Supporting Document 12.1.6
Network Power Quality Strategy
CEOP 2090
2019 - 2024

April 2018

essential energy

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1. Executive Summary

Asset Management Plan	> Network Strategy - Power Quality 2019 -2024: CEOP2090
Description	> This strategy provides the strategic basis for Power Quality Management in Essential Energy's network
Objectives	> To set out strategies that Essential Energy will use to manage safety of the network and its environmental impact in line with corporate requirements. In addition, this document will break down the Asset Management Objectives, as directed by the overarching Strategic Asset Management Plan (SAMP), into more specific Asset System and Class objectives and targets which are to be used in the Asset Management Plans and Investment Cases. > Ensure consistent and timely management through to resolution of customer power quality complaints > Manage customer safety and equipment malfunction or damage risks associated with network power quality performance > Migrate towards practical compliance with Electricity Supply Standard – CEOP8026 that incorporates statutory and/or mandatory provisions of Australian Standards, National Electricity Rules (NER), Service and Installation Rules of NSW (SIR NSW) and AEMO (Australian Energy Market Operator) Requirements > Gradual transition to the new 230-Volt Australian Standard to lower system voltages (as part of 230V Migration Strategy) > Progress towards a more proactive approach for management of power quality compliance and improved management of new customer connections.
Approach	REACTIVE MEASURES > Investigate received power quality complaints and customer feedback quickly and efficiently. > Verify that power quality problems are indeed network related and are outside the levels prescribed in Electricity Supply Standards. > Rectify any local or wider area problem in a timely, economic, and effective manner, including the use of alternate remediation solutions > Consult with and keep customer advised during all steps of investigation and rectification process. PROACTIVE MEASURES > Migrate towards a more proactive power quality management approach through an improved visibility of network power quality performance delivered by leveraging the rollout of power quality monitoring equipment as detailed in the Power Quality Monitoring in Zone Substations project > Systematic modelling of sub transmission and distribution performance, development of Harmonic Impedance Model and management of HV feeder voltage profiles > Improved management of new/additional loads and embedded generator connections process and develop new standards/ procedures for rooftop solar, large scale solar and wind farm connections in line with NER, Service and Installation Rules NSW and AEMO requirements > Reliance is placed on network asset management practices to improve network power quality > Set a consistent value methodology for investment decisions using C55 software.

Customer benefits	> Satisfy customers expectations for an acceptable and affordable quality of supply and mitigate PQ issues where there are noticeable serious PQ problems > Minimise public safety risks, e.g. shocks and tingles. > Minimise damage, degradation, life reduction and malfunction of customer equipment due to power quality problems. > Minimise customer nuisance, disruption, dissatisfaction, loss of production and income, and the need to seek compensation for damage.				
Implementation timing	2019/20 – 2023/24				
CAPEX phased forecast $ million (2019 Real)[1]	2019/20	2020/21	2021/22	2022/23	2023/24
	$4.04	$3.82	$3.71	$3.63	$3.6
OPEX phased forecast $ million (2019 Real)[1]	2019/20	2020/21	2021/22	2022/23	2023/24
	$3.18	$3.18	$3.18	$3.18	$3.18
Total forecasts $ million (2019 Real)[1]	**CAPEX Total - $18.8**		**OPEX Total - $15.9**		

1.1 Strategy Overview

Essential Energy is committed to using reasonable and practical methods to deliver cost effective power quality (PQ) solutions within its distribution and sub transmission network for its customers now and into the future. To this end, Essential Energy has established the power quality strategy set out in this document to instil a systematic and consistent approach for the effective management of the power quality compliance, associated customer complaints and new connection assessment framework across its electricity network.

This document provides direction for Essential Energy to move towards practical compliance to the relevant Power Quality (PQ) requirements as prescribed in Essential Energy's Electricity Supply Standard (CEOP8026) over the 2019-2024 period.

Increased customer expectations attributed to a greater reliance on electronic equipment, and an increase in small scale solar embedded generation has led to a growing trend in actionable PQ complaints. Customer expectations are expected to continue to increase with the uptake of storage technologies and electric vehicles.

A more stringent approach in application of the Electricity Supply Standards has led to a recent one off stepped drop in verified actionable PQ complaints. Improved scrutiny of proposed remedial projects has had positive impact on moderating project expenditures.

Essential Energy currently has a limited visibility of the power quality performance of its network which limits its ability to proactively and/or efficiently manage power quality issues. To date, the provision of capabilities for full visibility of the power quality performance of Essential Energy's entire network has been considered imprudent on economic grounds.

Essential Energy's power quality strategy is to supplement the existing reactive measures with an increase in the pro-active identification of power quality issues. The pro-active activities include, increased monitoring at critical locations, the allocation process of large embedded generations connections, and the development of capability to investigate and ensure network power quality performance is maintained within the levels set in the electricity supply standards in a timely, economic and effective manner.

Table 1 below shows the forecasted Capital and Operating expenditure necessary for the management of power quality complaints and power quality monitoring in zone substations.

Forecast capital investment is based on the weighted average of the actual annual power quality capital project expenditure for the past 5-year period of 2009-2014 and indexed annually by 1.0% to account for the anticipated growth trend in power quality complaints.

[1] Forecasts are exclusive of labour and material cost escalation

Forecast operating expenditure is based on the average of the annual power quality operating project expenditure for the 3-year period of 2009-2012 and indexed annually by 1.0% to account for the anticipated growth trend. Operating expenditure primarily covers the costs for power quality technician investigation activities, 230 V migration program activities and associated minor network remedial works.

Table 1 – Power Quality Investment Forecasts

	19/20	20/21	21/22	22/23	23/24	5 Yr. Total
Capital Investment forecast	$4.04	$3.82	$3.71	$3.63	$3.6	**$18.8**
Operating Expenditure forecast	$3.18	$3.18	$3.18	$3.18	$3.18	**$15.9**

Note: all forecasted costs used throughout this document use real 2017 direct cost dollars with no CPI adjustments

Investment Need and Justification Summary

- Obligatory investments required to rectify power quality issues resulting from customer complaints and verified as being outside the levels prescribed by Electricity Supply Standards. Includes rectification of ‘Shocks & Tingles’ reported incidents.
- Move towards compliance with Electricity Supply Standard – CEOP8026 that incorporates statutory and/or mandatory provisions of Australian Standards and National Electricity Rules (hereafter referred to as NER). The non-compliance issues relate to steady state voltage levels, harmonic emissions and voltage fluctuations.

Risks of Deferral or Cancellation of remedial project expenditure

- Breaching requirements of schedule 5.1 of the NER, supply quality standards as prescribed by Australian Standards AS61000 series, AS60038, Service and Installation Rules of NSW or NSW License Conditions.
- Damaged to Essential Energy’s Reputation
- Compromise public safety, e.g. shocks and tingles
- Damage, degradation, reduced life and malfunction of customer equipment and Essential Energy assets.
- Customer nuisance, disruption and dissatisfaction
- Loss of customer production and income
- Compensation claims for customer damages/losses
- Customer outages due to overloads

2. Introduction

This document sets out Essential Energy's Network Strategy - Power Quality as applicable over the 2019–2024 regulatory period.

2.1 Purpose

The purpose of this document is to provide direction to the business's asset management functions and ensure the effective and coordinated management of power quality compliance and associated customer complaints and mitigate power quality issues within Essential Energy's distribution network for the 2019-2024 period.

Essential Energy has developed this strategy to instil a systematic and consistent approach to the management of power quality throughout the asset management functions and valuing of investments. Consequently, this document provides guidance to, and is a key input for, relevant investment cases.

A key aspect of this strategy is to provide ongoing direction to migrate the business towards achievement of active compliance with relevant power quality requirements as stipulated in Supply Standards: Electricity Supply Standard (CEOP8026), that incorporates statutory and mandatory provisions of Schedule 5.1 of National Electricity Rules (Network Performance Standards), Service and Installation Rules of NSW, relevant Australian Standards and AEMO requirements in relation to connection of large Embedded Generators.

2.2 Scope

This strategy covers measurement, monitoring, management, and improvement of power quality across Essential Energy's sub-transmission and distribution network. It applies to the sub transmission and distribution network assets or its associated assets, but does not apply to network reliability and customer supply outages. For details of the strategy applicable to managing network reliability reference should be made to Essential Energy's Reliability Strategy (CEOP2463).

2.3 Information sources

This strategy has used information from the following sources:

> Electricity Supply Standards CEOP8026 [incorporates the statutory and/or mandatory provisions of AS/NZS 61000 series of Australian/ New Zealand Standards, AS60038, AS 61000.3.100, NER (National Electricity Rules), Service and Installation of NSW & NSW Licence Conditions]
> Network Planning Guidelines CEOP8003
> Capital Contribution Policy CEOP8019
> Network Planning Database and C55
> Power Quality Database
> CMS Database (Contact Management System)
> LV Shocks & Tinges Policy CEOP2189

2.4 Performance measurement and reporting to regulators

Essential Energy is required by the Electricity Supply Regulation 2008 (Safety and Network Management), to measure and report on network performance in its Electricity Network Performance Report. The report is prepared annually for submission to the regulator and sets out, among other things, the number of power quality complaints received that relate to quality issues such as voltage, current and other power quality parameters.

In addition to power quality complaint reporting, the following must also be reported:

> A commentary of the technical service standards used and where they may be obtained.
> Issues identified with power quality.
> A description of the method of monitoring supply quality.

- Performance data available for the current year and the previous year.
- A description of the results of the performance data and any conclusions drawn.

Power quality performance measurement and related reporting structure provides the feedback mechanism to gauge the effectiveness of strategies, plans, and expenditure work programs of power quality related investments.

2.5 Reporting responsibilities and review timeline

This strategy is an evolving document and requires periodic review to ensure it leads to the desired outcomes. Table 2 sets out the work group responsible for each part of the strategy and frequency of reports and review.

Table 2 - Work group responsibilities

Category	Activity	Work Group	Frequency
Reports **Power Quality complaints & Performance based on Customer complaints**	Monthly power quality performance reports Quarterly Network Complaints Investigation report	Power Quality Team Leaders (Network Services)	Monthly to Network Planning Group
	Report performance annually in the Electricity Network Performance Report Annual Regulatory Information Notice (RIN) Report		Annually to Director General Resources and Energy Annually to the Australian Energy Regulator (AER)
Power Quality Performance Reporting (ZS PQ Monitoring Program)	Report Performance Annually (based on high accuracy Class A fixed PQ Monitor data at ZS) in the Electricity Network Performance Report	Power Quality & Reliability Group (Asset Management)	Annually
Power Quality Strategy Review	Review of the Network Power Quality Strategy following the consideration and monitoring of emerging issues, opportunities and organisational requirements.	Network Strategy and Risk, Network Optimisation, Asset Engineering.	Annually or as required

3. Background

The purpose of this section is to provide background information on power quality and related issues that are relevant to the development and understanding of the power quality strategy for Essential Energy as detailed in section 6.

3.1 Power Quality

Power quality is the measure of how far the voltage delivered to the customer deviates from a perfect sinusoidal source.

The customers perspective of power quality is any power supply condition that causes appliances to malfunction or prevents their use.

Typical variations to the sinusoidal source are classified into distinct disturbance types. The distinct disturbance types commonly identified are as follows, interruption, voltage sag, voltage swell, voltage unbalance, transients, noise, flicker, harmonic distortion and frequency variation.

