Network Power Quality (NPQ)

Regulatory Business Case (RBC) 2024-29

PowerWater

Contents

1.	**Summary**	**2**
1.1	Business need	2
1.2	Options analysis	2
1.3	Recommendation	3
2.	**Identified need**	**4**
2.1	Background	4
2.2	Current management program	4
2.3	Common Power Quality Issues	5
2.4	Risk assessment	6
2.5	Summary	8
3.	**Options analysis**	**9**
3.1	Comparison of credible options	9
3.2	Non-Credible Options	14
4.	**Recommendation**	**15**
4.1	Strategic alignment	15
4.2	Dependencies	15
4.3	Deliverability	15
4.4	Customer considerations	15
4.5	Expenditure profile	16
4.6	High-level scope	16
Appendix A.	**Steady state power frequency voltage limits**	**17**
Appendix B.	**Annual network failures for 11kV underground cable**	**18**

1. Summary

This business case has been prepared to support the 2024-29 Regulatory Proposal. The business case demonstrates that Power and Water has undertaken appropriate analysis of the need and identified a full suite of credible options that will resolve the need, to ensure that Power and Water continues to meet the National Electricity Objectives and manage the network prudently and efficiently.

The project/program identified in this business case will undergo further assessment and scrutiny through Power and Waters normal governance processes prior to implementation.

This business case addresses Power Quality compliance for the Low Voltage network and voltage management projects at zone substation.

1.1 Business need

Power and Water must comply with power quality of supply (or 'PQ') requirements as defined in the Network Technical Code and Network Planning Criteria.[1] In particular, compliance to the prescribed voltage limits:

- Enable export of power from customers' PV systems.
- Enable customer's electrical equipment to function as designed and without damage or reduction in expected service life.
- Align with requirements of the Asset Management Policy means the steady state supply voltage at customers' terminals must remain within the range specified in the Networks Planning Criteria for normal conditions, and for planned and unplanned (credible) contingency conditions.

The Network Power Quality (NPQ) program is comprised of minor works programs to address identified non-compliance issues from individual residences in the Low Voltage network and voltage management projects at zone substations.

1.2 Options analysis

The options considered to resolve this need are shown in Table 1.

Table 1 Summary of credible options

Option No.	Option Name	Description	Recommended Option
1	Do Nothing	No investment in rectifying PQ issues in the next RCP	No

[1] Network Technical Code and Network Planning Criteria, Power and Water Corporation, Version 4, 30 March 2020

2	Complaints-driven PQ remediation	Respond to power quality issues informed by customer complaints	No
3	Proactive plus reactive PQ remediation	Network modelling to identify power quality issues before complaints are raised in addition to addressing PQ complaints reactively	Yes
4	Controlled network	In addition to option 3, retrospective installation of control devices on existing solar PV and full real time modelling of solar PV generation	No

As part of a holistic assessment, we considered non-network solutions (which essentially involve capex - opex trade-offs) but found that they were unlikely to be more cost effective than the recommended option.

1.3 Recommendation

The recommended option is Option 3 – Proactive plus reactive PQ remediation at an estimated cost of $3.8 million (2021/22). This comprises capex of $3.6 million (real 2021/22).

Table 2 shows a summary of the expenditure requirements for the next RCP. The detailed financial analysis is available in the accompanying Financial Model - NPQ Program.

Table 2 Annual capital and operational expenditure ($m, real FY22)

Item	FY25	FY26	FY27	FY28	FY29	Total
Capex	0.72	0.72	0.72	0.72	0.72	3.60
Opex	0.05	0.05	0.05	0.05	0.05	0.24
Total	**0.77**	**0.77**	**0.77**	**0.77**	**0.77**	**3.84**

2. Identified need

This section provides the background and context to this business case, identifies the issues that are posing increasing risks to Power and Water and its customers, describes the current management program, highlights challenges and emerging issues, and provides a risk assessment of the inherent risk if no investment is undertaken.

2.1 Background

Power and Water is required under Australian Standards[2] and the Network Technical Code[3] to comply with prescribed network performance standards.[4] The performance standards apply to power system frequency, power quality ('PQ'), electromagnetic interference, and stability. The PQ standards include:

- Steady state voltage levels – set out in clause 15.2 of the Network Planning Criteria in the Network technical Code – refer to Appendix A for a more complete description
- Voltage fluctuations – compatibility levels are defined in Table 1 of AS/NZS 61000.3.7 (2001)
- Harmonic distortion – compatibility levels are defined in Table 1 of AS/NZS 61000.3.6 (2001)
- Voltage unbalance – limits are described in Figure 4 of the Network technical Code

The PQ standards principally concern voltage management to enable customer's electrical equipment to function as designed and without damage or reduction in expected service life.

