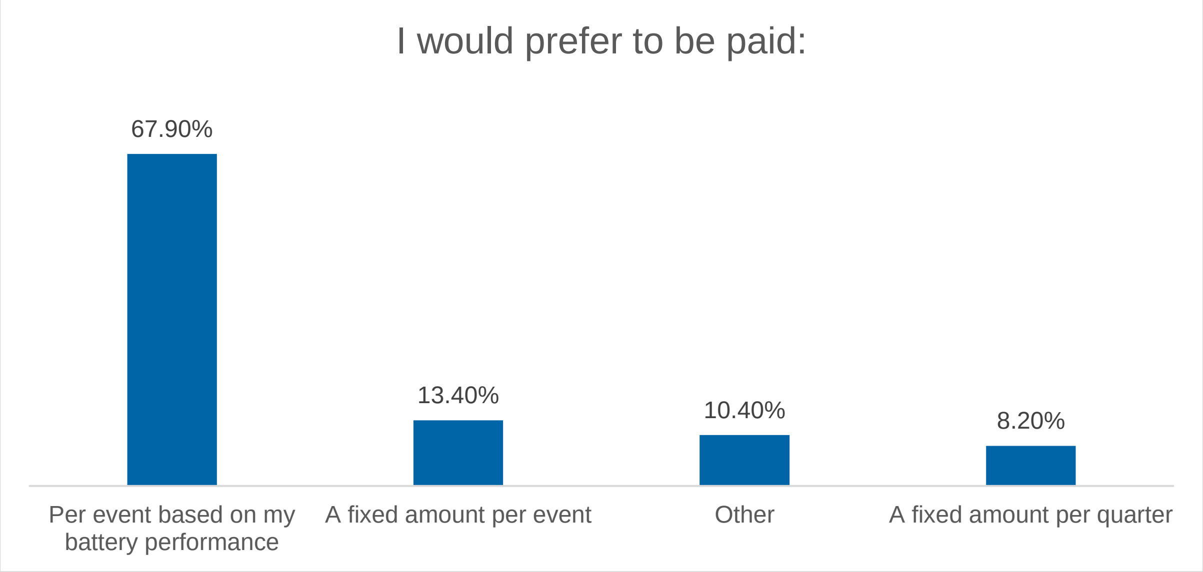
The characteristics mentioned previously regarding AC coupled and DC coupled sites are not intrinsic to those configurations. It is possible for other sites to have similar AC or DC coupled configurations and produce a different set of outcomes. For example, FiM wasn't responsive for AC coupled sites in Ausgrid's trial due to inability to control the solar inverter. Another site with the same AC coupled configuration could have a responsive FiM if it had the capability to control the solar inverter.

6.4 Participant survey

Results of a survey conducted in May 2021 with one of the VPP partners, which received 134 responses, are presented below.


How likely would you be to join a VPP again?
6%
4.50%
14.20%
24.60%
50.70%
1
Very Unlikely
2
3
4
5
Very Likely

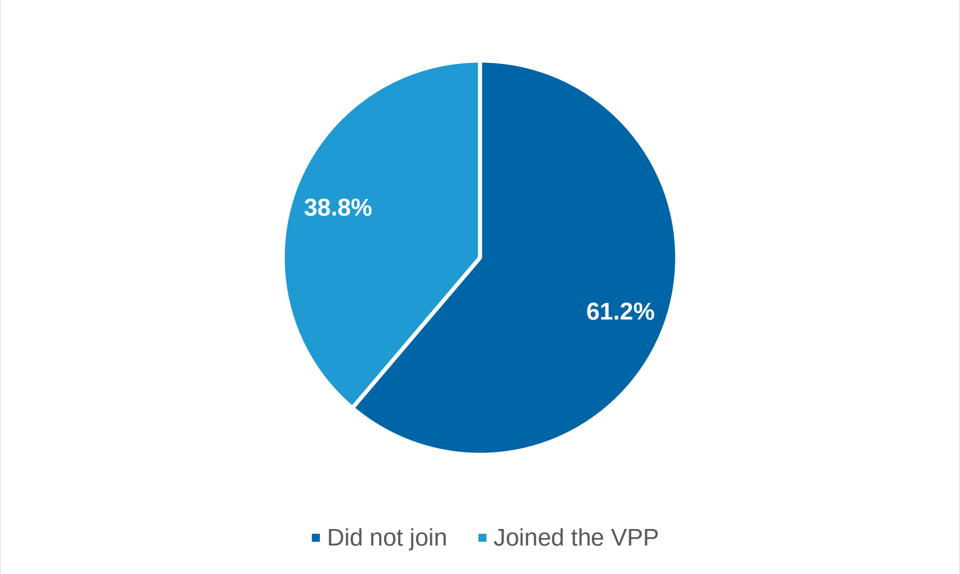

How satisfied were you with the incentive you were paid during the trial?
9%
3.70%
32.80%
37.30%
17.20%
1
Extremely dissatisfied
2
3
Neutral
4
5
Extremely satisfied



6.5 Recruitment

Figure 31 shows results of an email recruitment campaign organised by one of our VPP partners.

