Ausgrid's Battery Virtual Power Plant

PHASE 1 SUMMARY

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Contents

1 Introduction 3

2 Background 3

3 Objectives 4

4 Stage 1 results 5

4.1 'Business as usual' operation of Ausgrid's VPP fleet 5

4.2 VPP operation 9

5 Customer benefit 11

6 Future research objectives 13

7 Conclusion 14

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1 Introduction

Ausgrid's Battery Virtual Power Plant (VPP) project explores whether battery VPPs can provide reliable and cost competitive sources of demand reductions or voltage support services to avoid or defer network investment. This project will show how the grid can integrate with renewables and partner with industry and customers to maximise grid efficiency benefits and reduce costs for customers.

The VPP is part of Ausgrid's broader Demand Management Innovation program, one way Ausgrid is engaging with market providers and customers to shape the future of energy, by working smarter with the customers.

Ausgrid's partnership with Reposit Power marked the first stage of the program with hundreds of customers combining to form a 1 megawatt VPP. The second phase of the project will include additional VPP aggregators and technology providers to expand the scope and scale of the VPP and enable greater customer choice.

This interim report seeks to present the key results from phase 1 as well as highlighting challenges identified and future research objectives for phase 2. Additional information on Ausgrid's VPP is published on our website at www.ausgrid.com.au/vpp.

2 Background

Virtual Power Plants link decentralised and independent small-scale generators (such as solar power systems and batteries) into a network, forming a centrally controlled virtual generating unit. VPPs can be coordinated to provide support to the electricity grid on days of very high demand or can be used to trade electricity at times of high wholesale electricity prices. Participating customers are paid in return for this control of their batteries, lowering their energy costs. By dispatching stored energy from customers' batteries when required, VPPs may enable Ausgrid to increase the flexibility of the grid, eventually leading to lower costs for everyone on the network.

Throughout Ausgrid's VPP trial, participants are called upon to dispatch energy from their battery systems into their home and the grid. Each Ausgrid dispatch event is crafted to explore a research objective in areas such as performance variation by manufacturer or aggregator and the performance of battery management control systems. These dispatch events are expected to occur up to about 10-15 times per year. When Ausgrid activates signals to customers' batteries through their battery VPP provider, the stored energy is used within the home and any excess is exported to the grid. In return, participating customers are paid for the energy they supply, lowering their energy costs.

Ausgrid has been exploring the potential for behind the meter and grid 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[1] 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 control 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 the trials of 2014, there have been significant technological and market developments which has 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. Across Ausgrid's network there are about 4,000 – 5,000 residential battery installations and this number is expected to grow significantly in the future as battery costs continue to fall.

Ausgrid's current battery VPP project is seeking to build from previous trials to assess whether market providers can provide a commercially and technically viable demand management option, utilizing existing residential customer batteries. Reposit Power was selected as the VPP aggregator for phase 1 due to their track record with residential battery control and dispatch, significant experience with R&D and demonstration VPP projects and their established customer base. A total of 237 Reposit Power customers were initially included in Ausgrid's VPP, representing an aggregated dispatch power capacity of 1MW and a storage capacity of 2.4MWh.

3 Objectives

Ausgrid's VPP project seeks to leverage the existing customer battery capacity of VPP providers and provide additional value to customers to support additional market uptake. By providing dispatch and service payments, but not subsidizing customer acquisition or platform development, the service and dispatch costs can be directly compared to other demand management initiatives (typically considered as $/kVA for firm peak reductions).

Key research objectives from phase 1 included:

- whether VPPs can provide reliable short-term demand reductions (typically 2 – 4 hours) during hot summer and cold winter evenings when demand peaks;

[1] Newington Grid Battery Trial: https://www.ausgrid.com.au/-/media/Documents/Demand-Mgmt/DMIA-research/Ausgrid_Newington_Grid_Battery_Report_Final.pdf

- whether VPPs can provide reliable sources of voltage support in conditions of over-voltage (typically during sunny Spring and Autumn days) or under voltage; and
- determining the typical battery charge and dispatch profile, to assess 'business as usual' battery operation and to provide a baseline operating condition for the assessment of VPPs.

4 Stage 1 results

This section presents results and analysis on the operation of Reposit Power controlled residential battery systems when operating without VPP control ('business as usual' operation) as well as when dispatched as a VPP by Ausgrid.

4.1 'Business as usual' operation of Ausgrid's VPP fleet

Residential battery systems are typically optimised to charge during the day from the excess solar energy generated from the customers' solar power system. This excess solar energy is the energy generated by the solar power system but not used within the home and would otherwise be exported to the grid. For customers on flat retail tariffs, residential battery systems typically operate to commence discharge when household energy usage is greater than solar energy generation, with the goal to maximise self-consumption and therefore minimise grid import. For customers on time of use retail tariffs, the typical objective is electricity cost optimisation, to discharge batteries during peak and shoulder periods and therefore to minimise the import of electricity at higher retail prices. Reposit Power's control algorithms learn and forecast household consumption and solar generation with the goal to control batteries to minimise electricity expenditure for the customer.

