2023-27
POWERLINK QUEENSLAND REVENUE PROPOSAL

Project Pack – PUBLIC

CP.02584
Tarong Transformers 2 and 3 Replacement

CP.02584 – Tarong Transformers 2 and 3 Replacement

Project Status: Not Approved

1. Network Need

H018 Tarong 275/132/66kV Substation, approx. 90km north of Toowoomba, is a critical part of the 275kV network supplying South East Queensland. Tarong substation contains four aged transformers (T1, T2, T3 and T4) which were commissioned in 1986, 1982, 1983 and 1992 respectively.

A Condition Assessment (CA) conducted in December 2019 identified that all four transformers are approaching the end of their technical service life[1]. All are exhibiting end of life attributes such as HV bushings which have exceeded their design life, multiple oil leaks (except for T4) and deteriorated gaskets. Additionally, the CA found that all the transformers are underrated compared to the fault level at Tarong substation (35.9kA) and are susceptible to fault events when a parallel transformer is out of service. The CA recommended replacement of all four transformers prior to 2024, where they are required for network operation.

Planning studies also indicate that there is an ongoing need for Tarong substation to supply the 66kV load (supplied by T2 and T3) to ensure Powerlink's reliability and security obligations. The removal or failure of T2 or T3 at Tarong substation would violate Powerlink's Transmission Authority reliability obligations (N-1-50MW / maximum 600MWh unserved energy)[2]. An outage on the T2 and T3 transformers would leave up to 40MW and up to 850MWh of customer load per day at risk[2]. However, T1 and T4 can be removed from service, when they reach their end of life, as the Tarong Area Plan Strategy proposes to convert Chinchilla Substation to a transformer ended substation supplied from Columboola.

Further decline in transformer T2 and T3 asset condition increases the risk of failure that may cause network outages, safety incidents and additional network costs to replace assets under emergency conditions. The CA recommends reinvestment in the assets prior to 2024 to manage these risks and ensure network reliability. Failure to address the existing condition of this asset is likely to result in non-compliance with Powerlink's reliability and safety obligations[6].

2. Recommended Option

As this project is currently 'Not Approved', project need and options will be subjected to the public Regulatory Investment test for Transmission (RIT-T) consultation process to identify the preferred option closer to the time of investment.

The current recommended option is to replace T2 and T3 and retire T1 and T4 at Tarong Substation by 2024[2].

The following options have been identified to address the condition issues of the transformers:

- Do Nothing – rejected due to non-compliance with reliability standards and safety obligations
- Retain existing arrangement, replacing T1-T4 by 2024
- Non Network Option – parameters outlined, at present no viable options has been identified.

Figure 2-1 below shows the current recommended option reduces the forecast risk monetisation profile of Tarong substation T2 & T3 transformers by over $2m per annum in 2025. The recommended option will extend the asset life by 40 years.

Where a 'Do Nothing' scenario is adopted, the forecast level of risk associated with the asset escalates from ~2m in 2020 to ~$4m per annum in 2029 and continues to rise further. This is predominantly due to network risks (unserved energy) associated with potential concurrent outages of T2 and T3[3].

