PowerWater

Program Business Need Identification

Power and Water Corporation

NMP2

Low Voltage Cable Replacement Program Cullen Bay and Bayview

Proposed:

Stuart Eassue
Manager Strategic Asset Engineering
Power Networks
Date: 5 December 2017

Approved:

Michael Thomson
Chief Execitive
Power and Water Corporation
Date: 6/2/2018

Djuna Pollard
Execitive General Manager
Power Networks
Date: 5 December 2017

D2018/42761

Finance Review
Date: 05/ 12/2017

PMO QA
Date: / /20

1 Program Summary

Program Name:	Low Voltage Cable Replacement Cullen Bay & Bayview		
Program No:	NMP2	SAP Ref:	
Financial Year Commencement:	2019/20		
Business Unit:	Power Networks		
Program Owner (GM):	Djuna Pollard	Phone No:	08 8985 8431
Contact Officer:	Stuart Eassie	Phone No:	08 8924 5214
Date of Submission:		File Ref No:	
Submission Number:		Priority Score:	
Primary Driver:	Safety	Secondary Driver:	Renewal/ Replacement
Program Classification:	Capital Program of Works		

2 Recommendation

2.1 MINOR PROJECTS UP TO $1M NOT COVERED BY AN EXISTING BNI

It is recommended that the Chief Executive note the proposed five year low voltage cable replacement program for an estimated budget of $1.74 million, and approve the inclusion of this program into the SCI for this amount, with a corresponding completion date of June 2024.

The forecast for this program of work extends beyond the current SCI period. The first two years of this program aligns with the last two years of the 2017-18 SCI. This program 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 Case Category Cs to be approved by the Executive General Manager Power Networks.

3 Description of Issues

Included in the population of LV Mains Cables are 15 km of XLPE/PVC cable located the Cullen Bay and Bayview distribution areas. The majority of these cables were installed in the 1990's and have an age based remaining life of around 34.1 years.

Investigations undertaken during 2016 and 2017 identified that the low voltage cables in the Cullen Bay and Bayview areas were of particularly poor condition with consistent sheath and insulation deterioration. The poor cable insulation condition has accelerated moisture

ingress and the incidental development of calcium adipate leading to accelerated cable insulation and cable termination degradation. The level of deterioration of such a large proportion of cables is unprecedented based on their age and is considered a type issue unique to the cable installed.

The LV neutral earthing system in Cullen Bay is also compromised. The LV neutral conductor connection between a substation and the network being supplied is one of the fundamental components of the TN-C-S (Australia's MEN) network configuration as described by AS/NZS 3000. As such an LV neutral conductor is reticulated to all locations of the supplied LV network (Protective Earth and Neutral PEN). Throughout Australian utilities, this is generally achieved through the installation of a neutral conductor with each LV circuit leaving a substation. This is to ensure redundancy and interconnectivity of the MEN system. This is not the case in Cullen Bay. Neutral conductors are "shared" creating many single points of failure as explained in Figure 2.

The combination of factors creating a hazardous network are summarised below. For more detailed information refer to the Cables Asset Class Management Plan[1]. Additional actions are being considered to mitigate the direct public safety risks until replacement works commence in 2019/20, and during the execution of the program. This includes frequent testing of neutral integrity, frequent inspections of the area for civil works and additional earthing.

Risk Factor	Description of Hazards
Calcium Adipate	Calcium adipate is produced when water reacts with certain compounds or "fillers" in the cable insulation[2]. Examples shown in Figure 1 Places high physical stress on the cable insulation, resulting in localised insulation and sheath cracking and swelling. The adipate enters cable lugs, expanding the lug and causing high resistance joints, these are undetectable on neutrals. Conductive when wet placing personnel at risk when working on pillars or fault finding.
Sheath Degradation	Cables excavated for failure replacement or other works have consistent damage to the outer sheath. The damage allows water into cable to which then reacts with the cable insulation fillers to produce calcium adipate. Reduces insulation performance due to water ingress into cable and XLPE insulation.
Insulation Resistance	Insulation Resistance (IR) of 50% of cables sampled was very low, with a high proportion below 1MΩ. Refer to Appendix B for a summary of testing performed.

