Networks Renewed: Project Results and Lessons Learnt

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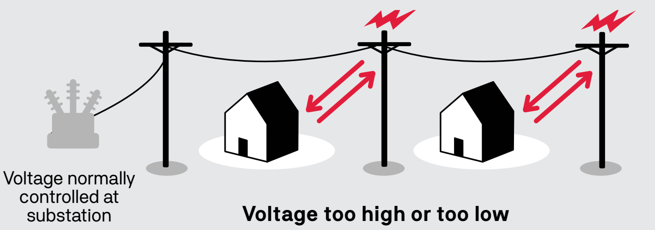
Networks Renewed: Making our electricity grids smarter

The challenge

Supplying safe, reliable power to our homes is a complex task, particularly when it comes to managing voltage. Managing voltage is not a new problem due to our long power lines and different demands for electricity. However, it has become a bigger issue recently as more solar systems are connected to the grid.

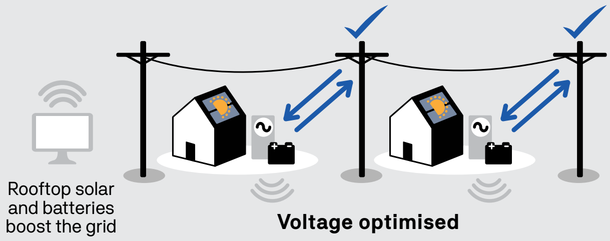
When solar generation is at its highest in the middle of the day, demand can be at its lowest (while people are at work), leading to a widening 'voltage envelope' that is difficult for the network business to resolve. This can limit the amount of solar that can be easily connected to the grid.



Voltage too high or too low

The innovation: Networks Renewed

Networks Renewed had two phases:
a pilot-scale demonstration (2017-18) to test the technical voltage control capability at a small scale; followed by a market-scale demonstration to ramp up the deployment and deliver significant network impact (2018-19). The trial recruited 90 customers under innovative commercial models with three network business partners – Essential Energy in NSW, and United Energy and AusNet Services in Victoria. The control and integration technology was provided by two new energy businesses: Reposit Power and Mondo.



Voltage optimised

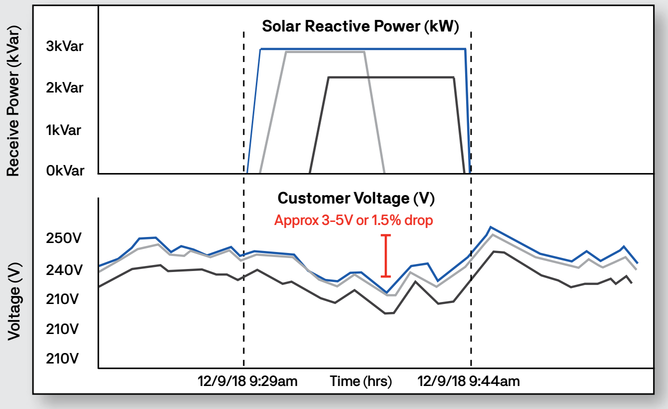
The trial's major achievement was to show how customers can help the grid host rooftop solar power.

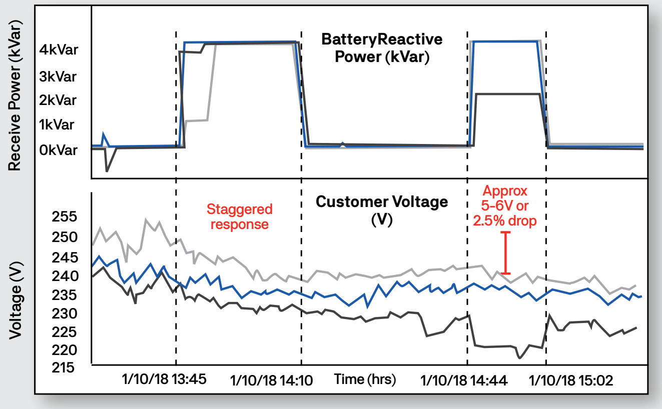
Results

The trial proved that both solar and batteries can support network voltage. Its success opens the door to a suite of new business opportunities based on the premise that rooftop solar can be an asset to everyone.

The other major outcomes were:

- Proving realistic alternatives to network-side voltage solutions
- Making voltage support services from solar and batteries accessible to network businesses
- Obtaining good results for participating customers, and
- Determining the network value of voltage support provided by customers.





What's next?

It is now time to move this technical solution to a viable mainstream option. The diagram below shows all the moving parts needed for customers to provide their support for the electricity grid Australia needs.

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Project Overview

Project summary

Networks Renewed is a smart inverter demonstration project to address network power quality issues that are emerging through widespread uptake of rooftop solar photovoltaics (PV). Its specific aim is to understand the extent to which residential solar panels and battery storage can manage voltage in distribution networks via active and reactive power. Thereby turning a potential problem into a solution.

If the solution is adopted, we hope that this will expand the PV hosting capacity of the grid.

Networks Renewed had two deployment phases: a pilot-scale demonstration in 2017-18 to implement and test potential inverter control algorithms for voltage regulation at a relatively small scale; followed by a market-scale demonstration to ramp up the deployment so that significant network impact could be achieved in 2018-19.

Pilot-scale demonstration

- United Energy (Victoria) tested eight dual solar-storage units at urban sites across two distribution substations to test methods for coordinated inverter actions using different control algorithms; and
- Essential Energy (NSW) tested solar-storage units at 22 sites near the end of a lengthy rural single-wire earth-return (SWER) feeder where demand variance and solar PV generation was creating voltage excursions.

Market-scale demonstration

- Based on the observed impact at pilot scale, Essential Energy (NSW) enlisted solar-storage units at a further 10 sites along the SWER and 3-phase feeder, and also tested reactive power controls at 9 solar-only sites in an urban setting.
- The scale-up in Victoria was undertaken in partnership with a different distribution network service provider (DNSP) in Victoria. AusNet Services tested 14 solar-storage devices from customers along a SWER feeder in Ben Valley and 35 solar-only devices in wider Yackandandah to substantially correct voltage on the low voltage (LV) network, with some impact also shown on the high voltage (HV) network.

Project scope

Networks Renewed is seeking to address the problem of solar-induced network voltage imbalance

The rapid uptake of rooftop solar PV worldwide is changing the way distribution network service providers (DNSPs) manage electricity, which creates new technical and social challenges.

Australia is a key market to investigate the impacts of distributed energy resources (DERs) on the electricity system with the highest uptake per capita of rooftop solar worldwide to date, collectively generating over 7 GWh of electricity each year (Australian PV Institute (APVI) Solar Map, accessed on 5 September 2018). In some areas of Australia's low voltage (LV) network, solar penetration is already over 50%. In locations with such high penetration, particularly where there is also low population density, Australian DNSPs are already experiencing grid management issues. A major issue that has been identified in areas of high solar penetration is greater voltage fluctuations and excursions, exacerbated by the new two-way flows of electricity.

The technical challenges of managing excess solar PV, and the voltage fluctuations it contributes to, can also lead to inequitable social outcomes, particularly regarding the distribution of the cost of solar, its management and the network. For example, the inverter-connected assets are owned by residential consumers who may be vulnerable through: information disparity either through a lack of access to information and/or the depth of understanding; financial exposure from both the cost of the asset and the network itself; and access to network infrastructure e.g. unequal provisions of connection approvals. In the Australian market, it is the responsibility of the energy market regulators to protect the interests of energy consumers as the energy system transitions to new technologies and business models.

Networks Renewed is seeking to overcome both technical and socio-economic barriers to DER-sourced voltage regulation by demonstrating a viable business model.

The aim of Networks Renewed is to provide the technical and economic rationale for Australian DNSPs to use solar PV inverters and battery energy storage inverters to manage voltage successfully. The project is specifically seeking to demonstrate that advanced, distributed control of inverter-connected resources can have a positive impact on voltage on the LV network, make economic sense for DNSPs, and be attractive for consumers, thus increasing the distribution networks' capacity for hosting more distributed renewable energy.

The core technical research question for the project is:

> *How can inverters connecting consumer solar PV and batteries be controlled to address power quality issues (especially voltage regulation), and what penetrations of distributed solar PV can then theoretically be achieved?*

A viable technical approach needs to work alongside other inverter functions to ensure that, taken as a whole, using inverters in this way is good value for money for all stakeholders including consumers, DNSPs, and potential new entrants that may deliver the novel business models required. This determines the parallel socio-economic research question:

> *Is using consumer inverters more cost effective than traditional network enhancements, and correspondingly, what is the value to DNSPs of services delivered by these inverters under effective control?*

To answer these questions, Networks Renewed sought to develop a practical understanding of the commercial value of new smart inverter technology by:

- Upscaling the technology and demonstrating a viable business model, and
- Using an industry-led approach to experimentation, in order to reflect the market as closely as possible.

By exploring questions of efficacy and value via real-world deployment of DER-based ancillary services, the project delivers findings which are relevant far beyond the extent of voltage control.

In the emerging ecosystem of DERs in the transforming grid, solutions such as demand response programs, other services like frequency support, and infrastructure paradigms like microgrids, share many overlapping challenges. These include: customer recruitment; logistical issues around hardware deployment; the need for novel business models; the need for intermediary services, such as brokerage and market platforms; regulatory hurdles, like ring-fencing and wholesale market access; ensuring positive customer experiences, along the full journey from consumer to prosumer; ensuring safety, by ensuring all installation, operation, and maintenance works are compliant with best practice; and the social and equity issues discussed in earlier sections. Equally as relevant are the potentially overlapping opportunities that such projects may deliver, including: improved visibility of network conditions through deployment of “Internet of Things” (IoT) systems; greater penetration of renewable generation; greater system resilience and improved energy security; and prosumer empowerment. The exploration of these shared challenges and opportunities is not only informing how future voltage solutions are deployed, but also demonstrating the future energy ecosystem that includes active DER-based solutions.

Networks Renewed approached these challenges by developing a business model for potential service options that are available to consumers with inverter-connected resources. The business model refers to the concept of how an organisation generates and captures value. The project investigated the types of network programs, consumer initiatives and third-party businesses to reflect the four elements of a business model - 1) the product, understood as a value proposition; 2) the consumer interface; 3) the organisational infrastructure and its management; and 4), financial considerations e.g. revenues and costs.

By demonstrating the viable technology and business model, Networks Renewed sought to both build capacity within the project partnership, and share the knowledge with other key energy sector stakeholders who could also implement the solution into the future.

Outcomes

The project’s major achievement was that it proved that both solar and batteries can support network voltage:

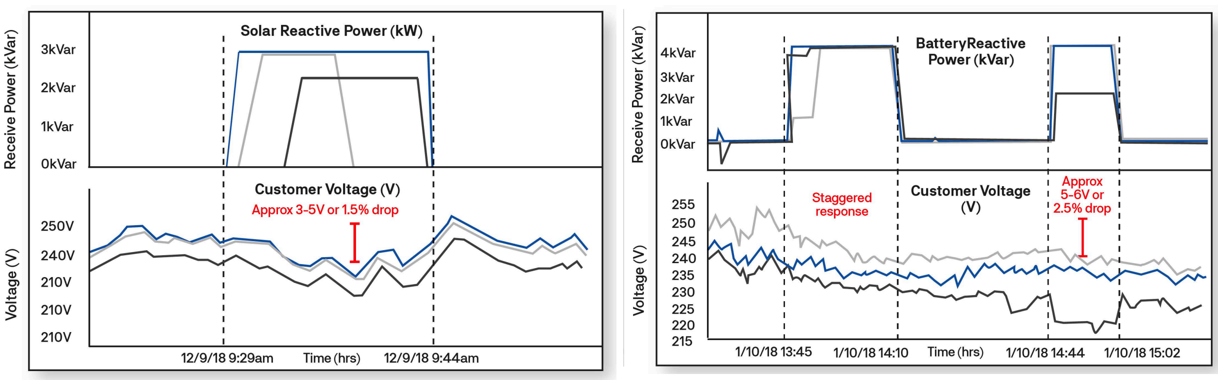
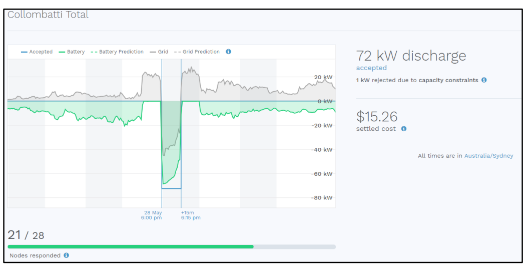


Figure 1. AusNet Services (Victoria) was able to use reactive power from both solar and batteries to regulate network voltage

Essential Energy (NSW) was able to use real power from solar storage units to regulate voltage



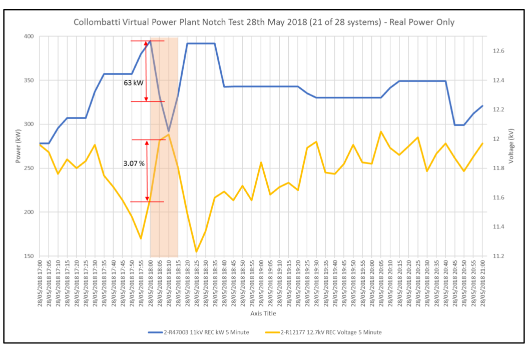


Figure 2. Essential Energy (NSW) was able to use active power from solar storage units to regulate voltage

There were also two other key technical and socio-economic outcomes detailed in the 'lessons learned' packages below:

Technical outcomes:

1. **Proving realistic alternatives to network-side voltage solutions.** Voltage was substantially corrected in two low voltage (LV) networks, with some positive impact observed at the high voltage (HV) level. Thus, the partners determined the extent to which customer and distribution network voltage can be influenced by real and reactive power.
2. **Integrating DER-based voltage support services into network operating practices.** Four inverter types were successfully controlled via two [third-party] aggregator platforms. These platforms were fully integrated with all three DNSP partner operations, however manually and separately to normal network operations.

Socio-economic outcomes:

1. **Obtaining good results for participating customers.** Trial participants were generally happy with their involvement in the project and expressed an interest in more deeply engaging with their energy production and use in the future.
2. **Determining network value of DER-sourced voltage support.** The project allowed for a high-level economic comparison of the DER solution with traditional network-side solutions.

The overall value of the trial is multi-faceted, bringing DNSP partners one step closer to being comfortable with replacing traditional network-side solutions with DER-based options. The project brought together the key players needed to create change allowing them to: build social networks; create a shared understanding of visions and expectations; and develop learning processes. The project also facilitated deep engagement with key stakeholders across the transitioning energy sector including: DNSPs, retailers, technology providers and aggregators, energy market institutions, government and research institutions.

A video of the Victorian trial was presented at the project roadshow and helps give a sense of the project's success: showing the geographic extent of the trial and some customer systems in context of the network they are supporting.

The technical results of the trial either met or exceeded our initial expectations, however the commercial-readiness of the solution is further away than we had thought. Each trial required bespoke design and application, particularly with regard to acquiring sufficient participation by customers and integrating remote DER-control with DNSP Supervisory Control and Data Acquisition (SCADA) systems. This resource-intensive process is too costly for all the partners involved, therefore each step of the process needs to be simplified and/or standardised in order for DER-based voltage regulation – or, in fact, any DER-based network support service – to become a viable alternative to network-side solutions. This issue is further explored in the following section.

From the lessons we have learned through this project, we have established a pathway for DER-based network support services to be commercially ready AKA "mainstreamed": a vision of the market conditions that will exist if customer-owned DERs are able to contribute network support services for a clean, reliable, affordable and equitable energy future.

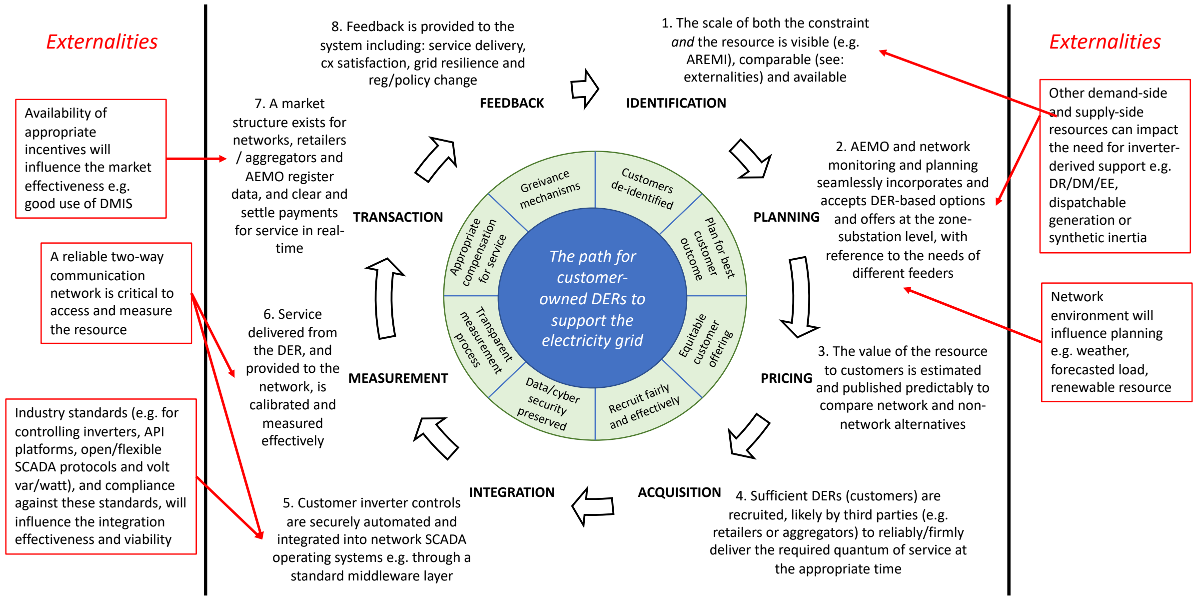


Figure 3. Proposed pathway for customer-owned DERs to support the electricity grid

1. The scale of both the constraint and the resource must be visible, comparable (see: externalities) and available; customer information must be de-identified
2. AEMO and network monitoring and planning must seamlessly incorporate and accept DER-based options and offers at the zone-substation level, with reference to the needs of different feeders; planning must deliver the best outcome for consumers
3. The value of the resource to customers must be estimated and published predictably to compare network and non-network alternatives; the customer offering must be equitable
4. Sufficient DERs (customers) can be recruited, likely by third parties (e.g. retailers or aggregators) to reliably/firmly and safely deliver the required quantum of service at the appropriate time; recruitment of customers must be effective and fair
5. Customer inverter controls can be securely and safely automated and integrated into network SCADA operating systems e.g. through a standard middleware layer; data/cyber security must be preserved
6. Service delivered from the DER, and provided to the network, must be calibrated and measured effectively; the measurement process must be transparent
7. A market structure must exist for networks, retailers / aggregators and AEMO to register data, and clear and settle payments for service in real-time; customers must be compensated appropriately, and
8. Feedback loops must exist for: service delivery, customer satisfaction, grid resilience and regulatory/policy change; grievance mechanisms must be in place.

