Appendix 4.14: Distribution Substation Monitoring and Supply Voltage Optimisation Program PJR

Revised regulatory proposal for the ACT electricity distribution network 2019–24

November 2018

evoenergy

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Glossary

Term	Definition
ADMS	Advanced Distribution Management System
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
APQRC	Australian Power Quality and Reliability Centre
CAPEX	Capital Expenditure
DER	Distributed Energy Resource
DNSP	Distribution Network Service Provider
HV	High Voltage
IED	Intelligent Electronic Device
IoT	Internet of Things
kV	Kilovolt
LDC	Line Drop Compensation
LV	Low Voltage
MDI	Maximum Demand Indicator
NEL	National Electricity Law
NER	National Electricity Rules
NSP	Network Service Provider
NPC	Net Present Cost
NPV	Net Present Value
OLTC	On Load Tap Changer
OPEX	Operational Expenditure
PoW	Program of Work
PQCA	Power Quality Compliance Audit
PQM	Power Quality Monitoring
PV	Photovoltaic
RTU	Remote Terminal Unit
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SCADA	Supervisory Control and Data Acquisition
STPIS	Service Target Performance Incentive Scheme

All analysis has been undertaken using 2017-18 real dollars unless otherwise stated. Budgeted expenditure for CAPEX & OPEX excludes indirect costs.

Document Purpose

This document is a Project Justification Report. It identifies a project to meet needs and/or opportunities within the Evoenergy electrical network, and explores a number of options to carry out the project. Each option is analysed and assessed on the basis of regulatory requirements, risk exposure, financial viability, customer benefits and alignment with organisational strategies and objectives. A recommended option is presented and costed for consideration by Evoenergy management and internal stakeholders.

Audience

This document is intended for internal review by Evoenergy management and staff. As part of legislative, regulatory and statutory compliance requirements, the audience of this document is extended to relevant staff of the ACT Technical Regulator and the Australian Energy Regulator.

Executive Summary

This program proposes the installation of distribution substation monitoring devices and upgrades to zone substation voltage regulation systems to manage power quality and supply voltage compliance for customers connected to Evoenergy's low voltage network.

This program will address power quality issues, which have largely arisen from increasing penetration levels of embedded generation connections to the Evoenergy distribution network. It will support the provision of reliable power quality supplied to our customers and help support Evoenergy customers' future energy ambitions.

The Challenges and Opportunities

Evoenergy is driven by quality of supply regulation from AEMO through the NEL, NER, and the ACT Government through the ACT Utilities (Technical Regulations) Act 2014. The requirements of these regulations and codes is to ensure the quality of supply for customers connected to the distribution network, and manage potential impacts on the operation and life of network assets.

Traditionally distribution networks were designed to accommodate the flow of power in one direction, from substations to the customer. Embedded generation changes the network dynamic and results in export energy flowing back into the network from customers. The Evoenergy network currently has 15% penetration of embedded generation and we forecast an increase to 24% during the 2019-24 regulatory period.

With increasing penetration of embedded generation, network modelling has predicted that there will be significant reverse power flow through the LV network and through existing distribution transformers. Reverse power flow causes voltage to rise on LV and HV feeders, and voltages exceeding the $V_{99\%}$ high voltage limit at customer connection points for extended periods of time will be the norm if network remediation works are not carried out.

The most recent Power Quality Compliance Audit (PQCA) Industry Benchmarking report (October 2018) by the Australian Power Quality and Reliability Centre at University of Wollongong assessed Evoenergy's non-compliance performance for voltage as amongst the worst of all participants, with 35% of sites exceeding the voltage limit compared to the national average of 25%. We believe that Evoenergy performance is impacted by a high penetration of PV in some areas of the network and unique challenges of operating in the ACT, including:

1. Climatic challenges operating in a region with the coldest climate of any Australian city, with a resultant peak winter heating load and peak PV generation in warmer periods. The opportunities for consumer self-consumption are far less than any other jurisdiction and this results in a greater range of energy import/export and issues with network voltage drop/rise.
2. Jurisdictional challenges with a progressive territory government mandating 100% PV in new developments and incentivising uptake of PV by consumers.
3. Higher than national average household disposable incomes and motivated consumers installing PV generation and other disruptive technologies at a high rate.

Evoenergy forecasts that supply voltage and power quality issues will increasingly be experienced if left untreated. All customers including those without embedded generation will be affected and experience increasing flicker, sags, swells and voltage issues. This will result in a negative experience for Evoenergy customers as they cannot utilise equipment to their full potential or maximise return on their investment in distributed generation, and it may cause potential damage to their equipment.

The preferred option proposed in this project justification report is to install real-time low voltage (LV) distribution substation monitoring to permit proactive energy and voltage management as an alternative to network reinforcement and additional asset replacement expenditure. The proposed network monitoring solution will offer customers an overall lower cost, and in particular ensure that low-income earners and those without PV generation systems are protected from cost increases.

The do-nothing option will incur additional CAPEX asset replacement costs and power quality investigation OPEX costs, which the proposed solution avoids. The objective of the proposed solution is to maintain (not to increase) the reliability and quality of supply performance with the forecast increase in penetration of embedded generation.

Solution Overview

The proposed distribution substation monitoring solution will provide real-time quality of supply monitoring from areas of the network most affected by disruptive technologies, and enable load flow and voltage profiling functionality within the Advanced Distribution Management System (ADMS). With this visibility in ADMS, network performance at the low voltage level can be managed proactively and more economically, with voltage compliance assured across the network for all Evoenergy customers.

The supply voltage optimisation component of the program will upgrade zone substation voltage regulation systems to accept remote voltage set point control from the ADMS. The overall solution will implement a feedback loop from distribution substation monitoring to zone substation voltage regulation and other points of control to dynamically adjust network voltage in real-time.

The program will address emerging network constraints and voltage issues arising from customers' energy generation, storage, and emerging technology use. The program will remediate problems at the lowest cost, avoid unnecessary augmentation and asset replacements in brownfield areas, and deliver better network planning and investment outcomes in new developments.

The avoidance of additional network investment will minimise costs for Evoenergy customers. Overall, the Evoenergy EN 2019-24 regulatory submission, which includes the distribution substation monitoring, will not increase customer costs on the average bill.

The program will ensure the minimum cost to serve customers connecting generation, storage, and electric vehicle chargers. The enablement of automated planning in ADMS will render individual network connection studies as part of the customer connection process unnecessary, thereby keeping customer connection charges as low as practically possible.

It will also permit customers to maximise their return on investment through continual availability and operation of their embedded generation, as Evoenergy will have the capability to proactively manage power quality issues.

In summary, the proposed Evoenergy distribution substation monitoring and supply voltage optimisation program expenditure is justified for the following reasons:

1. The current level of solar PV penetration on Evoenergy's network is already causing power quality issues and there has been an increasing number of customer complaints. Customer complaints include loss of generation when PV inverters cut out due to overvoltage, and also damage to customer appliances.
2. The cost of investigating customer complaints has increased from $68,422 in 2014/15 to $368,879 in 2017/18. Distribution substation monitoring aims to proactively address increasing customer complaints and control investigation costs.
3. Forecasts show that the number of customer energy systems on the Evoenergy network will rise from the current 15% to 24% penetration over the 2019-24 period. This will result in a substantial increase in power quality and voltage issues if left unaddressed; customers who cannot afford to install a PV system will be negatively affected by those who can.
4. A number of Evoenergy distribution substations are fixed tap or do not have the tapping adjustment required to maintain LV voltage compliance. Without the program, the distribution substations that are unable to maintain compliant voltage will need to be replaced at a cost of $5.4M during the 2019-24 period. The program avoids these replacement costs though real-time voltage optimisation.
5. The installation of distribution substation monitoring is targeted at areas expected to be impacted by quality of supply issues on the basis of observed measurements and modelling.

6. The installation of distribution substation monitoring offers significant benefits to customers who wish to install distributed energy resources by avoiding the need to perform network studies for individual customer connection applications, and containing connection charges that would otherwise be passed on to customers.

We have assessed a number of alternate options including the base case of do nothing; use of smart meters and 3rd party data; and extending the Evoenergy SCADA network. Distribution substation monitoring with supply voltage optimisation is shown to be the least cost option, with superior benefits and best NPV compared to other options.

Our analysis shows the do nothing approach will incur and additional **$6,151,991** in capex for distribution transformer replacements and low voltage feeder upgrades if this project does not proceed. These costs have not been included elsewhere in the Evoenergy 2019-24 Regulatory Proposal as the assumption is this business case will be approved.

The total cost of the preferred option to install distribution substation monitoring is **$6,212,500** over the 2019-24 period. This option shows a positive NPV of **$9,350,835** over the ‘do nothing’ counterfactual in the next ten years, and will have long lasting benefits for Evoenergy customers well into the future.

1 Introduction

This report outlines Evoenergy's proposed distribution substation monitoring project. This is a revised report, and additional information has now been included to address a number of comments raised by the AER in the draft 2019-24 regulatory determination.

A summary of the comments by the AER in the draft 2019-24 regulatory determination is given below:

> *Evoenergy has not justified that its proposed capex for chamber substation SCADA and distribution substation monitoring (reliability capex) is reasonably likely to reflect prudent and efficient costs. This is on the basis that Evoenergy has not demonstrated how the forecast benefits were incorporated into its overall proposal. …*
>
> *We note that Evoenergy has incentives to undertake these programs under the EBSS, CESS and STPIS due to the reduced expenditures it expects to incur elsewhere. These programs would provide Evoenergy with enhanced network capability to manage the operation and planning of the network in addition to ensuring compliance with regulations. We consider that, in the absence of evidence that Evoenergy has factored these programs into the proposal; Evoenergy could appropriately fund these programs through the respective incentive schemes.*
>
> *We are open to considering further information from Evoenergy, as part of its revised regulatory proposal, to demonstrate how it has identified the benefits of this expenditure and how it has accounted for these in its overall regulatory proposal, in particular by providing:*
>
> > *• analysis showing the counterfactual – Evoenergy's proposal on opex, augex, repex, etc. in the absence of the monitoring programs.*
> >
> > *• evidence supporting the counterfactual. For example, evidence that replacement costs would have remained around historical levels in the absence of the monitoring programs.*
>
> *In support of the projects, Evoenergy provided evidence that the presence of distributed generation (solar PV) has led to an increase in substantiated complaints from customers about high voltages.86 Notably, Evoenergy shows that, between 2012-13 and 2016-17, the number of substantiated high voltage complaints was 20–40 per year; however, this had increased to 238 complaints in 2017-18 year-to-date.*
>
> *With regard to the increase in power quality complaints, Evoenergy has suggested this is in part due to changes in customer behaviours and improved reporting processes. Nevertheless, we accept that Evoenergy will be required to incur costs to manage voltage issues, and that these costs will increase in the future. However, we do not consider the information before us provides an accurate representation of the voltage risks that Evoenergy is currently managing on its network. We invite Evoenergy to provide information on historical expenditure that demonstrates expenditure it has incurred in managing power quality risks.*
>
> *Source: AER - Evoenergy 2019-24 - Draft decision - Attachment 5 - Capital expenditure - September 2018_0*

This revised Project Justification Report for the Distribution Substation Monitoring and Supply Voltage Optimisation Program seeks to answer these comments as follows:

1. The primary benefits of the program comes from avoided asset replacement costs and avoided power quality complaint investigation costs. In the *do nothing option* these costs will otherwise increase from current levels. The base assumption in the Evoenergy regulatory submission is the distribution substation monitoring program will be approved, and no allowance for the additional asset replacement costs or increase in investigation costs is included elsewhere in the proposal.