Figure 31:Results of a VPP recruitment campaign directed at 219 eligible battery customers



7 Year 4 Results

The size of the fleet remained largely the same at 750 batteries in the final year of the trial. A total of 62 MWh of energy was dispatched across over 60 event days in the final year of the trial. Ausgrid continued to explore how VPPs could help support the network in the final year.

7.1 Peak demand reduction

Figure 32 shows a VPP dispatch on 10 February 2022 with approximately 670 batteries involved across Ausgrid's network. This was one of the largest dispatches conducted in the trial with over 3.7MWh of total energy discharged during the 4-hour event with all three VPP providers involved. The dispatch produced an average power output of 0.9MW and a maximum power output of 1.1MW at around 6pm. The reduction in energy output for the last hour of the dispatch event was due to one of the fleets unexpectedly running out of power. Further exploration into achieving consistent output is discussed in the next section 7.2 Optimising dispatch output.

Figure 32 - VPP Dispatch on 10 Feb 2022

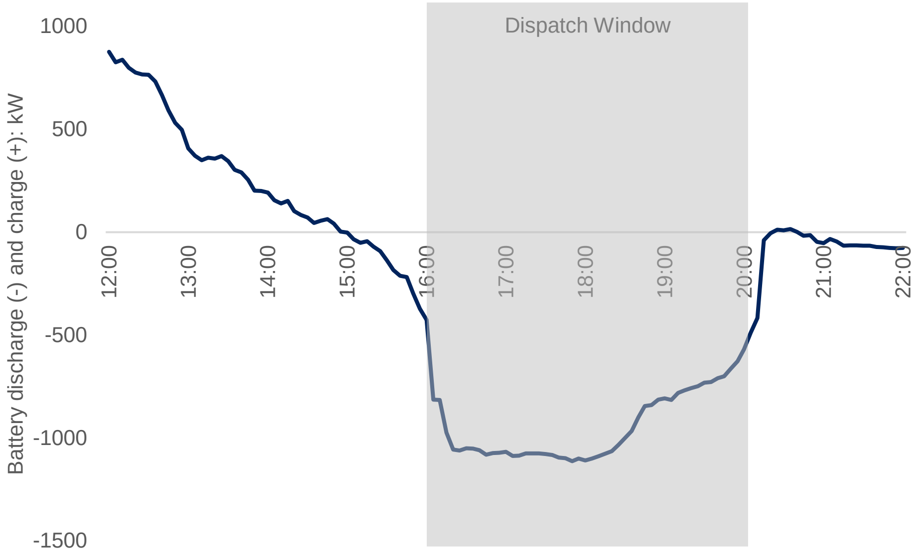
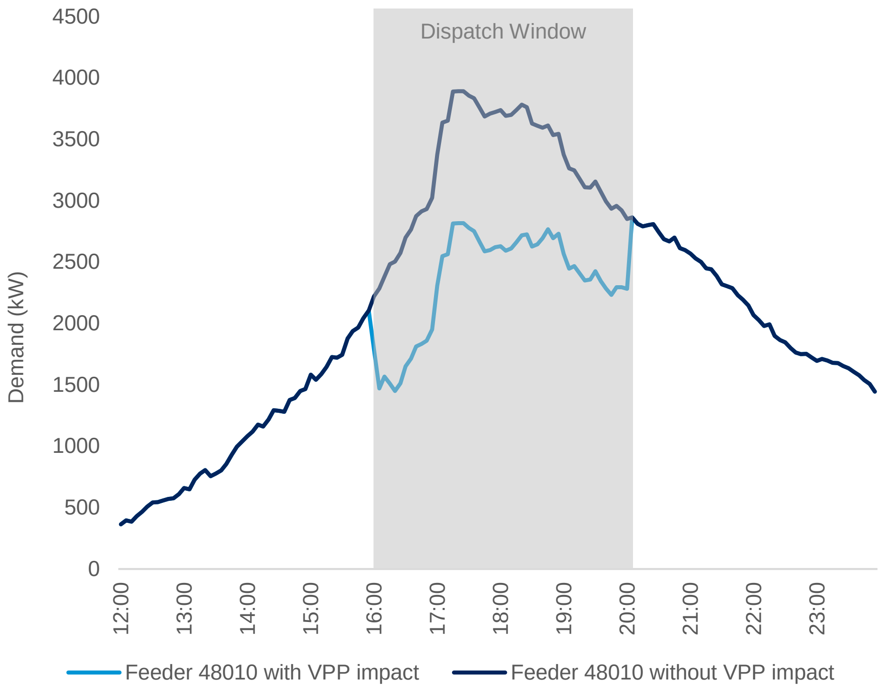


