PowerWater

Program Business Need Identification

Power and Water Corporation

NPQ (PRD33404)

Power Quality Compliance Program

Proposed:	Approved:	
Jim McKay A/Chief Engineer Power Networks Date: 6/2/2018	Michael Thomson Chief Executive Power and Water Corporation Date: 23/02/2018	
	Refer to email D2018/72353	Refer to email D2018/66214
Djuna Pollard Executive General Manager Power Networks Date: 15/2/2018	Finance Review Date: 06/02/2018	PMO QA Date: 13/02/2018

1 Program Summary

Program Name:	Power Quality Compliance Program		
Program No:	NPQ	**SAP Ref:**	
Financial Year Commencement:	2019/20		
Business Unit:	Power Networks		
Program Owner (GM):	Djuna Pollard	**Phone No:**	8985 8431
Contact Officer:	Peter Kwong	**Phone No:**	8924 5060
Date of Submission:	23/02/18	**File Ref No:**	D2017/511251
Submission Number:		**Priority Score:**	
Primary Driver:	Compliance	**Secondary Driver:**	Service Improvement
Program Classification:	Capital Program of Works		

2 Recommendation

2.1 MAJOR PROJECT >$1M OR PROGRAM

It is recommended that the Chief Executive note the proposed Power Quality Compliance Program for an estimated budget of $3.0M, and approve the inclusion of this Program into the SCI for this amount, with a corresponding completion date of June 2024.

This program is a continuing program from the current regulatory control period. The forecast for this program of work aligns with the 2019-24 regulatory period and will be included in the 2019-24 Regulatory Proposal to the Australian Energy Regulator (AER).

Note that individual projects within the program will be documented in Business Cases as per the Power and Water Corporation (PWC) governance framework for capital projects and programs.

3 Description of Issues

3.1 Background

Power Networks must comply with the quality of supply requirements, principally concerning voltage management so as to enable customer's electrical equipment to function as designed and without damage or reduction in expected service life.

To achieve the organisational objectives and meet the requirements of the Asset Management Policy this means delivering the correct voltage to all customers under all conditions to mitigate risks associated with:

- damage to equipment;
- compliance to standards; and
- enabling practical network access of customer's PV systems – the primary consideration.

The Network Technical Code and Planning Criteria[1] specify the Quality of Supply criteria that regulate:

- Voltage fluctuations;
- System Frequency;
- Harmonic distortion;
- Voltage unbalance; and
- Network reliability.

PWC is also required to analyse the network to ensure satisfactory performance in accordance with the Quality of Supply criteria when a new user is connected or a complaint from an existing user is received. The aspects that are analysed include steady state voltage, voltage fluctuations and network frequency on the distribution networks in Darwin, Katherine, Tennant Creek and Alice Springs.

PWC must achieve compliance and compatibility with Network Technical Code and Planning Criteria, based on Australian Standards and guidelines for power quality, as well as aligning to customer's expectations in the areas of:

- SA/SNZ TR IEC 6100.3.14 Assessment of emission limits for harmonics, inter-harmonics, voltage fluctuations and unbalance for the connection of disturbing installations to LV power systems;
- AS 4777 Grid connection of energy systems via inverters; and
- AS/NZS 61000.3.11 Limitation of voltage changes, voltage fluctuations and flicker in public low voltage supply systems.

[1] Network Technical Code and Planning Criteria, PWC Ref: D2014/8409

3.2 Power Quality Management Strategy

Current and emerging issues that have been identified on the network are detailed below. Further information and analysis is contained in the Power Quality Management Plan.[2]

3.3 Current and emerging issues

3.3.1Steady state voltage

The existing low voltage network was originally based on 240V single phase or 415V three phase systems and traditional design approaches with declining voltage profiles. The move towards a standard voltage of 230V in 2014 meant that the existing transformers in the distribution network are operating at the lower end of their available voltage range.

Steady state voltage issues can also be due to upstream conditions, like the Ferranti effect on long, lightly loaded transmission lines. In turn, this causes high voltages on medium and low voltage networks as the existing power transformer have limited capability to lower voltages.

