Program of Works

2017 – 2022

Transformer Life Extension

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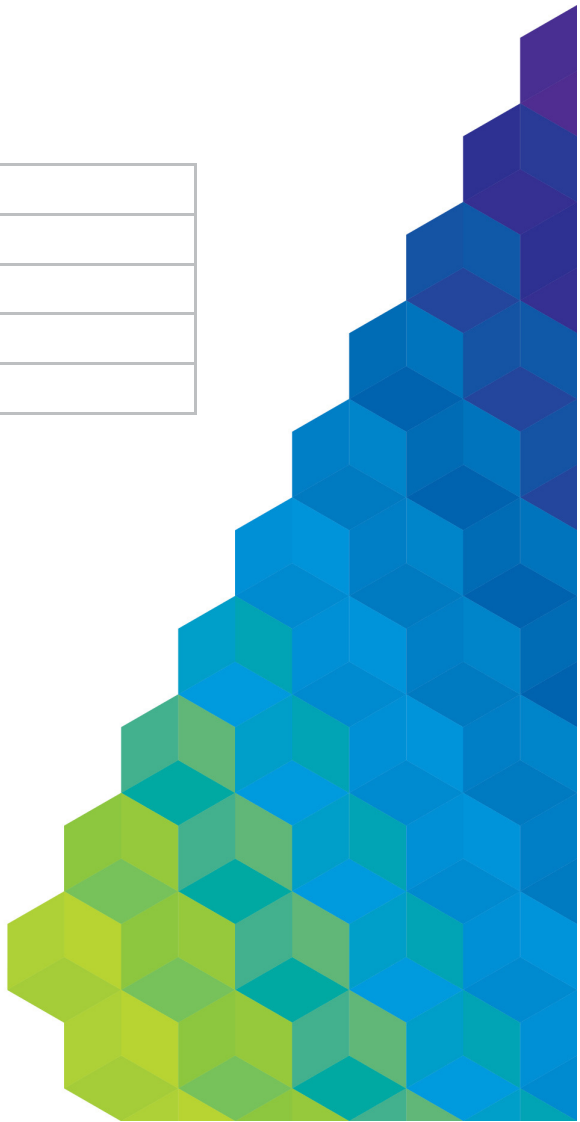

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1 Summary

PROGRAM	Transformer Life Extension Program 2017 – 2022
SERVICE DATE	On-going throughout period 2017 – 2022
LOCATION	Different Terminal Stations of Victorian Network
VALUE	$ 6.3M for the period 2017/18 to 2021/22

This works program document should be read in conjunction with AMS 10-67 Power Transformers Oil Filled Reactors. It details the background and options analyses performed in order to determine optimal transformer maintenance and replacement strategies.

1.1 Program Scope

The scope of this program includes various refurbishment activities on specific power transformers in various transmission terminal stations in the AusNet Services network. The activities are aimed to ensure that those transformer conditions are improved, thus extending their serviceable life beyond the expected 45 years. The activities are mostly:

- Oil leak Repairs (17 transformers);
- Corrosion mitigation (8 transformers);
- Oil quality improvement (2 transformers);
- On site insulation dry-out and winding re-clamping (1 transformer);
- Replacement of defective and inaccurate fittings (5 transformers);
- Fitting of online dissolved gas analysers (4 transformers).

A total of 28 transformers of different ages have been identified that require one or more of these abovementioned activities to be performed on them. The transformers have been manufactured by a range of local and international suppliers and their average age is 40 years. Where the same transformer requires multiple activities, it is understood that where possible these activities would be performed is such a manner as to be most cost effective.

1.2 Program Expenditure Forecast

The expenditure forecast is based on an equal spend across the 5 years that this program would be active.

2017/18 ($k)	2018/19 ($k)	2019/20 ($k)	2020/21 ($k)	2021/22 ($k)	Total ($k)
1,256	1,256	1,256	1,256	1,256	6,280

Table 1 – Forecast expenditure and forecast expenditure

Forecast costs shown in Table 2 are $2014/15 P50 direct costs. These costs exclude overheads, finance charges and cost escalation.

2 Business Drivers

- Network reliability, quality and security of supply:
    - The forced outages of transformers will result in unsecure network elements and increased losses.
    - Some of these transformers are critical transformers to the network as they are 500kV main tie transformers and are located at critical locations such as major generator connections (eg: HWTS[1]). Therefore outages of those transformers will result in constraining the market.
- Safety and Environment:
    - Transformer failures often result in failures of some bushings as a consequence, which can result in projectiles, spill of oil and fires. All of these will present a safety risk to people working in the switch yard. Spillage of oil also poses environmental hazards.
- Financial Impacts:
    - Failure of the critical transformers will result in high market impact costs.[2]
    - Financial penalties from the incentive scheme.[3]
    - Increased costs associated with emergency replacements following failure of transformers.
    - Costs associated with collateral damages to the adjacent plant caused as a result of projectiles and oil fires.
    - Costs associated with injuries/fatalities arisen to staff and contractors working on site as a result of projectiles and oil fires.
- Regulatory Compliance:
    - To comply with all applicable obligations or requirements associated with the provision of transmission services including capital expenditure objectives as described in National Electricity Rule 6A.6.7a and obligations set out in the Electricity safety Act. Rule 6A.6.7a requires the Transmission Network Service Provider (TNSP) to propose capital expenditure forecasts which meet the expected demand, comply with applicable regulatory requirements, and maintain the quality, reliability and security of supply of both prescribed transmission services and the transmission network. Under the Electricity Safety Act the TNSP must design, construct, operate, maintain and decommission its supply network to minimise as far as practicable the hazards and risks to the safety of any persons or damage to any person's property arising from the supply network.
- Corporate Image:
    - To maintain the corporate image as a prudent asset manager by managing risk as low as practicable.