Externalities that must be accounted for include: other demand- and supply-side resources that impact constraints; network forecasts; industry standards; the reliability of communication platforms; and the availability and effectiveness of incentives.

Customer equity and protection must underpin each stage of the pathway as italicised in the above pathway.

Transferability

Networks Renewed sits amongst a suite of complementary projects that are investigating smart grid options, including DER-based network support services.

- The key international project that we considered when developing the project was project 2.03A under the EPIC Program, run by PG&E in the US. This project is testing the capabilities of behind-the-meter inverters, as we have in Networks Renewed, however has focused its demonstration on the commercial & agricultural sector rather than residential applications.
- In Australia, ARENA funds several projects investigating the value-stack for DERs. There are several virtual power plant (VPP) projects being deployed to use customer solar and storage to help manage network demand and to explore the value of these resources to an energy retailer. Perhaps the most relevant concurrent project is research into consumer energy systems providing cost-effective grid support in Tasmania (CONSORT).

However, Networks Renewed is the only project focused on voltage, which has emerged as one of the main constraints to LV hosting capacity of renewables. Due to the technical sophistication of distributed voltage management and the highly nuanced concept of value for these services, our demonstrations have pushed limits and established the requirements and framework for a wide set of potential roles for customer solar and storage in supporting the reliability of our power grid.

The project was designed to test a viable commercial approach to smart inverter control, in particular for voltage regulation i.e. key actors, supporting a viable business model following a comprehensive pathway. However, the approach was bespoke to each network business. Considering the life cycle above, this meant:

1. The DNSP identified the constraint and sought solutions on a case-by-case basis;
2. Non-network alternatives were incorporated into DNSP planning based on business preference;
3. Customers were recruited through direct marketing, via an aggregator and installers;
4. Aggregator provides integration platform e.g. Reposit Marketplace;
5. Service delivery is measured at the meter level i.e. individual houses;
6. DNSP reimburses customers via the aggregator; and
7. DNSP evaluated the effectiveness of the solution compared with network alternatives and the aggregator measured customer satisfaction.

This is replicable but perhaps not the ideal model going forward.

Knowledge sourcing and sharing

Following the major project milestones, the project team sought feedback from key subject matter and industry experts to both reflect on the success of the work and inform the future direction of the project. The experts were targeted through ISF's extensive network of DNSPs, energy retailers, emerging energy businesses, policy makers and regulators, and research collaborators. In particular:

- ISF hosted an invite-only forum following the public release of the initial technical analysis, which informed the design of the pilot-scale trial;
- The project team ran an invite-only roadshow across four Australian capital cities in order to test the preliminary research findings with key members of the industry, in particular other DNSPs, energy market regulators and emerging energy businesses; and
- ISF collaborated with the social research team at the University of Tasmania – who are a partner in the concurrent CONSORT trial that investigated other network support mechanisms from battery storage – to design a best practice participant experience survey and interviews.

The project delivered a comprehensive knowledge sharing plan in order to share the findings across industry, academia and the wider public to hopefully influence transformation. Under this plan, the project team has:

- Presented at five industry conferences: 2017 & 2018 All-Energy Conference, ATA Canberra 2017, EECON Australia 2017 and Energy Networks 2018;
- Presented papers at two academic conferences: the 2016 Asia Pacific Solar Research conference (Canberra, Australia) and the 2019 International Conference on Applied Energy (Oxford, United Kingdom);
- Published three articles in key Australian industry magazines and journals including Ecogeneration Magazine, the Conversation and RenewEconomy;
- Held public forums with key industry and research stakeholders to share key findings, including the preliminary technical analysis and final business case;
- Held a roadshow across four Australian capital cities to share the final project findings with key industry and research stakeholders;
- Regularly updated the project website, accompanied by media releases.

Publications

Alexander D., Wyndham J., 2019, Harnessing voltage regulation services behind the meter: challenges to deployment, International Conference on Innovative Applied Energy 2019, Oxford, United Kingdom.

Alexander D., James G., 2018, Short-circuiting the voltage problem, Ecogeneration Magazine, Issue 109, December 2018, pp 46-50.

McIntosh L., Alexander D., 2017, Crisis, what crisis? How smart solar can protect our vulnerable power grids, The Conversation, 8 February 2017.

Wyndham, J., James, G., McIntosh, L., Alexander Danielle, 2016. Network Services from Distributed Solar PV and Inverters, Asia-Pacific Solar Research Conference 2016, Canberra, Australia.

Awards

We have submitted Networks Renewed to be considered for the Good Practice of the Year award, in the category "Technological Innovation & System Integration", of the Renewables Grid Initiative. This is a unique collaboration of non-governmental organisations and transmission system operators from across Europe. The evaluation period is ongoing at the time of writing. Winners will be announced at the Energy Infrastructure Forum on 23 May 2019 in Copenhagen.

Conclusion and next steps

Networks Renewed is the first Australian trial to demonstrate that voltage regulation services can be commercially obtained from customer-owned solar PV and battery storage.

We are confident that the technical application of the Networks Renewed approach would work for other network support services, with other DNSPs, on other LV networks for other customers. However, the current business model may not offer the best value for all the key parties involved. We are pursuing a follow-on project that investigates other options that may be more commercial. This is based on the proposed pathway for DER-based network support services to be commercially ready described above (Figure 3).

Based on this, we suggest the following research is needed to pave the path for customers to support our grid:

1. Publish a model of the LV network that visualises both network constraints and DER resources in real-time
2. Understand the implications of voltage impact on a 3-phase feeder compared with a SWER feeder
3. Develop a dynamic approach to pricing network support services, potentially including dynamic connection standards, according to a real-time market value to increase network hosting capacity and higher utilisation of DER
4. Test a business model that allows multiple aggregators to maximise the potential number of customers in an area to address a constraint
5. Develop a common API across the industry e.g. via the VPP Technical Reference Group developing standards/protocols for a shared API
6. Understand and quantify the impact of voltage improvements on surrounding customers e.g. on the HV network and other feeders
7. Increase the flexibility and reliability of service transactions with customer DERs
8. Develop a better understanding, now and over time, of customer motivation and capacity to provide network support services from their assets

Project design is currently underway in collaboration with partners, however we anticipate these main areas of activity:

- **Promoting standards and middleware** to achieve many-to-many relationships between DERs and aggregators on the one hand, and service off-takers (retail and network) on the other. This is necessary to achieve scale for impactful services, ensure positive customer experiences, minimise risks, enshrine safety, and to combine multiple values for customer DERs. This will complement ARENA's evolve DER project.
- **Integrating DERs, aggregators, and service off-takers** with the deX middleware that we suggest is the most viable present candidate to facilitate the full range of service elements in Figure 3 having received substantial ARENA investment. Development and support for the common good will be included.
- **Scalable customer acquisition** using a two-layer approach. General lifting of public knowledge will be achieved by television and internet campaigns to create informed

customers who know how to recognise a good deal. Specific customer approaches in network areas addressed by the project will be undertaken by project partners.

- General support and knowledge sharing between network businesses undertaking demonstrations of DER orchestration, that include voltage regulation and related network services, and other partners that provide aggregation, integration, and obtain value necessary for the business case.

Lessons Learnt

Lessons Learnt Report: providing realistic alternatives to network-side voltage solutions

Project Name: Networks Renewed

Knowledge Category:	Technical
Knowledge Type:	Technology deployment
Technology Type:	Voltage regulation, solar PV and battery storage
State/Territory:	Collombatti/Bellingen, New South Wales & Yackandandah/Mooroolbark, Victoria

Key learning

A major achievement of Networks Renewed was that it proved that both residential solar PV and batteries can support network voltage:

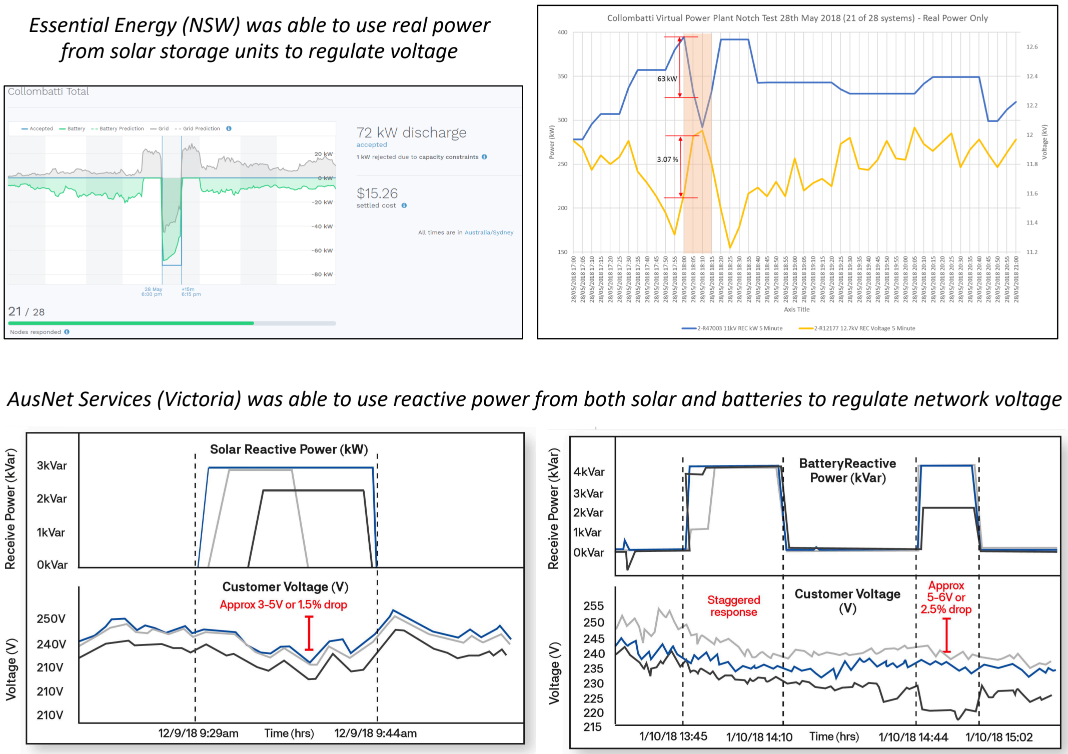


Figure 4. Project Results snapshot

- In Collombatti (NSW), it was possible to improve power quality on both low and high voltage (LV and HV) lines by dispatching active power and reactive power from smart solar PV and battery storage systems. This benefited all customers on the single-wire earth return (SWER) feeder. If commercially deployed, this could defer network investments of re-conductoring at cost of ~$300,000, which was the least cost network side option to address the emerging network constraint. See Figure 4.
- In Yackandandah (Victoria), reactive power sourced from inverter-connected solar and storage delivered a substantial (3-5V) voltage correction in the LV network due

reactive power response from inverters. The solar reactive power response was sporadic, suggesting that even greater impact could be possible if inverter control was improved. It is likely that a commercial deployment of this solution would be less expensive alternative to splitting the SWER feeder at a cost of $150,000.

- Despite low solar generation in the evenings, substantial reactive power is still available from the inverters used in Yackandandah even at very low levels of active power. These inverters have a specification of minimum 0.8 power factor, however, they were able to produce the requested 3 kVAr even when solar generation had fallen to the order of 100 W, which corresponds to a very small power factor.
- Dispatching reactive power (kVAr) slightly reduces active power (kWh) output, particularly when solar generation is high. Control algorithms can optimise the output of reactive power so as to leverage systems that generating less electricity, to minimise the impact on active power and thus payments for solar electricity export to the grid.
- In the future, oversizing inverters may result in higher return to customers based on increasing active export capacity while using reactive power to manage network voltage. This type of arrangement could be an option when connecting to the network e.g. when considering the cost-benefit trade-off of dynamic connection standards vs static connection standards.
- When providing reactive power from batteries, their rate of discharge slowed before the test window was complete, suggesting that the available service capacity and duration was not accurately predicted. The trial targeted the power factor based on lower battery export capacity to maximise network support potential. Improving prediction algorithms is important in order to provide a firm network service.

Implications for future work

The demonstrations were primarily run on rural SWER feeders that were identified as problem areas by the relevant distribution network service provider (DNSP): Essential Energy in NSW and AusNet Services in Victoria. Although the NSW trial touched on these elements, there was limited scope of the trial to fully understand the impacts on the range of feeders and on surrounding customers. Thus, there is now a need to upscale the demonstration in order to:

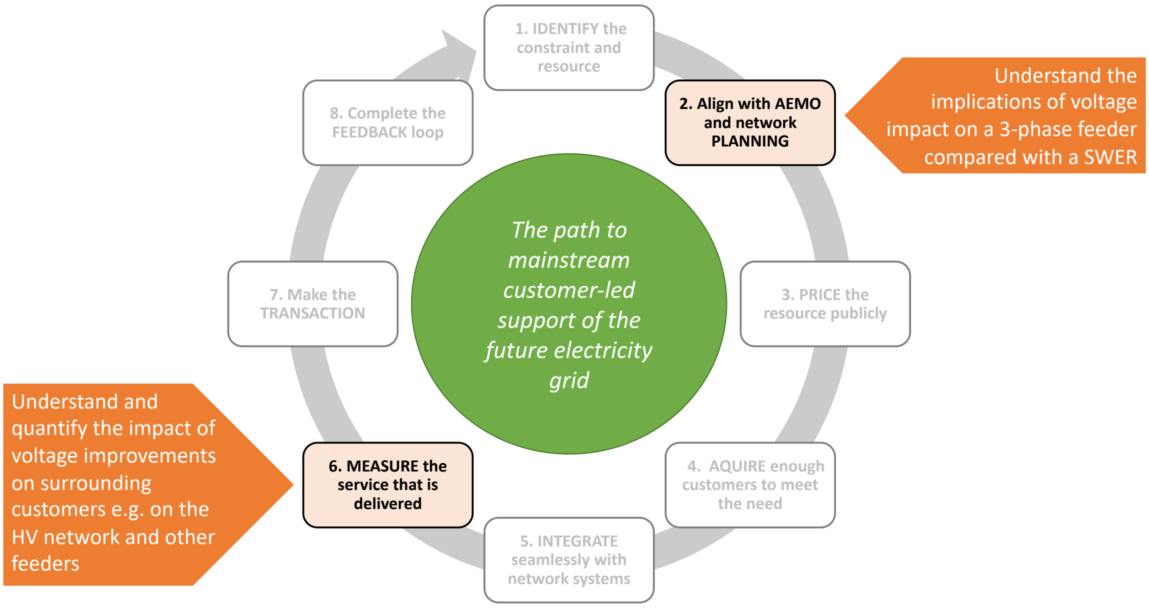


Figure 5. Proposed pathway for customer-owned DERs to support the electricity grid

Improving prediction algorithms will be critical to an upscaling strategy. This improvement would serve to de-risk aspects of the operation of DER-control for the DNSP, making the demand-side solution a more viable alternative to traditional network-side investments. This would be an ongoing process throughout any future projects as machine learning algorithms are better able to assess a broader array of informational inputs in making their predictions. Further detail is at Figure 7.

Background

Requirements of the Project

Given high solar uptake forecasts of larger PV systems, power quality issues such as voltage regulation are likely to become a bigger problem for DNSPs. The core technical research question of the project was: how can inverters connecting consumer solar PV and batteries be controlled to address power quality issues (especially voltage regulation), and what penetrations of distributed solar PV can then theoretically be achieved?

To address this question, the trials sought to understand the extent to which residential solar PV and battery storage could manage voltage in the distribution network, particularly the LV network, through active and reactive power[1].

[1] *Active power* (P) exists when voltage and current mirror each other i.e. are ‘in phase’. *Reactive power* (Q) exists when the current and voltage are out of sync i.e. not ‘in phase’. The combination of P and Q is *apparent power* (S).

Process undertaken

Networks Renewed deployed two market-scale demonstrations, large enough so that significant network impact could be achieved, addressing voltage problems for two different distribution network service providers (DNSPs):

- Essential Energy (NSW) enlisted solar-storage units at 32 sites near the end of a lengthy rural single-wire earth-return (SWER) and 3-phase feeder, where peak load and solar PV generation was creating voltage excursions, and also tested reactive power controls at 9 solar-only sites in an urban setting.
- AusNet Services tested 14 solar-storage and 35 solar-only devices at customer sites along a SWER feeder in Ben Valley to substantially correct voltage on the low voltage (LV) network, with some impact also shown on the high voltage (HV) network.

Prior to reaching this scale in 2019, Networks Renewed had a pilot-scale demonstration phase in 2017-18 to implement and test potential inverter control algorithms for voltage regulation at a relatively small scale. United Energy (Victoria) tested eight dual solar-storage units at urban sites across two distribution substations to test methods for coordinated inverter actions using different control algorithms. Essential Energy (NSW) tested solar-storage units at an initial 22 sites, to gather data on their effectiveness in voltage control, which allowed an estimate of the number of sites required for the market-scale demonstration.

Also, in Victoria, and concurrently with Networks Renewed, AusNet Services ran the Mooroolbark Community Mini Grid project to help prepare for a future where the electricity distribution network will be used in very different ways by customers. Solar and battery installations were hosted in the homes of 14 out of 18 customers in a single street, who agreed to participate and allow orchestrated control of these energy assets. This extremely high penetration of solar allowed voltage and frequency regulation and total harmonic distortion to be explored during islanded operation, which meant disconnecting this street from the wider grid and powering it entirely from customer solar generation and batteries, for a limited period of time. Results from this project are taken from an internal project report kindly made available to the project team: Mooroolbark Community Mini Grid Project Final Report, AusNet Services, December 2018.

The NSW demonstration conducted two main series of tests

- **Notch tests** where Essential Energy called on the inverter-connected battery storage systems to deliver active power to the network. These were 15 minute on-demand export events. The tests used “lock outs” from the battery systems’ normal optimisation process to gauge the full voltage improvement of the VPP compared with a case of no installed batteries. During the pilot-scale demonstration, Essential Energy was able to call on over 50 kW of active power to improve local voltage by 1.73%. The market-scale the trial and was able to expand the types of tests conducted and also focus a greater number of systems in a tighter geographic region. A test in January 2019 using power from only 17 systems achieved a 2.9% voltage impact, see Figure 6. Essential Energy also undertook a series of minor reactive power notch tests where reactive power was found to be able to contribute approximately 25% of the total voltage impact.
- **Evening peak abatement tests** where Essential Energy signalled a time period from 2.5 to 4 hours long, in the evening, when voltage sag was expected to occur. The signal picked up by the VPP systems would then allow them to optimise their charging behaviour during the day in order to maximise the contribution to the evening discharge window when support was required. These tests achieved the impact of a notch test over a longer period, however where not always able to perform for the full

amount of time predicted, with charge levels becoming depleted before the full discharge window had elapsed.