A key driver of this program is the significant increase in rooftop solar throughout the Northern Territory in a network that was designed for monodirectional power flow. This issue was highlighted in the Transmission and Distribution Annual Planning Report (TDAPR) 2021.[5]

Power and Water is 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 regarding the distribution networks in the Darwin-Katherine system, Tennant Creek, and Alice Springs.

2.2 Current management program

Power and Water has established a set of program initiatives to meet its current regulatory requirements for power quality, including to maintain statutory voltages within the nominal voltage. The Network Power Quality (NPQ) program is comprised of minor works programs to address identified non-compliance issues from individual residences in the Low Voltage network and voltage management projects at zone substations.

[2] AS/NZS 61000.3.100 Electromagnetic compatibility (EMC) Limits - Steady state voltage limits in public electricity systems Section 5
[3] Power and Water Corporation, Network Technical Code and Network Planning Criteria v4, 30 March 2020
[4] Network Technical Code and Network Planning Criteria, section 2
[5] Transmission and Distribution Annual Planning Report 2021, Power and Water Corporation, page 22

The NPQ program is estimated to incur $1.4 million (real 2021/22) during 2022/23 and 2023/24, at an annual average of $0.7 million.

2.3 Common Power Quality Issues

2.3.1 Over-voltage and AS 4777:2020 Compliance

The continued integration of residential and commercial embedded generation, predominantly solar PV, into Power and Water's network presents challenges to Low Voltage (LV) network power quality. As a result, there has been an increase in over-voltages (greater than 110% of nominal line voltage[6]) in the LV network, most recently in Katherine,[7] during low load conditions.[8]

Updates to AS 4777:2020 inverter standards and Power and Water's requirement for inverters to have both 'Volt-Var' and 'Volt-Watt' modes available[9] are designed to reduce the effect of small scale solar causing over-voltage in the LV network. However, over-voltage issues relating to older solar PV installations and new embedded generation in the network are still expected in the next RCP as Power and Water's network transitions to a smarter but more complex grid.

2.3.2 Under-voltage and Voltage Unbalance

Under-voltage (less than approx. 93.9% of nominal line voltage[10]) issues relating to the integration of commercial and residential developments into Power and Water's network are also expected to increase in line with the population growth of the Northern Territory. The inclusion of new loads in Power and Water's network results in voltage unbalance issues when single phase customers are unevenly connected to the distribution network. Voltage unbalances result in increased neutral currents impacting on the safe loading of these neutral conductors. Faulty connections can result from the excessive loading of under-sized lines, increasing the severity of voltage unbalance.

Increased energy demand, including Electric Vehicle (EV) uptake, may require network augmentation works through the NPQ program to address voltage issues, in addition to the Dynamic Operating Envelope (DOE)

[6] The range of LV supply is specified in AS61000.3.100 (2011) Section 5.
[7] Transmission and Distribution Annual Planning Report 2021, Power and Water Corporation, page 36
[8] During low load conditions, the combination of lightly loaded conductors and PV export into the network causes voltage rise
[9], Clause 4.4 Inverter Energy System e., D2020/380910 Basic Micro EG Connection Technical Requirements Specification v1, October 2020, page 10
[10] The range of LV supply is specified in AS61000.3.100 (2011) Section 5.

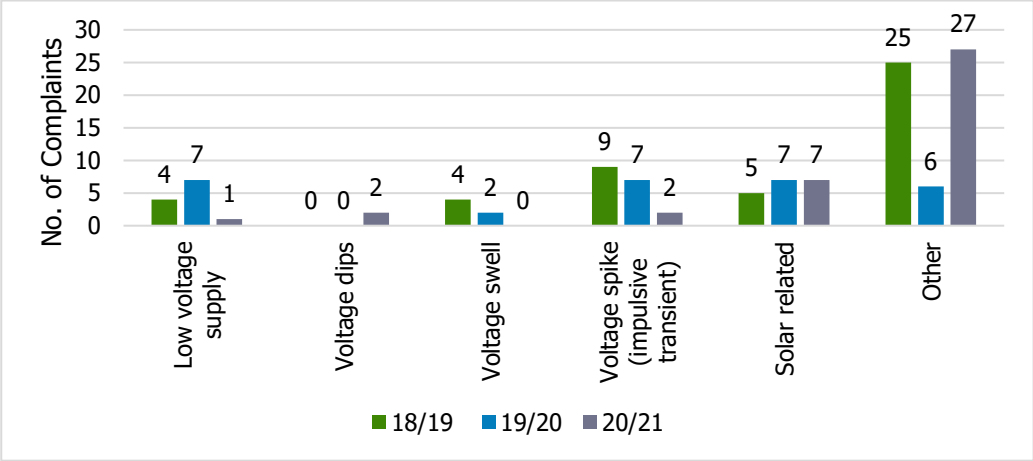
project[11] which is part of Power and Water's Future Networks Strategy but is unlikely to be delivered until the latter years of the next RCP.[12]

