Regulatory Information Notice (RIN)

Supporting Information for Demand Management Innovation Allowance Mechanism (DMIAM)

2019-2020

October 2020
Prepared by Essential Energy

Contents

1 Introduction

The Demand Management Innovation Allowance Mechanism (DMIAM) is applied to Essential Energy by the Australian Energy Regulator (AER) as per the *Demand Management Innovation Allowance Mechanism for distribution network service providers December 2017* and *Framework and Approach paper July 2017* regarding the application of the Allowance Mechanism to the NSW distributors in the 2019−24 regulatory control period.

The DMIAM aims to provide incentives for Distribution Network Service Providers (DNSPs) to conduct research and investigation into innovative techniques for managing demand so that, in the future, demand management projects may increasingly be identified as viable alternatives to network augmentation.

The Demand Management Innovation Allowance Mechanism (DMIAM) forms one component of the DMIS. It is a valued element in enhancing the distributors' understanding of Demand Management tools and incorporating those understandings into business process. This document outlines Essential Energy's DMIAM expenditure, the benefits of the projects and the outcomes achieved.

2 Summary of Submission

In 2019-20, Essential Energy's DMIAM expenditure has supported one ongoing project from previous years:

1. Continuation of Networks Renewed

Total program cost for the 2019-20 financial year is $13,220 with all of which is OPEX, as shown in Table 1. For ongoing DMIAM projects, actual and forecast expenditure is presented in Table 2.

Table 1: DMIAM Expenditure 2019-20

Name of Project	Total amount of the DMIAM spent in 2019-2020		
	Operating expenditure ($ nominal)	Capital expenditure ($ nominal)	Total expenditure ($ nominal)
Networks Renewed	$13,220		$13,220
Total	$13,220		$13,220

Table 2: Total amount of the DMIAM spent and forecast for ongoing DMIAM Projects within 2019-20

Name of Project	Total amount of the DMIA spent and forecast for ongoing DMIAM Projects					
	FY2016-17 Total expenditure ($ nominal)	FY2017-18 Total expenditure ($ nominal)	FY2018-19 Total expenditure ($ nominal)	FY2019-20 Total expenditure ($ nominal)	FY2020-21 Total expenditure ($ nominal)	Total expenditure ($ nominal)
Networks Renewed	$81,796	$107,548	$171,248	$13,220	$0	$373,812

For detailed information, please refer to the specific project reports or contact: dmcoordinator@essentialenergy.com.au

All costs are determined using appropriate procurement systems and time recording.

2.1 Developments from previous years' DMIAM

Development during the regulatory period included:

- Networks Renewed: Joint project with the Australian Renewable Energy Agency (ARENA), University of Technology Sydney, Reposit Power and Fronius, to test battery storage systems and advanced solar inverters with eligible customers within a virtual power plant arrangement to better manage the demand for network capacity and integration of renewables in a partially subsidised trial.

Knowledge gained from previous DMIAM projects has allowed Essential Energy to provide a more cost reflective evaluation of demand management options within Essential Energy.

- Peer to Peer review to expand Essential Energy's knowledge on new and emerging technologies and technology usage trends relating to distribution level markets, while facilitating development of a potential distribution level market road map specific to Essential Energy's network.
- eGrid: Essential Energy working group and trial to investigate the reliability performance and cost/ benefit analysis of standalone power system technology as a lower cost option compared to traditional network solutions at the fringe of grid.
- Switched Reactors: Developed to reduce reactive power demands in single wire earth return (SWER) systems, thereby reducing network voltage swing, line losses and the need for larger isolation transformers, deferring or removing the need for augmentation and lowering the cost of supply to customers.
- Demand and Energy - Technology and Environment Paper: A report on customer and utility scale technologies, trials and related environmental changes that are likely to impact electricity demand and energy use within a series of defined periods.
- Demand Management Best Practice Paper: A critical assessment of the world-wide best practice processes, information, and technology in electricity NNA analysis and selection with an understanding of the regulatory frameworks and incentives available.
- Conservation Voltage Reduction through the use of low voltage regulators to expand Essential Energy's knowledge in the area of a Conservation Voltage Reduction while also enabling evaluation of the potential for conservation voltage reduction techniques to reduce network peak demand as a secondary benefit in business as usual operation, i.e. changes to voltage regulation practices.
- Capacitor Package Development: Completion of standards and specifications to approach the market and guidelines for applications on the network.
- Controlled Load initiatives: Development of a Controlled Load Algorithm and NPV of alternative Controlled Load technology.

This renewed business case derivation for Demand Management was reflected in Essential Energy's most recent AER submission and will continue to be reflected in policy and project considerations.

3 Networks Renewed

3.1 Summary

The Networks Renewed project, delivered through network demonstration areas in NSW (Essential Energy) and Victoria (AusNet Services) with different technology partners, has provided real-world evidence of customer inverters overlaid with smart control providing voltage management services to Distribution Networks through dynamic control of both real and reactive power. This has enabled a higher uptake of solar PV with minimal customer impact, whilst enabled customer battery storage systems to be centred as a solution to address networks constraints at potentially lower cost compared to traditional network options.

The project has also provided valuable insight to the value a Distribution Level Market can provide to both customers and networks. In addition, it has helped identify and prioritise some of the foundation work required before networks can operate in an environment with a high uptake of Distributed Energy Resources (DER) that supports effective and efficient integration of renewables while maintaining downward pressure on network charges.

3.2 Background information

Traditionally, the capacity of the distribution network has been focused on supplying peak load. As the cost of renewables such as solar PV reduces, the focus is shifting towards peak generation.

The Electricity Network Transformation Roadmap (ENTR) estimates that, by 2050, 30-50 per cent of energy in the national electricity market (NEM) will be generated at the customer level, resulting in growth of two-way power flows within distribution networks. (Note: it is likely generation penetration for Essential Energy’s network will be higher than the ENTR forecasts, due to connection of larger average-size generator systems – particularly solar PV.)

Based on the percentage uptake of solar PV across its customer base, Essential Energy currently leads NSW distribution network service providers.

Figure 1 presents accumulated solar PV panel capacity for residential and business premises connected to Essential Energy’s network, Figure 1 is clear evidence that solar PV across Essential Energy’s network continues to grow year on year.

Figure 2 presents battery storage applications received since December 2016, which currently exceeds 3500 applications totalling more than 40MWh.

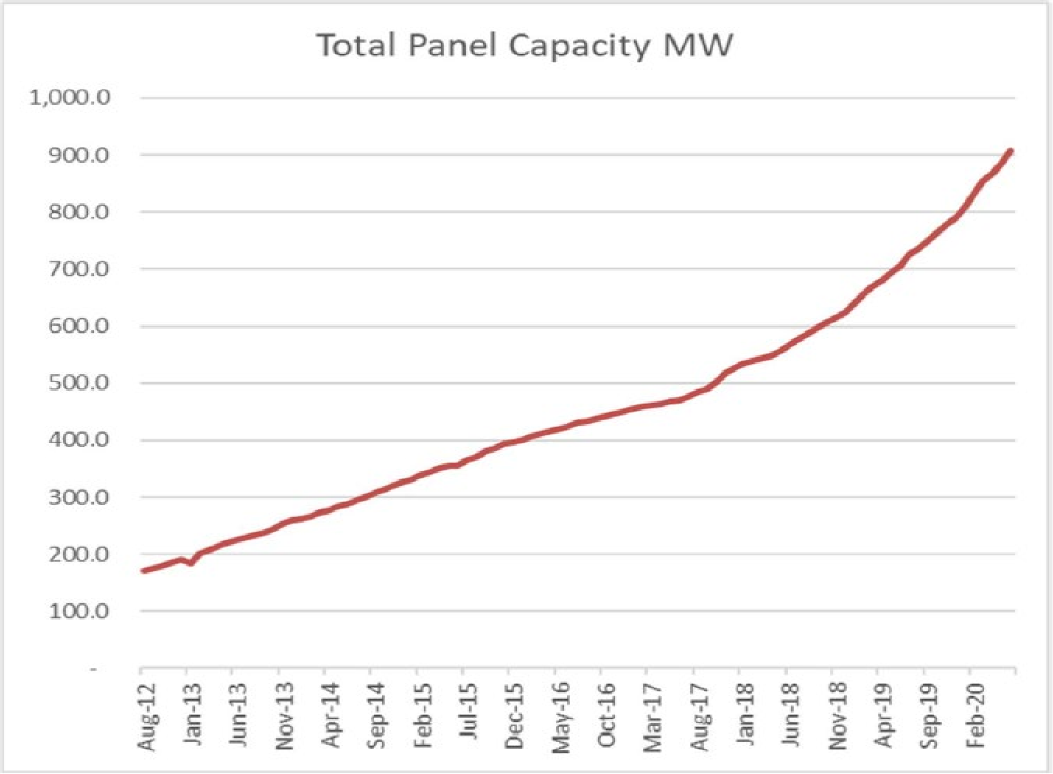

Figure 1: Installed Residential and Business Premise Solar Panel Capacity (MW)

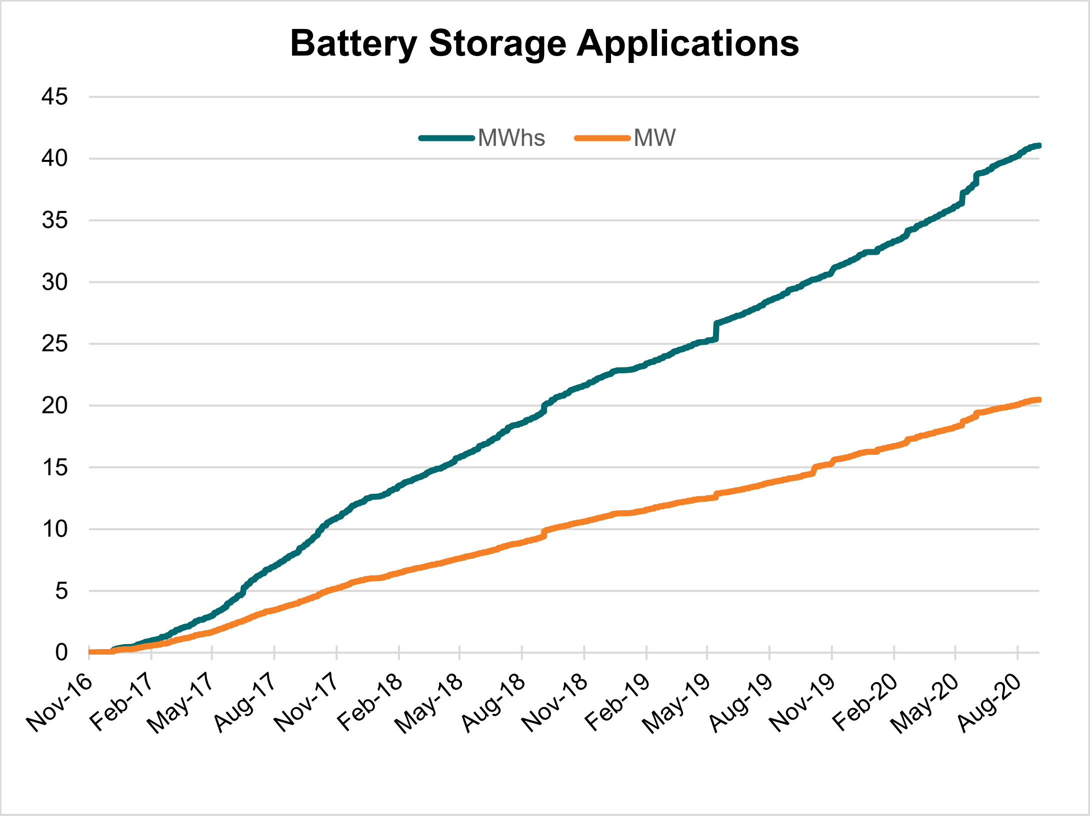

Figure 2: Battery Storage Applications

Essential Energy's electricity distribution network was planned, designed, and operated to supply peak load. As it transitions to peak generation, issues such as a reduction in network utilisation are starting to emerge. As a result, in some areas additional capacity is being demanded from the distribution network.

Figure 3 presents the top ten summer demand days at a sample zone substation (which is a common summer peak demand profile exhibited across the network). While solar PV was connected during 2015-16, peak load on the zone substation has not reduced. The surrounding network must therefore still have the capacity to meet this peak load.

As peak generation increases, or minimum network demand reduces, the zone substation experiences reverse power flow. Figure 4 presents the same sample zone substation during minimum demand with reverse power flow. As shown in Figure 3 and Figure 4, utilisation of the network has reduced.