[1] D2017/448007 PWC Asset Class Management Plan – AMP - Cables

[2] D2012/63469 20120208 Energy Aus - Cable white powder issue report Calcium Adipate

Risk Factor	Description of Hazards
	1 MΩ is considered a critical limit based on AS/NZS 3000:2008 Wiring Rules. Of six Australian utilities sampled, none have acceptance criteria below 1MΩ for LV cables[3]. While functional failures have not increased, it is expected that any failure will be extremely difficult to locate due to the amount of cables that will have very low IR values. As LV cables do not have an earth screen, it is common for faulted LV cables to still have high measured insulation values.
Neutral Arrangement	Common design practice for LV networks is to have a neutral conductor run with every LV circuit to ensure a robust return path to manage phase balance and provide a direct fault return path in addition to earthing for reliable protection operation. In Cullen Bay (not Bayview) this is not the case and most LV circuits do not have a dedicated neutral. Instead neutrals have been installed in essentially a separate network which tees off to individual pillars. This practice is highly susceptible to failure of individual neutral conductors which are generally undetectable, and relies heavily on the earthing system for fault return path and control of hazardous voltages on downstream neutrals and interconnected equipment during LV faults. Performing work on the network is hazardous. Maintainers are unable to determine if a neutral being disconnected for repair or otherwise will create a break in the neutral network. In this scenario hazardous voltages can be created at the point of disconnection placing the maintainer at risk, and protection systems may be compromised as described above.
Earthing Arrangement	Common practice in the NT is to run earth cables with LV circuits as very high soil resistivity reduces the effectiveness of earthing at pillars, without installing significant earthing infrastructure at each pillar. This design practice was not applied at Cullen Bay, instead local pillar earthing is applied using two 2m deep earth stakes at each pillar. This is not adequate based on the measured high soil resistivity in the area.
High Soil Resistivity	Soil resistivity testing in Cullen Bay shows a soil resistivity of 3000Ω to a depth of 4m. The high soil resistivity renders the earthing rods installed ineffective. Protection in the LV network does not have an effective return path in the event of a broken neutral which is not detectable when performing maintenance activities requiring disconnection of neutrals.

[3] D2017/369295 LV Cable Maintenance Specification Background

Figure 1 - Examples of Calcium Adipate in Pillars (left) and Substations (right)

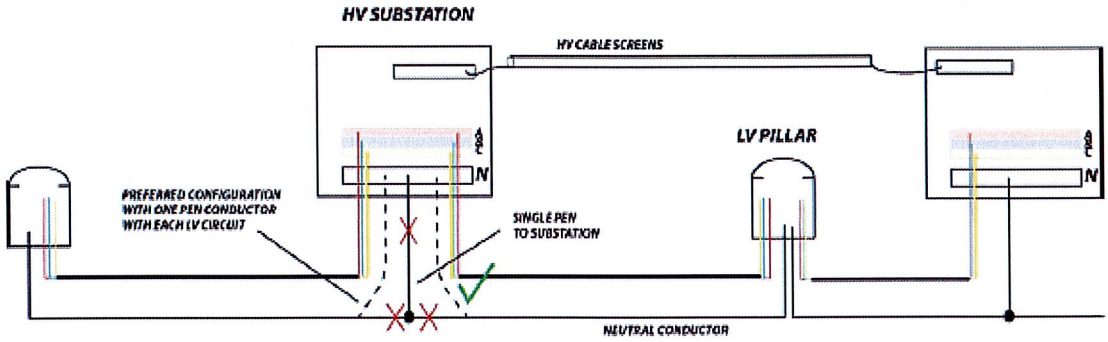


Figure 2 - Cullen Bay Neutral Configuration and Single Points of Failure

3.1 Project Needs

a. Safety

The unpredictable operational conditions resulting from neutral sharing applied in the Cullen Bay and Bayview distribution areas poses a safety risk to the public as well as PWC employees involved in undertaking works on and in the vicinity of the assets and fittings. The rapid deterioration of cables increases the risk of failure as cables reach end-of-servicable life well before expected service life. Replacement of the LV cables and coincident refurbishment of the earting and neutral system addresses the public and worker safety risk.

b. Compliance
A fundamental business driver for PWC is compliance with the relevant Health and Safety Legislation, the Network Technical Code and Network Planning Criteria objective of providing safe, secure, reliable, high quality power supply at a minimal cost. A detailed outline of compliance requirements is described in the Power Networks Strategic Asset Management Plan. Targeted replacement will maintain the effectiveness of the earthing system and reduce employee and public risk associated with asset failure compliant with the business objective.
c. Reliability
The deterioration in cables and associated replacement works have not impacted reliability to date. It is expected that the rapid deterioration of the cables will lead to an unpredictable increase in reliability impact at some stage. As the condition of the cables is very poor, when unplanned failures do occur it is likely that they will be extremely difficult to locate using traditional methods, leading to extended outages for customers in these areas.