Additional value can be provided on top of this existing 'business as usual' operation, when other value streams are captured through VPPs, such as for wholesale price arbitrage and network support.

The analysis of 'business as usual' battery operation is critical to assessing the typical impact or benefit of residential batteries on the electricity network, without any specific network requested dispatch. In effect, 'business as usual' battery operation becomes the baseline in assessing the operation of residential batteries when orchestrated as a VPP. Chart 1 following shows the average daily 'business as usual' charge and discharge profiles of the customers within Ausgrid's VPP group (based on Reposit Power control algorithms), measured and normalised per customer over a one-year period to June 2019.

Chart 1, the 'business as usual' 2018/19 daily battery cycle, normalised and averaged

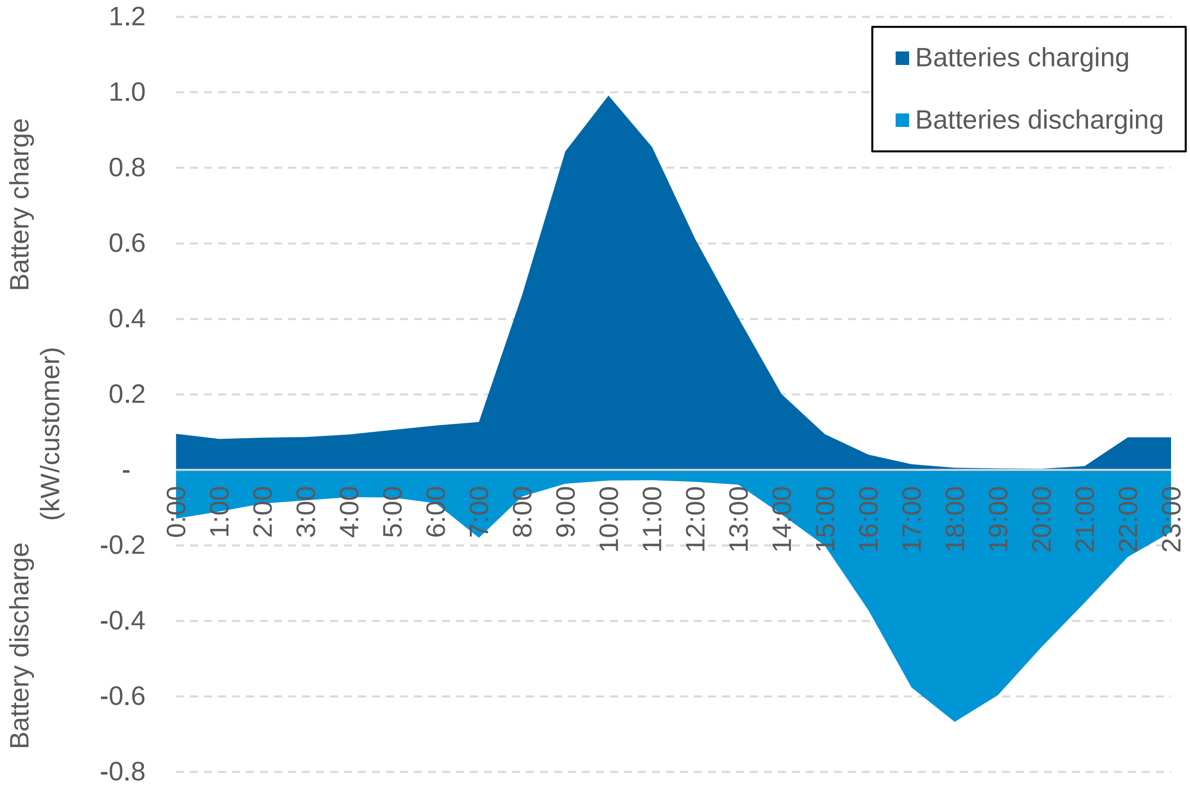


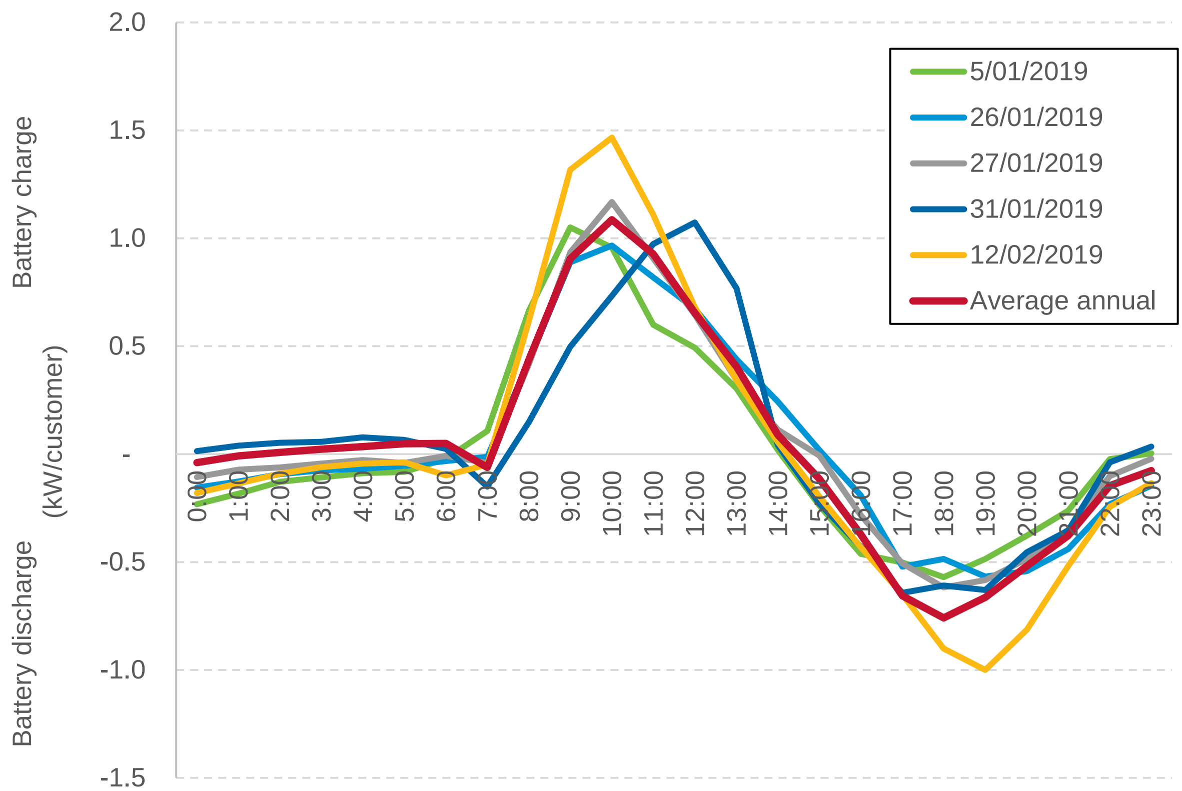
Chart 1 is split into charging and discharging groups to highlight the variation seen within the group – showing that some batteries are charging while others are discharging at the same time, depending on the customers' retail tariffs, their load and available site generation. The graph shows that some batteries are discharging (expected to be customers on flat retail tariffs) and some charging in the early hours of the morning (expected to be those on customers on time of use retail tariffs), with a slight increase in discharging at 7am, as battery systems for customers on time of use tariffs are expected to seek to minimise electricity import during the morning retail peak period.