2.4 Risk assessment

2.4.1 Power quality complaints

Figure 1 categorises the PQ complaints made to Power and Water (2018/19 - 2020/21).

Figure 1 Quality of supply complaints[13]



Further analysis of the cause of quality of supply complaints made by customers once investigated by Power and Water is shown in Figure 2. Many of the issues reported in 2020/21 were determined to be customer internal problems or no problem identified. Consequently, only a subset of the customer complaints are assigned to the NPQ program each year.[14]

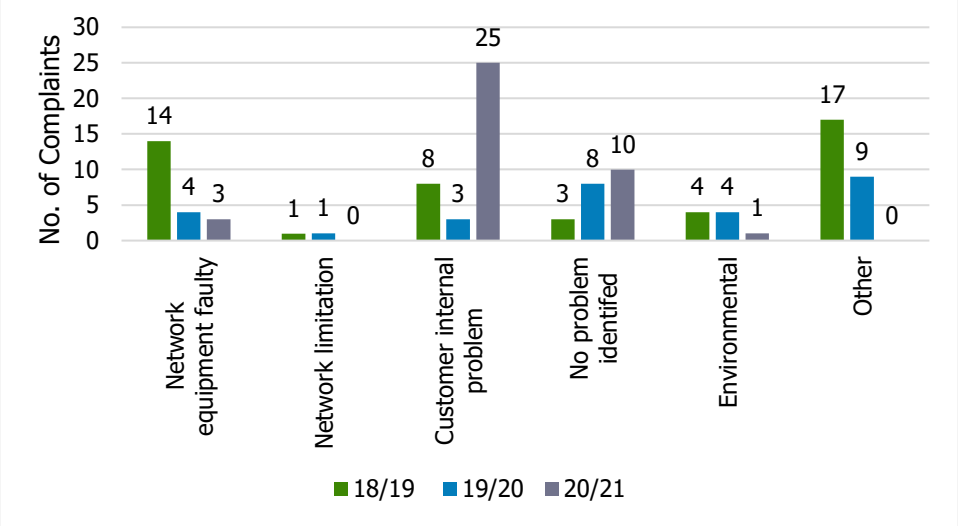
[11] Operating envelopes (OE) are the limits that an electricity customer can import and export to the electricity grid. These limits are agreed between networks, customers and the AER. In most cases, OEs are fixed at conservative levels regardless of the capacity of the network because they are static and need to account for 'worst case scenario' conditions. DOEs are where import and export limits can vary over time and location. Dynamic rather than fixed export limits could enable higher levels of energy exports from customers' solar and battery systems by allowing higher export limits when there is more hosting capacity on the local network

[12] The Future Networks Strategy explores options and defines strategies to evolve the network's capabilities in priority areas in the immediate future, over the next regulatory period and beyond.

[13] No further detail was available on the complaints to allow for categorisation of the 'Other' category.

[14] See Appendix, Table 10 Past projects of the NPQ program.

Figure 2 Cause of complaints[15]



2.4.2 Consequence of failure

The consequences related to power quality failure fall under the Customer Experience and Compliance value dimensions that are aligned to Power and Water's Risk Quantification Procedure and 'typical consequence areas' identified by the AER[16].

The financial risk of not meeting customer expectations and compliance with power quality is insignificant on the basis that the program is in place and results in negligible insurance and penalty payouts. No historical consequence cost can be allocated to this program.

The Network Planning Report[17] for the NPQ program provides further detail on these risks and their possible effect on the program. The nature of risks associated with customer experience and compliance are detailed below.

