# NEED/OPPORTUNITY STATEMENT (NOS)

Sydney East Tx 1,2,3 Need Statement

NOS- DCN548 revision 7.0

**Ellipse project no.:** P0008869
**TRIM file:**

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

**Approvals**

| | | |
|---|---|---|
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| **Date submitted for approval** | 25 November 2016 | |

**Change history**

| Revision | Date | Amendment |
|---|---|---|
| 0 | 7 May 2013 | Initial issue |
| 1 | 21 October 2013 | Updated Risk Assessment and TRIM link |
| 2 | 7 March 2016 | Not published |
| 3 | 23 March 2016 | Updated need description, risk score and document format. |
| 4 | 19 May 2016 | Updated regulatory dates. |
| 5 | 28 October 2016 | Minor update - added risk cost summaries in the attachment |
| 6 | 15 November 2016 | Minor update - attached latest risk tool output for No.3 transformer |
| 7 | 25 November 2016 | Minor update to Condition Summary and update to format |

# 1. Background

Sydney East Substation is comprised of the following transformers:

- Tx 1: 3 x 1 ph 330/132/16kV 400 MVA, Tyree make
- Tx 2: 3 x 1 ph 330/132/16kV 400 MVA, Tyree make
- Tx 3: 3 x 1 ph 330/132/16kV 400 MVA, Tyree make – Unavailable for service – bushings issue
- Tx 4: 1 x 3 ph 330/132/16kV 375 MVA, Hyosung make
- Tx 9: 1 x 1 ph 330/132/16kV 133.3 MVA, Tyree make – spare 1 ph transformer

Transformers 1, 2 and 3 were installed together and have been in operation since 1974. No. 4 Transformer was installed in 2013.

Sydney East substation currently supplies winter peak load of ~556 MVA, which consists of industrial, commercial and residential load (via DNSP - AusGrid connections). It is forecast to supply 630 MVA in 2023.

Transformer No. 3 has unserviceable 330kV (all phases) and 132kV (white phase) bushings and is presently not available for service. With three transformers in service, N-1 network security is maintained.

Transformers 1, 2 and 3 are approaching end-of-life due to a range of condition issues.

# 2. Need/opportunity

The condition issues with transformers 1, 2 and 3 are required to be addressed to reduce the network risk. The current condition of all three transformers suggests 'accelerated ageing' of the transformers. Key issues are outlined below.

## 2.1 Transformer Condition

Refer to attachment 1.1, 1.2 and 1.3 for detailed condition assessments.

**Carbon particle contamination:**

Contamination of the windings and leads is due to poor separation between the diverter switch cylinder oil volume and the main tank oil volume. The issue has been apparent on all nine single units in varying degrees of severity. Risks have been managed to a degree by replacement of seals, oil treatment and filtering during refurbishment work in the past in attempts to limit the introduction of additional carbon material into the main tank.

Overall, the work has not been sufficiently successful as indicated by ongoing dissolved gas analysis showing continued cross contamination of Acetylene. Contamination of the winding paper insulation system that has already occurred cannot be rectified and carbon particle contamination from affected diverter switch cylinders continues. Advice from the transformer manufacturer is that removal of carbon contamination is unlikely to be complete even if subjected to solvent washing and subsequent vapour phase treatment at the factory.

**Paper Insulation system:**

Each of the single phase units has a relatively low furan count (<0.45ppm), which indicates an average ageing rate for their age. However, paper samples analysed for 'Degree of Polymerisation' (DP) taken from each unit during refurbishment work shows that the aging rate for these transformers ranges between "Accelerated Aging Rate" to Excessive Aging Rate" (based on available research data). Most significantly affected units are in Transformer No.

2 where DP levels <180 have been measured on winding leads. All other units in the group have DP levels between 400 and 950.

**Moisture in Paper:**

Moisture in oil measurements are used to estimate the moisture in paper using industry accepted formulae. Estimates for all nine units range between 1.6% - 2% based on moisture in oil measurements. This data is considered to be unreliable due to the low transformer temperatures (<40°C) during oil sampling. It is also likely that estimations of moisture in paper using dielectric response testing will be ineffective due to the presence of carbon particulates throughout the windings. As a result, meaningful estimations of moisture content in paper are difficult to determine. However, these transformer units have been subject to dry-out during 2006 and 2010 refurbishments and the expectation is that they are relatively dry.