Using electricity generated from the homeowners' solar power systems in excess of what is being consumed in the home, batteries are principally charging from approximately 7am until about 2 – 3pm. At this point, most of the batteries are fully charged and commence discharging, with the discharge peaking at about 6pm. Discharging continues at a lower rate throughout the night to midnight. The increase in charging from 10pm likely represents customers on time of use retail tariffs and coincides with the start of the off-peak period for most retail time of use tariffs.

It is important to note that this is the typical 'business as usual' operation for Reposit Power customers and does not necessarily represent the typical behavior of other battery control systems. Although Ausgrid understand that approximately 70% of the Reposit Power customers within the Ausgrid VPP are on network time of use tariffs, it is not known whether that translates into retail time of use tariffs. Customer retail tariffs are not known at this time and so we cannot separate the 'business as usual' analysis into time of use and flat tariff groups. Requesting this information from participants to explore the tariff effectiveness of the battery system operation is an objective for phase 2 of the project.

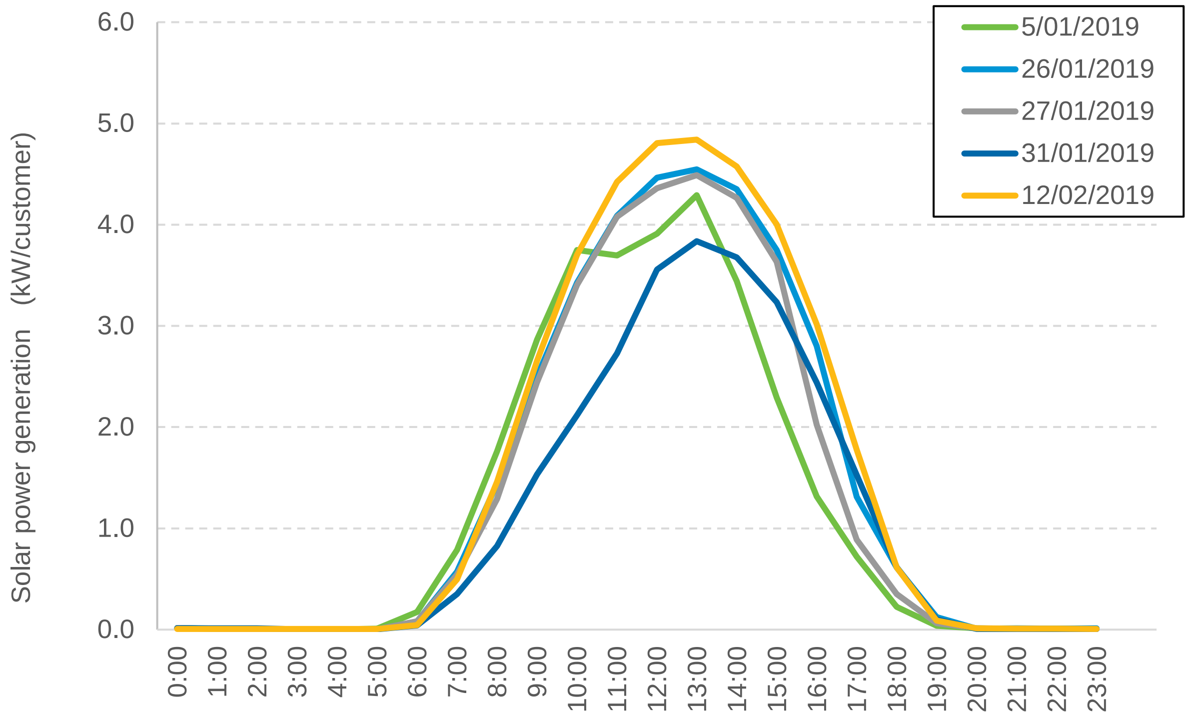
The average and normalised curves in Chart 1 has been merged in Chart 2 into a single average annual profile, in red. Five of the hottest days in the 2018/19 summer were then plotted to give an indication of the 'business as usual' operation during extreme days, where maximum temperatures were over 34°C, as recorded at Sydney Observatory Hill.

