PowerWater

Program Business Need Identification

Power and Water Corporation

CONTROLLED DOCUMENT

NMP12 (PRD33452)

Power Transformer Online Moisture Control Program

Proposed:

Stuart Eassie
Manager Asset Strategies
Power Networks
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Approved:

Michael Thomson
Chief Executive
Power and Water Corporatio
Date: 23/02/2018

Djuna Pollard
Executive General Manager
Power Networks
Date: 15/2/2018

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PMO QA
Date: 15/02/2018

1 Program Summary

Program Name:	Power Transformer Online Moisture Control Program		
Program No:	NMP18 / PRD33452	**SAP Ref:**	
Financial Year Commencement:	2019/20		
Business Unit:	Power Networks		
Program Owner (GM):	Djuna Pollard	**Phone No:**	
Contact Officer:	Stuart Eassie	**Phone No:**	08 8924 5214
Date of Submission:	23rd Feb 2018	**File Ref No:**	D2017/462957
Submission Number:		**Priority Score:**	
Primary Driver:	Commercial / Efficiency	**Secondary Driver:**	Renewal / Replacement
Program Classification:	Capital Program of Works		

2 Recommendation

It is recommended that Chief Executive note the proposed five year Power Transformer Online Moisture Control program for an estimated budget of $1M, and approve the inclusion of this Program into the SCI for this amount, with a corresponding completion date of June 2024.

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 C to be approved by the Executive General Manager Power Networks.

3 Description of Issues

3.1 Context

A revised approach is proposed to more efficiently manage of the water content in power transformer insulating oil, improve oil quality and maximise the serviceable life of transformers.

The climatic conditions experienced in the northern region of the Northern Territory as a result of its tropical climate, which bring high humidity and high rainfall, can result in a high water content in power transformer insulating oil, measured as parts per million (PPM).

Over time, the presence of high water levels in the insulating oil will reduce the serviceable life of the transformer and increase the likelihood of failure through normal operational pressures such as through-faults and lightning/switching surges. The key modes of failure are:

- Acceleration of the deterioration of the paper insulation, decreasing its mechanical and electrical (insulation) strength;
- Deterioration of the insulation properties of transformer oil;
- Deterioration of seals/gaskets and transformer tank through corrosion which can result in leaks and prevent effective leak repairs.

The deterioration drivers and failure modes are described in detail in the Power Transformer Asset Class Management Plan.

The concentration of water in the oil is measured as parts per million (PPM) along with the oil temperature. These two values are then used to calculate the percentage saturation of the insulating oil. Table below outlines the criteria and associated actions related to saturation.

Table 1 Oil Moisture Level Saturation Limits

Saturation Level	Action
<5%	No action required
5 to 20%	Increased monitoring to forecast treatment requirements
>20%	Oil treatment scheduled

3.2 Current Asset Management Approach

There are currently three approaches in place to remove water content from the oil:

- *Offline filtering*: transformers are taken offline (out of service) and the oil is filtered for one to three weeks prior to the transformer being returned to service. This process requires a mobile filtering plant that heats the oil as part of the filtering process. The deployment, set-up, ongoing monitoring and control required during filtering are labour intensive. The process is very effective at removing moisture from moderately saturated transformers; however the limited availability of transformers for filtering typically limits its effectiveness. Manual handling and working at heights hazards also require management and add cost to the safe deployment of filter plant.

- *Mobile online filtering*: transformers are filtered with online filtering equipment for three to six months before being removed and relocated to a new transformer. The extended time filtering the oil allows moisture within the paper to be removed gradually and limits the risk associated with rapid drying of paper. No outage is typically required. There are limited options in the market, with four mobile units purchased by PWC in 2010. Manual handling hazards are reduced due to the simpler nature of the plant setup.
- *Permanent online filtering*: new transformers are installed with a permanent online filtering device (zeolite molecular sieve type) already mounted and connected to the oil pipework of the transformer. This has been standard practice in PWC since 2009 when the technology has reached maturity and was widely adopted by industry. The oil is continuously pumped through the filter for continuous filtering. There is no set up or removal outages required. The filter can be maintained (cartridges replaced) while the transformer is in service. Various studies and papers have concluded that this type of filtering is the most effective and efficient form of moisture management for power transformers[1]. Manual handling and working at heights hazards are also eliminated.

There are limitations to the effectiveness and/or applicability of each of these practices. The key limitations are:

- Offline filtering requires the transformer to be out of service for a prolonged period of time. Although it is considered the most effective method of removing water from the oil, it is also the most expensive and has the potential to leave the network in a suboptimal configuration that is less resilient and more susceptible to outages. If transformers are allowed to become too saturated, even this method has proven ineffective at removing moisture from the paper insulation. The process also carries some risk to transformers with aged gaskets and poor structural design, causing leaks which can be difficult to repair on an aged unit due to deformation of sealing surfaces and established corrosion.
- Mobile online filtering equipment has not worked reliably to date. However, recent maintenance appears to have fixed some issues and the first of the four units has been successfully deployed for 3 months. However, this still represents a less than 1% availability since their purchase in 2010. There is also a reasonable opex cost for the set up and removal of these units at each site, as well as ongoing additional inspections to ensure leaks do not develop in the temporary pipework connecting the unit to the transformer. Other utilities have not experienced similar problems, these problems are considered to be related to the harsh climate of the NT.
- Permanent online filtering of molecular sieve type is only effective at maintaining the moisture levels but does not significantly reduce the moisture level. Therefore, filters need to be installed on a dry transformer or used in conjunction with another filtering method initially to reduce the water content.