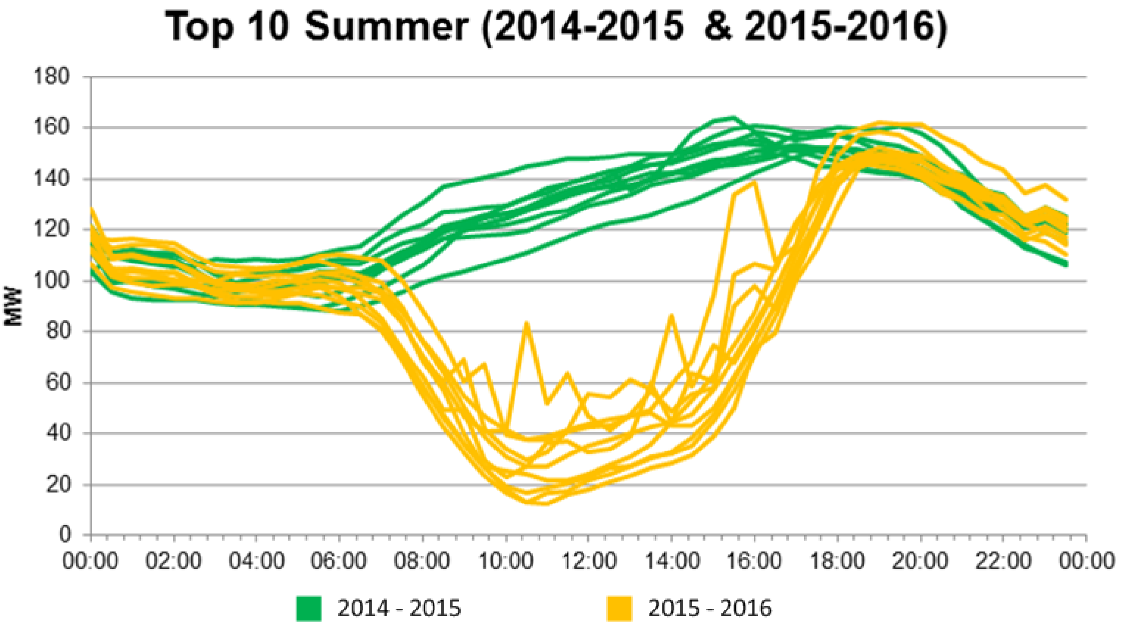

Figure 3: Sample Zone Substation before and after Solar PV connected

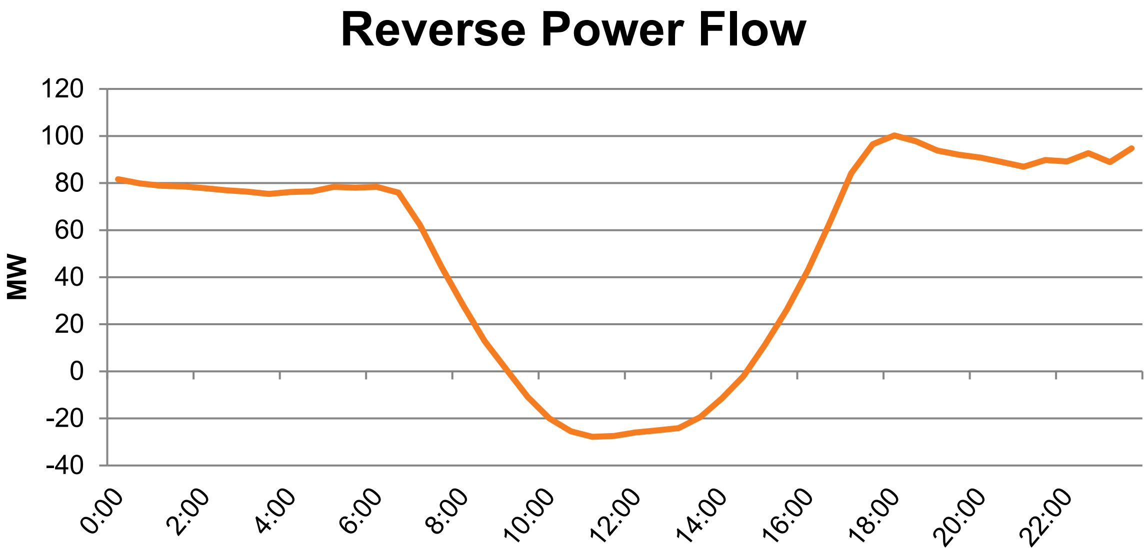

Figure 4: Sample Zone Substation – Minimum Demand

Dependent on network characteristics, a reduction in asset utilisation may result in additional capacity requirements. Referenced to Figure 5, generation results in voltage rise on the network. If combined with a reduction in network utilisation, this results in widening of the voltage envelope (due to the requirement of supplying peak load, as illustrated in Figure 3). Widening of the voltage envelope may result in challenges in achieving the required supply standards. On a voltage-constrained network, it may also result in a network constraint when supply limits cannot be maintained.

Figure 6 presents both a demand and voltage density plot for a single connection point and widening of the voltage envelope.

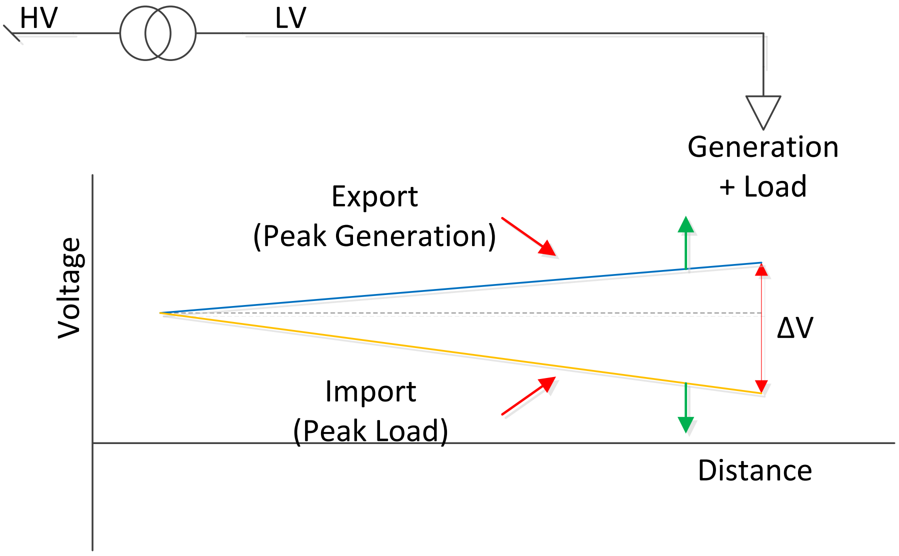

Figure 5: Peak Generation and Peak Load Widening the Voltage Envelope

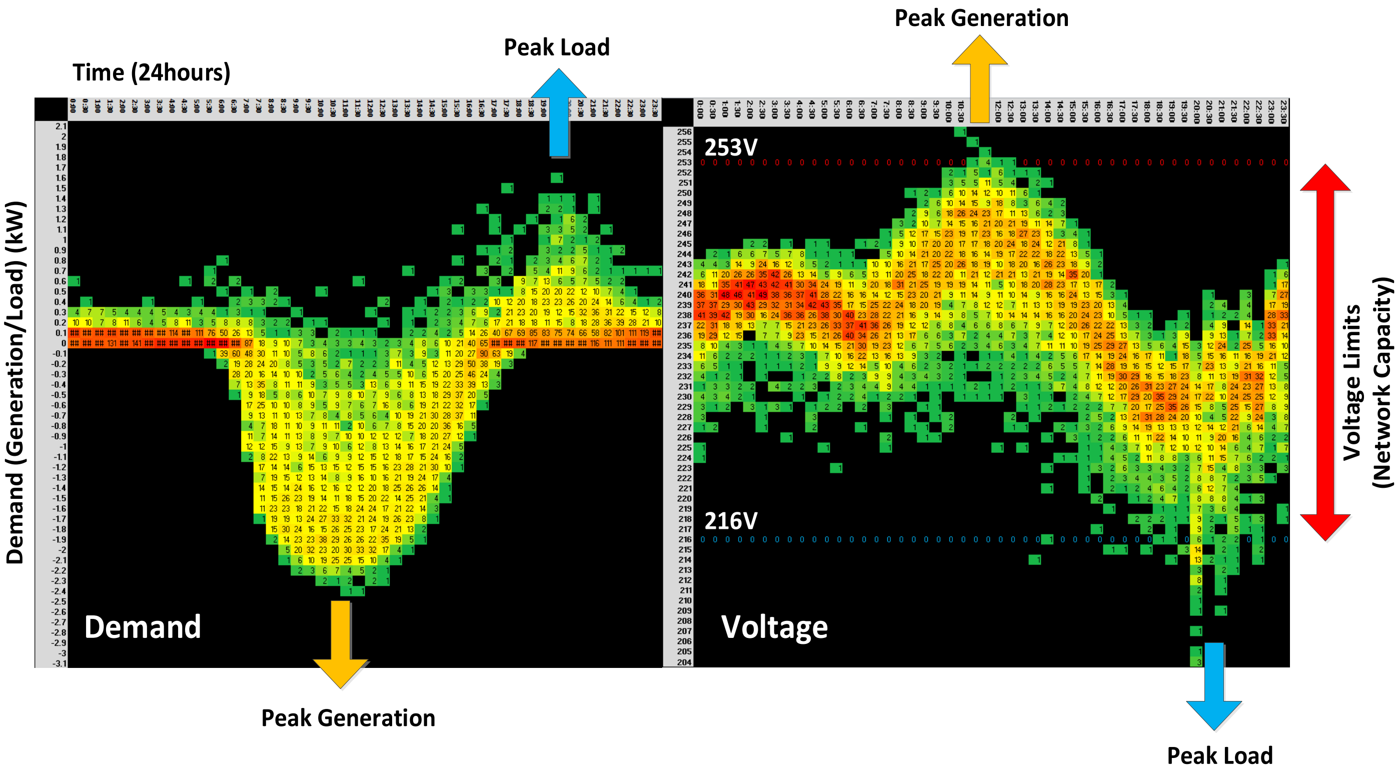

Figure 6: Demand & Voltage Density Plot Illustrating Widening of the Voltage Envelope at a single Network Connection Point

Essential Energy’s network (presented in Figure 7):

- by land mass covers 95 per cent of NSW
- has a total circuit length of approximately 191,000km – an equivalent total length almost five times the earths circumference
- comprises approximately 96 per cent of overhead network
- has ~75,000 km of steel conductors, with a typical resistance of 15 to 25 Ohms per km
- has ~30,000 km Single Wire Earth Return (SWER) rural lines.

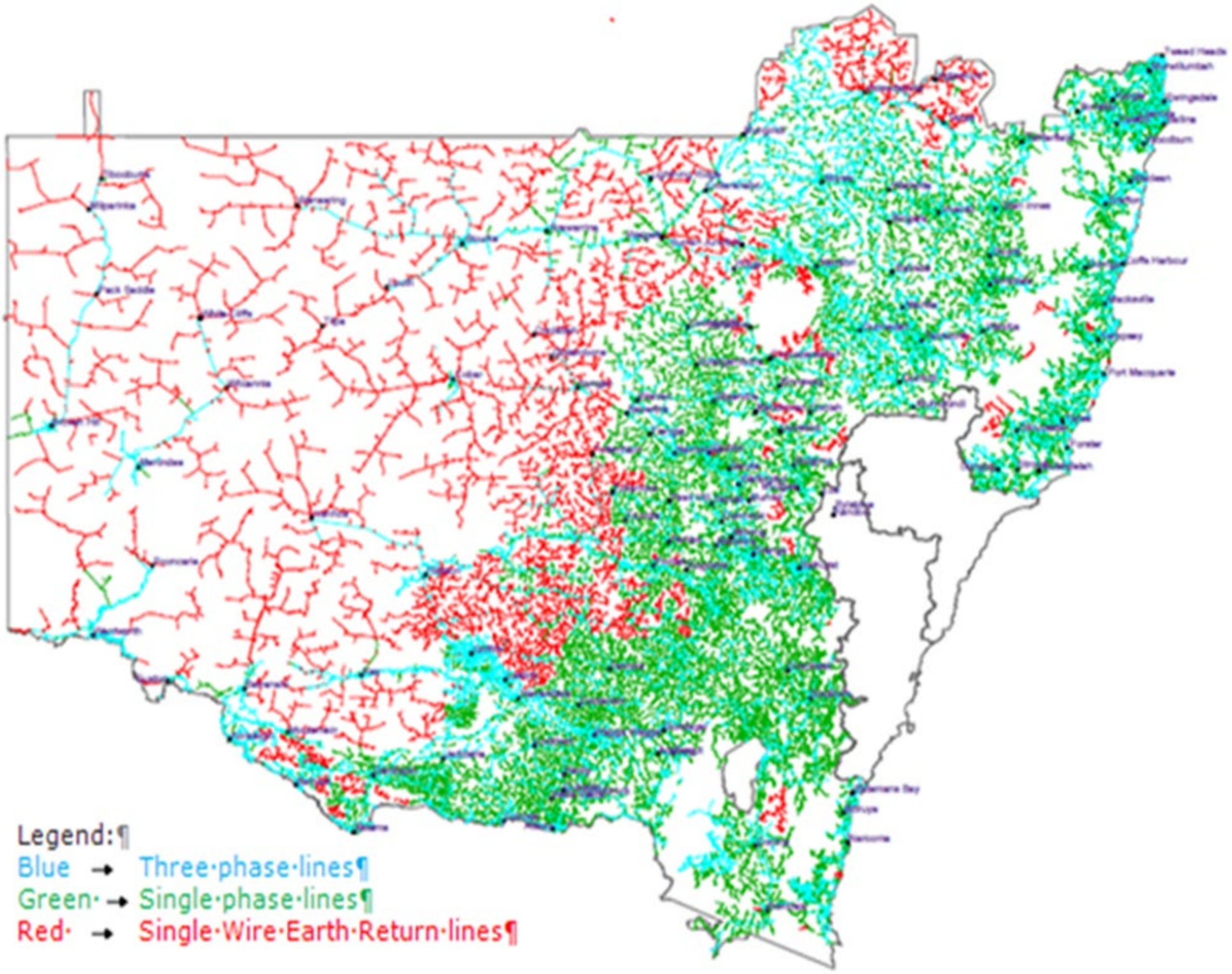

Figure 7: Essential Energy’s Distribution Network

Long feeder lengths (presented in Figure 8) built using high impedance conductors result in a high impedance network. A high impedance network exhibits strong voltage correlations to load and generation and is therefore more likely to develop a voltage constraint before reaching thermal limits. With the projected uptake of generation on Essential Energy’s network, it is expected that connection point voltage envelopes will continue to widen.

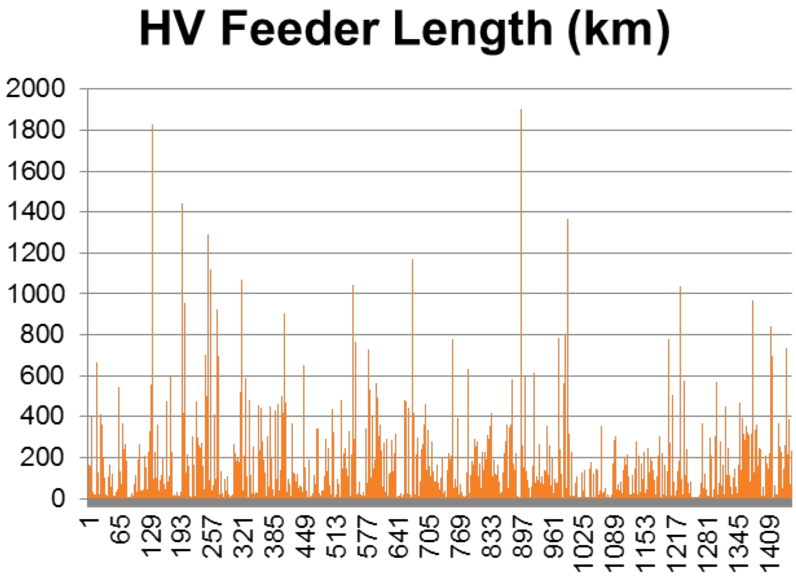

Figure 8: Essential Energy - HV Feeder Lengths

Inverters with real and reactive power control, coupled with or without battery storage, can be used to adjust power flows and significantly improve power quality, utilisation, and reduce losses on the existing infrastructure as an alternative to network augmentation.