The Victorian demonstrations were run by United Energy and AusNet Services. The research was directed at leveraging the reactive power function of the inverters to improve network voltage while maximising the participant's solar investment. These programs followed a 'local/global control' technique, global control over inverters was used to send participating inverters algorithms and parameters of how to respond automatically to changing local conditions. A before and after comparison on any one response is less clear than in the Essential energy notch tests, however the broad impact of the strategy in contrast with Business as Usual is nonetheless clear when viewed over many events. Once again two major types of tests were conducted:

- **Solar Only tests,** where reactive power capabilities of inverters was drawn upon with the only active power contribution being supplied directly from solar generation
- **Solar and Battery tests**, where greater flexibility of dispatch of reactive power was introduced with the inclusion of battery storage. We note that in a theoretical sense as it is not real power, reactive power dispatch should not require any energy dispatch. Despite this, inverters are often limited in the range of power factors at which they operate thus requiring some form of active power availability to also supply a reactive component.

Reactive power was found to improve conditions by an average of 5 to 10 V for a 40kVar injection in the Yackandandah trials

Supporting information

Impact of Active power: Peak abatement tests and VPP notch on

Impact of power export, effectiveness and longevity

Figure 6 shows two examples of typical evening dispatch test of the Collombatti market-stage trial in NSW. During the day, solar export and voltage is high, and voltage begins to sag in the early evening. Essential Energy triggered a 4-hour discharge just after 5pm and voltage increased instantly. However, the batteries' rate of discharge slowed before the test window is complete, demonstrating that future work should seek to improve control and prediction.

These tests included reactive and active power components in an attempt to test the maximum impact that the VPP could supply and sustain.

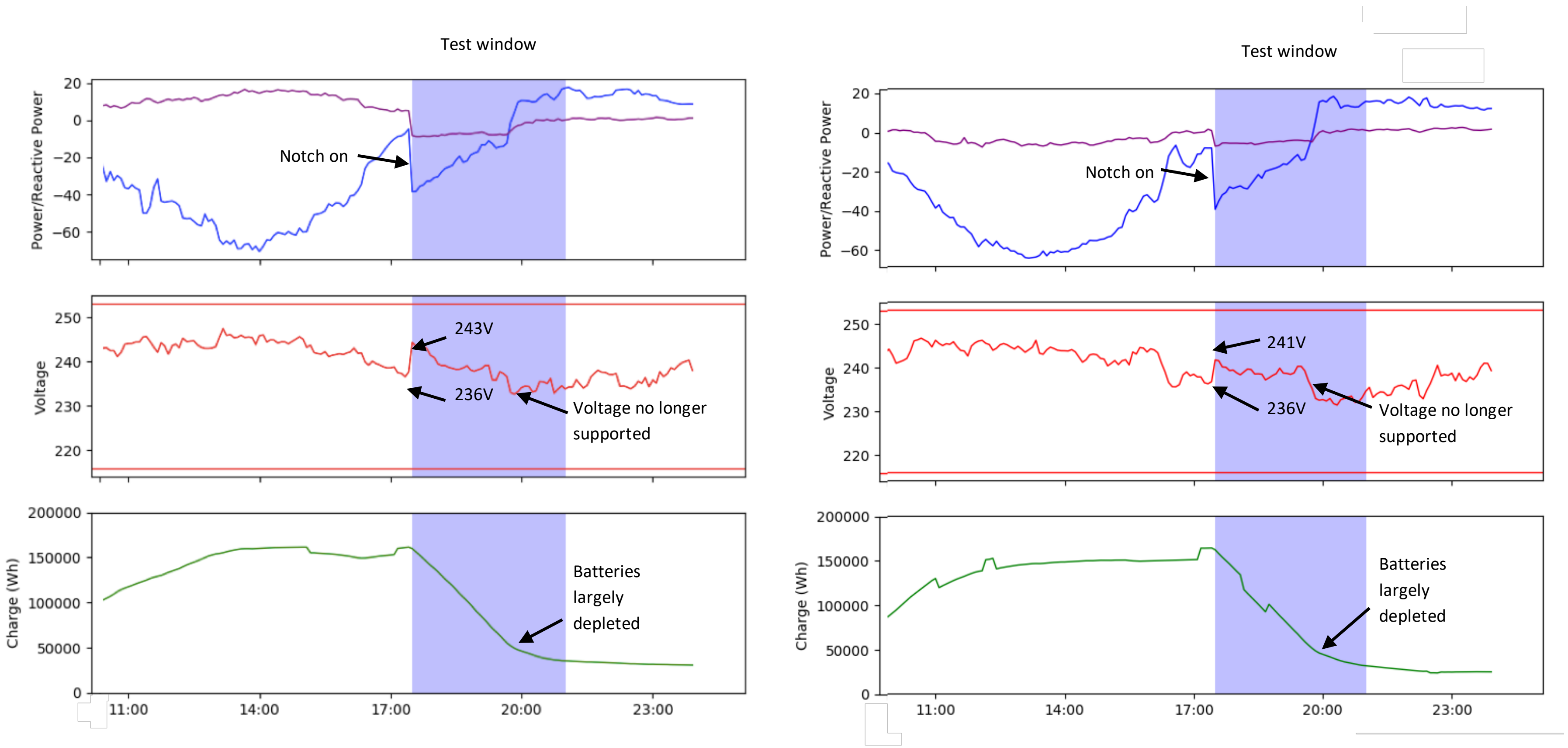


Figure 6. Peak shaving trial results from the Collombatti feeder in NSW

Improving estimation algorithms

Figure 7 below shows response from the Collombatti trial as a function of what was requested. In general system availability was lower than the platform indicated could be drawn. This was both in terms of kW response (below) as well as duration that the response could be provided for. For a perfectly responding system, points would be expected to appear entirely on the dashed line.

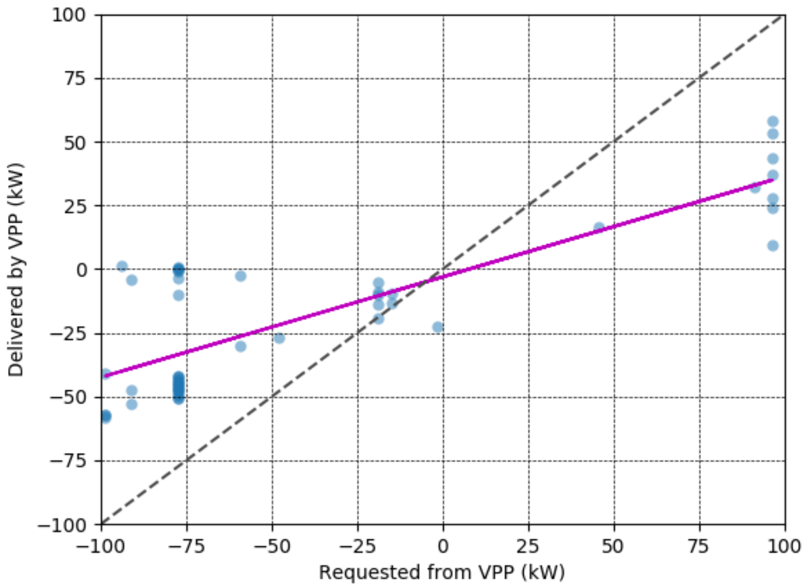


Figure 7. The potential to improve estimation algorithms

Reposit Power has already moved to implement a more adaptive estimation algorithm into their controller, which unfortunately was not able to be commissioned in time for the trials.

The Yackandandah sites were more consistently capable of performing according to control action requests. Notably this included solar only sites, even during low solar generation where performance was only marginally affected. Figure 8 and Figure 9 show this performance for solar and battery sites, and solar only sites respectively. Figure 10 shows the slightly reduced performance of a solar only site during the low solar day.

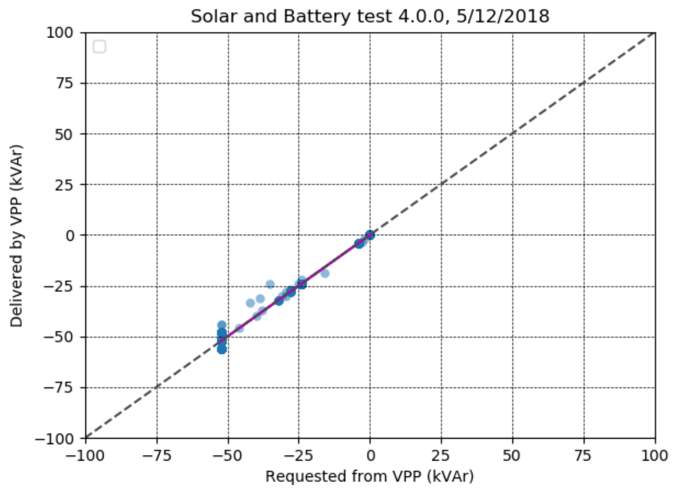


Figure 8 Capability of solar and battery to respond to reactive power request (Yackandandah)

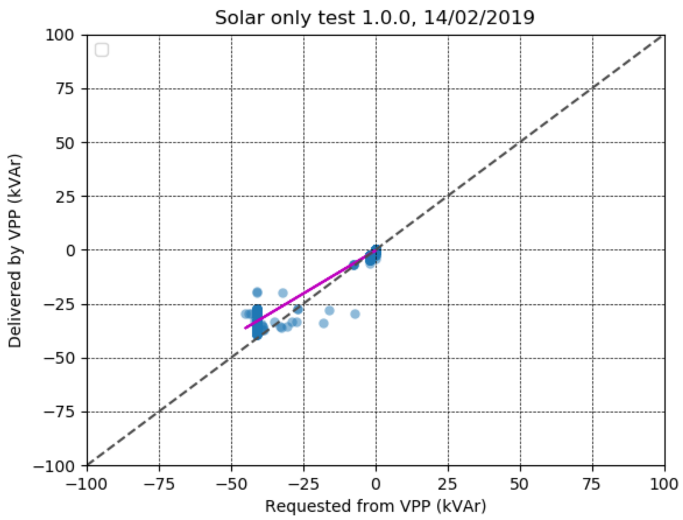


Figure 9 Capability of solar only to respond to reactive power request (Yackandandah)

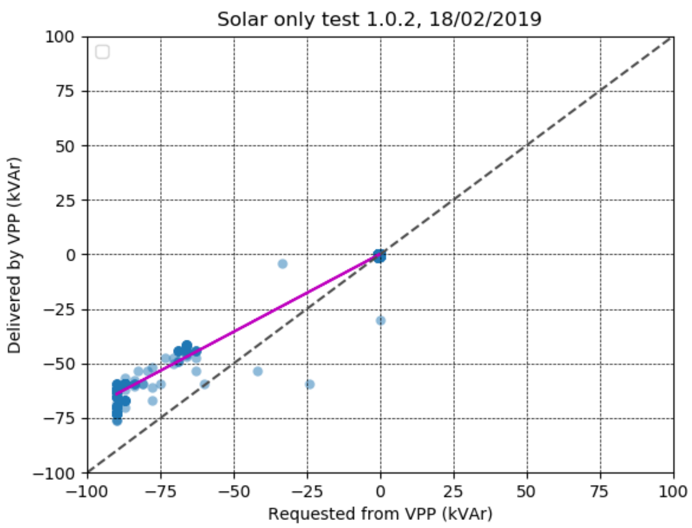


Figure 10 Capability of solar only to respond to reactive power request during low solar day (Yackandandah)

Impact of reactive power: Notch tests

Reactive power tests were carried out in both the NSW and the Victorian trials. NSW trials focussed once again on notch tests to quantify kVAR impact, while Victorian trials included the reactive power responses in local control algorithms. Both yielded positive results.

Figure 11 shows the isolated impact of lagging and leading reactive power through a notched test for a generating customer in the NSW trial. The test was commenced with full power export from the generator pf=0.7 improving voltage by 9V to 10V. The reactive power was then subtracted separately to isolate its impact.

The test indicated that power factor adjustment from 0.7 lagging to leading had approximately a 5V impact on the local voltage experienced by the customer. This figure needs to be halved to consider the contribution reactive power makes when it is included in export generation (2.5V). It is halved because the case to consider is what is the impact of including power factor or not (ie switching in pf from unity to 0.7) the full range was explored in this test to be maximise the chance of achieving a measurable result.

Thus, of the original 9V to 10V improvement in voltage, 2.5V of this or approximately 25% to 28% was due to the leading reactive power component.

Naturally the impact any individual customer will receive due to reactive power is dependent upon the reactance of the network serving them. As a significant portion of this will be present in the distribution transformer windings, it would be expected that this impact would be unlikely to be as detectable at the HV level. However, it does present opportunities for reactive power to manage customer voltage even on high resistive HV networks such as SWER and 3/single phase steel.

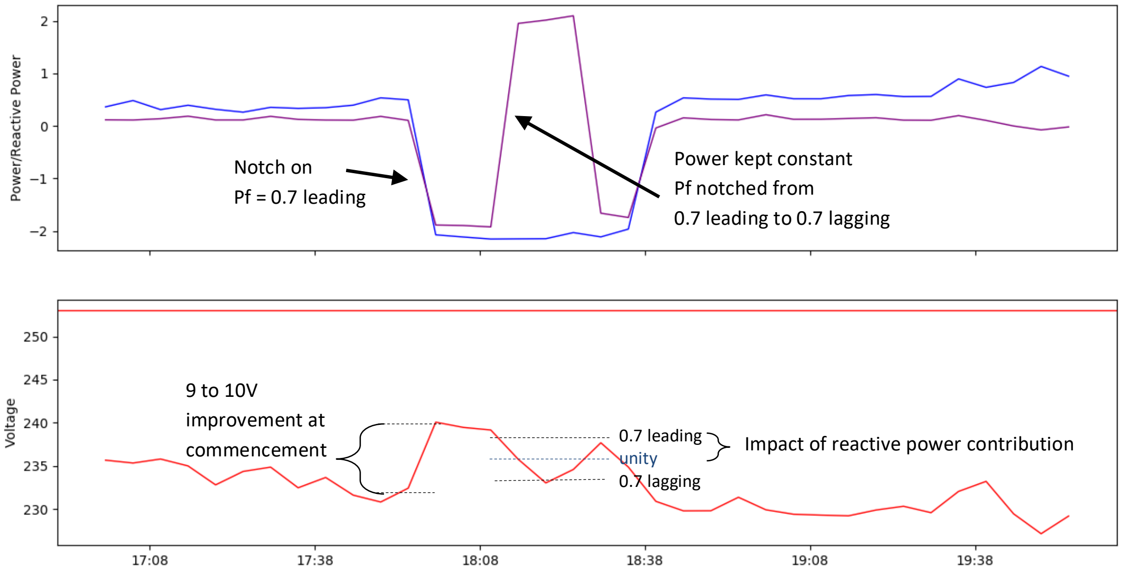


Figure 11: Leading and lagging reactive power notches

The scatter plots below show the effect of reactive power on voltage across the Yackandandah battery and solar, and solar only sites. The voltage shown is the average voltage across sites and both real and reactive power are shown as an aggregated sum across all sites. Reactive power is represented on a colour scale of purple (low) to green (high). During sunlight hours voltage typically rises linearly with solar generation on this area of network. This can be clearly seen on the purple regions of the plots where the data form uniform bands along increasing gradients from left to right. The green regions of the plot show how voltage values defy this trend when reactive power is applied.

Under the trialled control strategy, reactive power can clearly reduce the network voltage. Note that the switch between lagging and leading reactive power could also control a corresponding increase in voltage if required.

Impact of reactive power: Local control tests

Determination of the exact magnitude of impact of reactive power requires consideration of the volatility of voltage on the distribution network, which is influenced by a variety of factors. The sharp drops and rises at the commencement and completion of reactive power injections can directly measure of the impact with an error equal to the volatility of the voltage curve.

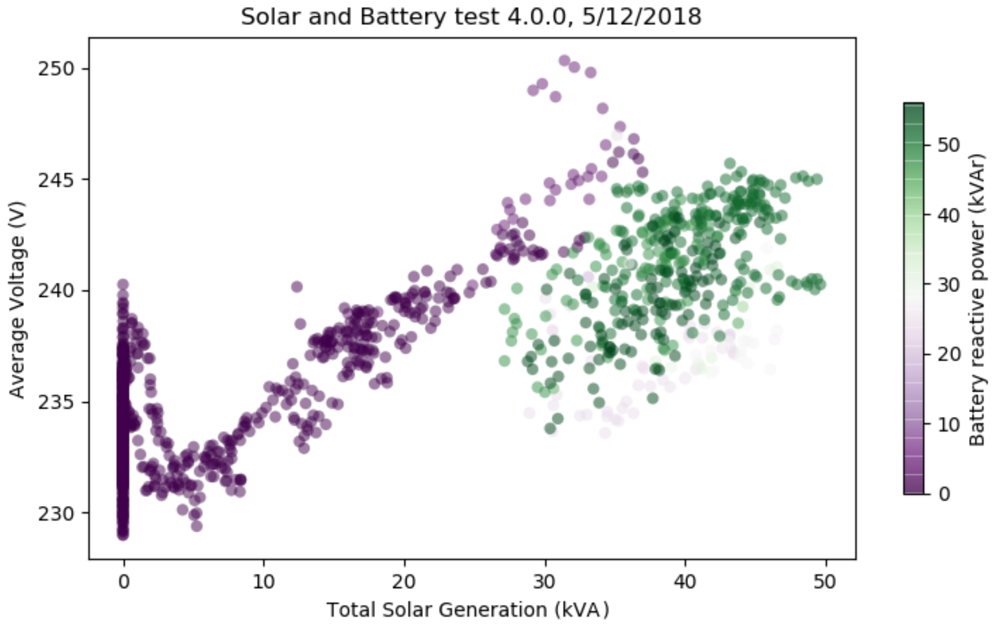


Figure 12 Relationship between average voltage and total solar generation across all sites, and effect of reactive power sourced from battery

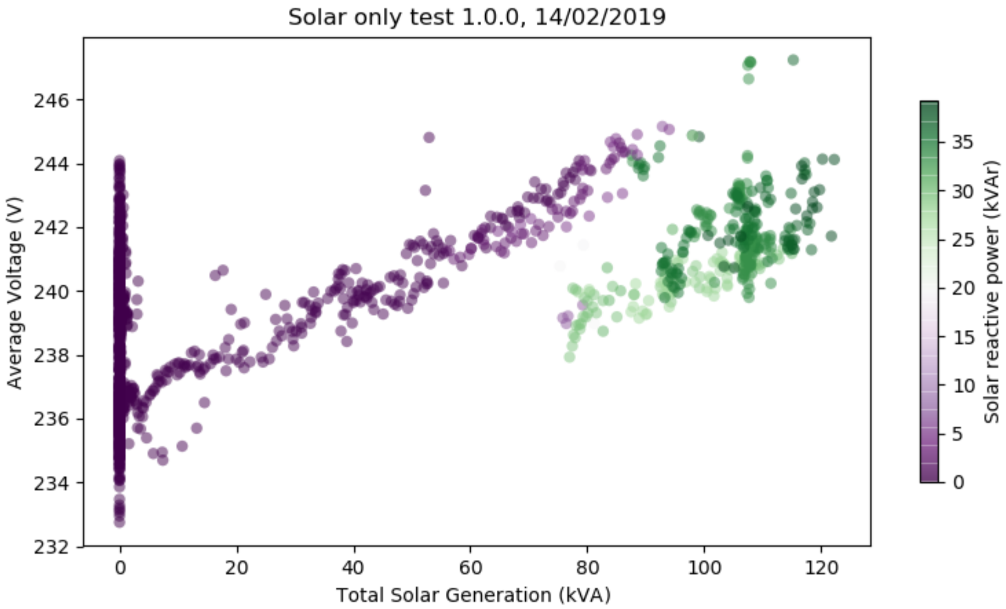


Figure 13 Relationship between average voltage and total solar generation across all sites, and effect of reactive power sourced from solar PV only

Volatility of voltage on a reference day, where solar generation was consistent and no reactive power was deployed, is represented in Figure 14 as a grey band and is two rolling standard deviations from the exponentially weighted mean (EWM). The volatility during solar hours is typically around ±2.5V. As a means to determine the average impact of reactive power, the test day voltage curve was deducted from the EWM of the reference day the curve, producing an effectively flat curve (noted as Voltage Difference), with the solar generation influence removed. By comparing the average voltage during the test and non-test periods of the flattened curve, we can estimate that the average effect of 40 kVAr of reactive power achieved a 5V to 10V reduction in average voltage. This can be normalised against reactive power as 0.125 V/kVAr to 0.25 V/KVAr. This was similar for the solar only sites whose data is shown in Figure 15.