3.3.1Solar PV

PWC has experienced a steady increase in the uptake of solar panels both domestically and commercially. This is more pronounced in Alice Springs where it has been part of the Solar Cities program. This increasing uptake of solar panels is causing voltage issues in the distribution network where the inverters are raising voltages above the steady state ranges due to long spans and voltage injection.

While the new construction standards for distribution transformers address the limited tapping range issue, the existing distribution transformers in the network are designed for boosting voltages and contain minimal buck taps. Furthermore, the operational cost of visiting individual sites to tap transformers is high and effectiveness is limited as it provides only local voltage adjustment, without regulation.

In the Darwin region we were able to change TF voltage set points at the 11kV Zones, effectively providing network wide, and reduced, regulated voltage levels on the LV. (See Figure 3) This is not possible on the 22kV networks, given the longer runs and widely varying conditions, and more localised solutions are needed.

In Alice Springs, as well as having large sections of rural 22kV (with the issues outlined above), there are generation directly connected onto the 11kV bus and the 66kV bus, interconnected by a 22kV system. Balancing the LV levels via the zone substations needs to account for the different system voltages, loads and power flows, network configuration and generation dispatch. The current system arrangement does not allow for the zone reduction approach like in Darwin, and again a more local approach is needed. However, the power station connected on the 11kV bus, Ron Goodin, is to be decommissioned and this may

[2] At the time of preparing this BNI, the Power Quality Management Plan had not been finalised

assist in achieving a centralised a system wide solution on the urban 11kV distribution network.

Figure 1 – PV Install Capacity, Darwin - Katherine Region

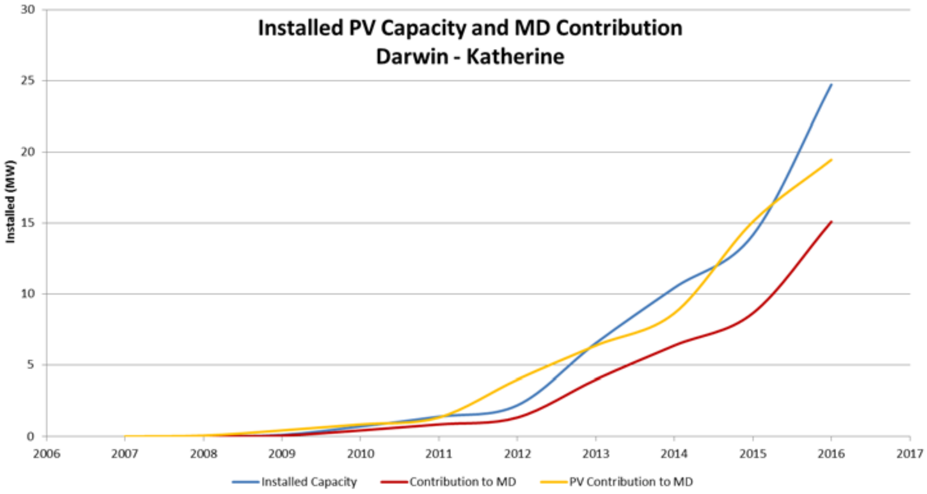
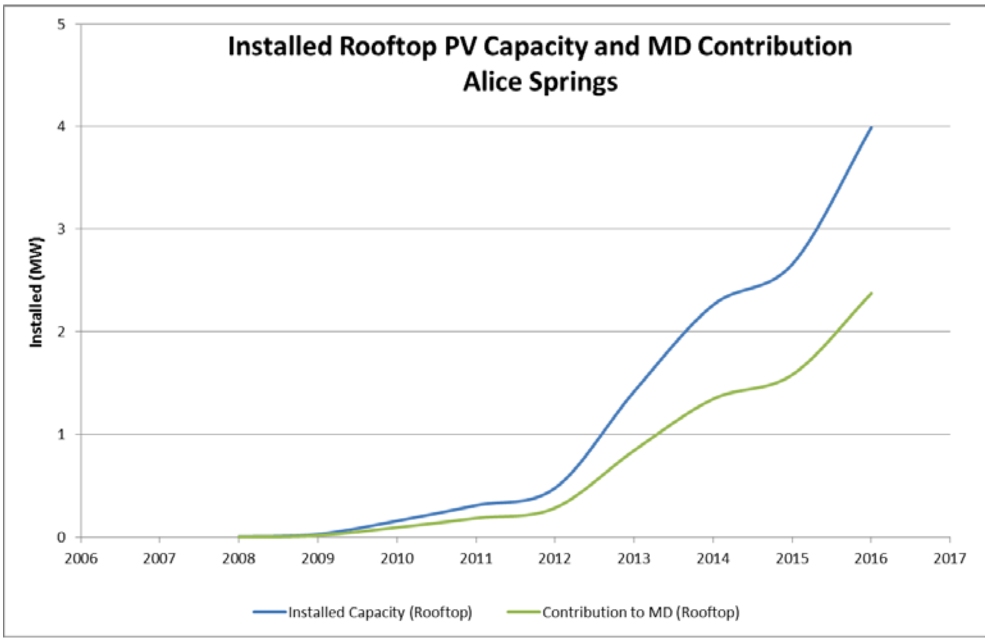


