OPTIONS EVALUATION REPORT (OER)

Forbes No.1 & No.2 Transformer Replacement

OER DCN276 revision 3.0

Ellipse project no.: P0001238
TRIM file: [TRIM No]

Project reason: Capability - Asset Replacement for end of life condition
Project category: Prescribed - Replacement

Approvals

Author	Chen Yi Wong Evan Lamplough	Design Engineer Asset Management Substations Asset Strategist
Endorsed	Tony Gray	Substations Asset Manager
	Azil Khan	Investment Analysis Manager
Approved	Lance Wee	Manager Asset Strategy
Date submitted for approval	12 December 2016	

Change history

Revision	Date	Amendment
0	15 June 2016	Initial issue
1	28 October 2016	Updated risk costs, Capex, SFAIRP/ALARP methodology, figures and wording throughout.
2	15 November 2016	Minor update to secondary system risk cost and associated NPV and ALARP values
3	12 December 2016	Update to format

1. Need/opportunity

The Forbes No. 1 and 2 transformers have reached an end of serviceable life condition due to their condition. Oil quality and DGA indicates extensive carbon contamination of the main tank and windings. Risks are presently managed to a degree by operating the transformer on fixed tap to prevent the introduction of additional carbon material into the main tank however Essential Energy is insisting that the functionality is restored, due to the impact of increased tap changer operations in their network. This will cause a continual increase in the carbon released into the main tank.

Besides deterioration due to ageing, both transformers at Forbes Substation are at increasing risk of failure as a result of carbon contamination of the main tank and winding originating from leaking diverter switches. Currently there are no established methods or guidelines to fully assess the scale of carbon contamination and associated risk. The health index used to determine transformer remaining life does not account for carbon contamination however it is clear that where significant carbon contamination is present the probability of failure (PoF) will be increased significantly. Therefore a model has been developed based on the normal transformer PoF model to incorporate an additional risk of failure due to carbon contamination. A sensitivity analysis has been completed to confirm its effect on the evaluation of the available options.

There are also oil leaks present around the transformers and accessories and the associated auxiliary transformers are in poor condition. Overall, the condition of the transformers presents an unacceptable and increasing risk of failure, as outlined in the Need/Opportunity Statement (NOS).

Consideration of how to address the risks associated with the Forbes transformers is outlined in this OER.

2. Related Needs/opportunities

- Need ID 1337 – Various Locations Circuit Breaker (CB) Renewal Program (replacement of associated 66kV circuit breakers and 66kV current transformers with dead tank circuit breakers)
- Need ID 621 - Replacement of Duobias (DB) Protection Replays (associated control systems)
- Need ID 629 - Replacement of Remote Terminal Units (RTUs) (associated protection systems)
- Need ID 610 - Replacement of EDMI MK111 Meters (transformers' metering systems)

3. Options

All dollar values in this document are expressed in un-escalated 2016/17 dollars.

The options screening report outlines the options which were not considered to address this Need. The option to refurbish these transformers was not considered feasible following a quotation from the original equipment manufacturer, ABB which was valued at almost the cost of a new transformer and in consideration of the anticipated remaining risk of failure subsequent to completion of overhaul.

The options considered are:

- Base Case – Do nothing
- Replace both transformers with new units
- Replace one transformer with new and another with No.1 Transformer when released from the reconstruction of Wagga 132kV Substation

Base Case

The Base Case is the 'do nothing option' whereby all assets (transformers, Circuit Breaker (CB) and secondary systems) will be run to failure. This option leads to large increases in the probability of failure as the assets age beyond their expected life. The risk costs (per annum) associated with this option is $0.7m.

Increasing maintenance on the equipment cannot reduce the probability of failure and corresponding risk cost.

Option A — Replace both transformers with new transformers [OFR DCN276A, OFS DCN276A]

This option consists of replacing No.1 and 2 transformers with new 132/66kV 60MVA transformers. One of the new transformers is required to be installed in a new compound and have associated assets installed in order to maintain N-1 reliability during construction.