One benefit of real power control is peak shifting, as depicted in Figure 9. This involves moving load (or generation) outside of the peak period – in doing so, total energy used is approximately the same (disregarding any efficiency losses or benefits). Referenced to the voltage envelope depicted in Figure 10, peak shifting within a voltage constrained network results in tightening of the voltage envelope. Therefore, battery storage could potentially address network constraints.

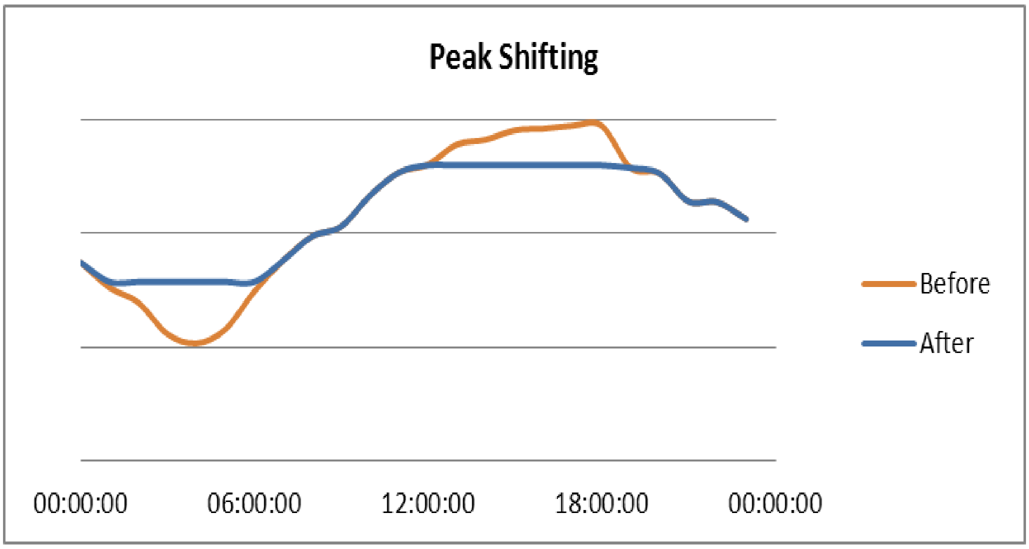

Figure 9: Peak Shifting Strategy

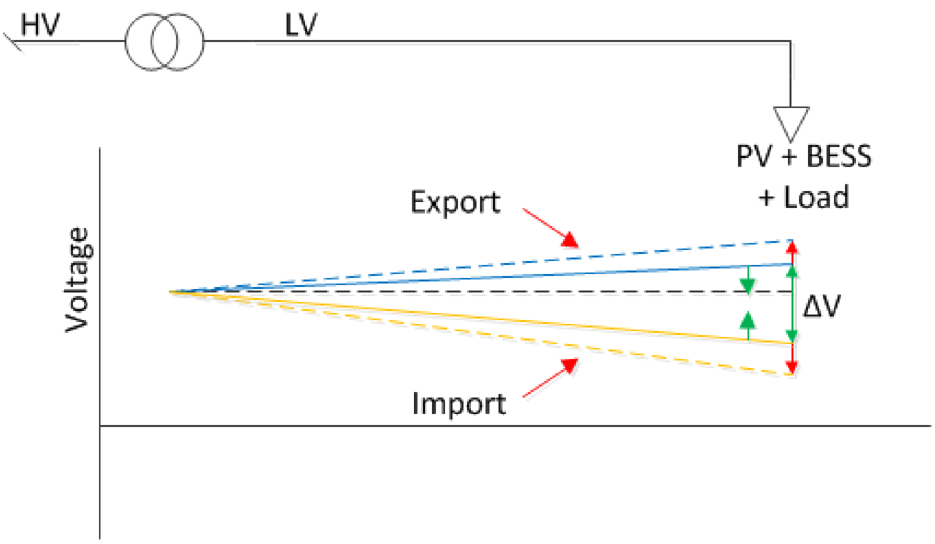

Figure 10: Tightening of the Voltage Envelope

Network benefits that can be derived from real and reactive power control through an individual inverter can be amplified by aggregating many inverters interconnected with communications. Figure 11 presents an example of a virtual power plant, used for peak shaving.

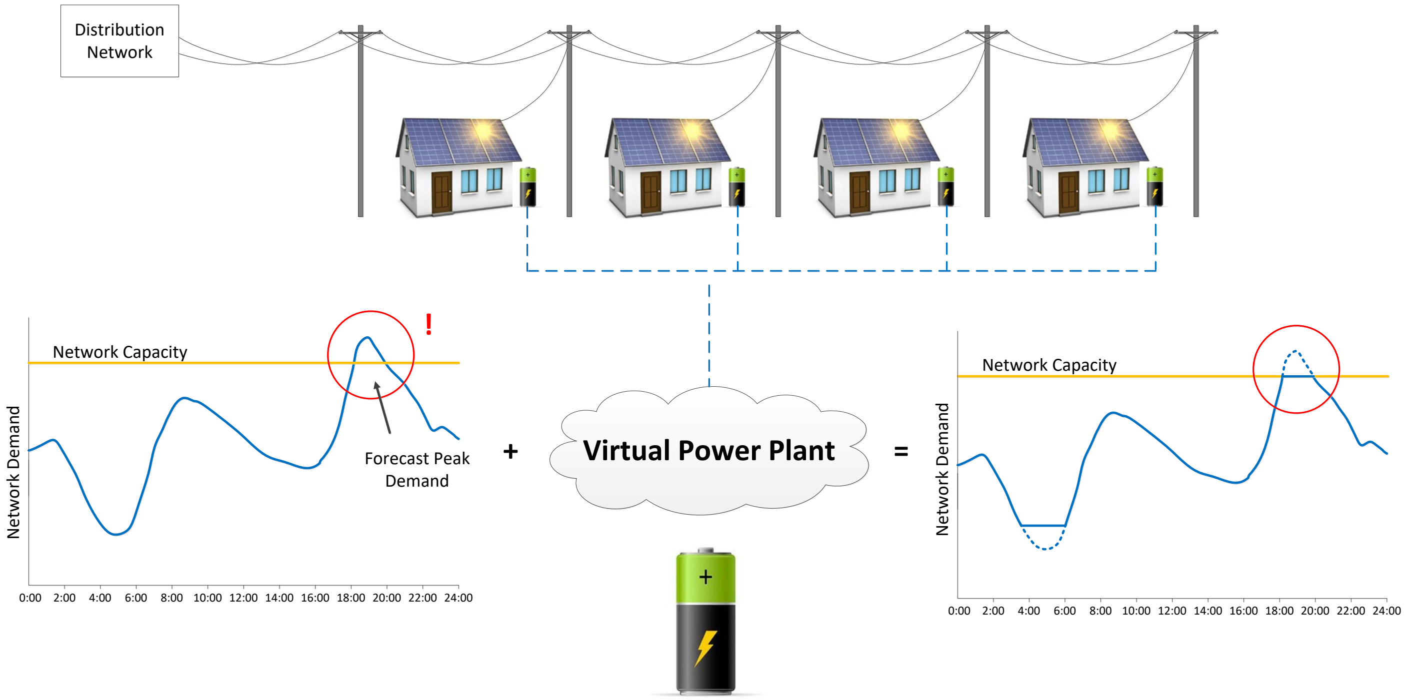

Figure 11: Peak Shaving Strategy with Aggregated Real Power through a Virtual Power Plant ([1])

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[1] Solar PV House: 1 https://energig.com/cat/house/
Battery: 2. http://www.djwarehouse.com.au/products/battery-power-pack#.WEd6gtV97mE

3.3 Project Overview

Networks Renewed was a joint project with the Australian Renewable Energy Agency (ARENA), University of Technology Sydney, Reposit Power and Fronius, to assess the potential of battery storage systems and advanced solar inverters with eligible customers in a two-year, partially subsidised trial to help better manage demand for network capacity. The NSW Mid North Coast rural towns of Collombatti, north-west of Kempsey, and Bellingen, south-west of Coffs Harbour, were selected for the trial due to the high concentration of customers with solar PV in the area and the potential to address an emerging network constraint.

The project's two key objectives include:

- Develop a set of guiding principles for future uptake to ensure such technology is optimally integrated and does not result in costly network expenditure.
- Explore the possible value such technology can provide on a least cost basis to address network constraints.

System installations were delivered in two separate stages, with the quantity of the installations dependent on achieving the required network benefit.

During the trial, 41 customers across Essential Energy's demonstration areas received a subsidised installation of a battery storage system and/or advanced solar inverter, customers have retained ownership of the equipment as part of the trial. During the trial period, participants received payments based on the level of network support their system provided.

The trial was designed around an open market approach, maximising customer choice, emerging market participants and the potential future energy market. Subsidies were used to reduce system costs today comparable to that likely to be seen over the next few years.

Within the rapidly changing energy ecosystem, the key objectives of the project will help Essential Energy operate a best practice business in performance, efficiency, offering value to customers while maintaining downward pressure on network charges.

3.4 Nature and Scope

To achieve the desired outcomes, the scope was limited to:

- modelling and simulation of networks to investigate the effect of virtual power plants on the energy capacity and delivered power quality
- literature review of virtual power plant control techniques
- subsidy design
- customer engagement plan
- contractor management plan
- network support payment design
- installation of appropriate metering equipment to monitor trial technology (if required)
- test and field trial verification of virtual power plants
- estimation of costs and benefits
- project analysis including suggested paths to business as usual programs if proven viable.

3.5 Aims and Expectations

The project aimed to develop knowledge and confidence in the application of aggregated smart inverters with/without energy storage, with two key objectives:

1. Develop a set of guiding principles for future uptake to ensure such technology is optimally integrated and does not result in costly network expenditure. Questions that we set out to answer include:
    a. How can greater amounts of generation be installed with minimal costs to customers?
    b. How can Essential Energy encourage generation in areas where it would be of benefit?
    c. What solutions or problems might the combination of solar and batteries bring?
    d. What solutions or problems might the aggregation of batteries by a third party bring?
2. Determine how best to implement solar and storage to address network constraints; Traditionally, when a network constraint such as the supply voltage being outside of acceptable limits arises, Essential Energy would install or replace network assets with assets able to deliver greater capacity, such as larger conductors or an additional voltage regulator. As an alternative, real power from battery storage could be used for peak shaving, while reactive power from advanced inverters could be used to better regulate network voltage simultaneously with solar PV export.

3.6 Implementation

Networks Renewed can be defined as five distinct stages:

1. Site Feasibility Studies

Based on the objectives of the project, discussions with local planners, costs associated with network monitoring and reconfiguration (if required) and anticipated measurable benefits, a list of potential trial sites was collated.

Based on network need and network modelling, relationships to real and reactive power flows were identified to refine the list down to two sites to demonstrate the benefits of real and reactive power through virtual power plants.

The two sites selected for the trial are presented in Figure 12:

1. Collombatti (smart inverters interfaced to battery storage) – emerging network constraint on a feeder
2. Bellingen (smart inverters interfaced to solar PV only) – high solar PV penetration on a single distribution substation.

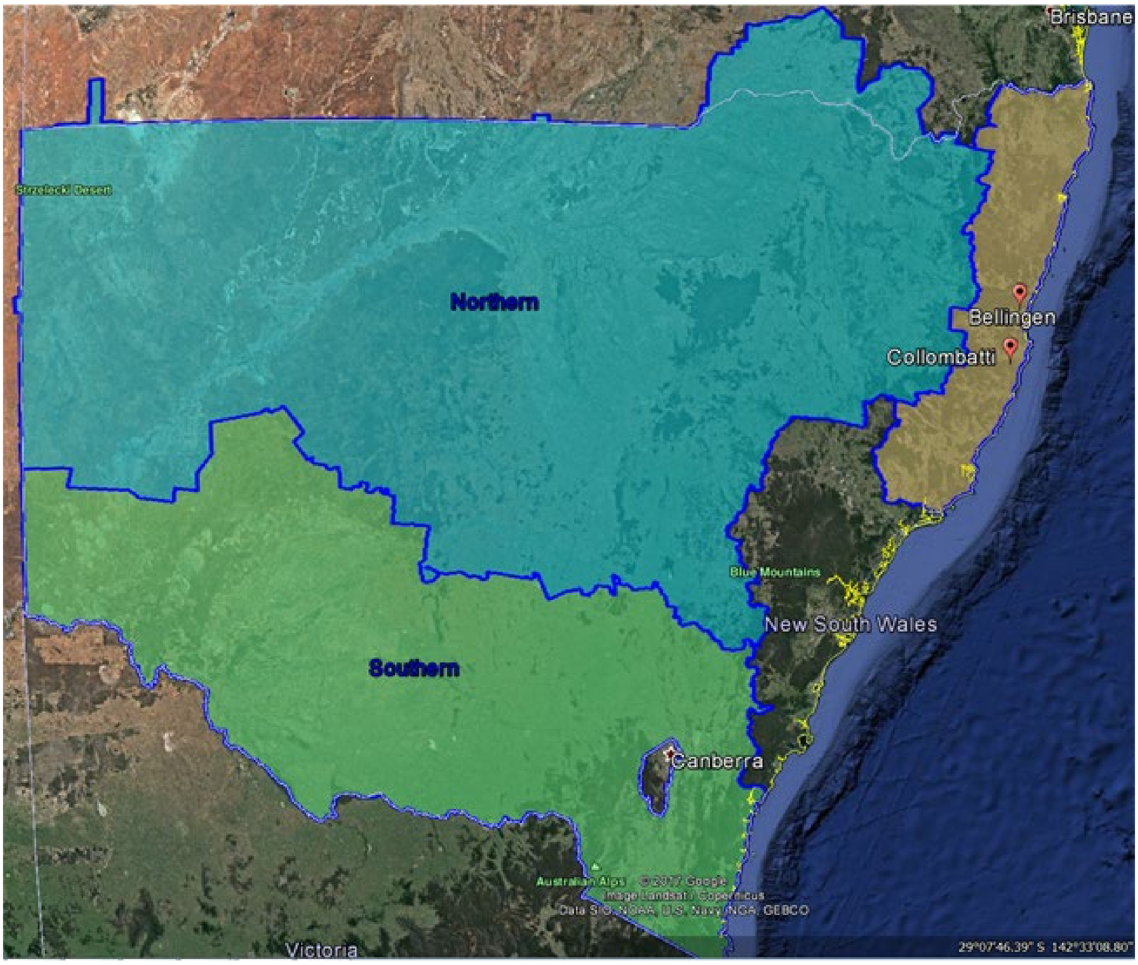

Figure 12: Essential Energy Regions and Trial Locations

2. Pilot Stage Implementation

The pilot stage of Networks Renewed included development of a subsidy, project webpages (https://www.essentialenergy.com.au/our-network/network-projects/collombatti-battery-trial , https://www.essentialenergy.com.au/our-network/network-projects/bellingen-solar-pv-inverter-trial) and Letters of Offer for each trial area.