Australian standards specify limits for steady state voltage, flicker, voltage unbalance, and harmonics.

3.2 Power Quality Issues at Essential Energy

Typically, complaints regarding power quality issues include, but are not limited to, the following:

- steady state voltage variations from acceptable levels (over voltage and under voltage)
- voltage sags (dips) and swells
- voltage unbalance
- excessive harmonic voltages and currents
- excessive voltage fluctuations and flicker [including Rapid Voltage Changes (RVCs)]
- television and radio interference

Steady state over voltage, poses the most significant ongoing performance and safety issue for Essential Energy within the current environment, followed by voltage fluctuations/flicker and harmonic issues. The biggest issue that Essential Energy facing in the future will be the penetration of large scale embedded generator connections, solar farms in particular which may cause harmonic and voltage fluctuations/ flicker and rapid voltage changes (RVC) issues in the network if not correctly addressed.

Based on connection applications received it is anticipated that the amounts of harmonics injected into the Essential Energy network will increase. To mitigate the effects of this harmonic distortion Essential Energy is likely to need to invest during the 2019-24 period in harmonic filtering and static var (volt-ampere reactive) compensation where there are high harmonics or a risk of voltage collapse respectively. Two locations that have been identified as requiring attention are Hay and Hillston zone substations.

The figure 1 below shows the current and future Embedded Generation map based on the Major Connections Applications received as of end of August 2017.

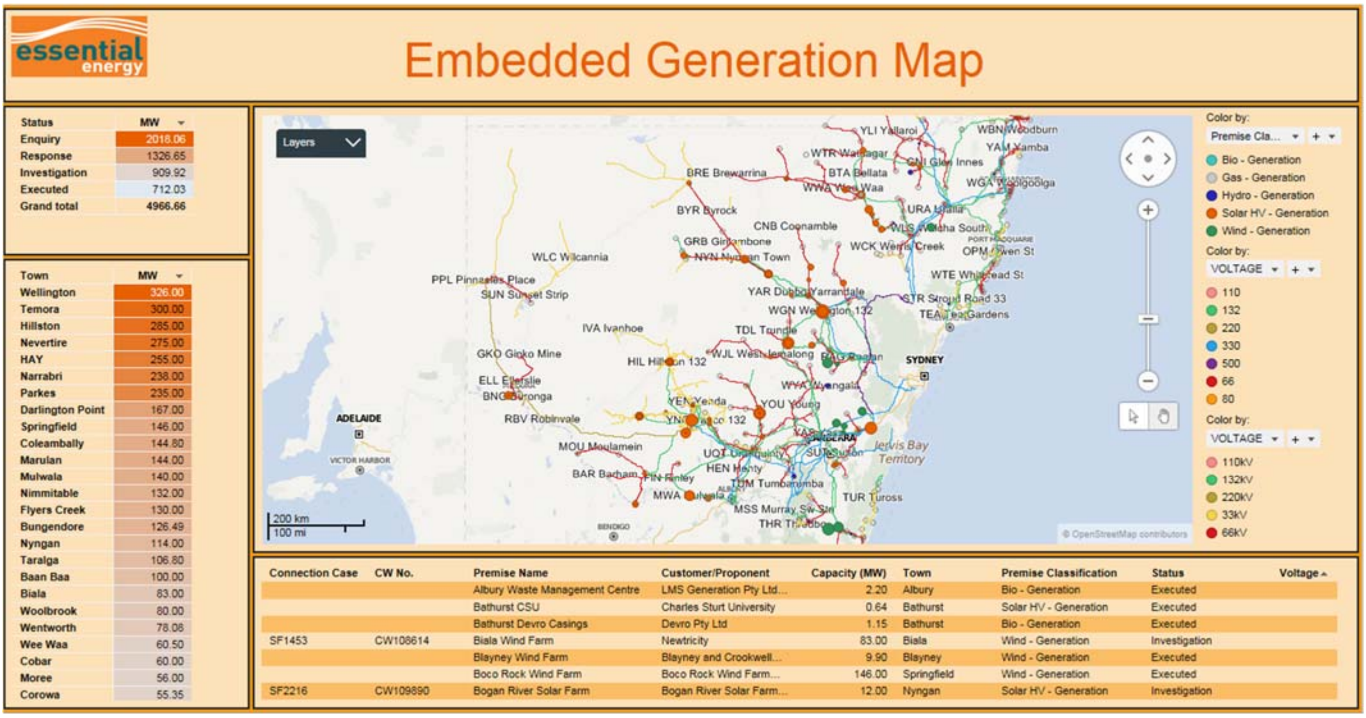

Figure 1 – Embedded Generation Map of Essential Energy[2]

As can be seen from figure 1, there is very high penetration of large solar and wind farms into the Essential Energy network. Approximately 5GW of Embedded Generator connections are at different stages of execution at present, the Essential Energy maximum demand is forecast at approximately 2.2GW. The highest penetration of embedded generation is Wellington and Temora with large solar farms connecting to the network at 132kV.

3.3 Customer satisfaction

The quality of supply delivered to a customer is a combined result of both the supply reliability and the power quality. Reliability of supply is addressed in the CEOP2463 Essential Energy Reliability Strategy.

As part of the network Strategy – Power Quality and in line with the asset management objective, customers receive a quality of service that is in line with community expectations, Essential Energy recognises that customers require a level of confidence in the quality of their electricity supply and has a long history of working with customers, communities and stakeholders, to identify and address quality of supply issues. Essential Energy commissioned a Customer Engagement Project[3] in 2017, to understand customer concerns and priorities. The Woolcott Research Group was engaged by Essential Energy to conduct AER Proposal Stakeholder Engagement Project in February 2017 (Figure 2). The findings of this research will be utilised within this strategy when the results are available.

With the advancement of technology, Essential Energy understands that our customers are seeking more flexible communication channels. Consequently, Essential Energy is progressively introducing technologies that allow customers to advise us of power quality complaints through simpler, more effortless channels such as social media. Further to this, the business is planning to increase the communications channels available to customers for planned and unplanned outages.

[2] Updated on 1 August 2017

[3] Essential Energy, 2017, 'Customer Engagement Project', Belinda Kallmier – Manager Customer Service at Essential Energy.

Figure 2 – Rolling 12 Month Snapshot of Essential Energy's Customer Engagement Project

Essential Energy will continue to engage with customers and stakeholders to ensure concerns and preferences are understood to inform the network management plan and strategically address Power Quality issues.

From the customer's perspective, it is vital that power quality issues are addressed promptly, as poor power quality can cause malfunction, premature ageing, or damage to customer equipment, and may be an indicator for potential serious underlying safety issues.

Poor power quality and supply interruptions can have a negative bearing on regional economies through increased costs or loss of productivity, this was noted in the 'Electricity Supply Issues for Farmers' report commissioned by Consumers Advocacy Panel and released in February 2013.

This combination of increased customer expectations, the proliferation of sensitive customer equipment across all sectors, embedded generation and storage technology is driving growth in actionable power quality complaints as well as network power quality management issues. There is a growing gap between the power quality that can be delivered and customer expectations in many parts of the network.

3.4 Network related issues

Essential Energy's electricity network has developed from 1940 to the present using planning, design and construction standards appropriate to the time of the development. Over time there have been significant changes to these standards as well as customers' equipment, and expectations of power quality.

Technical impacts on poor power quality

Customers utilise many devices in their installations that will draw harmonic current from the network potentially distorting the sinusoidal waveform supplied. The number of devices drawing harmonic current has increased with time and will continue to increase as the flexibility and energy reduction potential of full electronic control is exploited in more customer equipment. Distortion of the voltage wave form can lead to additional losses within the network as well as mal operation or accelerated failure of equipment.

Harmonic currents when combined with high grid impedance increases voltage distortions in the network and in extreme situations can shift zero-crossing points of the supply voltage waveform. This increases noise and electromagnetic interference in the network. Transformers, underground cables and power factor correction capacitors are the network equipment most impacted by harmonic currents.

Distributed Generation

The distribution grid was originally planned to deliver energy reliably and efficiently from the transmission grid to customers. The customers on the distribution grid acting as a load, the availability and affordability of small scale generation, battery storage, electric vehicles and potentially demand response (DR) means that the distribution network can no longer be considered a simple load. Small scale generation connected to the distribution network is mostly photovoltaic connected by inverters to the network, there is a small penetration of other technologies most of these are connected via inverter.

Essential Energy plans to develop tools and processes to make use of the power quality information gathered from power quality monitors and to build models that accurately represent the dynamic properties of the distribution and sub transmission networks. The development of these tools and models will enable the integration of embedded generation into the network without adverse impact on existing customers and indicate any mitigation strategy required.

230 Volt Migration Program to comply with Service and Installation Rules of NSW and Australian Standards (AS60038 and AS61000.3.100)

Historically, the setting of distribution transformer taps and voltage regulating relays was done to a 240V standard using setting philosophies that depended on the supply area. Many older distribution transformers were also designed for a 240V system, and may have a limited tapping range, or no taps. In addition, historically customer loads were smaller and more resistive in nature. Transformer tap settings have historically been set for a maximum output voltage of around 254 volts.

The recent chance to a 230V standard, and the increasing proliferation of embedded generation is contributing to voltage problems across the electrical network. A growing customer reliance on sensitive electronic equipment means that in many locations Essential Energy customers are now experiencing network voltages outside allowable limits. These factors have been steadily increasing the number of power quality complaints.

Essential Energy's current voltage limits prescribed in CEOP8026, serve as a proxy 230V standard and comply with the nominal steady state voltage limits prescribed in AS61000.3.100. This strategy promotes the gradual transition to the $V_{50\%}$ voltage range as opportunities arise. The voltage ranges are shown in table 3 below.

Table 3 - 230V Nominal Steady State Voltage Limits – per AS61000.3.100

Steady state voltage measure (10minute r.m.s)	Phase to neutral voltage limit		Phase to phase voltage limit		Single phase three wire, centre neutral, phase to phase voltage limit	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
$V_{1\%}$	216V	-	376V	-	432V	-
$V_{99\%}$	-	253V	-	440V	-	506V
Preferred $V_{50\%}$	**225V**	**244V**	**392V**	**424V**	**451V**	**488V**

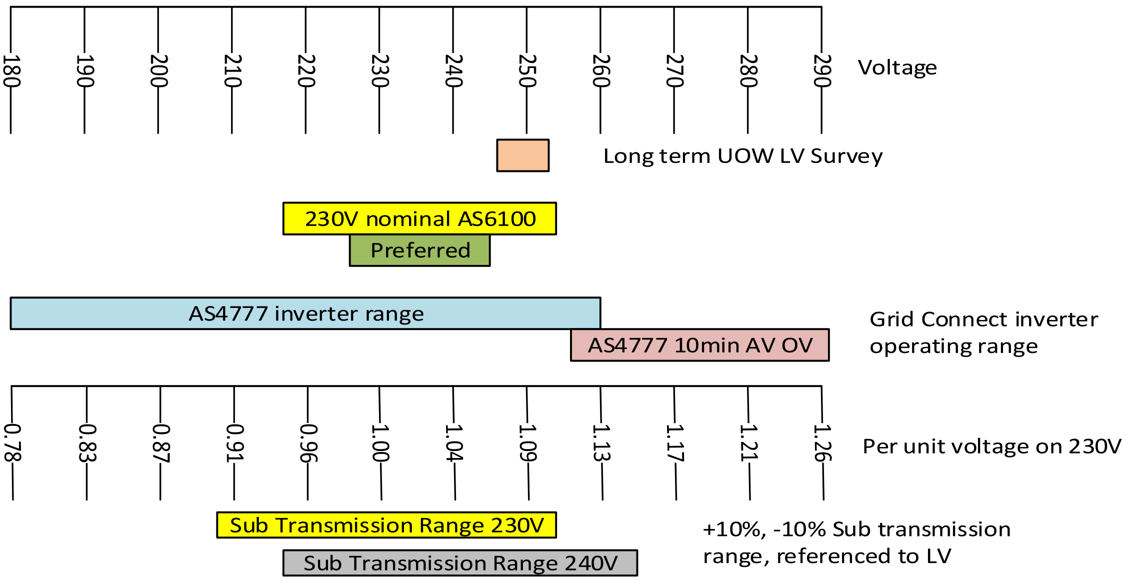

Figure 3 - Relationship between standard voltage limits and long-term survey results

Figure 3 shows the relationship between the voltages in both AS61000.3 and AS4777, AS4777 is the standard for low voltage grid connected inverters. The results of the long-term voltage study from the University of Wollongong (UOW) are also included in the chart to show the present steady state voltage conditions experienced by Essential Energy customers. The voltage range observed is at the upper end of the AS4777 inverter operating range while still being compliant with the AS61000.3.