[1] HWTS = Hazelwood Terminal Station.

[2] Market Impact Parameter Scheme (MIPS).

[3] AER Service Target Performance Incentive Scheme (STPIS).

3 Obligations

The National Electricity Rules (clauses 6A.6.6 and 6A.6.7) require AusNet Services to forecast operating and capital expenditures to, amongst other objectives, *comply with all applicable regulatory obligations or requirements associated with the provision of prescribed transmission services;*

The Electricity Safety Act (clause 98) requires a major electricity company, such as AusNet Services to design, construct, operate, maintain and decommission its supply network to minimise as far as practicable:

a) the hazards and risks to the safety of any person arising from the supply network; and
b) the hazards and risks of damage to the property of any person arising from the supply network; and
c) the bushfire danger arising from the supply network.

In the definitions of this Act, the term 'practicable', means having regard to:

a) the severity of the hazard or risk in question; and
b) the state of knowledge about the hazard or risk and any ways of removing or mitigating the hazard or risk; and
c) the availability and suitability of ways to remove or mitigate the hazard or risk; and
d) the cost of removing or mitigating the hazard or risk;

This means "as low as reasonably practicable" which has been interpreted as until the safety related costs are (grossly) disproportionate to the safety related benefit.

The *Occupational Health and Safety Act 2004* (Vic) (**OHSA**) requires AusNet Services to:

> *as far as is reasonably practicable, provide and maintain for employees of the employer a working environment that is safe and without risks to health.*[4]

When determining what is (or what was, at a particular time), reasonably practicable in ensuring health and safety, the OHSA requires that regard be had to the following matters:

a) the likelihood of the hazard or risk concerned eventuating;
b) the degree of harm that would result if the hazard or risk eventuated;
c) what the person concerned knows, or ought reasonably to know, about the hazard or risk and any ways of eliminating or reducing the hazard or risk;
d) the availability and suitability of ways to eliminate or reduce the hazard or risk.[5]

4 Section 21(1).

5 Occupational Health and Safety Act 2010, section 20(2).

4 Overview

The 2015 update of the Transmission Power Transformer and Shunt Reactor Asset Health report (AHR 10-67) portrays the condition of the transformers as a snapshot for 31 July 2014. The report assigns a condition score C1 to C5 based primarily on recorded condition monitoring tests and physical inspections of transformers. Various aspects of the transformers are considered and these are combined in a weighted average score for each transformer.

For this program of works, the individual scores for each of the different aspects are of particular interest as a transformer may have an overall fair condition, but one aspect could be very poor, putting the transformer at risk of failure. By addressing the particular poor aspect, the transformer overall condition can be improved with minimal expenditure.

A typical example of such a case would be a transformer of which the windings, bushings, OLTC, fittings and oil are in a good condition, but the tank has severe oil leaks requiring regular top ups and place the transformer at risk of tripping under low oil level conditions. By addressing the oil leaks, the full potential of the transformer could then be utilised.

4.1 Risks

AusNet Services network has experienced cases where oil leaks have deteriorated to the extent that it caused the particular transformers to trip on low oil level. The reinstatement of transformers after tripping comes at a cost of investigation and testing as well as the unavailability of those network elements.

Corrosion if left untreated, could lead to the deterioration of structural parts of the transformer that if fail could injure people and cause severe plant damage.

4.2 Designs

Oil leaks occur mostly where the sealing systems have deteriorated to the extent that the gasket materials have lost their resilience and no longer perform an adequate seal. Oil seals on transformers are two basic designs, o-ring in groove or flat cork / rubber gaskets. Over time and exposure to elevated temperatures, these materials harden and lose the ability to recover when thermal cycling occurs. There is no other way to repair such leaks than to drain oil, and replace the material with similar new gaskets. Unfortunately the removal of oil and reinstatement make up the major component of the gasket replacement costs. All transformers, irrespective of the manufacturers are subject to a similar fate.

5 Risk Matrix

This transformer life extension program (chosen option – Option 3) will reduce the likelihood of those transformers from causing risk from likely to unlikely and consequences from moderate to minor as shown in the risk matrix in Figure 1.

The consequences become minor as the result of the leaks and other poor conditions are reduced by the mitigation actions. Replacing the deteriorated gasket materials with new equivalents with high resilience will not only stop the current leak, but also prevent them from developing in the immediate future. Other activities will also reduce the network consequences by preventing trips and failures.