   The *Do Nothing option* presented here includes the resultant increase in OPEX, AUGEX, and REPEX that would otherwise apply in the absence of the monitoring programs. These costs are not included in Evoenergy's CAPEX and OPEX proposal for the 2019-24 period. This program maintains the cost base and current reliability, therefore funding from the EBSS, CESS and STPIS incentive programs would not apply. Conversely, STPIS penalties may apply if the program does not proceed and reliability is adversely affected.

2. This report provides a detailed discussion of the supporting factors and modelling related to the increasing penetration of PV and the resulting voltage and other power quality issues and risks.

   The options analysis and NPV calculations are based on historical expenditure for managing power quality risks including historical Polylogging[1] power quality investigations and historical asset replacement costs.

The AER draft determination stated that Evoenergy had not justified that its proposed CAPEX for distribution substation monitoring reflects prudent and efficient costs. Our revised proposal outlines the avoided costs benefits of the program as well as customer benefits. Anticipated avoided costs will be explained in the context of industry change and increasing Distributed Energy Resources (DER) in the ACT.

1.1 Consumer Engagement

Evoenergy conducted a consumer workshop on 7 November 2018 looking into power quality, reliability and the case for distribution substation monitoring. Evoenergy wanted to understand how consumers considered the importance and value of our approach to distribution substation monitoring as a means to delivering better power quality and reliability to consumers. Workshop participants included Energy Consumer Reference Council (ECRC) members and Evoenergy major customers. ACT Utilities Technical Regulator representatives also observed.

The following topics were discussed by participants during the workshop.

Challenges within the ACT electricity network

- That the ACT's unique climate contributed to challenges faced by Evoenergy in managing penetration of distributed generation.
- Participants noted that this proposal would be especially useful in existing suburbs and that newer estates in the ACT would benefit from Evoenergy's tailored approach to new infrastructure.
- Despite improvements in energy efficient appliances and equipment, consumer energy consumption continues to grow and pose challenges for distribution networks.
- Large customer representatives noted they had experienced increased voltage and power quality issues over the past 12 months. Also that they are increasingly impacted by power quality issues beyond the ACT within the national energy market e.g. frequency issues.
- There was some interest in whether policy settings (governments or regulatory) could address challenges associated with distributed generation. It was recognised that this was not a short-term solution.

[1] Polylogging is a method of carrying out power quality and loading measurements using a portable measurement instrument known as a "polylogger".

Forecast costs associated with Evoenergy’s proposal to install distribution substation monitoring

- That it *(Distribution Substation Monitoring and Supply Voltage Optimisation)* presented an affordable option for consumers, including older Canberrans, or those on lower income.
- It compared favourably with investment in smart meters to achieve the same power quality outcomes, although it was noted that smart meters do offer different, additional benefits beyond power quality.
- That ACT residential consumers’ appreciation of electricity reliability would justify the investment in distribution substation monitoring.
- Evoenergy has identified an effective, lower cost response to balance increased renewables penetration and the challenges this poses to network operators.

Considering perceived consumer benefits of distribution substation monitoring

- Distribution substation monitoring should provide ACT consumers with greater efficiency in network monitoring and improved response to any problems detected in the network.
- Benefits include supporting ACT consumers’ ability to invest in distributed generation (including solar PV).
- With a growing ACT energy load base, this approach will provide Evoenergy systems a point of control across a range of measures in real time.
- Large customers can do a lot to manage power quality at their premises; other consumer segments would also benefit from improved power quality monitoring.
- Consumers recognised that this proposal could also help avoid unplanned outages and the length of unplanned outages experienced by consumers.

Feedback gathered during the workshop has been incorporated into this project justification report and Evoenergy’s final regulatory proposal. It also inform Evoenergy’s approach more generally to managing power quality in the ACT electricity network.

2 Background

Evoenergy's proposal for the distribution substation monitoring program is based on the significant challenges in managing the low voltage network due to high growth in residential rooftop solar PV in the ACT.

The presence of solar PV has already been shown to have direct impacts on electricity networks, such as excessive voltage rise, thermal overload of low voltage feeders, harmonic excursion and load balancing on distribution feeders. Figure 1 shows the relationship between the growth in distributed generator installations and corresponding rise in power quality complaints. Since 2007, solar PV systems have started being connected to the Evoenergy LV network, and the number of power quality complaints has steadily risen.

In the 2017/18 financial year, Evoenergy saw a large rise in complaints that we believe is partly due to improved reporting processes and a change in customer behaviours, but the underlying issue is the network is exceeding technical limits by the rapid uptake of PV. The rise in customer power quality complaints is reflected in increasing power quality investigation costs over the period, and Figure 8 in Section 5.5.1 shows this has increased from $68,422 in 2014/15 to $368,879 in 2017/18. Figure 1 below also shows Evoenergy's forecast solar PV and Battery Energy Storage Systems uptake over the 2019-24 regulatory period. Over the last five years the number of PV installations has been rapidly increasing by an average of 2,000 per year, which amounts to between 15-20% year-on-year increases in the install base.

The total installations now averages 15% penetration across the network and is expected to rise to 24% average penetration over the 2019-24 period. The actual distribution of installations is however far from even, with some suburbs and streets approaching 100% and other areas nil.

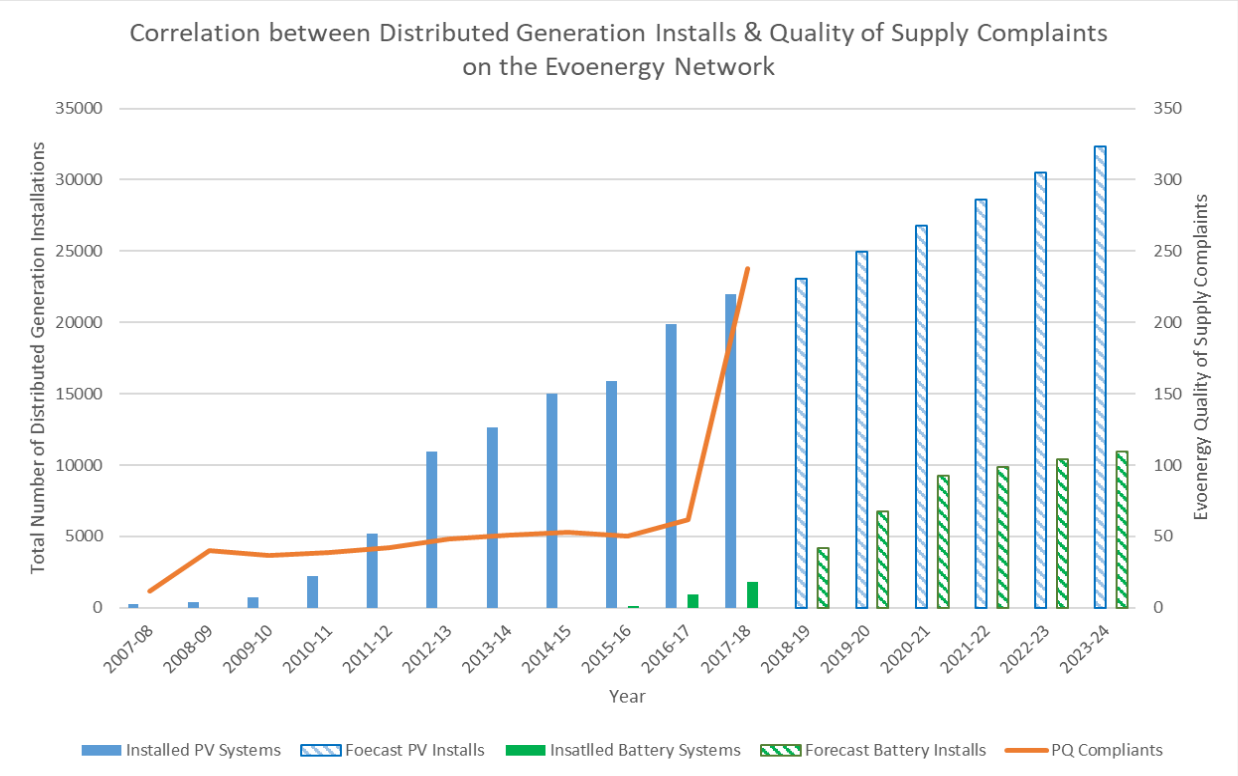

Figure 1 – Relationship between Distributed Generation Connection and Power Quality Complaints

The ACT residential rooftop solar PV market is one of the fastest growing in Australia. The extent of this is compounded by several new residential developments mandating 100% solar PV installations, with a minimum size of 3kW per dwelling required to be installed.

Within the ACT we are now seeing new developments, such as Denman Prospect and Ginninderry estates, mandating solar PV generation on all new homes. The ACT Government and Land Developers have entered into agreements to provide new dwellings with a minimum solar PV system size of 3kW. The effects of these developments on the Evoenergy network will see significant reverse power flows from the LV to the 11kV HV networks, affecting customer power quality.

The presence of residential rooftop solar PV connecting to the Evoenergy low voltage network has been shown to directly impact electricity networks via excessive voltage rise, thermal overload of low voltage feeders, harmonic excursion and load balancing challenges on distribution feeders.

Evoenergy is aware that other Australian electricity utilities have implemented low voltage monitoring programs to gain intelligence of the effects of distributed generation connecting to networks. Energex have implemented an extensive substation monitoring program by deploying power quality devices at the distribution transformer level,[2] while the Victorian government mandated the rollout of smart meters at the customer premise.[3] These programs have substantially increased the capability of distributors to monitor voltage delivered to customers.

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[2] Energex Revised Regulatory Proposal, 2015 https://www.aer.gov.au/system/files/Energex%20-%20Revised%20regulatory%20proposal%20FINAL%20-%20July%202015.pdf

[3] Victorian State Government, 2016, https://www.energy.vic.gov.au/electricity/smart-meters

3 Relevant Factors and Modelling

3.1 ACT Household Energy Consumption

ACT households are among the biggest users of energy on a per capita basis in Australia, consuming on average around 25GJ of energy per person annually, compared to an average of 13GJ per annum in NSW. Even with the ACT having some of the lowest prices, having high energy consumption per capita means the ACT has the highest total household energy expenditure of any State/Territory, as shown in Figure 2.

The high household energy expenditure is influenced by the cold climate, with around 58% of energy use associated with heating and cooling, 21% consumed by general appliances (e.g. refrigerators, TVs, lights), 18% being used for water heating, and 3% for cooking[4].

The ACT has some of the lowest electricity and gas prices in Australia, but our cold winters mean customers use a lot of energy for heating. Traditionally gas has been used for heating, however with increasing energy prices and the efficiency of reverse cycle air conditioning, electricity is now the default choice for homeowners. Recognising the reduced need for gas, some new residential Greenfield developments have proposed electricity supply only.