It is proposed to investigate strategies to migrate customers to a lower voltage and reduce the voltage bandwidth experienced to improve steady state power quality.

Participation in the University of Wollongong long term power quality survey is key to the continued monitoring of our steady state voltage compliance.

3.5 Network Power Quality Surveys

The initial Long Term National Power Quality Survey (LTNPQS) report, conducted by the University of Wollongong in 2001, identified that the single largest power quality issue across Australia is that distributors, including Essential Energy, are delivering voltage at levels above the Australian Standard upper limit in many cases. These results are supported by subsequent annual long-term power quality survey reports through to the latest 2015/16 report.

Subsequent LTNPQS reports have, along with voltage levels, also identified voltage unbalance and increasing harmonic levels in recent years as potential issues in Essential Energy network.

An independent survey carried out by Electrical Consulting and Training for Essential Energy in 2008 across the full spectrum of customer types revealed steady state voltages being delivered outside or on the upper margin of the standard.

The results of these surveys confirm that large numbers of customers are receiving steady state voltages that are outside the requirements of the Australian Standards, particularly from over-voltage, and to a lesser degree from under-voltage.

Australian Energy Market Operator (AEMO) Voltage Survey

Since December 2001 Essential Energy has been monitoring the maximum demands at 200 selected residential premises scattered across EE supply area. This information is used by AEMO to establish a daily net system load profile for all the type 6 (non-interval) metering installations in Essential Energy distribution network area. These profiles are published by AEMO on weekly basis. At 73 of these sites, the collected data also provides half hour voltage measurements that allow an assessment to be made of the voltage conditions at these same sites, and by proxy, throughout the network.

The results of this survey confirm that the distribution of low voltage supplied to customers is at the upper end of the standard limits.

One impact of increased supply voltage is the inability of grid connect inverters in small scale embedded generation systems to reliably connect to the network during times of light load.

The above surveys and analysis all relate to only a very small and decreasing sample population of customer premised across the Essential Energy network. This constraint highlights the need to increase the population of power quality sampling meters and data collection across the Essential Energy network to improve the validity of analysis and accuracy of reporting.

3.6 Other emerging issues

There are also other emerging issues that are likely to impact on network power quality across the 2019–2024 period and have the potential to result in significant changes to the power quality works program. These issues are:

- Large scale solar and wind farm connections in rural networks in Australia will have impact on Essential Energy network and change of focus on the network. Recent increase in embedded generator connection applications (solar in particular) suggests that the traditional customer base with passive loads is now changing to both generation and load customer base. Considering the total generation of up to 5GW connecting to the Essential Energy network in the next few years, Essential Energy will be facing various challenges in Power Quality in the future. One of the challenges is that Essential Energy will have to install harmonic filters at selected sites to bring the existing background harmonic levels below the planning levels. This is required to accommodate new customers connecting to the Essential Energy network (large scale generation and load customers).
- Essential Energy's experience indicates that customers are increasingly comparing the services provided by Essential Energy with those provided by other network businesses, as well as with services provided by those operating in other business sectors such as banks and telecommunications. Since some retailers have introduced smart meters at customer premises some of which have capability of logging power quality data that can be viewed through smart phones, tablets etc., customers will be able to compare with the PQ levels. Therefore, PQ complaints may rise in the future and we may have to compensate customers if Essential Energy breach any of the PQ limits imposed by standards. With Power of Choice Essential Energy will have a less visibility on the network as we will no longer own the meters in customers' premises and Essential Energy will have to pay the retailer for any data other than revenue data.
- Proliferation of embedded generation – when connected to the distribution network embedded generation can have an adverse impact on voltage regulation, voltage fluctuations, flicker, supply interruptions, and harmonic distortion. Voltage rise problems are by far the major issue caused by embedded generation. However, it should be noted that embedded generation in some circumstances can also provide power quality benefits, such as power factor correction and flicker reduction.
- Migration of customers from gross metered to net metered solar embedded generation may lead to a temporary increase in complaints as equipment is re-located on rural properties.
- Emergence of electric vehicle charging.
- Network planning and expansion – the impacts of the national framework for 'Electricity distribution network planning and expansion' has implications for power quality. These include annual reporting requirements for power quality.
- The adequacy of the network – was designed and constructed many decades ago to cope with the demands of the time. Today the capability and performance requirements of the network are far more demanding and are under more scrutiny by customers, especially the embedded generator connections both large scale and small scale.

4. Performance Requirements

As per Asset Management Objective, "Comply to applicable statutory and regulatory obligations or requirements that apply to Essential Energy's management of assets" and "Asset investment programs are optimally targeted to ensure risk is aligned with the Corporate Risk Tolerance", this section provides an overview of the power quality performance criteria that Essential Energy applies to its sub-transmission and distribution network under the reliability and quality of supply requirements of the Electricity Supply (Safety and Network Management) Regulation 2008 (NSW), and as reflected in Essential Energy's Standard Form Customer Connection Contract, Electricity Supply Standards, and Asset Management Strategies/ Plans/ Investment Cases.

Set out below is a summary of the criteria that Essential Energy applies to the management of power quality, including references to relevant standards:

- Frequency of supply – is a measure of the rate in cycles per second (Hertz) at which the alternating voltage and current oscillate between peak forward and reverse values. The 'nominal operating frequency band' as provided by the National Electricity Rules is set at 49.85 Hz and 50.15 Hz. However, Essential Energy does not control the frequency of supply and cannot warrant that the frequency will comply with any standard.
- Range of supply voltage – is the acceptable range at which customers should be supplied voltage. For LV customers, Australian Standard AS 61000.3.100:2011 (Amendment 2016) and AS 60038:2012 prescribes that under normal service conditions, the received voltage at the customer's connection point should not differ from the nominal voltage of 230/400V by more than +10%, -6%. Essential Energy's Electricity Supply Standards CEOP8026 section 3.3 currently prescribes a less onerous +10%, -2% for the customer to minimise the low end received voltage impact on customers and existing older 240V equipment.
- To transition to a lower maximum distribution voltage and provide voltage rise headroom for embedded generation, over the long term, the maximum average network operating voltage will be gradually reduced from +10% (253V) to +8% (248V). This reduction will in effect lead to a tighter distribution voltage bandwidth, and commence a move towards the AS61000.3.100 recommended preferred median voltage upper limit of 244V. However, at this time, the maximum customer receiving voltage limit of +10% (253V) currently prescribed in electricity supply standards for the customer's premise will remain unchanged. The minimum prescribed low end receiving voltage will also remain unchanged at -2% (225V).
- Voltage fluctuations – are short duration variations in voltage levels due to changes in, or switching of loads within the supply network. Australian Standards AS/NZS 61000.3.3, 61000.3.5 and AS/NZS TR IEC 61000.3.7 prescribe limits for voltage fluctuation caused by equipment under normal operation to prevent annoying lamp flicker or, in extreme cases, damage to electronic equipment.
- Voltage dips/sags – are a single short duration reduction in the supply voltage level generally due to faults on the distribution system, motor starts or the operation of other large current loads. Electricity Supply Standards CEOP8026 section 3.5.
- Transients – are short-term distortions (milliseconds) to the voltage waveform. They are generally caused by lightning (impulsive) or capacitor switching (oscillatory), and to a much lesser degree by system faults or load switching. Electricity Supply Standards CEOP8026 section 3.7.
- Step and touch voltages – can occur during distribution system faults where substantial voltage differences can occur within the ground or between metallic systems and earth in the immediate area of the fault. Requirements for design, installation and maintenance of earthing systems to mitigate risk are outlined in the ENA Earthing Guide and Australian Standard AS/NZS 7000.
- Voltage unbalance – is an unbalance between the phases of the supply system and can occur because of unbalance in customer loads and unbalance in distribution system phase loads and impedances. The National Electricity Rules (NER) and AS/NZS 61000.3.13: 2012 and AS/NZS 61000.3.14 Standards, prescribes the limits for voltage unbalance, i.e. Negative sequence voltage unbalance factor. Overheating and de-rating of induction motors is a major adverse impact of voltage unbalance.
- Direct current – is the one-directional flow of electric charge and may flow in the neutral conductor of a low voltage distribution system due to customer equipment with non-linear load characteristics. Electricity Supply Standards CEOP8026 section 3.10.
- Harmonic content of voltage and current waveforms – harmonic distortion is created by customer equipment with non-linear load characteristics such as rectifiers and variable speed motor drives. Harmonics can cause interference to customers' equipment, overloading of equipment and communication system disruption. The NER, AS/NZS 61000.3.6 and the ENA Guide for Power Quality prescribe the limits for harmonics for up to the 40th harmonic and the total harmonic distortion (THD). The methodology for allocating harmonics for individual connections is also included in the ENA Guide to Power Quality.
- Inter-harmonics interference – is caused by the presence of sinusoidal waveforms at frequencies lying between non-integer multiples of the supply frequency of 50 Hz (Electricity Supply Standards CEOP8026 section 3.12).
- Mains signalling interference – Essential Energy uses signal voltages injected in the distribution system at various frequencies primarily for the control of off-peak appliances. The signal can cause interference like inter-harmonics

distortion if the signal level is too high. Australian Standard AS/NZS 61000.2.12 prescribes acceptable signalling voltage levels.
- Noise – power system components can cause audible and electronic noise. Australian Standard AS/NZS 2344 prescribes acceptable levels for audible noise and interference.
- Notching – is a disturbance of opposite polarity to the normal voltage waveform and can cause interference to customers connected to the distribution system. Australian Standard TR/IEC 61000.3.6 prescribes acceptable notching levels.

For further details of these criteria, reference should be made to Essential Energy's Electricity Supply Standards (CEOP8026).

As recognised above, a complex set of power quality performance criteria defines the required level of performance. As Essential Energy has limited visibility of its network, inadequate power quality performance is currently addressed mainly on a reactive basis.

Provision for full visibility of the technical performance of every part of Essential Energy's network has to date been considered imprudent in the past on economic grounds.