Figure 33 demonstrates the projected demand reduction that could be achieved if all 670 batteries were connected to Ausgrid's 11kV feeder 48010 on Telarah Zone Substation on the day of the dispatch. The dispatch in Figure 32 would reduce the peak demand on 11kV feeder 48010 by over 1MW.

Figure 33 - Projected impact of VPP on 11kV Feeder 481010 for the dispatch on 10 Feb 2022



This 11kV feeder 48010 was part of Ausgrid's Gillieston Heights Demand Management program, which was initiated via an RFP published in 2019, in which Ausgrid invited non-network option providers to propose demand reduction initiatives to address capacity constraints in the area (see Table 1). The dispatch in Figure 32 would have been sufficient to address the capacity constraint in 2021-2022. This demonstrates that with a sufficiently sized fleet, VPPs have the potential to address network constraints. There were approximately 1600 customers connected to the 11kV feeder on the day, which means 40% of the customers would need to own a VPP battery to match the size of the dispatch on 10 February 2022. To meet this level of battery ownership, a significant increase in battery uptake on the feeder is required.

Table 1 - Annual forecast capacity constraint on 11kV Feeder 48010 for Gillieston Heights RFP in 2019

Measure	Year 2021-2022	Year 2022-2023	Year 2023-2024
Capacity Constraint (kW)	914	1448	1981

The Gillieston Heights Demand Management project solution involved an air-conditioning load control (ACLC) program (the 2019 market engagement did not yield a viable market-led solution). During ACLC events, audio frequency signals sent from Ausgrid's control room in

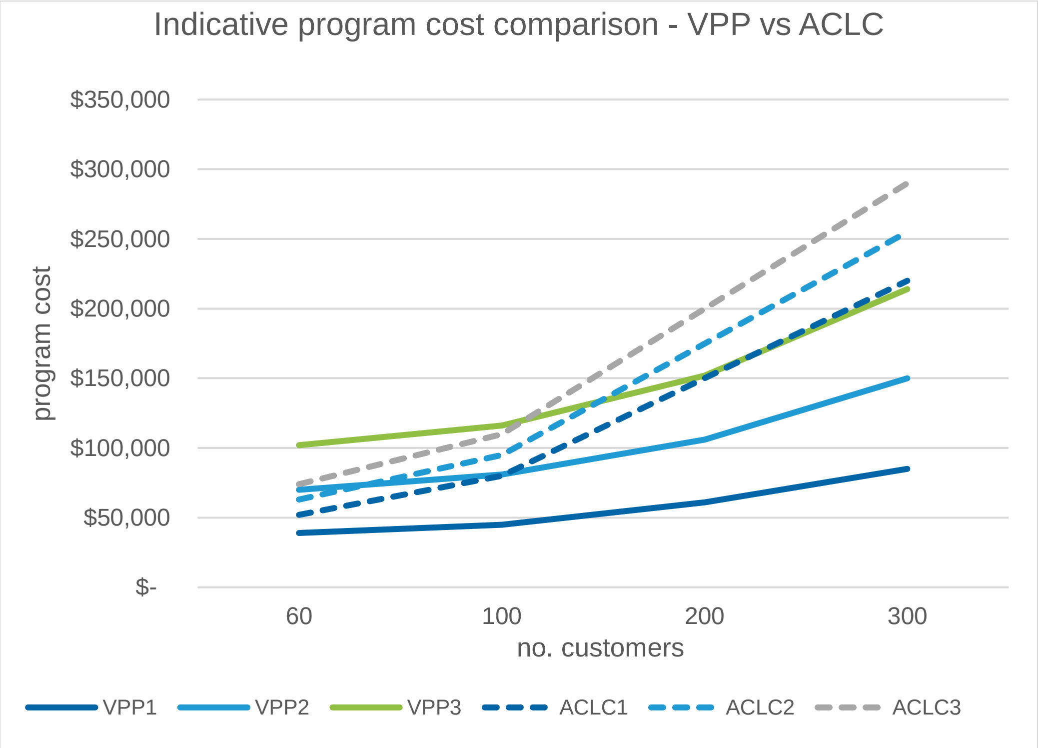
Newcastle were received by Demand Response Enabling Devices (DREDs) installed on participating customers' air-conditioning units. ACLC utilises the same signalling infrastructure used for controlled load management. The electrical input power is throttled down based on pre-defined conditions. The ACLC demand reductions achieved around 1.0 kW per customer, compared to around 1.5 kW per customer from the battery VPP trial (see section 7.2).