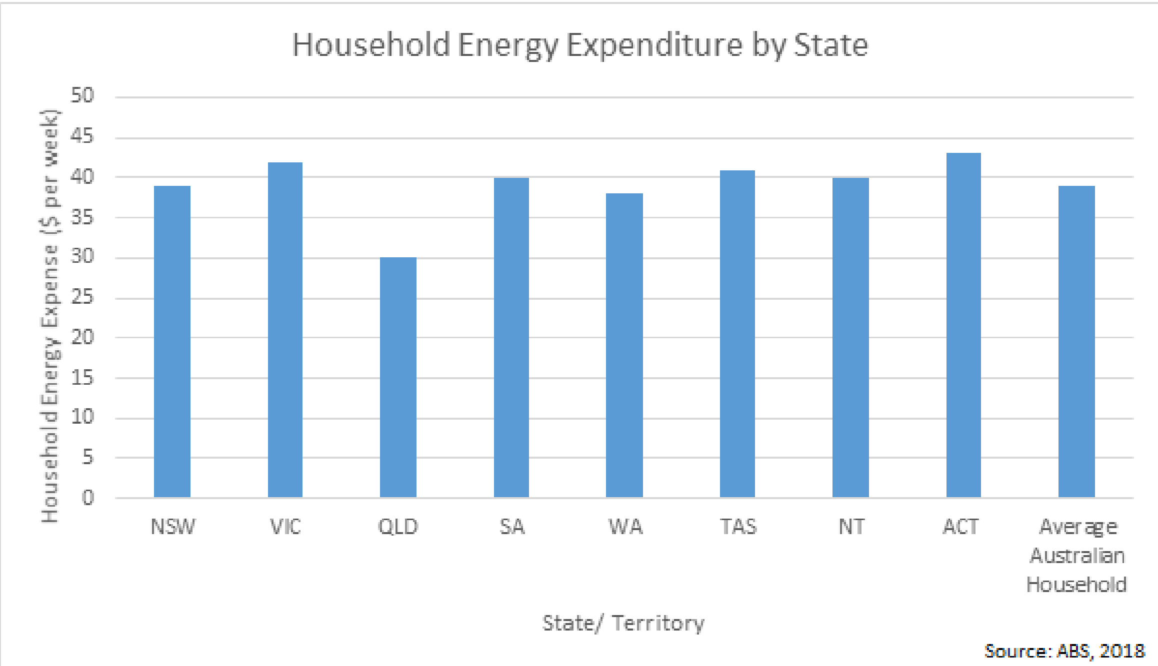

Figure 2 – Household Energy Expenditure by State/Territory

The peak household energy demand in winter is shown in Figure 3, showing seasonal daily energy usage. This data was derived from a sample of 200 dwellings in the suburb of Casey where interval metering data is available.

Casey is a relatively new suburb that has been developed in the last decade (from 2008) and has modern energy efficient homes that provides a good representation for future network load forecasting. The graph shows the average daily minimum and maximum electricity flow at the point of connection for all homes in the sample, for homes with and without PV generation.

[4] DEWHA, *Household Energy Use*, 2008

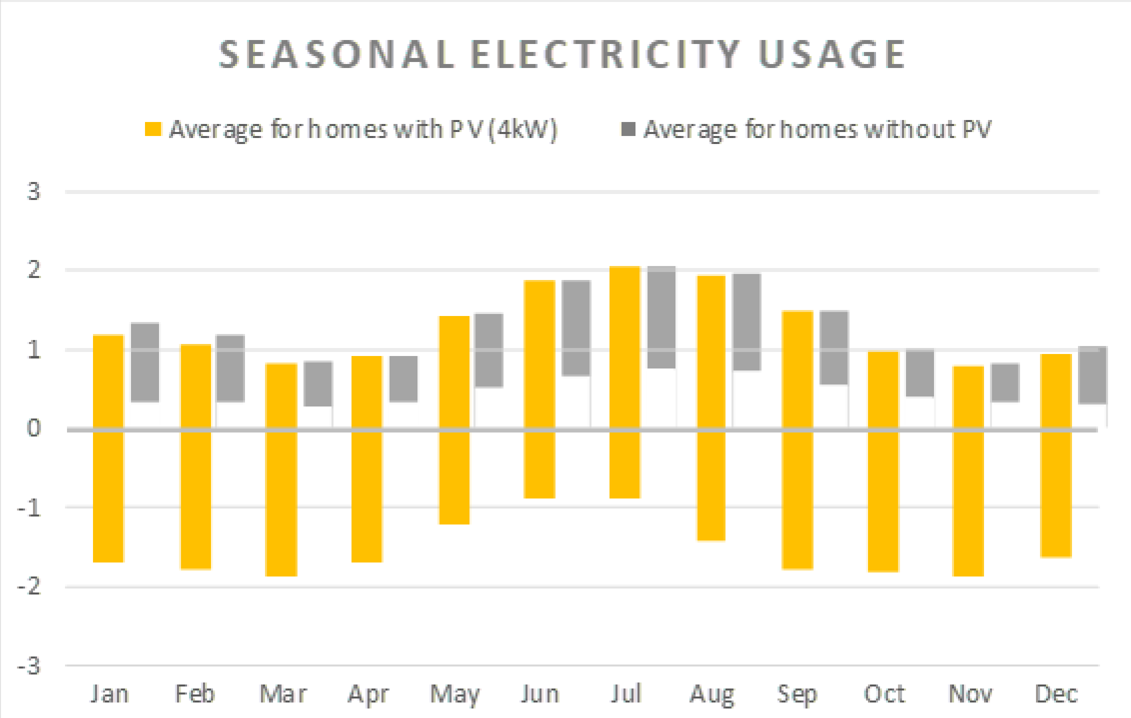

Figure 3 – ACT Household Seasonal Electricity Usage – Evoenergy Casey case study

Figure 3 shows that the peak household consumption is during the winter months (an average peak of 2kW), which is almost double the summer peak. For dwellings with PV generation, reverse power flow into the Evoenergy network peaks in autumn and spring at an average of -1.9kW per household, which is double the winter average of -0.9kW. The summer peak reverse power flow is -1.7kW, which reflects some internal self-consumption from cooling loads.

With peak winter heating loads during the colder months and peak generation in shoulder and warmer periods, the opportunities for self-consumption of generation by consumers is greatly reduced compared to other jurisdictions. Other areas, such as South-East Queensland and South Australia, which have high penetration rates of residential rooftop solar PV, have a much warmer climate with peak cooling load corresponding with peak generation resulting in greater self-consumption and less net export to the grid.

The challenges of the ACT climate and the winter peak load, combined with a high penetration of solar PV generation in parts of the network, means the Evoenergy network is subject to more extreme minimum and maximum power flows on a daily basis, and more extreme seasonal variation throughout the year.

3.2 Modelling High Penetration of PV in Canberra Suburbs

In the ACT, the residential rooftop solar PV uptake continues to grow and is now a mandated requirement in some new residential developments. Of note, Denman Prospect and Ginninderry Estate have mandated solar PV systems, with a minimum size of 3kW, installed on all new detached dwellings.

Denman Prospect will see approximately 4,500 new residential dwellings, while the Ginninderry Estate will see 11,500 new dwellings constructed, all with PV.

Evoenergy has completed modelling on the first stage of Ginninderry distribution substations for two contrasting scenarios:

- Minimum load with maximum solar generation at 12:30 pm in summer, and

- Maximum load with minimum solar generation at 7:00 pm in winter.

The results show voltages exceeding the 253V upper limit will be present on nine (9) LV feeders during the summer peak generation and voltages exceeding the 216V lower limit on two (2) LV feeders during the winter peak load. Other LV feeders are close to limits and likely to cause customer issues when voltage drop within the premises is accounted for. The results of this study are shown in Table 1.

Distribution Substation	LV Feeder	Voltage at the Customer Connection Point			
		Summer Min Load, Max Generation		Winter Max Load, Min Generation	
		LV Feeder Head	LV Feeder End	LV Feeder Head	LV Feeder End
S 11298	10GJ	244.8	252.3	230.4	225.2
	10FJ	246.0	254.0	229.2	222.9
	10EJ	248.3	255.2	222.9	218.8
	10DJ	248.8	257.5	226.9	215.9
S 11299	10HJ	244.2	255.8	228.6	218.2
	10GJ	248.8	255.8	218.8	215.9
	10FJ	250.0	255.2	224.6	218.2
	10EJ	250.6	255.8	221.7	217.7
	10DJ	245.4	255.2	228.1	220.0
S 11300	10HJ	245.4	252.3	228.1	221.1
	10GJ	244.8	251.1	229.2	225.7
	10FJ	245.4	248.3	227.5	223.4
	10EJ	245.4	255.2	228.6	220.0
	10DJ	245.4	252.9	227.5	220.0

Table 1 – Modelled LV Feeder Line Voltages – Ginninderry Distribution Substations

The future effect of mandated solar PV will see the supplying distribution substations in these developments likely subjected to solar PV penetration reverse power flow in excess of 75 per cent of the transformer nameplate ratings. The significant reverse power flows during off-peak periods in summer results in LV network overvoltage at the customer connection point.

When reverse power flows occur on LV feeders, the voltage level at the customer connection point will be higher than the voltage level at the transformer, as shown in the light load with PV scenario in Figure 4. This may result in customer equipment not operating correctly, and PV inverters and other equipment switching off as a protective function.

To lessen the impacts from voltage and power quality issues at new estates, Evoenergy has proposed a program to install larger distribution substations; however, developers have questioned the additional costs in servicing the estates.

The problem of connection point voltage rise has also been observed in the field where loading levels are low, and particularly where large rated solar PV installations are connected to weak networks. In these cases, significant investment in solar PV systems is not being recouped due to the fact that the inverters are often switching off due to operation of overvoltage protection. Evoenergy has a high proportion (76%) of weak customer connection points, particularly in older established areas. Weak sites are remote from the distribution transformer with lower capacity LV mains, have higher network impedance, voltage drop and voltage rise. Evoenergy will need to upgrade some of these LV feeders or otherwise implement the solution proposed in this report to enable the voltage to flex up and down to increase hosting capacity.

The alternate solution proposed in this report is to provide distribution substation monitoring with feedback and real-time control to zone substation voltage regulation. This can be used to dynamically reduce network voltage during daytime peak generation and boost voltage during evening peak load.