4 Potential Solution

Opportunities to maintain the safe and reliable operation of the network have been considered. These include:

Option 1 – Run to failure

Run to failure involves the reactive maintenance and repair of assets. It is characterised by increasing operations and maintenance costs, adverse system performance impacts, and unacceptable public and worker safety risk associated with the continued degradation of the assets.

Failure of the LV cables in these areas creates the conditions to realise the hazards outlined in section 3 Description of Issues.

Based on the outcome of investigations to date and the hazards associated with continued operation of the network, this is not aligned with PWC's business objective for operating a safe and reliable network.

Option 2 – Inspection, Repair and Earthing Upgrade

This approach involves the routine inspection and testing of LV cables and the associated earthing and neutral systems to determine high-priority repairs and to forecast asset failures. Based on the prioritised forecast, asset repairs and replacements are then scheduled. The time to failure for a cable cannot be determined based on any measurement and therefore predicting the failure is difficult and in many instances the repair and replacement work becomes reactive.

PWC has been implementing the testing and repair/replace approach on the LV cable network in Cullen Bay and Bayview and have recognised the need for a more effective approach to maintain the safe and reliable operation of the network. Testing of the neutral system gives no indication of whether one of the redundant fault return paths has failed so hazardous situations may still exist. Testing of specific return paths would require network wide outages to isolate sections of the network from possible shared neutral currents. This is not practical.

An earthing upgrade to provide at least one robust fault return path for continued safe network operation is currently being considered, however it does not ensure the dedicated connection between substations and network connection points i.e. customers. It would require significant earthworks and new earthing conductor to be installed at 77 distribution substations and pillars in Cullen Bay.

Option 3 – Targeted proactive replacement and refurbishment

The targeted proactive replacement of the cables and coinciding refurbishment of the earthing and neutral systems is a concerted approach directed at maintaining system safety and reliability in a prudent and cost efficient manner. It relies on a risk based prioritisation of cables taking into consideration asset health and criticality to inform a replacement program.

4.1 Preferred Option

A risk based approach has been used to establish a targeted replacement program as the preferred option. The program will replace 7.0 km, 46.3%, of the Cullen Bay and Bayview LV cable population in the next regulatory period, 2019/20 to 2023/24 focused on the highest risk assets. It is expected to cost $1.7 m over the 5 year period. This strategy will result in the replacement of 87% of the LV cable population in Cullen Bay and Bayview over a 20-year period.

The program considers asset criticality, health, and probability of failure to prioritise the cables that poses the higher risk. Criticality has been determined to be homogenous across the network, given the small size of the networks and the similarity in customer composition. The severity of calcium adipate deposit provided an indication of asset health.

The probability of failure has been based on recent cable insulation test results, and adjusted to allow for an expected initial increase in failure rates as the asset condition continues to deteriorate.

Year	2019-20	2020-21	2021-22	2022-23	2023-24	Total
	Qty	Qty	Qty	Qty	Qty	Qty
Replacement volumes (km)	1.8	1.6	1.4	1.2	1.0	7.0
Total	**1.8**	**1.6**	**1.4**	**1.2**	**1.0**	**7.0**

4.2 Non Network alternatives

No non-network alternatives were identified that would mitigate the need for the replacement of the LV cables.

4.3 Capex/Opex substitution

The proposed LV cable replacement program addresses construction and design issues that cannot be solved through operations and maintenance activities. Current Opex solutions being applied to mitigate the risk include additional periodic testing and inspections of the network, however testing practices cannot determine when the network degradation reaches a point where a single failure or maintenance action can isolate the neutral connection of a part of the network.

4.4 Contingent Project

The expenditure does not meet the criteria for a contingent project - National Electricity Rules, section 6.6A.1(b)(2).

5 Strategic Alignment

This program aligns with the Asset Objectives defined in the Strategic Asset Management Plan (SAMP) and Asset (Class) Management Plans (AMP). The capital investment into cables outlined in this program will contribute to the Corporation achieving the goals defined in the boards Strategic Directions and SCI Key Result Areas of Health and Safety and Compliance.

6 Timing Constraints

It is essential that this project commence as proposed to manage the continued safe and reliable operation of the network. Cables that fail to meet acceptable criteria prior to the commencement of this program will continue to be replaced and additional maintenance

activity to mitigate some of the risks will also continue until sufficient proportion of the cables are replaced to eliminate the risk.

