Essential Energy

Regulatory Information Notice (RIN)

Supporting Information for Demand Management Innovation Allowance (DMIA)

2016-2017

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Prepared by Essential Energy

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1 Introduction

The Demand Management Incentive Scheme (DMIS) applied to Essential Energy by the Australian Energy Regulator (AER) in the *Demand management incentive scheme for the ACT and NSW 2009 distribution determinations* (the Determination) 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 be increasingly identified as viable alternatives to network augmentation.

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

2 Summary of Submission

Essential Energy's DMIA expenditure for the 2016/17 financial year consisted of three new initiatives and the continuation of projects from previous years, with five different projects/programs in total including;

1. Commencement of Networks Renewed
2. Demand and Energy - Technology and Environment Paper
3. Demand Management Best Practice Paper
4. Continuation of Switched Reactors
5. Continuation of Conservation Voltage reduction through the use of low voltage regulators

Total Program cost for the 2016/17 financial year is $301,375 with $3,114 allocated to CAPEX as follows;

Table 1 DMIA Expenditure 2016/17

Name of Project	Total amount of the DMIA spent in:		
	2016-2017		
	Operating expenditure ($'000 nominal)	Capital expenditure ($'000 nominal)	Total expenditure ($'000 nominal)
Networks Renewed	81,796		81,796
Demand and Energy - Technology and Environment Paper	154,071		154,071
Demand Management Best Practice Paper	57,509		57,509
Switched Reactors		2,663	2,663
Conservation Voltage Reduction through low voltage regulators	4,884	451	5,335
Total	298,261	3,114	301,375

For further information refer to the specific project reports or contact dmcoordinator@essentialenergy.com.au

All costs are determined through the use of appropriate procurement systems and time recording.

2.1 Developments from previous years DMIA

Development during the regulatory period included:

- Commencement of Networks Renewed: Joint project with the Australian Renewable Energy Agency (ARENA), University of Technology Sydney, Reposit Power and SMA Australia, 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 two-year partially subsidised trial.
- 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 practise processes, information and technology in electricity NNA analysis and selection with an understanding of the regulatory frameworks and incentives available.
- Switched Reactors: Site installations and commissioning complete with data analysis underway.
- Conservation Voltage Reduction project through the use of low voltage regulators: Site installations and commissioning complete with data analysis underway
- 20kVA and 5kVA Grid Interactive Inverter program: Optimised control techniques to maximise network support.
- Capacitor Package Development: Completion of standards and specifications to approach the market and guidelines for applications on the network.
- Commencement of Controlled Load initiatives: Development of a Controlled Load Algorithm and NPV of alternative Controlled Load technology.

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

- The Energy and Network Capacity project has allowed Essential Energy to capture the long-term costs of the inherently lumpy augmentation characteristics of network assets, in the past Essential Energy has struggled to implement demand management programs based on cost effectively deferring any single network element.
- The Energy and Demand audits project showed that substantial low-cost demand management options are available, and as such Essential Energy is currently moving strategies into place to take advantage of the benefits found across power factor correction and pumping loads and moving toward further research into a number of other promising demand management options which still hold a degree of uncertainty such as standby generation, load shifting, load shedding and air conditioner efficiency.
- The Grid Interactive Inverter program highlighted the benefits of various inverter control techniques, specification requirements specific to Essential Energy's network and optimised control techniques to maximise network support. Since the commencement of the Grid Interactive inverter program a number of other suppliers have risen to deliver similar benefits, the evaluation of such emerging products and reduced costs in addition to the known benefits continues to permit cost reflective evaluation of demand management options within Essential Energy.

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

Networks Renewed is an Australian Renewable Energy Agency (ARENA) part funded industry project with the Institute of Sustainable Futures, Reposit Power, SMA and United Energy, New South Wales and Victorian Governments to connect over 1MW of customer and network owned solar systems and battery storage systems. As part of the project around 200 households or equivalent businesses will have a combination of solar and energy storage installed to support the distribution network by storing excess electricity and reducing peak demand on the network. Potentially up to half of the specified households and installed capacity may be connected to Essential Energy's network across two locations.

Undertaking the Networks Renewed project will facilitate the development of a set of guidelines for future uptake to ensure such technology is optimally integrated and does not result in costly network expenditure whilst also permit exploration of the possible value such technology can provide on a least cost basis to address network constraints.

3.2 Background information

Traditionally, the capacity of the distribution network has been focused on suppling peak load, now with the cost reduction of renewables, such as Solar PV, the focus is shifting towards peak generation. The Energy Network Transformation Road Map estimates that 30%-50% of energy in the NEM by 2050 will be generated at the customer level, resulting in growth of two-way power flows within distribution networks. Note, referenced specifically to Essential Energy's network it's likely generation penetration will be higher than that stated within the Energy Network Transformation Road Map due to larger average size generators (particularly solar PV) systems being connecting.

Figure 1 presents solar PV panel capacity connected to Essential Energy's network from mid-2011 to late 2015, excluding major generators. Evident from Figure 1, solar PV uptake continuous to grow each year. While Figure 2 presents battery storage applications received since December 2016, which currently exceeds 1000 applications totalling more than 10MWh.

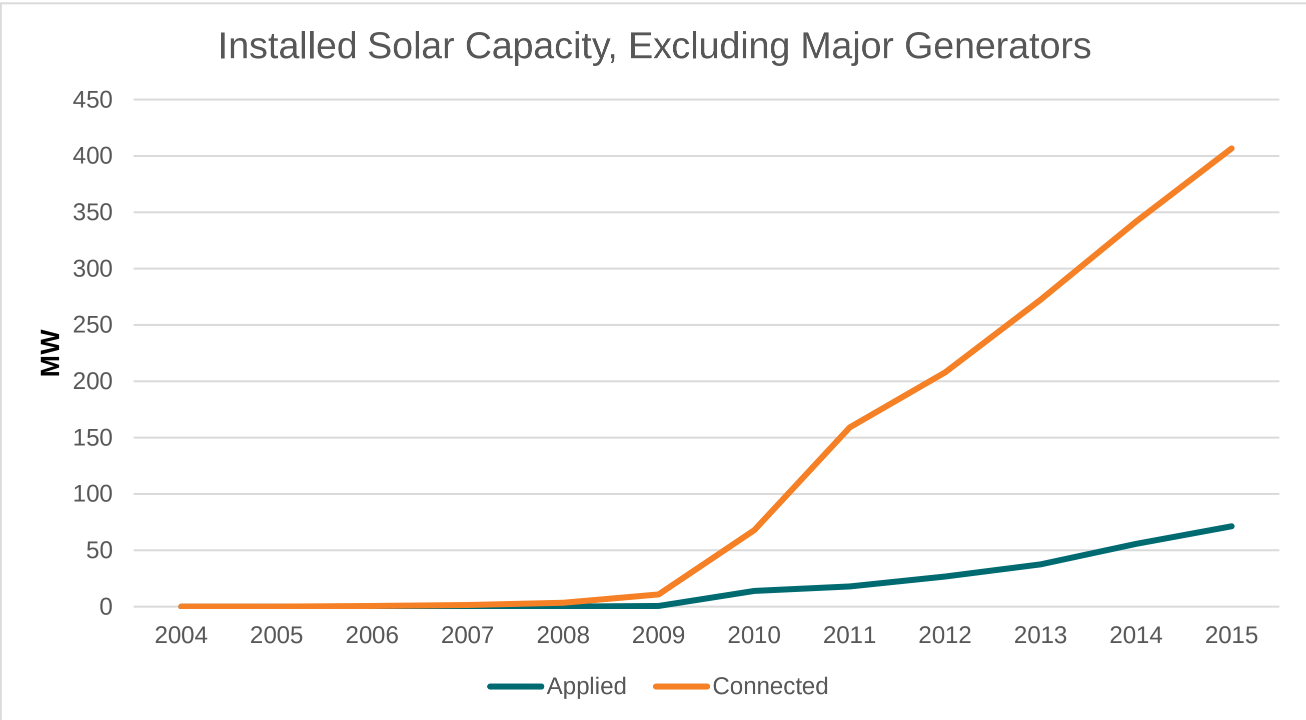

Figure 1: Installed Solar Capacity (Excluding Major Generators)

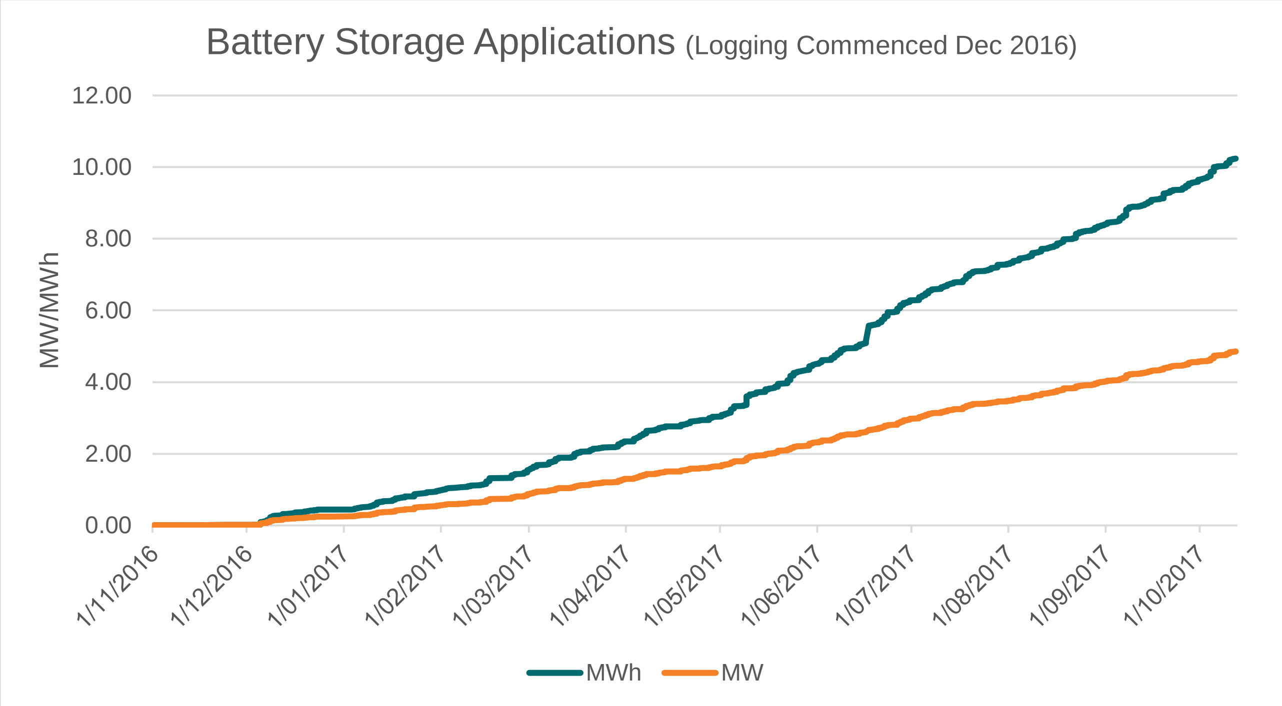

Figure 2: Battery Storage Applications

For a distributed network that was planned, designed and operated to supply peak load, now transitioning to peak generation, network issues are starting to emerge such as a reduction in network utilisation and as a result in some areas of the network, additional capacity is being demanded from the distribution network.

Figure 3 presents the top 10 summer demand days at a sample zone substation (which is a common summer peak demand profile exhibited across the network), during 2015-16 solar PV was connected, it is evident from Figure 3 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. Evident from Figure 3 and Figure 4, utilisation of the network has reduced.