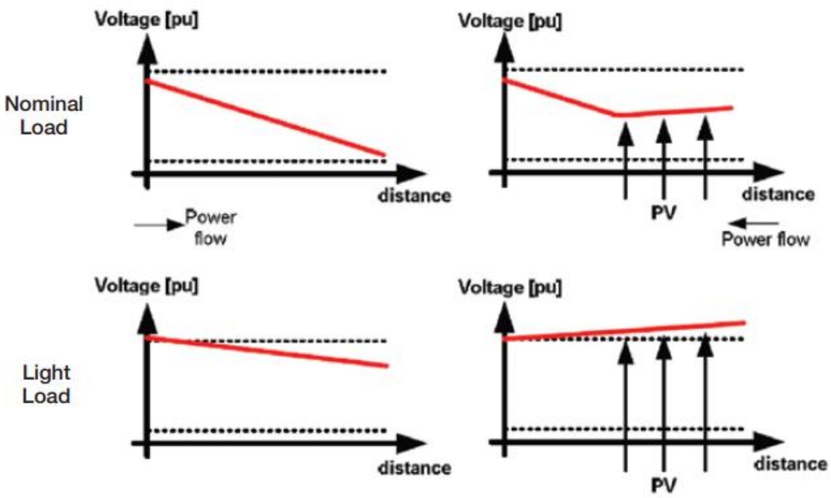

Figure 4 – Illustration of Voltage Rise on LV feeders due to PV Generation

3.3 Equipment Damage and Insurance Claims

An additional benefit of the distribution substation and supply voltage optimisation program is that it will assist to avoid customer equipment damage and subsequent related insurance claims. Between 2012 and September 2018, Evoenergy has paid out 103 equipment damage and insurance claims, totalling **$165,509,** attributed to power quality issues.

In general, the customer complaint that results in the highest cost to Evoenergy on the low voltage network relates to LV overvoltage at the customer connection point. In general, voltages above 260 Volts are likely to result in equipment damage with compensation claims in the thousands.

3.4 Distributed Generation Connection Restrictions

Due to voltage compliance and power quality issues, a number of other DNSPs have started to reject connection applications to limit the number of solar PV systems connecting to parts of their networks.

Evoenergy and most other DNSPs have implemented the new AS/NZS 4777 standards, limiting solar PV systems to 5kW of export. In Queensland Energex has begun declining new residential rooftop solar PV applications in some locations, and has spent considerable time and money developing a system where customers and installers are required to check that a solar PV system can be installed without jeopardising the operation of the network.

In Western Australia, Horizon Power has set hosting capacity limits on how much renewable energy can be installed in a system without affecting the power supply. Horizon is rejecting applications for new renewable installations in areas such as Exmouth and Carnarvon[5].

Evoenergy has implemented a limit of 5kW export for single phase systems[6] however we have not, nor do we wish to, enact any solar PV installation curtailment program. The ACT Government

[5] The Australian, *Rooftop solar panels overloading electricity grid,* 2011

[6] Evoenergy: *Requirements for Connection of Embedded Generators to the Evoenergy Network*

currently has several renewable energy incentive programs and has a target of the ACT being supplied by 100% renewable generation sources by 2020. The ACT Government would likely treat any curtailment as a breach under the ACT Utilities (Technical Regulation) Act. Limiting distributed generation connections to the Evoenergy network would impact customers who are unable to connect PV systems. This means a poor customer experience for customers wishing to invest in technology that could otherwise assist them in lowering household energy costs.

Implementing the distribution substation monitoring and voltage optimisation program will provide intelligence to the Advanced Distribution Management System (ADMS), permitting upstream high voltage network control in a real-time response to feedback from distribution substation monitoring, which aims to avoid any residential solar PV restrictions in the future.

4 Solar PV Forecast

The Evoenergy network currently has a high penetration of embedded generation in parts of the network and this is expected to increase significantly over the next five years and beyond.

Evoenergy has prepared a solar PV and Battery Energy Storage System forecast considering the ACT Government's commitment to its target of the ACT electricity supply completely from renewable sources by 2020. In addition, rooftop solar PV penetration is forecast to grow significantly over the next decade, where Evoenergy analysis expects a minimum of 1,800 to a maximum of 5,000 sites per annum, as shown in Figure 5.

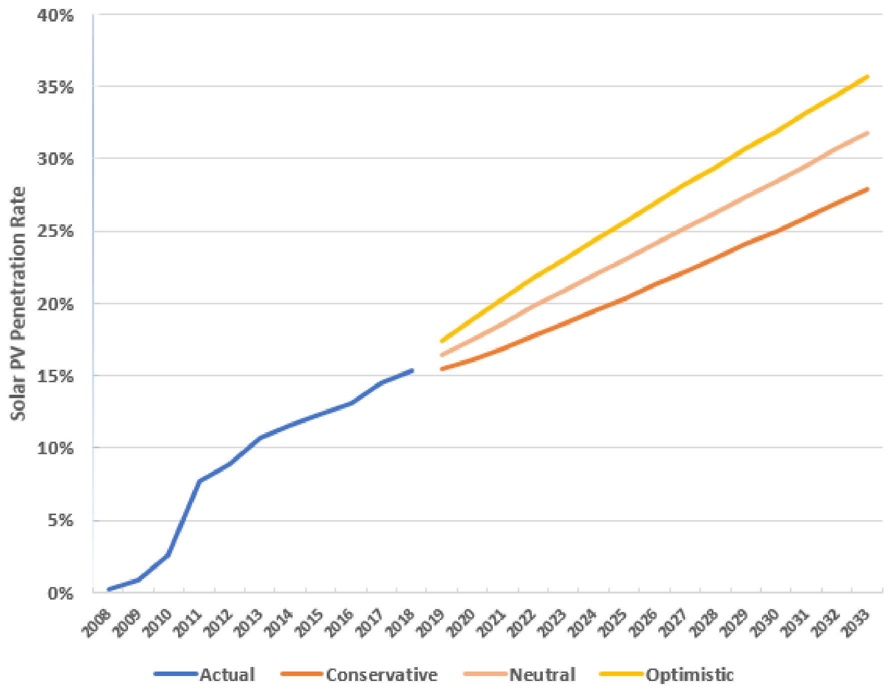

Figure 5 – ACT Residential Rooftop Solar PV Forecast

At the same time, the average solar PV installation size is growing. In May 2010, the average size residential rooftop solar PV system connecting to Australian network service providers was 2kW. In 2018, the average size has increased to 6.3kW[7]. The increase of residential solar PV systems has had a direct impact on the penetration of distribution substations across the network and the number of areas with power quality problems that need to be addressed to meet regulatory and legislative obligations.

[7] Australian Energy Council, *Solar Report,* January 2018

5 Low Voltage Network Monitoring

5.1 Proposed Solution

Evoenergy's proposed distribution substation monitoring and supply voltage optimisation program will address emerging network constraints, along with voltage issues arising from customers' energy generation, storage, and emerging technology use. The program will remediate problems at the lowest cost, avoid unnecessary augmentation and asset replacements in brownfield areas, and deliver better network planning and investment outcomes in new developments.

5.1.1 Distribution Substation Monitoring

The distribution substation monitoring component of this program involves the installation of remotely monitored electronic devices on distribution transformers installed throughout Evoenergy's network to provide voltage, current, power and harmonic data at the LV feeder head.

It will provide real-time data from areas of the network most affected by disruptive technologies to enable load flow and voltage profiling functionality within the ADMS. With this function, the ADMS will provide accurate real-time voltage calculation at the customer connection point, providing visibility of power quality and voltage compliance.

With this visibility, network performance at the low voltage level can be managed proactively and more economically, with voltage and power quality compliance assured across the network for all Evoenergy customers, as shown in Figure 6.

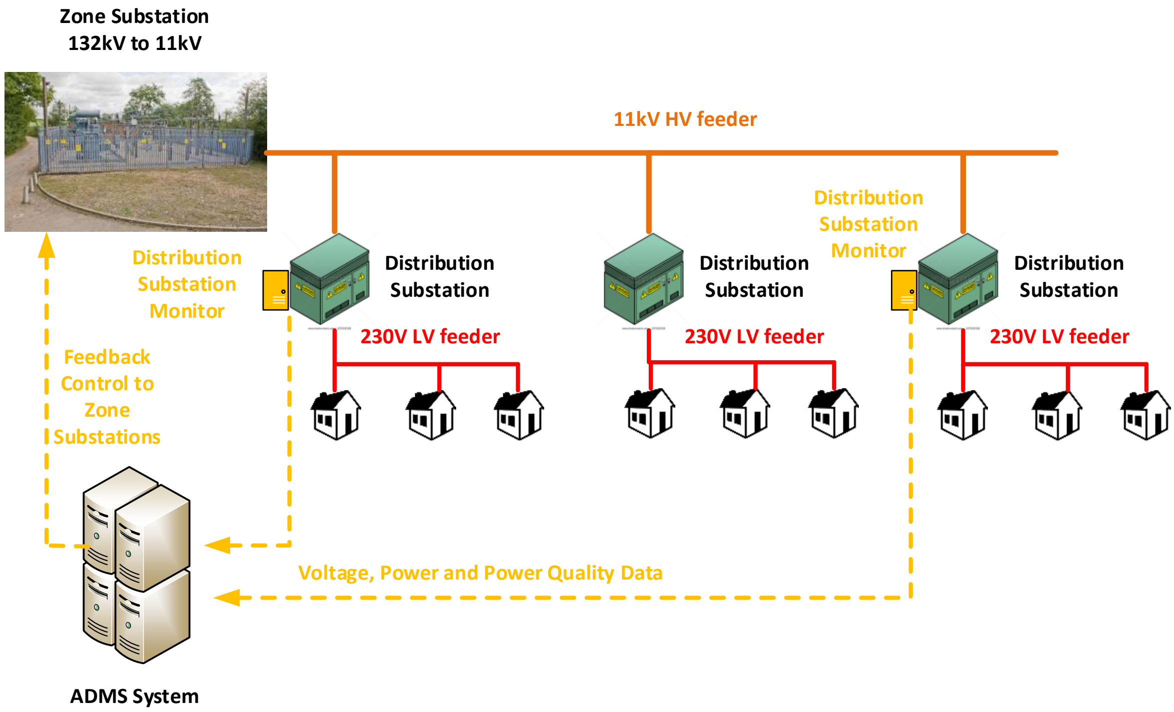

Figure 6 – Distribution Substation Monitoring with Voltage Optimisation Feedback

5.1.2 Supply Voltage Optimisation

The supply voltage optimisation component of this program will see the upgrade of zone substation voltage regulation systems to accept dynamic remote voltage set point controls from the ADMS. Voltage regulation can be used to reduce the voltage transmitted through the Evoenergy network during the daytime peak in PV generation, and increase voltage during peak load.

This overall solution will implement a feedback control loop from the distribution substation monitoring device to the zone substation voltage regulation system to dynamically adjust network voltage in real-time. It will be able to respond quickly to changing power flows and network voltage, such as from passing clouds that cause sudden changes in PV output and resulting voltage sags.

We have assessed that real time voltage optimisation is the preferred method for dealing with the daily and seasonal variations in power flow and voltage fluctuations. Overall, this will ensure a stable and reliable network power supply to Evoenergy customers, and ensure the built network can continue to fulfil its purpose without major upgrades.

5.2 Drivers

Traditionally, distribution networks were designed and constructed to accommodate power flow in one direction, from the supplying substation to the customer. At the monitoring level, basic Maximum Demand Indicators (MDIs) were installed to identify overload conditions of distribution substations that require upgrades or network reconfiguration.

Additionally, distribution transformers were designed to supply a nominal voltage at the high end of LV voltage at around 250V. While this worked well for the load only scenario of the past, it does not support embedded generation.