As part of the high voltage customer connection process, Essential Energy must check the background power quality measurements minimum of over a week period to provide the power quality allocations to new customers. Essential Energy have purchased Class A Portable Power Quality Analysers carry out these assessments. These portable Class A Power Quality monitors will be used to investigate Power Quality complaints in the future.

Essential Energy implemented a power quality monitoring in zone substations project to understand the power quality levels in various parts of the Essential Energy network. During the 2014-19 regulatory period, it is planned to complete the installation of Class A power quality meters in 30 zone substations at critical locations on the electrical network. The installation of further meters is planned for the 2019-24 regulatory period.

The power quality management process is progressing towards a proactive programme, the above criteria can be considered targets for the power quality performance of the Essential Energy network. The monitoring of power quality in zone substations will over time allow the assessment of the performance of the network against these targets. The measurement of these parameters will assist in preparing Essential Energy for the possible introduction a power quality service target performance scheme.

5. Performance and Gap Analysis

This section sets out analysis of the power quality performance of Essential Energy's network. In addition, this section also considers trend analysis and causal analysis to identify the drivers of power quality management needs over the 2019-2024 period.

5.1 Network power quality performance

As noted in section 4, Essential Energy cannot currently directly measure the power quality performance of the distribution network other than through limited sampling techniques or portable Class A PQ meters used as part of the high voltage connections power quality allocations process. Consequently, the number of legitimate actionable customer complaints in each calendar year is used as a proxy measure of this performance.

Figure 4**Error! Reference source not found.** shows the historical number and trends of power quality complaints investigated over the 2009/10 to 2015/16 period. Analysis of the complaint data shows that during this period:

- Essential Energy received an average of approximately 1,500 power quality complaints each year.
- Of these, on average approximately 1,200 were deemed valid power quality complaints that were referred to power quality technicians for further investigation.
- Of these complaints investigated, on average 700 were recorded as legitimate actionable complaints requiring rectification of network performance to be resolved.
- The remainder of the complaints received involved causes that were not network related, or no cause was identified.

Figure 4 shows the trend in power quality complaints and the long-term forecast in power quality complaints. There is a slight declining trend in the number of complaints received and an increase in the actionable complaints. The increase in actionable complaints is possibly linked to the increase in small scale solar capacity installed as shown in figure 5. The forecast level of power quality complaints is based on the average of the previous seven years.

Figure 6 shows the average number of power quality complaints received annually based on the type of complaint. The three largest contributions to power quality complaints would appear linked to embedded generation or the impact of embedded generation. The data is based on an analysis of the number of complaints received and actioned over the last five years.

The electricity network is experiencing rapid change driven by customers as they embrace technology, take control of their energy use and support action on climate change. As Essential Energy addresses, valid power quality complaints on a reactive basis and presently with little proactive management of power quality, it is expected that this trend will change over the 2019-2024 period. Moreover, as noted in section 3, with the gradual migration towards a nominal 230 Volt standard, the proposed reduction of maximum voltage levels, the proliferation of embedded generation devices together with a greater customer expectation of power quality, it is likely that this growth rate is conservative.

In recognition of emerging factors as discussed in section 3, changing customer behaviours, and within the context of ongoing technological change as well as associated changes in our society and regional economies, it is likely that the growth trend in valid actionable complaints will continue over the 2019-2024 period. To arrest this trend,

Essential Energy has developed the power quality management strategy set out in section 6.

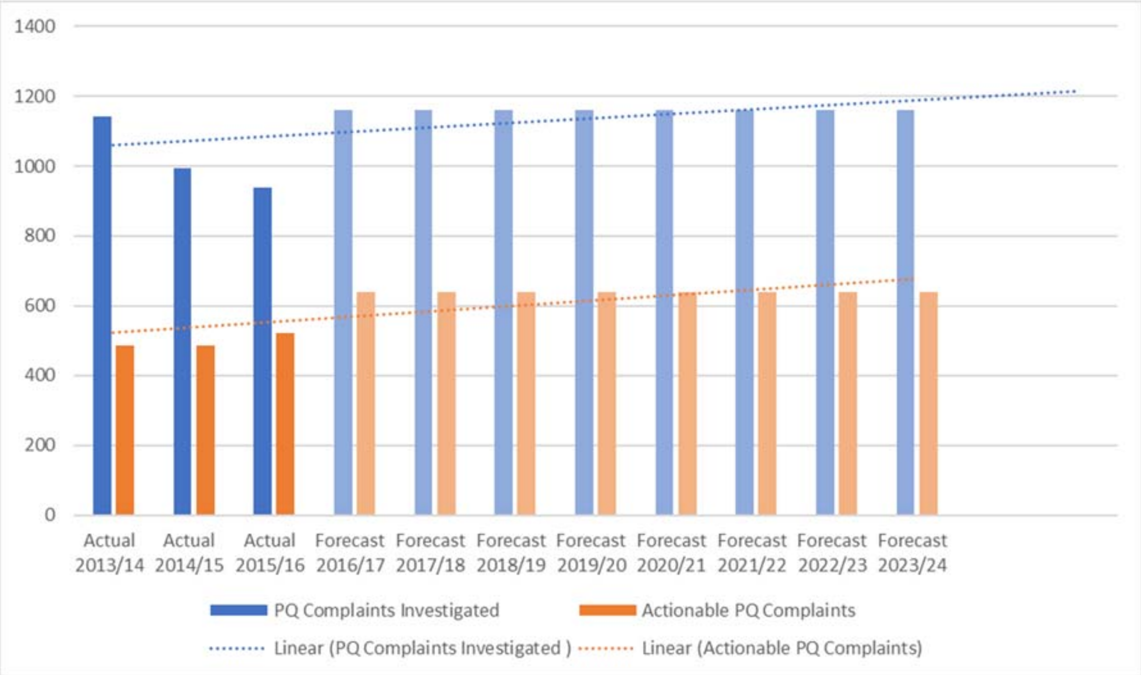

Figure 4 – Power Quality complaints

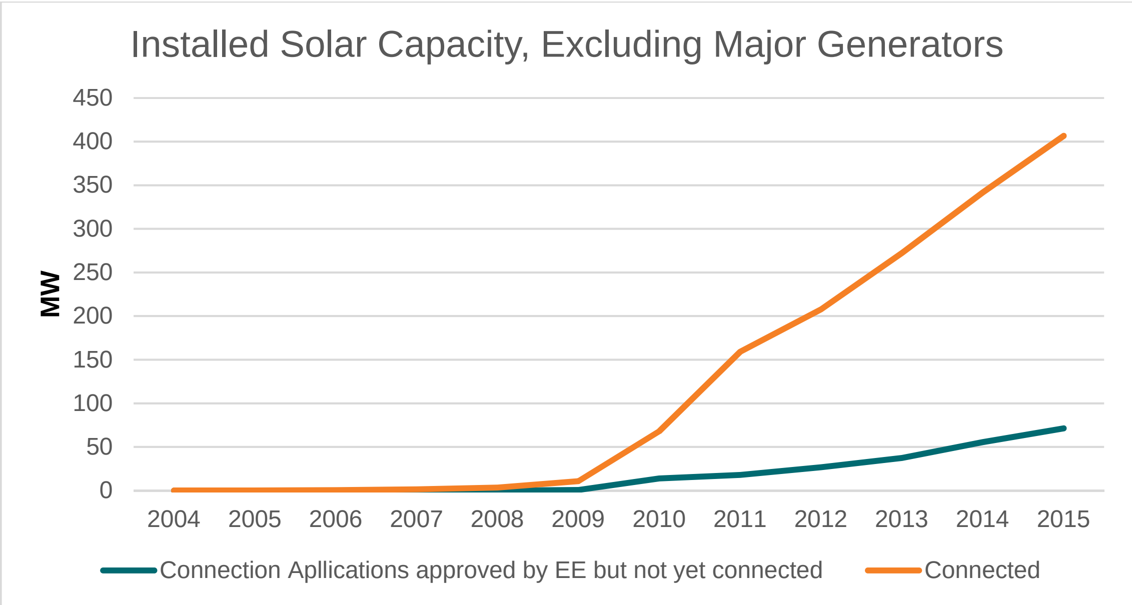

Figure 5 – Total Installed Solar Capacity in Essential Energy's Network

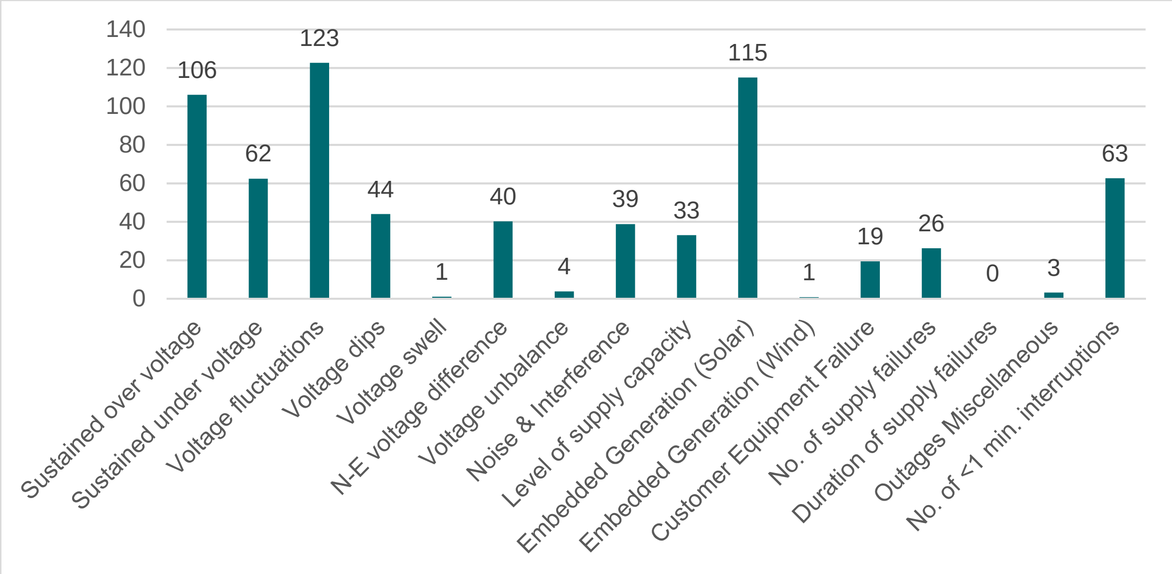

Figure 6 – Network Related Power Quality Complaint Types

6. Power Quality Strategy

This section sets out Essential Energy's strategy to manage the power quality of its network over the 2019-2024 period and migrate towards practical compliance with the power quality standards as discussed in section 4.

In developing this strategy, consideration has been given to the background issues discussed in section 3 as well as alignment with the broader asset management strategies of the business.

6.1 Network Power Quality Strategy

The power quality strategy aims to provide ongoing direction to migrate the business towards achievement and maintenance of practical compliance with relevant power quality requirements as stipulated in Electricity Supply Standard CEOP8026 (detailed in section 4), Australian Standards, Service and Installation Rules of NSW and National Electricity Rules (NER) and to address the range of issues detailed in section 3, at the lowest sustainable cost.

Due to current limited visibility of network performance, this will primarily be achieved by reacting to received power quality complaints and data from power quality monitoring sites. Where electricity supply standard non-compliance issues are identified during the investigation process they will be rectified in a timely, economic and effective manner.

To meet growing customer expectations of greater confidence in their supply and address the growth of embedded generation technologies while maintaining performance against power quality standards, this strategy also drives progressively towards adopting more proactive power quality management measures.