The Capex is $8.7m, which includes two new transformers and associated switchgear, protection and control systems (secondary systems) and civil works (where required), upgrading of the oil containment system.

Risk savings from this option is $0.68m, driven by reliability risk improvements as the option considers installing new transformers.

The asset life is of the new transformers is assumed to be 45 years. There will be a marginal reduction in opex associated with defect work and maintenance resulting from the transformer replacement with new units.

Option B — Replace one transformer with new transformer and another transformer with decommissioned unit from Wagga 132kV Substation [OFR DCN276B, OFS DCN276B]

This option consists of replacing No.1 transformer with new 132/66kV 60MVA transformer and the second transformer with the Wagga 132kV Substation (WG2) No.1 transformer to be will be decommissioned at the end of 2016 (refer project P0000950).

The new transformer will be installed in a new compound and with associated bays in order to maintain N-1 reliability during construction.

The Capex is $7.6m, which includes one new transformer, transport and minor works on the Ex-Wagga transformer, associated switchgear, protection and control systems (secondary systems) and civil works (where required) and upgrading of the oil containment system.

Risk savings from this option is $0.64m, driven by reliability risk improvements and reduced probability of failure (Wagga transformer is in reasonably healthy condition).

The asset life is assumed to be 45 and 14 years for the new and refurbished transformer respectively.

The Net Present Value (NPV) analysis includes the costs and benefits associated with this scope of works.

There will be a marginal reduction in opex associated with defect work and maintenance resulting from the transformer replacement.

Other options

No feasible non-network options were identified for the Forbes 132kV transformers renewal project.

4. Evaluation

4.1 Commercial evaluation

The result of commercial evaluation for each of the technically feasible options is summarised in Table 1.

Table 1 — Commercial evaluation ($ million)

Option	Description	Total capex	Annual opex	Annual post project risk cost	Economic NPV @10%	Rank
Base Case	Do nothing	-	-	0.7	-	3
A	Replace both transformers with new transformers	8.7	-	0.02	4.39	1
B	Replace one transformer with new and other with WG2 No. 1 transformer	7.6	-	0.06	4.36	2

The economic evaluation is based on a 10% discount rate. The number of years of benefits in the NPV for each option has been determined based on expected timeframe until the existing transformers fail due to carbon contamination according to the transformer failure model. A small Opex reduction has been included in the NPV calculations.

As shown in Table 1, the NPV for Option A is higher than Option B. Due to the small difference between the options, there are additional considerations which have not been quantified and included in the economic NPV analysis which are relevant to the selection of the preferred option. These include:

- The Option B Option Feasibility Study (OFS) pricing for the refurbishment of the WG2 transformer does not include any allowance for risk of additional costs being incurred due to additional issues being discovered and requiring rectification (e.g. component replacement, tap changer maintenance)
- Option B contains the risk of damage to the WG2 transformer during dismantling, transport and erection (which would usually be covered by manufacturer warranty for a new unit)
- Option B does not include the likelihood that the cost of defects for the older WG2 will increase over the time as it ages further (a fixed value representing the defect costs have been included based on averaged historical data)
- There may be an even greater reduction in PoF and risk associated with the two new transformers provided under option A due to supply of new technologies (vacuum tap changers and resin impregnated paper bushings). However, there is insufficient data to determine this for the life of the asset and the standard transformer PoF model has been used.

Based on consideration of these factors (which would each increase the NPV of Option A), the preferred option remains as Option A which is to replace both transformers with new units.

Table 2 — Discount rate sensitivities ($ million)

Table 2 provides a sensitivity analysis based on TransGrid's current AER-determined pre-tax real regulatory Weighted Average Cost of Capital (WACC) of 6.75% and an upper bound of 13%. The sensitivity analysis demonstrates a positive NPV for the range of discount rates considered.

Option	Description	Economic NPV @13%	Economic NPV @6.75%
A	Replace both transformers with new	1.5	9.5
B	Replace one transformer with new and other with WG2 No. 1 transformer	1.8	8.9

Technical Sensitivity Analysis

Sensitivity analyses have been completed to confirm the effect of variations in the failure model of transformers with carbon contamination and for partial reduction in scope.