Figure 2 – PV Install Capacity, Alice Springs Region



3.3.2Voltage unbalance

Instances of voltage unbalance on the low voltage network are mostly due to uneven loading of the single phase customers on the distribution network or internal loading on larger three phase customer connections. This can lead to excessive loads on under-sized neutrals (previous old standards) causing faulty connections, which will increase the severity of the voltage unbalance.

3.3.3LV network design

Traditional design assumptions regarding voltage drop in the low voltage network are no longer applicable largely due to the influence of PV systems exporting via the low voltage network. Although an improvement on previous years, the higher voltage values within the low voltage network are evident in the histogram below where almost 50% of voltages are above the preferred range. To address this, Power Networks have been adjusting local transformer tap positions and investigating a broader solution of a significant reduction of the medium voltage at Zone Substations.

Figure 3 – Darwin voltage histogram

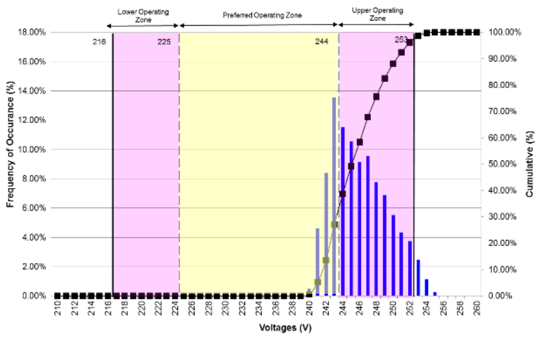


Figure 3– RMS Voltage Distribution Histogram **(Pre-change)**, January 2017 Update

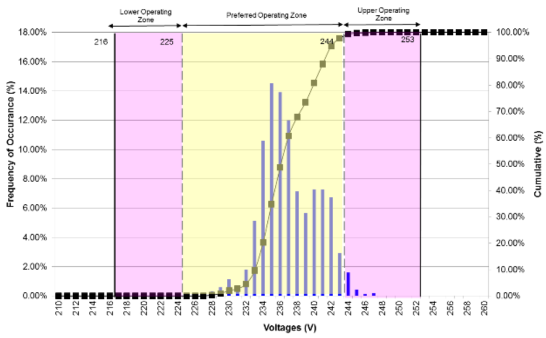


Figure 4 – RMS Voltage Distribution Histogram **(Post-change)**, January 2017 Update

In 2015, Power Networks began to reduce the voltage regulating set points at zone substations across the 11kV network in the Darwin Region. The histograms indicate the success of this approach at a customer's supply point. In this instance, prior to the change less than 40% of sampled voltages were within the preferred range during normal conditions. Subsequent to the change more than 95% of sampled voltages fell within the preferred range. Further work is being conducted for this approach to be applied in the rural 22kV networks as well as in the Alice Springs and Tennant Creek power networks.