The main cost drivers for ACLC are DRED purchase, DRED installation and removal and customer payments. For VPP, the cost drivers involve payments made to aggregator partners that cover dispatch costs, monthly "rental" of VPP customers' batteries, fixed costs and a modelled signup bonus.

Figure 34 below presents an indicative cost comparison of the VPP trial compared against the Gillieston Heights ACLC program. While the ACLC program had around 60 participating customers, the analysis is extended for a larger program (more participating customers) using the same respective cost structures. Costs are estimated for 1, 2 and 3 year programs.

While ACLC is cost competitive with VPP for small programs, the VPP solution scales more favourably for larger programs where variable costs are a significant factor. The higher ACLC variable costs are driven by DRED purchase, DRED installation and removal and customer payments. While VPP has higher fixed costs, variable costs are much lower.

Figure 34 - Program cost comparison of VPP vs ACLC based on 1, 2 and 3 year programs



Finally, ACLC uses audio frequency infrastructure that is likely to be gradually phased out as smart (advanced) meter penetration increases. Future demand side participation including scaled VPP and similar solutions are able to take advantage of 2-way communications layers that allow for dynamic updating of instructions in near real-time.

7.2 Optimising dispatch output

Figure 35 and Figure 36 below show dispatches where the discharged power significantly declined during the final 25-40% of the dispatch window. The fleet continued to discharge power after the dispatch event, which indicated that there were batteries in the fleet that had the capacity to deliver additional power during the dispatch window. For this particular fleet, the dispatch instruction with a target output was sent to each battery prior to the event. No further instructions were sent during the event. Where batteries were unable to deliver their target power during the event, updated instructions were not sent to other batteries to deliver additional power to make up for the shortfall, which resulted in a decline in overall fleet output.