Customer experience

PQ issues that result in complaints from customers need to be managed carefully to avoid damaging Power and Water's reputation:

- Issues that are propagated by the network to the customer's premise need to be rectified promptly with good communication between the customer and Power and Water
- Issues that derive from within the customer's premises typically result in an expense to the customer (i.e. an electrician is usually required and is paid for by the customer, not Power and Water) which can lead to customer dissatisfaction if expectations are not managed well

[15] Pg. 37, Transmission and Distribution Annual Planning Report 2021, Power and Water Corporation.
[16] Industry practice application note: Asset replacement planning 2019, Australian Energy Regulator.
[17] NPR 2205 Network Power Quality 2022, Power and Water Corporation.

- Issues for which the root cause cannot be determined/fixed typically do not reoccur, but nonetheless require Power and Water staff to communicate with the customer to manage expectations.

Compliance

Risks that apply to the NPQ program and were considered for this business case but were ultimately unable to be quantified using the Risk-Quantification Procedure include:

- Rooftop solar PV compliance with AS 4777:2020 and Power and Water requirements for embedded generation and inverters[18]
- Forecast increases Electric Vehicle adoption rates[19] resulting in higher electricity demand throughout the network, and
- The introduction of Essential System Services[20] (ESS) may also pose risks[21] to the network as the effect of ESS on power quality is uncertain.

2.5 Summary

The NPQ program is largely a series of minor works programs to address identified non-compliance issues from individual residences in the Low Voltage network as well as some larger voltage management projects at zone substations in Power and Water's network. As the network develops, the NPQ program remains essential to network performance and reliable supply of power to LV customers.

This business case is focused on management of power quality issues that occur in the network. Augmentation and maintenance of assets that contribute to power quality issues are covered by the NPQ program.

Section 3 discusses the options for addressing the identified PQ risks.

[18] Pg. 10, Clause 4.4 Inverter Energy System e., D2020/380910 Basic Micro EG Connection Technical Requirements Specification v1, October 2020, Power and Water Corporation.
[19] Pg. 28, Transmission and Distribution Annual Planning Report 2021, Power and Water Corporation.
[20] ESS typically include Regulation Raise, Regulation Lower, Contingency Reserve Raise, Contingency Reserve Lower and Rate of Change of Frequency Control Service.
[21] Pg. 70, Transmission and Distribution Annual Planning Report 2021, Power and Water Corporation.

3. Options analysis

This section describes the various options that were assessed. The options are analysed based on ability to address the identified needs, prudency and efficiency, commercial and technical feasibility, deliverability, benefits and an optimal balance between long term asset risk and short-term asset performance.

3.1 Comparison of credible options

Credible options are identified that address the identified need, are technically feasible and can be implemented within the required timeframe. The following options have been identified:

- Option 1 – Do Nothing. This option is based on undertaking no remedial work to address PQ issues raised by customers during the five years of the 2024-29 regulatory period ('the next RCP').
- Option 2 – Complaints-driven PQ remediation. This option is based on Power and Water responding reactively to investigate customer PQ complaints to determine the root cause, determine the appropriate remedy, and, if the prudent response is to augment or otherwise modify the network, undertake the work within a reasonable time.
- Option 3 – Proactive plus reactive PQ remediation. Option 3 builds on the complaints-driven response (i.e. per Option 2) by incorporating proactive modelling of the LV network to help identify PQ issues before customers lodge complaints.
- Option 4 – Controlled network. This option involves real-time monitoring of solar PV generation to facilitate the integration of embedded generation. Monitoring and control, combined with market incentives, would be applied to identify and address power quality issues.

A comparison of the four identified credible options and the issues they address is summarised in the table below. A discussion of each option is provided below.

Table 3: Summary of options analysis

Assessment metrics	Option 1	Option 2	Option 3	Option 4
NPV ($m, real 2022)	0.00	-3.15	-3.35	Not available
Capex ($m, real 2022)	0.00	3.60	3.60	>>3.60
Opex ($m, real 2022)	0.00	0.00	0.24	>>0.24
Meets customer expectations	○	◕	●	◑
Aligns with Asset Objectives	○	◑	●	○
Technical Viability	○	◕	●	◕

Deliverability	○	●	●	○
Preferred	✖	✖	✓	✖

● Fully addresses the issue ◕ Adequately addresses the issue ◑ Partially addresses the issue ○ Does not address the issue

Notes to Table 1:

- The table above excludes the expenditure forecast for the remainder of the current period but allows for the non-compliance reduction achieved as it is a continuation of the existing program
- The NPV and capex were calculated over the five year regulatory period FY25-FY29.
- The cost of Option 4 was not assessed in detail because it was determined at a high level to be prohibitively expensive and undeliverable within the next RCP.