7 Expected Benefits

Driver	Benefit	Measure
Renewal/Replacement	Network safety Network reliability	Safety risk SAIDI/SAIFI performance
Compliance	Compliance with Network Technical Code and Network Planning Criteria objective	Safe network
Social / Environmental	Network safety	Duty of care to customers

8 Milestones (mm/yyyy)

Investment Planning	Project Development	Project Commitment	Project Delivery	Review
01/2018	NA	01/2019	06/2024	09/2024

The program delivery is scheduled to run over 5 years from July 2019 to June 2024. A program review will be held at the end of the 5 year program as well as interim reviews at the end of each Financial Year.

9 Key Stakeholders

Stakeholder	Responsibility
Internal governance stakeholders	Executive General Manager Power Networks
	Group Manager Service Delivery
	Chief Engineer
Internal design stakeholders	Senior Manager Network Development and Planning
	Senior Manager Contracts and Projects
	Senior Manager Asset Management
	Senior Manager Field Services

Stakeholder	Responsibility
External – Unions and public	Local Residents
	ETU
	Ministers
External regulators	Utilities Commission
	Australian Energy Regulator

10 Resource Requirements (to next gateway)

Not applicable. Resourcing requirements for this program are considered Business as Usual and will be incorporated into the development of Category C Business Case's for each individual replacement.

11 Delivery Risk

Site access for the removal and installation of cables may need to be negotiated on a site by site basis. These negotiations could impact on the timely and effective delivery of the program. Early stakeholder notification and consultation will assist in managing the delivery of the program.

Consequential, site specific costs may result from works being undertaken on existing installations in existing built up environments. The expenditure estimates have been based on similar brown field works undertaken in recent years in the Cullen Bay area and includes for potential variances in costs.

12 Financial Impacts

12.1 Expenditure Forecasting Method

The expenditure forecast has been based on a programmed approach. The forecast volumes have been determined using a risk based prioritisation of assets focusing on the replacement of the highest risk installations.

The asset replacement investment program is internally driven and no customer contributions are expected.

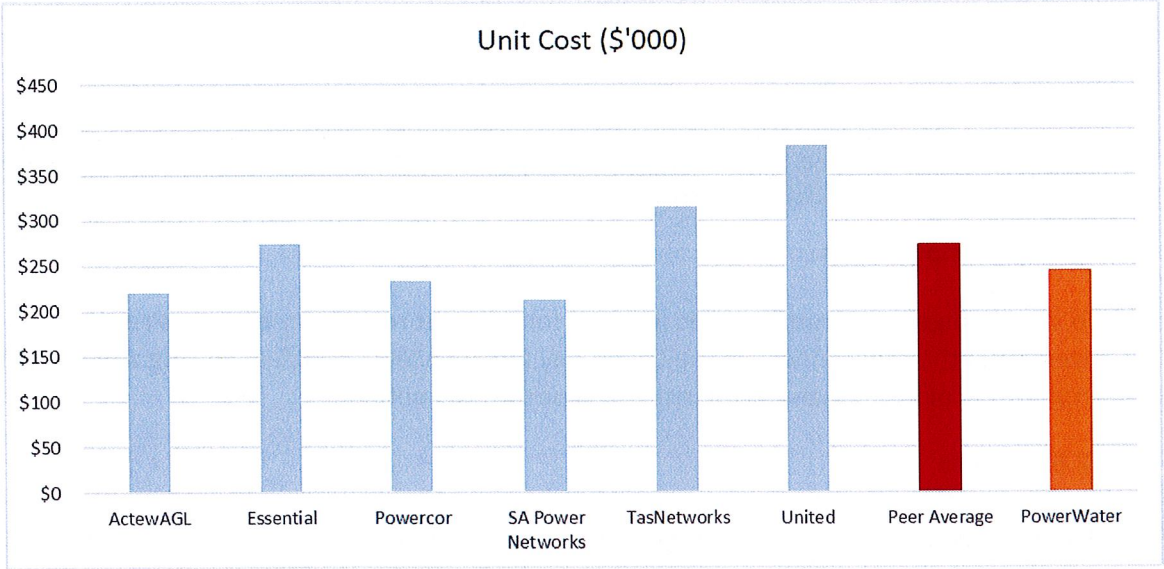
12.2 Historical and Forecast Expenditure

The annual forecast cable replacement capital expenditure for the 2019/20 to 2023/24 regulatory period is provided in Section 12.4 below. The risk associated with these cables has

been identified during the current regulatory period and no significant capital expenditure has occurred during the period.