Figure 35 – Dispatch on 25 May 2022 with fleet 1

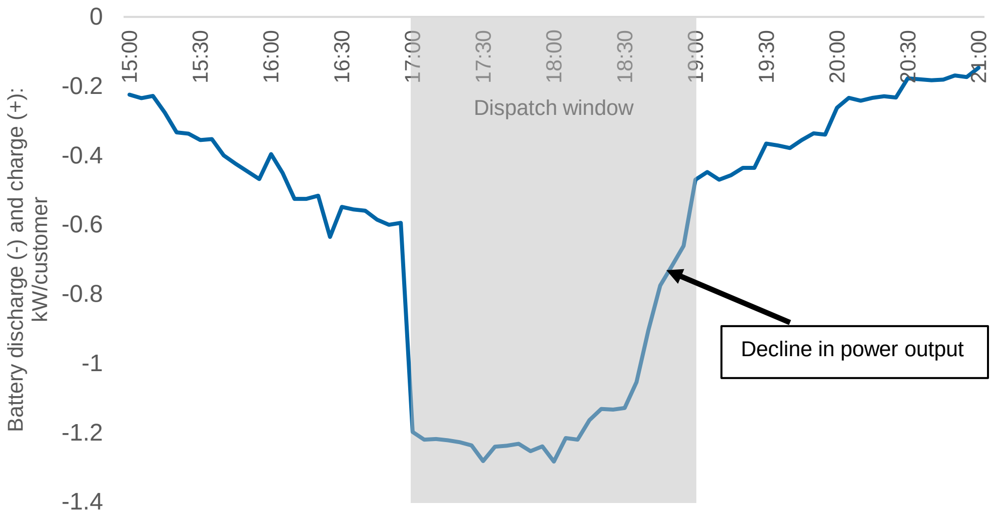


Figure 36 – Dispatch on 30 May 2022 with fleet 1

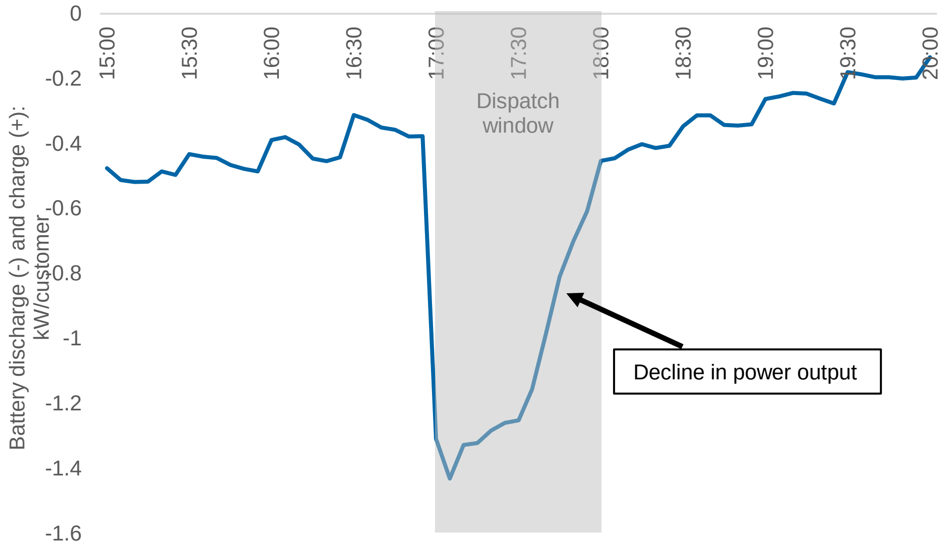


Figure 37 and Figure 38 show dispatches for two other fleets where updated dispatch instructions were sent constantly throughout the dispatch window. Where there were batteries that were unexpectedly unable to deliver the required amount of power, updated dispatch instructions were sent to other batteries for additional power output to make up for the shortfall, which enabled the fleet to deliver relatively constant amount of energy and meet the overall target power output. This type of dispatch requires a reliable communication network so that new dispatch instructions can be constantly sent to the batteries.

Figure 37 – Dispatch on 17 Feb 2022 fleet 2

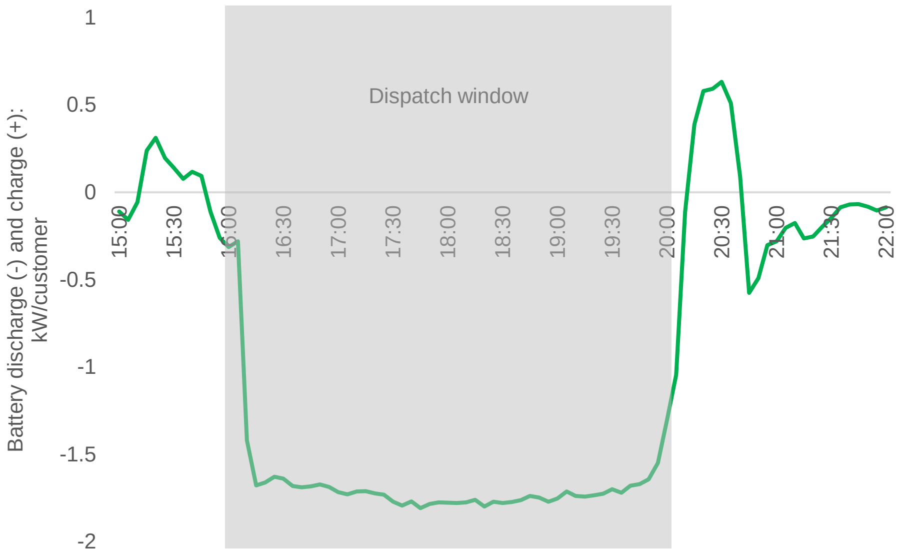
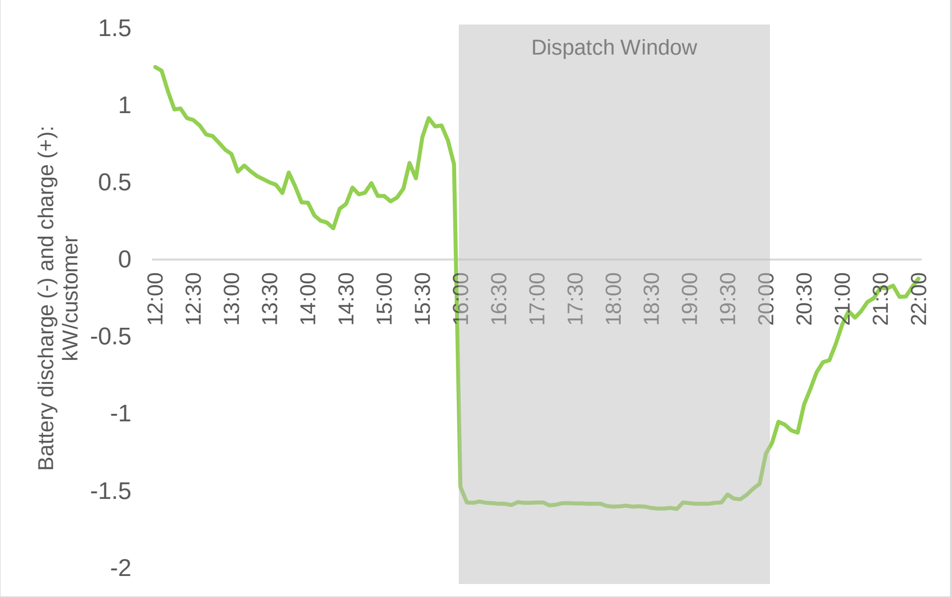