**Oil Quality:**

Oil quality parameters are currently in the acceptable range as per the Substations Condition Monitoring Manual GM AS S1 008, and appear stable after refurbishment work on all nine units (between 2006 and 2010). PCB measurements indicate the oil should be categorised as PCB Free. Tests for corrosive sulphur have returned positive results for some units, which increases the risk of failure.

There is a history of minor acidity problems across all nine units, although recent data shows that this issue is under control after oil treatment during refurbishment work.

**Dissolved Gas Analysis:**

All units have exhibited abnormal gas generation trends over the years due to the fitment of Reinhausen 'D' type diverter switches, which have a known history of poor sealing and cross contamination of diverter switch oil with the main tank oil. Gas generation trends in all nine single phase units is commensurate with tapchanger operations. This problem has been eradicated in only one phase of Transformer No. 3, with all other units showing signs of continued cross contamination even after the fitment of new seals. The presence of gasses generated in the diverter switch cylinder results in a loss of diagnostic ability using DGA analysis of main tank oil.

**Defect History:**

Each transformer in the group has a history of minor oil leaks on the coolers and main tank, although these have been controlled using routine defect management. Main tank lids on each unit were welded during refurbishment work to alleviate leak issues, with only minor leaks apparent around oil pump assemblies and gate valves. No other significant defects are apparent.

**Bushings:**

Original transformer bushings were manufactured by the Micanite Bushing Company and are of the oil impregnated paper type. Dielectric measurements for the LV bushings other than Red and Blue phase of Transformer No. 2 are currently within the acceptable limits.

All High Voltage bushings show increasing DDF trends, with the Transformer No. 2 and No. 3 bushings already in the Caution range (as per the Condition Monitoring Manual). Replacement is recommended as there is a past history of catastrophic failure for this bushing type.

Red and Blue phase Low Voltage bushings on Transformer No. 2 and White phase bushing of Transformer No. 3 show increasing DDF trends and should be replaced. It should be noted that White Phase No. 2 transformer LV bushing and the Red and Blue Phase LV bushings of Tx 3 have already been replaced, which have DDF within the acceptable limits.

**Tap Changer and Diverter Switch:**

Reinhausen 'D' type diverter switches are fitted to all units in the group, and are known to leak oil/gas from the diverter switch cylinder into the main tank. Inspection by the original equipment manufacturer during previous refurbishment work confirmed the leaking issue and work to seal the cylinders has been successful on only the White Phase of Transformer No. 1 and the Blue phase of Transformer No. 3. All other units show continuing cross contamination ranging from minor to significant.

Complete rectification of this issue would require replacement of the bakelised paper cylinder with more modern fibreglass/resin types as has been completed on the Red Phase of Transformer No. 3 in 2010. Replacement of the cylinders onsite requires internal access to the transformer tank and would be problematic after the welding of the main tank lid.

The diverter switches on each unit have completed approximately 300,000 operations (with an operational life of 800,000 operations as per manufacturer's advice) which is moderate for a transmission transformer of this age. Selector switches have no known or apparent issues.

## 2.2 Oil Containment

It is noted that the existing oil containment system for each unit is comprised of concrete slab and brick walls draining into a primary spill oil tank. Joints in the compound were sealed during recent overhaul work and leaks have been eliminated. Hence the condition of the main transformer bunds is not a major issue at this time. However, the design does not reflect current standards and consideration should be given to upgrading the compound to current standards where major work is planned.

## 2.3 Other Risks

The condition of the transformer No. 3 HV and LV bushings recently prevented a return to service at the conclusion of routine maintenance, resulting in the loss of one of three auxiliary supplies for this substation. A forced or planned outage of either Transformer No. 1 or Transformer No. 2 during the continued outage for Transformer No. 3 will require the installation of LV diesel generator back-up to support the cooling load for the remaining two in-service units. This is required to cover against the possible loss of the remaining transformer that is equipped with an auxiliary transformer. Loss of this transformer may result in a loss of load due to the lack of forced cooling capability on the remaining in-service transformer.

There are no spare bushings available.

## 2.4 Summary

1. The condition assessment and health index suggest that all three transformers 1, 2 and 3 are in poor condition with significant risk cost to TransGrid. Refer to Condition Summary in table 1.

2. Due to unavailability of Transformer No. 3, auxiliary supply is available from Transformer Nos. 1 and 2 only. There is a need to establish auxiliary supply from Transformer No. 4.