Chart 2, the daily battery cycle for 'business as usual' and five extreme temperature days for 2018/19, normalised averaged



It can be seen in Chart 2 that the charge and discharge profiles on hot days generally follow the shape and timing of the annual average, with several slight variations. The 31st January 2019 (dark blue) was an exceptionally hot day, peaking at 39.6°C at Sydney Observatory Hill. This was the day of maximum demand in 2018/19 across Ausgrid's network when electricity demand peaked at 5,612MW. Referring to Chart 3 below, electricity generation from the residential solar power systems on 31st January 2019 (dark blue) was lower in the morning, resulting in a delayed battery charge. The 12th February 2019 (yellow) saw a particularly efficient day for solar power production, and as such solar electricity generation and resultant battery charging was higher.

Chart 3, Solar power generation on five high temperature days in 2018/19, aggregated and normalised



The assessment of the average annual 'business as usual' profile during the evening (5 – 8pm) as well as for the five high temperature days (used as an indication only) can help establish the benefits to the electricity network of the installation and smart control of residential batteries, without any VPP or network interaction.

As detailed below in Table 1, using results from Chart 2, the annual 'business as usual' battery operation of Reposit Power customers results in an average dispatch of 0.69kW/customer and a minimum dispatch of 0.66kW/customer during the 5 – 8pm period. The average of the five high temperature days in 2018/19 results in an average dispatch of 0.62kW/customer and a minimum dispatch of 0.55kW/customer during the 5 – 8pm period. Further analysis on high temperature days will be required to validate these results and better understand variation on network peak days. The dispatch of battery power from customers' battery systems provides electricity to meet household requirements and any excess is sent into the grid – in both instances dispatches reduce the grid supply requirements and therefore helps lower network electricity demand.

Table 1, 'business as usual' dispatch power for Reposit Power customers between 5 – 8pm

Group	Calculation	Battery power dispatched between 5 – 8pm
Annual average 'business as usual' profile	Average dispatch power	0.69 kW/customer
	Minimum dispatch power	0.66 kW/customer
Average of five high temperature days	Average dispatch power	0.62 kW/customer
	Minimum dispatch power	0.55 kW/customer