To commence the expression of interest (EOI) process, and based on proposed network benefit, Letters of Offer were mailed to eligible customers within the two subsidy areas. A community forum was held in Collombatti on 9 December 2016 to provide an overview of the project and to answer any questions from customers regarding the trial.

In response to the initial limited number of expressions of interest received, the Collombatti pilot stage subsidy area was expanded (see Figure 13), followed by a second community forum aimed at increasing the number of trial participants.

Following a subsidy claim approval process, battery storage installations on the Collombatti feeder commenced.

Essential Energy obtained access to the Virtual Power Plant (VPP) in late August 2017. Since then, several VPP notch tests have been undertaken to gauge the effectiveness of systems installed.

The first round of EOIs and subsidy claims were received for the Bellingen trial. However, installations were delayed due to extended equipment lead time, overlapping into the Collombatti Market stage. Installations were completed in mid-2018.

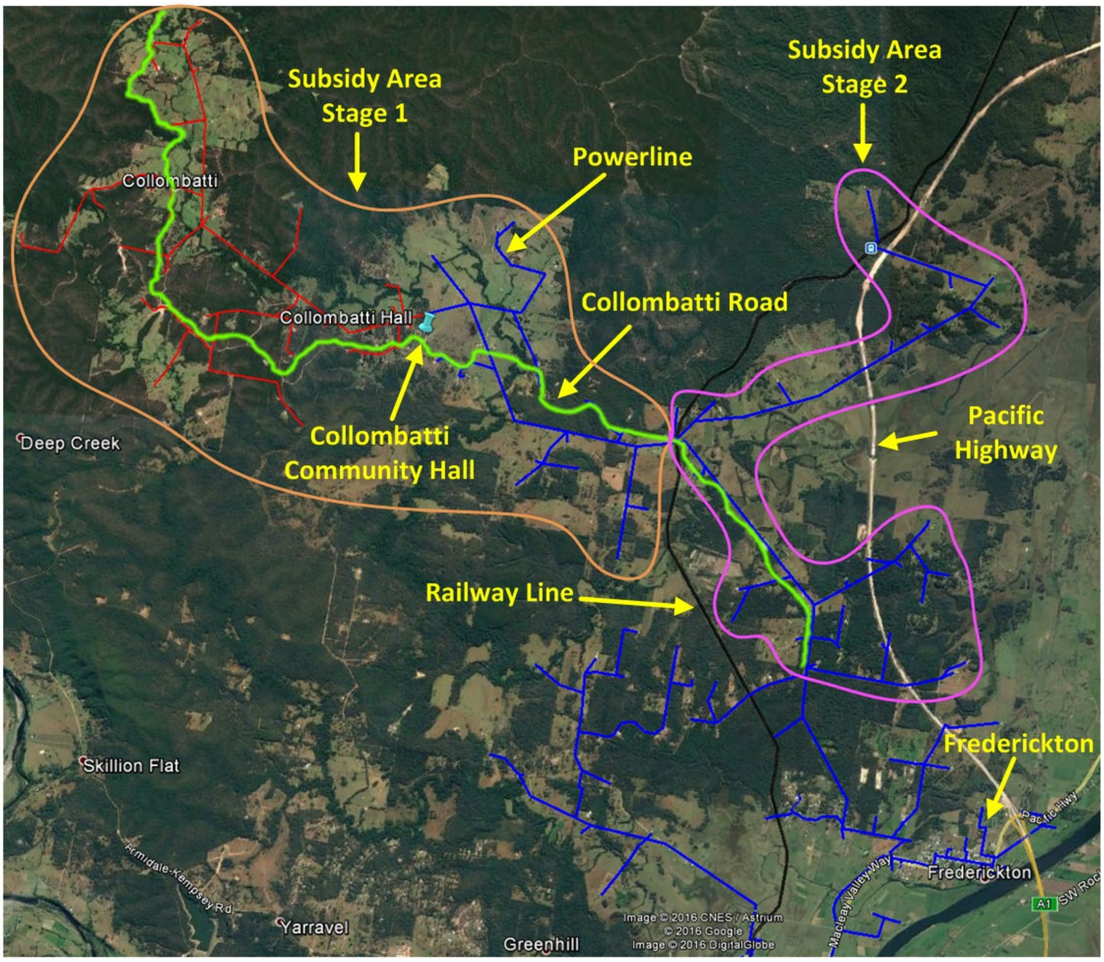

Figure 13: Collombatti Subsidy Area (Pilot Stage)

3. Pilot Stage Evaluation

Notch test results from the Collombatti pilot stage virtual power plant have demonstrated a measurable network benefit. As shown in Figure 14, a voltage improvement of 1.73 percent was achieved. Based on the results, Essential Energy was satisfied that the reduced quantity of pilot stage systems installed compared to target is sufficient to ascertain the network benefit characteristic from aggregated battery storage, permitting optimisation and commencement of the market stage.

Based on site feasibility studies, Table 3 presents the two trial sites selected to ascertain benefits and explore control techniques to achieve the objectives of the project. System installations were delivered in two separate stages, with the quantity of these installations dependent on achieving the required network benefit.

As shown in Table 3, the target uptake across both pilot stage sites was 40 systems, allocated to each demonstration site based on the desired outcome of achieving a clear measurable network benefit. Signing up trial participants in Collombatti has proven to be challenging but has also generated valuable learning outcomes used to optimise the market stage.

Through the pilot stage, 23 subsidy claims were received from Collombatti and 11 from Bellingen. A total of 16 systems were active within the Collombatti Virtual Power Plant, with the remaining systems experiencing communication issues.

Following measurements obtained from active systems through the pilot stage within Collombatti, further network modelling was completed to ascertain the required additional number of systems to address the emerging network constraint. This analysis assisted in refining the market stage subsidy design.

Inverter installations were completed in Bellingen mid-2018. Throughout 2018-2019 Reposit Power have developed and refined reactive power control for solar PV only sites in Bellingen, with reactive power control online late 2018-2019.

Table 3 – Pilot Stage

Trial Site	Configuration	Pilot Stage Target Uptake	Pilot Stage Uptake
Frederickton Feeder – Collombatti Area (emerging network constraint)	Smart inverters interfaced to Battery Storage	31	23
Single Distribution Substation within Bellingen Town	Smart inverters interfaced to Solar PV only.	9	11

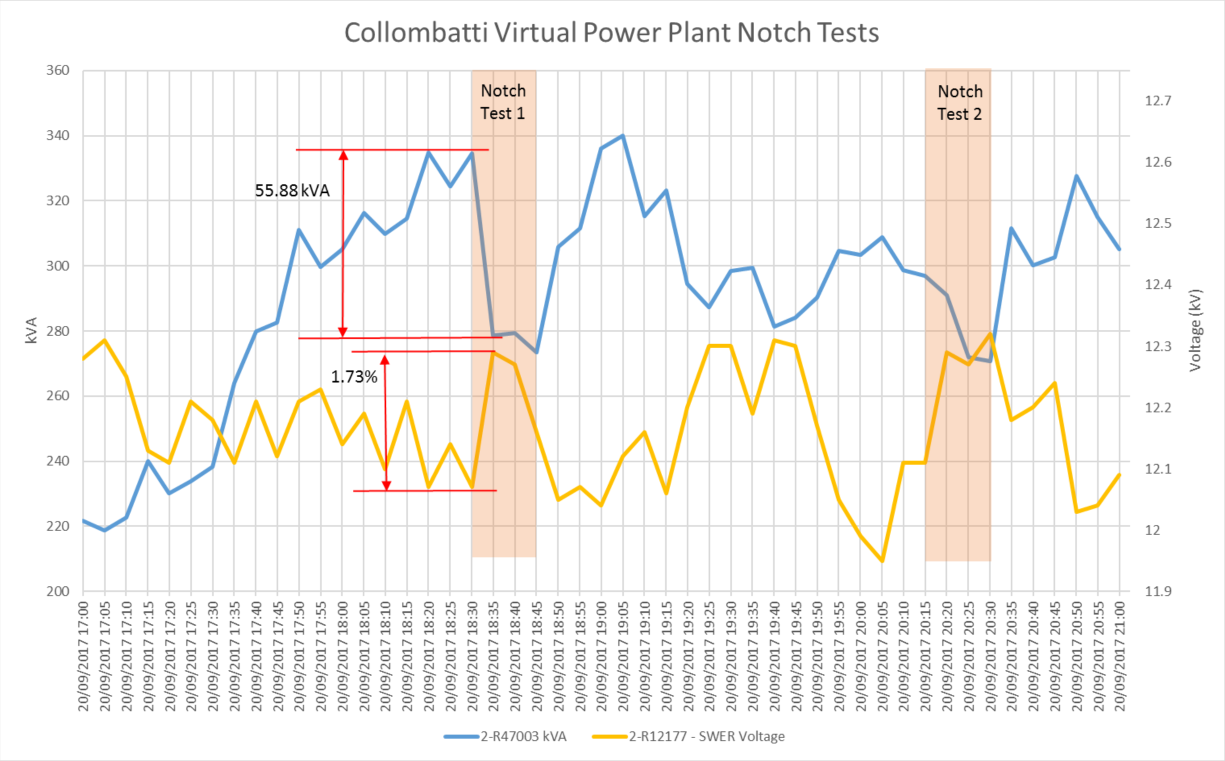

Figure 14: Collombatti Notch Test Detail (Pilot Stage)

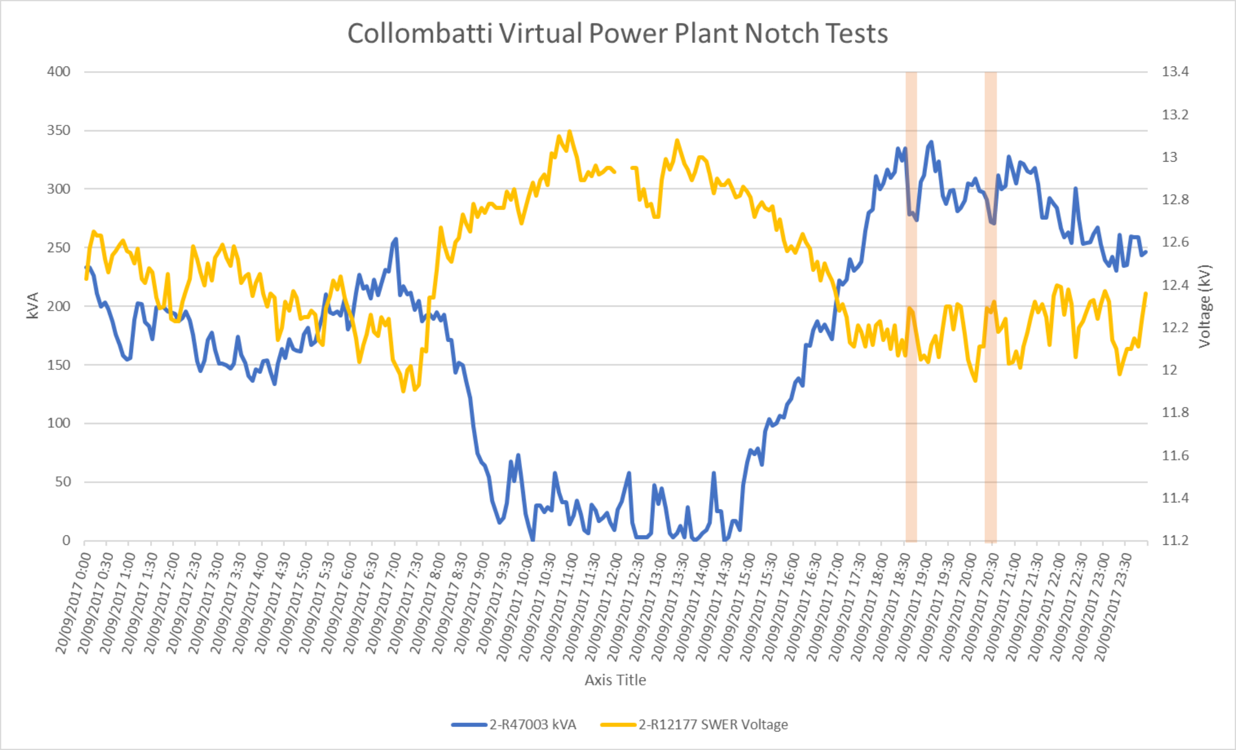

Figure 15: Collombatti Notch Tests (Pilot Stage)

4. Market Stage Implementation

Once measurements were obtained from the pilot stage systems within Collombatti, further network modelling was completed to ascertain the required additional number of systems to address the emerging network constraint, and the market stage subsidy design was refined accordingly. The market stage commenced during the fourth quarter of 2017. To commence the market stage expression of interest (EOI) process, Letters of Offer were mailed to eligible customers within the two subsidy areas (shown in Figure 16) based on proposed network benefit. Following the mail out of Letters of Offer, two community forums were held in Collombatti on 6 and 7 December 2017 to provide an overview of the project and to answer any questions from customers regarding the trial.

In response to the initial limited number of expressions of interest received for the market stage, a third market stage community forum was held on 31 January 2018, with the aim of increasing the number of trial participants. Following the subsidy claim approval process, market stage battery storage installations on the Collombatti feeder commenced.

Due to equipment availability delays leading to Bellingen installations rolling into the Collombatti Market Stage, it was decided not to proceed to a market stage offer for Bellingen following the first round of EOIs and subsidy claims received. Installations in Bellingen were completed in mid-2018.