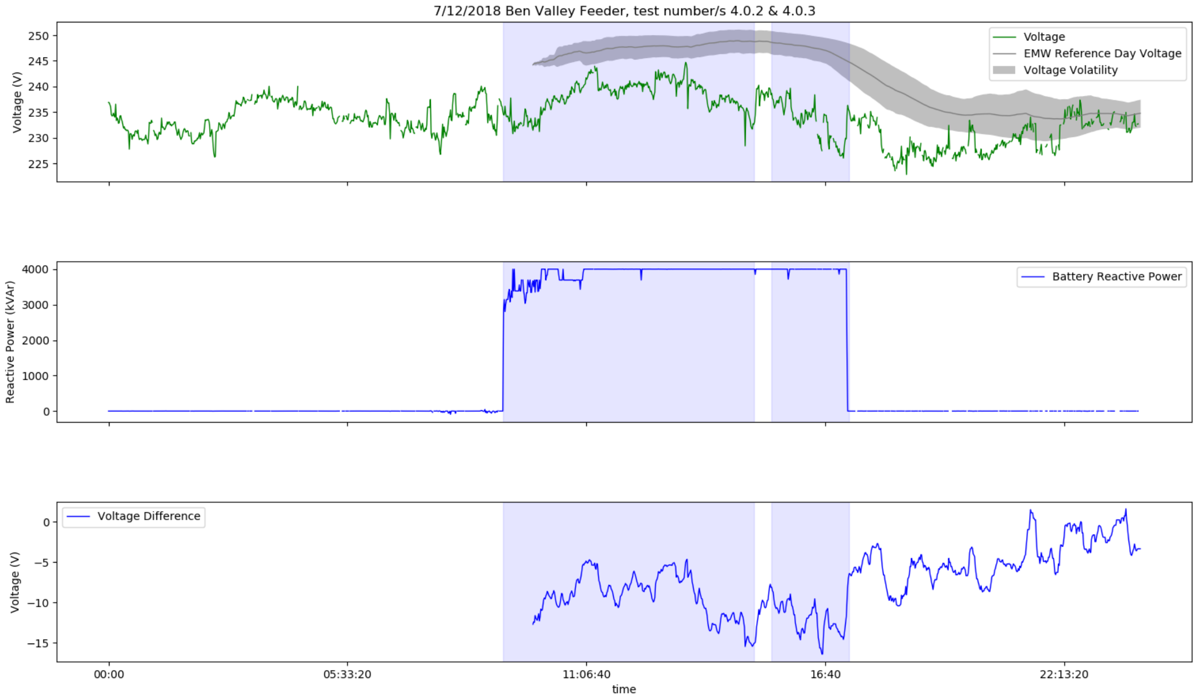


Figure 14 Voltage, reactive power, and voltage effect (difference) during a solar and battery trial

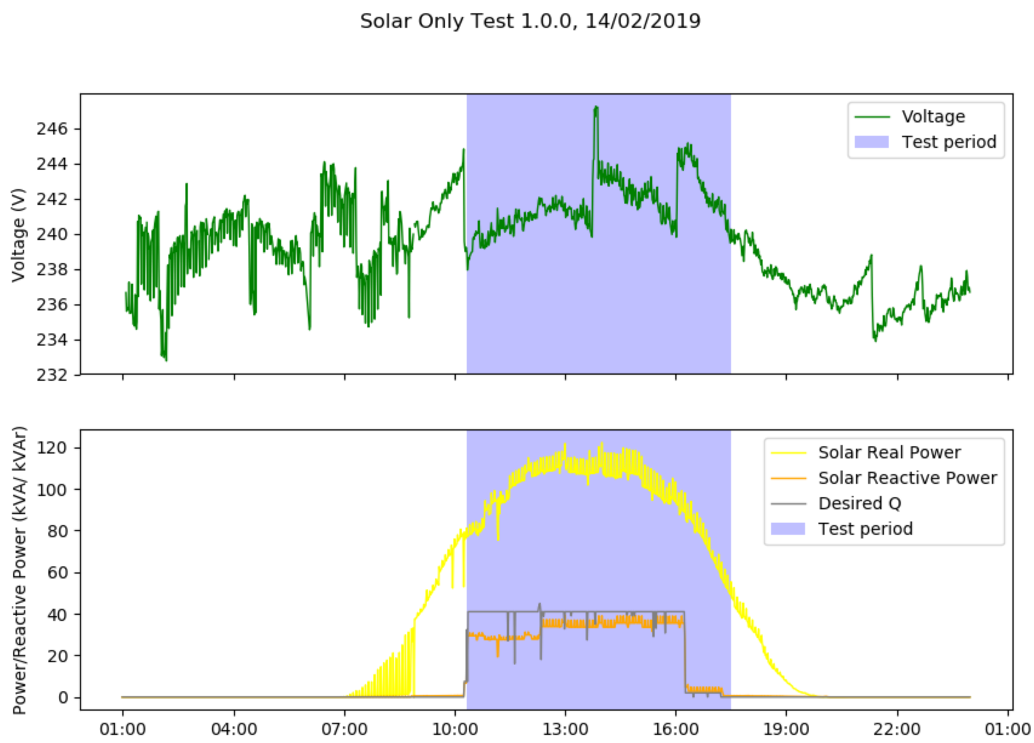


Figure 15 Voltage, requested reactive power (desired Q), delivered reactive power and solar generation

Importantly, the impact of aggregated reactive power across multiple sites was observable on the distribution network at the LV feeder level show aggregated reactive power across the 14 solar and battery sites and the corresponding voltage on their 12kV LV feeder supply, as measured by a power quality meter installed by the DNSP. Here we see the same relationship as was observed at the household level, where voltage drops sharply with the onset of reactive power, and rises sharply when reactive power ceases. In the Figure 17 scatterplot we can see the relationship between solar generation and voltage at the LV feeder level, and again the difference in this relationship when reactive power is applied.

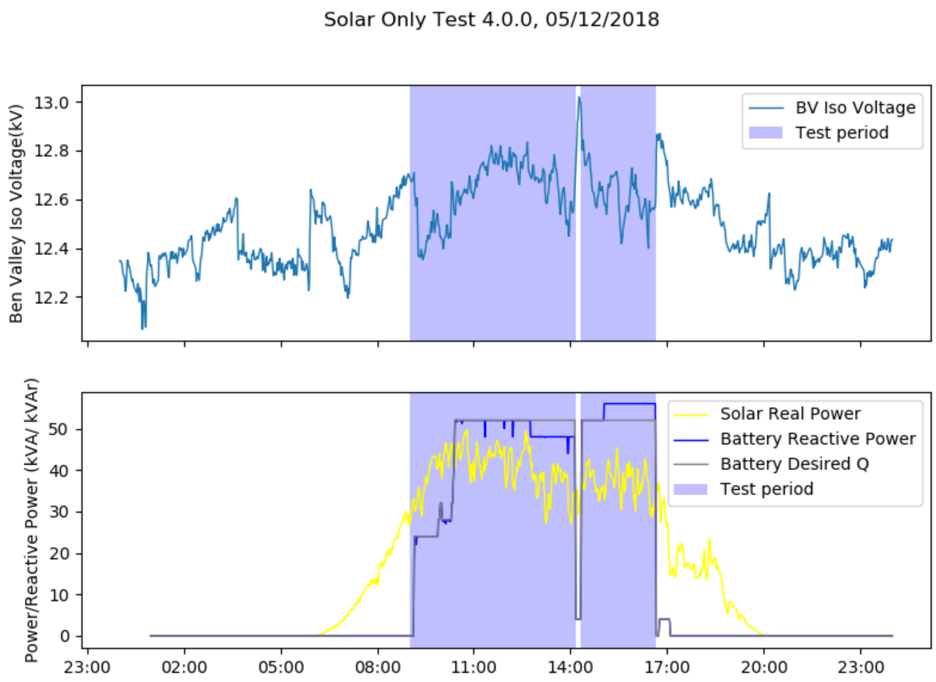


Figure 16 Effect of reactive power at the LV feeder level

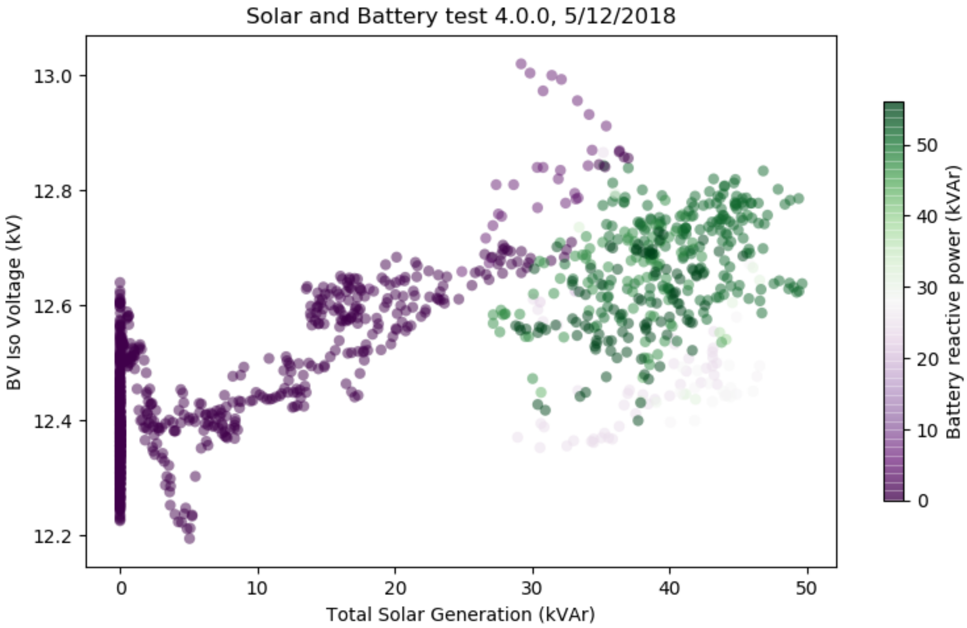


Figure 17 Relationship between solar export and voltage, and the effect of reactive power at the LV feeder level

An important consideration for solar only houses is whether reactive power support can be provided when solar PV generation is poor. Figure 18Figure 18 shows that the system was unable to deliver the total requested reactive power (desired Q), however, it was able to provide a substantial proportion. The test 1.0.2 chart in Figure 20 (top right) shows that, at higher voltages when support is most required, this limited delivery of reactive power support was sufficient to reduce voltage substantially.

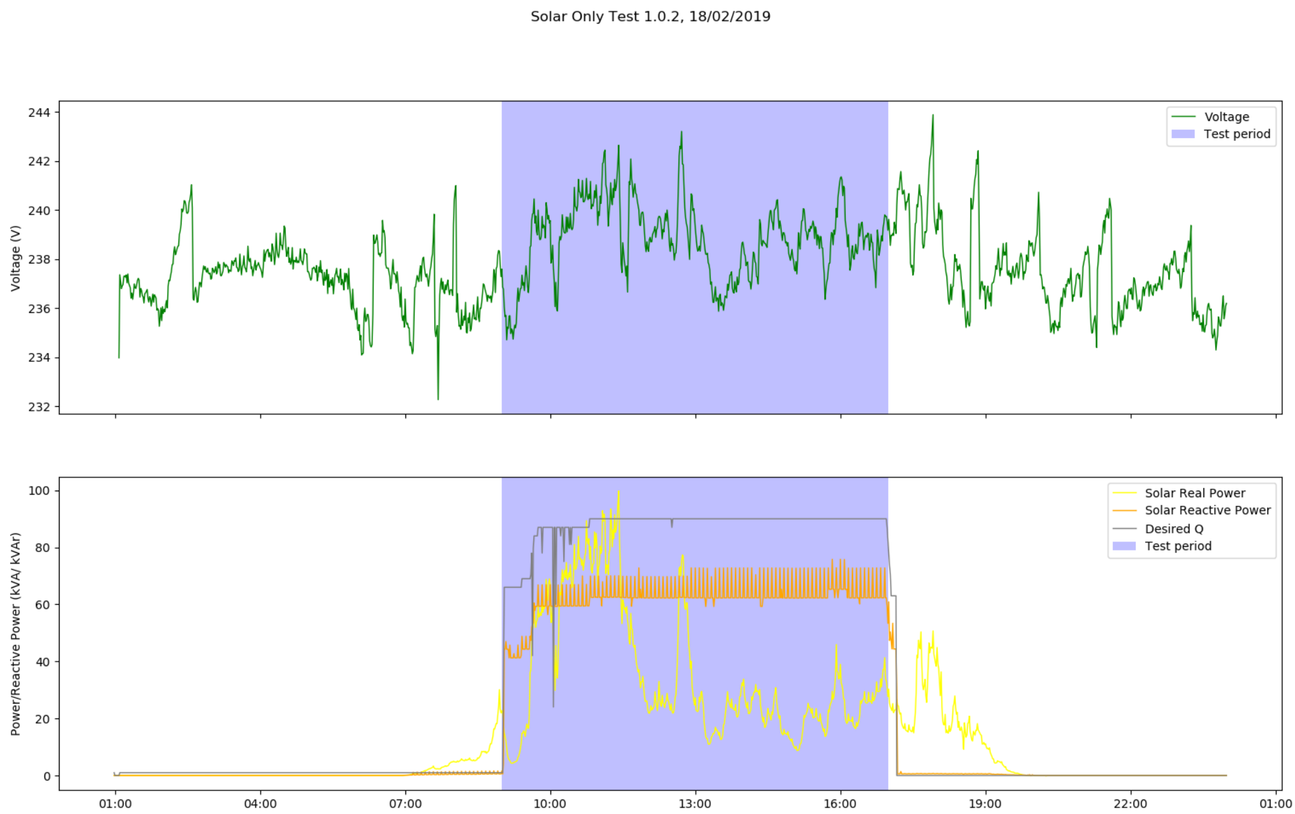


Figure 18 Reactive power support capability despite poor solar PV generation day

A voltage response local control strategy was tested in addition to the simple constant application of reactive power. This strategy has each household system react to the local voltage level to inject reactive power at a rate determined by a voltage envelope. That is, the higher the voltage level, the more reactive power is injected as the voltage crosses given thresholds. The effectiveness of this strategy is more difficult to determine because the causal relationship between reactive power and voltage is bi-directional. That is, reactive power levels are determined by voltage which changes according to reactive power. This means that voltage will often appear high despite the apparent injection of reactive power. This is shown in Figure 20. However, it we can also clearly see that the average voltage is significantly lower during times when reactive power is present, defying the voltage-solar PV generation relationship. We therefore conclude that while the average voltage levels were reduced, the peak voltage levels remained. More work is required to determine the optimum control method for this technology.

Figure 19 Local control strategy with reactive power support response as a function of voltage

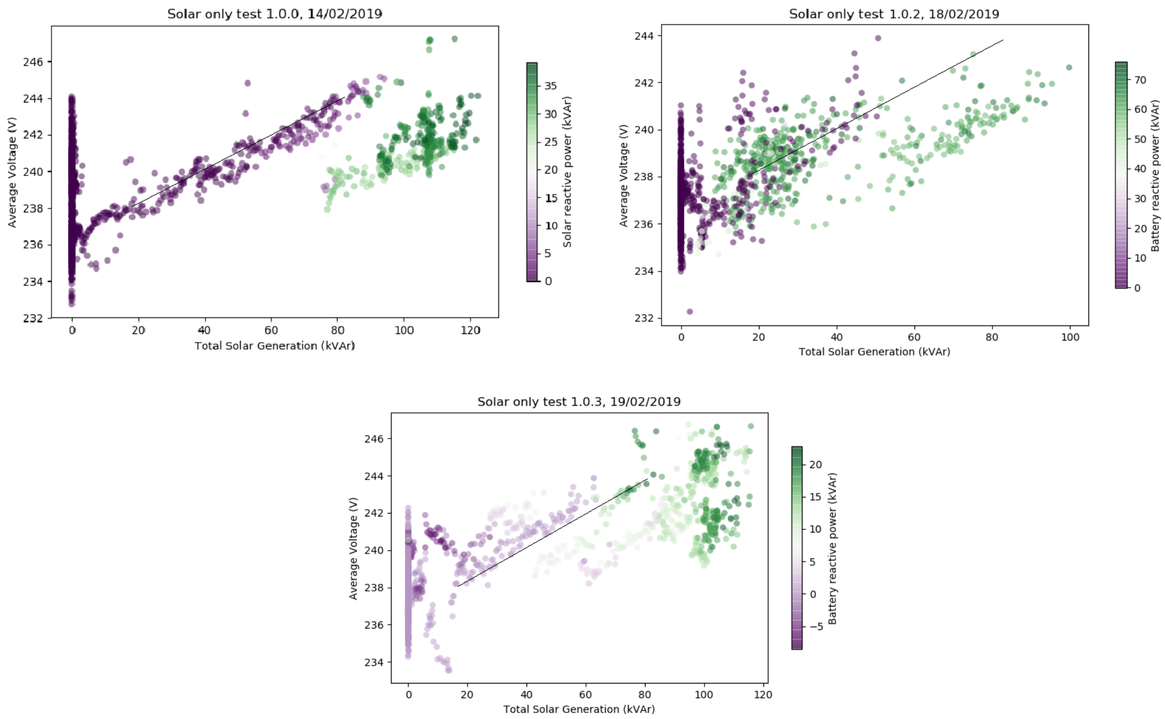


Figure 20 Comparison of solar only test outcomes with solar PV generation/voltage relationship represented as a line

Voltage management during islanded operation

The Mooroolbark Community Mini Grid offered two important scenarios in which to investigate voltage management: the emergent business model of virtual power plants (VPPs) to sell distributed energy into the NEM, and concept of communities using their own residential DER to form a 100% renewable energy supply system using the legacy distribution network. Both were successfully demonstrated with important lessons regarding voltage.