To achieve these outcomes Essential Energy's power quality strategy consists of the following strategic elements:

Proactive Initiatives (medium to longer term)

- Power quality monitoring in zone substations, permanent class A power quality meters to be installed in 30 zone substations by the end of the 2018/19 fiscal year. This installation project is to continue into the next regulatory period.
- The 230V Migration program to meet requirements of Australian Standards compliance with AS60038 and AS 61000.3.100 (Australian Power Quality Standard) and Service and Installation Rules of NSW.
- Management of high voltage feeder voltage profiles and performance.

> New high voltage connections management process to manage new or additional load and generation impacts on Essential Energy network by means of the power quality allocation process and network modelling assessments as required by National Electricity Rules (NER) Schedule 5.1
> Low voltage power quality allocations process as required by Service and Installation Rules NSW and Australian Standards (e.g. AS/NZS 61000.3.14)
> Monitoring of network power quality performance that will help Essential Energy to build a network wide database to identify potential power quality problems.

Reactive Measures (short to medium term)

> Customer complaints are investigated on regular basis.
> Temporary monitoring used to investigate complaints.
> Alternate solutions are investigated and assessed.
> Targeted solutions are implemented.
> Customers are advised of outcomes.
> Post implementation reviews are undertaken to assess effectiveness.

SWER Network Initiatives

> SWER line power quality monitoring program.
> SWER network performance review

Each of these strategic elements are discussed in more detail in sections to follow, and where relevant, reference to further supporting information is provided.

6.2 NER Compliance

The National Electricity Rules (NER) require Essential Energy to use reasonable endeavours to design and operate its transmission (i.e. sub-transmission) and distribution network and to include suitable conditions in connection agreements to deliver defined outcomes at connection points in terms of voltage ranges, voltage fluctuations, voltage harmonic or voltage notching distortion, and voltage unbalance.

Chapter 5 (Network Connections) of the NER sets out the rules in relation to: connection to Essential Energy's sub-transmission and distribution networks; the planning and development of these networks; and the system and performance standards to which our networks (and plants connected to our networks) must be designed and operated.

The relationship between Essential Energy and registered participants in the National Electricity Market is managed on a case by case basis based on the principles outlined in Chapter 5.

Table 4– NER Requirements on Power Quality

NER Clause	Transmission Network[4].	Distribution network	Compliance Requirement
S5.1a.4 power frequency voltage system standard	Applies	Applies	Essential Energy to set appropriate voltage ranges for **all** connection points (voltage ranges are given in AS60038:2012 and AS61000.3.100:2011).
S5.1.4 magnitude of power frequency voltage network performance requirement	Applies	Does not apply	Manage compliance via the transmission planning & design process, still good engineering practice to manage distribution network appropriately but **no** need to report on distribution network compliance with this clause in the NERs.

[4] Transmission Network criteria applies to Essential Energy's Sub Transmission Network which consists of 33kV and above network voltages of up to 132kV

NER Clause	Transmission Network[4].	Distribution network	Compliance Requirement
S5.1a.5 voltage fluctuations system standard	Applies	Applies	Essential Energy is responsible for Establishing planning levels for all new connections to ensure Voltage Fluctuations (Flicker) emission levels are kept below the planning levels (Note: Essential Energy Planning Levels are subject to the connection agreement with the upstream NSP. In most cases, Essential Energy and TransGrid connection agreement limits apply).
S5.1.5 voltage fluctuations network performance requirement	Applies	Applies	Require all new connections to comply with planning levels via a connection agreement. The NSP (Essential Energy) must allocate flicker emission limits in response to a connection enquiry or an application to connect and evaluate the acceptability for connection of fluctuating sources (As per AS 61000.3.7 and ENA Guideline for Power Quality – Flicker)
S5.1a.6 voltage waveform distortion system standard	Applies	Applies	Essential Energy is responsible for establishing planning levels for all new connections to ensure voltage harmonic or voltage notching distortion emission levels are kept below the planning levels. (Note: Essential Energy Planning Levels are subject to the connection agreement with the upstream NSP. In most cases, Essential Energy and TransGrid connection agreement limits apply).
S5.1.6 voltage waveform distortion network performance requirement	Applies	Applies	Require all new connections to comply with planning levels through use of connection agreement. The Essential Energy must allocate harmonic emission limits in response to a connection enquiry or an application to connect and evaluate the acceptability for connection of distorting loads/generators (As per AS61000.3.6 and ENA Guideline for Power Quality – Harmonics)
S5.1a.7 voltage unbalance system standard	Applies	Applies	Voltage unbalance requirements for all connection points are set in this clause.
S5.1.7 voltage unbalance network performance requirement	Applies	Applies	A TNSP must balance the effective impedance of the phases of its network, and a DNSP must balance the current drawn in each phase at each of its connection points, to achieve the required average negative sequence voltages. Current balance is to be achieved by requiring connection applicants to balance the currents drawn, and by limiting the voltage unbalance caused by the network. Manage transmission phase impedance balance via the planning & design process (To achieve average levels of negative sequence voltage at all connection points that are equal to or less than the values set out in Table S5.1a.7, Essential Energy has followed the ENA Guideline for Power Quality – Unbalance to establish the method to allocate unbalance limits for new connections).

Schedule 5.1a sets out system standards for the performance of the power system. The term “power systems” is defined broadly as the electricity power system of the national grid, including associated generation, transmission, and distribution networks, operated as an integrated arrangement. The schedule states that the system standards that have been established are necessary or desirable to enable safe and reliable operation of the facilities of registered participants and equipment, could be reasonably considered good electricity industry practice, and seek to avoid the imposition of undue costs on the industry or registered participants.

Schedule 5.1 (Network performance requirements) sets out the planning, design and operating criteria that must be applied by network service providers to their networks, and describes the requirements on NSPs (Network Service Providers) to institute consistent processes to determine the appropriate technical requirements to apply for each connection enquiry or application for connection with the objective that all connections satisfy the requirements of this schedule.

The **Error! Reference source not found.** gives an overview of the power quality system standards and performance requirements that apply to Essential Energy’s sub transmission and distribution network.

6.3 Investigation of customer complaints

The management of power quality issues are primarily dependent on customers notifying Essential Energy of any suspected power quality problems. Customer complaints are received are logged for action in Essential Energy's Contact Management System (CMS).

Suitably qualified staff then assess the customer complaints received to determine the nature of the complaint and determine if any immediate action is needed (i.e. for safety related issues), consider known issues existing in the area, or if the complaint appears valid and requires further investigation. Subject to this assessment, power quality technicians or other appropriate staff are deployed to investigate the nature of the complaint and where possible undertake rectification, make safe, or recommend further investigation or work.

During the investigation process, the customer is consulted and kept informed of the schedules, progress and outcomes of the investigations. The detailed process of managing power quality complaints are recorded in the Power Quality Database in Lotus Notes.

6.4 Temporary monitoring is used to investigate complaints

Following initial investigations, portable power quality monitors may be deployed to monitor power quality at the customer's premise and in surrounding area. Other power quality monitoring data that may be available in the area will also be assessed. The results of this monitoring are assessed against the power quality criteria discussed in section 4.

This approach of receiving customer complaints and installing temporary monitoring devices is necessitated by the limited visibility of network performance. However, like all other network service providers in Australia and globally, Essential Energy is progressively leveraging modern and increasingly economic technologies to provide critical network performance information. Essential Energy's power quality monitoring in zone substation project is the first of those initiatives which will continue to be installing Class A permanent monitoring devices to capture zone substation power quality information on the network.

6.5 Alternate solutions are investigated and assessed

In co-ordination with the power quality technicians, network planners and power quality section staff to assess alternative solutions on technical and economic merits, the preference is given to the least cost option where it provides a solution for the customer and meets the prudent future needs of the network development strategy for the area in terms of power quality.

To arrive at a suitable solution, consideration is given to:

- historic and known power quality performance and trends in the area
- trends of population, economic activity and load growth or decline in the area
- abnormal weather events that impact on power quality (e.g. prolonged hot weather period)
- impacts of embedded generation (both small scale and large scale)
- historic network voltage studies and protection studies, loading of feeders and system assets, zone substation voltage regulation performance
- condition of the network in the area including maintenance
- customer expectations, concerns or issues raised

Visual inspections of the network in the area may also be carried out, along with consideration of customer equipment or embedded generation to identify any obvious causes that may be contributing to poor power quality.

All power quality CAPEX remediation projects will be managed through C55 and are the subject to scrutiny by the local network planners to ensure appropriate solutions are applied. Further, all power quality remedial projects are subject to individual investment cases, approvals and cost monitoring. This is to ensure that all power quality remediation expenditure is appropriate, prudent and efficient.

6.6 Customers advised of outcomes

The customer is advised by written correspondence of the findings of an investigation. Where a network constraint has been identified that Essential Energy has responsibility for, the customer is advised on what remedial actions Essential Energy plans to take and when they are likely to occur. Alternatively, the customer is advised that the quality of supply is within the limits given in the relevant standards and therefore no further action is required to be taken by Essential Energy. If the investigation identifies a problem within the customer's installation the customer is advised and where possible suggestions on remedial actions that the customer can undertake themselves to eliminate or improve their Power Quality is offered.

6.7 Targeted solutions are implemented

Once investigations are complete, a solution specifically targeted to the identified cause of the power quality issue is developed.

Solutions may include (but are not limited to):

> Rectification of distribution transformer issues, including:
  - Re-tapping the distribution transformer to a more suitable tap setting if appropriate taps are available. Where the tapping range is not suitable, or where the transformer is of a fixed tap design, then the transformer is replaced with a suitable unit with a tapping range suitable for a 230V system.
  - Where the transformer is found to have an inadequate capacity for the current load, then the transformer or substation (if required) is upgraded to the nearest standard capacity transformer appropriate for the expected loading. In some situations, the installation of an additional substation rather than simply upgrading the existing transformer, may be a more prudent technical solution for the location.
  - Where transformer replacements are required they are referred to and managed by the distribution planners and C55 as a CAPEX project.

> Power quality and voltage performance issues often relate to incremental load growth or more recently embedded generation (both large scale and small scale) and can arise from undersized transformers or where customers are supplied from inadequate sized low voltage mains or service mains. In such situations, as noted above, the transformer may be re-tapped or upgraded, and any identified low voltage mains problems will be addressed. In addition, the transformer (or an additional substation) may be installed closer to the customer's connection point. For situation in high voltage connections, customers are advised install suitable power quality mitigating devices to improve power quality issues to meet the compliance requirement of the NER. If the issues caused by network elements such as harmonic amplification due to line capacitance, Essential Energy will rectify issues by installing suitable power quality mitigating equipment such as harmonic filters.

> Rectification of low voltage mains issues, including:
  - rebalance of loads and system impedance issues
  - rearrangement of low voltage feeders and open points
  - augmentation of low voltage distribution mains or
  - upgrade replacement of customer service mains
  - installation of a low voltage regulator or low voltage static var compensator.
  - installation of additional substations to reduce low voltage line lengths and voltage drops.

> Rectification of high voltage feeder voltage performance issues. This work mainly relates to voltage swings and under voltage resulting from incremental load growth. Augmentation of high voltage mains will be undertaken only if deemed a necessary solution resulting from power quality investigations. Essential Energy is implementing a practice of monitoring and managing the voltage profiles on high voltage network as discussed below.