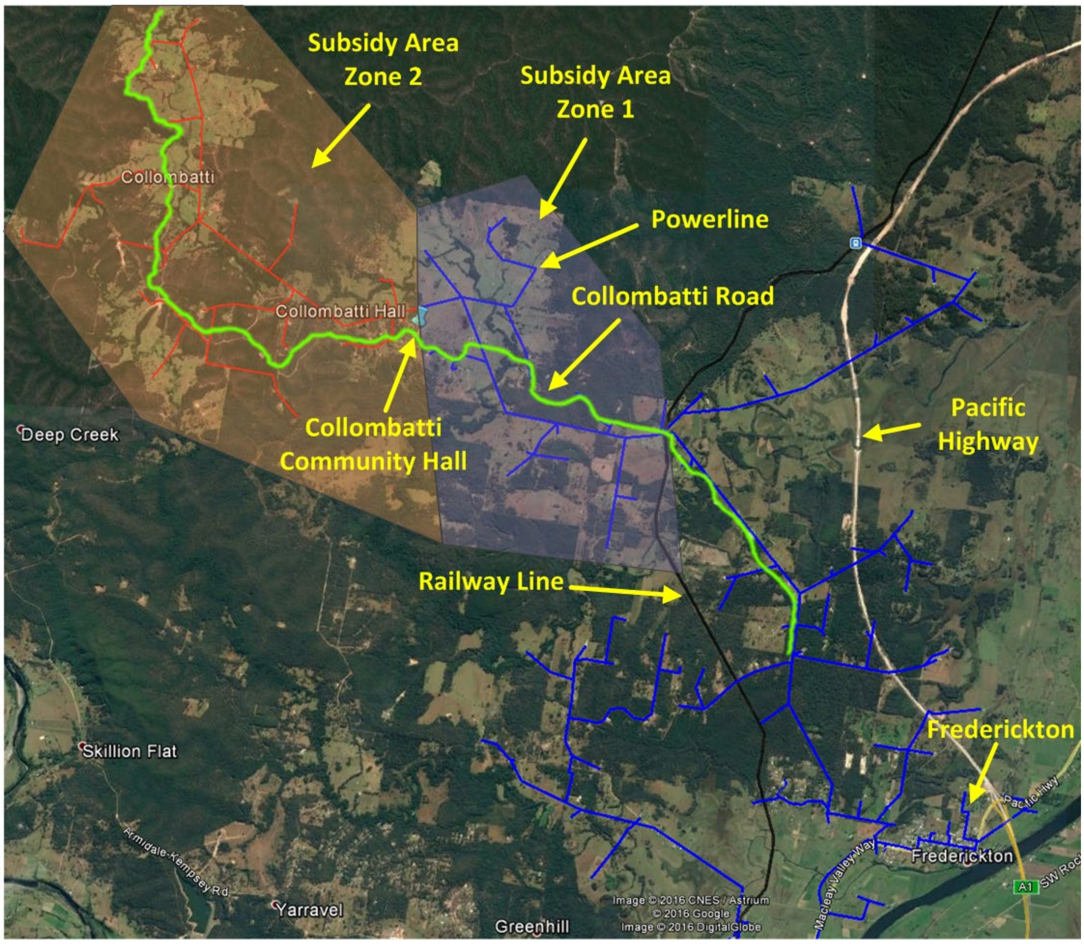

Figure 16: Collombatti Subsidy Area (Market Stage)

As seen in Table 4, under the market stage, another nine customers in Collombatti agreed to participate in the trial, while one customer joined the Bellingen trial and three customers decided to leave.

5. Market Stage Evaluation

Notch test results from the Collombatti market stage virtual power plant have demonstrated improved network support. Figure 17 presents a voltage improvement of 3.07 percent from 23 systems active within the virtual power plant.

Figure 19 presents the feeder voltage profile generated from network monitoring points along the feeder. By comparing the feeder voltage profile just before and after the notch test, the approximate profile improvement can be observed, with the majority of voltage improvement exhibited on the SWER and towards the end of the three-phase steel section of the network. This supports outputs generated from modelling the network.

Table 4 – Market Stage

Trial Site	Configuration	Pilot Stage Uptake	New Market Stage Systems	Total Systems
Frederickton Feeder – Collombatti Area (emerging network constraint)	Smart inverters interfaced to Battery Storage	23	9	32
Single Distribution Substation within Bellingen Town	Smart inverters interfaced to Solar PV only.	11	1	9

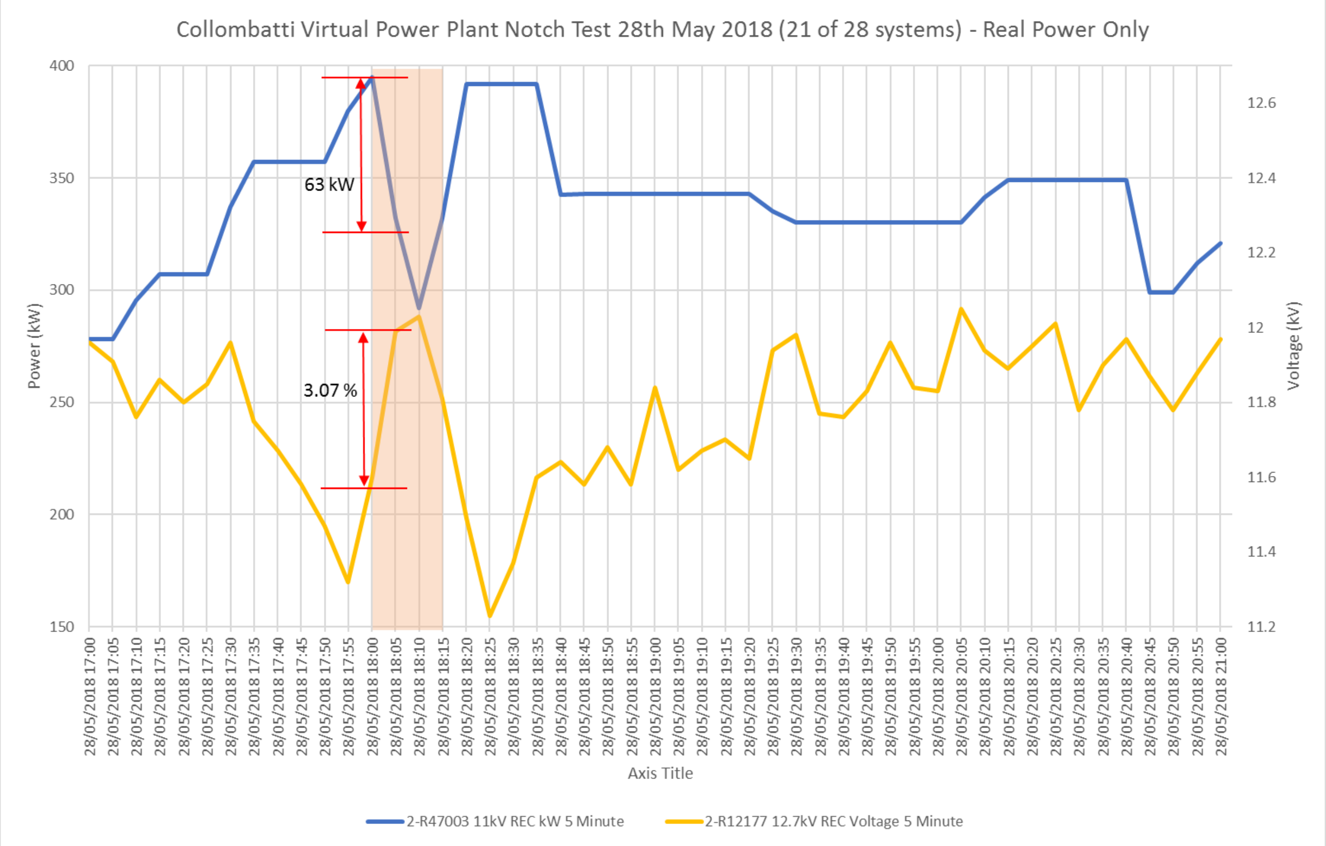

Figure 17: Collombatti Notch Test Detail (Market Stage)

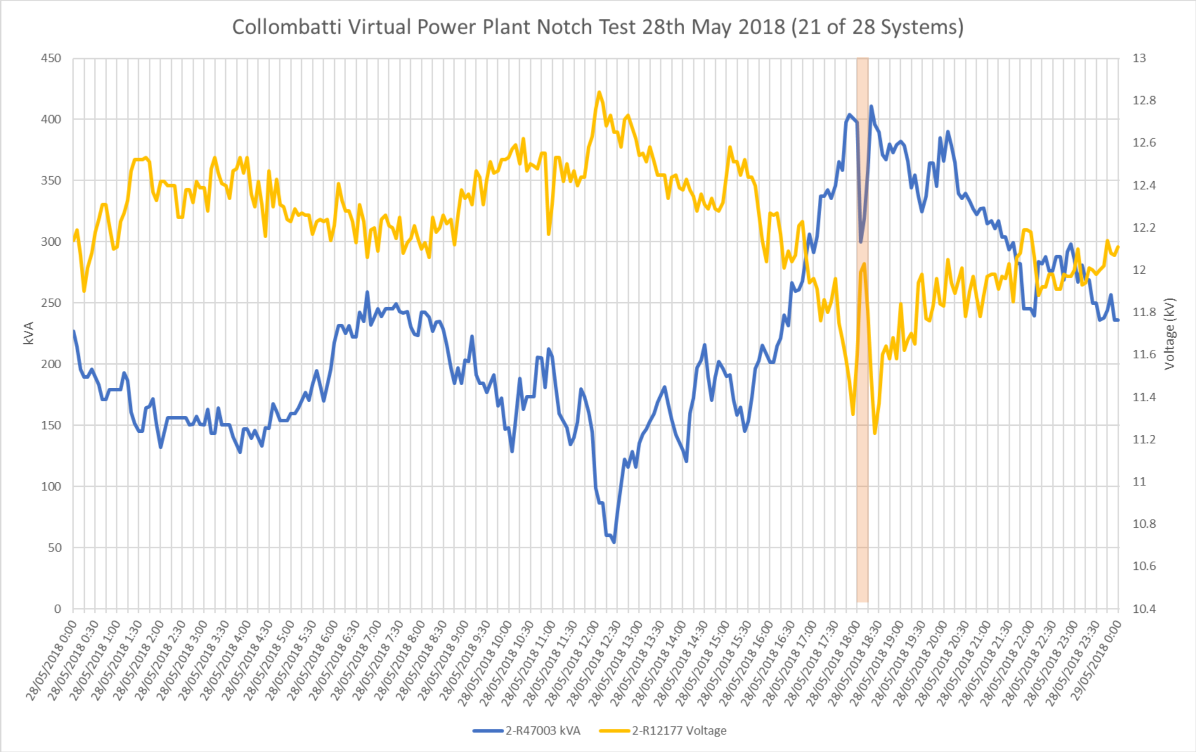

Figure 18: Collombatti Notch Tests (Market Stage)

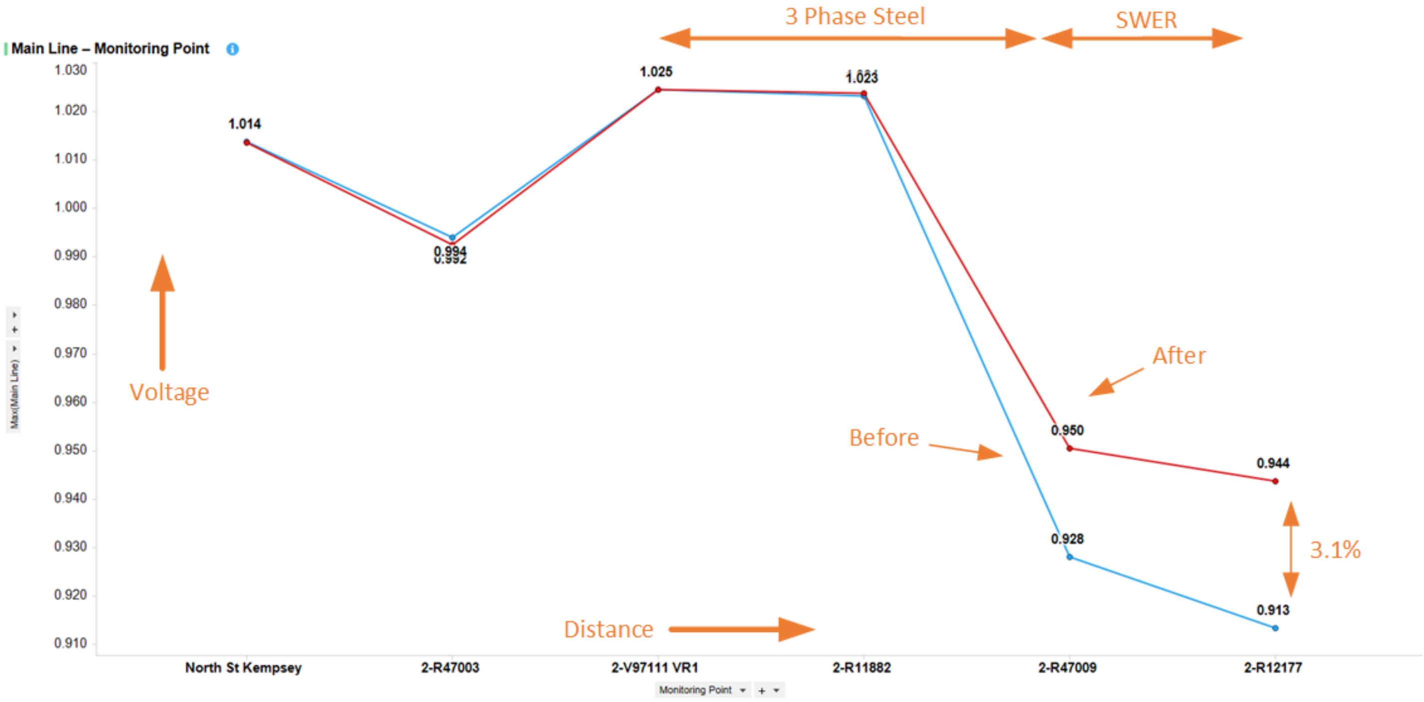

Figure 19: Feeder Voltage Profile - Notch Test (Market Stage)

Virtual Power Plant (VPP) dispatch only through global/master control adds a level of risk to network support events due to the dispatch relying 100% on the communication system to end nodes that make up the VPP at the time of the request. The level of risk is inversely proportional to the reliability of the communication system used to transport the control/bid signal(s).

Assessing the known risk from global only control together with communication coverage and reliability across a rural network such as Essential Energy's presents a challenge we must address before Virtual Power Plants present as a commercially ready solution for a rural distribution network. To reduce or eliminate the risk of a virtual power plant not dispatching when required some form of backup or failsafe mode to the global/master control is required.

A good, but basic example of incorporating failsafe mode into network support is the controlled load system that has been operating within industry for 50+ years. Controlled load plants located in zone substations transmit commands to controlled load relays at customer premises to turn load on and off to help manage network peak demand, each relay also includes a failsafe mode typically labelled as "time-clock backup", with its basic switching routine stored in non-volatile memory which can run autonomously until the device detects global commands from the controlled load plant.

