

OPTIONS EVALUATION REPORT (OER)



Transformer Renewal 2018 – 2023

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Approvals

| | | |
|------------------------------------|-----------------|------------------------------|
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| Date submitted for approval | 9 December 2016 | |

Change history

| Revision | Date | Amendment |
|----------|-----------------|--|
| 0 | 1 July 2016 | Initial issue |
| 1 | 28 October 2016 | Updated risk costs, Capex, SFAIRP/ALARP methodology, figures and wording throughout. |
| 2 | 9 December 2016 | Update to format |

1. Need/opportunity

This transformer renewal program is being considered as a result of a review of TransGrid's aging transformer population.

Detailed condition assessments have been conducted on 14 transformers (including 6 single phase units at Kemps Creek 500kV Substation), and have identified issues including insulation, leaks, diverter switch and bushings. Refer to the Need/Opportunity Statement (NOS) [NS 1354](#).

There is an increasing risk cost associated with each of the identified transformers and methods to reduce this risk should be considered.

2. Related Needs/opportunities

Programs for other substation assets are being developed and should be considered when packaging work for delivery, however it is unlikely that these will be closely related.

3. Options

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

Base Case

The Base Case is the 'do nothing option' whereby the transformers will be run-to-failure. This option leads to ongoing increases in the probability of failure due to the continual degradation in asset condition.

The total pre-investment risk for the transformers identified is \$2.58m (per annum in 2021).

Option A — Refurbish Transformers [[OFR 1354A](#), [OFS 1354A](#)]

This option consists of refurbishing the transformers according to the individual condition issues in order to extend their lives, as per the requirements stated in Options Feasibility Request (OFR) OFR 1354A.

The estimated capex associated with the refurbishments is \$12.397m.

The post-investment risk cost is \$1.25m, which is a risk reduction of \$1.33m.

The risk savings from this option are through a decrease in the probability of failure due to the refurbishment of the transformers in order to extend their life, which is modelled through a reduction in the effective age of the transformer. The amount of risk reduction is dependent on the condition issues of each transformer and the effectiveness of the available treatments.

Option B — Replace Transformers [[OFR 1354B](#), [OFS 1354B](#)]

This option consists of replacing transformers like for like.

The estimated Capex associated with the replacement of all of the identified transformers is \$94.4m.

The post-investment risk cost is essentially zero (due to the low probability of failure of brand new asset), which is a risk reduction of \$2.58m. The asset life is assumed to be 45 years for new transformers.

Other Options

No feasible non-network options were identified for the included transformers.

4. Evaluation

Both options proposed in section 3 are technically feasible and evaluation of the options has been completed using the ALARP (As Low as Reasonably Practicable) regulatory requirements and economic considerations. The results of this evaluation are outlined below.

The transformer risk increases over time as the age of the transformer increases. For most transformers this increase in risk is based on TransGrid's transformer probability of failure model. Where the detailed condition assessment has identified the transformer bushings as needing to be replaced and this is the primary issue to be addressed, the bushing asset probability of failure curve along, with its actual age, has been used to model the overall increasing risk to the transformer. This probability of failure was derived from the transformer probability of failure curve and is sufficient to describe the overall transformer risk.

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)

| Transformer | Option | Description | Total capex | Annual opex | Annual post project risk cost | Economic NPV @10% | Rank |
|------------------|-----------|---------------|-------------|-------------|-------------------------------|-------------------|------|
| Ingleburn No.1 | Base Case | Do nothing | - | - | 0.29 | - | - |
| | A | Refurbishment | 0.73 | - | 0.16 | 0.79 | 1 |
| | B | Replacement | 6.00 | 0 | 0.00 | (1.24) | 2 |
| Kemps Creek No.2 | Base Case | Do nothing | - | - | 0.43 | - | - |
| | A | Refurbishment | 1.55 | - | 0.24 | 0.83 | 1 |
| | B | Replacement | 17.10 | 0 | 0 | (8.52) | 2 |
| Kemps Creek No.3 | Base Case | Do nothing | - | - | 0.46 | - | - |
| | A | Refurbishment | 1.55 | - | 0.24 | 0.83 | 1 |
| | B | Replacement | 17.10 | 0 | 0 | (8.52) | 2 |
| Liverpool No.1 | Base Case | Do nothing | - | - | 0.15 | - | - |
| | A | Refurbishment | 0.81 | - | 0.03 | 0.26 | 1 |
| | B | Replacement | 6.50 | 0 | 0 | (3.34) | 2 |
| Liverpool No.2 | Base Case | Do nothing | - | - | 0.07 | - | - |
| | A | Refurbishment | 0.42 | - | 0.04 | 0.02 | 1 |
| | B | Replacement | 6.50 | 0 | 0 | (4.19) | 2 |
| Moree No.1 | Base Case | Do nothing | - | - | 0.09 | - | - |
| | A | Refurbishment | 0.54 | - | 0.05 | 0.05 | 1 |
| | B | Replacement | 4.10 | 0 | 0 | (2.15) | 2 |