> Consideration is also given to the following non-traditional alternative solutions:
  - Low voltage regulators
  - Power factor correction equipment
  - Dynamic var control
  - Energy storage systems
  - Power quality mitigation equipment (e.g. harmonic filters)

  - Four quadrant inverters
  - Control of grid connected inverter power factor.
  - Demand management and load reduction initiatives (refer Demand Management Strategy CEOP1121)
- Where a customer's installation or connected equipment is identified as the cause of the power quality issue, a defect notice will be issued to the customer requiring them to rectify their installation to comply with AS/NZS 3000 and relevant associated standards. In extreme cases disconnection can occur where compliance cannot, or is not, achieved in the prescribed timeframe.
- Where poor power quality performance is related to extreme events, including weather, a watching brief may also be adopted.

6.8 Post implementation reviews are undertaken to assess effectiveness

Once Essential Energy is of the view that a power quality complaint has been resolved or the problem is not associated with Essential Energy's network, the customer is advised of the outcome.

Follow up customer contact or system monitoring may also be used to confirm that a resolution has been achieved, and all such actions are recorded within Essential Energy's power quality database.

Post implementation review, as well as quarterly and annual reporting, is undertaken to validate the impact of power quality management practices and monitor overall trends, as well as assess performance and identify emerging issues.

It is a condition of Essential Energy's licence that an annual report on the number of power quality complaints received is produced.

6.9 Progress towards proactive power quality monitoring

As discussed in section 5, there is a trend of increasing actionable power quality complaints, this is expected to increase with the uptake of small scale embedded generation and the customer's ability to monitor power quality conditions.

Essential Energy intends to move towards a more proactive power quality management approach over the 2019-2024 period.

Essential Energy undertakes proactive power quality monitoring as part of the connection process large embedded generation connections. This typically establishes existing voltage levels, background harmonics, unbalance and flicker levels. The survey is repeated post connection to confirm network connection studies and that no adverse impacts on the network have arisen. This program is managed on a case-by-case basis and will continue.

This progressive move towards proactive power quality management aims to leverage increasingly available network monitoring technologies to slow the rising trend of actionable customer complaints and improve network compliance and safety. It is recognised that proactive measures may have delayed outcomes with benefits not being fully realised until some years after these management practices are implemented. Consequently, it is anticipated that customer complaint trends will continue over the 2019-2024 period.

6.10 Reduction of maximum low voltage distribution voltage for embedded generation

To provide sufficient voltage rise headroom for the growing number of small scale low voltage embedded generation (EG) connections and commence a move towards the AS 61000.3.100 preferred median range limit of 244 volts, Essential Energy will in the long term, gradually reduce the current 253V (230V +10%) maximum network voltage with high embedded generation penetration locations to a lower maximum voltage of 248V (230V +8%). This move is subject to further analysis of the impacts of such a change on network operation, performance, costs, and customers. A reduction of maximum network operating voltage will lead to a reduction of hazardous over voltage complaints.

To prevent an increase in customer over voltage complaints, the maximum customer receiving voltage limit of +10% (253V) prescribed in Essential Energy's electricity supply standards for the customer's premise will not be lowered.

To mitigate a possible increase in the number of under voltage complaints resulting from the overall lowering of the maximum network operating voltage, accompanying voltage bandwidth reduction projects may also be required in some cases.

New electrical reticulation systems such as URD subdivisions, commercial developments and similar will be designed and constructed with the AS61000.3.100 preferred median ($V_{50\%}$) operating voltage of between 225 to 244 volts in mind.

6.11 Management of high voltage feeder voltage profiles

In addition to addressing power quality complaints through specific measures as discussed above, Essential Energy is now moving towards proactively managing the voltage profile across the high voltage network to ensure that the performance is maintained within required operational limits. This involves gaining more visibility and a better understanding of high voltage network performance and operating conditions. This involves the following approaches:

- High voltage feeder loads are monitored annually, and feeders are systematically modelled and performance assessed every five years. Where performance issues are identified, remedial actions are planned to address the specific performance issue identified. These actions may include the installation of voltage regulators, capacitors, or inductive reactors, or the augmentation or rearrangement of high voltage feeders.
- A review of zone substation voltage regulation and distribution substation tap settings is undertaken and findings are implemented (as required).

  To facilitate this approach, it is necessary to capture distribution transformer tap settings and associated distribution transformer ratio information. This is a large task; it is proposed that this information can be gathered over time via substation defect rectification and maintenance activities, the substation refurbishment program and routine asset inspections. This information will be used to validate models developed for thermal ratings used in demand management, forecasting and planning.
- Voltage regulation performance at zone substations and field regulators are reviewed every five years to determine if float voltage settings and line drop compensation (LDC) are appropriate for current and predicted load profiles.
- Part of the strategy to undertake the transition to the lower voltage standard is to review voltage regulation in zone substations. Where appropriate a new float voltage and an adjustment to the load drop compensation settings may be required. In locations with a mixture of heavily loaded feeders and lightly loaded feeders load drop compensation may be delivering high voltages to customers located close to the zone substation.
- Power quality trends and causal analysis is to be used to identify and assess any systematic issues that are occurring in any specific areas. The data gathered from the permanent zone substation power quality meters will be utilised to analyse these trends.

6.12 SWER Network Initiatives

SWER Line PQ Monitoring Program

SWER system performance from a can be problematic due to the limited capability and characteristics of this type of network, the general environments that SWER networks tend to operate in, and the typical length of such networks.

To more proactively manage the performance of SWER networks, particularly voltage issues, Essential Energy has installed a limited number of power quality monitoring meters at some SWER Isolating substations to capture network power quality performance information.

As a part of the power quality monitoring meter installations program detailed in section 6.15, the deployment of power quality monitoring meters on the SWER network will be expanded. These meters will be installed at the peripheries of SWER networks (i.e. SWER Isolator and the remote end of lines) to capture network performance information. (Note: limited communication facilities in these remote areas may restrict the widespread rollout of these meters on SWER networks)

For further information on this specific strategic element, reference should be made to section ‘6.15 Distribution Network PQ Performance Monitoring’.

SWER Network Performance Review

To understand the voltage and power quality performance of the SWER network, periodic modelling and review of each SWER feeder is undertaken as discussed above. Where this periodic modelling and review identified performance issues, consideration will be given to one or more of the following solutions:

- Low voltage regulators at customer substations.
- High voltage regulators on SWER lines.
- Power factor correction equipment, including switched reactors and capacitors.
- Dynamic VAR control.
- Four quadrant inverters.
- Embedded generation.
- Battery Energy Storage Systems (BESS).
- Inverter power factor control.
- Demand management options (refer Demand Management Strategy CEOP1121)
- Capacity upgrades for overloaded SWER isolating transformers.

Notwithstanding the need to reduce system impedances to ensure correct protection operation and safety, the following traditional network solutions are considered ‘last resort’ options because of poor economic return.

- Upgrading of conductors
- Increasing SWER operating voltages to 19.1kV
- Splitting larger SWER systems into smaller systems (where economic solutions are available)
- Duplexing or multi phasing a SWER system

6.13 Manage New - or Additional – Load/Generation Impacts

Currently, there is limited management of voltage disturbing equipment being connected to the network. Only large load connections greater than 100A are notified to Essential Energy and therefore they are the only loads able to be vetted prior to connection. The majority of new and additional loads are not scrutinised prior to connection; therefore the monitoring and management of uncontrolled additional load connections can be problematic from a power quality perspective.

Where possible planning and connection officers and installation inspectors do endeavour to assess loads and equipment proposed to be connected to the network and try to identify any potential voltage disturbing loads and manage their connection in a manner that will avoid subsequent power quality issues. Essential Energy has recently introduced a power quality allocations process for both low voltage (where an installation with a single equipment drawing current greater than 75A) and high voltage connections. High voltage connections will have a detailed power quality allocation, where customer engages a consultant to provide a power quality assessment report based on the allocation given by Essential Energy. A rigorous process has been introduced to assess large scale Embedded Generators connecting to the network.

6.14 Network Asset Management Practice

Ongoing management of power quality is also supported through network asset management practice, including:

- planning practices appropriate to the requirements of our network licence and in line with good industry practice
- sound design practices appropriate for Essential Energy’s unique operating environments
- maintenance practices appropriate to achieving and maintaining the required service levels of our network within the risk tolerance of our business – particularly voltage regulation and harmonic management.
- System operations actions to restore or keep customers’ supply on during abnormal network conditions. Switching the network is to be managed to maintain voltages within the normal operating window. This is supported by improved real time monitoring of the network and operational tools.

Adherence to these practices, while not specifically aimed at management of power quality, is relied upon to support and enable Essential Energy’s power quality management strategy. Further details of these practices can be found in the Network Planning Criteria & Guidelines (CEOP8003), and the Distribution Planning Operation Manual (CEOM7092).

6.15 Distribution network power quality performance monitoring

Essential Energy utilises temporary monitoring using portable PQ monitoring devices and network modelling approaches to investigate and manage power quality complaints, the business's current visibility of network performance is limited.

Much of the information needed to understand, monitor or model the network's power quality performance is limited, and generally from temporary sources, and only valid over quite short periods of time.

To efficiently support the ongoing management of power quality over the 2019-2024 period, and enable the progressive development of a proactive management approach within the emerging context of an improved network surveillance capability, the following practices are to be implemented:

- Voltage monitoring of existing customers with power quality monitoring enabled meters will be enhanced
- Arrangements to be made with meter data agencies for the ongoing downloading and storage of power quality metering data at a cost agreed with retailers.
- VIPER will be upgraded and/or operationally maintained to facilitate improved data management practices and the automatic generation of daily power quality exception reporting. Alternatively, Spotfire may become an option to replace VIPER reporting.
- Business procedures will be enhanced, and relevant staff trained to improve utilisation of the VIPER system and the power quality database. These systems are to be integrated into routine business operations and a new power quality management module within C55 to improve reporting and support the power quality technicians.
- Working with and encouraging solar installers to report to us any non-compliant customer installations before commissioning of small scale embedded generation systems.
- Encouraging large scale solar farms to install Essential Energy power quality system compatible permanent power quality monitors in their installation enabling real time power quality monitoring by Essential Energy.

6.16 Zone Substation power quality performance monitoring

Essential Energy has an obligation under the NER to provide and co-ordinate Network Performance Requirements as described above. These requirements are defined in relevant clauses of Schedule 5.1 of the NER and include the provision of 'planning levels', 'compatibility levels', emission limits, background monitoring, compliance, and mitigation of the parameters defined in the AS/NZS 61000 Electromagnetic Compatibility (EMC) standard relating to voltage fluctuations, harmonic voltage distortion, and voltage unbalance.

Essential Energy, in accordance with the NER, is required to manage these parameters with respect to the connection of loads and generators through 'Connection Agreements' with 'Registered Participants' and other interconnected network service providers.

A prioritised roll-out of metering (power quality analysers) will be implemented across the network at pertinent zone substations. Sites will be prioritised on immediate needs and related to existing and potential major customer connection points.

Around 15 sites per year are to be installed at a cost of about $10k per site using Eberle PQI-DA Smart branded IEC 61000-4-30 Class A (Edition III) equipment, including server management and proprietary software installation.