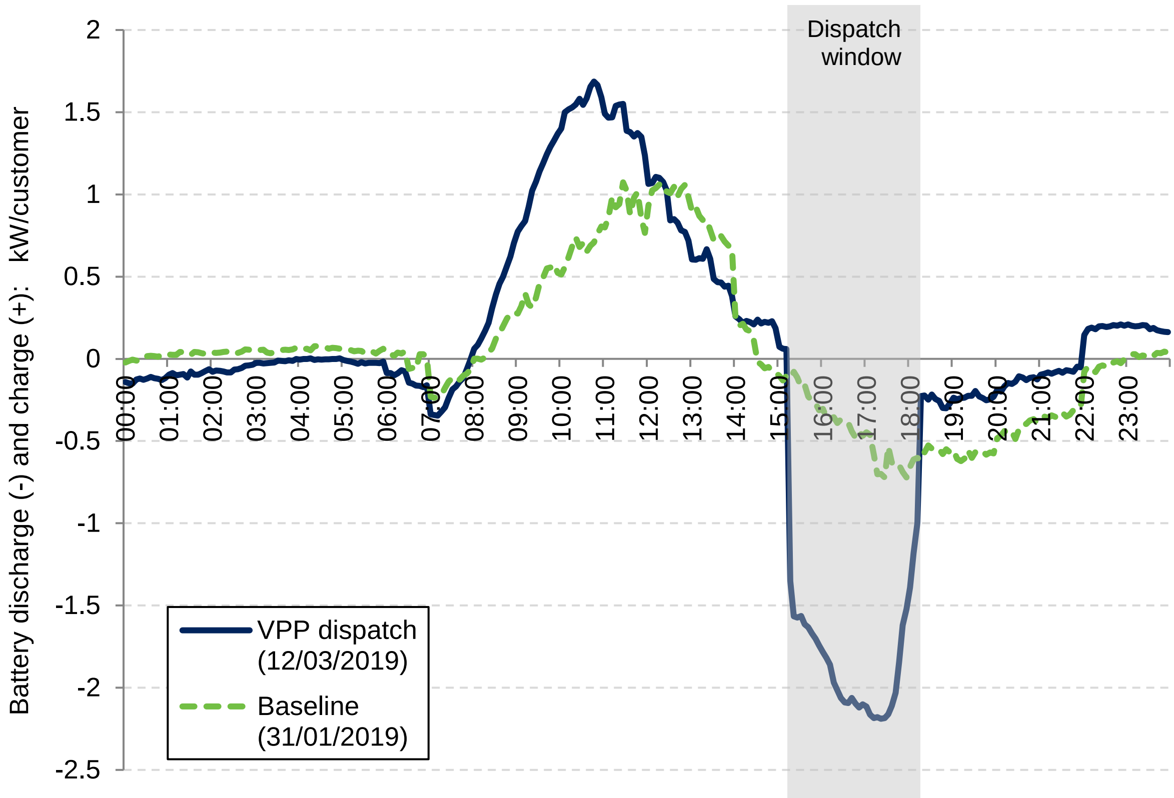
Through an analysis of the customers over the one-year period, an annual battery round trip efficiency was calculated at 87%. Further analysis is required to assess the battery round trip efficiency (and in addition whole of system efficiency) on hot days that would represent network peak demand days.

4.2 VPP operation

Ausgrid's dispatch testing commenced in March 2019, primarily during the late afternoon and evening when the grid's maximum demand typically occurs. A total of 45 dispatches were conducted with VPPs of various sizes and groups (groups split randomly, by location or by battery/inverter brands) between March and June 2019, equating to 7 dispatches per customer on average. The results of two dispatches are presented below, giving an indication of the performance of various VPP groups in responding to Ausgrid's dispatch requirements.

The 12th March 2019 was a hot day, peaking at 34.6°C at Sydney Observatory Hill. Ausgrid's dispatch involved 207 customers, between 3:15 – 6:15pm. The 207 customers have an average storage capacity of 9.6kWh/customer and an average maximum battery dispatch power rating of 3.7kW/customer. The customer battery systems were primarily LG Chem and Tesla batteries. For this dispatch event, an average of 3kW/customer was requested and an average of 2.4kW/customer was accepted by Reposit Power's dispatch engine. See Chart 4 below.

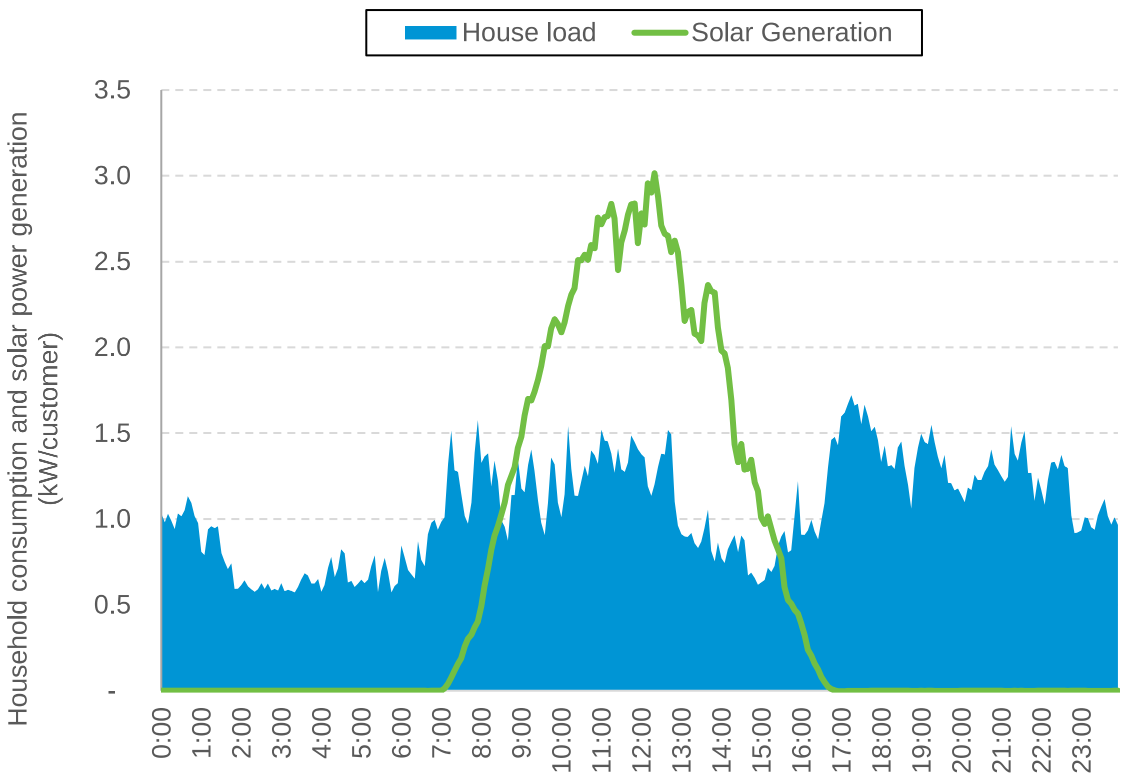
Chart 4, average battery charge and discharge profile on 12 March 2019