During the first half of 2019, we explored three local control techniques embedded within the local smart controller at a select few individual premises over a limited number of days, the three local control techniques developed and implemented include:

1. Time clock control – predefined dispatch (power, date, time & duration)
2. Volt-Watt control superimposed to the existing optimiser function
3. Volt-Watt control superimposed to the existing optimiser function with reserved battery capacity

Time clock control is basically a predefined dispatch based on agreed power (kW), date, time and duration held in memory, much like the controlled load system. Time clock backup control was simple to implement and resulted in dispatch as programmed but also resulted in times of wasted dispatch or of the wrong magnitude (if programmed many days ahead as it may not have been required due to changed network conditions). This provided motivation to investigate a closed loop control algorithm dependent on local parameters. The purpose of the VPP was to address a voltage constraint, we therefore used sampled premise level voltage to feed back into the local control algorithm.

Our first closed loop local control was a linear battery power (kW) add function (effectively a Volt-Watt response) superimposed to the normal optimisation function, when voltage deviated outside set voltage bounds the battery power ramped over the normal optimisation function to "arrest" the local voltage. When voltage dropped below the lower voltage bound the battery export was higher than the local premise load for the purpose of supporting the local network, however we found that most batteries where discharged before the network peak event based on the normal optimisation function due to limited capacity (i.e. kWh and programmed maximum depth of discharge).

Based on lessons learnt through local control algorithms 1 and 2, our 3rd local control algorithm implemented was a Volt-Watt response mode with reserved battery capacity, effectively locking out the optimiser from using the battery during forecast network peak event.

With reference to Figure 20, we established a local control test case with 90% reserved battery capacity during the evening period with a Volt-Watt response mode set to a 4V bandwidth with a power (kW) add function starting from 230V to maximum power output at 226V just for test purposes (Figure 20 presents the test parameters in brackets).

Referenced to Figure 21 it's evident that the battery state of charge was locked to 90% leading up the peak event, with the battery discharging when the voltage was below 230V with magnitude (kW) proportional to range from and below 230V. It's also evident that the voltage was clamped (minimal deviation) until the battery reached cut off (maximum depth of discharge), Figure 22 presents a closeup of the resultant voltage during the local control test.

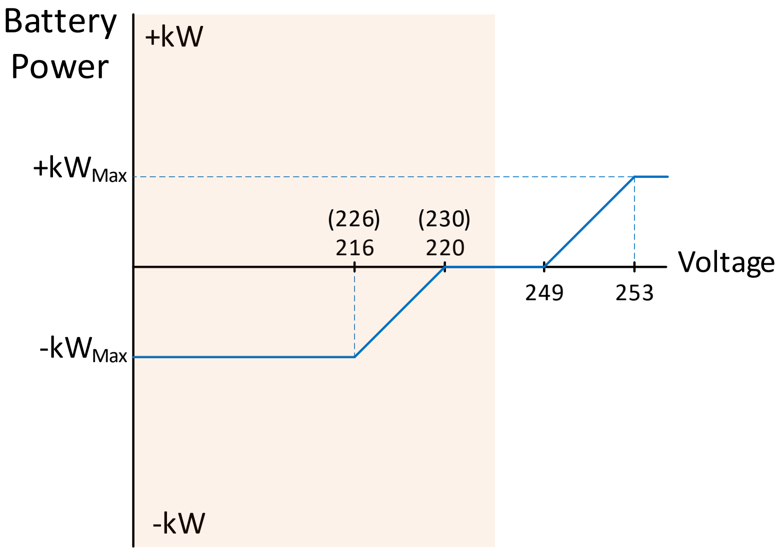

Figure 20: Collombatti Local Control Algorithm (Test Case)

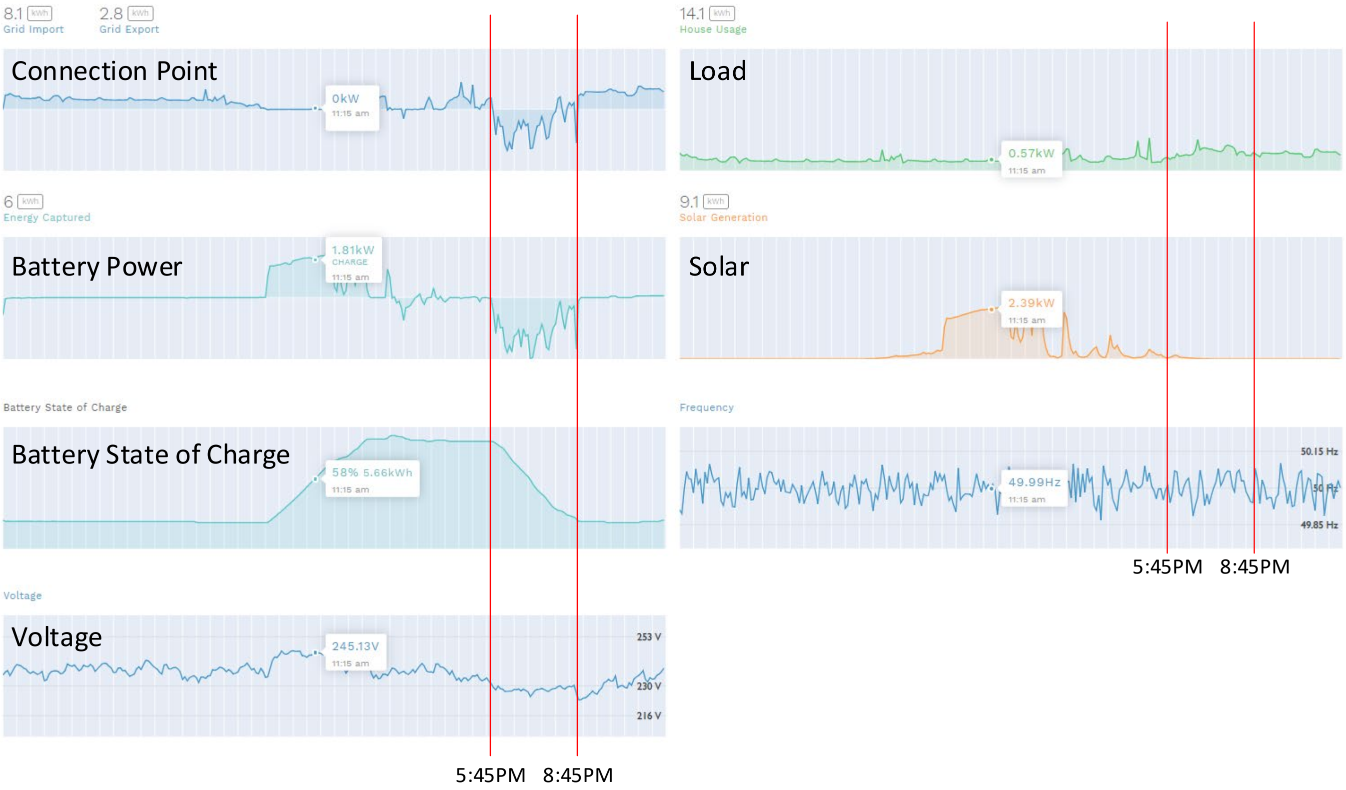

Figure 21: Collombatti Local Control Algorithm Results

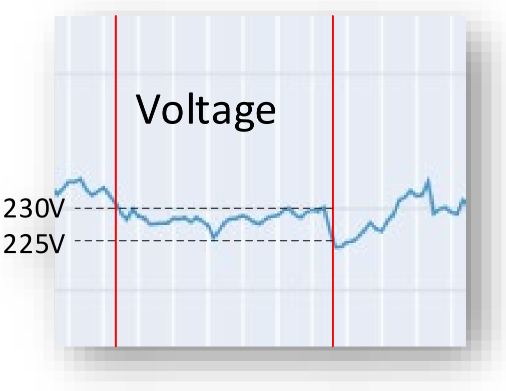

Figure 22: Collombatti Local Control Algorithm Results (Closeup of Voltage)

With reference to Figure 16, Figure 23 presents simulated voltage support characteristic for systems west of the railway line in order (left to right) from the end of the line Evident from Figure 23, as the location of the injected power from individual sites increases in distance from the end of the feeder voltage support reduces (i.e. %V/kW). The result of the network support characteristic was the reasoning behind the market stage area limited to west of the railway line where value from network support is highest.

Based on validations through field measurements and continued improvement to the network model throughout the market stage we expect to achieve ~5.2% voltage improvement if all system where online west of the railway line, this is very close to the required 5.5% voltage improvement to address the emerging network constraint

Figure 24 presents the output of the VPP notch tests for all online systems west of the railway line early August 2019. Figure 25 and Figure 26 present the network response from the VPP notch tests, and Table 5 presents the network results with a weighted average of the three notch tests and scaled calculation to estimate network response with all system west of the railway line online. Comparing Table 5 and Figure 23, while noting error introduced through granularity of the voltage measurement, field measurements are aligned to that expect through network simulations

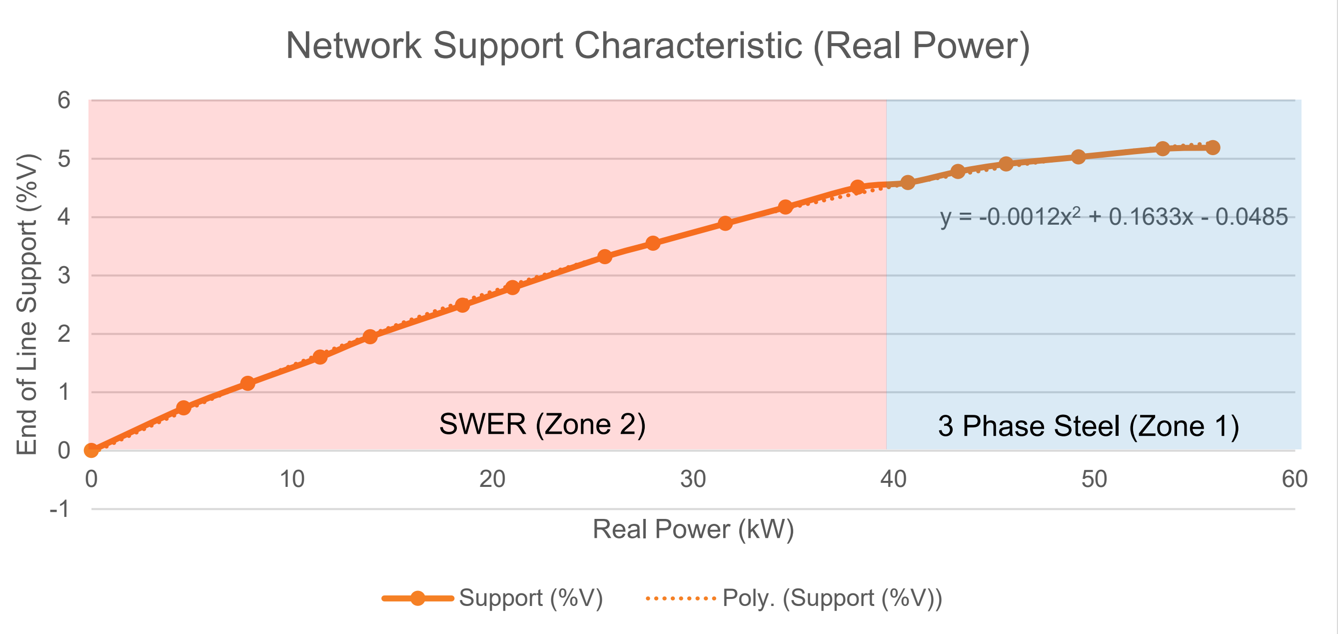

Figure 23: Market Stage Systems West of the Railway Line only – Simulated Network Support Characteristic

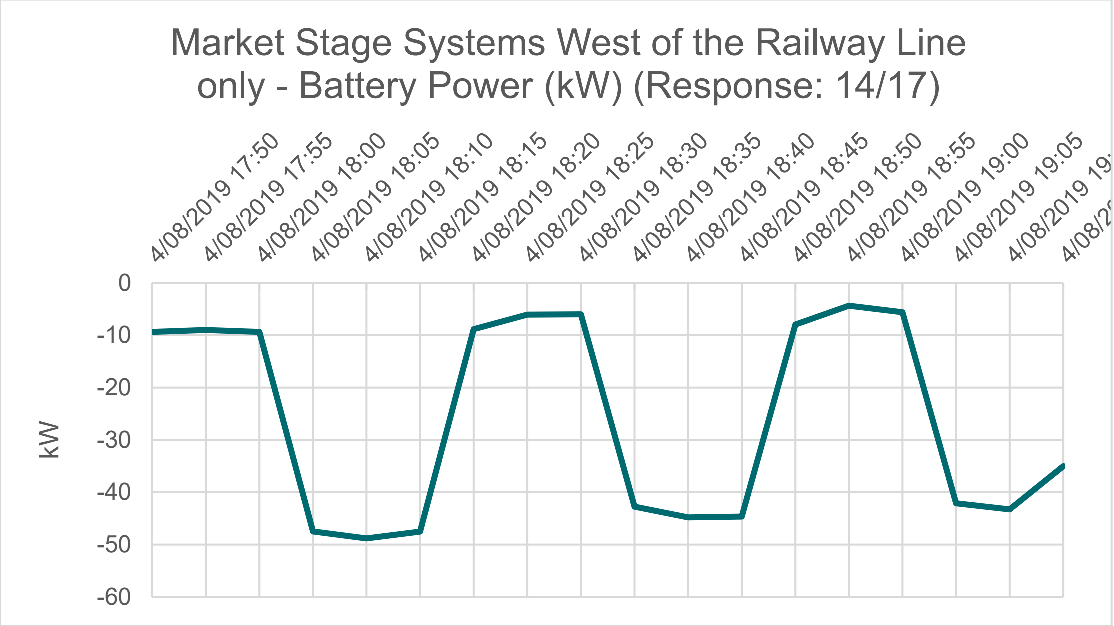

Figure 24: Market Stage Systems West of the Railway Line only – Notch Test Battery Power (kW) (Response: 14 of 17 Systems)