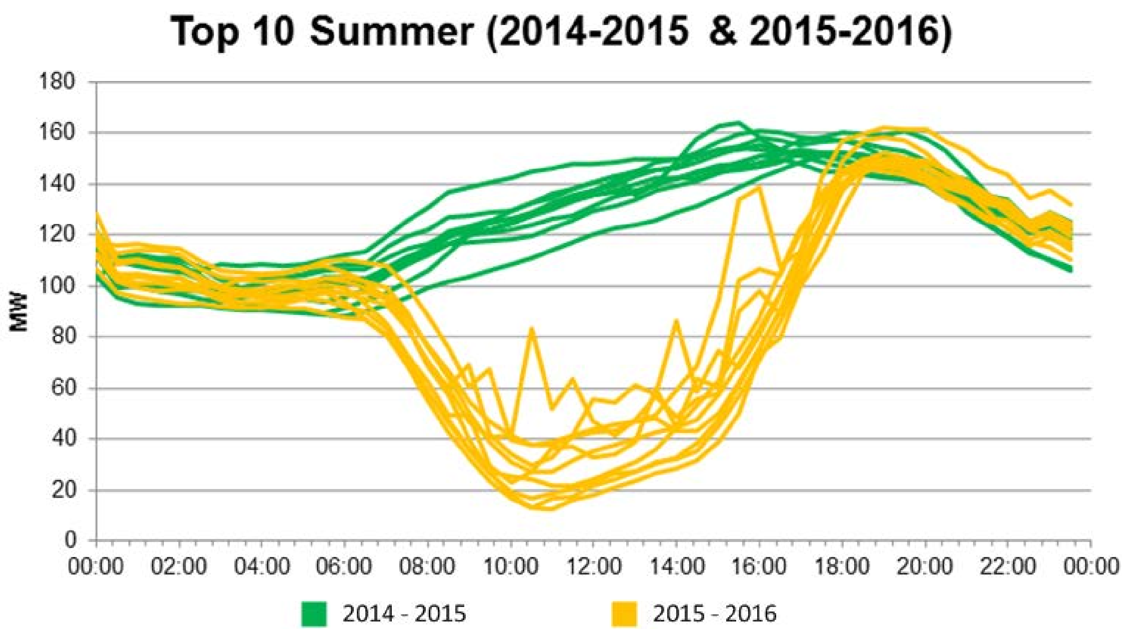

Figure 3: Sample Zone Substation before and after Solar PV connected

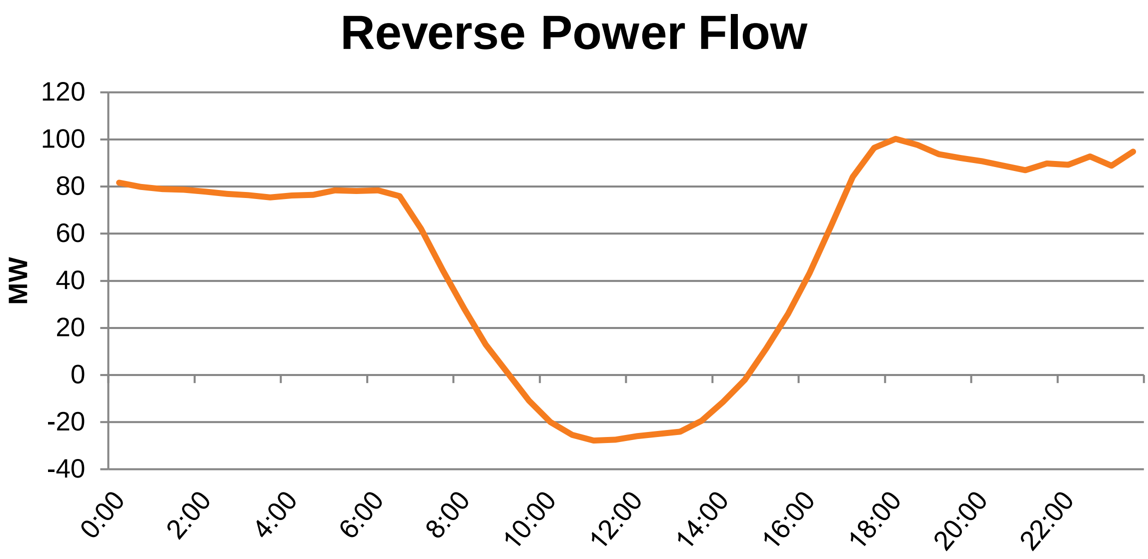

Figure 4: Sample Zone Substation – Minimum Demand

Dependent on network characteristics, a reduction in asset utilisation may result in additional capacity requirements from the network. Referenced to Figure 5, generation results in voltage rise on the network, if combined with a reduction in network utilisation results in widening of the voltage envelope, due to the requirement of supplying peak load, as illustrated in Figure 3.

Figure 6 presents both a demand and voltage density plot for a single connection point and widening of the voltage envelope. Widening of the voltage envelope may result in challenges achieving the required supply standards. Widening of the voltage envelope on a voltage constrained network may also result in a network constraint when supply limits cannot be maintained.

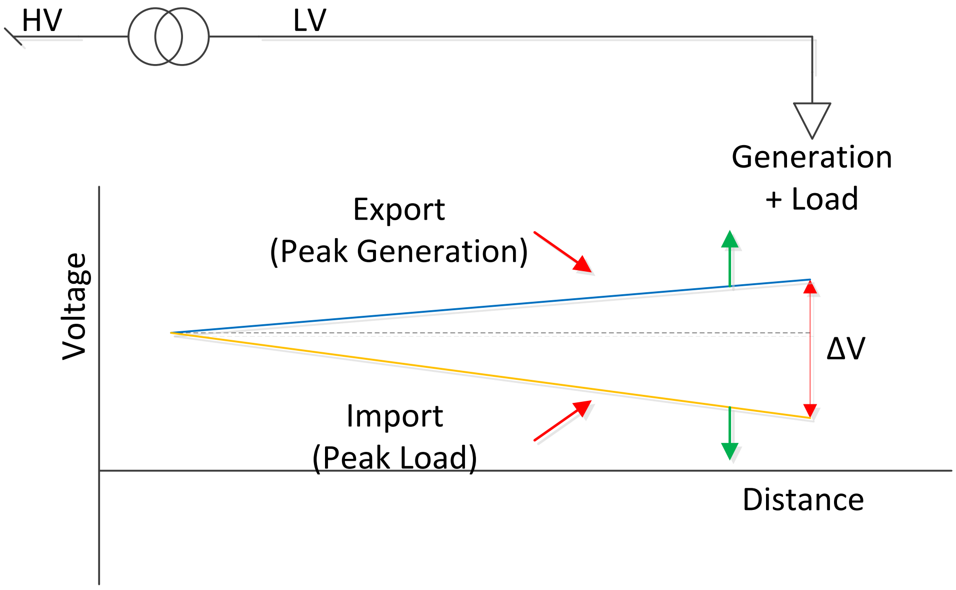

Figure 5: Peak Generation and Peak Load Widening the Voltage Envelope

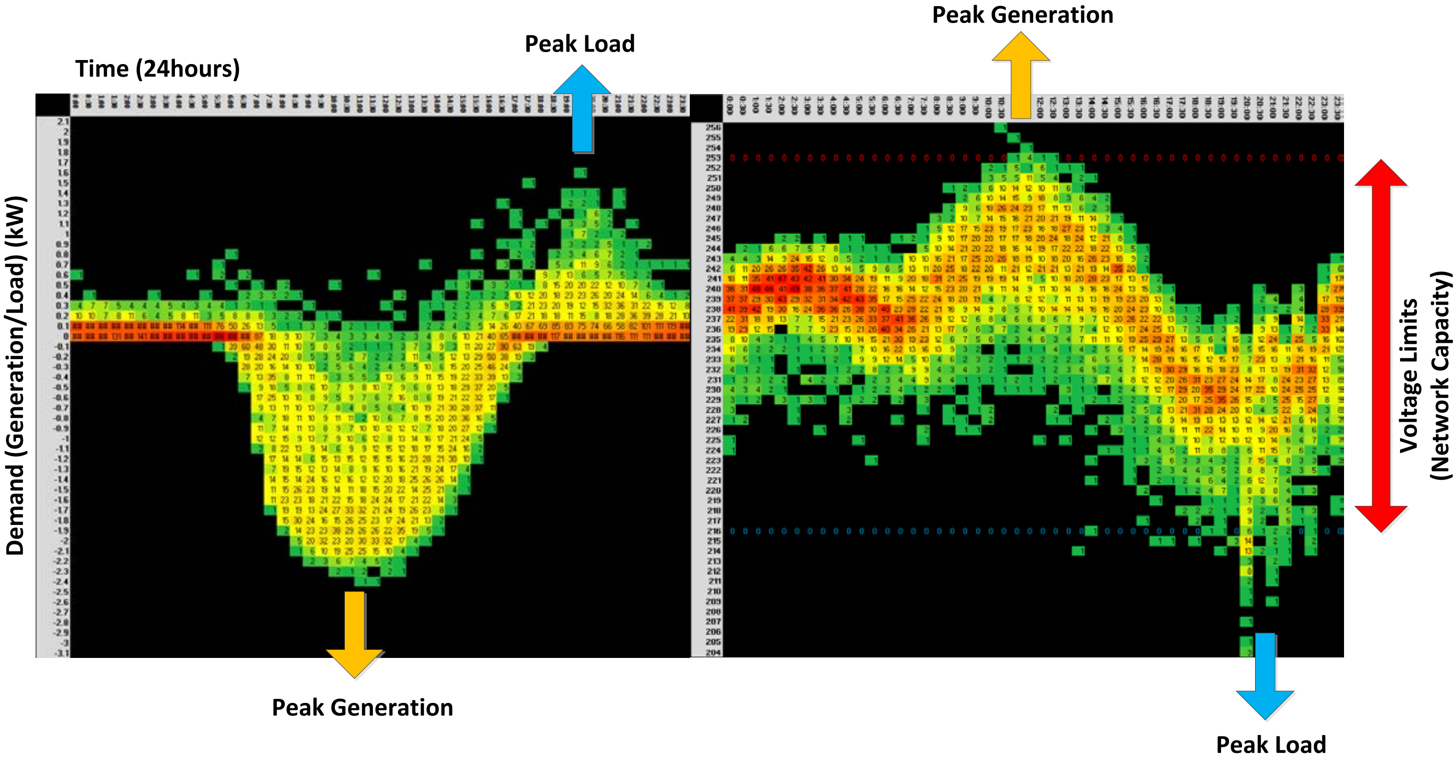

Figure 6: Demand & Voltage Density Plot illustrating Widening of the Voltage Envelope at a single Network Connection Point

Noting the challenges linked to the growth of generation across the distribution network, referenced specifically to Essential Energy's network presented in Figure 7:

- By land mass covers 95% of NSW,
- Total circuit length of approximately 191,000km, to put that into perspective if all feeders were joined end to end the total length is almost five times the earths circumference.
- Approximately 96% of the network is overhead
- ~75,000 km of network has been built using steel conductors, with a typical resistance of 15 to 25 Ohms per km.
- ~30,000 km rural lines are Single Wire Earth Return (SWER).

Combining the long feeder lengths presented in Figure 8 built using a high impedance conductor results 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. Therefore, under the projected uptake of generation on Essential Energy's network, it is expected connection point voltage envelopes will continue to widen.