The current level of low voltage network monitoring is not sufficient to develop robust models that can be applied across the entire low voltage network with varying levels of solar PV penetration and long LV circuit lengths. Figure 7 shows the Australian Power Quality and Reliability Centre (APQRC) analysis for low voltage site compliance for reference. The uptake of solar PV and other emerging technologies is increasingly affecting the quality of supply across the Evoenergy network, particularly at the low voltage customer connection points.

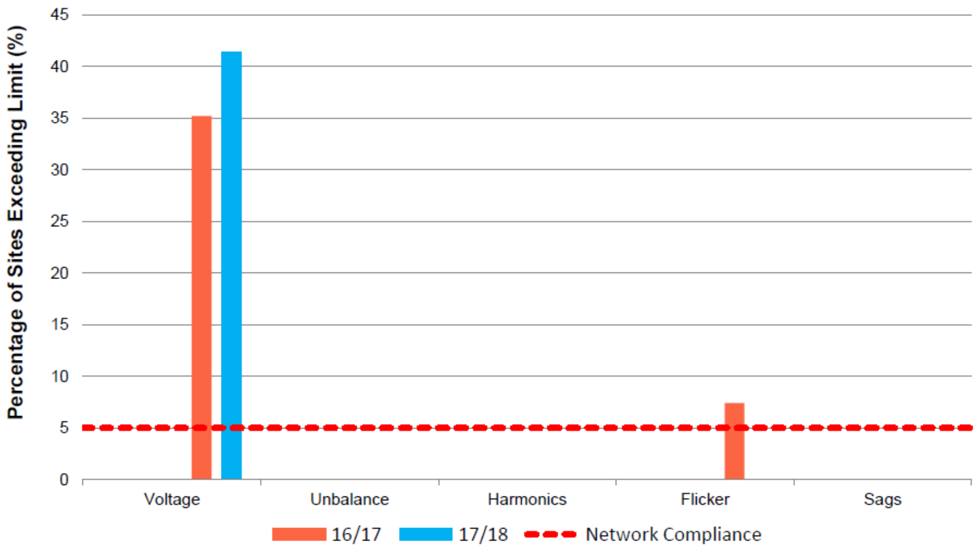

Figure 7 – Evoenergy Trend of Low Voltage Site Compliance

The growth in renewable energy sources, particularly solar PV, has seen the level of reverse power flow between the LV and 11kV networks increase substantially over the past decade. Due to this, maximum demand indicators can no longer accurately determine substation capacity, and a more continuous method of monitoring is required.

Network modelling has predicted that there will be significant reverse power flow through the existing distribution transformers with voltages exceeding the $V_{99\%}$ for extended periods of time. Evoenergy's proposed distribution substation monitoring program is a key part of the Evoenergy Quality of Supply Strategy.

It will extend its network data streams past the zone substation level to the distribution substation, and in combination with load flow functions in the ADMS, will provide accurate information about the voltage and power quality values seen at the customer connection point to enable a more proactive and dynamic quality of supply strategy.

5.3 Regulatory Requirements

Evoenergy has an obligation to comply with the National Electricity Law, National Electricity Rules and the ACT Utilities ACT (2000) to provide a safe and reliable power system. The following extracts from the various regulatory compliance documents that apply to this program are listed below.

5.3.1 National Electricity Rules

National Electricity Rules 6.5.7 Forecast capital expenditure

(a) A *building block proposal* must include the total forecast capital expenditure for the relevant *regulatory control period* which the *Distribution Network Service Provider* considers is required in order to achieve each of the following (the *capital expenditure objectives*):

(1) meet or manage the expected demand for *standard control services* over that period;

(2) comply with all applicable *regulatory obligations or requirements* associated with the provision of *standard control services*;

(3) to the extent that there is no applicable *regulatory obligation or requirement* in relation to:

(i) the quality, reliability or security of supply of *standard control services*; or

(ii) the reliability or security of the *distribution system* through the supply of *standard control services*,

to the relevant extent:

(iii) maintain the quality, reliability and security of supply of *standard control services*; and

(iv) maintain the reliability and security of the *distribution system* through the supply of *standard control services*; and

(4) maintain the safety of the *distribution system* through the supply of *standard control services*.

5.3.2 National Electricity Law

National Electricity Law Chapter 7 — National electricity objective

The objective of this Law is to promote efficient investment in, and efficient operation and use of, electricity services for the long term interests of consumers of electricity with respect to

(a) price, quality, safety, reliability and security of supply of electricity; and

(b) the reliability, safety and security of the national electricity system.

5.3.3 ACT Utilities Act (2000)

> **Utilities (Management Electricity Network Assets Code) Determination 2013**
>
> The Management of Electricity Network Assets Code is a technical code under Part 5 of the *Utilities Act 2000* (the Act).
>
> **5.3 Safe Design, Construction, Operation and Maintenance**
>
> (1) An electricity distributor must design, construct, operate and maintain its aerial lines, underground lines, substations, equipment and metering with reasonable care to avoid injury to any persons or damage to property or the environment and to provide a reliable and efficient power supply.

5.4 Benefits

5.4.1 Avoid Network Replacements and Augmentation

A number of Evoenergy distribution substation transformers have a fixed ratio without a tapping adjustment that can be used to lower LV network voltage.

Recently overvoltage issues have been identified at two fixed ratio distribution substations in the suburb of Wanniassa. These substations have approximately 20% of connections with PV. As a remediation, Evoenergy has disabled zone substation Line Drop Compensation (LDC) with minimal improvement.

Evoenergy has identified 32 fixed ratio distribution substations that will be at risk of exceeding voltage limits in the 2019-24 period. Other transformers have run out tapping adjustment; of the 388 distribution substations that have had their tap position adjusted since September 2017, 54 have been tapped down to the lowest possible setting.

A smart solution proposed in this report is to optimise the 11kV zone substation voltage through control of voltage regulation; conversely, if nothing is done we estimate an additional 47 distribution substations will need to be replaced during the 2019-24 period.

We have also identified areas of the network with low capacity LV feeders that are subject to excessive voltage variation. Smart control of upstream 11kV zone voltage regulation would also avoid the need to perform LV network re-conductoring.

Without this distribution substation monitoring and supply voltage optimisation program, Evoenergy estimates additional distribution substation replacements and LV network re-conductoring works will cost $6.2M over the 2019-24 period, as described in Section 6.

5.4.2 Enabler for New Estate Development at the Lowest Cost

There are a number of new residential developments in the ACT, such as Denman Prospect and Ginninderry, which have mandated that new detached dwellings must have rooftop solar PV installed. These developments present challenges to managing the Evoenergy network, as considerable reverse power flow has been detected, which is now causing voltage compliance and power quality issues.

To enable these developments to be built with 100% of dwellings with PV, Evoenergy either needs to upgrade the network at significant cost, or build an intelligent network with distribution substation monitors combined with other solutions such as energy storage systems.

5.4.3 Ensure Existing Customers are not Impacted

Evoenergy has an obligation to provide its customers with a reliable electrical supply that allows them to utilise appliances and equipment to their full potential. Poor power quality at the customer premises can mean that lights may flicker or dim, and in the worst case cause damage to appliances.

With the level of distributed generation systems connecting to the low voltage network, the effects of poor power quality are not just limited to those customers with these systems installed. Surrounding customers are also susceptible to power quality issues, which Evoenergy only becomes aware of due to a customer-initiated complaint. This program will ensure the proactive remediation of network issues prior to existing customers becoming aware of any issue.

5.4.4 Support Customers' Future Energy Ambitions

Customers have become more energy conscious and are increasingly taking advantage of opportunities to generate and store electricity within their homes and businesses to save money on electricity bills. The ACT Government has instilled renewable energy targets and incentives designed to deliver cheaper energy bills provided by renewable generation sources, with its full implementation by 2020, which will present additional challenges to the management of the Evoenergy network.

Over the next five years, the number of renewable energy connections to the Evoenergy network is expected to double, as new technologies such as energy storage and electric vehicles become more prevalent in the market. The challenge faced by Evoenergy will be in permitting the connection of these installations to the existing network at the lowest cost, while maintaining a reliable supply.

The implementation of intelligent, real-time network management devices, such as the proposed distribution substation monitors will avoid the additional costs of network planning studies that may otherwise be imposed as part of the customer connection application. This program will ensure that customers have the full use of their investment in distributed energy and storage systems, and see Evoenergy avoid the need for curtailment of excess generation due to network constraints or voltage compliance issues.

5.5 Network Solutions – Avoided Opex

5.5.1 Power Quality Investigations

Currently, Evoenergy relies on customer complaints to gauge the state of its low voltage network. The process for a customer power quality investigation is as follows:

1. Customer or service provider raises a power quality concern over equipment damaged or not working correctly through the Evoenergy Network Contact Centre.
2. Evoenergy conducts network integrity testing at the customer connection point. This requires the isolation of the customer's electrical supply to undertake testing, which means the customer is without electrical supply for approximately 1 hour.
3. Temporary power quality monitors are installed at the customer point of connection for a minimum of one week. Depending on the number of power quality monitors available, an additional monitor will be installed at the supplying substation for the same duration of time. Depending on the availability of the temporary power quality monitors, a customer experiencing poor power quality may have to wait until one is available.
4. The network integrity testing and power quality monitoring data is evaluated for voltage compliance to verify a complaint is justified. Using the load profiles obtained, a decision on the transformer's suitability for re-tapping is made.
5. Corrective actions are undertaken if required. This can include substation re-tapping or phase re-balancing at the customer's point of connection. In more extreme cases, recommendations are made to Primary Asset and Network Planning Managers for advice on possible network augmentation or reconfigurations that will assist in remediating the issue.

Evoenergy has recorded noticeable increases in the number of LV network overvoltage complaints over the last decade. Historical data on quality of supply investigations undertaken by Evoenergy show an upward trend concerning costs to conduct power quality investigations, as shown in Figure 8.