| Transformer | Option | Description | Total capex | Annual opex | Annual post project risk cost | Economic NPV @10% | Rank |
|-------------------|-----------|---------------|-------------|-------------|-------------------------------|-------------------|------|
| Moree No.2 | Base Case | Do nothing | - | - | 0.17 | - | - |
| | A | Refurbishment | 0.44 | - | 0.10 | 0.32 | 1 |
| | B | Replacement | 4.70 | 0 | 0 | (1.87) | 2 |
| Murray No.1 | Base Case | Do nothing | - | - | 0.09 | - | - |
| | A | Refurbishment | 0.80 | - | 0.06 | 0.43 | 1 |
| | B | Replacement | 3.00 | 0 | 0 | (1.40) | 2 |
| Murray No.2 | Base Case | Do nothing | - | - | 0.07 | - | - |
| | A | Refurbishment | 0.49 | - | 0.03 | (0.02) | 1 |
| | B | Replacement | 3.00 | 0 | 0 | (1.62) | 2 |
| Murrumburrah No.1 | Base Case | Do nothing | - | - | 0.15 | - | - |
| | A | Refurbishment | 0.69 | - | 0.09 | 0.11 | 1 |
| | B | Replacement | 4.00 | 0 | 0 | (1.48) | 2 |
| Panorama No.1 | Base Case | Do nothing | - | - | 0.21 | - | - |
| | A | Refurbishment | 1.03 | - | 0.06 | 0.64 | 1 |
| | B | Replacement | 4.70 | 0 | 0 | (1.33) | 2 |
| Panorama No.2 | Base Case | Do nothing | - | - | 0.22 | - | - |
| | A | Refurbishment | 0.93 | - | 0.08 | 0.62 | 1 |
| | B | Replacement | 4.70 | 0 | 0 | (1.17) | 2 |
| Sydney North No.3 | Base Case | Do nothing | - | - | 0.08 | - | - |
| | A | Refurbishment | 1.23 | - | 0.03 | 0.05 | 1 |
| | B | Replacement | 6.50 | 0 | 0 | (4.13) | 2 |
| Sydney North No.4 | Base Case | Do nothing | - | - | 0.11 | - | - |
| | A | Refurbishment | 1.23 | - | 0.04 | 0.05 | 1 |
| | B | Replacement | 6.50 | 0 | 0 | (3.87) | 2 |

The economic evaluation is based on a 10% discount over a 30 year analysis period, including the 5 year investment period during next regulatory period. There is a small estimated Opex reduction due to reduced maintenance and defects in the case of the transformer replacement and this has been included. There may be small reductions in defect Opex following transformer but this is not significant and has been excluded from the analysis.

The results of the economic evaluation are:

- > Refurbishment is the preferred option over replacement for all transformers
- > Refurbishment has a positive NPV for all transformers except for Murray No.2 transformer, which is slightly negative NPV at 10% discount rate.

The negative Net Present Value (NPV) for the Murray No.2 transformer should be reviewed in light of other considerations. The IRR is 9.38% which is closer to the 10% discount rate. A sensitivity analysis shows that the NPV would be positive if the assessed age in 2021 is 2 years older, or a Weighted Average Cost of Capital (WACC) of 6.75%. The cost estimates for the transformer program include an appropriate allowance for construction and scope risk which may eventuate, however it is not possible to determine which individual ones may incur these risks, and therefore the actual achieved NPV of each individual transformer. Based on these considerations it is recommended that the Murray No.2 transformer still be included in the transformer refurbishment program.

A summary of the options for all of the transformers is provided in Table 2.

Table 2 — Commercial evaluation - summary (\$ million)

| Option | Description | Total capex | Annual opex ¹ | Annual post project risk cost | Economic NPV @10% | Rank |
|-----------|---------------|-------------|--------------------------|-------------------------------|-------------------|------|
| Base Case | Run to fail | N/A | N/A | 2.58 | N/A | 3 |
| A | Refurbishment | 12.40 | - | 1.25 | 4.99 | 1 |
| B | Replacement | 94.40 | (0.03) | 0 | (44.80) | 2 |

The table below outlines provides a sensitivity analysis based on TransGrid's current AER-determined pre-tax real regulatory WACC of 6.75% and an upper bound of 13%. The sensitivity analysis demonstrates a positive NPV for the preferred option for the range of discount rates considered.