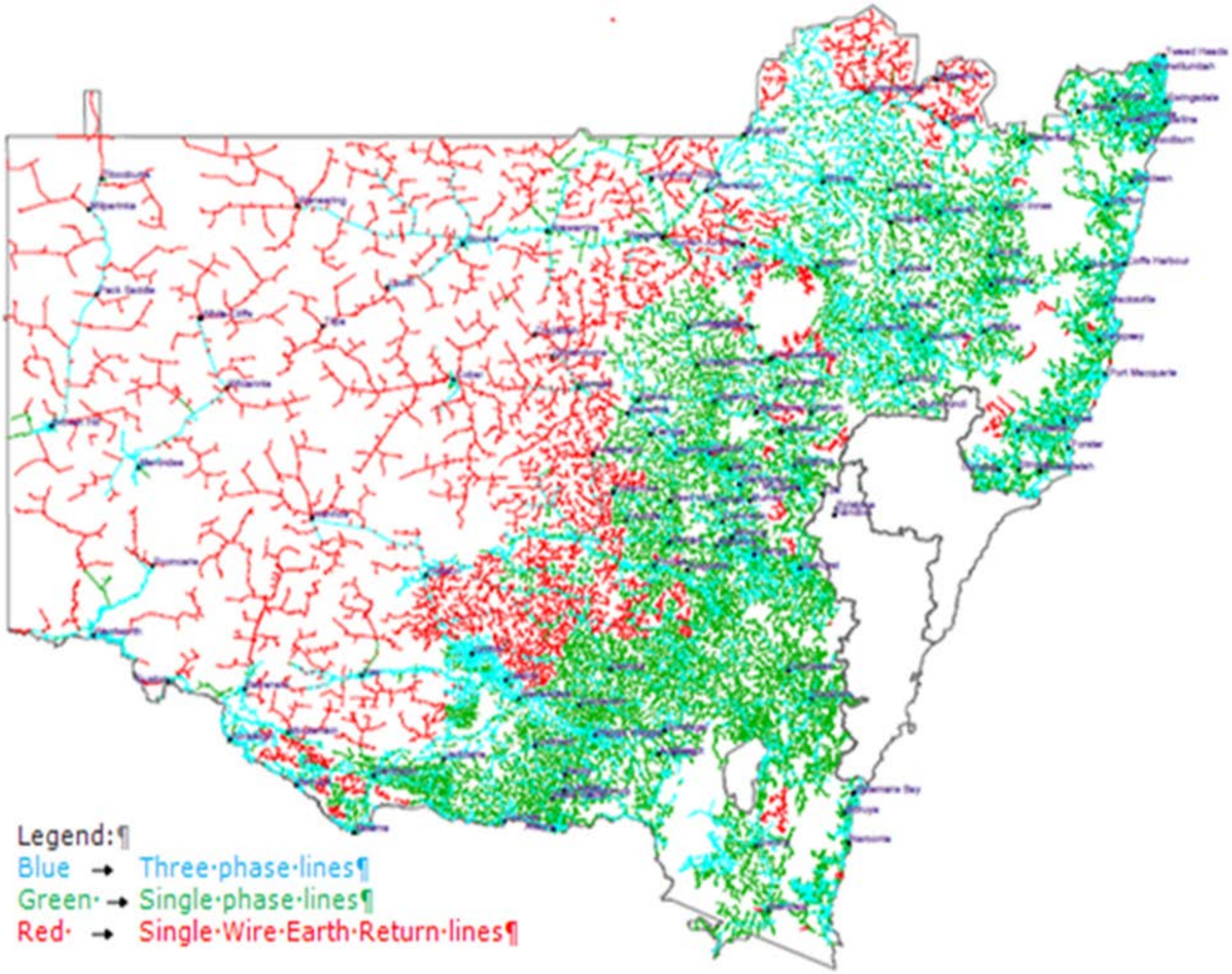

Figure 7: Essential Energy's Distribution Network

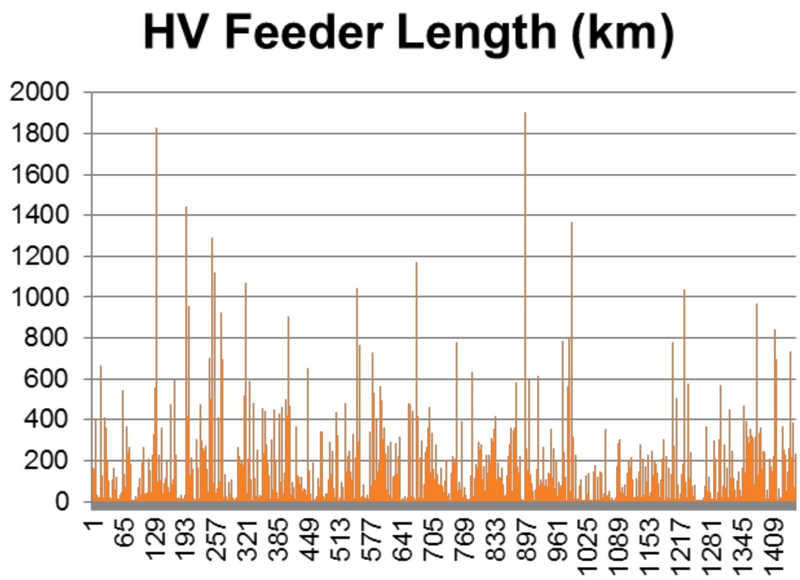

Figure 8: Essential Energy - HV Feeder Lengths

Inverters with real and reactive power control coupled with or without battery storage can be used to adjust power flows and significantly improve voltages, currents, utilisation, and losses on the existing infrastructure as an alternative to network augmentation.
Regarding real power control one benefit is peak shifting, as depicted in Figure 9. Peak shifting 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 shaving within a voltage constrained network results in tightening of the voltage envelope. Therefore, battery storage could potentially address network constraints.

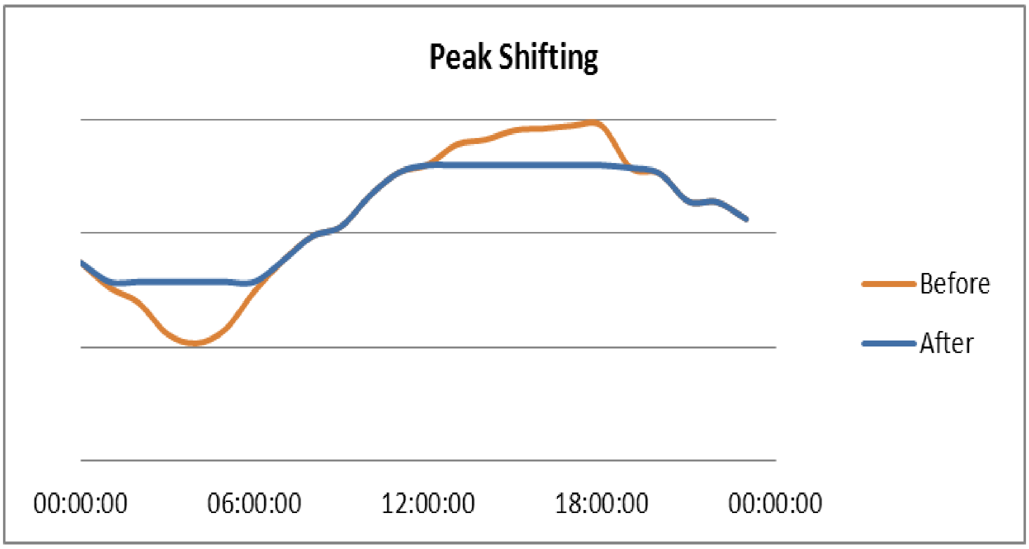

Figure 9: Peak Shifting Strategy

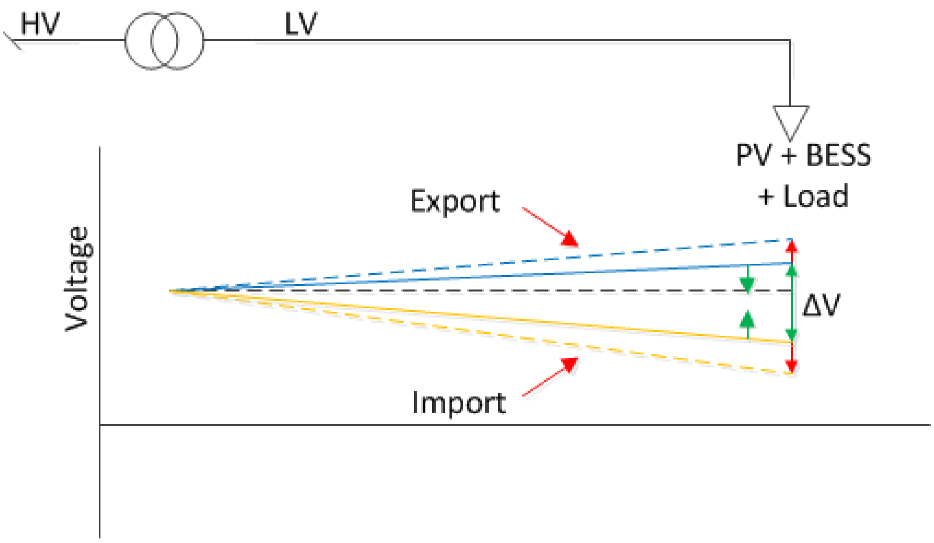

Figure 10: Tightening of the Voltage Envelope

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

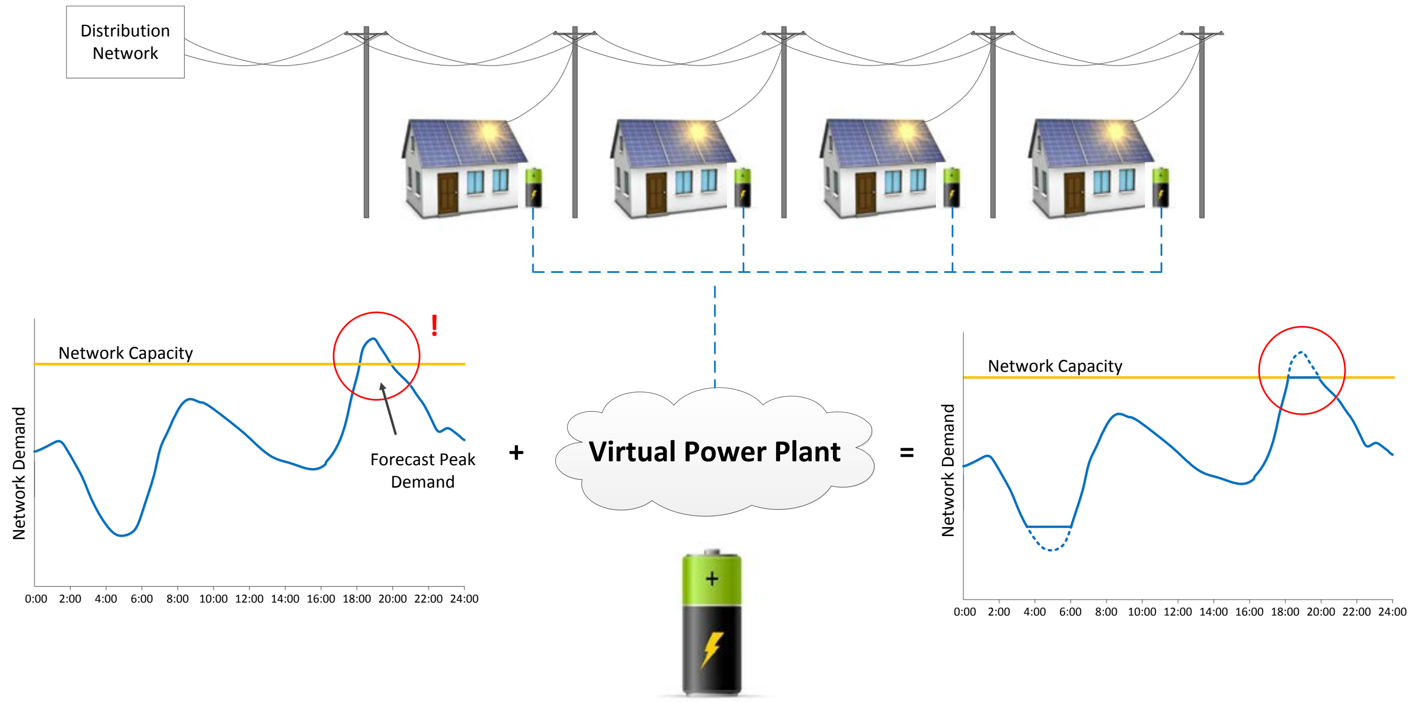

Figure 11: Peak Shaving Strategy with Aggregated Real Power through a Virtual Power Plant ([1])

3.3 Project Overview

Networks Renewed is a joint project with the Australian Renewable Energy Agency (ARENA), University of Technology Sydney, Reposit Power and SMA Australia, 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 rural towns of Collombatti, north-west of Kempsey, and Bellingen, south-west of Coffs Harbour, have been selected for the trial due to the high concentration of solar customers in the area and the potential to address an emerging network constraint.

The project's two key objectives include:

- Develop a set of guidelines 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 will be delivered in two separate stages, with the quantity of these installations dependant on achieving the required network benefit.

During the initial pilot stage, up to 40 customers will receive subsidised installation of the battery storage systems or advanced solar inverters and will retain ownership of the equipment as part of the trial. During the trial period, participants will receive payments based on the level of network support their system provides.

The trial has been designed around an open market approach, maximising customer choice, emerging market participants and the potential future energy market. Subsidies have been 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.

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

3.4 Nature and Scope

With the desired outcomes in mind (develop knowledge and confidence in the application of aggregated smart inverters with/without energy storage), the scope will be limited to the following:

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

1. Develop a set of guidelines for future uptake to ensure such technology is optimally integrated and does not result in costly network expenditure. Questions that we hope 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 arises such as the supply voltage being outside of acceptable limits, Essential Energy would install or replace network assets with assets able to deliver greater capacity, this may include 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 of trial sites down to two sites to demonstration the benefits of real and reactive power through virtual power plants.