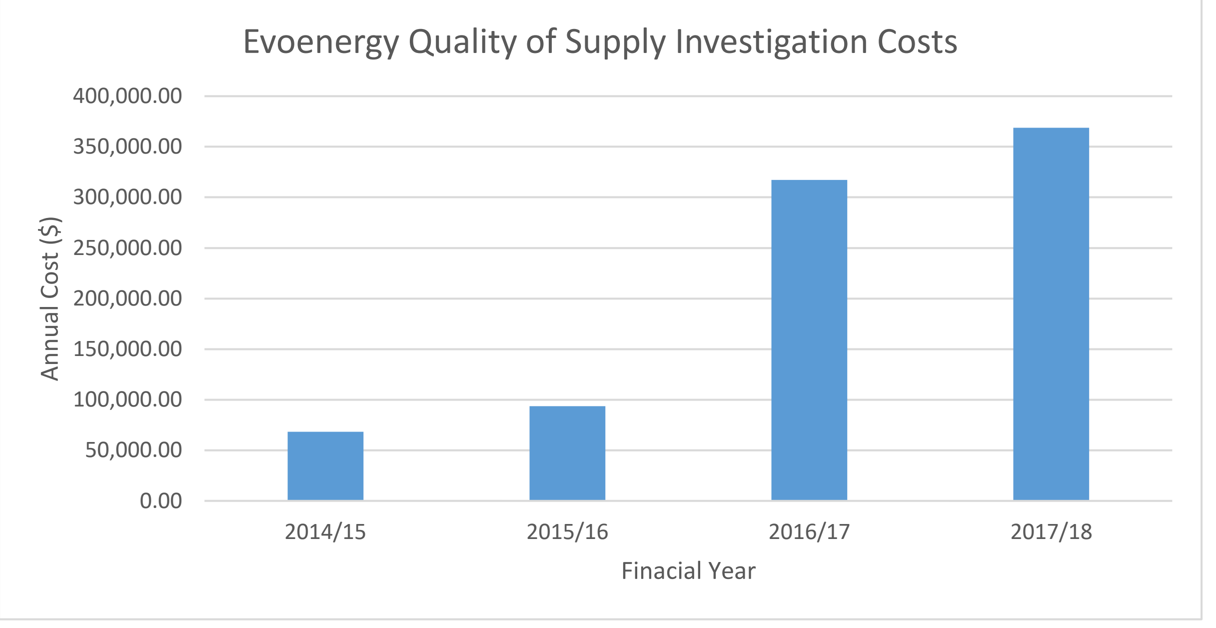

Figure 8 – Evoenergy Quality of Supply Investigation Annual Costs

In the 2016/17 and 2017/18 financial years, Evoenergy has seen large increases in the amount of power quality investigations. In the 2017/18 financial year, there was a total expenditure of $368,879.58 to conduct customer initiated power quality complaints at a cost of $1,592 per investigation.

While a voltage investigation is being undertaken, the customer continues to have an installed system that is not functioning as intended, which affects the customers return on investment.

On numerous occasions, Evoenergy has had to re-visit a site to undertake further investigation, adding additional investigation costs.

The installation of the distribution substation monitors will provide Evoenergy with a permanent site solution that delivers real-time data that will be used to address power quality issues on a more proactive basis than current methods.

Evoenergy’s proposed distribution substation monitoring program would significantly address the issue outlined above by monitoring and adjusting the voltage levels at positions along the low voltage network in real-time, which will provide the following benefits:

- In most cases, fix the voltage issue before it affects the customer.
- Minimise the need for quality of supply inspections, ensuring expenditure for investigations is contained.
- Minimise the need to purchase additional temporary power quality monitors used in customer voltage inspections.
- Allow the transformer tap setting to be optimised by utilising the data from the distribution substation monitoring device.
- Assist in low voltage network fault finding activities by utilising data trends.
- Allow Evoenergy to move to dynamic auto-voltage regulation schemes at its 132/11kV zone substations, rather than the static set-point schemes it currently uses.

While the key driver is to resolve network power quality and voltage issues, this solution provides additional benefits for customers in terms of improved voltage regulation for operation of equipment and appliances, while reducing safety risks. The selection of this proposed option is discussed in Section 6.

5.5.2 Low Voltage Network Overvoltage Costs

A further benefit of the distribution substation and supply voltage optimisation program is that it will mitigate the increase in customer equipment damage and need for subsequent insurance claims. Since 2012, Evoenergy has resolved totalling **$164,442** for quality of supply related claims.

This is because the monitors will provide early warnings with regards to low voltage connections which can be addressed before equipment is damaged due to:

1. Overvoltage at the customer premises.

   Evidence suggests that increased voltages over 1.3 times the nominal voltage can have impacts on customer equipment. Evoenergy has settled insurance claims for refrigerators, air conditioners, televisions, etc., which are due to, increased voltages at the customer's installation.

2. Loss of neutral at the customer connection point.

   A broken or lost neutral at the customer connection point can cause equipment to not work; e.g. heating or cooking appliances, lights may flicker and electronic equipment fail. Where the customer's premises has metallic piping for plumbing installed, this equipment can become live, increasing the risk of electric shock to the customer.

3. Loss of neutral at the supplying distribution substation.

   If the neutral conductor is opened, broken or lost at the supply point, the distribution system's neutral conductor will "float" or lose its reference to ground. This can cause voltages to rise and potentially cause harm to customers, livestock, equipment or the public.

5.6 Network Solutions – Avoided Capex

5.6.1 Single Tap Distribution Substation Transformers

Through voltage investigations, Evoenergy has identified 42 distribution substations that only have a single transformer tap position setting and another 54 transformers that are already at the lowest tap setting. Of these, Evoenergy has already received eleven overvoltage complaints from customers supplied by these substations.

Evoenergy's estimates for the replacement and re-configuration works for these assets will cost an average of **$107,338** per site (based on historical unit costs) with 47 requiring replacement over the next 5 years. The total additional capex that would be required is **$5.4 million** over the 2019-24 period. More importantly, these assets have not approached their useful design life and any early retirement of these assets has not been factored or costed as part of the replacement program in the regulatory submission.

Implementing the distribution substation monitoring and supply voltage optimisation program, would allow these distribution substation assets to remain in service over the 2019-24 period, and avoid the addition capex costs.

5.6.2 Low Voltage Distribution Network Upgrades

5.6.2.1 Re-conductoring and Upgrading Distribution Transformers

Two conventional network solutions are available to address the voltage compliance issues on the low voltage network:

- Replace smaller cross-sectional LV circuit mains and/or service conductors to customers.
- Reduce excessive lengths of LV circuit mains (those in excess of 400m) by installing additional distribution transformer points and re-configuring LV open points.

These solutions work by reducing the impedance at the customer point of connection, and have the advantage of providing additional benefits for the network in terms of reliability, safety, and capacity improvement to allow for future growth in residential demand and distributed generation. This solution has high capital costs associated with its implementation and is one of the more complex to undertake.

We have conservatively estimated an additional **$796K** in capex for LV re-conductoring can be avoided under the recommended solution for distribution substation monitoring and supply voltage optimisation.

5.6.2.2 Installation of Distribution Transformers with On Load Tap Changers (OLTC)

This proposed upgrade would move the point of regulation from the zone substation level to the distribution substation level, by managing the specific needs of individual areas through the installation of distribution substations with on-load tap changing functionality.

These upgrades are currently being trialled in new suburbs with mandated distributed generation requirements, and provides a possible Greenfield solution to meet the growing Evoenergy network needs. However, these on-load tap changer distribution substations are cost prohibitive for a network-wide deployment due to the higher capital costs. Evoenergy has costed the on-load distribution substations to be 1.5 to 2 times the cost of a typical off-load tap changer substation, depending on the installation's required configuration.

This additional investment will not be required in the majority of cases if distribution substation monitoring and supply voltage optimisation program is implemented.

5.6.2.3 Installation of Voltage Regulators and Power Factor Correction Devices

Voltage Regulators and Power Factor Correction Devices may offer a solution to voltage levels and customer load issues where customers are connected to long HV or LV lines, however they do not provide a complete solution to cater for all power quality parameters.

These devices have high capital costs, along with high maintenance and operational costs, making their network-wide implementation cost prohibitive.

5.6.3 Cost Optimisation of Non-Network Technology Deployments

5.6.3.1 Reactive Power Control of Customer PV Systems

Since the introduction of the revised AS/NZS 4777 standards in 2015, inverters now have reactive power control embedded within their settings. Prior to 2015 this set point was not required in inverter systems, and they are unable to have this requirement added. Evoenergy figures place the number of existing inverters without reactive power control to be 16,276. The newer solar PV inverters with reactive power control have the capacity to assist with voltage rise by absorbing reactive power.

In the future control of inverter reactive power could be used to for voltage optimisation in conjunction with the proposed distribution substation monitoring and other measures. The application of reactive power control is limited by the reactive power and power factor in the network and will only ever offer a partial solution for voltage control.

5.6.3.2 Installation of (Customer) Battery Storage

Further into the future, as the take up of battery energy storage systems combined with solar PV installations increases, this may provide opportunities to store energy produced at peak times during the day that can be used during the evening period to offer demand response arrangements to better manage network capacity and voltage constraints. This requires considerable customer investment and incentives from Evoenergy and the ACT Government in order for such an initiative to be taken up. As this solution is very much customer driven, and the take up of battery energy storage systems in the ACT being relatively low, this proposed solution will take considerable time to gain the required network coverage levels to be used constructively for network voltage optimisation.

In the future once sufficient installed capacity exists, battery storage could be used to assist with voltage optimisation in conjunction with the proposed distribution substation monitoring. It needs to be noted that Evoenergy would need to pay customers and virtual power plant operators for this service. In contrast, voltage optimisation via zone substation voltage regulation as proposed in this business case does not incur an operating expense for Evoenergy.

5.7 Cost of Proposed Investment

In Evoenergy's regulatory proposal, the capital expenditure required for dedicated power quality remediation works totalled **$6.2M** over the five year 2019-24 period that will address 20% of the network area worst affected by DER penetration.

The financial breakdown of this amount constitutes **$3,500** per site for the installation of the distribution substation monitor device inclusive of ADMS integration. 200 devices are proposed to be installed for each year of the program for a total cost of **$3.5M** over 5 years.

We also propose voltage regulation system upgrades at 25 132/11kV zone substation transformers for a total cost of **$2.7M** over the 5 year period. The voltage regulation system upgrades implement voltage set point control required for voltage optimisation.

6 Options for Low Voltage Network Management

Due to the Power of Choice legislation coming into effect on 1 December 2017, Evoenergy is unable to install smart metering at the customer premises. As such, any use of smart metering data would entail purchasing data from metering providers. Smart metering is considered in the option analysis in Section 6.1 of this report; however, distribution substation monitoring is identified as the most cost-effective and more beneficial solution.

Distribution substation monitoring is a superior technical solution, compared to smart metering, as it is capable of providing minute-by-minute real-time data. Smart meters do not provide real-time data as they store 30-minute interval data (or in the future 5 minute interval data) and smart meters are read on a 4-hour or daily cycle. In contrast, distribution substation monitoring is able to provide minute–by-minute data in real-time that permits real-time voltage optimisation.

Evoenergy is conducting field trials of power quality monitoring devices in 2018 and has identified an Internet of Things (IoT) device that is able to provide a complete monitoring solution at a low cost. This monitoring device commenced field trials in September 2018 and has been integrated into Evoenergy's ADMS to prove interoperability and assess benefit realisation.

Table 2 provides the CAPEX cost breakdown of the distribution substation monitoring program and associated voltage optimisation remediation works for Evoenergy's 2019-24 regulatory proposal.

Program	$M, 2019-24					
	2019-20	2020-21	2021-22	2022-23	2023-24	Total
Distribution Substation Monitoring	0.7	0.7	0.7	0.7	0.7	3.5
Voltage Optimisation Remediation Works	0.54	0.54	0.54	0.54	0.54	2.7
Evoenergy Proposal	**1.24**	**1.24**	**1.24**	**1.24**	**1.24**	**6.2**

Table 2 – Evoenergy Distribution Substation Monitoring Program Capex Breakdown

Evoenergy has engaged the Australian Power Quality Centre at the University of Wollongong to analyse its low voltage network power quality surveys over the 2016-2018 years. The APQC analysis agrees with Evoenergy's analysis and indicates that the disturbance of most concern is the 99th percentile voltage. From the data supplied, a significant proportion of surveyed residential sites show non-compliant voltage levels, as shown in Table 3.