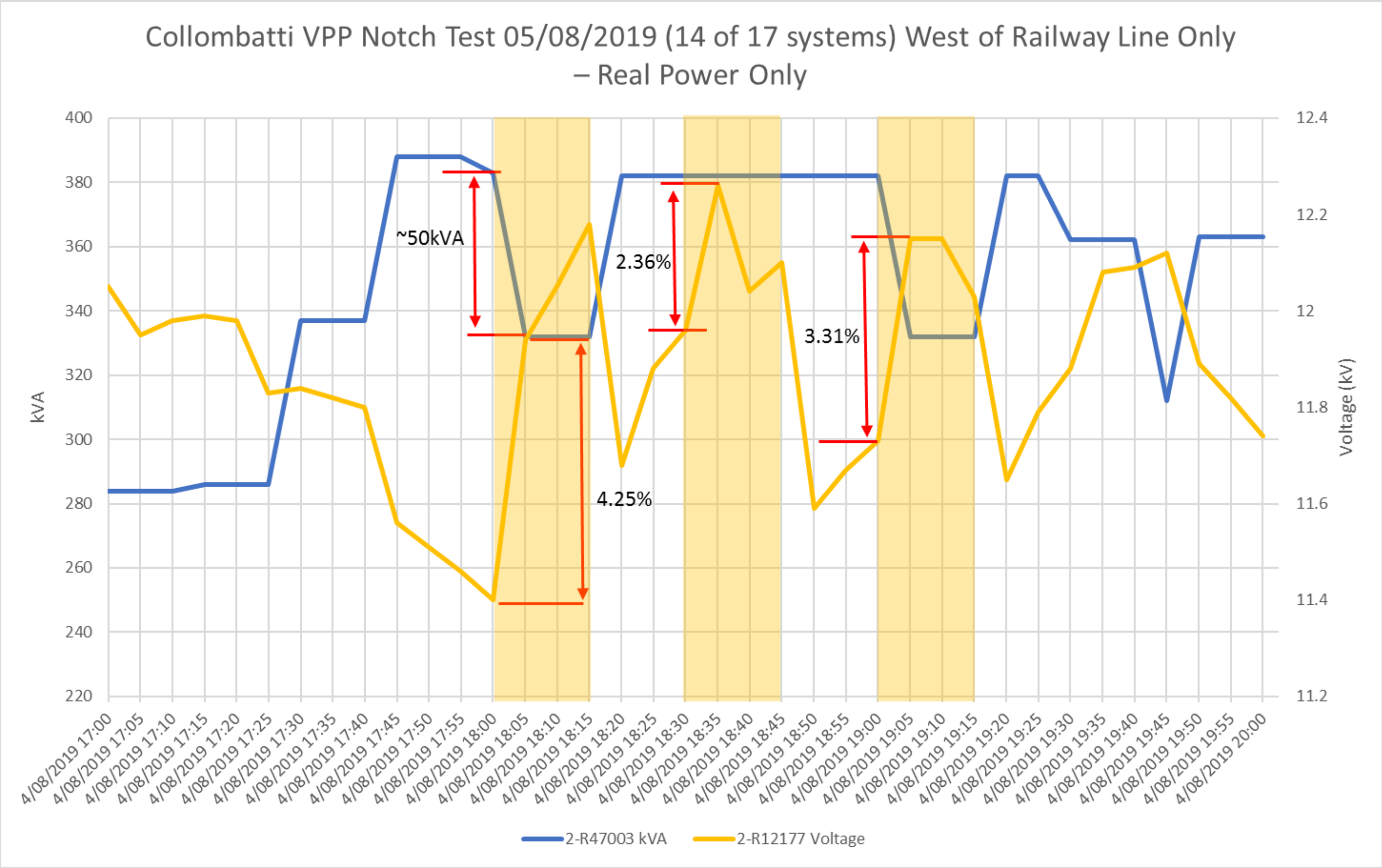

Figure 25: Collombatti VPP Notch Test 05/08/2019 (14 of 17 systems) West of Railway Line Only – Real Power Only

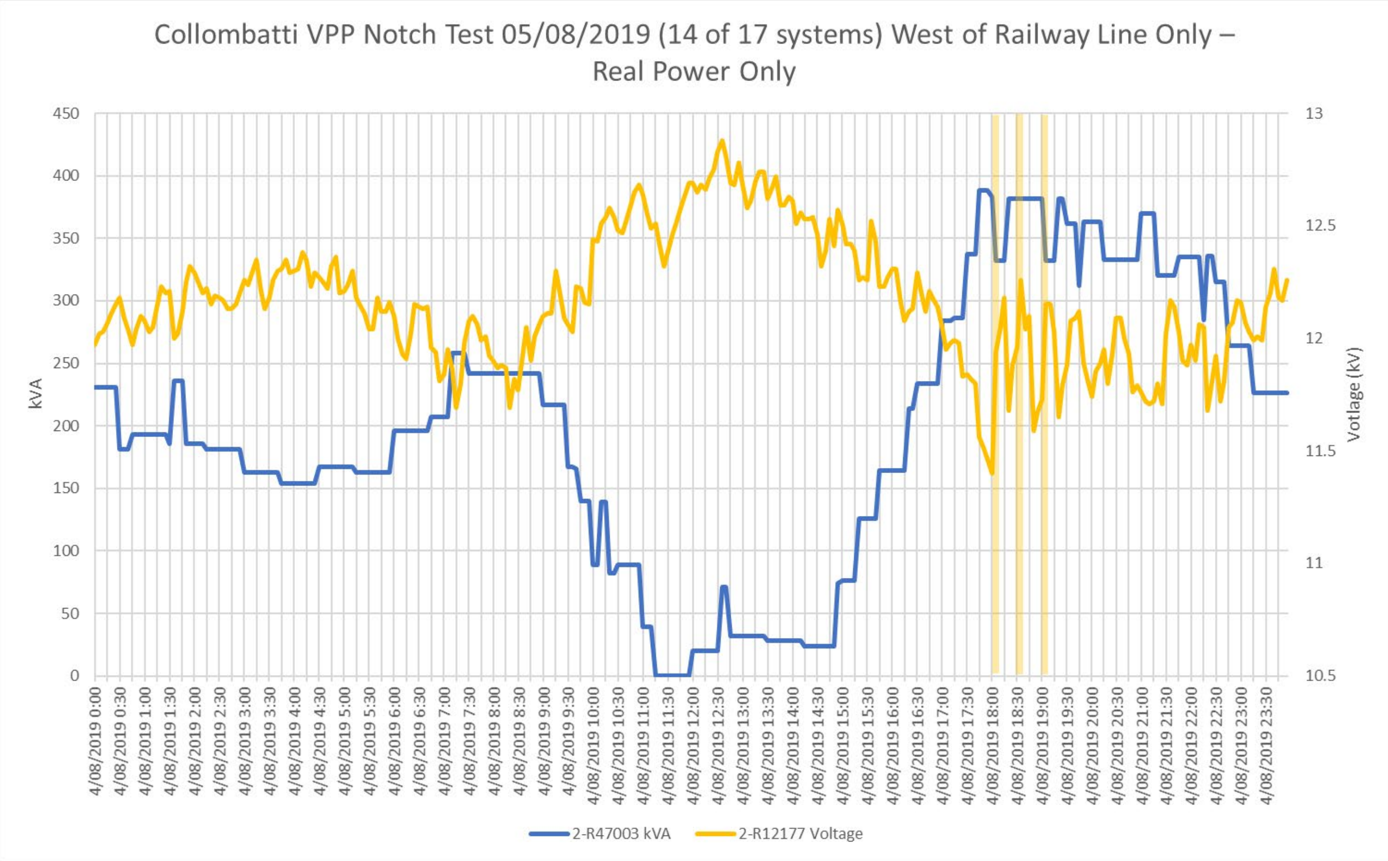

Figure 26: Collombatti VPP Notch Test 05/08/2019 (14 of 17 systems) West of Railway Line Only – Real Power Only

Table 5: Notch Test Results

Notch Test	% Voltage Improvement	VPP kW Change (Notch edge)	% Voltage Improvement At VPP Full Power
1800	4.25	-38.12	6.23
1830	2.36	-36.79	3.59
1900	3.31	-36.49	5.07
Average			**4.96**

On the 29th of April 2019, a community forum was held within Collombatti to update trial participants on project results, collect feedback and inform on next steps during the close out phase of the trial commencing May 2019.

To help support the network while Essential Energy investigates the lowest cost and practical solution to address the emerging network constraint within Collombatti, from May 2019 network support payment opportunities were only made available to systems west of the railway line aligned to where network support is needed based on learnings from the trial.

Throughout May and June, compliance audits were completed on all trial solar PV and battery storage system within Collombatti.

During the close out phase customer feedback on all areas of the trial was collected through online surveys, in-person interviews and community forums to help identify any improvement opportunities for future customer trials. Some feedback includes:

> *"We want to continue to be involved very much in this innovative and practical solution to the issues with the energy grid in our region. I hope the other participants have had a positive experience with their solar battery installations and have been experiencing the benefits to their own situations and giving them much encouragement to continue along this path."*

During the remainder of 2019 reactive power notch tests were performed to ascertain the voltage management potential of reactive power. Figure 27 presents reactive power notch test results at a single LV premise.

By completing several real and reactive power notch tests, site specific electrical characteristics were calculated in terms of Volt/VAr and Volt/Watt relationships. From such information approximate reactive power required to cancel voltage rise or drop from real power export or import to the premise was calculated, results were published in Table 6.

Using the approximated site specific Volt/Var and Vol/Watt characteristic's in Table 6, Figure 28 presents an example utilising reactive power to increase the real power hosting capacity of the local network. Assuming an inverter overvoltage cut-off set at 255V as an example, sinking reactive power during solar PV export can clamp the network voltage to enable an additional 1.5kW export compared to no reactive power support, the same process can be applied during the evening peak load period to boost network voltage.

It should be noted that some residential batteries are limited to 2.5 kW to 4 kW connected behind a 5kVA inverter, therefore inverter headroom can be utilised during the evening peak load period to further support network voltage without impacting customer real power revenue. Figure 29 presents the non-linear relationship between real and reactive power at constant apparent power.

Noting the limited number of trial inverters with dynamic/dispatchable reactive power, highly resistive HV network, and noise in the HV measurement, reactive power-based voltage improvement on the HV network was unascertainable, hence reactive power voltage improvement was measured at LV. It should be noted that HV network simulations were completed for the Collombatti demonstration site based on the limited number of sites with dispatchable reactive power capability resulting in approximately 1% voltage improvement.

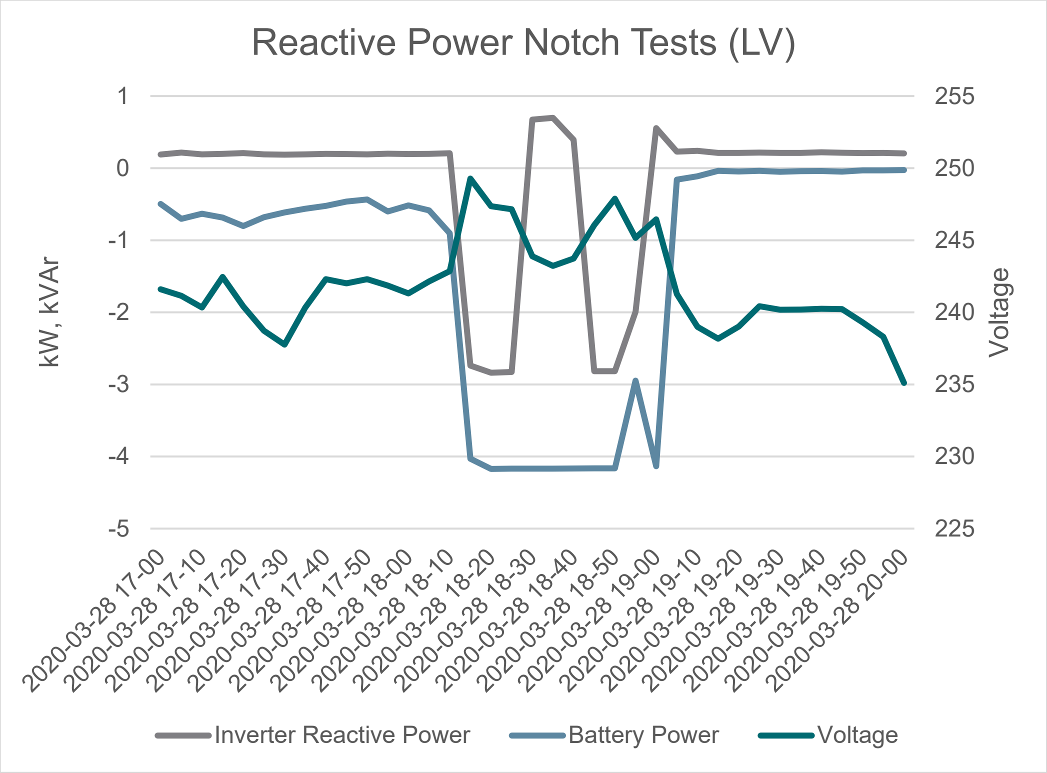

Figure 27: Reactive Power Notch Tests (LV)

Table 6: Sample Site (LV) Real and Reactive Power Response

Sample Site Real and Reactive Power Response (LV)	
0.83	Volt/kVAr
1.16	Volt/kW
1.4	Approximated kVAr/kW to achieve zero voltage rise/drop

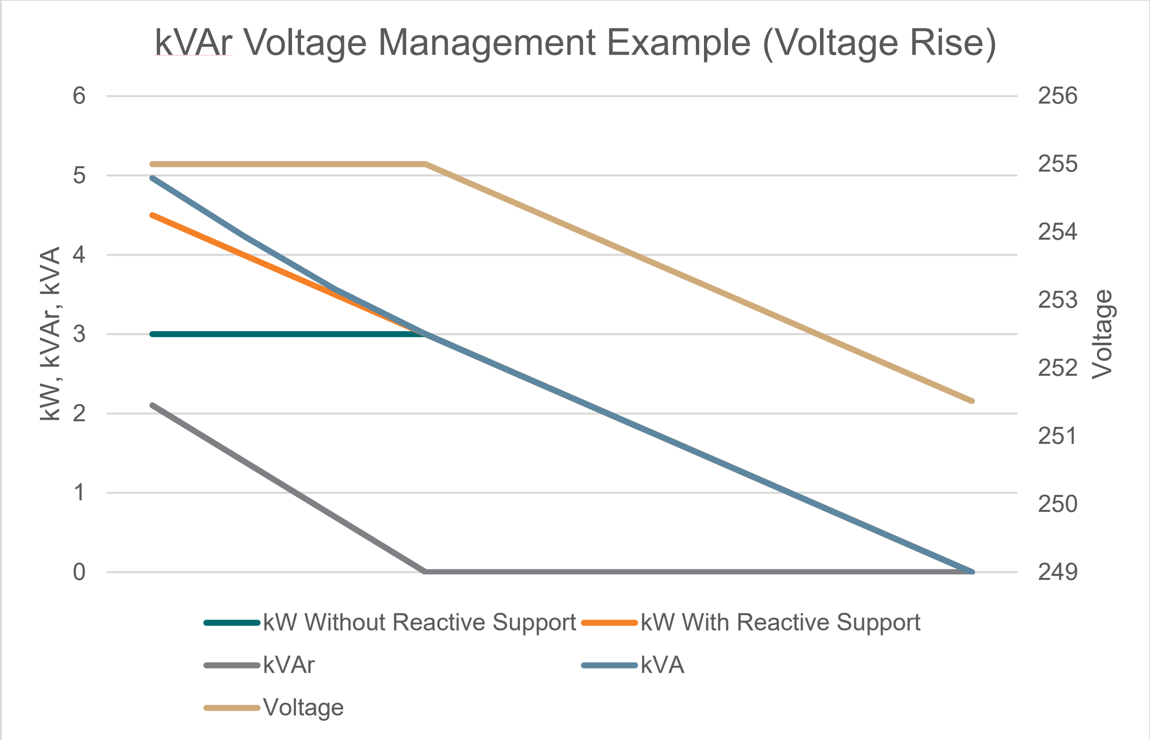

Figure 28: Approximated Sample Site Reactive Power Voltage Management to Increase Network Real Power Hosting Capacity