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

1. Collomabtti (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

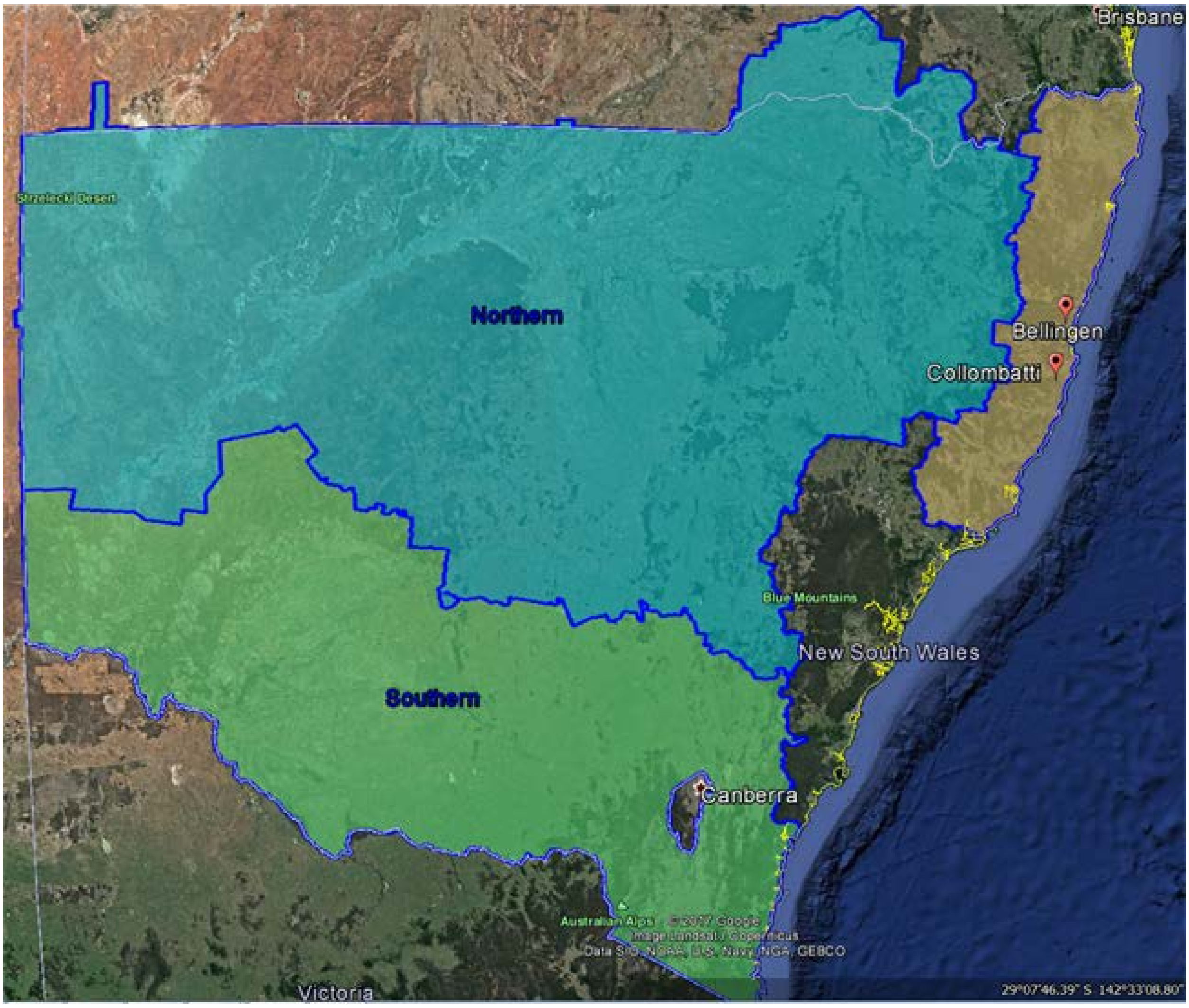

Figure 12: Essential Energy Regions and Trial Locations

2. Pilot Stage Implementation

The pilot stage of Networks Renewed included development of a subsidy, project webpages (http://www.essentialenergy.com.au/content/batterytrial , www.essentialenergy.com.au/content/invertertrial) and Letters of Offer for each trial area. Letters of Offer were mailed to eligible customers within the two subsidy areas based on proposed network benefit to commence the expression of interest (EOI) process. Following the mail out of Letters of Offer, a community forum was held in Collombatti on the 9th of December 2016 to provide an overview of the project and to answer any questions from customers regarding the trial.

With reference to Figure 13, in response to the initial limited number of expressions of interest received, the Collombatti pilot stage subsidy area was expanded, followed by a second community forum with the aim of increasing the number of trial participants. Following the subsidy claim approval process battery storage installations on the Collombatti feeder commenced.

Essential Energy obtained access to the Virtual Power Plant (VPP) late August 2017. Since being provided access Essential Energy has undertaken a number of VPP notch tests to gauge the effectiveness of systems installed.

Regarding Bellingen, the first round of EOIs and subsidy claims have been received, however, due to unforeseen circumstances with inverter supplier, Bellingen installations have been delayed. It's planned for inverters to be distributed from the new supplier towards the end of 2017.

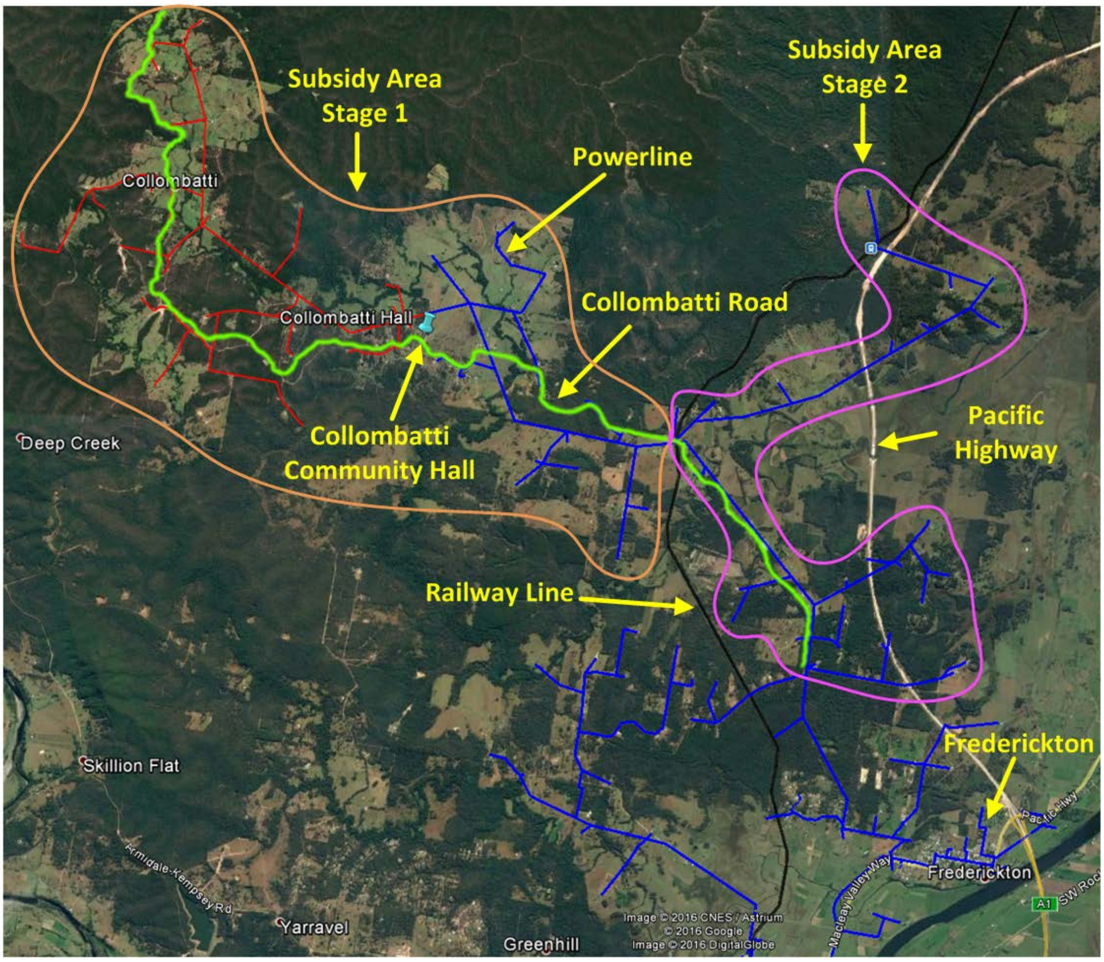

Figure 13: Collombatti Subsidy Area

3. Pilot Stage Evaluation

Recent "notch test" results from the Collombatti pilot stage virtual power plant have demonstrated a measurable network benefit. Evident from Figure 14, a voltage improvement of 1.73 percent has been achieved. Based on such results, Essential Energy is satisfied that the reduced quantity of pilot stage systems achieved 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 2 presents the two trial sites selected to ascertain benefits and explore control techniques to achieve the objectives of the project. System installations are to be delivered in two separate stages, with the quantity of these installations dependant on achieving the required network benefit.

Evident from Table 2, the target uptake across both pilot stage sites was 40 systems, such quantities were allocated to each demonstration site based on the desired outcome of achieving a clear measurable network benefit. Regarding Collombatti, signing up trial participants has proven to be a challenging process, but has also generated valuable learning outcomes that will be used to optimise the market stage.

To date, 23 subsidy claims have been received from Collombatti and 11 from Bellingen. 16 systems are currently active within the Collombatti Virtual Power Plant with the remaining systems to be online in the coming weeks.

Following measurements obtained from the 23 pilot stage systems within Collombatti, further network modelling will be completed to ascertain the required additional number of systems to address the emerging network constraint, such analysis will drive the market stage subsidy design. Regarding Bellingen, once inverters have been allocated to the subsidy claims, installations will commence, followed by similar tests performed within Collombatti.

Table 2 – 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

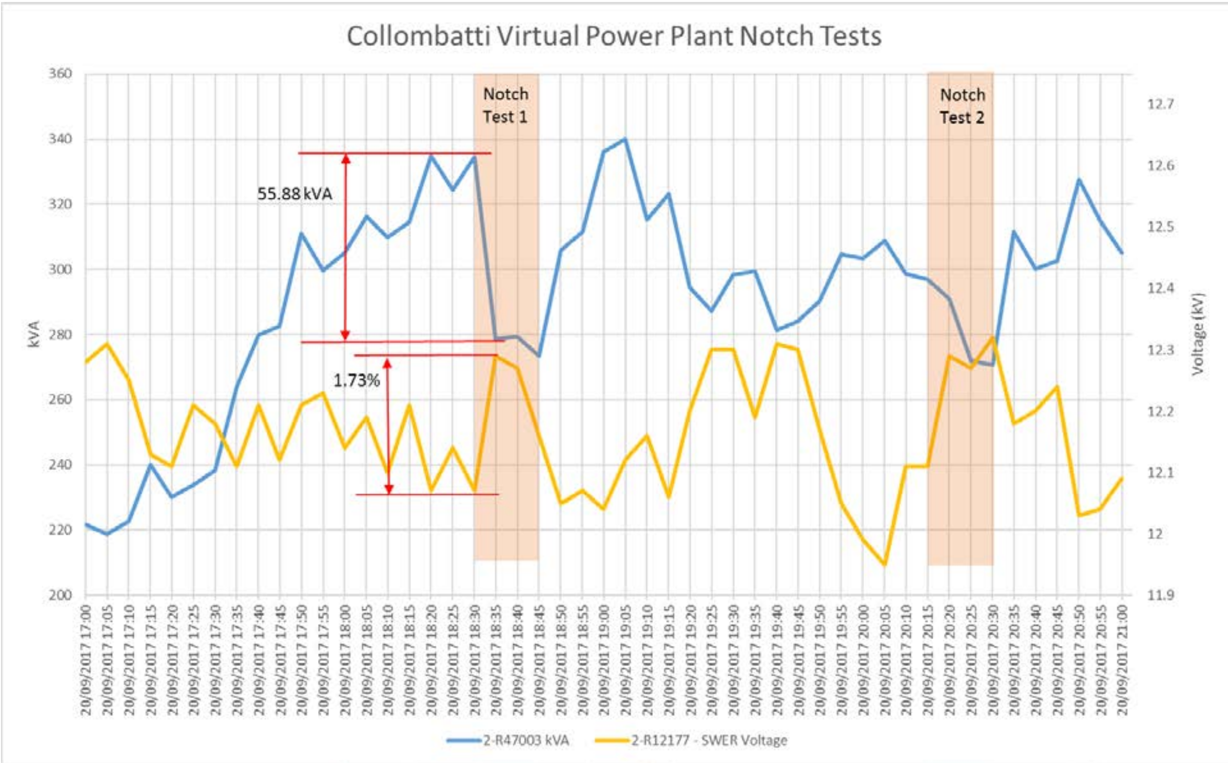

Figure 14: Collombatti Notch Test Detail

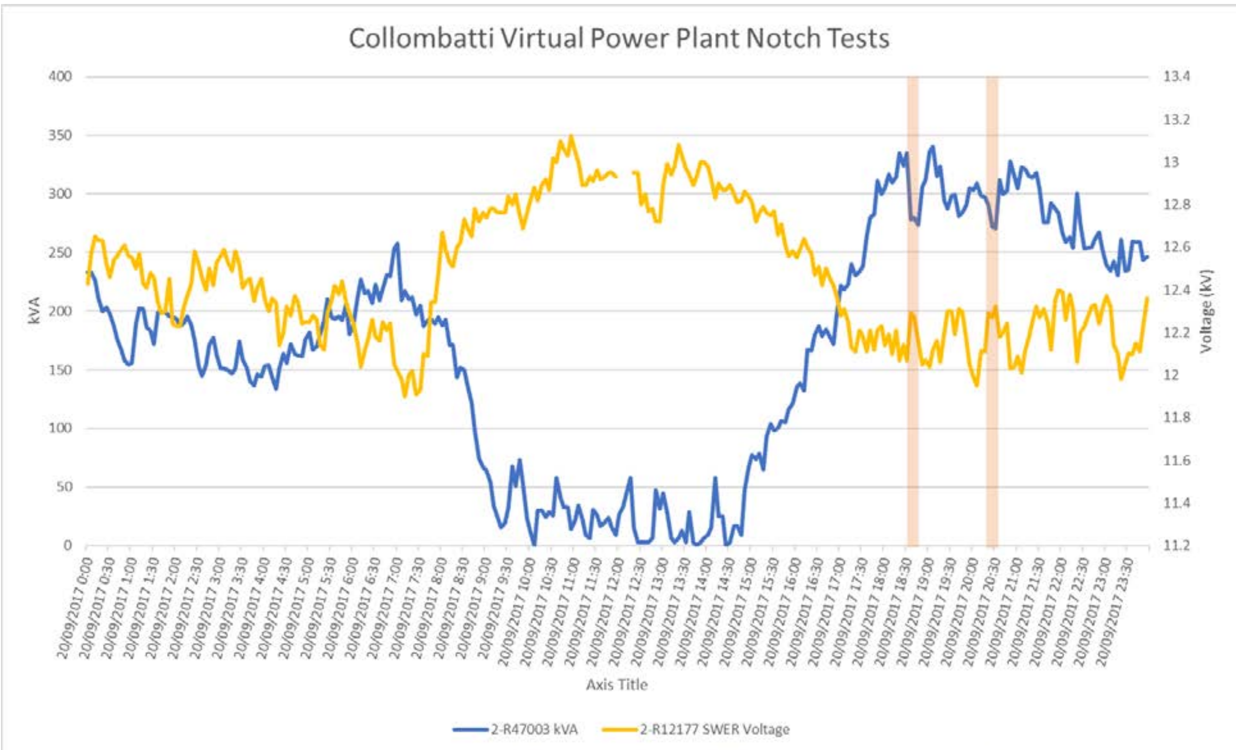

Figure 15: Collombatti Notch Tests

4. Market Stage Implementation

Following measurements obtained from the 23 pilot stage systems within Collombatti, further network modelling will be completed to ascertain the required additional number of systems to address the emerging network constraint, such analysis will drive the market stage subsidy design. It is planned for the market stage to commence during the 4th quarter of 2017

5. Total Project Evaluation

Following the market stage implementation, a detailed evaluation will be completed in line with the project key objectives, namely:

> Development of a set of guidelines for future uptake to ensure such technology is optimally integrated and does not result in costly network expenditure.
> Ascertain the possible value such technology can provide on a least cost basis to address network constraints.