3.1.1 Option 1 – Do Nothing (Base Case)

The Do nothing option is based on not undertaking any work to respond to identified power quality issues or customer power quality complaints for the duration of the next RCP.

This is not a technically acceptable option as Power and Water is required to take reasonable and prudent action to ensure compliance with Technical Rules and Planning Criteria.

This option does not impose any additional costs on Power and Water. However, the disadvantages of this option are that for every case in which the PQ issue is verified[22] and are found to be related to the network,[23] and for which Power and Water ignores or declines to respond, the following consequences are likely to arise:

- Breach of Power and Water's Technical Rules and Planning Criteria.
- Reputational damage: disgruntled customers may seek help from the Utilities Commission, the Energy Minister, the energy ombudsman and/or raise the issue in the media all of which could lead to censure and reputational damage for Power and Water.
- Cost being incurred to remedy the issue and compensate the customer for damage to their equipment or for some other financial loss.

This option is not recommended.

[22] In some cases, measurements indicate that the PQ issue was a once-off due for example to a system fault, rather than a systemic issue on the customer or network side

[23] In some instances, PQ issues arise because of the configuration and/or settings of the customer's electrical system, including non-compliant inverter settings

3.1.2 Option 2 – Complaints-driven PQ remediation

This option is based on Power and Water responding to customer PQ complaints. The process for addressing the complaint involves an investigation by Power and Water to determine the root cause. The issue will fall in to one of three types:

- Verified PQ issue with corrective action required on the network, including
  - Upgrading or installing conductors and cables
  - Upgrading or installing voltage support equipment, or
  - Upgrading or installing distribution transformers
- Verified PQ issue with corrective action required by the customer (as the cause is withing the customer's electrical boundary), which will require a licensed electrician to undertake remedial work, including for example:
  - Correcting the settings of the PV inverter to be compliant with AS/NZS 4777
  - Addressing an internal fault in the wiring
- One-off or indeterminate PQ issue – no remedial action is required.

The advantage of this approach is that Power and Water need only respond to customer-driven complaints, which provides a relatively effective means of addressing PQ issues, albeit reactively.

The disadvantages of this option are:

- An unresolved PQ issue may develop into a potentially unsafe electrical condition, and which goes undetected (i.e. if the customer does not complain).
- An unresolved PQ issue may result in equipment damage for which Power and Water may be required to compensate the customer.
- It does not improve Power and Water's reputation – the process involves a deliberate strategy of requiring a customer to raise a complaint against Power and Water, which is contrary to the principles of a customer centric organisation (which Power and Water aims to be).

This option would require annual capital expenditure of $0.72 million p.a, or capex of $3.6 million (real 2021/22) over the next RCP.

As a customer focussed organisation, Power and Water aims to address network issues, including quality of supply, as early as feasible before customers are affected. The reliance of this option on reactive processes is not aligned with Power and Water providing sustainable long term solutions for the network.

This option is not recommended.

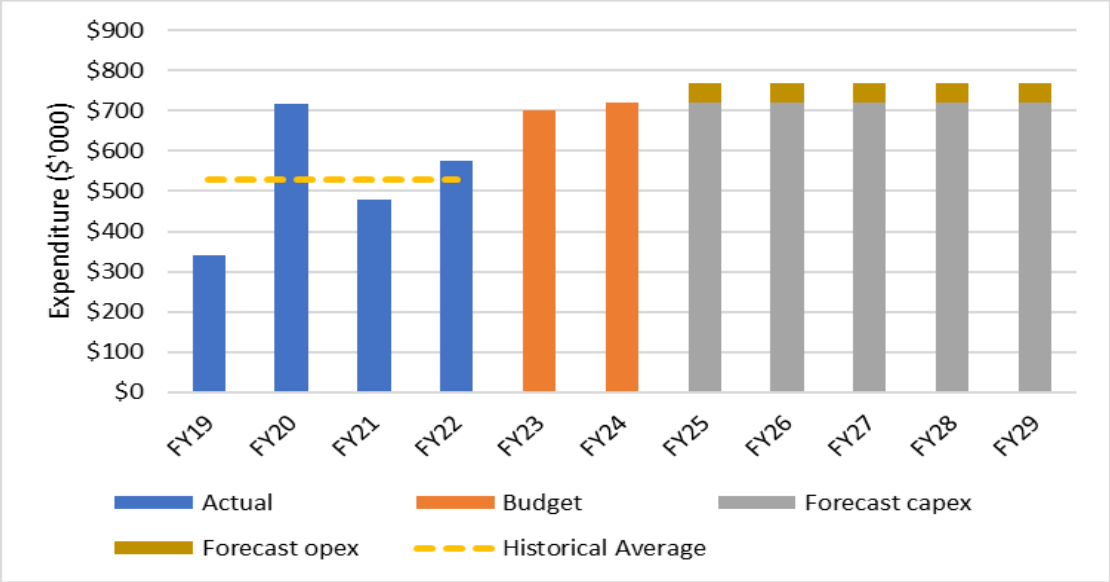
3.1.3 Option 3 – Proactive plus reactive PQ remediation