Coordinated VPP dispatch was proven to reach the technical voltage limits of the distribution network, even in the relatively strong network area of the project site. This reinforces the need to integrate network constraints into VPP activity via a dynamic orchestration method. Combining this need with findings from the demonstration in Yackandandah suggests that reactive power can be a helpful part of an orchestration strategy to maximise dispatch opportunities within voltage constraints.

Operating an islanded network feeder as a 100% renewable energy system is a globally significant experiment. In particular, the protection configuration for the Mini Grid project is unique when compared to traditional protection schemes in order to operate in island mode with 100% inverter connected sources. This is because inverters can supply only relatively small fault currents, in the range of two to three times the continuous rating of the inverter, which is considerably less that the fault current supplied by the grid. This required a special protection load flow model to be constructed. Such detailed attention is necessary to ensure safe operation of the islanded Mini Grid.

To achieve islanded mode, a three-phase battery storage system functioned as a “stabiliser” to mimic the main grid by providing a voltage and frequency reference. The household solar and battery inverters cannot discern the difference between this and the normal grid so they continue to operate normally. During the experiment of longest duration, the entire mini grid, including 14 project participants and 4 non-participants, separated from the main grid and remained self-sufficient for 22 hours. The three phase voltage measurements before, during, and after this experiment are shown in Figure 21 and exhibit increased variability while remaining well inside the limits allowed by electricity distribution code. There is a lack of step changes that, in grid-connected mode, may be associated with events in different parts of the network.

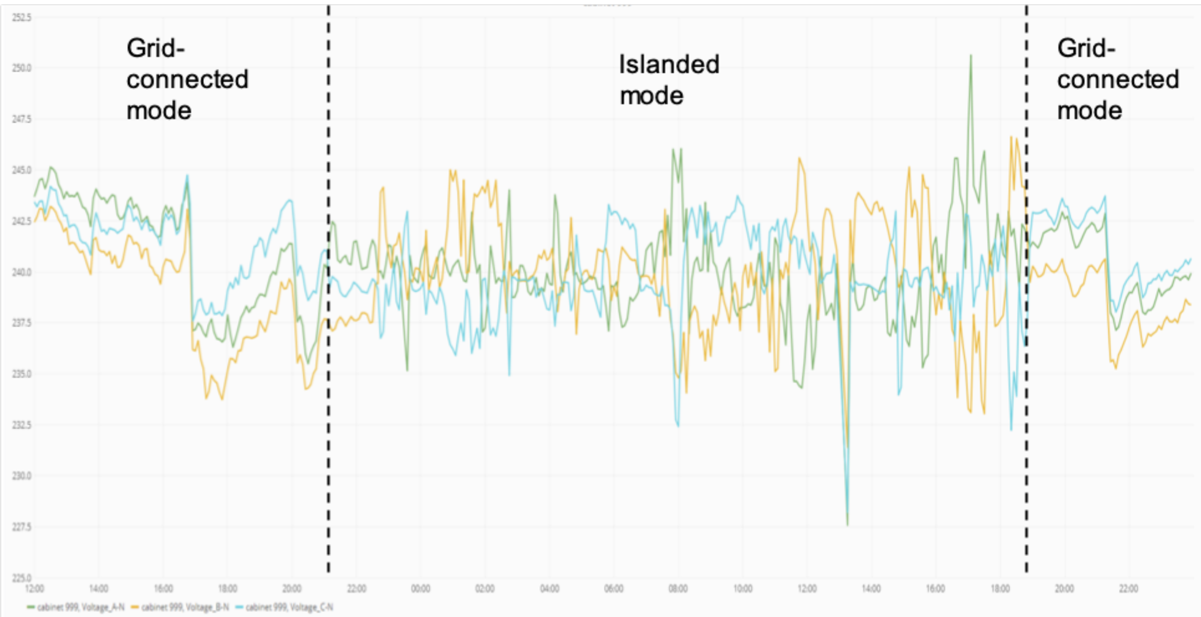


Figure 21 Three phase network voltage as the Mooroolbark Mini Grid changes from grid-connected to islanded mode and back again

Lessons Learnt Report: integrating control platforms for DER-based voltage regulation into network operations

Project Name: Networks Renewed

Knowledge Category:	Technical
Knowledge Type:	Technology deployment
Technology Type:	Voltage regulation, solar PV and battery storage
State/Territory:	Collombatti, New South Wales & Yackandandah, Victoria

Key learning

Networks Renewed demonstrated that smart inverters can be successfully controlled via third-party aggregator platforms and fully integrated with the distribution network service provider (DNSP) system operations. This approach was bespoke to each DNSP and would need to be simplified and/or standardised for mainstream uptake.

For NSW, Reposit Power's distributed inverter control systems provide dynamic network management services delivered via a manual user interface (UI) that sits on top of an Application Programming Interface (API). The customisable API allows for automated methods of control and support, via integration with a DNSP Distribution Management System (DMS). The centralised control architecture is designed to act as an economic optimisation engine, thereby working to maximise the returns to the customer. In the trial, Essential Energy's DMS was not linked to Reposit Power's fleet account via their API. The fleet account was instead used to publish network support bids to customers. Further detail is at Figure 22.

Figure 22. Essential Energy and Reposit Power's control platform for NSW.

In comparison, AusNet Services developed a Distributed Energy Network Optimisation Platform (DENOP) for the central level controls. Information from the batteries and solar are sent to the Mondo cloud which is then sent to the AusNet Cloud (DENOP). The DENOP combines these signals with network, external and other third party data to optimise the control to benefit both the end customer and the network. Further detail is at Figure 23.

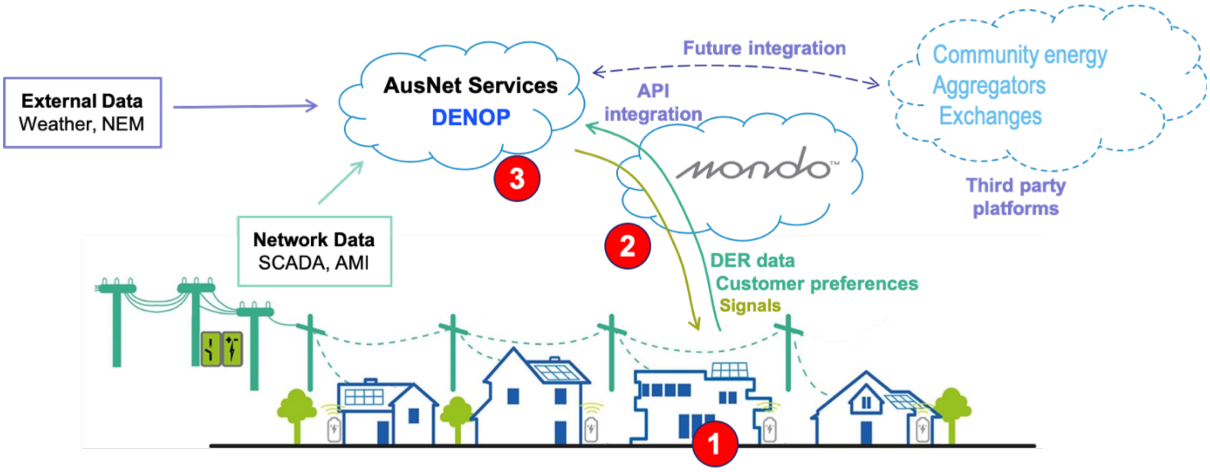
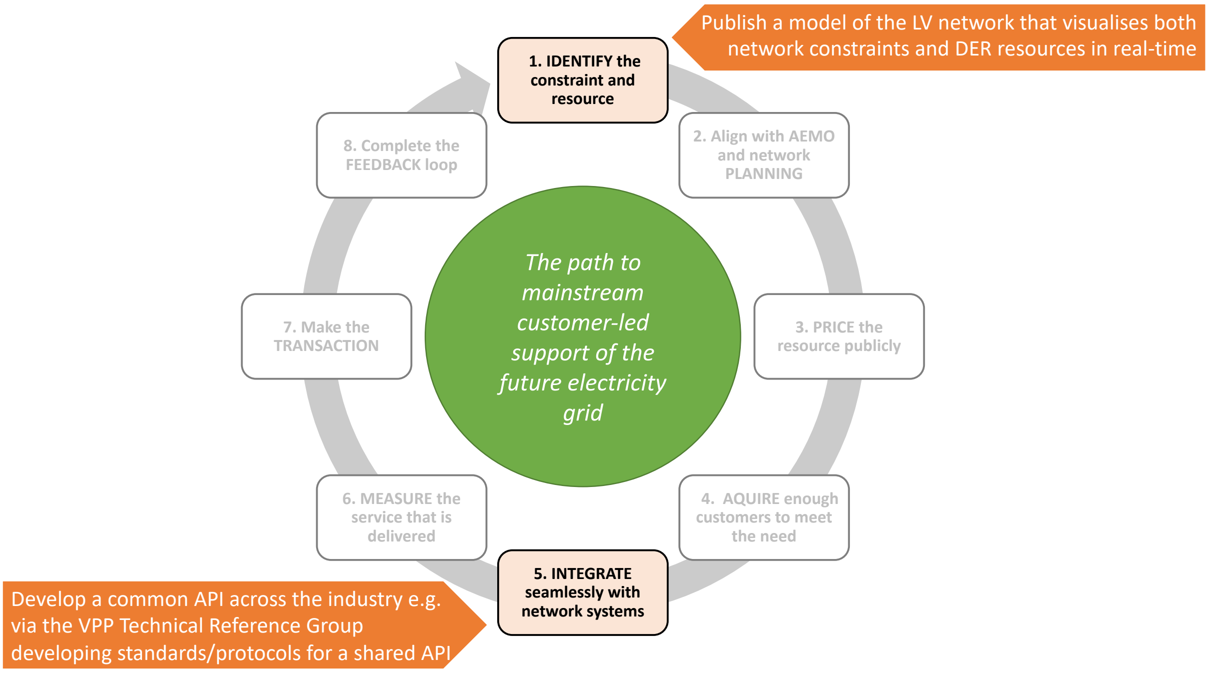


Figure 23. AusNet Services' Distributed Energy Network Optimisation Platform (DENOP) for Victoria.

Implications for future work

Given the novelty of the solution, both DNSPs required manual transfer of control information between the DMS and the inverter control application(s). Thus, in the future there is a need for industry cooperation to effectively integrate customer inverter controls to support normal network operations at scale. For example, following the trial, Essential Energy is now exploring auto-dispatch with the plan of keeping network support in place until the least-cost practical option to address the emerging voltage constrain is identified. Across the industry, mainstream integration can be achieved by the following activities:



Develop a common API across the industry. It will be essential to improve control algorithms to better predict usable energy and deliverable capacity of DERs that can deliver network support services. While there are many demonstration virtual power plant (VPP) projects deploying across Australia (as well as internationally), each is bespoke and involves a multitude of different stakeholders, technologies, platforms, assets, and customer types. Standards and protocols for enabling communication between assets are needed if the solution is to be treated as business-as-usual for DNSPs. This includes a common API for VPPs to be agreed across the industry, such as the work being undertaken via the VPP Technical Reference group developing standards and protocols for a shared API.

Publish a model of the LV network that visualizes both network constraints and DER resources in real-time. As DNSPs' knowledge of their LV networks is improving they are constructing LV network models to allow a full understanding of the impacts of DERs. Modelling actual network conditions, rather than potential scenarios, requires knowledge of customer DERs to be integrated with LV network models. Static knowledge – location, capacity, and potential for control of DERs – allows network planning to include both impacts and services from customer DERs. To support network operations, and obtain the best available network services, requires real-time data of network conditions and DER status so that a control regime can be implemented.

The Australian Renewable Energy Mapping Infrastructure (AREMI) Network Opportunity Maps (NOM) are currently the most comprehensive place providing data from DNSPs aimed at a similar audience. This represents a natural place to consider as the potential host of visualising network constraints that would enable DG and VPP providers to best locate and pitch solutions. The maps have the benefit of receiving contributions from most major DNSPs, especially those operating in rural areas, and are already extensively used by renewable energy developers. Time series data are accommodated by AREMI, currently with a time step of 1 year. However, AREMI maps are currently only updated at regular, approximately annual, intervals. While more frequent updates are possible, establishing a data pipeline that visualizes constraints and DER resources in real time is a significant technical jump from the current platform. For time series data, the sheer amount of additional data involved in a transition from an annual timestep to one approximating real-time is an additional technical challenge. Finally, LV data may have the additional privacy risk of the potential for customer identification, depending on the spatial resolution at which they are provided. This can be managed through aggregation of customers, but in rural areas, as customers can be relatively far apart, this may then lose the ability for a VPP provider to currently geographically target their solution.

Background

Objectives or project requirements

The introduction of the inverter standard AS4777:2016 means that all new solar PV and battery systems can help to provide network support services such as regulating network voltage as well as managing peak demand. Networks Renewed sought to leverage these capabilities to demonstrate voltage support services on two low voltage (LV) networks. The project required multiple systems to be controlled simultaneously by the DNSPs in order to respond to changes in voltage, whether charging or discharging batteries or adjusting reactive power levels.

All advanced control methods require some integration with the network management practices of the distribution network operator. At the very least, the network operator needs to understand the impact of inverter controls, and to have a model for their anticipated response on each feeder under different load and generation conditions. The methods and the outcomes the control methods facilitate for a network operator differ in the degree of integration required.

Network operators use a Supervisory Control And Data Acquisition (SCADA) system to monitor and control devices they own. Such a system will typically include many distributed devices with data capture and control functions, a communications infrastructure, and a control room. The distributed devices are often called Remote Terminal Units (RTUs) that will have some automated (programmed) responses and routines that will operate network assets independently and send data back to the control room. The industry has well recognised communications protocols for integrating many different manufacturers' devices into a SCADA system such as Modbus, DNP3 or IEC61850.

To integrate with a network operator's control system, solar inverters must interface with some point of that network operator's infrastructure. Figure 24 shows the main possibilities for integration points that were considered in the design of Networks Renewed.

Process undertaken

Developing an integrated and verifiable control strategy for both DNSPs was a large task. The final control paradigms were determined based on: an assessment of when it was best to have DNSP direct control of the inverters for aggregated response; when it was best to have autonomous intelligent local response based on grid conditions as viewed by an individual inverter; and the ease or difficulty of integrating either control paradigm with network operations.

In other words, for each trial the partners considered, based on Figure 24:

- Is the DNSP or a third party interacting with the DER (A vs. B)?
- Will the system be integrated directly with the network infrastructure (such as A or B+C) or through a third party product (D)?
- If a third party aggregator is used, how fine or coarse will DSO's control be over devices?

- How will data and control security be upheld?

Both market-scale demonstrations were run separately to normal network operations but with some status signalling, using a third-party platform (Option B). In Victoria, Mondo's Ubi devices were accessed via the Distributed Energy Network Optimisation Platform (DENOP) developed and maintained by AusNet Services (Option C). In NSW, Reposit Power's MarketPlace provided an end-to-end system for Essential Energy in NSW (Option D).

Both DNSPs required manual transfer of control information between the DMS and the inverter control application(s). significant work involved in manual dispatch events but inverter volt/VAr and volt/kW responses were automatic once set up. Significant work involved in manual dispatch events but inverter volt/VAr and volt/kW responses were automatic once set up. Thus, in the future there is a need for effective DMS integration of customer inverter controls so they can be effectively accessed to support normal network operations.

Supporting information

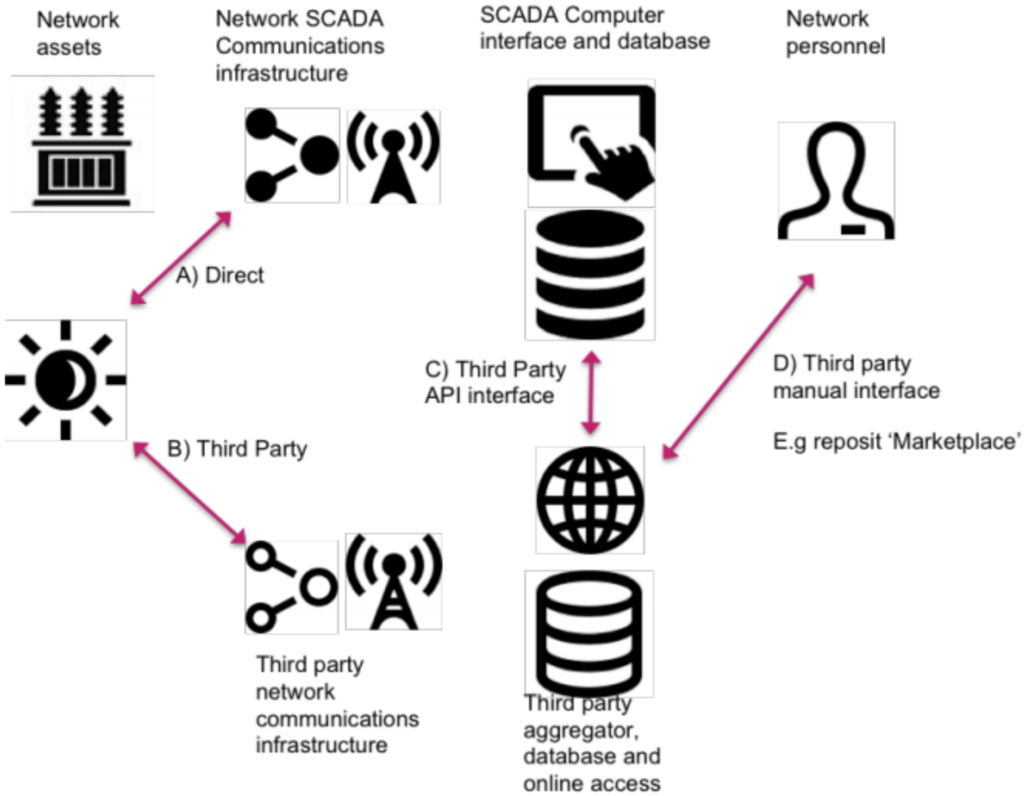


Figure 24. Possible options for integrating DER control with network operations

Lessons Learnt Report: developing a successful business model for DER-sourced voltage services

Project Name: Networks Renewed

Knowledge Category:	Economic
Knowledge Type:	Business case/business model
Technology Type:	Voltage regulation, solar PV and battery storage
State/Territory:	Collombatti, New South Wales & Yackandandah, Victoria

Key learning

Networks Renewed developed a sample business case for demonstrating that the use of inverter control of distributed energy resources (DERs) can be an economic solution to regulating network voltage. The case, developed for each trial, outlined how the value of network services can be realised, and this includes a comparison table of the technical requirements, performance, and cost of behind the meter inverter control against traditional voltage regulation options. It also assessed the market participation value, drawing on results from the NSW demonstration. Figure 25 provides a summary of the business models underpinning the cases and

Table 1 outlines the comparison.