3.7 Benefits

Undertaking the Networks Renewed project will facilitate the development of a set of guidelines for future uptake to ensure such technology is optimally integrated and does not result in costly network expenditure whilst also permit exploration of the possible value such technology can provide on a least cost basis to address network constraints.

A number of anticipated benefits are highlighted below;

> Confidence in the use of innovative technology solutions such as virtual power plants which may then be used to meet legislated power quality standards more efficiently than traditional network investment or as a means of deferring network investment.
> Understanding of the control structures available for virtual power plants and their relative costs, benefits and issues
> A tool for use in the economic deferral of network investment, through the reduction of demand and losses.
> Avoid network augmentation through reducing/limiting peak demand and improved power quality
> Decrease network losses
> Facilitating the integration of distributed generation into the grid
> Improving network visibility via remote monitoring and control

4 Demand and Energy - Technology and Environment Paper

4.1 Summary

In 2017, Essential Energy engaged a consultant to identify, assess, forecast and 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. Quantifying such impacts will help Essential Energy optimise internal strategies whilst also drive change within the broader energy market for the long-term interest of customers within the NEM.

4.2 Background information

The energy market is currently experiencing one of its largest transformations since its creation, such change is presenting both challenges and opportunities to existing and new market participants. To adapt to such changes in the long-term interest of customers within the NEM it's important that Essential Energy takes a proactive approach to identifying from a holistic view the market challenges and opportunities today and into the future, this includes:

- New and emerging technologies and technology usage trends
- Technology impact potential and cost pathways,
- Existing Pilots, trials and related announcements from other utilities in Australia and around world
- Related regulatory changes underway

Knowledge of such will permit optimisation of Essential Energy's Demand Management strategy, that will drive not only internal initiatives, but also within the much broader energy market.

4.3 Project Overview

In 2017, Essential Energy engaged a consultant to identify, assess, forecast and 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.

Referenced to Figure 16 and Figure 17, highlights of this study were that, from an electricity demand perspective, solar photovoltaic (PV) and behind-the-meter storage will be of highest importance for Essential Energy for the foreseeable future. This is because of the anticipated high uptake levels and their direct impact on energy use patterns. PV and storage are predicted to reduce energy use from the network significantly, leading to reduced asset utilisation and potentially an increased cost per kWh delivered. The impact on maximum demand will vary, depending on how many customers take up PV and system sizes installed. With moderate market penetration, we expect the bandwidth of network voltage to expand, while in very high penetration areas, we anticipate new maximum local demands under reverse-flow conditions. Benefits such as the potential price smoothing effect of behind-the-meter storage will depend on the tariffs and/or control schemes.

From a network asset perspective, Essential Energy will need to ensure assets are deployed that are relevant to the long-term forecast for demand and connections. From a regulatory and tariffs perspective, Essential Energy will need to actively adapt tariffs and/or control schemes to the uptake of these technologies. In this way, Essential Energy can limit the adverse effects of PV (mainly voltage impact and reverse flows) and leverage their potential benefits (peak shaving, reliability improvement, voltage support etc.).

Off-gridding and electric vehicles uptake is expected to remain relatively limited, but will present specific opportunities. With off-gridding, Essential Energy could lower the average cost to serve by using lower cost options to supply customers on the fringe of the grid.

Among the topics studied, electric vehicles were the only technology driving an increase in energy use. Essential Energy could potentially limit their maximum demand increase, which would lower the cost per kWh distributed and increase grid efficiency. To achieve this, appropriate charging patterns could be incentivised and various mechanisms could be investigated such as specific tariffs, smart chargers and workplace charging stations. These would ensure the integration of electric vehicles into the grid benefits all stakeholders.

In addition to the topics studied, Essential Energy anticipate other major changes during the defined periods resulting from the AEMC Power of Choice Review recommendations. These will drive expanded energy market governance frameworks that facilitate customer choice, drive efficient investment, and promote demand-side options.

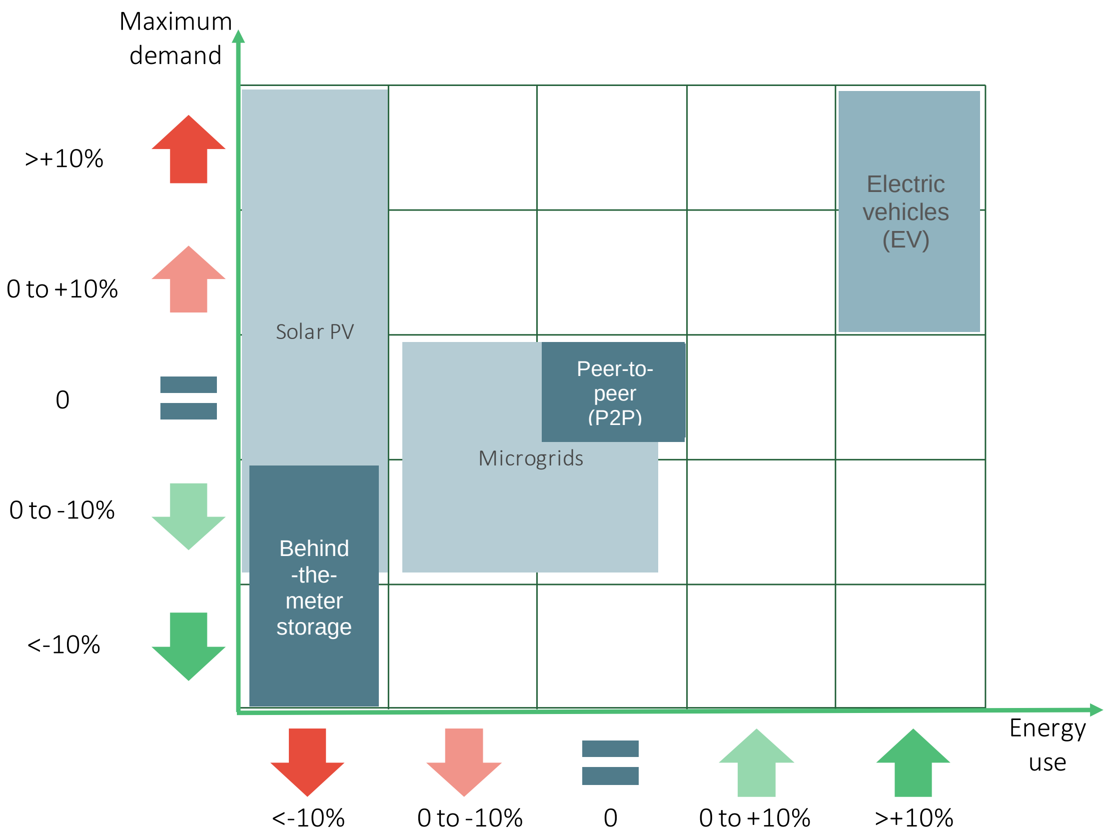

Figure 16 - Potential Demand and Energy Impacts of New Technologies

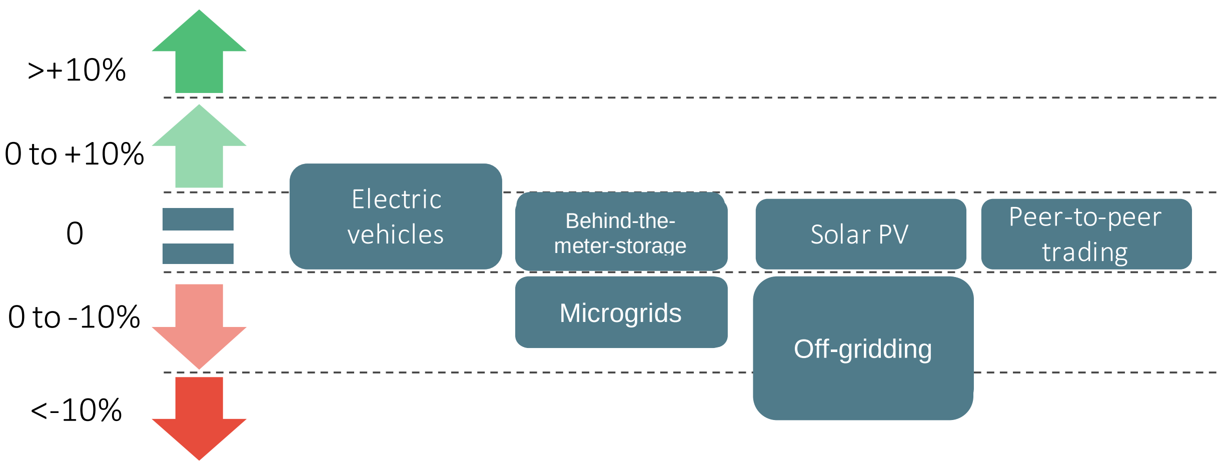

Figure 17- Potential Customer Base Impacts of new Technologies

4.4 Nature and Scope

The objective for the scope of works is a critical assessment of the potential and likely impacts on Essential Energy's electricity demand, energy usage and customer base within 5, 10 and 20-year time horizons as a result of changing technologies and related environmental conditions, specifically:

- New and emerging technologies and technology usage trends
- Technology impact potential and cost pathways
- Pilots, trials and related announcements from other utilities in Australia and around world
- Related regulatory changes underway

Areas of study include (but not limited to);

- Energy storage; domestic, commercial and grid scale; behind and in-front of the meter
- Energy usage; smart appliances, smart homes, home energy management systems, electric vehicles, customer load patterns
- Energy sources; solar, wind, gas, micro hydro
- Information technology; metering, customer energy interfaces
- Network technologies; reactive support,
- Market changes; energy trading, peer to peer, block chain trading, demand management services, reactive or voltage based pricing,

4.5 Aims and Expectations

The minimum key deliverable is the provision of a report, reference documentation and any supporting models including:

- For each of the objective items:
  - The outcome of the critical assessment
  - The method and breadth of the research and the specific resource information used
  - Segmentation of likely impacts by geography, customer type, etc.
  - Potential precursor trends that may provide early indicators
- Recommendations on specific items for further research

4.6 Selection

The best candidate to meet the objectives of the project was achieved through Essential Energy's normal procurement process under a Request for Quote. Proposals were ranked based on capability against project objectives, with the successful applicant agreed from the project steering committee.

4.7 Implementation

The approach taken to identify, forecast and 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 comprised of the following steps:

- Literature review
- Discussions with Subject Matter Experts (SMEs) within Essential Energy and externally
- Final report
- Final presentation/workshop

4.8 Benefits

Development of the Demand and Energy - Technology and Environment Paper has expanded Essential Energy's knowledge on;

- New and emerging technologies and technology usage trends
- Technology impact potential and cost pathways
- Pilots, trials and related announcements from other utilities in Australia and around world
- Related regulatory changes underway

Quantifying the impacts of such technologies under different tariffs, regulations and operating models within a road map to the future network will help Essential Energy optimise internal strategies to achieve a best practice business in performance, efficiency, offering value to customers while maintaining downward pressure on network charges. Such knowledge will also help Essential Energy drive the required change within the broader energy market, that may include technology and non-technology based initiatives, for the long-term interest of customers within the NEM.

5 Demand Management Best Practice Paper

5.1 Summary

Essential Energy engaged a consultant to complete a critical assessment of the world-wide best practise processes, information and technology in electricity NNA analysis and selection with an understanding of the regulatory frameworks and incentives available to the individual businesses such that the potential for application to Essential Energy can be understood.