This option builds on Option 2 by proactively identifying power quality issues through load flow studies and system modelling (opex), in addition to resolving PQ issues identified by customers. The identification of potential power quality issues as well as constraints in the network provides a key input to the NPQ

program that enables issues to be managed before they impact customers and subsequently become complaints. To complement proactive identification, power quality issues that are not discovered through network studies and modelling, continue to be addressed on an ad hoc basis.

The historical average expenditure incurred under the current NPQ program has informed the forecast expenditure, as shown in Figure 3.

Figure 3: NPQ program historical and forecast expenditure



Reactive PQ remediation (capex)

The forecast takes into consideration the historical program expenditure with an increase of $200k per annum above the historical average to allow for the growing uptake of distributed energy resources. It is expected that the number of customer complaints will increase in the next regulatory control period.

Proactive analysis (opex)

Focused system modelling to assist the NPQ program would require approximately one Power and Water network modeller 0.75[24] hours per week at a semi-professional rate of $105/hr[25] which equates to an annual opex cost of $4k.[26] The weekly hours stated to complete network studies and modelling assumed that analysis is conducted on current network models.

Power and Water aim to develop more accurate LV network and solar PV models in the future which would increase the time required for PQ studies and enable proactive identification of a greater number of potential voltage issues. An estimated eight[27] hours per week to develop new LV network and improved PV models is also included under Opex costs and would be completed, leading to an opex requirement of $44k per annum to develop and/or maintain models.[28]

The total opex cost, inclusive of proactive complaints modelling and model development allowance, for this option is $48,000 per annum.

For a marginal increase in opex, this option allows for the proactive identification of power quality issues and reduction of customer complaints raised, leading to increased compliance and improved customer experience. It is for these reasons that this approach is recommended.

3.1.4 Option 4 – Controlled network

This option involves full real-time monitoring of solar PV generation to facilitate the integration of embedded generation. Monitoring and control, combined with market incentives, would be applied to identify and address power quality issues.

This option would have a materially higher cost than Option 3 but is not quantifiable under this program because it consists of a system wide investment. Additionally, it cannot be delivered in full in the 2024-29 regulatory period and therefore is not considered a feasible alternative.

[24] Note this figure is an estimation based on our experience. Addressing one power quality issue or project requires 2-4 hours of modelling work, averaged at 3 hours per project. As a worst-case scenario, the maximum number of projects completed in a year for the NPQ program was 11 in 2018/19 – see Appendix, Table 10. On average this equates to approximately one project per month. Proactive modelling to prevent one project per month would require 3 hours per month or 0.75 hours per week of labour.

[25] Labour cost of a Power and Water semi-professional employee calculated based on Power and Water's 2020-21 Regulatory Information Notice (RIN) submission to the Australia Energy Regulator – Table 2.11.1 of Power and Water Corporation (Power and Water) 2020-21 - Category Analysis - RIN Response - Consolida(13029379.1).

[26] Calculations assume network modelling is completed for 52 weeks per year.

[27] Note this figure is an estimation based on our experience of network model development. This is an assumed budget of time taking into account economy of scale over the 5 year regulatory period. Further, the time required to develop models may differ from one to the next.

[28] Power and Water only has HV models - there will be significant work to create and update the LV network models. Some of this can be automated from GIS but manual work will be required

3.2 Non-Credible Options

Our analysis also identified options found to be non-credible. These options are described below and were not taken through to detailed analysis for the reasons provided.

3.2.1 Non-Network alternatives

Due to the type and function of the assets affected by power quality issues, there are no cost-effective non-network alternatives or solutions that can be implemented in place of direct asset upgrades and replacement with like for like (modern equivalent) assets. For example, Power and Water has introduced a requirement for Volt-Var control for new PV installations and proposes instituting dynamic operating envelopes (DOE) to help increase DER hosting capacity without compromising power quality. Over time these initiatives will improve power quality, with benefits to customer likely beyond the next RCP RCP.