Figure 38 – Dispatch on 16 Jun 2022 with fleet 3



7.3 Template dispatch

The previous charts (Figure 37 and Figure 38) show dispatches where the aim is for the VPP fleet to discharge constant power throughout the event, which allows for better predictability of the energy output. One of the issues with this type of constant dispatch is that the output is unlikely to match the load profile as load profiles are usually not constant.

Another type of VPP dispatch, template dispatch, was tested in the summer of 2021-2022 (see Figure 39 and Figure 40). The objective of this type of dispatch is to discharge VPP power in a particular shape that resembles a typical load. The output shape for the dispatch is set by the user prior to the event. In comparison to a constant dispatch, this type of discharge allows for the discharge profile to better match the load profile. One of the advantages of this type of dispatch compared to dynamically dispatch (see section 6.1) is that the shape is set at the start and doesn’t require constant feedback based on the changing load so it has less communication requirements. However, as the template shape is not dynamically updated throughout the event, the shape of the output and the actual load profile are unlikely to exactly match, and in many cases could be significantly different.

Figure 39 – Template dispatch on 31 May 2022

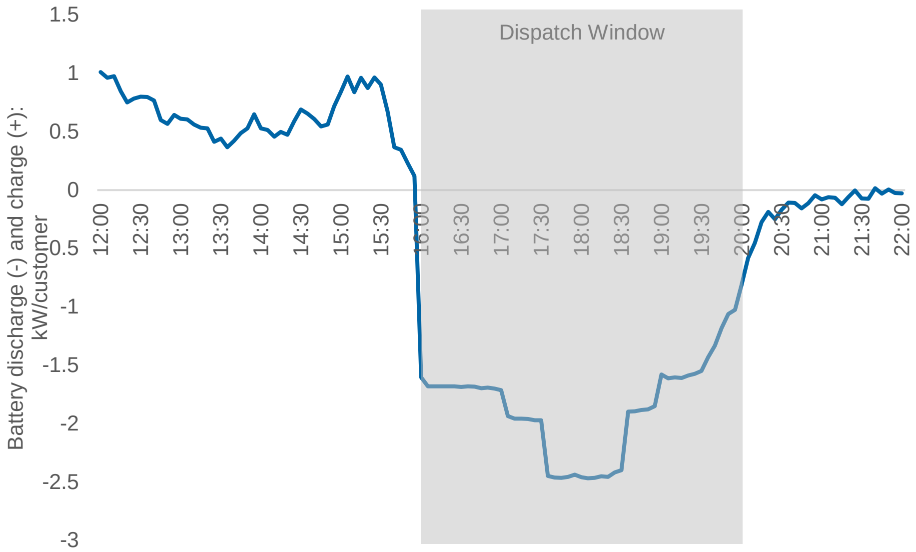
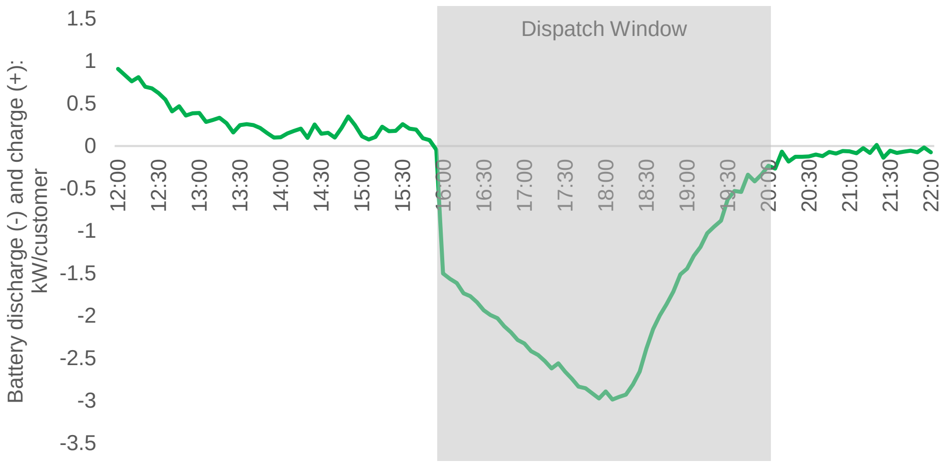