On average between 3:15 – 6:15pm on 12th March 2019, 1.8kW/customer in battery dispatch power was delivered. The 31st January 2019 was a non-dispatch day and was selected as a visual comparison of battery operations. The dispatch on the 12th March 2019 resulted in 1.4kW/customer in extra dispatch power when compared against the 31st January 2019 baseline, 1.5kW/customer against the average annual 'business as usual' profile and 1.5kW/customer extra against the average high temperature profile.

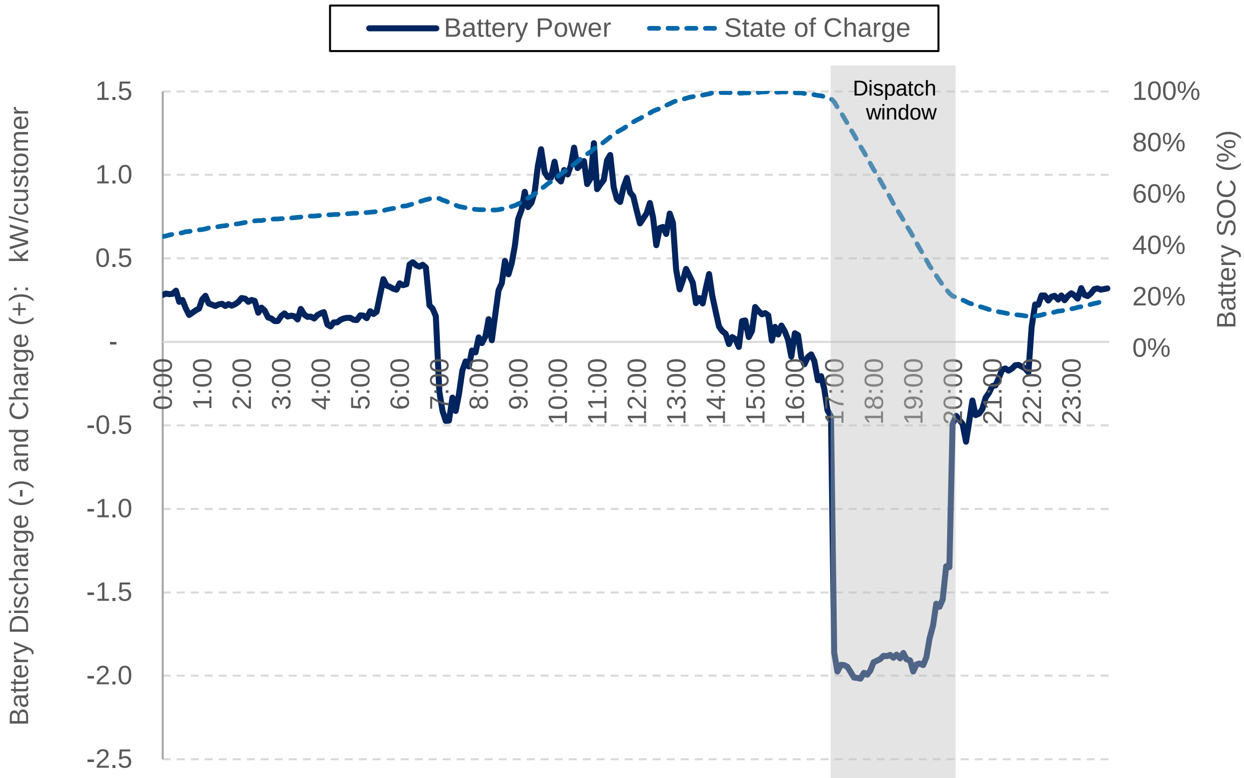
Analysis of the Ausgrid VPP dispatch on 27th June 2019 presents further details on the operation of the battery systems including state of charge, solar power generation and household load. The Thursday 27th June 2019 was a mild day with a maximum temperature of 20.1°C at Sydney Observatory Hill. In this instance, 26 customers with LG batteries and SMA inverters were dispatched, with an average storage capacity of 9.8kWh per customers' battery (one customer had three batteries) and 2.5kW/battery maximum dispatch capacity. Chart 5 below shows the average household load for the 26 customers. Consumption increases from 7am, dips down around midday and spikes up again in the early evening around 5pm. Average solar power generation is relatively smooth throughout the winter day, and peaks at about 3kW/customer.