4. Recommendation

The recommended option is Option 3 – Proactive plus reactive PQ remediation to be most prudent and cost effective to meet the identified need. This option represents a continuation of the current NPQ program, at an estimated cost of $3.8 million (real 2021/22) for the next RCP, including capex of $3.6 million (real 2021/22).

The proposed program is consistent with the National Electricity Rules Capital Expenditure Objectives as the expenditure is required to maintain the quality, reliability, and security of supply of standard control services and maintain the safety of the distribution system.

4.1 Strategic alignment

The "Power and Water Corporation Strategic Direction" is to meet the changing needs of the business, our customers and is aligned with the market and future economic conditions of the Northern Territory projected out to 2030.

This proposal aligns with Asset Management System Policies, Strategies and Plans that contributes to the D2021/260606 "Power and Water Strategic Direction" as indicated in the table below.

Table 4 Alignment with corporate strategic focus areas

No.	Strategic Direction Focus Area	Strategic Direction Priority
1	Living within our means	Cost Prudency
2	Customer and the community at the centre	Enhance Customer Experience and Engagement
3	Sustainable solutions for the future	Renewables Enablement

4.2 Dependencies

There are no known projects or other network issues that are dependent on the resolution of this network issue.

4.3 Deliverability

The proposed works are equivalent to the similar activities to be completed in the current RCP. No delivery risks have been identified.

4.4 Customer considerations

As required by the AER's Better Resets Handbook, in developing this program Power Services has taken into consideration feedback from its customers.

Feedback received through customer consultation undertaken at the time of writing this business case, has demonstrated strong support amongst the community for appropriate expenditure to enable long term maintenance of the network to ensure continued reliability, maintainability, and safety of supply.

The focus of this program is to directly address customer complaints associated with power quality issues in the distribution network in a timely manner. With the increasing uptake of distributed energy resources, there is almost certain there will be pockets of the low voltage network that breaches technical code in relation of power quality. Customers can contact PWC to lodge an enquiry and existing systems will record this as a power quality issue. There are processes in place to track and record the outcomes of investigations and the subsequent response to the customer.

4.5 Expenditure profile

The table below shows a summary of the annual expenditure requirements during the next RCP.

Table 5 Annual capital and operational expenditure ($m, real FY22)

Item	FY25	FY26	FY27	FY28	FY29	Total
Capex	0.72	0.72	0.72	0.72	0.72	3.60
Opex	0.05	0.05	0.05	0.05	0.05	0.24
Total	**0.77**	**0.77**	**0.77**	**0.77**	**0.77**	**3.84**

4.6 High-level scope

The scope of this program is a continuation of past NPQ programs. Work required for this program is largely carried out on a site-by-site basis where complaints have been recorded.

Aims of this program include:

- Address power quality issues in the LV network; and
- Complete general maintenance, safety, and capacity work, such as upgrading conductors or overloaded transformers.

To achieve these aims, it will be necessary to:

- Conduct regular load flow analysis modelling to proactively identify power quality issues
- Attend locations where complaints are raised and remedy power quality issues, as required, and
- Complete LV network voltage management works, as required.

Appendix A. Steady state power frequency voltage limits

This is an extract from clause 15.2 in the Network Technical Code (pages 131-132)

The range of steady-state *voltage* at different *voltage* levels of the *power system* under normal operating conditions is set out in this clause.

The *Australian Standard* for *low voltage* was altered in 2000. *Australian Standard* AS 60038-2000 establishes a revised nominal *voltage* of 230/400 V (single/three phase), to match the European standard set out in IEC 60038:1983.

Australian Standard AS 6038-2000 notes that 240/415 V systems shall evolve towards the new standard and a revised *supply voltage* range. *Power and Water* is participating in an Energy Networks Association review of issues associated with the potential migration from a nominal mid- range *voltage* of 240 V to 230 V.

(a) For *voltages* of 11 kV or more, the *network* shall be planned and designed to maintain a continuous *network voltage* at a *User's connection* not exceeding

the design limit of 110% of nominal *voltage* and not falling below 90% of nominal *voltage* during normal and maintenance conditions.

(b) The *network* shall be designed to maintain the *low voltage* steady state levels within the range set out in Figure 16 for *credible contingency events*. These are referenced to the nominal *voltage* of 230/400 V.