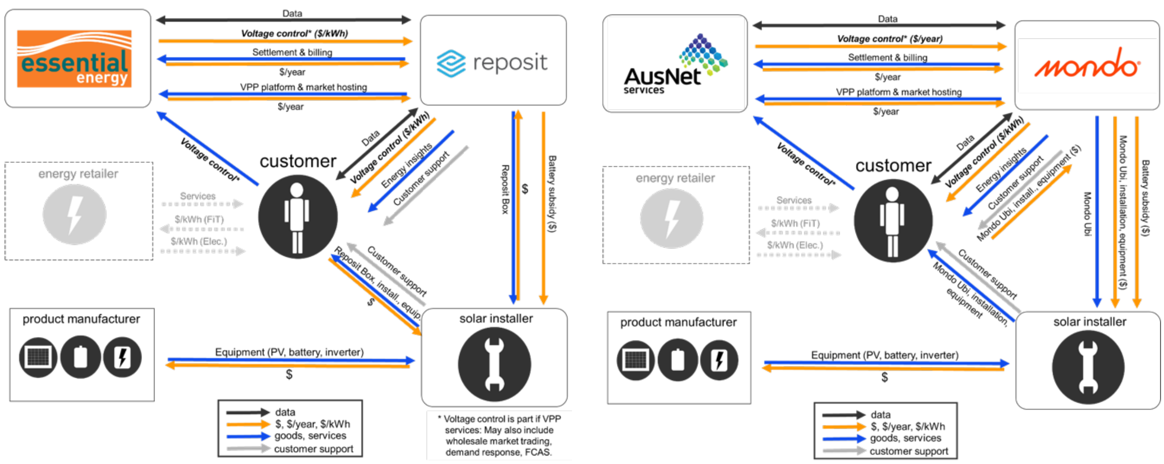


Figure 25. Business models were developed for the two market-scale trials in Collombatti and Yackandandah

Table 1. Business case comparison

	NSW Trial	Victoria Trial
Partners	Essential Energy Reposit Power	AusNet Services Mondo Power
Commonalities	• Ownership model type • The types of stakeholders involved • The main customer value proposition (energy bill savings)	
Differences	• The main financial transaction takes place between the installer and the customer • The customer is remunerated for providing voltage regulation services on an 'Earn as you Go' basis – with the customer paid $1 per kWh per event	• The main financial transaction takes place between the customer and Mondo • The customer is remunerated for providing voltage regulation services on an 'Upfront Payment' basis – with the customer paid $200 per year

The trial recruited 90 customers under these business models, which was a strong level of penetration (18% in Collombatti and 13% in Yackandandah) but not sufficient to fully address the voltage constraint.

Risks and their implications

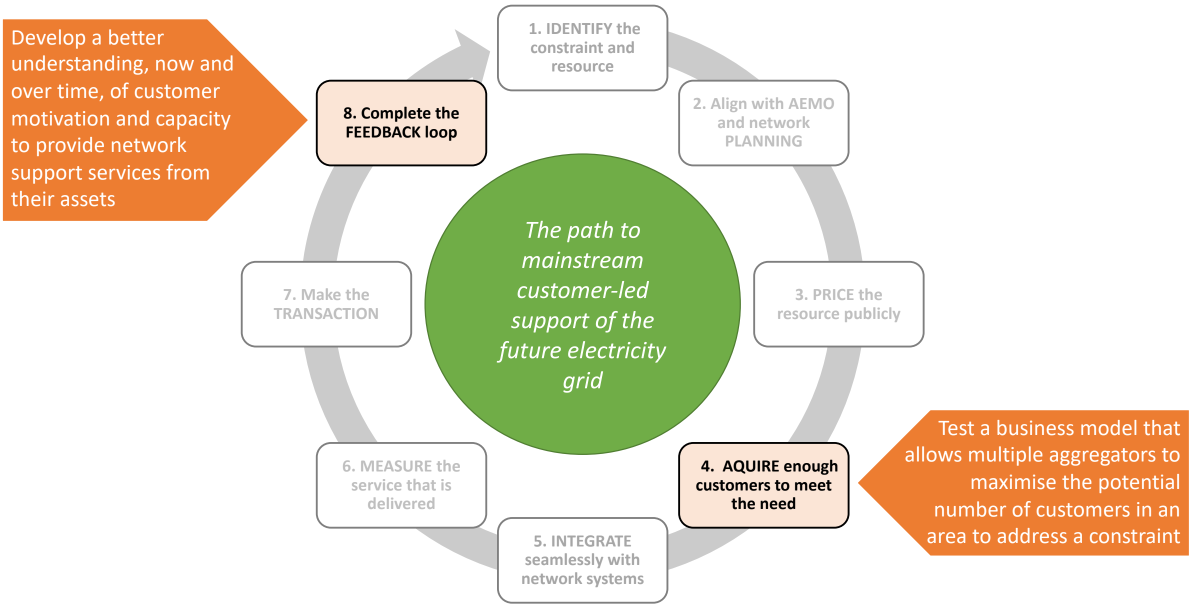
Every business model can be categorised by a specific way of allocating risks. Some risks are explicitly allocated in a contract, while others are implicitly allocated. Naturally during the project inception phase, risks considered acceptable by the different parties were accepted and this shaped the business models for each of the different trials. However the risks, their allocation, and mitigation strategies aren't typically recorded but it was important to understand this. During a workshop phase, stakeholders in the trials were asked about what risks existed (see table below), who bears them (e.g. installer, manufacturers, aggregator, DNSP), what are the impacts (e.g. safety, loss of earnings, reputation), and how are they managed (e.g. cost sharing, performance guarantees, warranties). A description of the risks is contained in Table 2 below:

Table 2. Risk Description

Relevant Risk	Notes
Investment	Bearing the risk (and assuming the obligation) of providing the investment needed for the deployment of the BTM voltage control system.
Insolvency (Supplier)	Bearing the risk that is linked to the potential insolvency/bankruptcy of the Supplier.
Insolvency (3rd party)	Bearing the risk that is linked to the potential insolvency/bankruptcy of the third party (e.g. inverter manufacturer, aggregator, etc.).
Insolvency (Customer)	Bearing the risk that is linked to the potential insolvency/bankruptcy of the Customer.
Installation	Bearing the risk of installing the BTM voltage control system.
Maintenance & breakdown	Bearing the risk of providing the ongoing service and maintenance regarding the BTM voltage control system and the corresponding risk of temporary breakdown of the equipment.
Warranty and guarantee	Bearing the risk of obligations that arise out of legal warranties or issues guarantees.
Total loss	Bearing the risk of a total loss of the BTM voltage control system.
Performance	Bearing the risk of the amount of power available for providing BTM voltage control.
Energy price	Bearing the risk of changes in the price of energy.
Voltage payment incentive	Bearing the risk of the amount the customer's being paid for providing BTM voltage control
Customer behaviour	Bearing the risk of customer´s behaviour regarding their use of power and the amount of BTM voltage control they choose to make available.
Weather	Bearing the risk of unusual weather
Policy / regulatory	Bearing the risk of changes of the legal/regulatory framework that are linked to the business model (e.g. surcharges, taxes, discontinuation of subsidies)
Hardware durability	Bearing the risk of any accelerated ageing of the hardware through increased utilisation as part of the VPP.
Safety	Bearing the risk of any health and safety risks arising from BTM voltage control using PV and/or battery storage and participation in the VPP

Implications for future projects

A business case will only be viable if, at the very least, it maximises value for both the customer and the distribution network service provider (DNSP). Given Networks Renewed was not able to reach its target participant cohort, there is still work needed to better understand customer motivation and access customer cohorts from multiple aggregators simultaneously:



Develop a better understanding, now and over time, of customer motivation and capacity to provide network support services from their assets. There must be a suitable understanding of the drivers that will motivate customers to participate and be part of new energy deals involving network services. A significant amount was invested by the project partners in a process that educated and informed customers about the demonstration project, including why they were being paid to help provide network services. Recruitment delays were directly attributed to complex customer messaging, both in relation to the value proposition and the payment/subsidy. More work is needed to expand this understanding beyond the two market scale demonstration projects.

Test a business model that allows multiple aggregators to maximise the potential number of customers in an area to address a constraint. Complexity is increasing with a growing number of assets under the control e.g. by independent aggregators and virtual power plant (VPP) trials. A common approach that will allow multiple aggregators to maximize the potential number of customers able to help solve a network constraint would likely be more efficient and effective. Such an approach would then help ensure the maximum benefit to customers, the electricity distribution network, and the energy system as a whole. Future work could facilitate this, potentially in order to inform an industry standard for recruitment, asset control and/or compensation.

Risks issues and their implications

Trial participants were generally happy with their involvement in the project and expressed an interest in more deeply engaging with their energy production and use in the future. As expected with a trial, a number of issues were experienced driven by non-compliance issues and poor customer support. The implications of such issues, especially with regards to safety, are important to take as learnings for any subsequent stage. For instance, to address some immediate concerns, Essential energy inspected all systems that were part of the trial during the project close-out phase in May and June 2019, resolving any customer concerns or complaints. As part of any subsequent project, we recommend committing additional resources to stricter compliance for installers.

For example:

1. Electrical Auditor / Technical regulator

Some states (e.g. ACT) have a technical regulator / electrical inspector who inspects every system installed. NSW is somewhat lax in this regard, only requiring an ASP level2 and conducting a random audit of a 3-4% sample of installations. Any subsequent program should ensure that an electrical inspector is funded, who inspects every system in the program's compliance with AS3000 AS5033, (and 4777), and some of the below additional items.

This role would perhaps best sit within the DNSP, as Essential Energy has conducted at the close of this project. Or alternatively program management could subcontract this out to a third party electrical inspector.

2. Commissioning checklist and a compliance manager.

A compliance manager to ensure that a full commissioning checklist is completed (and verified) before subsidy payment released to installer. This could include:

- Smart meter installed
- System communicating and verified as receiving commands by DNSP
- Certificate of electrical safety completed
- Control system confirms generation is occurring at or around expected levels.
- Photographs of key components of installation
- Details of data plan of 3G connected devices (if relevant)

A compliance manager could sit within the DNSP or could be part of the UTS program management team

3. Criteria for participating installers

Points 1&2 may meet resistance with installers and their representatives due to a perceived additional time and financial obligation. Delays in addressing communication issues could delay subsidy receipt. Consultation with installers and industry groups would be important to ensure buy in to any proposed scheme.

4. Documentation T&Cs quotes and contracts.

As learned in the trials, installers don't always include the same information on quotes, invoices and terms and conditions. Steps were made to ensure that quotes included the correct discounts and itemised various costs, but there is scope to go further here and ensure that installation contracts adequately protect the customer. This may include:

- Payment terms that incentivise the installer to finish the job properly,
- Timeframes for completing installations
- Further consultation with stakeholders would support what else should be included.

5. Customer Advocate

There needs to be a customer advocate with relationships with retailer, installer, aggregator and network that is able to advocate and get a customer's problem solved on their behalf.

A customer advocate could sit within aggregator, DNSP or could be part of the UTS program management team, it could potentially be the same person as the compliance manager.

Background

Objectives or project requirements

The business case is crucial to the goal of encouraging wide adoption of residential inverter control to regulate voltage, of equal importance to the technical findings of the project, and requiring dissemination to a wider group of stakeholders.

A business model canvas is a method that provides a compact overview regarding all aspects of a business model. The business model canvas provides a compact overview regarding all aspects of each business model. It helps succinctly characterise the different aspects of the current business models being deployed for behind the meter (BTM) voltage regulation, as well as identify key barriers and risks. The business model canvas was populated for each of the demonstration projects, using feedback received on telephone calls, teleconferences, and workshops with the different stakeholders.

The business model canvas features eleven key sections as shown in Figure 26. While typically the canvas features ten sections, due to the importance of the DNSP role in this project and in DER-based voltage control, an additional section has been added for the DNSP value proposition.

The canvas is constructed from the point of view of the 'Customer' and the 'Supplier'.

For the 'Customer'

This is the end customer in the case of this project. In the case of this project, it is the person(s) purchasing the hardware (solar PV, battery storage, smart inverter, and smart controls) and providing their system for control by the DNSP to stabilise voltage in their area.

For the 'Supplier

This is the main actor who interfaces with the Customer for the supply of the main goods and services. In the case of this demonstration project, it can mean either the 'Installer' or the 'VPP Aggregator'.

Process undertaken

The two Networks Renewed market-scale trials required subtly different business cases to accommodate their unique group of stakeholders. These were developed based on discussions with project partners, including two workshops dedicated to recording what is happening in practice as the solar and storage systems are marketed, sold, installed, commissioned for control, and used to obtain voltage outcomes. Although the process and relationships to support these steps were defined in the first stage of the project, they were significantly elaborated and refined as experience has uncovered issues not anticipated, and the various transactions involved have been tested in practice. The customer journey was considered central to the business case, which is summarised in the supporting information.

The outcomes of this process delivered the two business model canvasses outlined in Figure 27 and Figure 28, which were summarised in the snapshots provided in Figure 25.

Supporting information

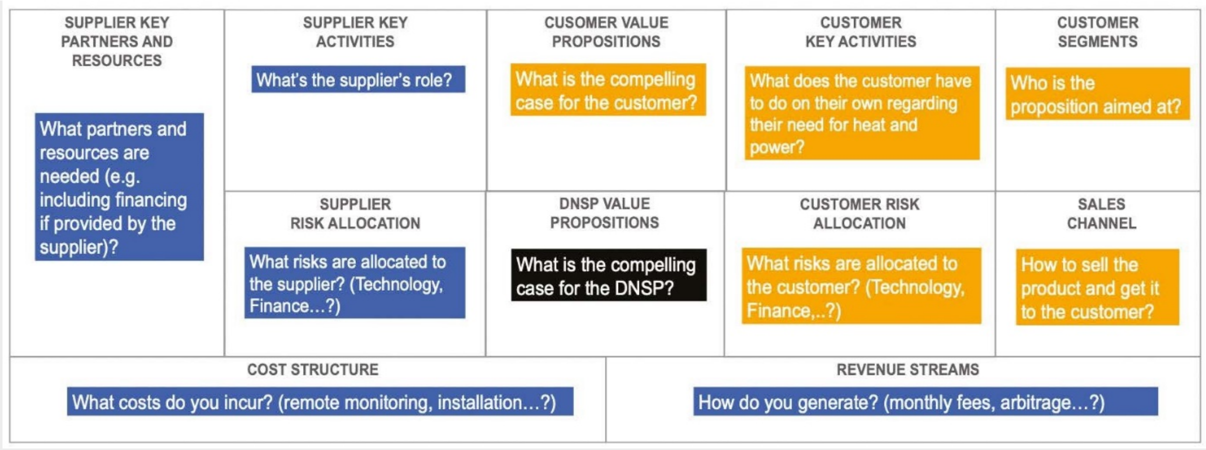


Figure 26. The business model canvas

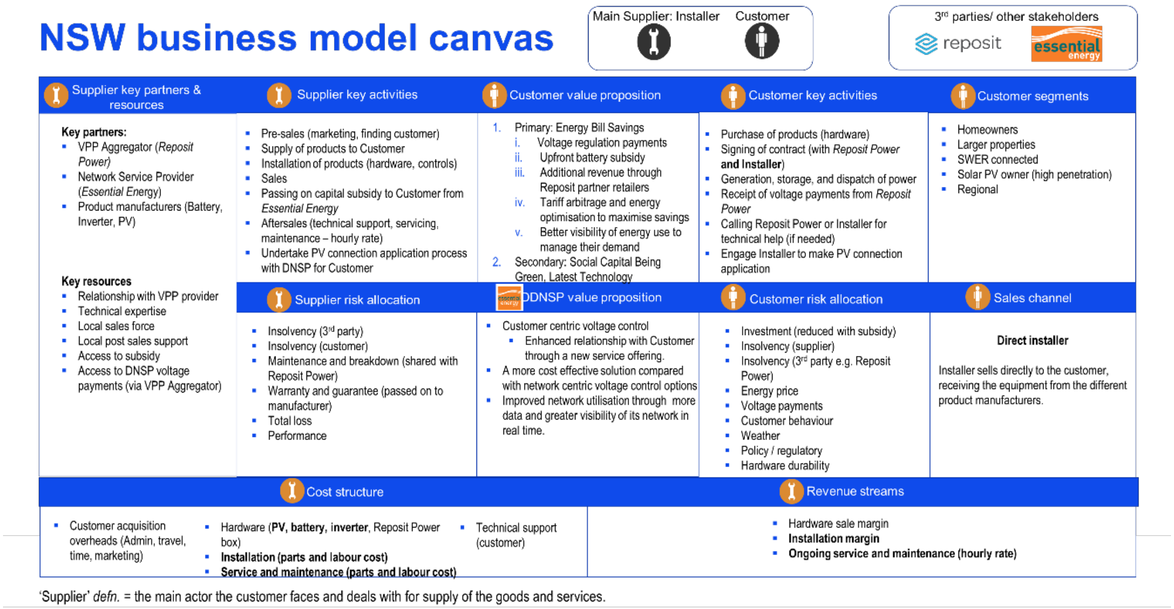


Figure 27. NSW business model canvas

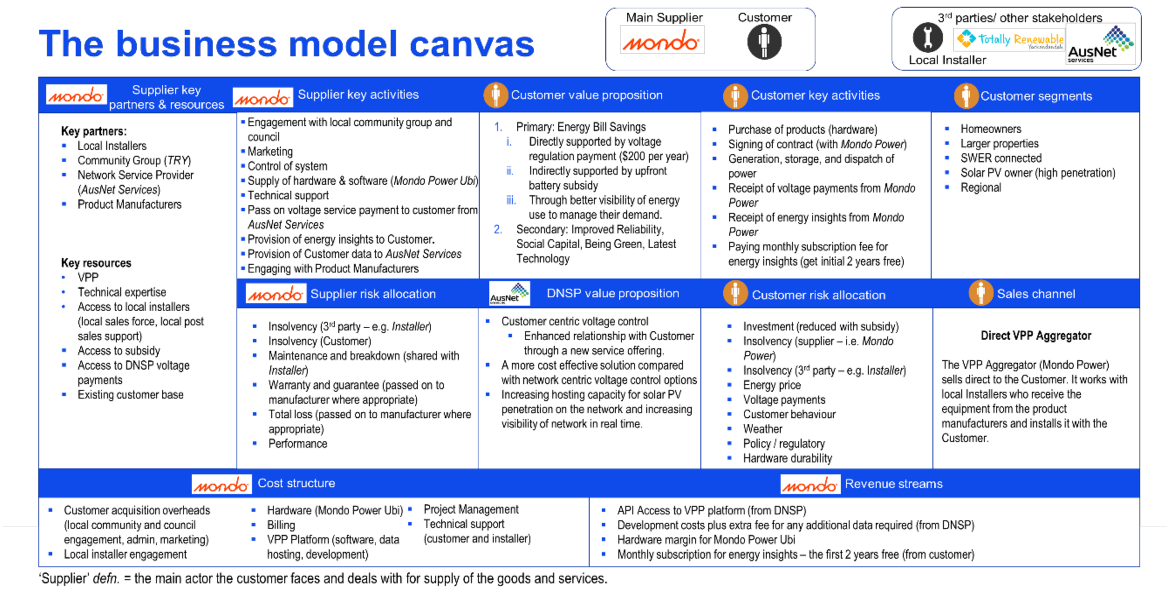


Figure 28. Victorian business model canvas

The Customer Journey

The customer journey illustrates the steps customers go through when engaging with a company supplying a product or service. For the two trials this was broadly the same, although there were subtle differences. The main steps have been characterised below.