6.17 Strategic outcomes are evaluated and built upon

The Network Power Quality Strategy is reviewed annually, or as required, to assess its ongoing relevance and ensure it is achieving the performance requirements established in section 4. Based on this periodic review, Essential Energy may modify this strategy to build upon experience, learning's and technologies to strengthen our current practices and assist in the development of proactive power quality management.

6.18 Strategic Alignment

Essential Energy aims to maximise the efficiency of its management of network power quality performance through alignment of its power quality strategy with other asset management strategies across the business.

In addition to the SWER power quality strategies, a particularly strong reliance is placed on regular and effective maintenance regimes for SWER substations, particularly the earthing systems to maintain consistent voltage levels at SWER substations (poor SWER earthing systems can lead the abnormal and fluctuating voltages, including seasonal variation of voltages).

6.18.1 Value

The corporate risk methodology uses a risk mitigation questionnaire in C55 to capture the before and after consequence and likelihood of an event once an investment has been made.

The methodology to assess risk has been to examine the financial impact of voltages outside the standard limits on customer equipment, electric motors have been selected for the analysis as the impact of voltage deviation is well documented.

The financial risk value calculation is split into two components, the estimated impact of sustained overvoltage and the estimated impact of sustained under-voltage. The overvoltage calculation is based around electrical equipment damage. The under-voltage calculation is focused around motor degradation and has been broken up into pump motor degradation to estimate the impact of under-voltage on agricultural and industrial pumping loads, and fridge motor degradation to estimate the residential impact of under-voltage.

The annualised estimated value of equipment damage due to overvoltage is divided into two parts, annual customer equipment damage, and value of lost equipment life.

Operating a motor at a voltage below the nominal operating voltage results in the life of the motor's insulation being reduced. Therefore, to determine the benefit of undertaking a project to improve the voltage profile for a given segment of the network it is necessary to estimate the prevented motor life loss.

These methodologies will be applied within C55 for the justification of network augmentation projects relating to the rectification of customer voltage complaints.

7. Power Quality Investment Plans

This section summarises the investment plans that implement Essential Energy's Network Power Quality Strategy set out in section 6. These plans are aligned with the AER's regulatory expenditure categories and the relevant linkages to the power quality strategy are identified. These plans are not covered by a separate investment case.

7.1 Capital Investment Plan

This section summarises the capital investment plan that implements those components of Essential Energy's Network Power Quality Strategy related to resolution of customer complaints and PQ mitigation strategies for allowing new customer connections both Load and Embedded Generators connecting to Essential Energy Network.

PQ Remedial Work Type	Forecast 2019/20	Forecast 2020/21	Forecast 2021/22	Forecast 2022/23	Forecast 2023/24	5YR Total Investment	5YR Average Annual Investment
ESS_35 Substation Augmentation Total - PQ Substation Augmentation	$.74	$.7	$.68	$.66	$.66	$3.44	$.69
ESS_21 LV Network Augmentation Total PQ LV Augmentation	$1.33	$1.24	$1.2	$1.18	$1.17	$6.13	$1.23
ESS_20 HV Network Augmentation							

Total PQ HV Augmentation	$.61	$.57	$.56	$.55	$.54	$2.83	$.57
ESS_1017 ZS Fixed PQ Monitoring							
Total PQ ZS Monitoring	$.34	$.32	$.3	$.29	$.28	$1.52	$.3
ESS_4100 Power Quality Mitigation							
Total PQ Mitigation Equipment	$1.02	$.99	$.97	$.96	$.95	$4.89	$.98
TOTAL ALL PQ CAPEX	$4.04	$3.82	$3.71	$3.63	$3.6	$18.8	$3.76

details the High-Level Summary of the proposed capital expenditure to implement the Network Strategy - Power Quality set out in section 6 required to achieve the performance requirements noted in section 4. Forecast volumes of work are based on the analysis set out in section 5.

The following are the five main streams of capital network investment associated with the rectification of reported and verified power quality complaints, zone substation fixed power quality monitoring and power quality mitigation strategies for new customer connections.

> **Substation Augmentation** - Primarily involves upgrading distribution transformer capacities to rectify overloaded substations that are causing or are a contributing factor of a power quality complaint or problem. This work includes:
  - Upgrading the capacity of existing transformer and associated substation equipment. In many cases the associated substation structure may also be upgraded where deemed necessary for safety or operational reasons.
  - Installation of additional new substations to relieve an overloaded transformer and reduce the length of low voltage distribution conductors between a substation and customer loads.
  - Replacement of transformers with inadequate tap change facilities or unsuitable tap range availability.

> **Low Voltage Network Augmentation** - Primarily involves upgrading the low voltage distribution network capacity to rectify voltage or capacity constrained low voltage network conductors and equipment that are causing or are a contributing factor of a power quality complaint or problem. This work includes:
  - Upgrading the capacity and voltage performance of the existing low voltage network by replacing and upgrading the existing conductors to improve voltage profiles and performance. Commonly, this work also involves replacing existing bare overhead conductors with low voltage ABC
  - Installing additional new low voltage distribution circuits to alleviate capacity or voltage constraints
  - Re-configuration of the existing low voltage network by adjusting distribution supply boundaries and load balancing to optimise voltage performance
  - Replacement and upgrading capacity of service conductors
  - Installation of low voltage regulation equipment, usually at the substation of rural type customers

> **High Voltage Network Augmentation** - Primarily involves upgrading the high voltage distribution network capacity to rectify voltage or capacity constrained high voltage network conductors and equipment that are causing or are a contributing factor of a power quality complaint or problem. This work includes;
  - Upgrading the capacity and voltage performance of the existing high voltage network by replacing and upgrading the existing conductors to improve voltage profiles and performance.
  - Installing additional new high voltage distribution mains to alleviate capacity or voltage constraints or to facilitate reconfiguration of the high voltage network. This work also includes the installation of new high voltage mains to supply a new distribution substation being installed to rectify a PQ problem.
  - Installation or upgrading of high voltage regulation equipment on high voltage distribution feeders

> **Zone Substation Fixed Power Quality Monitoring -** Primarily a regulatory requirement, but also aids Essential Energy in early detection of electrical anomalies that are potentially harmful to customer equipment or the network itself. The power quality meters will provide the ability to scrutinise the efficient operation of Essential Energy's network. To comply with National Electricity Rules (NER) in relation to power quality reporting and planning, monitoring devices are to be installed at priority sites across the Essential Energy network. This work includes**:**

- Installation of AS/NZS 61000.4.30 Class A compatible power quality meters and associated current transformer and voltage transformers in zone substations.
- Fifteen IEC 61K-4-30 Class A fixed power quality monitors are to be installed in zone substations in each year of the 2019-24 regulatory period. At the end of the regulatory period this will provide power quality monitoring to almost 30% of Essential Energy zone substations.

> **Power Quality Mitigation Equipment Installations** - Primarily involves identifying problematic zone substations associated with large scale solar or wind farm connections where there are significant power quality issues and the identification of suitable power quality mitigation solutions. This work involves:

- Internal power quality investigations, power quality modelling and engaging external consultants to identify major power quality issues in the network where the problems are identified as being beyond the limit of Essential Energy's expertise.
- Investigations have revealed high harmonic levels at Hay 132/33kV zone substation this will require the installation of harmonic filters on the 33kV bus. The estimated cost for this work is $400,000 including the necessary switch bay works and purchase and installation of the filter.
- Investigations have revealed high harmonic levels at Hillston 132/33kV zone substation this will require the installation of harmonic filters on the 33kV bus. The estimated cost for this work is $400,000 including the necessary switch bay works and purchase and installation of the filter.
- These two projects are planned for the 2019/20 fiscal year.
- Initial planning has identified the following sites as requiring harmonic filters or voltage stabilisation installations during the regulatory period.
- Darlington Point, during the period 2019/21, with $1,200,000 budgeted for voltage stabilisation and harmonic filtering equipment.
- Temora, during the period 2021/22, with $1,200,000 budgeted for voltage stabilisation and harmonic filtering equipment.
- Narrabri, during the period 2022/23, with $1,200,000 budgeted for voltage stabilisation and harmonic filtering equipment.
- Broken Hill, during the period 2023/24, with $1,200,000 budgeted for voltage stabilisation and harmonic filtering equipment

The total forecast capital investment for the management of power quality over the 2019-2024 five-year regulatory period is $14.10M as shown in

PQ Remedial Work Type	Forecast 2019/20	Forecast 2020/21	Forecast 2021/22	Forecast 2022/23	Forecast 2023/24	5YR Total Investment	5YR Average Annual Investment
ESS_35 Substation Augmentation Total - PQ Substation Augmentation	$.74	$.7	$.68	$.66	$.66	$3.44	$.69
ESS_21 LV Network Augmentation Total PQ LV Augmentation	$1.33	$1.24	$1.2	$1.18	$1.17	$6.13	$1.23
ESS_20 HV Network Augmentation Total PQ HV Augmentation	$.61	$.57	$.56	$.55	$.54	$2.83	$.57
ESS_1017 ZS Fixed PQ Monitoring Total PQ ZS Monitoring	$.34	$.32	$.3	$.29	$.28	$1.52	$.3
ESS_4100 Power Quality Mitigation Total PQ Mitigation Equipment	$1.02	$.99	$.97	$.96	$.95	$4.89	$.98
TOTAL ALL PQ CAPEX	$4.04	$3.82	$3.71	$3.63	$3.6	$18.8	$3.76

and

PQ Remedial Work Type	Forecast 2019/20	Forecast 2020/21	Forecast 2021/22	Forecast 2022/23	Forecast 2023/24	5YR Total Investment	5YR Average Annual Investment
ESS_35 Substation Augmentation							
Dist Transformers - New	$0.32	$0.34	$0.31	$0.32	$0.32	$1.62	$0.32
Dist Transf - Tap Settings	$0.00	$0.00	$0.00	$0.00	$0.02	$0.02	$0.00
Dist Transf - Upgrade/ Replacement	$0.42	$0.36	$0.37	$0.34	$0.31	$1.80	$0.36
Total - PQ Substation Augmentation	**$.74**	**$.7**	**$.68**	**$.66**	**$.66**	**$3.44**	**$.69**
ESS_21 LV Network Augmentation							
LV OH - new	$0.08	$0.12	$0.08	$0.06	$0.08	$0.43	$0.09
LV OH to UG conversion	$0.00	$0.17	$0.10	$0.06	$0.04	$0.37	$0.07
LV reconductoring/ relocation	$0.17	$0.33	$0.31	$0.28	$0.16	$1.26	$0.25
LV recond./relocation with ABC	$0.65	$0.52	$0.53	$0.59	$0.59	$2.88	$0.58
LV UG - New	$0.08	$0.00	$0.02	$0.06	$0.18	$0.35	$0.07
LV UG - Switch Gear upgrade	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
LV Voltage Regulators	$0.25	$0.00	$0.08	$0.02	$0.02	$0.37	$0.07
LV Minor works, reconfig, LV links	$0.08	$0.10	$0.08	$0.10	$0.10	$0.47	$0.09
LV PQ Service Replacements (ESS_27)							
Total PQ LV Augmentation	**$1.33**	**$1.24**	**$1.2**	**$1.18**	**$1.17**	**$6.13**	**$1.23**
ESS_20 HV Network Augmentation							
HV OH Feeders - New	$0.53	$0.47	$0.54	$0.41	$0.50	$2.44	$0.49
HV OH Lines - Miscellaneous works	$0.00	$0.02	$0.02	$0.00	$0.00	$0.04	$0.01
HV OH to UG conversion	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
HV reconductoring	$0.00	$0.00	$0.00	$0.00	$0.04	$0.04	$0.01
HV UG Feeders - New	$0.08	$0.02	$0.00	$0.00	$0.00	$0.10	$0.02
HV Voltage Regulators/ Capacitors	$0.00	$0.06	$0.00	$0.14	$0.00	$0.20	$0.04
Total PQ HV Augmentation	**$.61**	**$.57**	**$.56**	**$.55**	**$.54**	**$2.83**	**$.57**
ESS_1017 ZS Fixed PQ Monitoring							
Class A fixed PQ equipment including PQ analysis & reporting software. Fifteen ZS each FY during the 2019-24 regulatory period	$.34	$.32	$.3	$.29	$.28	$1.52	$.3
Total PQ ZS Monitoring	**$.34**	**$.32**	**$.3**	**$.29**	**$.28**	**$1.52**	**$.3**
ESS_4100 Power Quality Mitigation							
PQ mitigation equipment installations (Initially Harmonic Filter Installations to be carried out at Hay and Hillston 132kV ZS to meet compliance objectives. Successive projects are detailed in the text.)	$1.02	$.99	$.97	$.96	$.95	$4.89	$.98
Total PQ Mitigation Equipment	**$1.02**	**$.99**	**$.97**	**$.96**	**$.95**	**$4.89**	**$.98**
TOTAL ALL PQ CAPEX	**$4.04**	**$3.82**	**$3.71**	**$3.63**	**$3.6**	**$18.8**	**$3.76**

. This forecast is based on the weighted average of the actual annual power quality project expenditures for the past 10 years financial-year periods of 2009-2014 and 2014-2019 combined with planned projects.