The 11kV voltage set-points in the Darwin network have been reduced at the transformers from a nominal set point of 11.2 kV to 10.7 kV, resulting in a reduction in the low voltage levels supplied to customer and significant operational savings.

The 22kV networks predominantly supply the rural network and additional studies are required to ensure that transformer voltage regulating set-points and voltage regulators function in unison to provide suitable voltages across the full range of electricity demand, networks configuration and seasonal conditions.

In Alice Springs, major issues from low voltage regulation are being experienced. Resolving the issue in the short term is complicated by:

- the nature of the embedded generation at the Ron Goodin Power station on the 11kV network with the interconnected 22kV lines to the 66kV substation from OSPS
- the 22kV rural network,
- the recent implementation of the remote automated generator control in the region,
- the closure of Brewer power station, and
- the expansion of the Owen Spring Power Station.

Minor changes to the network confirmation are planned in the short-term, however more significant changes will be required when Ron Goodin Power Station is decommissioned in 2018. Changes to supply voltage will require direct generation action and coordination.

3.4 Current performance

3.4.1 Customer complaints

Customer notifications regarding power outages or power quality are logged through Power and Water's Call Centre or website. The number of customer notifications and the percentage of total notifications are shown in the table below[3]:

2016/17	Fluctuating		Low Power		Part Power		High Power	
	Total	%	Total	%	Total	%	Total	%
Darwin	120	5	65	3	587	23	27	1
Katherine	10	3	7	2	123	31	4	1
Tennant Creek	7	8	2	2	15	17	4	4
Alice Springs	26	6	19	4	82	17	49	10
2015/16	**Fluctuating**		**Low Power**		**Part Power**		**High Power**	
	Total	%	Total	%	Total	%	Total	%
Darwin	130	4	127	4	674	21	13	1
Katherine	11	2	22	4	181	32	3	1
Tennant Creek	2	2	4	5	16	18	2	2
Alice Springs	29	5	29	8	87	14	35	6
2014/15	**Fluctuating**		**Low Power**		**Part Power**			
	Total	%	Total	%	Total	%		
Darwin	139	4	105	3	635	20		
Katherine	18	4	17	4	129	27		
Tennant Creek	3	4	1	1	12	16		
Alice Springs	33	6	45	8	91	15		
2013/14	**Fluctuating**		**Low Power**		**Part Power**			

[3] "High Power" complaint category was introduced in 2015/16

	Total	%	Total	%	Total	%	
Darwin	259	5	114	2	1126	23	
Katherine	19	3	10	2	176	31	
Tennant Creek	7	5	6	4	16	11	
Alice Springs	33	6	15	3	109	18	

3.4.2 Quality of supply investigations and compliance breaches

All complaints associated with power quality are investigated by Power Networks. Where the outcome of the investigation indicates a compliance breach, corrective works are developed to correct these issues.

In the past year, there were over 30 investigations completed in response to quality of supply complaints. After the initial investigation, about 75% of the cases required some form of corrective action, which range from a tap change on the distribution transformer to augmentation of the LV network.

3.4.1Corrective programs

Power Networks has a metering program to change old and obsolete meters with digital replacements. These new meters contain a voltage channel to measure and log LV voltages to allow compliance breaches to be identified.

The Standards section also recently made changes to the distribution transformers to included greater voltage step control in both directions to cater for a wider range of operating conditions.

It is also planned that system modelling software will be used to identify pockets of non-compliance so that there will be a move to a more proactive approach in identifying possible power quality issues.

3.5 Technology Drivers

The Northern Territory Government has introduced a target of 50% renewable energy by 2030[4]. This is at the opposite end of the system from the network's original design and presents a very significant range of technical, economic and regulatory challenges. An integrated set of actions are required to enable balanced, long term outcomes for customers, enable the maximum value of customer distributed energy resources. PWC must ensure that the network supports distributed generation (and storage) and the growing range and diversity of market participants.