Awareness

Raised through press releases, word of mouth, 'Townhall' meetings, mass mail drops.

Consideration & research

Undertaken through visiting stakeholder websites, completion of online EOI forms, discussing directly with installers (through phone call and home visit).

Purchase

Initiated through review and signing of contract, paying the Supplier, agreeing an installation date.

Service

Receiving of alerts on mobile phone via app, checking of smart phone app, contacting VPP aggregator or Installer by phone or email.

Retention

Visiting online portal, opening smartphone app, reviewing energy usage and any savings or payments.

Advocacy

Attending community form events, discussing with neighbours, engaging with social media platforms.

Lessons Learnt Report: determining the network value of DER-based voltage support

Project Name: Networks Renewed

Knowledge Category:	Financial
Knowledge Type:	Valuation methodology
Technology Type:	Voltage regulation, solar PV and battery storage
State/Territory:	Collombatti, New South Wales & Yackandandah, Victoria

Key learning

Networks Renewed successfully contracted revenues for the voltage support between two distribution network service providers (DNSPs) and the 90 customers involved in the trial. The payments were designed to exceed the value of any other values available as well as any lost customer solar production. The transactions were processed as direct payments ($1/kWh) in NSW and as $200 upfront as gift cards in Victoria. No additional value for the customers through market participation (revenue stacking) was known to have been achieved, as this is still an evolving opportunity with the Australian Energy Market Operator (AEMO).

These costs can be compared to an equivalent network-side solution. In Collombatti, the reconductoring was seen as the preferred network option, a distance of approximately 5km between the existing voltage regulators and the start of the single wire earth return (SWER) network, for a cost of approximately $300,000. Allowing for a reconductoring cost of $60,000 per km, and assuming a 40 year life time and 8% discount rate, the annualised cost of the reconducting solution in Collombatti is $5,000/km/year. In Yackandandah, reconductoring was also seen as suitable, the backbone of the Ben Valley feeder is approximately 10km in length and the solution cost estimate was $300 to $700k when combined with appropriate new transformers. An alternative solution of splitting the SWER at a cost of $150,000 was also considered for Yackandandah.

Table 3. Costs of solutions

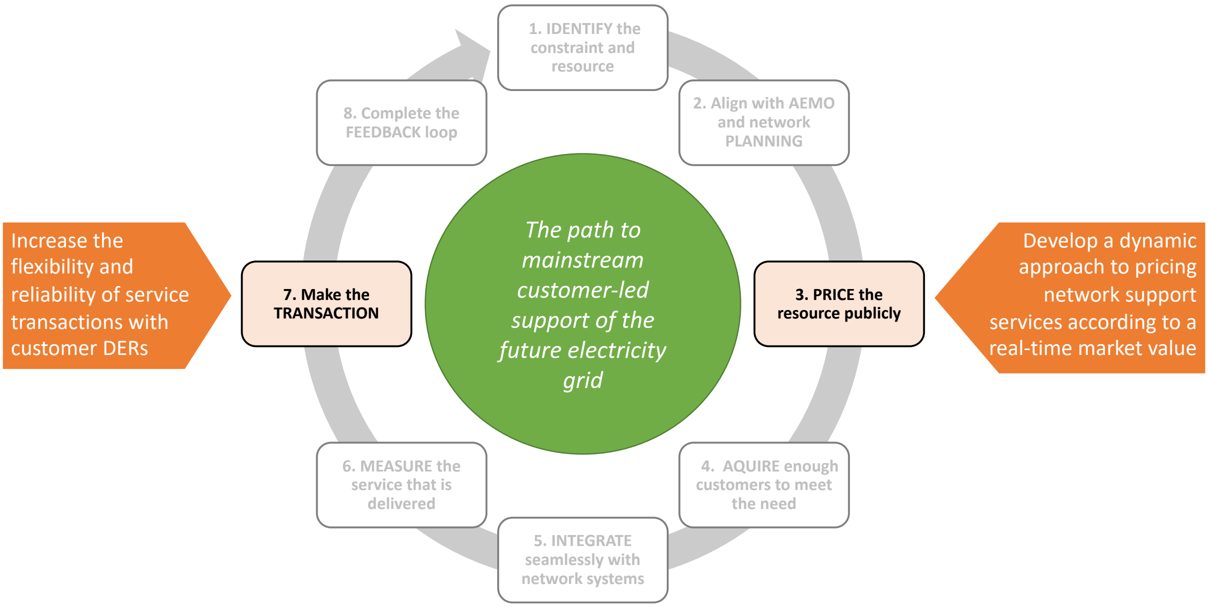
	Yackandandah	Collombatti
Reconductoring (annualised cost per km)	$5,000	$5,000
Number of customers	49	97
Line length	10km	5km
Annualised network solution cost	~$50,000 (Reconductoring) ~$12,500 (Spitting SWER)	~$25,000 (Reconductoring)
Value per load customer ($/year)	~$1,020 / ~$255	~$257

Costs needs to be considered in terms of upfront and ongoing budgets. An important distinction with a traditional investment is that ongoing voltage support services will not fall into the DNSP's regulated asset base, which may create an incentive bias against demand-side solutions. This issue is explored deeply in ISF's Demand Management Incentives Review and is driving a general trend in exploring what it means to move towards a Distribution System Operator (DSO) frame of thinking.

Both trials experienced some communications problems and learned lessons about how the DNSP would seek to set commands and strategies for the distributed energy resources' (DERs') response. This highlighted some strategies that third-party aggregators can employ to improve the value of their offering by increasing the flexibility and responsiveness.

Implications for future projects

The key knowledge gaps that still exist relate to the commercial implementation of pricing that matches the shared value to both the customer and DNSP, along with establishing a flexible and reliable means of transacting for the service once it is provided.



Develop a dynamic approach to pricing network support services according to a real-time market value. In the trial, customers received either $1 per kWh in NSW, or $200 per year gift certificate in Victoria. These pricing levels were chosen in order to ensure the customer systems would always respond to the voltage control signals and would provide enough compensation for any lost solar production. In future, a more dynamic approach to the pricing of services could be used that responds and fluctuates according to a (real or simulated) market value for that service.

Increase the flexibility and reliability of service transactions with customer DERs, through improving control and communications.

- For DER-based network support to be a viable alternative to traditional solutions, they will need to be responsive to a multitude of different command instructions or operating regimes. Thus, the DNSP must be able to set volt-watt and volt-VAr responses as a standard.
- The portfolio nature of an aggregated resources increases the risk to the reliability of the service, particularly instances where devices are 'out of communication'. Future projects should include a strong component of de-risking the portfolio operation by assessing its robustness and resilience through contingency-type events e.g. establishing a fall-back operation such as discharging and charging on a timeclock, or in response to local conditions (local voltage sensing).

Background

Objectives or project requirements

The project aimed to quantify the network value of voltage support services that could be provided by a coordinated virtual power plant comprising distributed residential solar and battery units.

The network value of DER-based voltage support is dependent on five primary factors:

- **Power and Energy:** It is clear that the power and energy capacity of DER will affect the value that a DNSP can derive. Both peak power (kW), and the amount of time the peak power can be delivered, were important. To achieving a high value to the network, a DER must optimise this ratio. For example, in the Essential Energy trials, 2.5x was the most desirable energy/power ratio for DERs installed, matching the two and a half hours that evening peak loads were usually experienced.
- **Flexibility & responsiveness:** The ability for a DNSP to flexibly adapt its charging, discharging and reactive power delivery strategy is important in assessing DER value. This includes ability for prescribed responses to commands (or bids), or preprogramed responses to local conditions.
- **Risk:** To source voltage support from DERs, a DNSP must gain comfort with uncertain levels of control over the asset. This involves an element of risk. In the Networks Renewed trials, this was experienced due to poor quality communication links. However, customer assets may be unable to respond to voltage support signals for other reasons such as the DERs providing other services (e.g. frequency), limited reactive power capacity or simply customer preference to withhold the service. DNSPs are not new to risk, already having to manage outages, repairs and maintenance on their own equipment, however responding to the risk of the performance of a fleet of generators is a different mode of doing business. The questions shift from 'is the asset working or not?' to 'what percentage of units are in service?'

However, there is also an element of alleviating risk. A DNSP investing in a network solution takes the risk of a long-term asset investment. By acquiring voltage support as a service, the DNSP has no sunk-cost in redundant assets. The problem may potentially abate in time, or a new technology solution may be developed. By shifting asset ownership to another party, the DNSP has increased optionality that reduces its exposure to technology risk.

- **Location and Concentration:** DERs must be located in the right place, downstream of an asset which is at or near its voltage limit. The trials revealed a willingness by DNSPs to incentivise battery storage towards the end of the line where possible. However, the concentration of DERs must also be sufficient to have a meaningful impact on power quality.
- **Cost of alternative:** Finally, the value of the DER-based solution is dependent on the next best alternative available to the network, its operational risks and its lifetime costs.

Ultimately a metric to compare value with other solutions is required.
Two suitable examples are:

- **$/Volt/customer/year; or**
- **$/V /MW of load/year**

Process undertaken

This general process for quantitatively determining network value for the next best alternative was established:

1. Obtain statistical or explicit data on the occurrence of voltage issues across the network and categorise the types of voltage pathology that occur (they are not always due to solar generation).
2. [for extrapolating findings to other network areas] Determine the set network types that will exhibit similar voltage behaviours and for which a similar approach is likely to apply.

(for example, single-wire earth-return rural network, high-density urban overhead three-phase low voltage (LV) network, low-density suburban overhead three-phase LV network, commercial high voltage (HV) feeder hosting MW-scale rooftop solar generation, etc.);

3. Assign network-side solutions to each type and estimate their cost as a function of MW of load or solar capacity. This will be inherently uncertain but within a factor of two is a reasonable expectation.
4. Consider what fraction of the cost of each solution should be assigned to voltage regulation, because some network upgrades will solve multiple problems (for example, reconductoring permits load growth as well as reducing the voltage envelope).

Both trial areas, Yackandandah and Collombatti, assessed a comprehensive suite of alternatives ranging from low cost, limited-impact solutions such as transformer taps and load balancing, to network level investments such as re-conductoring or static VAr compensators. In both the Yackandandah and Collombatti trials, reconductoring was seen as the traditional network option, as voltage swings were already beyond what could be addressed through smaller measures. It was also noted that VAr compensation may not be particularly effective on resistive networks.

By using reconductoring as benchmark, the process for estimating network value of a demand-side alternative is somewhat simplified. It is worth noting that reconductoring needs to be costed on a per kilometre basis, whereas a demand-side model incurs costs on a per customer basis. Thus, the demand-side solution is likely to increase in favour for longer feeders with lower customer density per kilometre.

Lessons Learnt Report: obtaining good value for customers who provide voltage services from their solar or batteries

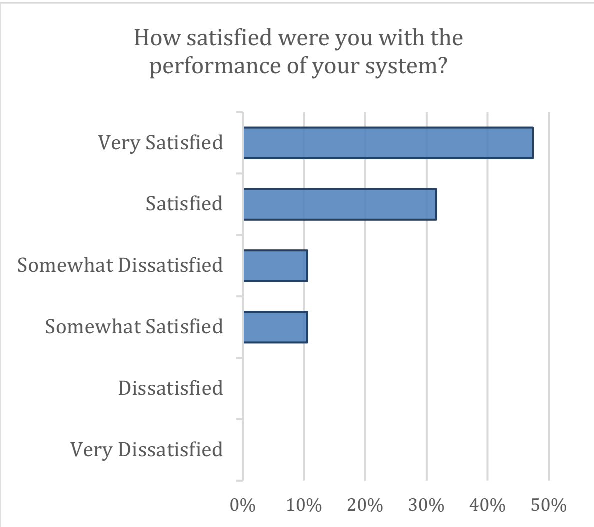
Project Name: Networks Renewed

Knowledge Category:	Customer Experience
Knowledge Type:	Procedural
Technology Type:	Voltage regulation, Solar PV and Battery storage
State/Territory:	Collombatti & Bellingen, NSW & Yackandandah, Victoria

Key learning

Customers were happy with their experience in the Networks Renewed trial, and are keen to more proactively manage their energy in the future. However customer engagement, particularly when communicating and installing new energy technologies, could be improved.

- Most respondents (79%) were pleased with the performance of their installed systems although 57% of the respondents did not notice any change in their power quality. However, 68% did notice that their electricity bills were much lower after the commencement of the trial and 74% were satisfied with the bill savings achieved.



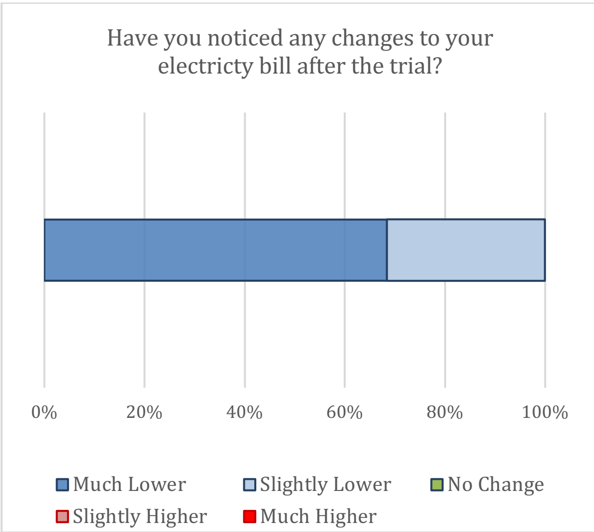


Figure 29: Customer satisfaction on system performance in NSW (left), Impact of NSW trial on customer bill savings (right) (n=19)

- At the end of the trial, participants reported an increased understanding of their electricity use. Mobile apps (64%) were the most popular mode of tracking and more than half of these check their app daily or weekly (some customers reported issues with using the app). Only 8% of the respondents relied on just their electricity bills to track their electricity use. Almost all participants track their energy more since the trial started.

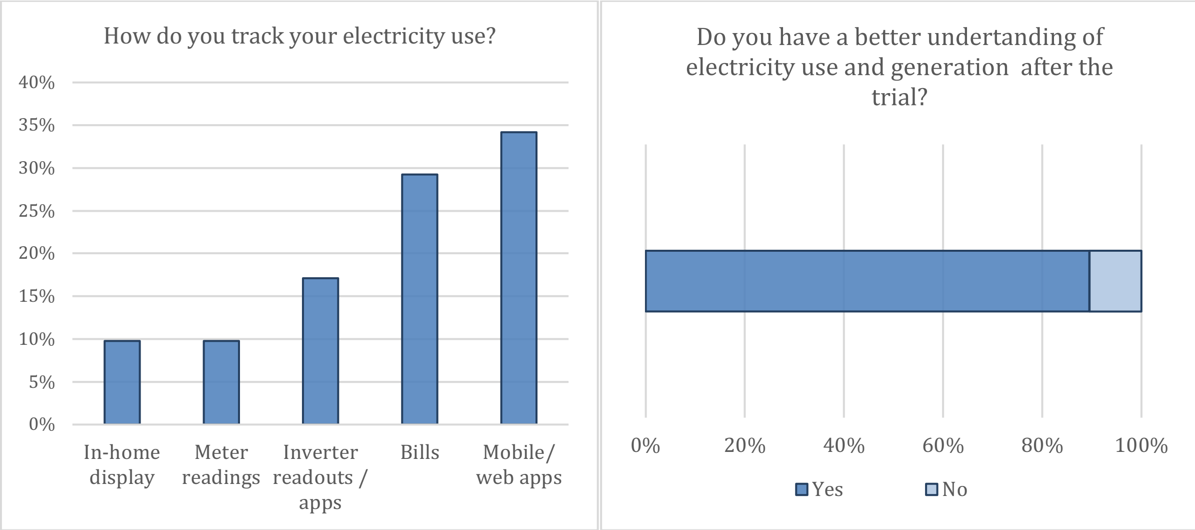


Figure 30: Mode of tracking electricity use (left, n=22), Improved customer understanding on electricity use (right, n=19)

- The main motivator for the NSW trial participants was economic (Figure 31a). Saving money on their electricity bills was rated as an extremely important consideration for joining the trial. Other reasons that found resonance included: benefitting from rebates and subsidies; being efficient with resources; storing excess solar; and doing their bit for the community. The size of the block indicates the range of responses from least important (1) to most important (5).
- In Victoria, however the key motivations were environmental (Figure 31b). While bill savings rated as a very important motivator, reducing carbon emissions and being efficient with resources were the top reasons people chose to join the trial, closely followed by doing their bit for the community.
- The trials engaged approximately 25-30% of the target population on the chosen feeders. However, customer acquisition was a difficult and time-consuming process. Informal feedback was collected from eligible households in the area, who did not join the trial. A common response was that the high upfront capital cost of the system, despite the subsidies, was a barrier for people to join the trial. The complexity of the offer was also challenging to understand, which provides an impetus for future work. Other reasons that affected the value proposition included: residents planning to sell their property; part-time residents; and customers that were unsure about committing to a long-term investment.