Table 3 — Discount rate sensitivities (\$ million)

| Option | Description | Economic NPV @13% | Economic NPV @6.75% |
|--------|---------------|-------------------|---------------------|
| A | Refurbishment | 1.03 | 12.74 |
| B | Replacement | (52.68) | (26.61) |

4.2 SFAIRP/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 4.

¹ No Opex savings are included in the economic NPV analysis, since there is no significant change in maintenance between the existing and renewed assets.

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 are summarised in the tables below.

Table 4 – Feasible options (\$ thousand)

| Transformer | Option | Description | CAPEX | Expected Life | Annualised CAPEX |
|-------------------|--------|---------------|--------|---------------|------------------|
| Ingleburn No.1 | A | Refurbishment | 728 | 13 years | 56 |
| | B | Replacement | 6,000 | 45 years | 133 |
| Kemps Creek No.2 | A | Refurbishment | 1,545 | 9 years | 172 |
| | B | Replacement | 17,100 | 45 years | 380 |
| Kemps Creek No.3 | A | Refurbishment | 1,545 | 9 years | 172 |
| | B | Replacement | 17,100 | 45 years | 380 |
| Liverpool No.1 | A | Refurbishment | 809 | 17 years | 48 |
| | B | Replacement | 6,500 | 45 years | 144 |
| Liverpool No.2 | A | Refurbishment | 416 | 20 years | 21 |
| | B | Replacement | 6,500 | 45 years | 144 |
| Moree No.1 | A | Refurbishment | 535 | 15 years | 36 |
| | B | Replacement | 4,100 | 45 years | 91 |
| Moree No.2 | A | Refurbishment | 440 | 8 years | 55 |
| | B | Replacement | 4,700 | 45 years | 104 |
| Murray No.1 | A | Refurbishment | 798 | 8 years | 100 |
| | B | Replacement | 3,000 | 45 years | 67 |
| Murray No.2 | A | Refurbishment | 485 | 13 years | 37 |
| | B | Replacement | 3,000 | 45 years | 67 |
| Murrumburrah No.1 | A | Refurbishment | 688 | 10 years | 69 |
| | B | Replacement | 4,000 | 45 years | 89 |

| Transformer | Option | Description | CAPEX | Expected Life | Annualised CAPEX |
|-------------------|--------|---------------|-------|---------------|------------------|
| Panorama No.1 | A | Refurbishment | 1,028 | 17 years | 60 |
| | B | Replacement | 4,700 | 45 years | 104 |
| Panorama No.2 | A | Refurbishment | 928 | 14 years | 66 |
| | B | Replacement | 4,700 | 45 years | 104 |
| Sydney North No.3 | A | Refurbishment | 1,226 | 22 years | 56 |
| | B | Replacement | 6,500 | 45 years | 144 |
| Sydney North No.4 | A | Refurbishment | 1,226 | 19 years | 65 |
| | B | Replacement | 6,500 | 45 years | 144 |

Table 5 – Annual risk calculations (\$ thousand)

| Transformer | Option | Annual Residual Risk | | Annual Risk Savings | |
|------------------|--------|----------------------|------------------|---------------------|------------------|
| | | Safety Risk | Reliability Risk | Safety Risk | Reliability Risk |
| Ingleburn No.1 | Base | 4 | 183 | N/A | N/A |
| | A | 2 | 97 | 2 | 86 |
| | B | 0 | 0 | 4 | 183 |
| Kemps Creek No.2 | Base | 7 | 4 | N/A | N/A |
| | A | 4 | 2 | 3 | 2 |
| | B | 0 | 0 | 7 | 4 |
| Kemps Creek No.3 | Base | 7 | 4 | N/A | N/A |
| | A | 4 | 2 | 3 | 2 |
| | B | 0 | 0 | 7 | 4 |
| Liverpool No.1 | Base | 2 | 49 | N/A | N/A |
| | A | 0 | 9 | 2 | 39 |
| | B | 0 | 0 | 2 | 49 |
| Liverpool No.2 | Base | 1 | 22 | N/A | N/A |
| | A | 1 | 14 | 0 | 8 |
| | B | 0 | 0 | 1 | 22 |
| Moree No.1 | Base | 2 | 30 | N/A | N/A |
| | A | 1 | 16 | 1 | 13 |
| | B | 0 | 0 | 2 | 30 |
| Moree No.2 | Base | 4 | 56 | N/A | N/A |
| | A | 2 | 32 | 2 | 24 |
| | B | 0 | 0 | 4 | 56 |
| Murray No.1 | Base | 6 | 6 | N/A | N/A |
| | A | 4 | 4 | 2 | 2 |
| | B | 0 | 0 | 6 | 6 |