[1] A field study of two online dry-out methods for power transformers, IEEE Electrical Insulation Magazine (Volume: 28, Issue: 3, May-June 2012)

There are 22 transformers on the network that currently do not have permanent filters installed, this excludes transformers that are planned for replacement during the next regulatory period. Based on the transformer ages:

- 4 are expected to have at least 10 years of serviceable life;
- 10 are expected to have at least 20 years of serviceable life; and
- 8 at least 30 years remaining.

These expected lives are dependent on maintaining the condition of the oil by ensuring low moisture content.

A number of options have been developed and assessed to identify the most cost effective approach to reduce and then maintain moisture levels in transformers at acceptable concentrations. These options are discussed in the following section.

3.3 Project Needs

a. Customer Consultation and other benefits
Efficient management of assets to maximise their life at a reduce opex cost aligns with customers expectations to deliver reliabile services at lowest cost.

4 Potential Solution

Four potential options have been identified for the ongoing management of moisture in transformer oil are discussed below:

Option 1 – Do nothing

This approach assumes no filtering will be undertaken and permanent online filters will only be installed on new transformers. This will likely result in early asset failure of existing transformers due to reduced dielectric strength of the insulating medium (oil), deterioration of the paper insulation, seals and corrosion of the tank.

This option is not consistent with good industry practice and is not aligned with historical maintenance practices of PWC.

The cost of this option would be the incremental cost of early transformer replacement. This has not been calculated at this stage as it will vary depending on the existing transformers age, current condition and location.

Option 2 – Business as usual using mobile online filters

There are four mobile online filters that historically have not been operating reliably, or at all, since they were purchased in 2010. However, recently some issues have been resolved

and one unit has been in operation since the 27th October 2017. The remaining units are in the process of being repaired and will be deployed when ready.

This option proposes an ongoing deployment of these units where they are continuously rotated through the substations. The mobile filters can be rotated through these transformers on an as needed basis subject to oil testing results. The 4 mobile units each need 3 to 6 months at each site for the filtering process and it is likely that there will be some time required for servicing the units following each deployment.

In addition, given the historical poor reliability of these assets, it is likely that not all filtering units will be available concurrently and that there will be minor and major maintenance/repairs required every two years (based on costs incurred between 2014 and 2017, inclusive). The average cost of parts plus an estimate for labour has been included in the evaluation of this option.

The mobile online filters were purchased in 2010 and have an expected serviceable life of 15 years, meaning they will require replacement in 2025. The cost of replacement of the four units has been included in the evaluation of this option.

- Therefore, it is estimated that up to 9 transformers can be filtered each year.
- The historical costs per transformer filtering cycle are:
    - Set up, filtering and removal: $3.6k
    - Servicing: $1.5k (estimated)
    - Minor maintenance/repair: $8.0k
    - Major maintenance/repair: $35.3k
    - Replacement: $90k per unit

Benefits of this option include the reduction of moisture in oil and the ability to deploy the units quickly to transformers that are identified to have high levels of moisture. The units can be left at a single site for the duration required to achieve the target moisture level.

The Net Present Cost of this option is $1.05M when assessed over a 30 year period with a WACC of 6.5%.

Option 3 – Use a combination of mobile and permanent online filters (preferred option)

As discussed in section 3, there are 22 transformers that that do not have permanent filtering units already installed. These transformers are expected to have remaining serviceable lives ranging from 10 years to over 30 years. This option proposes to:

- retrofit permanent online water filtering units to each of these transformers over a 2 year period; and
- deploy the mobile filters to each of these units to reduce the moisture content so the permanent filters can maintain the lower oil moisture concentration.

The permanent filter units will continually filter the oil and remove water. This will ensure that the insulation properties of the oil are retained and the impact on the internal components of the transformer is reduced.

This program is expected to commence during 2019 and be competed in 2020. The capital cost of this program is $1.0 million based on the vendor quote of $45k per transformer.

Based on existing installation maintenance and inspection costs, the ongoing opex per permanent unit is $1.25k per unit every 3 years. Each transformer is expected to require one period of online filtering using the mobile filters to reduce the water concertation to an acceptable level. The Net Present Cost of this option is $1.11M when assessed over a 30 year period with a WACC of 6.5%.

Option 4 – Offline Oil Filtering

Although offline filtering is an option, it is not a preferred approach due to:

- being significantly more expensive due to the outage planning, mobilisation and demobilisation, setup, commissioning and ongoing monitoring and control of the filter plant.
- putting the network in a sub-optimal configuration from a network security perspective as the transformer being filtered will be off line for one to three weeks and typically requires several hours to bring back on line, depending on its location.
- limiting the number of transformers that can be filtered due to constraints set by System Control for network security and potentially damaging older transformers.
- infrequent filtering of each transformer resulting in sub-optimal fleet condition compared to Options 2 and 3.
- issues with establishing a vacuum on old tanks as it can damage the tank and its internal structure and structurally weaken the core support system and clamping.
- failure to get an adequate seal during the vacuum process due to deteriorated gaskets and seals, and therefore being less effective at removing moisture from the oil.