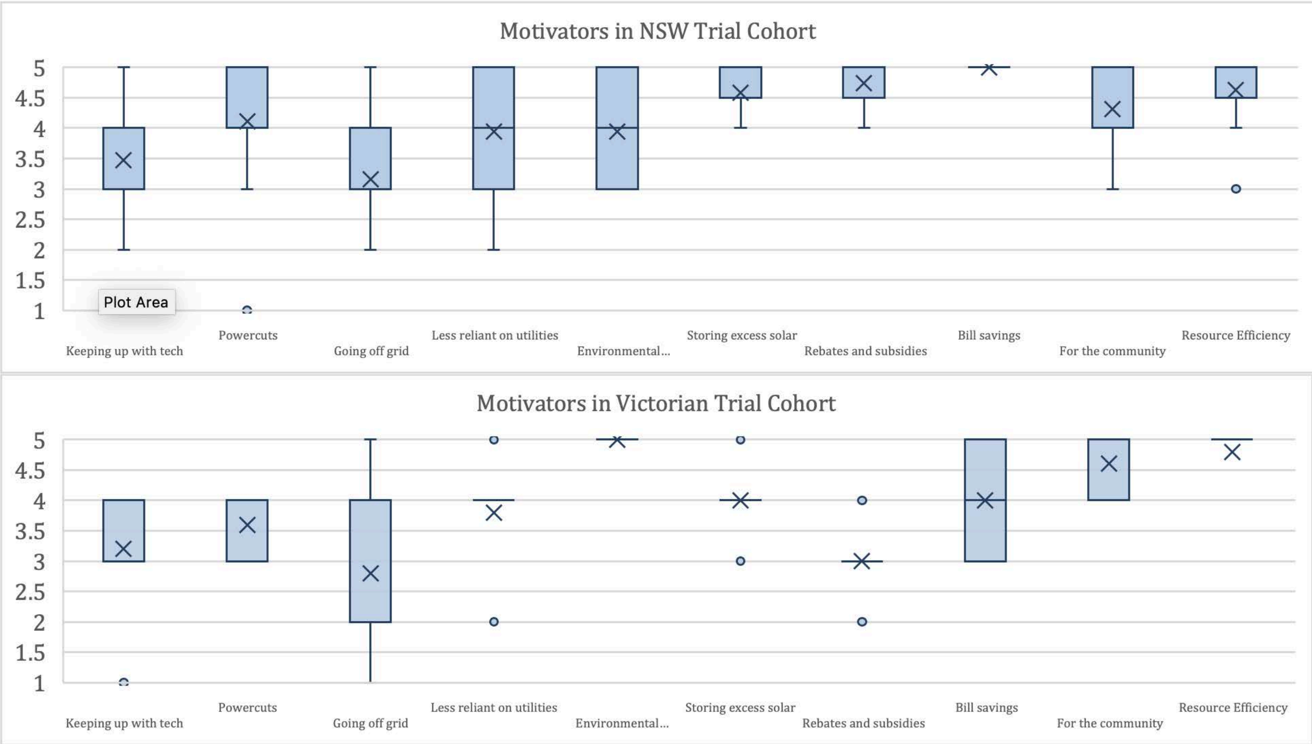
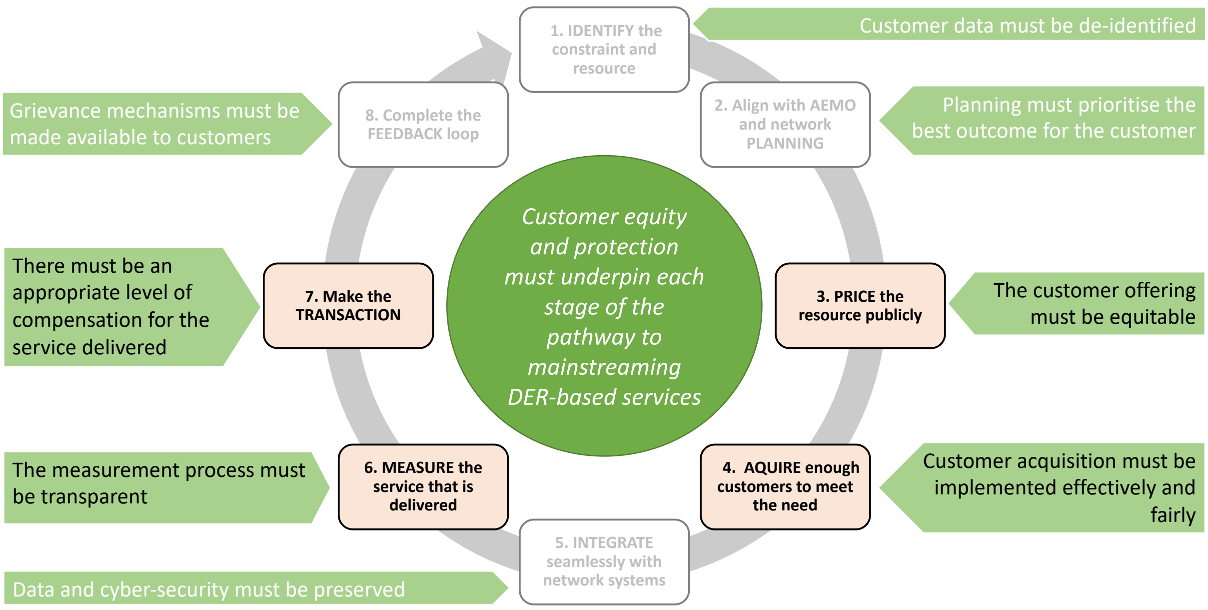


Figure 1: Motivators for joining the Networks Renewed Trial in NSW (a) and Victoria (b)

Implications for future projects

Future projects must ensure that customer equity and protection is deeply embedded at each stage of the commercial pathway. In the short-term it will be particularly important to: determine an equitable customer offering, including price; and ensure that the recruitment and implementation of the DER-based solution best serves the customer's needs.



The customer offering needs to be simple and effectively communicated, which requires a more detailed understanding of customer motivations and financial constraints. Over a quarter of participants did not find the communication tools used by the project team useful (Figure 32). The project websites appeared to be the least useful mechanism. In general, there was discrepancy in the amount of information each respondent received. Overall respondents were satisfied with their interactions with Essential Energy, somewhat satisfied with Reposit power. Especially in NSW, there appeared to be a lack of clarity on the customer offering since customers found it difficult to assign an appropriate value to the subsidy they wished to receive. In contrast, Victorian customers received a voucher in exchange of their systems being used / trialled, which seemed to be a clearer value proposition.

The impact of the customer offering on equity should also be investigated.

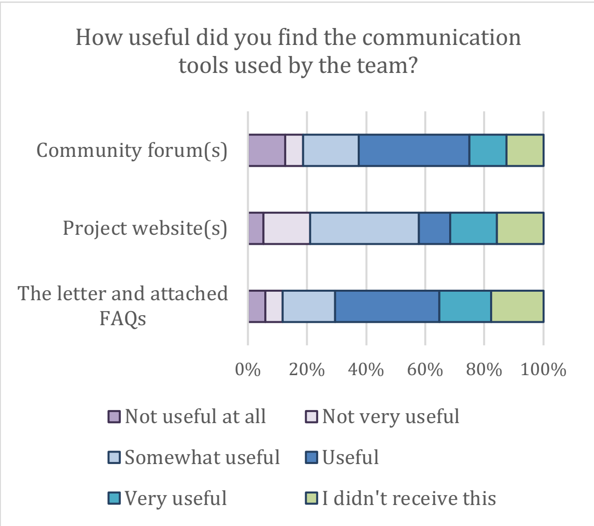


Figure 32. Participants felt that communication within the trial could be improved

DER-based network support services - including customer recruitment, measurement and transacting for service - must be fairly and effectively implemented. A specific source of dissatisfaction in Networks Renewed was the installation experience in NSW. It is important to note that installers were the primary contact that NSW participants had with the trial. Many installations were delayed as installers were not available[2], and there were issues with connectivity and billing once the system was installed. In contrast, in Victoria where a local installer (also involved in a long-term solar project in the town) was used, the levels of satisfaction was much higher and more positive. The emergence of challenges around installation and compliance, due to the rapidly evolving and expanding market, needs to be addressed for the long-term interest of customers.

Background

Objectives or project requirements

A key objective of Networks Renewed was to demonstrate that advanced distributed control of inverters connecting small scale solar PV and battery storage can be attractive to customers, while delivering network benefits. It thus sought to compare different ownership and operating arrangements for this behind the meter infrastructure. The project aimed to test the long-term viability of a customer owned business model for providing network support services.

[2] Most delays can be attributed to the 'solar boom' that occurred in the area at the same time as the trial was deployed

As the first demonstration of this technology in Australia, the project was required to recruit a significant number of customers to achieve these impacts.

Process undertaken

Customer acquisition was key part of both the pilot and market-scale demonstration stages. The process of customer selection and acquisition was primarily influenced by the feeders identified by the partner distribution network service providers (DNSPs). Acquisition was guided by a customer engagement plan and procurement model developed by the project partners. This process sought to mimic as closely as possible the process a customer would follow in the real world when purchasing and installing a storage system. A summary of the plan is below:

- The project group selected and set the subsidy model. In NSW, this was based on a per event payment to the customers who responded when network support was requested. In Victoria, customers received a lump sum payment in the form of a gift voucher to allow the DNSP to access their systems during the trial period.
- Solar installers were recruited to take part in the project. In NSW, these installers became part of Reposit Power's approved partner network. To be part of the network an installer had to meet minimum industry standards for accreditation and training for the installation of solar and storage equipment. Each installer signed a deed with Reposit/Mondo.
- The DNSPs approached customers in targeted areas to elicit expressions of interest (EOI's). Letters are sent from the DNSP directly to target customers for the trial outlining: the goals of the Networks Renewed project; their proposed role if they chose to participate; a link and phone number to express interest in participation; and the details of a community forum to learn more about the project and query the project team.
- The community forums were the main venue for customer recruitment. In Victoria, the customer engagement process relied heavily on the ground work done by Totally Renewable Yackandandah (TRY).
- Customers in NSW were encouraged to engage multiple installers to compare quotations for various supported storage systems. In Victoria, a local installer, already part of a previous solar installation initiative, was assigned for all customers. Once the customer received their quotations from the participating installers they choose which system they would like to go with and confirmed the final quotation with the installer.
- The installer then completed an application for the subsidy to the aggregator.
- In NSW, Reposit Power reviewed and approved or rejected the subsidy applications including the final subsidy amount to be paid to the customer based upon the system chosen and quoted. This subsidy was paid directly to the installers to be taken off the final cost price of the customer's system.
- The installer supplied, installed and commissioned the customer's storage and/or PV system including the Reposit/ Mondo controller.

Feedback on the experience was collected through an online exit survey at the end of the project. In NSW, the response rate was 60%, while in Victoria it was 36%. Informal feedback was also collected through phone calls and in-person interactions during the project.

Supporting information

Survey Questions (15 min)

Hello!

Essential Energy / AusNet Services and the University of Technology Sydney are conducting a survey following a recent trial in your area called Networks Renewed. The trial investigated the ability for solar PV and battery storage to make the local grid more reliable.

The survey takes around 10-15 minutes, all answers are confidential and we're not trying to sell anything. We would greatly appreciate your response as we evaluate the performance of the Networks Renewed trial and consider future trials of this nature.

General questions

Location details (NMI/Name/Address)

---Page 1---

Q1. How do you rate the following aspects of your electricity supply overall?

A. Reliability (e.g. have you noticed flickering, brownouts, blackouts or faulty appliances)

Very dissatisfied	Dissatisfied	Somewhat dissatisfied	Somewhat satisfied	Satisfied	Very satisfied

B. Responsiveness to outages (e.g. are you satisfied with the effort Essential Energy / AusNet Services puts in to fix a blackout? how quickly are blackouts fixed)

Very dissatisfied	Dissatisfied	Somewhat dissatisfied	Somewhat satisfied	Satisfied	Very satisfied

C. Cost:

Very dissatisfied	Dissatisfied	Somewhat dissatisfied	Somewhat satisfied	Satisfied	Very satisfied

Any other comments:

Q2. Do you keep track of your electricity use?

Yes	No

Q2. A. If Yes, how often do track your electricity use?

More than once a day	
Daily	
More than once a week	
Weekly	
More than once a month	
Monthly	
More than once a year	
Yearly	
Other	[please specify]

Q2. B. How do you track your use?

In-home display	
Mobile/ web apps	
Meter Readings	
Invertor readouts / apps	
Bills	
Other	[please specify]

Q3. How interested are you in reducing your electricity bill?

Very disinterested	Disinterested	Somewhat disinterested	Somewhat interested	Interested	Very interested

Q4. How willing would you be to make changes to when and how much electricity your household uses?

E.g. would you be happy to shift large energy uses to when solar energy was available i.e. in the middle of the day this could include practices like pre-cooling your home in the afternoon in summer so you do not need to have the air conditioner on in the evening when demand is high?

Very unwilling	Unwilling	Somewhat unwilling	Somewhat willing	Willing	Very Willing

Q5. Do you feel you know enough to reduce the amount of electricity your household uses?

No knowledge	Little knowledge	Average knowledge	Good knowledge	Excellent knowledge

Any other comments:

--Page 2--

Q6. Have you changed electricity retailers since 2016?

Yes	No
If yes, when did you change?	[please specify]
If yes, why did you change?	[please specify]

Q7. Have you sought quotes from PV (solar) and or battery storage system installers since 2016?

Yes	No
If yes, when did you get the quote?	[please specify]
If yes, what system did you install?	[please specify]
If not, why not?	Not interested / Already have one / Considering to get one in the future / Others [please specific]

Q7. A. If Yes, are you a participant of the Networks Renewed trial?

Networks Renewed is a trial run by Essential Energy / AusNet Services, Reposit / Mondo Power and the University of Technology Sydney to assess the potential for customer-owned battery storage systems to better manage electricity network demand. As part of the trial customers were offered subsidised batteries that were connected to the grid to offer network support services for a fixed payment.

Yes	No
If No, Why? Please specify	Not aware / not interested / not eligible / Others [please specific]

Any other comments:

If no to Q7 or Q8 go to Q17 If Yes, Participant questions

--Page 3--Motivation

Q8. Please rate how important were these reasons in your decision to participate in the trial?

A. Keeping up with the latest technology

Not at all important	Slightly important	Moderately important	Very Important	Extremely important

B. Operating independently from the grid during power interruptions

Not at all important	Slightly important	Moderately important	Very Important	Extremely important

C. Being able to disconnect from the grid permanently / going off grid

Not at all important	Slightly important	Moderately important	Very Important	Extremely important

D. Being less reliant on electricity utilities

Not at all important	Slightly important	Moderately important	Very Important	Extremely important

E. Reducing my household carbon emissions / environmental reasons

Not at all important	Slightly important	Moderately important	Very Important	Extremely important

F. Storing excess solar electricity from my solar system

Not at all important	Slightly important	Moderately important	Very Important	Extremely important

G. Benefitting from rebates and subsidies

Not at all important	Slightly important	Moderately important	Very Important	Extremely important

H. Saving money on my electricity bill

Not at all important	Slightly important	Moderately important	Very Important	Extremely important

I. Doing my bit for the community

Not at all important	Slightly important	Moderately important	Very Important	Extremely important

J. Being efficient with our resources

Not at all important	Slightly important	Moderately important	Very Important	Extremely important

Any other comments:

--Page 4------------------------

----------------------Performance

Q9. How satisfied were you with your battery storage / PV system's performance?

Very dissatisfied	Dissatisfied	Somewhat dissatisfied	Somewhat satisfied	Satisfied	Very satisfied

Q10. Have you noticed any changes to power quality before and during the trial?

(e.g. have you noticed any change in how often there are occurrences of flickering, brownouts, blackouts or faulty appliances)

Much declined	Slightly declined	No change	Slightly improved	Much improved

Q11. A. Have you noticed any changes to your electricity bill before and during the trial?

Much lower	Slightly lower	No change	Slightly higher	Much higher

Q11. B. How satisfied are you with your electricity bill savings as a result of installing your battery storage / PV system?

Very dissatisfied	Dissatisfied	Somewhat dissatisfied	Somewhat satisfied	Satisfied	Very satisfied

Any other comments:

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---------------------Behaviour change

Q12. Do you have a better understanding of your electricity use and generation after the trial?

Yes	
No	

Q13. A. As a result of the trial have you made any changes to your electricity use patterns / habits? (tick all that apply)

I reduced the amount of energy I used	
I changed the time that I used energy/appliances (e.g. to when solar is generating)	
I staggered my use of energy/appliances	
Other	[please specify]

Q13. B. How often did you check the Reposit / Mondo Power app/web portal? (select one)

More than once a day	
Daily	
More than once a week	
Weekly	
More than once a month	
Monthly	
More than once a year	
Yearly	
Other	[please specify]

Q13. C. How often did you track your electricity after the trial started?

More than before	
Less that before	
About the same	

Any other comments:

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-----------------------Communication

Q14. How did you hear about the trial? (tick all that apply)

Letter from Essential Energy/ AusNet Services	
Friends & Family	
Solar Installers	
Reposit / Mondo	
Community forum(s)	
Other	[please specify]

Q14. A Did you find the communication with the project team* useful? (tick all that apply)

The letter and attached FAQs	Yes / No / I didn't receive this
Project website(s)	Yes / No / I didn't access this
Community forum(s)	Yes / No / I didn't attend this
Other	[please specify]

*The project team includes Essential Energy/ AusNet Services, Reposit / Mondo Power, technology installers, and the University of Technology Sydney.

Q14. B. How satisfied were you with your interaction with the following as part of the trial?

Installer (getting quotes, getting the system installed)

Very dissatisfied	Dissatisfied	Somewhat dissatisfied	Somewhat satisfied	Satisfied	Very satisfied

Reposit power / Mondo Energy

Very dissatisfied	Dissatisfied	Somewhat dissatisfied	Somewhat satisfied	Satisfied	Very satisfied

Essential Energy / AusNet Services

Very dissatisfied	Dissatisfied	Somewhat dissatisfied	Somewhat satisfied	Satisfied	Very satisfied

Q15. Has your understanding of Essential Energy/ AusNet Services changed during the Networks Renewed trial?

Much declined	Slightly declined	No change	Slightly improved	Much improved

Q15. A. Has your opinion of Essential Energy/ AusNet Services changed during the Networks Renewed trial?

Much declined	Slightly declined	No change	Slightly improved	Much improved

Any other comments:

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----------------------Conclusion / Follow up questions

Q16. Did you find participating in the trial worthwhile?

Yes	
No	
Would you like to add any comments or suggestions?	[please specify]

Q16. A. Based on your recent experiences, how likely would you be to recommend this trial to others?

NA	Not at all likely	Slightly likely	Likely	Very Likely

Q16. B. Would you be happy to be contacted for a follow-up interview?

We would like to get some detailed feedback on your experience of the trial. This will take about 30 mins of your time. This will help us improve the design of any future trials and programs Essential Energy / AusNet Services might offer.

Yes	
No	
If yes, please provide contact details	[please specify]

If No, Control group gets added at this point, Trial participants continue from above

Q17. In the medium term (<5 years), do you think you will install new or additional energy technology? (tick all that apply)

Solar PV	
Batteries	
Energy management software e.g. Nest	
Other	[please specify]

Q18. In the medium term (<5 years), would you be interested in new energy deals that include new energy technology?

Solar	
Batteries	
Energy management or reduction	
Other	[please specify]

Q19. Would you consider participating in a future energy program?

Yes	
No	If no, why not?
If yes, please provide your contact details	[please specify]

Any other comments:

That brings us to the end of the survey. The Networks Renewed project team, including Essential Energy / AusNet Services and the University of Technology Sydney, greatly appreciate your time and feedback. Please feel free to leave any comments or questions below, along with contact details if you would like us to follow up with a phone call:

[insert comment]
[insert contact details]

Appendix

Keywords

Voltage, DER, distributed generation, solar PV, battery storage, distribution network, ancillary services, smart grid, inverter, reactive power, value stack, LV network, hosting capacity, export limits

Glossary of terms and acronyms

Term	Description
AEMO	Australian Energy Market Operator
ARENA	Australian Renewable Energy Agency
BTM	Behind the meter
AS4777:2016	Revised standard for grid connection of energy systems via inverters
DER	Distributed Energy Resource
DNSP	Distribution Network Service Provider
HV	High voltage
LV	Low voltage
PV	Solar photovoltaics
SCADA	Supervisory Control and Data Acquisition
VAr	Volt-ampere reactive
VPP	Virtual Power Plant