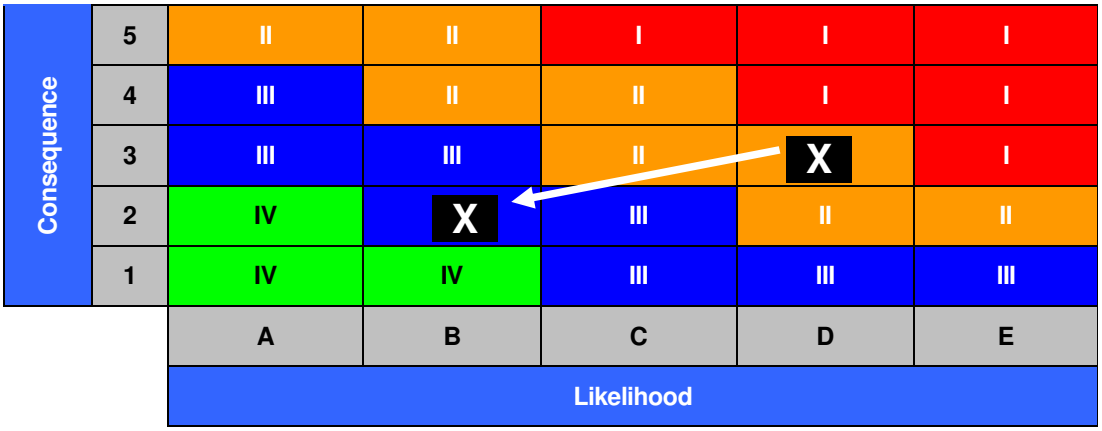

Figure 1 – Risk Matrix

6 Options

The following three options consider the benefits and consequences of completing the selected activities to extend the expected transformer life or not.

- Do nothing
- Replace on condition
- Refurbish transformers to extend life

6.1 Option 1 – Do Nothing

The 'Do nothing' involves routine inspection and maintenance but takes no action to refurbish or replace assets as they deteriorate and ultimately fail in service. In this option the functionality of the assets is progressively lost and service to consumers progressively declines and ultimately ceases.

In addition, this option includes the probability that the terminal failure of assets may involve explosions and fires which presents safety risks to workers within the switchyard and collateral damage risks to adjacent electrical equipment.

This option does not address AusNet Services' obligations:

- under the National Electricity Rules to maintain the quality, reliability and security of supply of prescribed transmission services.

- under the requirements of the Electricity Safety Act to operate, maintain and decommission its supply network to minimise as far as practicable the hazards and risks to the safety of any person arising from the supply network.

This option is not consistent with AusNet Services' accepted Electricity Safety Management Scheme. This implies a very high risk to the business and it fails to address key business drivers listed above in Section 2.

In respect to risk analysis for this option, the likelihood will remain likely and consequences will remain moderate (i.e.: as it is at the moment) if this option is chosen. Therefore do nothing is not recommended.

6.2 Option 2 – Replace on condition

The 'Replace on condition' involves routine inspection and maintenance and complete transformer replacement where some aspects of their condition have been found to be poor, rather that addressing only the subsystem or component that was found to be poor. For example – replace the whole transformer when it starts to leak oil rather than fixing the leak.

This option is very expensive, is not aligned with asset management strategies and not recommended.

6.3 Option 3 – Refurbish transformers to extend life

This option involves proactively addressing only the aspects of the transformers that require refurbishment when it is most economical to do so. The likely risks are addressed and become unlikely and the consequence is reduced from moderate to minor. This is the preferred option.

7 Financial Analysis

All three options have been financially analysed[6] using an NPV model – as shown in Table 2. Option 2, (replace with new transformers) has a more positive NPV than Option 3 (Refurbish transformers on condition to extend life). However, the capital cost of Option 2 is 20x more than the capital cost of Option 3 and therefore Option 3 is preferred.

Economic Analysis of Options ($'000s)	PV Capital Cost	PV Opex Costs	PV Community Benefits	PV Proceeds From Sales	Total PV Cost	NPV including Reg Return
Do Nothing	-	(8,920)	(4,765)	-	(13,685)	**-**
Replace with new transformers	(131,572)	-	-	-	(131,572)	**4,023**
Refurbish Transformers to extend life	(5,823)	-	-	-	(5,823)	**2,228**
	-	-	-	-	-	**-**
	-	-	-	-	-	**-**

All figures are in $000's unless otherwise stated.
(nominal and discounted)

Table 2 – NPV Analysis

[6] The analysis does not include supply reliability consequences, impact on incentive schemes or effects on company reputation as a result of a transformer bushing failure

8 Recommended Action

The refurbishment of transformers on condition, Option 3, is recommended.

This program scope is to perform remedial actions on 28 transformers over 5 years as outlined in SectionProgram Scope.

9 Reference Documents

- National Electricity Rules.
- Electricity Safety Act.
- Electricity Safety (Management) Regulations.
- Work Health & Safety Act (2011).
- AMS 10-01 – Victorian Electricity Transmission Network.
- AMS 10-67 – Power Transformers Oil Filled Reactors.
- AMS 10-141 – Power Transformer Asset Health Report.