12.3 Validation

The cost estimate has been based on recent, 2016/17, replacement works undertaken by PWC in the Cullen Bay area, characterised by sandy soil and relatively clear cable corridors, simplifying civil works. A benchmark of the cost against similar works undertaken by peer utilities indicates that the unit cost is reasonable. In comparison with peer utilities PWC's unit cost compares with the peer average.



The comparison has been based on publicly available data sourced from the Australian Energy Regulator's (AER's) Repex modelling and utility Regulatory Information Notice (RIN) submissions. There are a number of internal and external operational, asset type, and environmental factors that influence the benchmark costs and provide a challenge in respect of the ability to undertake accurate comparisons. Normalisation for these factors has not been undertaken and the benchmark comparisons provided are an indicative measure of reasonableness only.

12.4 Capex Profile

Phase	2019-20 ($'000)	2020-21 ($'000)	2021-22 ($'000)	2022-23 ($'000)	2023-24 ($'000)	Total ($'000)
Investment Planning						
Project Development						
Project Commitment						
Project Delivery	207	297	369	426	442	1,740
Review						
Total	207	297	369	426	442	1,740

12.5 Opex Implications

No step change in operating cost is forecast for the next regulatory period as result of investing in the replacement of the Cullen Bay and Bayview LV cables. Testing and inspection programs in place to manage the risk are expected to continue.

12.6 Variance

The forecast for this program of work extends beyond the current SCI period. The first two years of this program aligns with the last two years of the 2017-18 SCI.

APPENDIX A

1 Forecast Expenditure by Expenditure Category

The forecast is in today's dollars ($2017-18).

RAB Category	Regulatory Year (A$M, $2017-18, Jul to Jun years)				
	2019-20	2020-21	2021-22	2022-23	2023-24
Total	0.207	0.297	0.369	0.426	0.442
Labour	0.101	0.144	0.179	0.207	0.215
Materials	0.049	0.071	0.088	0.101	0.105
Contractors	0.057	0.082	0.102	0.117	0.122
Other	0	0	0	0	0

Definitions

Labour – The cost of direct Labour for the project. No overheads.

Materials – the cost of materials used in the project. No overheads.

Contractors – the cost of work performed by Contractors in the project, whether Labour or Materials. No overheads.

Other – expenditure that is not Labour, Materials or Contractors. No overheads.

2 Forecast Expenditure by RAB Category

The forecast is in today's dollars ($2017-18).

RAB Category	Regulatory Year (A$M, $2017-18, Jul to Jun years)				
	2019-20	2020-21	2021-22	2022-23	2023-24
Total	**0.21**	**0.30**	**0.37**	**0.43**	**0.44**
System Capex					
Substations					
Distribution Lines	0.21	0.30	0.37	0.43	0.44
Transmission Lines					
LV Services					
Distribution Substations					
Distribution Switchgear					
Protection					
SCADA					
Communications					
Non-system Capex					
Land and Easements					
Property					
IT and Communications					
Motor Vehicles					
Plant and Equipment					

3 Forecast Expenditure by CA RIN Category

The forecast is in today's dollars ($2017-18).

RAB Category	Regulatory Year (A$M, $2017-18, Jul to Jun years)				
	2019-20	2020-21	2021-22	2022-23	2023-24
Total	**0.21**	**0.30**	**0.37**	**0.43**	**0.44**
Repex	0.21	0.30	0.37	0.43	0.44
Augex					
Connections					
Non-network: IT					
Non-network: Vehicles					
Non-network: Buildings and property					
Non-network SCADA & network control					
Non-network: Other					

APPENDIX B

Summary of testing sample which represents 4% of the Cullen Bay and Bayview LV cables affected. Detailed results available in D2017/364535.

Cable section	Cable Route Length (m)	Test results
P010CB - P009CB	48.8	Tested - okay. Encroaching 1MΩ.
P001CB - SUB 2280	102.9	Tested - okay
P004CB - P005CB	69.92	Tested - okay
P005CB - P0012CB	101.37	Tested – less than 1MΩ.
P007CB - P008CB	51.07	Tested - less than 1MΩ.
P008CB - P0014CB	227.66	Tested - less than 1MΩ.
Total length tested:	**601.72**	
Total population length:	**15,058.20**	
Percentage of population:	**4.0%**	