**Table 1 - Condition Summary**

| | Tx 1 | | | Tx 2 | | | Tx 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | R | W | B | R | W | B | R | W | B |
| **PIC No.** | A02080/1 | A02080/2 | A02080/3 | A02080/4 | A02080/5 | A02080/6 | A02081/1 | A02080/8 | A02080/9 |
| **Last Refurbishment Completed** | Oct 2006 | Oct 2006 | Oct 2006 | Oct 2006 | Oct 2006 | Oct 2006 | Nov 2010 | Nov 2010 | Nov 2010 |
| **Health Index** | 5.29 | 4.39 | 3.77 | 9.41 | 9.96 | 9.74 | 4.21 | 4.54 | 8.31 |
| **Remaining Life Estimate** | 6.74 | 9.56 | 12.19 | 1.3 | 1.04 | 1.13 | 10.24 | 7.72 | 2.04 |
| **Carbon Contamination** | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| **DP** | 565-600 | 505-649 | 445-569 | 462-899 | 180-653 | Not Available | 373-951 | 602-790 | 291-429 |
| **Paper insulation system** | Accelerated ageing | Accelerated ageing | Accelerated ageing | Accelerated ageing | Excessive accelerated ageing | Accelerated ageing | Accelerated ageing | Accelerated ageing | Excessive accelerated ageing |
| **Moisture in Paper** | Within acceptable limits | Within acceptable limits | Within acceptable limits | Within acceptable limits | Within acceptable limits | Within acceptable limits | Within acceptable limits | Within acceptable limits | Within acceptable limits |
| **Oil Quality** | Within acceptable limits | Within acceptable limits | Within acceptable limits | Within acceptable limits | Within acceptable limits | Within acceptable limits | Within acceptable limits | Within acceptable limits | Within acceptable limits |
| **DGA results** | C2H2 - Danger<br>C2H6 - Caution | Acceptable | C2H2 - Caution | C2H2, C2H4 - Danger<br>C2H6, CH4 - Caution | C2H2, C2H4 - Danger<br>C2H6, CH4 - Caution | C2H2 - Danger<br>C2H4, C2H6, CH4 - Caution | Acceptable | C2H2 - Caution | C2H4, CH4 - Danger<br>C2H2, C2H6 - Caution |
| **Defect History** | Leaks on coolers, main tanks. | | | Leaks on coolers, main tanks, diverter switch. | | | Leaks on coolers, pipe work, main tanks, bushings, tapchanger faults. | | |
| **Bushings** | Acceptable test results.<br>No spare bushings available. | | | In poor condition. No spare bushings available.<br>HV - DDF in Caution range, Nearing the Danger threshold<br>LV - DDF in Caution range | | | In poor condition. No spare bushings available.<br>HV - DDF in Caution range, Nearing the Danger threshold<br>LV - DDF for W phase in Caution range. | | |
| **Tap Changer (MR type 'D')** | Leaks from diverter switch. Repairs have been unsuccessful. | | | Leaks from diverter switch. Repairs have been unsuccessful. | | | Leaks from diverter switch. Red phase cylinder was replaced in 2010. Repairs have been unsuccessful. | | |
| **Oil Containment Condition** | Joints sealed and bunds generally in good condition.<br>Not to the current standard. | | | Joints sealed and bunds generally in good condition.<br>Not to the current standard. | | | Joints sealed and bunds generally in good condition.<br>Not to the current standard. | | |
| **Other** | Corrosive Sulphur in insulating oil for R & B phases.<br>Minor leaks and corrosion. | | | Corrosive Sulphur in insulating oil for R & B phases.<br>Minor leaks and corrosion. | | | Corrosive Sulphur in insulating oil for R & B phases.<br>Minor leaks and corrosion. | | |

## 3. Related needs/opportunities

Transformer bund and compound walls – The walls and bunds are made up of brick and masonry blocks, which do not meet the current standards. Should a transformer be replaced, reconstruction of compounds and walls is expected to be necessary due to the change in transformer from three single phase units to a single 3 phase transformer.

## 4. Recommendation

The issues identified with the poor condition of Sydney East transformers 1, 2 and 3 greatly increase the risk of transformer failure at the site, resulting in significant network risk and total risk cost. It is recommended that options be considered and analysed to address the need and opportunities within the 2018/19 – 2022/23 regulatory period.