Figure 40 – Template dispatch on 28 January 2022



8 Comments from our partners

Ausgrid invited our VPP partners to provide commentary on the trial and the future of VPPs in November 2021 and below are some of their comments in no particular order.

8.1 ShineHub’s Comments

We have worked with Ausgrid in the VPP trial for the last a couple of years. Initially, the goal was simply to show that residential batteries can be orchestrated together to provide reliable grid support services. Once the basic VPP functionality was shown to be effective, we moved to more advanced VPP operation, building out custom features that would accentuate the value of VPPs for Ausgrid and successfully deploying them in the field.

The first feature we built on top of standard battery discharge was a smart pre-charge function that would ensure the batteries had enough power at the start of an event to sustain the desired power throughout the event time period.

The second feature was to model how an individual transformer could be supported to keep the load within a safe bandwidth. The goal was to only use battery power to the extent needed to keep the total power of a group of homes between a minimum and maximum power range. This required the VPP system to constantly monitor the threshold power levels in real time, and adjust the VPP output so that it provided enough power to keep within the desired ranges, but not overdo it and therefore deplete the battery resource unnecessarily. While this took a bit longer to build and roll out, it was very effective and first example of its kind in Ausgrid's VPP trial.

Finally, we built a new template based discharge feature which discharges the battery fleet on a proportional schedule over a given time period. It's similar to responsive dispatch because the dispatch power levels fluctuate over the course of the event. The main difference is that the dispatch levels are set from the start of the event, and therefore are easier to rely on when forecasting power support resources [updated in February 2022]

As a result of this VPP partnership with Ausgrid we have been able to develop new features and functionality for VPPs that has the potential to extend beyond the trial and into the normal markets.

I want to thank Ausgrid for their enthusiasm throughout the project and willingness to push into new VPP territory.

For all of you reading this, thanks for reading. I hope our efforts have helped you see the immense future of VPPs to unlock a new renewable energy future for Australia.

8.2 Evergen's Comments

The move from small numbers of large generators dispatching power, to many thousands of inverter connected devices doing so as part of a harmonious system is well underway.

As Ausgrid recognises, it requires new ways of thinking and new approaches to system management. Evergen has been pleased to be a part of the Ausgrid Virtual Power Plant (VPP) project, and to be demonstrating that a software led approach to controlling batteries to enable the grid to better integrate with renewables to this end is both viable and effective.

As this report outlines, over the course of this project Ausgrid have been able to show that VPPs comprised of residential batteries have the potential to deliver:

- *Demand reduction; and*

- *Voltage support services.*

Most importantly, the project confirms that Battery VPPs have the potential to help avoid or defer network investment, delivering greater value to consumers.

As well as potentially providing value in terms of avoided or deferred network investment, the VPP gives customers another chance to participate in the energy market.

The importance of visibility and control of distributed energy resources (DER) to help maintain grid stability will only increase as more and more homes install solar and batteries, and more and more consumers start to drive electric vehicles.

Projects like this give a perfect test bed to trial a variety of services and approaches, learn from them and develop new capabilities.

Heading into 2022 Evergen looks forward to working with Ausgrid on future research objectives. Ausgrid has investigated "feed-in management" to affect grid voltage. This control focuses on curtailing solar output. It is useful to explore this method as one of several approaches to using DER to mitigate minimum demand voltage issues.

Solar curtailment is a useful mechanism for reducing the impact of solar-only DER. However, it is a 'high impact' measure since it involves throttling an end user's solar output, temporarily removing utility to the customer.