Chart 5, average battery charge and discharge profile on 27 June 2019



As presented in Chart 6, the VPP was dispatched at 5pm on the 27th June for a duration of 3 hours, with an accepted dispatch target of 2.0kW/customers (2.1kW/customer was requested). In total, 143kWh was discharged at an average discharge power of 1.9kW/customer. When comparing to 'business as usual', 1.2kW/customer of extra power dispatch was delivered on top of the 0.69kW/customer 'business as usual' baseline. Of interest is the fact that the combined batteries average state of charge reached 100% at 2:05pm. As such, from this point on excess solar power generation was exported directly to the grid.

Chart 6, average battery charge and discharge profile and state of charge on 27 June 2019



5 Customer benefit

From a customer perspective, Ausgrid's key trial objectives were to test customer take up, retention and to understand customers' experience and satisfaction. Ausgrid is also seeking customers' views on incentive offers and their motivations for participating in the VPP.

As customer relations are managed by our VPP market partners, Ausgrid is collaborating with our partners to explore customer preferences and experiences. Ausgrid is currently in the process of developing customer surveys with Reposit Power and will publish survey results in an update to this interim report.

With Reposit Power managing the communication and 'onboarding' of customers into the VPP and providing the dispatching software, customer interaction was seamless. A notable outcome was that 97% of Reposit customers in Ausgrid's network area joined Ausgrid's VPP, indicating an exceptionally strong interest and support for the VPP. Over the course of trial activities in 2019, only 3% of customers opted out of Ausgrid's VPP.

Customer solar and battery survey

In 2016, Ausgrid surveyed residential customers to better understand customers' level of knowledge, usage and motivation drivers for installing solar and battery systems. The research, published *here*, (28 April 2017, Household Solar and Battery Survey Project Report) explored customer willingness to participate in demand management trials.

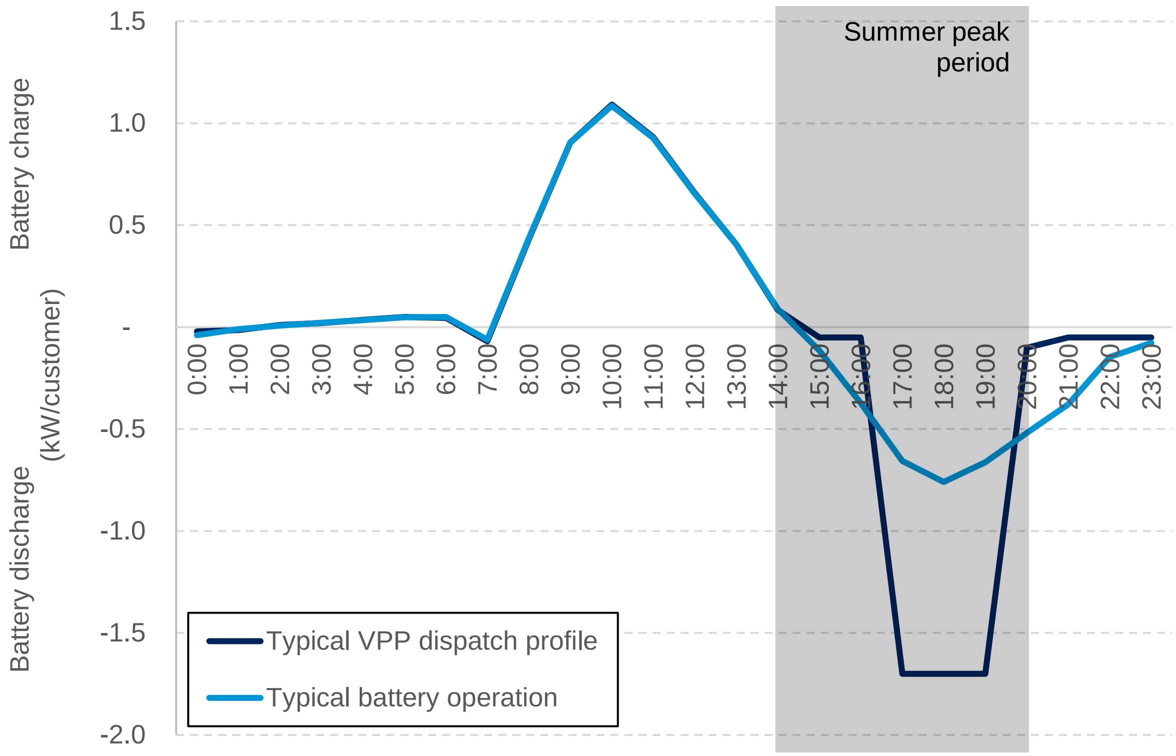
Ausgrid gathered insights from our customers who were battery owners (86 responses), through survey participation. Some of the key findings included:

- The main motivation for purchasing the system was to store excess solar and to save money on their energy bills;
- Over 50% of the battery owners said they were satisfied with their bill savings, however 60% of the battery owners couldn't quantify the amount saved.
- A significantly large proportion of battery owners (71%) check their battery system's performance once a week and the most popular way of checking their system was through an online portal.