# Current Option Assessment - Risk Summary

Project Name: Transformer Sydney East No.1 330kV

Option Name: DCN548a - Base Case

Option Assessment Name: DCN548a - Base Case - Assessment 1

Rev Reset Period: Next (2018-23)

| Major Component | No. | Minor Component | Sel. Hazardous Event | LoC x CoF ($M) | Failure Mechanism | NoxLoC xCoF ($M) | PoF (Yr 1) | Total Risk ($M) | Risk ($M) (Rel) | Risk ($M) (Op) | Risk ($M) (Fin) | Risk ($M) (Peo) | Risk ($M) (Env) | Risk ($M) (Rep) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Main Transformer | 1 | Winding and Core | Explosive Failure of Asset (Main Transformer) | $0.30 | Failure | $0.30 | 2.11% | $0.01 | | | $0.00 | $0.01 | | $0.00 |
| Main Transformer | 1 | Winding and Core | Failure that Releases Pollutant (Main Transformer) | $0.00 | Failure | $0.00 | 2.11% | $0.00 | | | $0.00 | | $0.00 | $0.00 |
| Main Transformer | 1 | Winding and Core | Unplanned Outage - HV (Main Transformer) | $59.07 | Failure | $59.07 | 2.11% | $1.25 | $1.09 | | $0.16 | | | $0.00 |
| | | | | $59.37 | | $59.37 | | $1.25 | $1.09 | | $0.16 | $0.01 | $0.00 | $0.00 |

Total VCR Risk: $1.09

Total ENS Risk: $0.00

# Current Option Assessment - Risk Summary

Project Name: Transformer Sydney East No.2 330kV

Option Name: DCN548b - Base Case

Option Assessment Name: DCN548b - Base Case - Assessment 1

Rev Reset Period: Next (2018-23)

| Major Component | No. | Minor Component | Sel. Hazardous Event | LoC x CoF ($M) | Failure Mechanism | NoxLoC xCoF ($M) | PoF (Yr 1) | Total Risk ($M) | Risk ($M) (Rel) | Risk ($M) (Op) | Risk ($M) (Fin) | Risk ($M) (Peo) | Risk ($M) (Env) | Risk ($M) (Rep) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Main Transformer | 1 | Winding and Core | Explosive Failure of Asset (Main Transformer) | $0.30 | Failure | $0.30 | 3.98% | $0.01 | | | $0.00 | $0.01 | | $0.00 |
| Main Transformer | 1 | Winding and Core | Failure that Releases Pollutant (Main Transformer) | $0.00 | Failure | $0.00 | 3.98% | $0.00 | | | $0.00 | | $0.00 | $0.00 |
| Main Transformer | 1 | Winding and Core | Unplanned Outage - HV (Main Transformer) | $59.07 | Failure | $59.07 | 3.98% | $2.35 | $2.05 | | $0.30 | | | $0.00 |
| | | | | $59.37 | | $59.37 | | $2.36 | $2.05 | | $0.30 | $0.01 | $0.00 | $0.00 |

Total VCR Risk: $2.05

Total ENS Risk: $0.00

# Current Option Assessment - Risk Summary

Project Name: Transformer Sydney East No.3 330kV

Option Name: DCN548c - Base Case

Option Assessment Name: DCN548c - Base Case - Assessment 1

Rev Reset Period: Next (2018-23)

| Major Component | No. | Minor Component | Sel. Hazardous Event | LoC x CoF ($M) | Failure Mechanism | NoxLoC xCoF ($M) | PoF (Yr 1) | Total Risk ($M) | Risk ($M) (Rel) | Risk ($M) (Op) | Risk ($M) (Fin) | Risk ($M) (Peo) | Risk ($M) (Env) | Risk ($M) (Rep) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Main Transformer | 1 | Winding and Core | Explosive Failure of Asset (Main Transformer) | $0.30 | Failure | $0.30 | 2.64% | $0.01 | | | $0.00 | $0.01 | | $0.00 |
| Main Transformer | 1 | Winding and Core | Failure that Releases Pollutant (Main Transformer) | $0.00 | Failure | $0.00 | 2.64% | $0.00 | | | $0.00 | | $0.00 | $0.00 |
| Main Transformer | 1 | Winding and Core | Unplanned Outage - HV (Main Transformer) | $59.07 | Failure | $59.07 | 2.64% | $1.56 | $1.37 | | $0.20 | | | $0.00 |
| | | | | $59.37 | | $59.37 | | $1.57 | $1.37 | | $0.20 | $0.01 | $0.00 | $0.00 |

Total VCR Risk: $1.37

Total ENS Risk: $0.00