5.2 Project Overview

Essential Energy engaged a consultant to complete a critical assessment of the world-wide best practise processes, information and technology in electricity NNA analysis and selection with an understanding of the regulatory frameworks and incentives available to the individual businesses such that the potential for application to Essential Energy can be understood.

The assessment included case studies on four distribution network business selected from around the world, detailing:

- Indication or measures of the success of the NNA selection
- The detailed process used by the business to identify NNA
- The information and tools available at each stage of the process
- The performance monitoring method of the NNA analysis and selection process
- The NNA used by the business
- The indicative costs of the NNA used by the business
- The research and implementation methods used by the business
- The resource available throughout the process
- The similarities and differences in the incentives, resources, business structure and regulatory framework Potential pathways for application to Essential Energy

5.3 Nature and Scope

The approach taken to identifying suitable case study distribution businesses and collecting the information sought comprised of the following steps:

- Literature review to develop a list of case study candidates
- Shortlist case study candidates
- Email and telephone follow-up with businesses selected for case studies
- Final report on the four case study distribution businesses

5.4 Aims and Expectations

Based on the four case study candidates, each assessment included;

- Indication or measures of the success of the NNA selection
- The detailed process used by the business to identify NNA
- The information and tools available at each stage of the process
- The performance monitoring method of the NNA analysis and selection process
- The NNA used by the business
- The indicative costs of the NNA used by the business
- The research and implementation methods used by the business
- The resource available throughout the process
- The similarities and differences in the incentives, resources, business structure and regulatory framework Potential pathways for application to Essential Energy

5.5 Selection

The best candidate to meet the objectives of the project was achieved through Essential Energy's normal procurement process under a Request for Quote. Proposals were ranked based on capability against project objectives, with the successful applicant agreed from the project steering committee.

5.6 Implementation

The approach taken to identifying suitable case study distribution businesses and collecting the information sought has comprised of the following steps:

- Internal file review, web search and literature review to develop a long list of case study candidates:
    - identify distribution businesses or regulatory authorities in other jurisdictions that are known to have taken a proactive approach to the identification and use of demand management and other non-network approaches.
    - networking with other organisations (e.g., the Regulatory Assistance Project in Vermont in the US, and VaasaETT, who cover the involvement of European utilities in these activities from their office in Finland) to identify other distribution businesses or regulatory authorities that are known to have taken a proactive approach to the identification and use of demand management and other non-network approaches.
    - From these activities, a long list of case study candidates was assembled.

- Selection of the short list:
    - In consultation with Essential Energy a short list was created of those distribution businesses who were deemed to offer a combination of innovative applications of DM/NNA, a strong process for DM/NNA planning and transferability to Essential Energy
    - The following businesses were prioritised for case study treatment:
        - Western Power
        - Ergon Energy
        - Orion Energy

        - Sacramento Municipal Utility District (SMUD)

- Literature review and email and telephone follow-up with business selected for case studies:
    - Literature searches and desktop review of the case study businesses' involvement in and processes for DM/NNA planning and integration.
    - Email and telephone follow-up contact was then undertaken with the case study businesses to assemble as much detail as possible on the specific topics of interest that were specified in Essential Energy's RFQ.
    - A tailored set of questions was developed for each of the case study distribution businesses. The questions were developed to probe beyond the information available through the literature searches and desktop in order meet the objectives of the project.

5.7 Benefits

The learnings from the assessment will allow Essential Energy to:

- identify ways to improve its resource and methodological approaches for identifying and analysing the potential benefits and costs of demand management and other non-network alternatives,
- deliver a greater range of choice to its customers and, through the exercise of those choices benefits to all customers and the network itself, and
- potentially, suggest approaches that the AER can use in improving its administration of existing regulatory incentive mechanisms or that the AEMC could consider for enhancing the contribution of demand management and non-network alternatives to the NEO.

6 Switched Reactors

Figure 18: Nyngan SWER Switched Reactor

6.1 Summary

The switched reactor project has been developed to reduce reactive power demands in single wire earth return (SWER) systems thereby reducing the network voltage swing, reducing loses, reducing the need for larger isolation transformers, deferring or removing the need for augmentation and lowering the cost of supply to customers.

6.2 Background information

Single wire earth return (SWER) feeders are a highly cost-effective method of distributing power over large areas with low load density, however due to their long line length the augmentation cost for SWER feeders can be prohibitively high for the load served.

One issue with SWER systems is their propensity for voltage rise due to charging currents, long line lengths and high impedance of the conductors and supplying source. In order to counteract charging currents shunt reactors are applied to the SWER feeder, thereby reducing line losses and minimizing isolation transformer sizes. Essential Energy has approximately 340 SWER lines and 250 reactors in service.

Reactors allow voltages to be reduced to acceptable levels and a reduction in line losses at low load periods; however, as the network demand increases voltages can be brought down below acceptable levels during high load periods, thus the need for augmentation arises as the voltage envelope is pushed further and further between voltage rise at low load periods and low voltage at high load periods.

6.3 Switched Reactors project overview

In 2012/13 Essential Energy signed a memorandum of understanding and began consultation with an external university based research group with strong industry ties to evaluate potential methods of deferring expenditure on SWER feeders.

Augmentation expenditure on SWER feeders is largely related to voltage swing as described in section 6.2 or thermal limitations through the isolation transformer. The technical analysis was completed by the university group which included equipment such as capacitor banks, switched reactors and statcoms and reviewed by Essential Energy, whilst the analysis of the costs and benefits was completed by Essential Energy. The outcome of this analysis was that switched reactors would provide the most cost-effective solution when taking into account the longer-term benefits of decreased losses and reduced upstream demands.

In 2013/2014 Essential Energy placed an order for 5x switched reactors to trial in a constrained location and began development of the product with the manufacturer, during this period a number of revisions were made. Since this time substantial work has been completed, including finalising the unit design, completion of factory acceptance testing, integration to Essential Energy's SCADA system, completion of site designs, and completion of installation and commissioning procedures at the switched reactor sites. Figure 19 presents the results of the 'Notch' test during the field commissioning phase, where '1' on the right vertical axis corresponds to the switch in the closed position (reactor in service) and '0' the open position (reactor out of service).

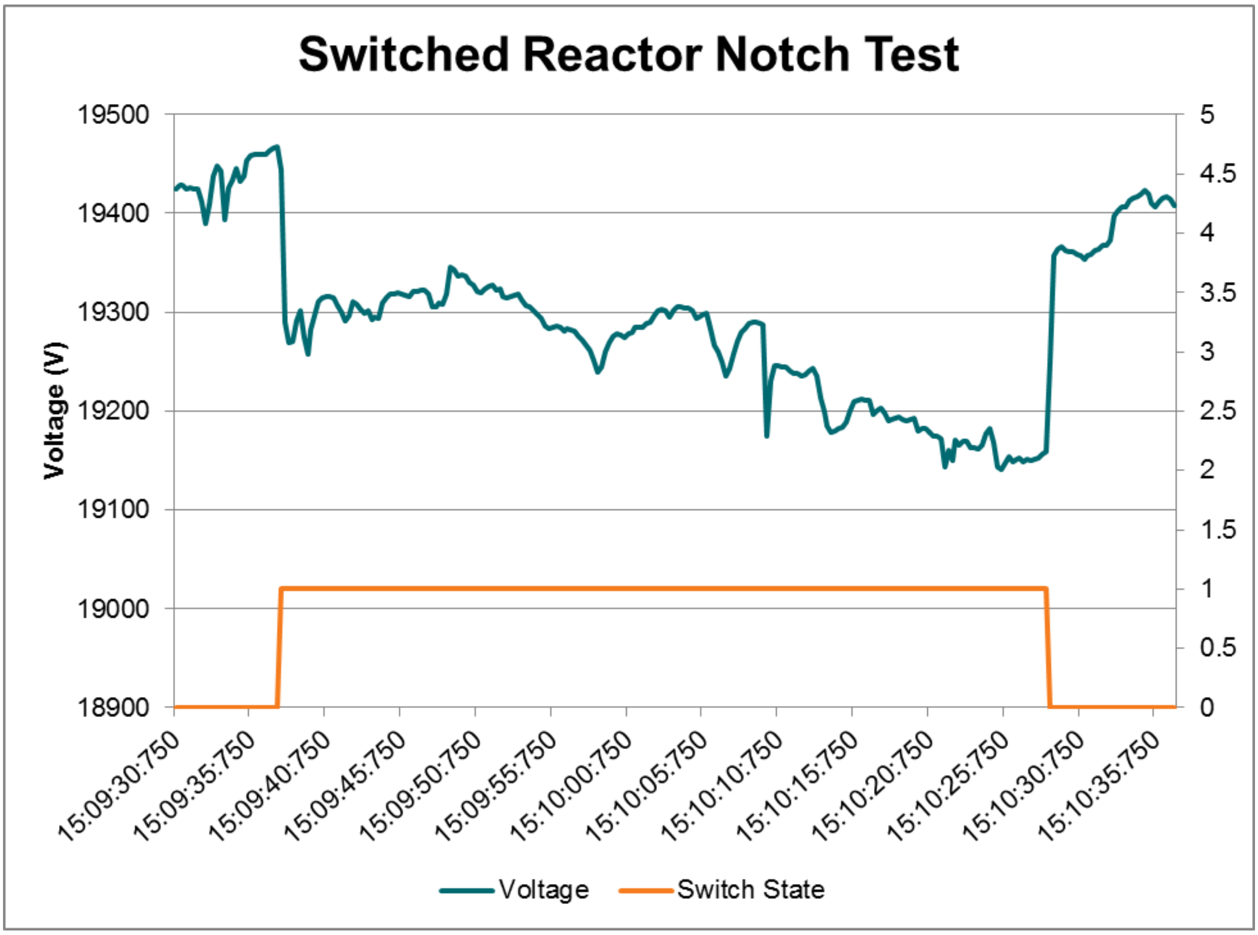

Figure 19: Switched Reactor Notch Test

Data collection and analysis commenced late 2014/15, identifying a normal operating voltage range for all the monitored locations on the feeder, an example daily profile is plotted in Figure 20. Switched reactor voltage thresholds, time delays and hysteresis settings were then chosen based on this analysis to minimise unnecessary switching operations, and were programmed to operate automatically beginning early 2015/16. The data collected since the reactors were activated has confirmed the voltage improvements expected from early simulations, with the furthest switched reactor providing the greatest benefit, reducing the network voltage along the entire feeder as shown in Figure 21.

The Switched Reactors are currently being sent back to the manufacturer for hardware upgrades to improve the devices resilience to lightning impulses. Once reinstalled, testing can commence on the voltage impacts of the reactors constantly switched on. Once testing is complete, should the anticipated benefits be reached at an efficient cost, then Essential Energy will go to market with a specification in 2017/18.

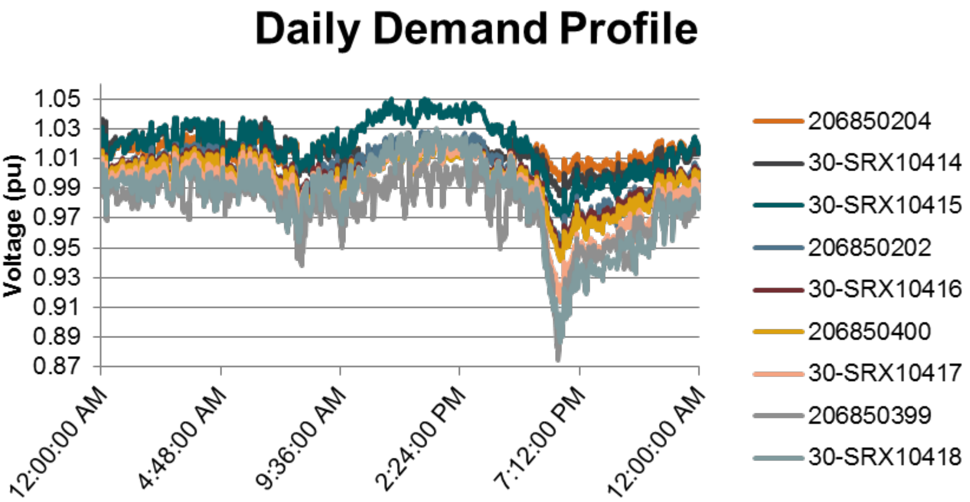

Figure 20 Nyngan network Voltage profile before Switched Reactors were placed in service