[4] Northern Territory Roadmap to Renewables – Fifty per cent by 2030

Areas considered by Power Networks include:

- Domestic PV, alternative energy generation/storage
- Network automation/self-healing
- Distribution Management System (DMS/OMS)
- New loads – electric vehicles
- Communications/Metering technology
- Power quality equipment
- Energy Storage

PWC will continue to monitor technology advancements as they apply to the customer and electricity networks in the Territory, and review the nature and scope of program initiatives required to meet customer expectations on power quality.

3.6 Project Drivers

3.6.1 Compliance – Quality of Supply
This program is required to ensure PWC comply with the Quality of Suppy criteria in the Network Techical Code and Planning Criteria, and other relevant guidelines and Australian Standards.
3.6.2 Customer consultation or other benefits (if not compliance obligation)
This program will address customer complaints concerning power quality performance.

3.7 Operational performance targets

To demonstrate operating in accordance with good industry practice, PWC has developed a set of asset management objectives drawing from the knowledge and experience of asset management objectives used by electricity network operators in other jurisdictions. The asset management objectives, KPIs and targets related to maintain compliance with PWC's power quality obligations are detailed below.

Asset management objective: Ensuring connected generators and customer loads are of appropriate quality and comply (on connection and over their service life) with the provisions of the Codes, Regulations, Rules and Standards to achieve Power Quality Management.

Measures of Success	Target (Existing & TBD)	Primary Risk Driver							
		H & S	Finance	Leg/Reg	Environ	Strgc Mgt	Serv Del	Corp Img	Stake Mgt
Power Quality High Volts • for systems with nominal voltage ≥11kV : • for systems with nominal voltage <11kV :	≤ +10%; ≤ +11%			☐ ☐					☐ ☐
Low Volts • for systems with nominal voltage ≥11kV • for systems with nominal voltage <11kV	: ≥ -10%; : ≥ -2%			☐ ☐					☐ ☐
Voltage Unbalance • for systems with nominal voltage >100kV • for systems with nominal voltage between 10kV and 100kV • for systems with nominal voltage <10kV	= 1.0%; = 1.5%; = 2.0%			☐ ☐ ☐					☐ ☐ ☐
Flicker • "short term" (Pst) on a 10 minute sample interval • "long term" (Plt) on a 2 hour sample interval	= 1.0 (<1kV), 0.9 (≥1kV, ≤ 66kV), 0.8 (> 66kV) = 0.65 (<1kV), 0.7 (≥1kV, ≤ 66kV), 0.6 (> 66kV)			☐ ☐					☐ ☐
Compliance	100%	☐		☐					☐

3.8 Risk Analysis

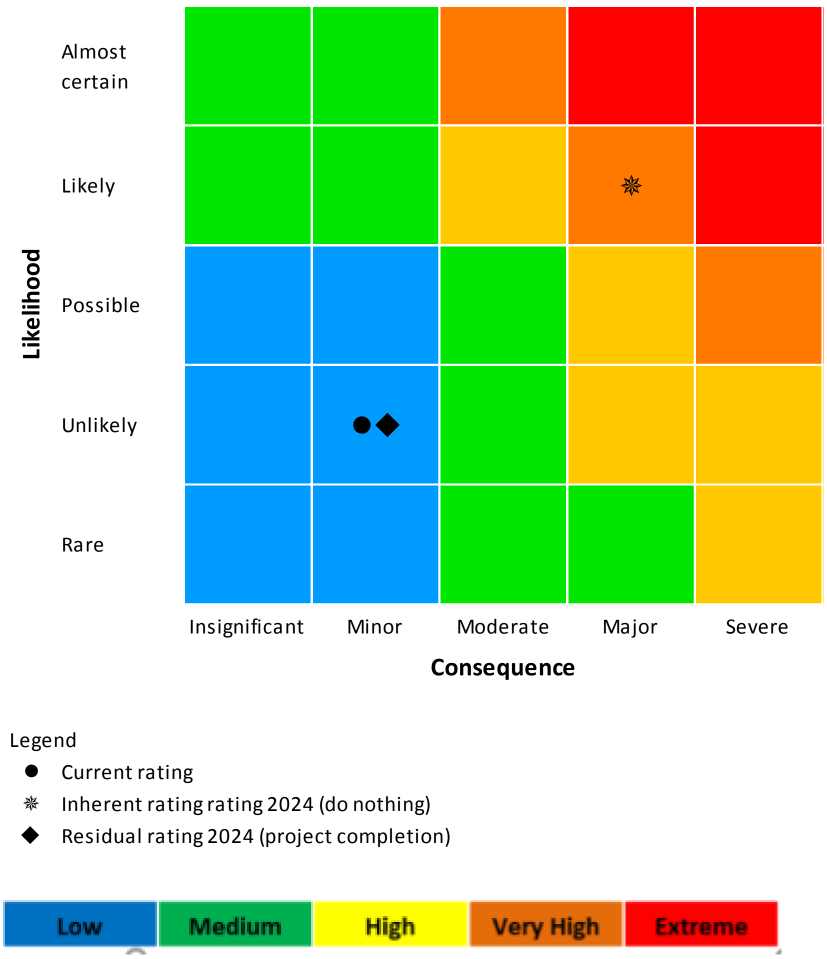
Figure 1 shows the current rating, inherent rating (in 2024, i.e. no action is taken in the interim), and the residual (post-treatment) risk ratings associated with power quality issues in Darwin, Katherine, Tennant Creek and Alice Springs:

(i) Current rating: The current rating (2017) is assessed to be "Low" because of the existing program to identify and address customer complaints on power quality, it is "Unlikely" that there would be negative affect to corporate image and if so, it would be once-off negative media attention and localised community impacts and customer concerns. This consequence is classed as "Minor"

(ii) inherent rating: If the program does not continue in the next regulatory period, the probability of significant power quality issues by 2024 is "Likely", and the number of unaddressed customer complaints will result in prolonged adverse media attention and customer condemnation weeks. This consequence is classed a “Major”. The overall risk rating is therefore “Very High”.

(iii) Residual rating: The continuation of the proposed program will address the probability and consequence of future power quality issues. The program will analyse and address power quality problems as they become evident and ensure that customer complaints are addressed effectively. Therefore, the likelihood of an event is “Unlikely“ and the impact of the event will be significantly lessened, to a level classified as “Minor”. The overall risk rating is therefore “Low”.

Figure 1: Feeder Augmentation Risk Assessment[5]



It is Power and Water’s current practice to take action on risks that have an inherent rating of ‘HIGH’ or above. The BNI summarises the proposed response to this impending risk.

[5] Based on PWC’s Risk Assessment Guide

4 Potential Solution

PWC has developed a set of program initiatives with the goal of meeting the current regulatory requirements, including to maintain statutory voltages within the nominal voltage range of 230 V +6%/-2%, and will focus on addressing the worst performing areas on the network, including in response to growth of solar PV.

To meet the future requirements, PWC has developed the CAPEX program based on extrapolation from historical costs.

PWC will manage the power quality performance of the transmission and distribution networks to maintain the current level of compliance with the minimum service standard levels set in in Territory regulatory and legislative instruments, where reasonably practical. These requirements essentially are to maintain network parameters within a specified range of values so that the power system, including customers' equipment, operates satisfactorily.

This will be achieved by appropriately designing the network and managing the health of the in-service network assets (including the use of new and emerging technology and non-network solutions) and limiting the impact on customers of supply interruptions through fault and emergency response, keeping in mind the corporate objective regarding efficiency.

4.1 Preferred Option

A set of program initiatives have been developed to support the Power Quality Management Plan and identification of future requirements in the business plan.

The bulk of power quality issues emerge on the LV distribution network. PWC has identified solutions to address these emergent issues.

Due to the complexity of the issues involved, and the disproportionate impact that many of these have on the low voltage networks in the Territory, the ongoing management of power quality issues is challenging. PWC is developing a more holistic power quality management plant to:

- Establish the requisite data and systems to assist predict where power quality issues may arise;
- Establish a framework to assist prioritise areas for required augmentation works;
- Develop reporting systems to understand the effectiveness of the augmentation works undertaken; and
- Develop reliable models to monitor the impact of changes on the LV network.