While this is not the preferred method it is still an option that can be applied to wet transformers when other filtering options are ineffective due to availability or other transformer condition issues.

If this was to be the primary method of filtering transformer oil, it is estimated that only two transformers could be filtered each year which would result in a poor outcome in terms of oil quality across the fleet. Historical costs indicate that each offline filtering session costs are estimated to be between $40k and $50k per transformer. The model assumed two transformers could be filtered per year and the filtering equipment would be cycled through the fleet on an ongoing basis.

The Net Present Cost of this option is $1.1M to $1.4M when assessed over a 30 year period with a WACC of 6.5%.

This option is not recommended due to a poor technical outcome and high cost.

4.1 Non-cost Comparative Analysis

Table 2 shows that the preferred option is Option 3.

Table 2 Weighted Comparative Analysis

	Technical & System Risk	Stakeholder Risk	Opex Efficiency	Commercial	
Criteria	Reliability	Safety	Opex Reduction	NPC	Weighted Scores
Weighting (%)	20%	30%	10%	40%	100%
Option 1	0.2	0.3	0.3	0.4	1.2
Option 2	0.6	0.9	0.1	2.0	3.6
Option 3	1.0	1.5	0.5	1.2	4.2
Option 4	0.4	0.9	0.1	0.4	1.8

4.2 Preferred Option

Table 2 shows that based on the multicriteria analysis, Option 3 is the preferred option. Options 2 and 3 both have similar outcomes in terms of the expected cost of the capital and operational costs as there is only $0.06 million (approximately 5%) difference which is greater than the uncertainty in the model inputs. Therefore, the selection of the preferred option is based on the other benefits to PWCs asset fleet that were not able to be robustly quantified in the model.

The benefits of Option 3 compared to Option 2 include:

- the potential to reduce overall opex due to reduction in labour intensive work.
- permanent online units have demonstrated higher reliability compared to the mobile units, removing an area of risk to the transformer assets. The mobile units have historically had very low availability which has resulted infrequent or no oil filtering. This is a risk to the long term health of the high value transformer assets.
- permanent filtering will facilitate maintaining low moisture concentration levels which will help prolong the life of power transformers. Use of the mobile units only is likely to result in a cyclic reduction/increase of water concentration in the oil as transformers will only be filtered once every few years. This increases the likelihood of higher levels of moisture being absorbed into the paper insulation.

As a result, Option 3 to install permanent online filters on the 22 identified transformers for a total capital expenditure of $1M (FY18 dollars) is recommended.

4.3 Non Network alternatives

No non-network alternatives were identified that would mitigate the risk associated with moisture ingress into transformers.

4.4 Capex/Opex substitution

The proposed solution will reduce opex by removing labour intensive processes.

4.5 Contingent Project

The expenditure does not meet the criteria for a contingent project as outlined in the Northern Territory National Electricity Rules, section 6.6A.1.

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 Power Transformers outlined in this program will contribute to the Corporation achieving the goals defined in the Board's Strategic Directions and SCI Key Result Areas of Health and Safety and Operational Performance.

6 Timing Constraints

There are no time constraints associated with this program however deferral increases the likelihood of additional operational costs and network risk for offline filtering of transformers with moisture levels approaching acceptable limits.

7 Expected Benefits

Driver	Benefit	Measure
Asset Renewal	Maintain the condition of the transformers and defer transformer replacement	Water concentration in oil as found through oil analysis
Commercial / Efficiency	Reduce opex intensive tasks to assist achieve opex efficiency benefits	Reduced maintenance costs

8 Milestones

Investment Planning	Project Development	Project Commitment	Project Delivery	Review
01/2018	06/2018	07/2019	06/2021	09/2021

The program delivery is scheduled to run over 2 years from July 2019 to June 2021. A program review will be held at the end of the 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
	Manager Test & Protection Services
	General Manager System Control
	Manager SCADA and Communication Services
External – Unions and public	ETU
	Ministers
External regulators	Utilities Commission
	Australian Energy Regulator

10 Resource Requirements

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 batch of replacements.

11 Delivery Risk

There are no delivery risks identified with the program.

12 Financial Impacts

This program is forecast based on an estimate provided by the Vendor. Actual costs will be developed on a site by site basis as the installation is dependent on the individual site layout and condition at each substation.

The unit cost is quoted to be [redacted] per unit installed.

12.1Capex 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)	Total ('000)
Investment Planning						
Project Development						
Project Commitment						
Project Delivery	0.5	0.5				1.0
Review						
Total	**0.5**	**0.5**				**1.0**

12.2Opex Implications

Implementation of the preferred option will result in some opex reduction associated with less frequent deployment of mobile online filters once permanent filters are installed.

12.3Variance

This program aligns with the last two years of the 2017-18 SCI.