Index	Limit (V)	Number of Sites Exceeding Limit	Percent of Sites Exceeding Limit
$V_{99\%}$	253	24	41%
$V_{1\%}$	216	0	0%

Table 3 – 2017/18 Site Compliance Statistics for Voltage at Low Voltage Sites

The distribution substation monitoring project developed by Evoenergy plans to address power quality issues over the 2019-24 regulatory period. The benefit for our customers will be increased reliability and quality of supply, which will assist our customers' ability to connect distributed generation to the Evoenergy network while maximising their return on investment.

Evoenergy has considered a number of options for this program based on the Evoenergy Quality of Supply[8] and Secondary Systems Strategy[9].

Since January 2018, Evoenergy has field-tested three different devices, and we have now identified a device capable of providing power quality monitoring at a lower cost. We also identified that voltage regulation system upgrades at 132/11kV zone substations would be prudent to permit active voltage optimisation and management from the ADMS system.

The preferred option (Option 5) will see 200 transformer monitor devices installed per year, targeting sites with known power quality issues to assist in the remediation of issues in the low voltage network. These devices will also allow Evoenergy to move to a dynamic automatic voltage regulation scheme at its 132/11kV zone substations, which will greatly improve the overall voltage profile at the customer connection point. This will allow a network-wide solution to non-compliant power quality issues in the most cost-effective method available.

6.1 Options Assessment

6.1.1 Option 1 – Base Case (Do Nothing)

The Base Case (“*Do Nothing*”) for this program is to not install distribution substation monitoring devices on the Evoenergy low voltage network. This approach will not address the increasing number of customer power quality complaints as shown in Figure 1, and would require remediation of low voltage assets, which is expected to deteriorate further and affect quality of supply if no action is taken. In addition, the “Do Nothing” approach has the following disadvantages:

- It results in the continued requirement to use mobile power quality loggers on the LV network. This manual process is OPEX intensive and is expected to rise 20% per annum. Mobile loggers only provide quality of supply data over the period of installation (typically 7 days) where a distribution substation monitoring solution provides a permanent data source from the date of installation for life (10 years+). Opex for investigations is estimated at $2,934,988 for the period 2019-24.
- It does not provide data to the ADMS and will not realise any customer, business or ADMS benefits.
- It does nothing to address or manage Evoenergy’s increasing quality of supply complaints. This will negatively affect customer satisfaction and may lead to regulatory penalties.
- The modelling shows that the do nothing approach will require Evoenergy to replace 47 distribution transformers and upgrade 5 low voltage feeders during the 2019-24 period at a capex cost of **$6,151,991**.

  Please note these costs is not included elsewhere in the Evoenergy Regulatory Proposal as the assumption is this business case will be approved.
- Overall the do nothing option has a NPC of **$7,648,200** higher than our preferred option.

This option is not an acceptable solution.

Detailed financial analysis is provided in Appendix A.3.

[8] Evoenergy Quality of Supply Strategy SM11150

[9] Evoenergy Secondary Systems Strategy V3.0

6.1.2 Option 2 – Use Smart Meters and 3rd Party Data Sources

Smart meters (also known as advanced meters or type 4 meters) are devices that digitally measure energy usage at a premises at regular intervals. It sends this data to the retailer remotely via a communications link. Enhanced smart meters and 3rd party data sources can be configured to record condition monitoring parameters that will be used for analysing network power quality to ensure compliance with standards and codes.

Potential advantages of this approach are:

- It avoids the need for CAPEX investment by Evoenergy.

Potential disadvantages of this approach are:

- High Opex cost of $1,859,618 per year for 20% network coverage.
- Capex cost of **$4,186,671** and a very high NPC of **$12,123,288** over the 2019 to 2024 period.
- Due to Power of Choice legislation, Evoenergy cannot install smart meters, therefore we would be reliant on retailers (Metering Coordinators) for the provision of data. In addition, the smart meter rollout in the ACT market is still quite low, meaning this option would be much slower to implement.
- There is difficulty and cost of integration with Evoenergy's ADMS, with data sources coming from multiple 3rd part suppliers.
- Smart meters do not provide real-time data, which limits the application of real-time supply voltage optimisation, as smart meters typically only provide updated data streams every four hours.
- There are no set requirements for retailers to configure smart meters with voltage or power quality measurement. This would require Evoenergy to request the retailer to amend settings within the meter, and we would be liable for the costs of these amendments.
- There is no common data format or simple way to authorise third party access to the data, which generates extra costs to Evoenergy customers.
- Small numbers of type 4 smart meters are currently installed in the Evoenergy network and metering providers are unable to provide sufficient endpoint data to cover the required 20% of network coverage. To date, there are 13,365 type 4 meters installed, which provides a network coverage of 6.39%; however very few of the currently installed type 4 meters have the necessary voltage or power quality measuring elements enabled.

Currently, this option is not a viable solution due to the low number of suitable smart meters and the lack of 3rd party data available. It has substantially lower relative NPV compared to other options and is not preferred.

Detailed financial analysis is provided in Appendix A.4.

6.1.3 Option 3 – Extend Existing SCADA Network Monitoring to the Distribution Substation Level

200 monitors will be installed per year at known and problematic sites on the Evoenergy network. This solution has centralised management features and is flexible for managing changes to individual service profile requirements. It will also provide automatic alarming for any communication network failures, and integrate with the existing BSD management systems.

Installation of the monitoring devices realises the holistic business benefits of an LV monitoring network that is integrated with SCADA and ADMS to provide continuous monitoring and control functions.

Potential advantages of this approach are:

- Customer unplanned outage times decrease due to the capability of the SCADA network to remotely operate field isolation points in the event of a network fault.
- Ease of integration with Evoenergy's ADMS and associated back end systems.
- SCADA devices could integrate data from other devices, for example from fault passage indicators on the HV side of distribution substations.

Potential disadvantages of this approach are:

- Highest Capex cost of **$15,694,625** and a very high NPC of **$14,768,816** over the 2019 to 2024 period.
- SCADA devices have control and other advanced functions that would not be used for monitoring of the LV network, meaning the simple monitoring function is provided by a more expensive complex device.

This option is considered not acceptable to meet the needs of the distribution substation monitoring program. It has substantially lower relative NPV compared to other options and is not preferred.

Detailed financial analysis is provided in Appendix A.5.

6.1.4 Option 4 – Install Distribution Substation Network Monitoring Devices

200 monitors will be installed per year at identified sites within the Evoenergy network. The initial location of the monitors will be based on identification of areas within the LV network that are known to be experiencing power quality issues and high penetration of DER. This option will provide monitoring capabilities that can be used to drive a bottom-up approach to analysing network power quality and ensuring compliance with supply quality standards.

Power quality data captured will support analytic processes for resolving power quality issues to better prepare Evoenergy for the regulator-imposed Quality of Supply STPIS component as well as providing a greater number of sources for ACT technical regulatory reporting. Furthermore, distribution substation monitoring also provides a platform for enacting power quality remediation works including management of LV voltages and VARs, identification of optimum tapping on distribution transformers, and management of distributed generation impacts.

For Evoenergy customers, this means that they are able to install their desired equipment without the downside of intermittent operation or damage to appliances from overvoltage. Evoenergy will be able to remotely monitor various points on the LV network to identify power quality issues before it's noticed by the customer.

This option is considered acceptable to meet the needs, with a capex cost of **$5,977,382** and a NPC of **$7,022,630** over the 2019 to 2024 period. However, Option 5 provides additional capacity with superior NPV to meet the needs of the business and customers.

Detailed financial analysis is provided in Appendix A.6.

6.1.5 Option 5 – Implement Distribution Substation Monitoring and Supply Voltage Optimisation Program

As detailed in this report, Evoenergy has identified a distribution substation LV monitoring device that offers a cost effective solution to provide data to manage the challenges resulting from DER.

200 monitors will be installed per year at identified sites within the Evoenergy network. The initial location of the monitors will be based on identification of areas within the LV network that are known to be experiencing power quality issues.

In addition to distribution substation monitoring under option 4, this option also includes voltage regulation system upgrades at 132/11kV zone substations that will permit active voltage optimisation and management from the ADMS system. Option 5 extends the benefits of monitoring with real-time optimisation of network voltage to increase DER hosting capacity.

This option provides the greatest benefit and will avoid 47 distribution transformer replacements and 5 low voltage feeder upgrades. It will also contain further increases to power quality investigation opex costs.

This is the preferred solution as our assessment demonstrates that it has the lowest NPC of **$6,825,640**. It is a modern and cost-effective way to implement a networked distribution substation monitoring and supply voltage optimisation program to meet Evoenergy's requirements, customer needs and the challenges of increasing DER for the future. This option is considered acceptable to meet the needs. It has the highest NPV and is the preferred option.

Detailed financial analysis is provided in Appendix A.7.

6.1.6 Options Evaluation

Option	Description	NPC
1	Base Case (Do Nothing)	7,648,200
2	Use Smart Meters and 3rd Party Data Sources	12,123,288
3	Extend Existing SCADA Network Monitoring to the Distribution Substation Level	14,768,816
4	Install Distribution Substation Network Monitoring Devices only	7,022,630
5	Implement Distribution Substation Monitoring and Supply Voltage Optimisation Program	6,825,640

Table 4 – 5 year NPC Option Comparison

Option 5 is the preferred solution and has been selected has it has the lowest NPC.

The full benefits of this program's implementation will be realised beyond this period as the number of distribution substation monitors installed on the Evoenergy network increases.

A scoring matrix approach has been used to assess the advantages, disadvantages, risks and benefits of each of the options. Each option has been given an overall score, based on the scoring criteria detailed in Table 5 on the following page.

Criteria	Criteria and Weighting
Cost	*Accuracy of the cost estimate prepared for the project.* *30% weighting.*
Project Objective	*The extent to which the proposed solution meets the requirements of the project.* *20% weighting.*
Schedule	*The risk associated with meeting the required project completion date.* *20% weighting.*
Risks	*The extent to which the proposed project provides mitigation/controls to risks identified.* *20% weighting.*
Benefits	*The extent to which the proposed project meets the immediate scope requirements and the associated business benefits identified in this document.* *10% weighting.*

Table 5 – Scoring Matrix Criteria

	Criteria					
	Cost	Project Objective	Schedule	Risks	Benefits	Overall Score
Criteria Weighting	30%	20%	20%	20%	10%	100%
Options 1 Base Case (Do Nothing)	3	0	1	1	0	**43**
Option 2 Smart Meters and 3rd Party Data Sources	2	2	1	1	2	**53**
Option 3 Extend the existing SCADA network to the distribution substation level	1	2	3	2	3	**67**
Option 4 Implement Distribution Substation Monitors Program	3	3	3	3	2	**93**
Option 5 Implement Distribution Substation Monitors and Supply Voltage Optimisation Program	3	3	3	3	3	**100**

Scoring Key			
0	Fatal flaw	1	Unattractive
2	Acceptable	3	Attractive

Table 6 – Scoring Matrix

The scoring matrix shows that Options 4 and 5 both meet the project need, with Option 5 being the more attractive option based on financial return.