4.1.1 LV network (Distribution) augmentation

This program involves augmentation of the low voltage network to address voltage regulation on the LV network. A combination of initiatives will be considered including

- reduce the length of the LV network supplied by the distribution transformer;
- reconfigure the LV network; and
- reconductor (or upgrade) the LV network to a modern standard, such as a conductor with a larger cross-sectional area.

This would reduce the need to raise the secondary voltage of the distribution transformer, to improve the voltage delivered to customers at the end of the distribution run.

In limited circumstances, the distribution transformer may need to be replaced with a newer specification unit to allow for broader range of tapping voltages. However is unlikely to completely address any voltage regulation issues in the LV network.

Sites will be selected following review of LV regulation issues including customer complaints and power quality investigations. These are more likely to arise in areas of in-fill development of older residential areas that has contributed to higher demand growth, and where penetration of solar PV is higher.

4.1.2 11kV Voltage Set Point Reduction

This program involves reducing the voltage set point on the automatic voltage regulator (AVR) at the zone substation of 11kV networks. This has been completed for the Darwin system and has successfully reduced the number of high voltage complaints received from customers[6] connected to the LV distribution system.

Sites will be selected following review of substation planning studies, and review of voltage regulation issues arising from customer complaints and power quality investigations. New substation designs have the ability to monitor voltage as part of the standard functionality, and a combination of options will be considered to address the voltage regulation across the HV distribution network.

4.1.3 Install reactive or capacitive compensation

This program involves installing new reactive compensation, such as capacitor banks into the zone substation or HV distribution network to provide voltage support. This would be considered for MV or HV networks to control voltages and allow the effective use of tap changers on power transformers to maintain voltage within the required range.

Sites will be selected following review of substation planning studies, and review of voltage regulation issues arising from customer complaints and power quality investigations.

4.1.4Repair/Upgrade Neutral Conductor

This program involves replacing the neutral conductor in some LV networks. Previously the PWC standard specified a smaller conductor/cable for the neutral compared to the phase

[6] Summary Update – Voltage Reduction in the Darwin 11kV Network (PWC Ref: D2016/499333)

conductor. This would involve upgrading the neutral conductor to the current PWC specification.

Sites will be selected following review of voltage regulation issues arising from customer complaints and power quality investigations.

4.1.5 Harmonic Contribution Investigations

This program involves conducting investigations to locate the source of the harmonic contribution and liaise with the offending party to cease the generation of the harmonic voltages. This would involve the installation of harmonic filters to remove the harmonic voltages before connection to the LV network.

4.1.6 Voltage Imbalance Investigations

This program involves conducting investigations to locate the source of the voltage imbalance and liaise with the offending party to rectify the unbalance loading. This can be due to an imbalance of single phase loads or a solar PV generation on the distribution network.

4.1.7 Summary

The capex in the table below is in $2017-18, and is excluding capitalised overheads and cost escalation.

Program / initiative	Expenditure forecast ($,000)				
	2019-20	2020-21	2021-22	2022-23	2023-24
LV network (Distribution) augmentation	200	200	200	200	200
11kV Voltage Set Point Reduction	50	50	50	50	50
Install reactive or capacitive compensation	50	50	50	50	50
Repair/Upgrade Neutral Conductor	200	200	200	200	200
Harmonic Contribution Investigations	50	50	50	50	50
Voltage Imbalance Investigations	50	50	50	50	50
Total	**600**	**600**	**600**	**600**	**600**

4.2 Non Network alternatives

Non-network options will be considered on a case by case basis.

4.3 Capex/Opex substitution

Capex/opex substitution will be considered on a case by case basis.

5 Strategic Alignment

This project aligns with the Corporation's key result areas of operational performance and customer centricity, where the goals are to be an efficient provider to services and delivering on customers' expectations.

This project will allow PWC to safely and reliably meet the needs and expectation of PWC's customers in Darwin, Katherine, Tennant Creek and Alice Springs.