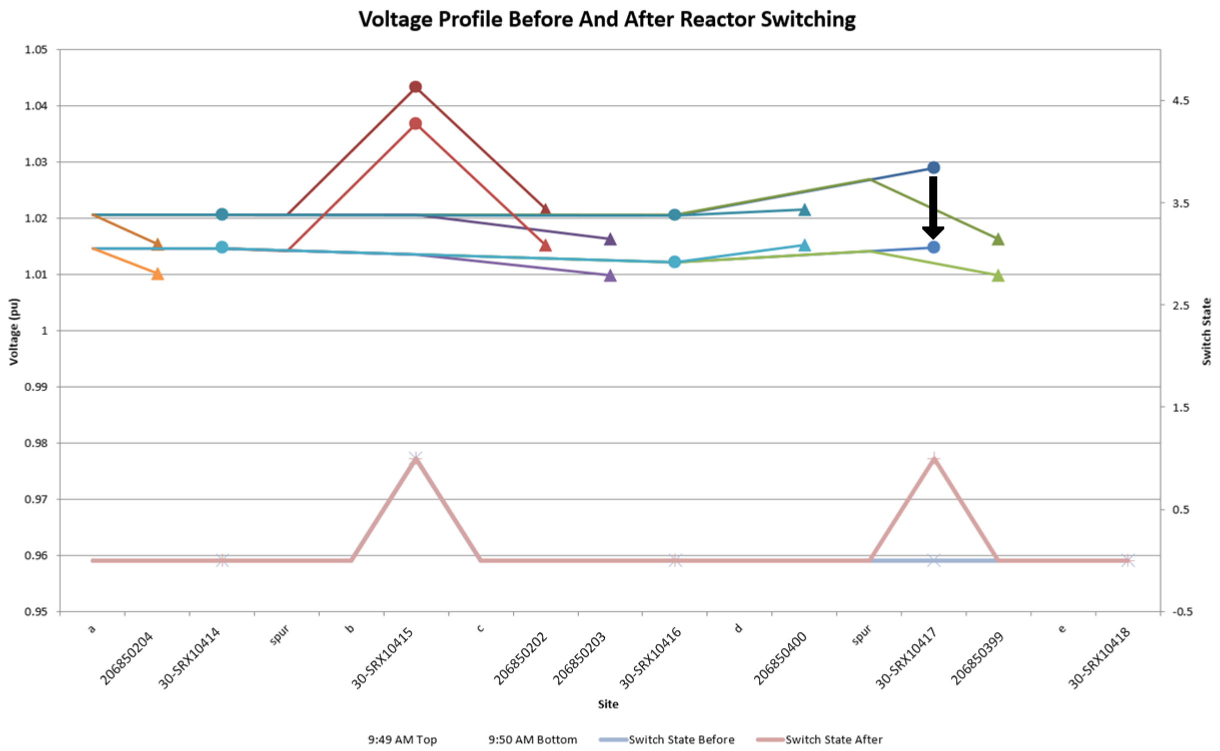

Figure 21 Nyngan network - 30-SRX10417 switch event

6.4 Nature and Scope

The switched reactor project is a non-tariff based project involving the combination of two existing, widely used pieces of equipment (reactors and switches) with the addition of specifically developed control algorithms and ancillary technology.

The scope of the project is limited to;

- Design, modelling and simulation of SWER networks to investigate the effect of new equipment proposals on the energy capacity and delivered power quality;
- Estimation of costs and benefits
- Conceptualize, design, simulate and investigate the proof of concept equipment.
- Purchase of the equipment to carry out field trials
- The physical installation
- Test and field trial verification of equipment
- Project analysis including suggested paths to business as usual programs if proven viable

6.5 Aims and Expectations

The switched reactor project aims to develop knowledge and confidence in the application of controlled switching to SWER line reactors, this knowledge developed will include the following areas;

- The physical installation
- The configuration of the controls
- The operational aspects
- The network impacts
- The estimated package costs

As well as provide confirmation on the cost effectiveness of reducing peak demand through the use of switched reactors.

6.6 Selection

Given the information sought (set out in section 6.5), specific to Essential Energy's network area the following options were considered;

1. Customer based power factor correction

Customer based power factor correction can be some of the cheapest demand reductions available, however customer based power factor correction is not particularly relevant to SWER feeders for a number of reasons including;

- Individual customers on SWER feeders generally have relatively low individual demands and therefore due to the applicable tariffs, minimal financial incentive to install power factor correction equipment or more generally control their network demands. Essential Energy does not currently believe that relatively low demand or energy usage customers have enough information to enable the use of appropriate demand based tariffs.
- Customer based power factor correction may help correct voltage issues at high loads, however it has little reference to power factor of the line when the power factor is caused by capacitive charging currents

Therefore, this was not the preferred solution.

2. Embedded Generation with/without energy storage

Uncontrolled embedded generation is unable to reliably provide the peak demand reduction / voltage control required. Controlled embedded generation in the form of a controlled generator or with energy storage can meet the requirements of the project, however the indicative costs are much higher than the preferred solution with little reduction in reactive power flows. Therefore, this was not the preferred solution.

3. Capacitor banks

Capacitor banks can be used to control voltage levels on SWER feeders if this is the primary concern, however due to the nature of SWER feeders and the capacitive charges present on such feeders they will also tend to increase currents and losses along the SWER feeder. Therefore, this was not the preferred solution.

4. Switched reactors

Reactors already exist on the Essential Energy network and have relatively few issues, their standard sizing allows for distributed locations, which in turn provides the greatest reduction in losses and demand, they are connected to the HV and therefore can be controlled directly from the HV voltage and or power factor. For these reasons switched reactors were the preferred solution.

6.7 Implementation

The switched reactor project can be defined as three distinct stages;

1. Simulation and Development

Refer to section 6.3

2. Implementation and Evaluation

Refer to section 6.3

3. General deployment phase

Refer to section 6.3

6.8 Benefits

With the field installation completed late 2014/15 and the devices set to automatically operate early 2015/16, a large amount of data has been gathered. With the revised hardware reinstalled on the network and some specific scenarios tested, there will be enough data available to evaluate the expected benefits. A number of anticipated benefits are highlighted below;

- Confidence in the use of innovative technology solutions such as switched reactors which may then be used to meet legislated power quality standards more efficiently than traditional network investment or as a means of deferring network investment.
- Understanding of the control structures available for switching of a tool kit of network elements and their relative costs, benefits and issues
- A tool for use in the economic deferral of network investment, through the reduction of demand and losses.
- Avoid network augmentation through reducing/limiting peak demand and improved power quality
- Increase end use efficiency and equipment life
- Decrease network losses
- Facilitating the integration of distributed generation into the grid
- Improve power factor
- Improving network visibility via remote monitoring and control

7 Conservation Voltage Reduction through the use of low voltage regulators

Figure 22 - Low Voltage Regulator

7.1 Summary

The project “Conservation Voltage Reduction through the use of low voltage regulators” has been developed in order to;

- Evaluate the technical requirements and performance characteristics of conservation voltage reduction (CVR) in the Essential Energy network
- Build Essential Energy’s technical knowledge for further development in the areas of power quality rectification, remote control, CVR and small-scale generation
- Evaluate the reliability, usability and functionality of three phase low voltage regulators

7.2 Background information

Conservation voltage reduction (CVR) is a lowering of voltage at the customer connection point in order to increase end use efficiency, lower peak demand, lower energy use and decrease losses without adversely power quality. CVR is currently implemented in some commercial premises for financial benefit under the name of “voltage optimisation”.

CVR is a relatively unused concept for most utilities due to a number of technical issues in its implementation. Instead CVR’s main proponents are those in the energy efficiency sector.

The CVR factor (CVRf) is the percentage change in energy for a given percentage change in voltage i.e.

$$\frac{\%\ \Delta\ \text{energy}}{\%\ \Delta\ \text{voltage}}$$

The CVRf can also be expressed in terms of kW, kVAr demand reduction as;

$$\frac{\%\ \Delta\ X}{\%\ \Delta\ \text{voltage}}$$

Where X is kW or kVAr, however unless explicitly stated CVRf refers to the change in energy.

Numerous studies have been completed on CVR with many stating the average CVRf for both demand and energy to be around 1.0 or slightly below. A CVRf of above zero is beneficial (ignoring fixed energy requirements) to a customer who is charged on kWh or on kW as any reduction in voltage, will decrease power. Figure 23 depicts an example of a CVRf test where a step change in voltage corresponds to a step change in power.

A CVRf of greater than one (i.e. where current decreases with voltage) or a negative CVRf (where voltage can be increased to decrease current) is required to be of direct benefit to a distributor whose lines and losses are related to current rather than energy or power. The addition of a voltage regulator provides a separation between the HV voltage levels and LV voltage levels and changes the interaction from the HV voltage to one of constant power.

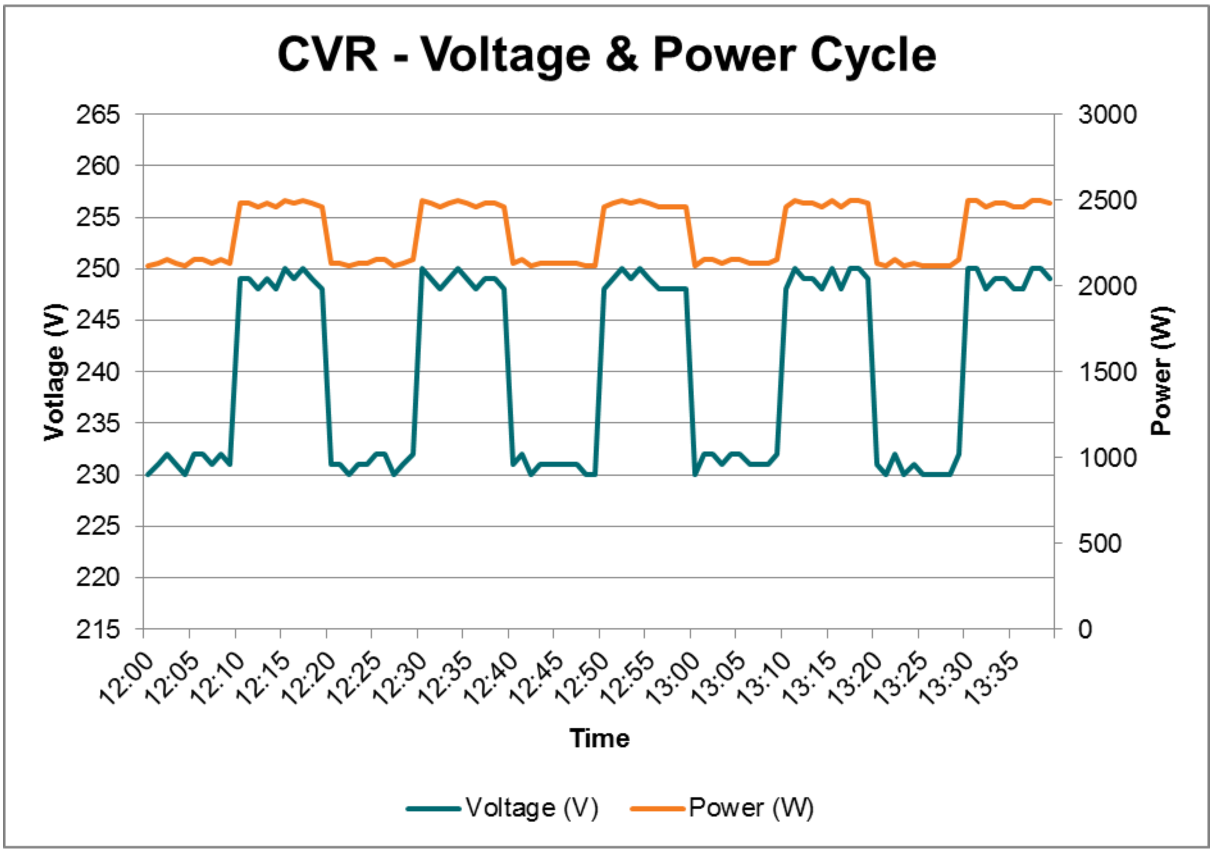

Figure 23 - Example CVRf test

7.3 Conservation Voltage Reduction through the use of low voltage regulators project overview;

The chosen device to investigate the CVRf theories outlined above is a three-phase low voltage regulator, the benefits of using such a device are;

> Connected at LV, therefore trials can be small and with minor impacts to Essential Energy's business as usual operations
> The three-phase regulator, once brought into the operational environment can be used in other sites for correction of voltage issues that would have required costly augmentation
> Allows the creation of a "constant power" LV network, thereby greatly improving the benefits of CVR over a HV controlled CVR implementation

Whilst the main aim of the project is a thorough understanding of CVR, CVRf and its implementation (innovation), the project has a secondary aim of evaluating the three-phase regulator for business as usual use (building of capability) and determining the value of CVR when the regulator is used as a secondary function.

With this in mind it is planned that the Conservation Voltage Reduction through the use of low voltage regulators project will consist of the following;

> One three phase low voltage regulator installed for testing of CVR in a residential area
> One three phase low voltage regulator installed for testing of CVR in a commercial area
> One three phase low voltage regulator installed for testing of CVR in an industrial area
> Five three phase low voltage regulators installed for evaluation as a business as usual tool for voltage support, with CVR as the secondary consideration.