| Transformer | Option | Annual Residual Risk | | Annual Risk Savings | |
|-------------------|--------|----------------------|------------------|---------------------|------------------|
| | | Safety Risk | Reliability Risk | Safety Risk | Reliability Risk |
| Murray No.2 | Base | 5 | 5 | N/A | N/A |
| | A | 3 | 3 | 2 | 2 |
| | B | 0 | 0 | 5 | 5 |
| Murrumburrah No.1 | Base | 3 | 59 | N/A | N/A |
| | A | 2 | 36 | 1 | 23 |
| | B | 0 | 0 | 3 | 59 |
| Panorama No.1 | Base | 3 | 105 | N/A | N/A |
| | A | 1 | 31 | 2 | 74 |
| | B | 0 | 0 | 3 | 105 |
| Panorama No.2 | Base | 3 | 113 | N/A | N/A |
| | A | 1 | 43 | 2 | 70 |
| | B | 0 | 0 | 3 | 113 |
| Sydney North No.3 | Base | 3 | 8 | N/A | N/A |
| | A | 1 | 3 | 2 | 6 |
| | B | 0 | 0 | 3 | 8 |
| Sydney North No.4 | Base | 4 | 11 | N/A | N/A |
| | A | 2 | 4 | 3 | 7 |
| | B | 0 | 0 | 4 | 11 |

Table 6 – Reasonably practicable test (\$ thousand)

| Transformer | Option | Description | Network Safety Risk Reduction ² | Annualised CAPEX | Reasonably practicable ³ ? |
|------------------|--------|---------------|--|------------------|---------------------------------------|
| Ingleburn No.1 | A | Refurbishment | 14 | 56 | No |
| | B | Replacement | 29 | 133 | No |
| Kemps Creek No.2 | A | Refurbishment | 11 | 172 | No |
| | B | Replacement | 22 | 380 | No |
| Kemps Creek No.3 | A | Refurbishment | 11 | 172 | No |
| | B | Replacement | 22 | 380 | No |
| Liverpool No.1 | A | Refurbishment | 9 | 48 | No |
| | B | Replacement | 11 | 144 | No |

² 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.

³ Reasonably practicable is defined as whether the annualised CAPEX is less than the Network Safety Risk Reduction

| Transformer | Option | Description | Network Safety Risk Reduction ² | Annualised CAPEX | Reasonably practicable ³ ? |
|-------------------|--------|---------------|--|------------------|---------------------------------------|
| Liverpool No.2 | A | Refurbishment | 2 | 21 | No |
| | B | Replacement | 5 | 144 | No |
| Moree No.1 | A | Refurbishment | 4 | 36 | No |
| | B | Replacement | 9 | 91 | No |
| Moree No.2 | A | Refurbishment | 7 | 55 | No |
| | B | Replacement | 18 | 104 | No |
| Murray No.1 | A | Refurbishment | 8 | 100 | No |
| | B | Replacement | 20 | 67 | No |
| Murray No.2 | A | Refurbishment | 7 | 37 | No |
| | B | Replacement | 15 | 67 | No |
| Murrumburrah No.1 | A | Refurbishment | 6 | 69 | No |
| | B | Replacement | 16 | 89 | No |
| Panorama No.1 | A | Refurbishment | 13 | 60 | No |
| | B | Replacement | 19 | 104 | No |
| Panorama No.2 | A | Refurbishment | 13 | 66 | No |
| | B | Replacement | 21 | 104 | No |
| Sydney North No.3 | A | Refurbishment | 7 | 56 | No |
| | B | Replacement | 11 | 144 | No |
| Sydney North No.4 | A | Refurbishment | 9 | 65 | No |
| | B | Replacement | 14 | 144 | No |

4.3 Preferred option

The outcome of the SFAIRP/ALARP evaluation is that neither of the options presented in Table 4 are reasonably practicable for any of the included transformers and are therefore not required to satisfy the organisation's SFAIRP/ALARP obligations.

The preferred option is Option A (transformer refurbishment) based on the commercial evaluation.

Capital and operating expenditure

There are no other Capex or Opex considerations beyond those already included above.

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 Project Approval Documents be prepared to implement Option A.