An interesting avenue for future Ausgrid VPP research would be to compare whether batteries may reduce grid exports at times of minimum demand as effectively as the feed-in management solar-curtailment mechanism researched to date. This new research could compare:

a. Grid export reduction via Feed-in management for solar-only DER

b. Grid export reduction just via the default self-consumption mode of solar and battery DER

c. Grid export reduction with forecast, optimisation and control of batteries to determine the best profile for allowing batteries to charge to mitigate high grid voltages during times of minimum demand.

d. A combination of solar curtailment (feed-in management) and battery optimisation

e. Direct reactive power dispatches from VPP battery inverters to impact grid voltage.

Ausgrid identified challenges for feed-in management measures, especially with either older solar inverters or else AC-coupled systems.

These challenges are also mirrored in the management/configuration of AC-coupled solar-battery systems more broadly, with respect to behaviour under adverse grid conditions. For example, the solar inverter and battery inverter at a site could be independently configured according to the prevailing Australian Standard (AS/NZ4777) at time of install to respond to high grid voltages, especially if they were not installed at the same time. This is common for end users who have had solar for many years, and have more recently added a battery to augment their system. This independent behaviour may not always result in a response to high grid voltages that is good for either the grid or for the customer.

Evergen intends to further investigate these differences across our fleet of both AC-coupled and DC-coupled systems, to observe in practice responses to high grid voltages in local areas.

8.3 Reposit Power's Comments

Virtual Power Plants continue to demonstrate their capability in helping to deliver a more integrated, stable and resilient grid of the future powered by clean, green, and consumer owned electricity generation. The rapid, and ever accelerating deployment of rooftop solar and residential battery storage will continue to place increasingly material pressure on our national electricity infrastructure. Reverse power flows, voltage fluctuations, and degradation of power quality are all negative side effects that unfortunately come hand-in-hand with uncontrolled renewable electricity generation connected to our grid.

Projects such as Ausgrid's VPPs trial demonstrate, however, that it doesn't have to be this way. By having the ability to view, aggregate and orchestrate these assets in real time, the VPP will be an essential component of the safe, reliable and green grid of the future.

Reposit was the first VPP provider to join Ausgrid's VPP trial when it commenced in 2019, and has been an enthusiastic partner right throughout the trial. Following from the foundation set by the VPP trial, we are excited to continue our collaboration with Ausgrid in progressing VPP technology via Project Edith.

Reposit congratulates Ausgrid on the operation of its VPP trials and for having the vision to undertake such important research work in combination with key industry partners. We look forward to continuing to work with Ausgrid in delivering the next evolution of the VPP and progressing toward our mission of making energy reliable, safe, green and abundant for all.

9 Future Considerations

VPPs have the potential to play an important role in the transformation that the energy industry is currently going through. The future of VPPs as a demand management solution is likely to be impacted by a number of factors that are outlined below:

- Customers' willingness to allow electricity distributors and battery aggregators to manage their devices will be important to the future success of VPPs. While the majority of the customers in the trial have been largely supportive in allowing Ausgrid to control their device, there were customers who had raised concerns. It is important for electricity distributors, VPP providers and other stakeholders to engage customers, build trust and create value for them to increase participation in VPPs.
- As demonstrated by this trial, the size of the VPP needs to be sufficient for it to be considered as a viable demand management option. The growth of CERs (Consumer Energy Resources) will be important in realising the potential of VPP as a demand management option. With the transition to net zero future for the energy industry, investments in CERs are likely to grow significantly leading to greater opportunities for VPPs.
- As highlighted in 7.2 Optimising dispatch output, the ability to update dispatch instructions during an event resulted in improved dispatch outcomes compared to issuing instructions prior to the event only. Reliable communications are an important consideration in being able to realise desired dispatch outcomes.
- While Ausgrid VPP trial only tested the ability of residential batteries and solar FiM, VPPs can encompass a broader range of technologies such as smart home appliances and EVs. By integrating a broader range of technologies, VPPs have the potential to create more value for the customers and produce a larger demand response.
- Regulatory framework around the participation of VPPs in markets such as FCAS could impact the value VPPs can generate and the growth of VPPs.
- Integration of CER with the energy and services market will also help realise the potential of VPP. As part of Project Edith, Ausgrid is currently exploring how the grid can facilitate technology and green energy solutions (such as VPPs) through the use of tools such as dynamic operating envelope and dynamic network pricing.
- Future tariff structures may alter the BAU battery operation and therefore impact dispatch potential.

10 More Information

More information about the VPP project, including previously published reports, can be accessed on Ausgrid VPP trials website.