5.1 Nature and Scope

The Conservation Voltage Reduction through the use of low voltage regulators project is a non-tariff based project with the following objectives;

> Evaluation of the technical requirements and performance characteristics of conservation voltage reduction (CVR) in the Essential Energy network
> Building Essential Energy's technical knowledge for further development in the areas of power quality improvement, remote control, CVR and small-scale generation
> Evaluation of the reliability, usability and functionality of three phase low voltage regulators

To complete the above objectives, the project will include the acceptance and functionality testing of a three-phase low voltage regulator (in both voltage support and CVR functions), to determine the business as usual cost effectiveness (i.e. the calculation of total installed cost and benefits) of the product and bring the documentation around the product up to the level required for business as usual use. Given these desired outcomes the low voltage regulator development and testing will be limited to the following;

> CVR functionality
> The physical installation
> The configuration
> The operational aspects
> The network impacts
> The total known package costs
> Internal standards for installation and maintenance
> Education on product use

While testing development is to be limited to the above items, issues, risks and learnings will be unlimited in nature.

5.2 Aims and Expectations

The aim of the program is to test CVR at low voltage, in order to allow a separation between HV and LV voltages. Longer term, if successful, the completion of this project will allow Essential Energy to provide the business case for CVR at low voltage, and through previous research completed compare this to the benefits of CVR at HV, develop programs for the conservation of energy where economically viable, and defer network augmentation through either the reduction of demand through the use of CVR or the implementation of low voltage regulators to support the voltage at times of peak demand, with energy conservation as the secondary benefit.

5.3 Selection

Conservation Voltage Reduction is considered to be an effective tool in the conservation of energy, however for the reduction of network loads (current) ideally a separation between LV and HV voltages would exist to ensure the benefits of CVR are available in the HV feeder.

Initial options considered;

1. Single phase low voltage regulators

   Single phase low voltage regulators are already used by Essential Energy to maintain voltages in constrained areas. Essential Energy has a firm appreciation of the costs involved in these installations, and due to the relatively high installed costs compared to the small loads passed through the device (typically one or two customers) it is not considered economical to install single phase low voltage regulators for the primary use of implementing CVR. Additionally, installation and data from the existing single phase low voltage regulator installations is atypical, as the short distance between the installed single-phase regulators and the customers has meant that taking into account the voltage drop and losses between the regulator and the customer has not been a major issue.

2. The use of LV reactive compensation

   The use of low voltage reactive compensation can provide voltage regulation, but with the regulation comes the possibility of increased losses as power factor strays away from unity. It could be possible to constrain the reactive compensation in such a way as to ensure losses are not increased and that voltage regulation for the purpose of CVR is maintained, however the complexities and development involved would be far beyond what Essential Energy could hope to achieve in the timeframe scheduled for this project. The use of LV reactive compensation for voltage regulation in order to achieve CVR is not the preferred option at this stage, however it has been highlighted for consideration as a future project, should CVR prove economically viable under this project.

3. High Voltage Regulation

   High voltage regulation with the use of HV regulators and zone substation load drop compensation is already implemented on many of Essential Energy's feeders and high voltage distribution capacitors are in the initial stages of being used in business as usual situations. CVR for use in conserving energy can be implemented on some of these feeders provided monitoring or analytics are used, however in theory the peak current reductions for CVR on the HV feeder are minimal compared to using CVR on the low voltage side, that said the cost should also be significantly less, it will be part of learnings of this project to determine whether, given the differences in benefits achieved at HV and LV where CVR is most cost effective to implement.

4. Distribution Transformer regulation

   HV transformers use on-load tap changers to regulate voltage at the zone substation or on the HV feeder. On-load tap changers require a degree of maintenance and monitoring to ensure adequate operation and lifetime. The costs involved with this work and the additional capital cost of on-load tap changers has largely precluded their use on distribution transformers, however recent developments claim maintenance free on-load tap changers for distribution networks offering a potential opportunity for future CVR implementation. Essential Energy currently has in service approximately 130,000 distribution transformers which would likely rule out any large-scale roll-out, nor would not be considered to be cost effective to remove and replace transformers for the trial period. However, as a transformer requires an upgrade or reaches the end of serviceable life, then it may be cost effective to replace it for the purposes of CVR, if this project proves successful the business case for regulating low voltage transformers will be evaluated.

5. Low Voltage 3ph regulators

Low voltage regulators provide the decoupling between LV and HV voltages required for the optimal demand reductions (current). It is estimated that low voltage three phase regulators will provide a greater benefit/cost ratio than a single-phase regulator due to the increased capacity for load being serviced and similar requirements for installation. Low voltage regulators will allow all objectives to be met with minimal intrusion into business as usual systems and therefore lower costs, low voltage regulators are also predicted to have business use outside of this project in deferring voltage constraint based augmentations. Therefore, this is the preferred solution.

5.4 Implementation

The project has been broken into three distinct stages;

1. Knowledge acquisition phase

The units were installed in a workshop environment to permit completion of type tests, creation of site designs, unit settings, and integration of remote monitoring and control equipment to Essential Energy's SCADA system. During this phase of the project substantial development of the product with the manufacturer was undertaken, with a number hardware and software design revisions made due to the multitude of issues experienced with the operation of the technology. This work was completed late 2014/15, with a number of units now installed in the field.

2. Field trial phase

Three units have been installed in field locations experiencing voltages at the higher end of the acceptable range, thereby allowing the greatest improvement and measurement of CVR potential. These installations are across three load types of commercial, residential and industrial. During 2014/15 the commercial site was installed and commissioned, shown in Figure 24, with the remaining two sites installed during 2015/16. During 2015/16, preliminary notch tests were performed at each site, however two of the three CVR sites have entered an error state with fault finding underway to resolve the issues to permit continuation of notch tests.

During 2014/15 four units were installed and commissioned in field locations suffering from voltages outside of the acceptable range as this best represents the business as usual use for low voltage regulators. However, mid 2015-16 a number of units failed with the fifth unit used as a replacement to continue the trial measurements.

Figure 24: 3 phase LV regulator connected to a commercial load

3. Business as usual readiness

At the completion of the field trail conclusions will be drawn on the effectiveness of CVR in the Essential Energy area, and of the three-phase regulator as a cost-effective means of performing the CVR function. If the business case proves viable further evaluation will be undertaken to ensure the most cost-effective implementation of CVR.

Finally, an evaluation on the three phase regulator installations will ensure any issues or risks raised during the project are addressed before claiming the specific device as business ready.

5.5 Benefits

Due to various issues with the units, only a small amount of testing has been completed to date. Notch tests have been completed for the commercial installation (Figure 25), allowing calculation of the CVRf of primarily air conditioning load, with the results in Table 3. Through more testing, it is expected that a number of benefits will be realised from this strategy, with a number of anticipated benefits highlighted below;

- Knowledge acquisition in the area of conservation voltage reduction
- Evaluation of the potential for conservation voltage reduction as a secondary benefit in business as usual operation
- Avoided network augmentation through reducing/limiting peak demand and improved power quality
- Increased end use efficiency and equipment life
- Decreased network losses
- Facilitating the integration of distributed generation into the grid
- 3 phase voltage balancing
- Improved power factor
- Improving network visibility via remote monitoring and control

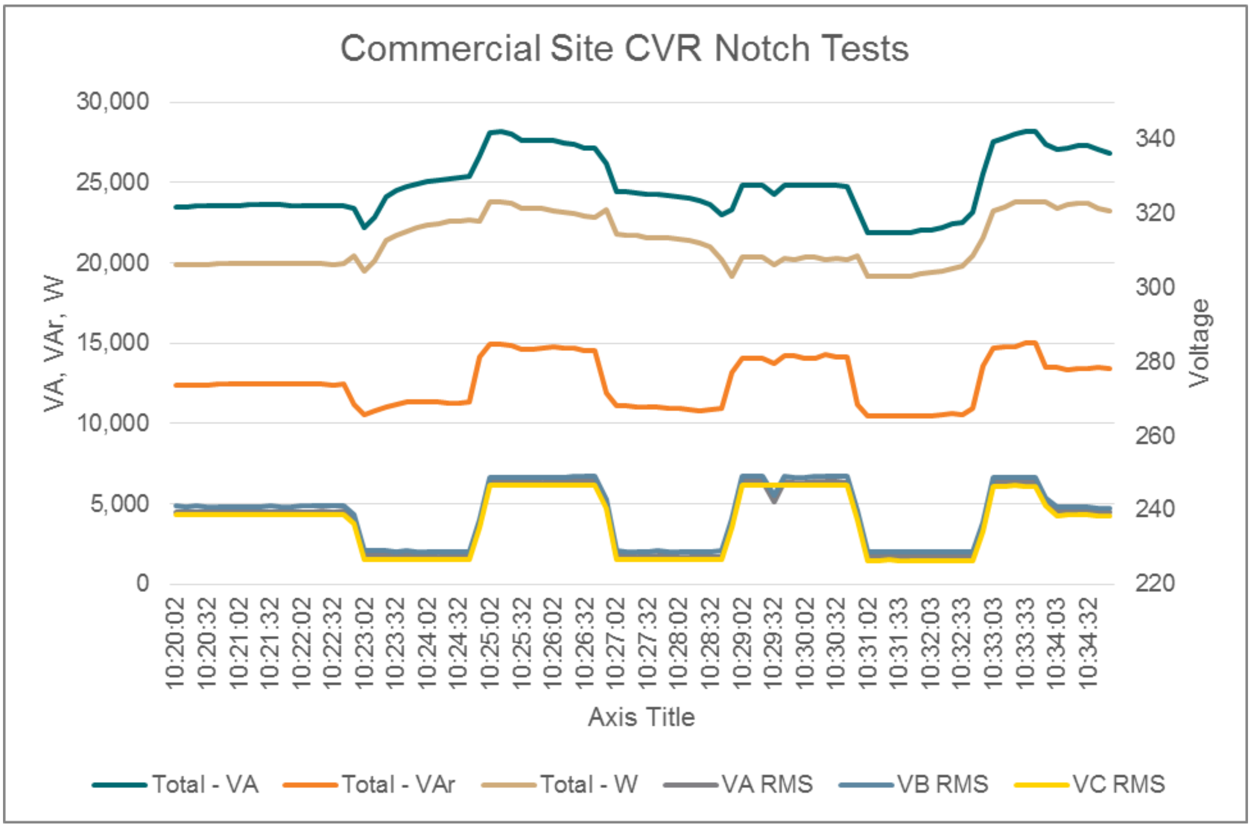

Figure 25 Notch testing to calculate CVRf of a commercial load

Table 3 CVRf results of the Commercial load notch test

Unit	CVRf
VA	1.21
W	0.57
VAr	3.33

8 Compliance Summary

As per section 3.1.3 of the Determination, projects under the DMIS must meet the following criteria;

1. Demand management projects or programs are measures undertaken by a DNSP to meet customer demand by shifting or reducing demand for standard control services through non–network alternatives, or the management of demand in some other way, rather than increasing supply through network augmentation.

2. Demand management projects or programs may be:
   a. broad–based demand management projects or programs—which aim to reduce demand for standard control services across a DNSP's network, rather than at a specific point on the network. These may be projects targeted at particular network users, such as residential or commercial customers, and may include energy efficiency programs; and/or reduce demand for standard control services across a DNSP's network, rather than at a specific point on the network.
   b. peak demand management projects or programs—which aim to address specific network constraints by reducing demand on the network at the location and time of the constraint.

3. Demand management projects or programs may be innovative, and designed to build demand management capability and capacity and explore potentially efficient demand management mechanisms, including but not limited to new or original concepts.

4. Recoverable projects and programs may be tariff or non–tariff based.

5. Costs recovered under this scheme:
   a. must not be recoverable under any other jurisdictional incentive scheme,
   b. must not be recoverable under any other state or Australian Government scheme, and
   c. must not be included in forecast capital or operating expenditure approved in the distribution determination for the next regulatory control period, or under any other incentive scheme in that determination.

6. 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 3.1.4.1 of the Determination requires that each ACT and NSW DNSPs must submit to the AER annual reports on their expenditure under the DMIA for each regulatory year.

The following table provides the details of Essential Energy's DMIA projects undertaken in the 2015/16 financial year as outlined above.

Table 4 - Details of Essential Energy's DMIA projects undertaken in the 2016/17 financial year

	The projects outlined meet the DMIA criteria under the following conditions;						
Name of Project	1. Meets demand needs other than through increasing network supply through augmentation ?	2a. Relevant to broad–based programs?	2b. Relevant to specific network constraints ?	3. Innovative? Designed to build demand management capability and capacity? Explores potentially efficient demand management mechanisms?	4. Is the project tariff or non–tariff based/	5. 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	6. Is the expenditure capex or opex in nature?
Networks Renewed	Yes	Yes	Yes	Yes	Non-tariff	Yes	Opex
Demand and Energy – Technology paper	Yes	Yes	Yes	Yes	Non-tariff	Yes	Opex
DM Best Practise Paper	Yes	Yes	Yes	Yes	Non-tariff	Yes	Opex
Switched Reactors	Yes	Possibly	Yes	Yes	Non-tariff	Yes	Opex/Capex
Conservation Voltage Reduction through low voltage regulators	Yes	Possibly	Yes	Yes	Non-tariff	Yes	Opex/Capex