Support payments that customers received from participating in Ausgrid's VPP are typically in addition to the bill benefits they received from the usual operation of their battery. By combining benefits from multiple value streams, customers can maximise the financial value of their investment.

As shown in Chart 7 following (with an indicative dispatch profile), batteries typically discharge from about 2 – 3pm until about 9 – 10pm (light blue). This largely coincides with the weekday 2 – 8pm peak period for retail time of use tariffs, resulting in lower imported energy (a common current peak retail offer is roughly between $0.40 – $0.50/kWh). For residential areas, Ausgrid's network typically reaches peak demand from 5 – 8pm in summer and from 5 – 9pm in winter, consequently VPP dispatches would typically fall during peak tariff periods. As such, during an Ausgrid VPP dispatch, customers with time of use tariffs receive the dual benefit of lower electricity import during peak periods and dispatch payments. For customers on flat retail tariffs, in addition to the avoidance of grid electricity imports, customers would receive dispatch payments for any Ausgrid VPP dispatches. As such, customers are financially better off under the Ausgrid VPP program. During a four-month period in early 2019, a total of $7,800 was paid directly to customers in the form of dispatch payments. Phase 2 will further explore the customer bill benefit of VPP dispatch events, to identify the total customer benefit of being involved in an Ausgrid VPP program.

Chart 7, Typical battery operation and a typical network VPP dispatch profile



6 Future research objectives

The results of the phase 1 trial activities highlight the potential offered by residential batteries and VPP solutions in providing demand reductions to avoid or defer network investment. Further research is required to expand and verify the preliminary results and to answer broader research objectives. A larger customer sample size and broader set of VPP providers will aid in achieving these trial objectives. From phase 1 outcomes, we have identified the need to explore the following:

- Dispatch profile: how can the dispatch operation be optimised to deliver an optimal dispatch profile? For example, in the dispatch on 27th June 2019 (Chart 6), 2kW/customer was accepted. Almost 2kW/customer was delivered for the first 2 ½ hours, but dispatch energy declined to about 1.4kW/customer at the end of the dispatch event.
- Dispatch timing: accurate short-term forecasting of customer demand is necessary to ensure that battery dispatch events are optimised to deliver maximum demand reduction benefits for the grid. For example, in the case of the dispatch on 12th March 2019 (Chart 4), the dispatch ended at 6:15pm. Between 7 – 8pm on the 12th March, the VPP group is only providing approximately 0.25kW/customer of benefit to the grid, whereas on the 31st January (the visual baseline) between 7 – 8pm the customers were providing a ‘business as usual’ benefit to the grid of approximately 0.6kW/customer. If very high demand on the electricity network had continued until 8pm, but the dispatch ended as planned at 6:15pm, then the dispatch event would have reduced the demand reduction on the grid by about 0.35kW/customer between 7 – 8pm.

- Requested, accepted and delivered dispatches: Why under some conditions does the accepted energy dispatched not match the requested energy dispatched? Further investigation is required to understand the root cause at each battery when the requested dispatch is not delivered. For example, a battery not dispatching may be due to communications failure, its battery control algorithm, battery state of charge or other site specific reasons.
- Voltage control: further exploration in phase 2 is required to assess the value of VPPs in operating to increase or decrease the grid voltage to manage fluctuations in the grid voltage.
- Time of use and flat retail tariffs: future analysis and information is required to assess the typical 'business as usual' operation of battery systems when customers are on time of use retail tariffs in comparison to flat retail tariffs.
- Customer and aggregator surveys: explore customer and aggregator satisfaction and preferences over the course of the trial.

Are behind-the-meter batteries ready to be orchestrated to address network needs?

While this battery VPP project is seeking to test technical and commercial viability, a challenge in the use of residential batteries to meet existing network needs is the concentration of residential batteries.

Ausgrid recently released a request for proposals, published *here*, seeking providers to propose solutions to provide 190kVA of redundancy support to the Gillieston Heights area. Of the 2,800 residential customers in the region of the network need, only 15 customers had batteries, representing 0.5% of the customer base and roughly equivalent to a potential for 15-25kVA in peak demand reductions.

While no demand management providers proposed the use of customer battery systems, an internally developed solution is currently in planning which seeks to include an element of customer battery systems.

7 Conclusion

Results from phase 1 of the Ausgrid VPP project with Reposit Power were very encouraging. The results suggest that residential battery systems without VPP control (Reposit Power's 'business as usual' operation) typically reduce grid electricity demand during evening peak periods, suggesting that the wider rollout of residential batteries will have a positive benefit on the network. Results highlight the significant potential for the orchestration of residential batteries to support Ausgrid's network needs, above and beyond typical 'business as usual' operation, suggesting that VPPs can offer both a cost-effective source of demand reductions for Ausgrid and additional income for customers. Further investigation and a larger customer sample set (with multiple VPP aggregators) throughout phase 2 will assist in the validation of existing results and will enable the investigation of broader and more detailed research objectives.