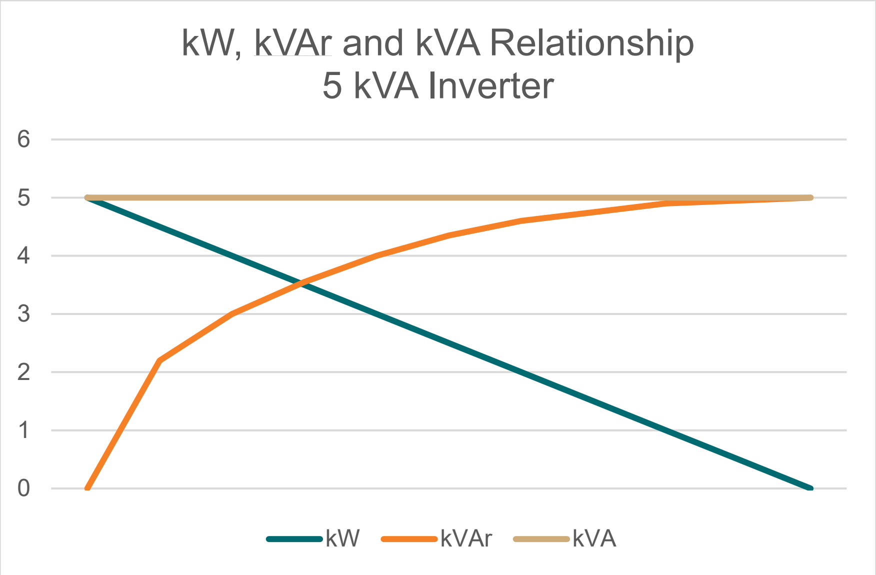

Figure 29: The Relationship between Real and Reactive Power at Constant Apparent Power

3.7 Benefits

The Networks Renewed project has provided real-world evidence of customer inverters overlaid with smart control providing voltage management services to Distribution Networks through dynamic control of both real and reactive power. This has enabled a higher uptake of solar PV with minimal customer impact, whilst enabled customer battery storage systems to be centred as a solution to address networks constraints at potentially lower cost compared to traditional network options. The Networks Renewed project has also provided valuable insight to the value a Distribution Level Market can provide to both customers and networks.

The project has provided the following benefits:

- Higher utilisation of customer DER. Dynamic management of network voltage (both customer and network side) has increased the solar PV hosting capacity of the network, this has enabled higher solar PV export during the middle of the day and battery storage export during peak load responding to network support payment opportunities.
- Lowering the cost of electricity to customers through:
    - Access to distribution market revenue streams (network support payment opportunities)
    - Automatic tariff arbitrage using behind the meter solar PV and battery storage through advanced energy management of solar PV and battery storage
    - Lower network losses. By reducing peak demand network losses reduce by a squared function of line current.
    - Downward pressure on network charges achieved through voltage support services from customer DER at a potential lower cost compared to traditional network solutions.
- Improved power quality through dynamic voltage management at the premise level
- Significantly enhanced visibility of the LV network (directly DER sensors) and HV network (indirectly through data analytics and asset models using LV level data) via the remote monitoring and control platform developed for the trial. It’s important to note that only 10% of Essential Energy’s customers today have a smart meter installed, in addition, voltage data is not accessible from these sites.

Networks Renewed has advanced existing technologies, services and techniques in the Australian energy system as follows:

- Dispatch of real and reactive power from sites with solar PV and battery storage. In addition, configuration of inverter power factor and/or volt/watt curves remotely, previously these have been manually set at the time of installation.
- Contracting residential customers to provide voltage services from their inverter-connected resource. There have previously been contracts for demand management services, using customer resources such as air conditioners and hot water systems, but even these are rare. This enabled the demonstration site to serve the purpose of testing the value of voltage regulation from customer inverters to the distribution network for which there is presently no accepted market value or penalty regime.
- Combining network services revenues with market revenues i.e. “value stacking”. While it was not compulsory for participation in the project, some customers elected to enable this feature by switching retailers partnered with Reposit Power to access “Grid Credits’.
- Improved understanding of the control structures available for virtual power plants and their relative costs, benefits and issues. Through the project a range of global and local control techniques were explored, in addition, testing in the real-world environment has identify issues that must be addressed before voltage support services from customer DER can be used under business as usual (particularly in rural areas of the network).

The Networks Renewed project is also contributing to leading innovation across the energy network sector through using lessons learnt to assist with the development of new industry projects, such as ‘Evolve’ being led by Zeppelin Bend, which Essential Energy is a project partner.

3.8 Lessons Learnt

Project learnings have helped identify and prioritise some of the foundation work required before networks can operate in an environment with a high uptake of DER that supports effective and efficient integration of renewables while maintaining downward pressure on network charges, this includes:

Customers

The final number of trial participants was below target even though significant effort was redirected towards boosting customer engagement through multiple community forums, project information packs and redesign of the subsidy. Lesson learnt is that application under business as usual will require a significant step up to customer engagement focusing on making the opportunity easy to understand, educating about the changing market, emerging market participants and types of DER.

Tariffs and Connection standards

To maximise utilisation of the network and customer DER while minimising solution cost, networks need to shift from static to dynamic connection standards. Through the trial area, conditional network connection approvals were required to enable full capacity export from customer battery storage systems during network peak load to support the network. Traditional (static) connection standards limit customer DER based on worst case conditions, which is typically during the middle of the day when solar PV is at peak output, and network voltage and thermal limits to ensure the network maintains operation at all times within its physical limits.

In addition to optimising connection standards a shift towards cost reflective network tariffs is required to drive efficient use of the network, this is particularly important with DER energy management based on financial signals from the market. It was found that some late requested dispatch events resulted in a peak before the peak event to charge customer batteries.

Network

Traditionally, distribution networks have been planned, designed, and operated for peak load, as a result of accelerating the growth of generation within the trial area a multitude of challenges were identified, some not known before the trial, this includes

- abnormal network asset operation resulting in amplification of existing network issues
- reverse power flow conditions difficult to detect due to historical network monitoring configuration, Figure 27 presents an example where current is not signed.
- Basic connection approvals resulting in some premise voltage levels above the upper end of the statutory supply limit, this is due to both the network set for load and lack of visibility of voltage at the low voltage level of the network.

Linked to the challenge of reaching the target number of trial participants, it was challenging to achieve optimised placement of customer DER through a subsidy area approach to minimise the cost of network support (i.e. ∆V/$) and overall cost of DER as a voltage support service to the network.

Through the trial Essential Energy's utilised Reposit Power's platform to manually set dispatch events, deployment under business as usual requires automatic dispatch through integrating DER dispatch events into Essential Energy's Advanced Distribution Management System (ADMS).

Market Development

During the trial we experienced multiple communications issues and a server failure, leveraging customer DER under business as usual as a voltage support service requires the integration of failsafe mode at the device level for the purpose of backing up global/master control.

Today there are many DER trials across Australia with networks creating bespoke interfaces, this is not an efficient approach if carried into business as usual. Noting the continued strong growth of customer DER, and the need of interoperability to realise the benefits and address the identified challenges, generates motivation for a collaborative effort across industry to work towards an Application Programming Interface (API) standard for the long-term interest of customers.

Learning outcomes of the trial can be applied across industry in two areas:

1. **Voltage support services from customer DER as a potential lower cost solution compared to traditional network options:** likely applied to rural areas of the distribution network where network capacity is defined by network voltage limits and through a targeted approach based on use as a planning tool where economical guided by the business case developed.
2. **Support the effective and efficient uptake of renewables while placing downward pressure on network charges:** driving informed changes to both network connection standards and tariffs to improve the utilisation of both networks and customer DER, whilst also guiding the market in terms of future capability requirements.

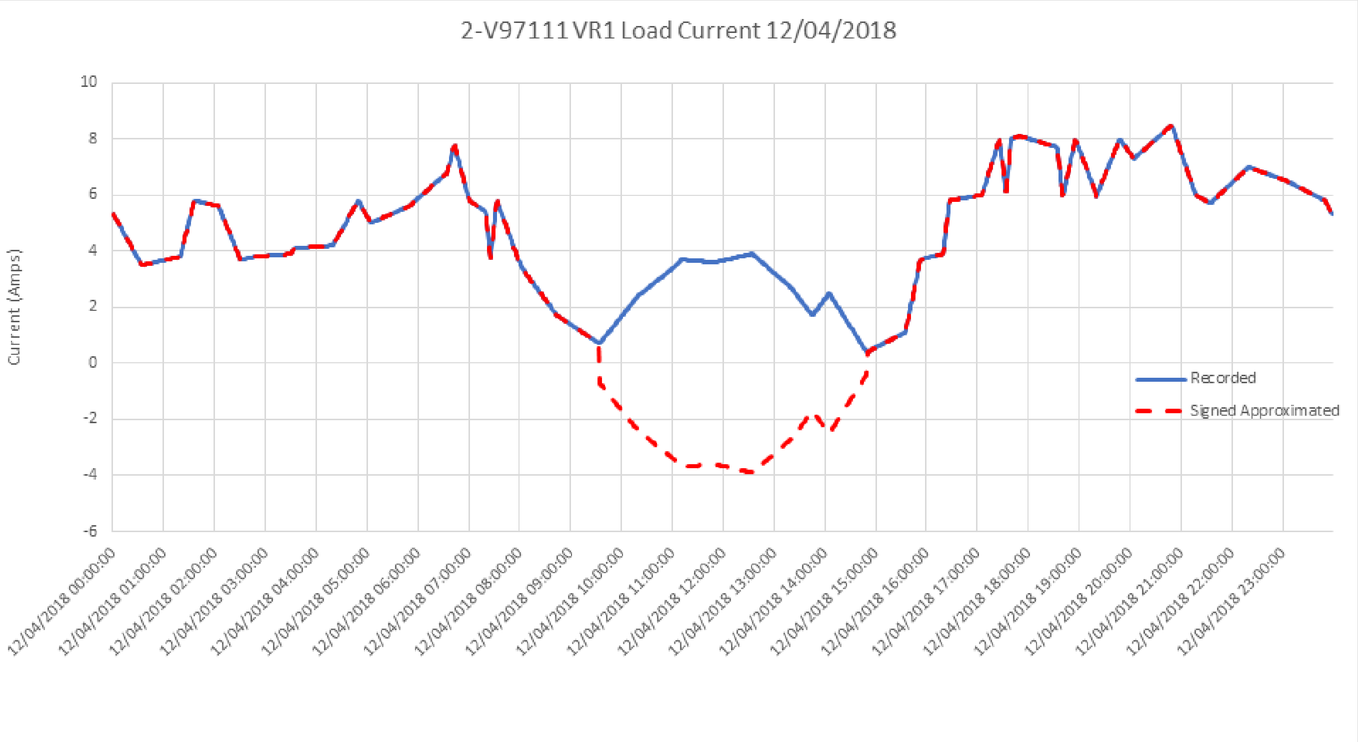

Figure 30: Reverse Power Flow

4 Compliance Summary

As per section 2.2.1 of the Demand Management Innovation Allowance Mechanism December 2017, projects under the DMIAM must meet the following criteria:

1) An eligible project must:
    a) be a project or program for researching, developing, or implementing demand management capability or capacity; and
    b) be innovative, in that the project or program:
        i) is based on new or original concepts; or
        ii) involves technology or techniques that differ from those previously implemented or used in the relevant market; or
        iii) is focused on customers in a market segment that significantly differs, from those previously targeted by implementations of the relevant technology, in relevant geographic or demographic characteristics that are likely to affect demand; and
    c) have the potential, if proved viable, to reduce long term network costs.

2) A distributor's costs of a project or program are not eligible for recovery under the mechanism if those costs are:
    a) recoverable under any other jurisdictional incentive scheme;
    b) recoverable under any state or Australian Government scheme; or
    c) otherwise included in forecast capital expenditure or operating expenditure approved in the distributor's distribution determination.
3) For avoidance of doubt, the mechanism does not require a distributor's eligible project to be geographically constrained to its distribution network.
4) Expenditure under the DMIA can be in the nature of capex or opex. The AER considers that capex payments made under the DMIA should be treated as capital contributions under clause 6.21.1 of the NER and therefore not rolled into the regulatory asset base at the start of the subsequent regulatory control period. However, the AER's decision on the treatment of capex will only be made as part of the subsequent distribution determination.

Section 2.3.1 of the Demand Management Innovation Allowance Mechanism December 2017 requires that each DNSPs must submit to the AER annual reports on their expenditure under the DMIAM for each regulatory year.

The following table provides the details of Essential Energy's DMIAM projects undertaken in the 2019/20 financial year as outlined above.

Table 7 - Details of Essential Energy's DMIAM projects undertaken in the 2019-20 financial year

Name of Project	The projects outlined meet the DMIA criteria under the following conditions:			
	1a. a project or program for researching, developing, or implementing demand management capability or capacity	1bi. based on new or original concepts; or 1bii. involves technology or techniques that differ from those previously implemented or used in the relevant market; or 1biii. is focused on customers in a market segment that significantly differs, from those previously targeted by implementations of the relevant technology, in relevant geographic or demographic characteristics that are likely to affect demand; and 1c. have the potential, if proved viable, to reduce long term network costs.	2. Yes/No, the costs allocated to the project are; a/b. not recoverable under any other jurisdictional, state or Australian Government scheme c. not be included in forecast capital or operating expenditure	4. Is the expenditure capex or opex in nature?
Networks Renewed	Yes	Yes	Yes	Opex