6.2 Recommendation

This project justification report recommends that **Option 5 to Implement Distribution Substation Monitoring and Supply Voltage Optimisation Program** be approved and implemented over the period from 2019-24.

Option 5 satisfies all program requirements and is considered the least cost, yet most cost-effective approach to implement Evoenergy's distribution substation monitoring and supply voltage optimisation program to address the growing number of power quality concerns.

This program provides positive returns, as shown with the relative net present value of **$1,360,831** over the five year period. It will also provide additional benefits as detailed throughout this report for an extended period beyond 10 years.

The program requires total capex funding of **$6,212,500**.

Appendix A Financial Analysis

A.1 5 Year NPV Analysis – Summary

Option	5 Year Financial Analysis				
	NPC	Relative NPC	NPV	Relative NPV	Capex Cost
1	$7,648,200	$0	-$7,648,200	$0	$6,151,991
2	$12,123,288	-$4,475,088	-$12,123,288	-$4,475,088	$4,186,671
3	$14,768,816	-$7,120,616	-$14,230,545	-$6,582,345	$15,694,625
4	$7,022,630	$625,571	-$7,022,630	$625,571	$5,977,382
5	$6,825,640	$822,561	-$6,287,369	$1,360,831	$6,212,500

Table 7 – 5 Year NPV Analysis

A.2 10 Year NPV Analysis – Summary

Option	10 Year Financial Analysis				
	NPC	Relative NPC	NPV	Relative NPV	Capex Cost
1	$16,871,780	$0	-$16,871,780	$0	$12,944,287
2	$22,508,941	-$5,637,161	-$22,508,941	-$5,637,161	$8,809,094
3	$26,261,146	-$9,389,367	-$24,569,082	-$7,697,302	$31,614,443
4	$11,921,740	$4,950,040	-$11,921,740	$4,950,040	$8,712,611
5	$8,745,976	$8,125,804	-$7,520,945	$9,350,835	$6,212,500

Table 8 – 10 Year NPV Analysis

A.3 NPV Analysis – Option 1

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Non Financial										
PQ Complaints	237	284	341	410	491	590	708	849	1019	1223
Monitoring Devices active	0	0	0	0	0	0	0	0	0	0
Transformer Replacements	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4
Network Upgrades	1	1	1	1	1	1	1	1	1	1
Opex										
Voltage Investigations	376,258	460,539	563,700	689,969	844,522	1,033,695	1,265,243	1,548,657	1,895,556	2,320,161
Insurance claims	23,644	28,373	34,048	40,857	49,028	58,834	70,601	84,721	101,665	121,999
Capex										
Single tap transformer replacements	1,029,157	1,049,740	1,070,735	1,092,149	1,113,992	1,136,272	1,158,998	1,182,178	1,205,821	1,229,938
Low voltage network upgrades	153,000	156,060	159,181	162,365	165,612	168,924	172,303	175,749	179,264	182,849
Indirect Benefits										
Total Cost	1,582,058	1,694,712	1,827,664	1,985,340	2,173,155	2,397,726	2,667,144	2,991,305	3,382,307	3,854,946
Total Benefits	0	0	0	0	0	0	0	0	0	0

NPC	16,871,780	7,648,200
NPB	0	0
NPV	-16,871,780	-7,648,200
Capex Cost	12,944,287	6,151,991
	10 year	**5 year**

A.4 NPV Analysis – Option 2

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Non Financial										
PQ Complaints	193	193	193	193	193	193	193	193	193	193
Monitoring Devices active	0	0	0	0	0	0	0	0	0	0
Transformer Replacements	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4
Network Upgrades	1	1	1	1	1	1	1	1	1	1
Smart meters monitored	38,400	38,400	38,400	38,400	38,400	38,400	38,400	38,400	38,400	38,400
Avoidable voltage investigations due to monitoring installations										
Opex										
Voltage investigations										
Insurance claims	19,229	19,229	19,229	19,229	19,229	19,229	19,229	19,229	19,229	19,229
Data costs	1,785,234	1,785,234	1,785,234	1,785,234	1,785,234	1,785,234	1,785,234	1,785,234	1,785,234	1,785,234
Tap Changes	184,202	221,042	265,251	318,301	381,961	458,353	550,024	660,028	792,034	950,441
Capex										
Single tap transformer replacements	689,754	703,549	717,620	731,972	746,612	761,544	776,775	792,311	808,157	824,320
Low voltage network upgrades	114,750	117,045	119,386	121,774	124,209	126,693	129,227	131,812	134,448	137,137
Indirect Benefits										
Total Cost	2,793,169	2,846,099	2,906,719	2,976,510	3,057,245	3,151,053	3,260,489	3,388,613	3,539,101	3,716,360
Total Benefits	0	0	0	0	0	0	0	0	0	0

NPC	22,508,941	12,123,288
NPB	0	0
NPV	-22,508,941	-12,123,288
Capex Cost	8,809,094	4,186,671
	10 year	**5 year**

A.5 NPV Analysis – Option 3

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Non Financial										
PQ Complaints	237	266	282	279	252	193	193	193	193	193
Monitoring Devices active	200	400	600	800	1,000	1,000	1,000	1,000	1,000	1,000
Transformer Replacements	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
Network Upgrades	1	1	1	1	1	1	1	1	1	1
ZS Votage Optimisation upgrades active	5	10	15	20	25	25	25	25	25	25
Avoidable voltage investigations due to monitoring installations	44	73	89	87	60	-	-	-	-	-
Opex										
Voltage Investigations	306,000	312,120	318,362	324,730	331,224	337,849	344,606	351,498	358,528	365,698
Insurance claims	23,644	26,544	28,120	27,880	25,189	19,229	19,229	19,229	19,229	19,229
Data costs	0	0	0	0	0	0	0	0	0	0
Monitoring device opex	10,000	20,000	30,000	40,000	50,000	50,000	50,000	50,000	50,000	50,000
Tap changes (excluding via voltage investigations)	8,771	18,528	30,628	45,596	64,079	86,868	114,931	149,452	191,880	243,992
Capex										
Single tap transformer replacements	262,763	268,019	273,379	278,847	284,424	290,112	295,914	301,833	307,869	314,027
Low voltage network upgrades	153,000	156,060	159,181	162,365	165,612	168,924	172,303	175,749	179,264	182,849
Monitoring devices	2,163,695	2,163,695	2,163,695	2,163,695	2,163,695	2,163,695	2,163,695	2,163,695	2,163,695	2,163,695
ZS Voltage optimisation	542,500	542,500	542,500	542,500	542,500	542,500	542,500	542,500	542,500	542,500
Indirect Benefits										
Future remote dist sub tap change capability	-	-	-	-	-	86,868	114,931	149,452	191,880	243,992
Reduced outage times due to dist sub alarming and remote ops	-	-	-	-	-	-	-	-	-	-
Reduced Unserved Energy	44,883	89,767	134,650	179,533	224,417	224,417	224,417	224,417	224,417	224,417

Total Cost	3,470,373	3,507,466	3,545,865	3,585,612	3,626,723	3,659,178	3,703,178	3,753,955	3,812,965	3,881,991
Total Benefits	44,883	89,767	134,650	179,533	224,417	311,285	339,348	373,868	416,297	468,409
NPC	26,261,146	14,768,816								
NPB	1,692,064	538,271								
NPV	-24,569,082	-14,230,545								
Capex Cost	31,614,443	15,694,625								
	10 year	**5 year**								

A.6 NPV Analysis – Option 4

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Non Financial										
PQ Complaints	237	275	300	306	288	237	237	237	237	237
Monitoring Devices active	200	400	600	800	1,000	1,000	1,000	1,000	1,000	1,000
Transformer Replacements	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4
Network Upgrades	1	1	1	1	1	1	1	1	1	1
Avoidable voltage investigations due to monitoring installations	44	82	107	113	95					
Opex										
Voltage Investigations	306,000	312,120	318,362	324,730	331,224	415,419	423,727	432,202	440,846	449,663
Insurance claims	23,644	27,427	29,886	30,529	28,721	23,644	23,644	23,644	23,644	23,644
Data costs	0	0	0	0	0	0	0	0	0	0
Monitoring device opex	6,000	12,000	18,000	24,000	30,000	30,000	30,000	30,000	30,000	30,000
Tap changes (excluding via voltage investigations)	35,083	74,114	122,510	182,384	256,317	308,739	420,214	557,507	726,416	934,041
Capex										
Single tap transformer replacements	361,300	368,526	375,896	383,414	391,082	398,904	406,882	415,020	423,320	431,787
Low voltage network upgrades	114,750	117,045	119,386	121,774	124,209	126,693	129,227	131,812	134,448	137,137
Monitoring devices	700,000	700,000	700,000	700,000	700,000					
Indirect Benefits										
Total Cost	1,546,777	1,611,232	1,684,041	1,766,831	1,861,554	1,303,399	1,433,695	1,590,184	1,778,674	2,006,271
Total Benefits	0	0	0	0	0	0	0	0	0	0

NPC	11,921,740	7,022,630
NPB	0	0
NPV	-11,921,740	-7,022,630
Capex Cost	8,712,611	5,977,382
	10 year	**5 year**

A.7 NPV Analysis – Option 5

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Non Financial										
PQ Complaints	237	275	300	306	288	237	237	237	237	237
Monitoring Devices active	200	400	600	800	1,000	1,000	1,000	1,000	1,000	1,000
Transformer Replacements	0	0	0	0	0					
Network Upgrades	0	0	0	0	0					
ZS Votage Optimisation upgrades active	5	10	15	20	25	25	25	25	25	25
Avoidable voltage investigations due to monitoring installations	44	82	107	113	95					
Opex										
Voltage Investigations	306,000	312,120	318,362	324,730	331,224	415,419	423,727	432,202	440,846	449,663
Insurance claims	23,644	27,427	29,886	30,529	28,721	23,644	23,644	23,644	23,644	23,644
Data costs	0	0	0	0	0	0	0	0	0	0
Monitoring device opex	6,000	12,000	18,000	24,000	30,000	30,000	30,000	30,000	30,000	30,000
Tap changes (excluding via voltage investigations)	8,771	18,528	30,628	45,596	64,079	77,185	105,054	139,377	181,604	233,510
Capex										
Single tap transformer replacements	0	0	0	0	0	-	-	-	-	-
Low voltage network upgrades	0	0	0	0	0	-	-	-	-	-
Monitoring devices	700,000	700,000	700,000	700,000	700,000	-	-	-	-	-
ZS Voltage optimisation	542,500	542,500	542,500	542,500	542,500	-	-	-	-	-
Indirect Benefits										
Reduced Unserved Energy	44,883	89,767	134,650	179,533	224,417	224,417	224,417	224,417	224,417	224,417

Total Cost	1,586,915	1,612,576	1,639,376	1,667,355	1,696,525	546,248	582,425	625,223	676,094	736,817
Total Benefits	44,883	89,767	134,650	179,533	224,417	224,417	224,417	224,417	224,417	224,417
NPC	8,745,976	6,825,640								
NPB	1,225,031	538,271								
NPV	-7,520,945	-6,287,369								
Capex Cost	6,212,500	6,212,500								
	10 year	**5 year**								