6 Timing Constraints

There are no specific timing constraints for this program. It is important to complete the identified augmentation works so that PWC can met all its regulatory obligations and customer service levels. The program outlines a prudent level of work over the forecast period to be completed based on historic levels.

7 Expected Benefits

Driver	Benefit	Measure
Compliance	Quality of supply for customers	Meets the Network Technical Code regarding Quality of Supply Meet Australian Standard requirements for customer voltages.
Service Improvement	Improved power quality to customers.	Reduction in complaints Power quality measures achieved

8 Milestones (mm/yyyy)

Investment Planning	Project Development	Project Commitment	Project Delivery	Review
08/2017	03/2019	06/2019	06/2024	06/2024

9 Key Stakeholders

Stakeholder	Responsibility
General Manager Power Networks	Internal governance stakeholders

Stakeholder	Responsibility
Group Manager Service Delivery	
Chief Engineer	
Senior Manager Network Development and Planning	Internal design stakeholders
Senior Manager Contracts and Projects	
Senior Manager Asset Management	
Manager Test & Protection Services	
General Manager System Control	
Manager SCADA and Communication Services	
Local Residents	External – Unions and public
ETU	
Ministers	
Utilities Commission	External regulators
Australian Energy Regulator	

10 Resource Requirements

Resource Type/Role	How Many	Internal/ External	Anticipated Start Date	Duration Required	Review Allocation (% time or # hrs/days/ wks/mths)
Planning Engineer	1	Internal	Jun 2019	5 years	5%
Procurement Officer	1	Internal	Jun 2019	5 years	5%
Program Manager	1	Internal	Jun 2019	5 years	50%

11 Delivery Risk

A Preliminary Project Implementation Assessment was conducted for this project and the key risks to delivery of the investment are detailed below:

Risk/Impact Description	Proposed Action
System Outages will be required for connection of new equipment or modifications to existing equipment	Cutover/outage plan to be developed to minimise customer interruptions.
Work on or near existing high voltage lines/equipment	Personnel and operational staff shall follow existing Access to Apparatus Rules.
Possible budget overruns	Ensure detailed budget and business case are completed during the project development phase.

The project will be delivered by the Power Networks Contracts and Projects group or the Network Engineering group, with the Investment Planning phase completed by the Power Networks Network Development and Planning group.

12 Financial Impacts

12.1 Expenditure Forecasting Method

The expenditure forecast is based on extrapolate from historical cost and the number of customer complaints received.

12.2 Historical and Forecast Expenditure

The table below shows the previous expenditure (2014-17) and forecast expenditure (2018-19) for the Power Quality Compliance Program. It can be seen that the program expenditure shows an increase in recent years.

Program	2013/14 ($'000)	2014/15 ($'000)	2015/16 ($'000)	2016/17 ($'000)	2017/18 ($'000)	2018/19 ($'000)
Power Quality Compliance Program	348	229	241	627	600*	600*

*Budgeted for 2017/18 and 2018/19

12.3 Validation

The expenditure forecast is based on previous expenditure in the regulatory period.

12.4 Capex Profile

The capex in the table below is in $2017-18, and is excluding capitalised overheads and cost escalation.

Phase	2019/20 ($'000)	2020/21 ($'000)	2021/22 ($'000)	2022/23 ($'000)	2023/24 ($'000)	Balance ($'000)	Total ($'000)
Investment Planning	50						50
Project Development	50	50	50	50	50		250
Project Commitment	50	50	50	50	50		250
Project Delivery	450	500	500	500	450		2400
Review					50		50
Total	**600**	**600**	**600**	**600**	**600**		**3000**

12.5 Opex Implications

Opex for distribution networks after augmentation works associated with power quality will remain similar and is not expected to change. There will be opex increases associated with extra distribution transformers to reduce the length of a distribution run. The operational cost of a distribution transformer is estimated to be approximately $701 per unit and for conductors the operational costs are about $173 per km.

13 Document History

Date of Issue	Version	Prepared By	Description of Changes
20/11/17	1st Draft	Peter Kwong	