A transformer failure model has been developed assuming a rapid increase in PoF due to the ongoing accumulation of carbon contamination in the transformers. The carbon contamination will continue to increase until the transformers fail due to insulation breakdown. Three transformer PoF models were developed to account for carbon contamination and the above NPV is based on the model which assumed a moderate delay before this rapid increase in PoF occurs. It is likely that the transformer PoF will actually increase earlier than this, as reflected in one of the other models, and other model considered a greater delay until the rapid increase. The resulting NPVs under these other models are still positive (assuming the same discount rate) and with each model the preferred option is unchanged. Therefore based on the available data and modelling, the preferred option remains unchanged.

The secondary systems and 66kV circuit breakers associated with the transformers have been included in the scope because this will allow for this need to be addressed efficiently. These assets have positive NPVs when considered as standalone projects, and therefore contribute to the total NPV included above. A sensitivity check has been completed to confirm the effect of removing these items from the option scope. This has shown that the NPV for each option remains positive, and the preferred option is unchanged.

These sensitivity checks confirm that the option selected has both positive NPV and is the preferred option even with changes from the technical assessment and methodology used in the evaluation.

4.2 ALARP evaluation

Options to reduce the network safety risk as per the risk treatment hierarchy have been considered in other lifecycle stages of the asset, and it has been determined that no reasonably practicable options exist to reduce the risk further than those capital investment options listed in Table 3.

Evaluation of the proposed options has been completed against the SFAIRP (So Far As Is Reasonably Practicable)/ALARP (As Low As Reasonably Practical) obligation, as required by the Electricity Supply (Safety and Network Management) Regulation 2014 and the Work Health and Safety Act 2011. The Key Hazardous Events and the disproportionality multipliers considered in the evaluation are as follows:

- Catastrophic failure of asset/uncontrolled discharge or contact with electricity/ unauthorised access to site - 3 times the safety risk and 10% of the reliability risk (applicable to safety)
- Unplanned outage of High Voltage (HV) equipment - 10% of the reliability risk (applicable to safety)

The results of this evaluation is summarised in the tables below.

Table 3 – Feasible options ($ thousand)

Option	Description	CAPEX	Expected Life		Annualised CAPEX
Base	Do nothing	N/A	N/A	N/A	N/A
A	Replace both transformers with new	8,700	No.1 transformer No. 2 transformer	45 years 45 years	190
B	Replace one transformers with new and second with ex- Wagga 132kV No.1 transformer	7,600	No.1 transformer No. 2 transformer	45 years 14 years	300

Table 4 – Annual risk calculations ($ thousand)

Option	Annual Residual Risk		Annual Risk Savings	
	Safety Risk	Reliability Risk	Safety Risk	Reliability Risk
Base	11	482	N/A	N/A
A	0	6	11	476
B	1	26	10	456

Table 5 – Reasonably practicable test ($ thousand)

Option	Network Safety Risk Reduction[1]	Annualised CAPEX	Reasonably practicable[2]?
A	82	193	No
B	77	298	No

4.3 Preferred option

The outcome of the SFAIRP/ALARP evaluation is that none of the options presented are reasonably practicable, and are therefore not required to satisfy the organisation's SFAIRP/ALARP obligations.

Based on the economic evaluation, the preferred option is Option A, which is to replace both transformers with new units.

Capital and operating expenditure

There are no other ongoing capital expenditure considerations beyond the initial asset replacement project.

Regulatory Investment Test

A Regulatory Investment Test for Transmission (RIT-T) is not required as this is an asset replacement project with no augmentation component.

5. Recommendation

It is recommended that the project be scoped in detail to implement Option A (replacement of both transformers with new units).

[1] The Network Safety Risk Reduction is calculated as 3 x Safety Risk Reduction + 0.1 x Reliability Risk Reduction. No bushfire risk is applicable for the consequences considered

[2] Reasonably practicable is defined as whether the annualised CAPEX is less than the Network Safety Risk Reduction