Table 5 – Expenditure – Proposed PQ Capital investment Summary

PQ Remedial Work Type	Forecast 2019/20	Forecast 2020/21	Forecast 2021/22	Forecast 2022/23	Forecast 2023/24	5YR Total Investment	5YR Average Annual Investment
ESS_35 Substation Augmentation Total - PQ Substation Augmentation	$.74	$.7	$.68	$.66	$.66	$3.44	$.69
ESS_21 LV Network Augmentation Total PQ LV Augmentation	$1.33	$1.24	$1.2	$1.18	$1.17	$6.13	$1.23
ESS_20 HV Network Augmentation Total PQ HV Augmentation	$.61	$.57	$.56	$.55	$.54	$2.83	$.57
ESS_1017 ZS Fixed PQ Monitoring Total PQ ZS Monitoring	$.34	$.32	$.3	$.29	$.28	$1.52	$.3
ESS_4100 Power Quality Mitigation Total PQ Mitigation Equipment	$1.02	$.99	$.97	$.96	$.95	$4.89	$.98
TOTAL ALL PQ CAPEX	$4.04	$3.82	$3.71	$3.63	$3.6	$18.8	$3.76

Table 6 – Expenditure - Annual Forecast PQ Capital Investment

PQ Remedial Work Type	Forecast 2019/20	Forecast 2020/21	Forecast 2021/22	Forecast 2022/23	Forecast 2023/24	5YR Total Investment	5YR Average Annual Investment
ESS_35 Substation Augmentation							
Dist Transformers - New	$0.32	$0.34	$0.31	$0.32	$0.32	$1.62	$0.32
Dist Transf - Tap Settings	$0.00	$0.00	$0.00	$0.00	$0.02	$0.02	$0.00
Dist Transf - Upgrade/ Replacement	$0.42	$0.36	$0.37	$0.34	$0.31	$1.80	$0.36
Total - PQ Substation Augmentation	**$.74**	**$.7**	**$.68**	**$.66**	**$.66**	**$3.44**	**$.69**
ESS_21 LV Network Augmentation							
LV OH - new	$0.08	$0.12	$0.08	$0.06	$0.08	$0.43	$0.09
LV OH to UG conversion	$0.00	$0.17	$0.10	$0.06	$0.04	$0.37	$0.07
LV reconductoring/ relocation	$0.17	$0.33	$0.31	$0.28	$0.16	$1.26	$0.25
LV record./relocation with ABC	$0.65	$0.52	$0.53	$0.59	$0.59	$2.88	$0.58
LV UG - New	$0.08	$0.00	$0.02	$0.06	$0.18	$0.35	$0.07
LV UG - Switch Gear upgrade	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
LV Voltage Regulators	$0.25	$0.00	$0.08	$0.02	$0.02	$0.37	$0.07
LV Minor works, reconfig, LV links	$0.08	$0.10	$0.08	$0.10	$0.10	$0.47	$0.09
LV PQ Service Replacements (ESS_27)							
Total PQ LV Augmentation	**$1.33**	**$1.24**	**$1.2**	**$1.18**	**$1.17**	**$6.13**	**$1.23**
ESS_20 HV Network Augmentation							
HV OH Feeders - New	$0.53	$0.47	$0.54	$0.41	$0.50	$2.44	$0.49
HV OH Lines - Miscellaneous works	$0.00	$0.02	$0.02	$0.00	$0.00	$0.04	$0.01
HV OH to UG conversion	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
HV reconductoring	$0.00	$0.00	$0.00	$0.00	$0.04	$0.04	$0.01
HV UG Feeders - New	$0.08	$0.02	$0.00	$0.00	$0.00	$0.10	$0.02
HV Voltage Regulators/ Capacitors	$0.00	$0.06	$0.00	$0.14	$0.00	$0.20	$0.04
Total PQ HV Augmentation	**$.61**	**$.57**	**$.56**	**$.55**	**$.54**	**$2.83**	**$.57**
ESS_1017 ZS Fixed PQ Monitoring							
Class A fixed PQ equipment including PQ analysis & reporting software. Fifteen ZS each FY during the 2019-24 regulatory period	$.34	$.32	$.3	$.29	$.28	$1.52	$.3
Total PQ ZS Monitoring	**$.34**	**$.32**	**$.3**	**$.29**	**$.28**	**$1.52**	**$.3**
ESS_4100 Power Quality Mitigation							
PQ mitigation equipment installations (Initially Harmonic Filter Installations to be carried out at Hay and Hillston 132kV ZS to meet compliance objectives. Successive projects are detailed in the text.)	$1.02	$.99	$.97	$.96	$.95	$4.89	$.98
Total PQ Mitigation Equipment	**$1.02**	**$.99**	**$.97**	**$.96**	**$.95**	**$4.89**	**$.98**
TOTAL ALL PQ CAPEX	**$4.04**	**$3.82**	**$3.71**	**$3.63**	**$3.6**	**$18.8**	**$3.76**

7.2 Operating Investment Plan

The following section summarises the operating investment plan that implements Essential Energy’s Network Power Quality Strategy.

Table 7 details the proposed operational expenditure required for the management of power quality complaints, Power Quality mitigation issues including investigations and minor operational works, in accordance with the Network Power Quality Strategy set out in section 6.

The costs for tap changes, 230V migration program, background power quality monitoring for high voltage power quality allocations and other minor power quality remedial works are estimated costs based on the average historical quantities of work over the past nine years and calculated unit costs for such works.

Total forecast operation expenditure for power quality technician investigation activities and minor remedial works over the five-year 2019-2024 regulatory period is $15.9M. This forecast is based on the actual nine-year average annual power quality expenditure from 2009/10 to 2016/17 in relation to actionable power quality complaints.

Table 7 - Expenditure - Proposed Power Quality Operating Expenditure

Description	Forecast 2019/20		Forecast 2020/21		Forecast 2021/22		Forecast 2022/23		Forecast 2023/24		5YR Total Investment	
	No of Projects	Cost $M	No of Projects	Cost $M	No of Projects	Cost $M	No of Projects	Cost $M	No of Projects	Cost $M	No of Projects	Cost $M
Power Quality (PQ) Investigations	1500	$1.70	1500	$1.70	1500	$1.70	1500	$1.70	1500	$1.70	7500	$8.50
Individual Transformer tap setting changes	320	$0.70	320	$0.70	320	$0.70	320	$0.70	320	$0.70	1600	$3.50
Minor PQ works, load rebalancing, connection replacements, etc	105	$0.60	105	$0.60	105	$0.60	105	$0.60	105	$0.60	525	$3.00
Background PQ monitoring at the PCC (Point of Common Coupling) using Portable PQ Monitors for new HV connection PQ allocations	25	$0.03	25	$0.03	25	$0.03	25	$0.03	25	$0.03	125	$0.15
230 V Migration Program	1	$0.15	1	$0.15	1	$0.15	1	$0.15	1	$0.15	5	$0.75
Total		**$3.18**		**$3.18**		**$3.18**		**$3.18**		**$3.18**		**$15.90**

Appendix A – Referenced Documents, Legislation and Standards

Internal Documents

Document	Relevance to Network Strategy
CEOP1121 - Demand Management Strategy	Internal documents that provide guidance for Power Quality Strategy.
CEOP2091 - Distribution Network Growth Strategy	
CEOP2463 - Reliability Strategy	
CECP8096 - Electrical Safety Policy	
CECP0002.03 - Risk Management Policy	
CEOP2111.01 - Asset Risk Management	
CECP0002.32 - Financial Management Investment Evaluation Procedure	
Embedded Generator Connection Policy	
Strategic Asset Management Plan	Key output documents.
Investment Cases	
Asset Management Plans	

Legislation

Document	Relevance to Network Strategy
Electricity Supply Act 1995	Legislation that Essential Energy must adhere to. Provides guidance to safety based target setting and used to meet the Power Quality Management Objectives on Compliance.
Work Health and Safety Act 2011	
Work Health and Safety Regulation 2011 (NSW)	
Electricity Supply (Safety and Network Management) Regulation 2014 (NSW);	
National Electricity Rules (NER)	
Service and Installation Rules of NSW	
Electrical Safety Act 2002	
Electrical Safety Regulation 2013	
National Energy Customer Framework (NECF)	
IPART Reliability and Performance Licence Conditions	
National Greenhouse and Energy Reporting Act 2007 (NGER Act)	
AER STPIS (Service Target Performance Incentive Scheme)	

Standards

Document	Relevance to Network Strategy
AS 4777 Grid connection of energy systems via inverters	Standards used to set Power Quality Management Objectives and limits on Compliance.
AS 61000.3.100 Steady state voltage limits in public electricity systems	
AS/NZS 3000 Electrical installations (known as the Australian/New Zealand Wiring Rules)	

AS/NZS 61000.3.6 Assessment of emission limits for distorting loads in MV and HV power systems	
AS/NZS 61000.3.7 Assessment of emission limits for fluctuating loads in MV and HV power systems	
AS/NZSTR IEC 61000.3.13 Assessment of emission limits for the connection of unbalanced installations to MV, HV and EHV power systems	
ENA Doc 001-2008 National Electricity Network Safety Code	
SA/SNZ TR IEC 61000.3.14 Assessment of emission limits for harmonics, inter-harmonics, voltage fluctuations and unbalance for the connection of disturbing installations to LV power systems	
ENA Guides on Power quality - Recommendations for the application of AS/NZS IEC TR 61000.3.6, AS/NZS IEC TR 61000.3.7 and AS/NZS IEC TR 61000.3.13	
AS 60038 Standard Voltages	
AS/NZS 61000.2 Electromagnetic compatibility (EMC) – Environment	
AS/NZS 61000.3 Electromagnetic compatibility (EMC) - Limits	