Figure 16 – *Supply voltage* range

System condition	Lower range	Upper range
Normal conditions	- 2%	+ 11%
Planned maintenance conditions	- 4%	+ 13%
Unplanned *outage* conditions	- 6%	+ 15%

(c) The power *frequency voltage* may vary outside the ranges set out in this clause 15.2 as a result of a *non-credible contingency event*.

Appendix B. Annual network failures for 11kV underground cable

The series of projects that make up the program are typically small projects, as seen in Table 10, hence NPQ operates as a program of works rather than separate, individual projects.

Table 6 Past projects of the NPQ program

Year	Project Title	Estimated Cost ($AUD)
18/19	UPGRADE POWER QUALITY ISSUES IN WAGAMAN	$27,791.00
18/19	UPGRADE POWER QUALITY ISSUES LOVELOCK ROAD, BEES CREEK HUNDRED OF STRANGWAYS	$113,154.00
18/19	LOW VOLTAGE ISSUE LOT 7 (205) ARNHEM HIGHWAY HUMPTY DOO HUNDRED OF STRANGWAYS	$38,466.00
18/19	LOT 3011 (FINLAYSON PARK) CARRUTHERS CRESCENT POWER SUPPLY UPGRADE.	$88,868.00
19/20	POWER QUALITY ISSUES 135 WOODCOTE RD GIRRAWEEN HUNDRED OF STRANGWAYS	$70,841.00
19/20	POWER QUALITY ISSUES ALONG WESTALL ROAD HOWARD SPRINGS HUNDRED OF BAGOT	$106,314.00
19/20	POWER QUALITY ISSUES ALONG REDGUM DRIVE HUMPTY DOO	$58,717.00
19/20	POWER QUALITY ISSUES ALONG JESSE ROAD GIRRAWEEN HUNDRED OF STRANGWAYS	$72,802.00
19/20	POWER QUALITY ISSUES ALONG DOXAS ROAD HUMPTY DOO HUNDRED OF STRANGWAYS	$53,069.00
19/20	POWER QUALITY ISSUES 280 KENTISH ROAD LIVINGSTONE HUNDRED OF CAVENAGH	$43,020.00
19/20	POWER QUALITY ISSUE LOT PAPERBARK DRIVE MCMINNS LAGOON HUNDRED OF STRANGWAYS	$30,290.00
19/20	POWER QUALITY ISSUE LOT 7 (1470) COX PENINSULA ROAD SOUTHPORT	$37,107.00
19/20	POWER QUALITY ISSUE GALBRAITH ROAD VIRGINIA HUNDRED OF STRANGWAYS	$46,241.00
19/20	POWER QUALITY ISSUE ALONG LAMBELLS LAGOON ROAD LAMBELLS LAGOON HUNDRED OF GUY	$136,364.00
19/20	POWER QUALITY ISSUE ALONG GOLDING ROAD ACACIA HILLS, HUNDRED OF STRANGWAYS	$61,841.00

20/21	POWER QUALITY ISSUES LOT 19 (10) LOVELOCK ROAD BEES CREEK HUNDRED OF STRANGWAYS	$54,753.00
20/21	POWER QUALITY ISSUES LOT 1605 LEONINO ROAD DARWIN RIVER HUNDRED OF CAVENAGH	$88,060.00
20/21	POWER QUALITY ISSUES IN THE JINGILI AREA	$134,397.00
20/21	POWER QUALITY ISSUE OSBECK & EUGENE ROADS VIRGINIA	$126,668.00
20/21	POWER QUALITY ISSUE LOT 4773 ROGERS ROAD GIRRAWEEN HUNDRED OF BAGOT	$28,902.00
20/21	POWER QUALITY ISSUE LOT 160 MADSEN ROAD HOWARD SPRINGS HUNDRED OF BAGOT	$46,215.00
21/22	ALICE SPRINGS VOLTAGE MANAGEMENT – LOVEGROVE ZSS 22KV CONNECTION	$300,500.00
21/22	UPGRADE OVERLOADED DIST. TRANSFORMER DT-0490 595 ARNHEM HWY	$27,870.00
21/22	AMEND LV POWER QUALITY SUPPLY ISSUES – SAMUEL ROAD, HERBERT	$46,500.00
21/22	POWER QUALITY IMPROVEMENT WORKS - BATU RD, HERBERT	$164,982.00
21/22	POWER UPGRADE TO LOT 3045 (363) GORGE ROAD LANSDOWNE KATHERINE	$36,737.00

Power and Water Corporation

55 Mitchell Street, Darwin NT 0800

Phone 1800 245 092

powerwater.com.au