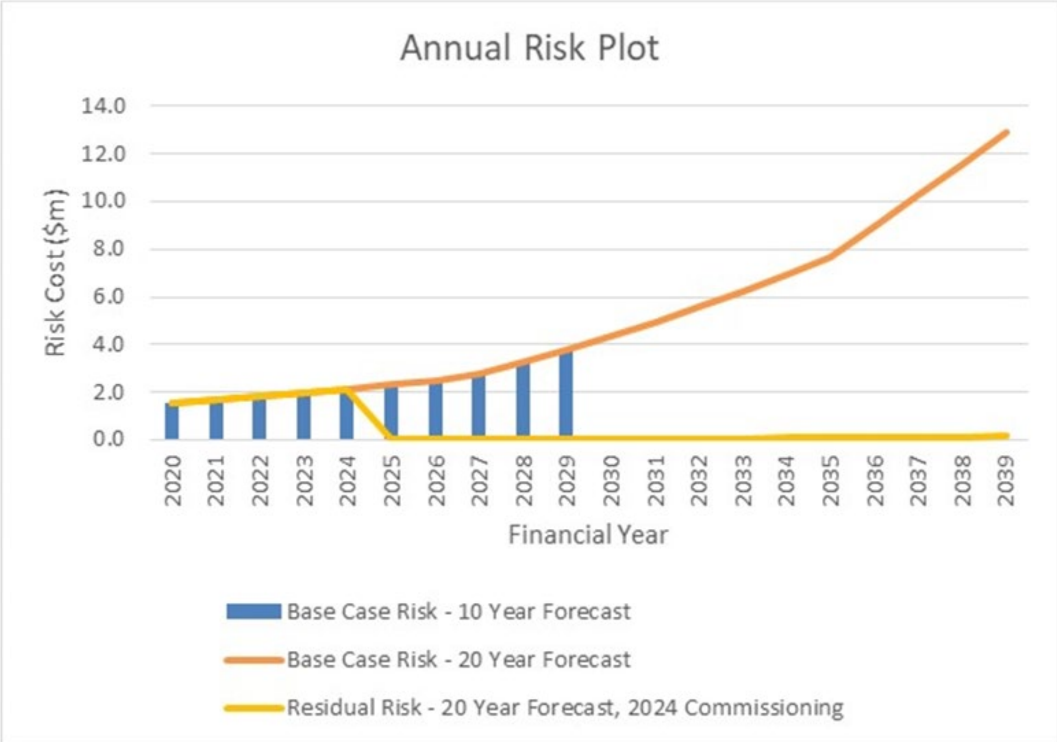

Figure 2-1 Annual Risk Monetisation Profile (Nominal)

3. Cost and Timing

The estimated cost to replace T2 and T3 in as a single stage replacement is $14.1m ($2019/20).

Target Commissioning Date: June 2024

4. Documents in CP.02584 Project Pack

Public Documents

1. H018 Tarong Transformer T1, T2,T3 & T4 Condition Assessment
2. Tarong Transformer Planning Report
3. Base Case and Maintenance Costs Summary Report CP.02584 Tarong Transformers Replacement
4. Project Scope Report CP.02584 Tarong Transformers Replacement
5. CP.02584 Tarong Transformer Replacement Project Management Plan

Supporting Documents

6. Asset Reinvestment Criteria - Framework
7. Asset Management Plan 2021

H018 Tarong Transformer T1, T2,T3 & T4 Condition Assessment

Report Prepared by:	[redacted]	**Date of site visit:**	10/12/2019
AUTHOR/S:	[redacted]		
Report Approved by:	[redacted]	**Report Approval Date:**	23/12/2019
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IMPORTANT: - This condition assessment report provides an overview of the condition of all four 275 kV transformers (excluding internal transformer inspections) and high level indications of their residual reliable service life. As it is a snapshot in time and subject to the accuracy of the assessment methodology and ongoing in-service operating environment, the comments in this report are valid for 3 years from the date of the site visit stated above.

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SUMMARY

At H018 Tarong Substation, transformers T2 & T3 are 37 years old and T1 & T2 are 33 and 29 years old respectively. All four transformers were manufactured by GEC Rocklea. A condition assessment was performed, consisting of on-site visual assessment, desktop analysis of historical oil and insulation test data, maintenance history and through fault data history where available.

No attempt has been made in this report to cover any detailed economic analysis of the viability of rectifying any highlighted issues associated with these transformers but it provides a condition assessment of the “key” parameters for these transformers and what may need to be actioned by Powerlink if operational ownership is to continue for a further 10-15 years.

A summary of the findings is shown in Table 1.

TABLE 1: Summary of Estimated Residual Life of Transformers’ “Key” Components

Parameter	Estimated Residual Life		Further Comments
	Transformer T1&T4 275/132kV	Transformer T2&T3 275/66kV	
Anti-corrosion system	10 years	10 years	Existing paint system for all transformers is in good condition, although hiding corrosion problems in some locations.
Winding paper life	>50 years	>50 years	Assuming same operational environment. Paper DPv is in the range 750-900, and likely 700-850 at hot spots.
Winding mechanical stability	5-10 years	5-10 years	Questionable due to inherent manufacturing design and exposure. All transformers have been subjected to a number of through faults, which causes weakness in clamping pressures despite paper being in reasonable condition.
External HV bushings	3-5 years	3-5 years	HV & LV bushings are all oil impregnated paper bushings in porcelain housing and older than the nominal 25 years suggested by the OEM. Whilst monitored with DLA and capacitance tests every 6 years, they still represent increased safety risk for personnel.
Insulating Oil	5-10 years	5-10 years	Good condition, acceptable moisture and acidity content but low resistivity.
Radiators	5-10 years	5-10 years	Many oil leaks, except T4 radiators, which are in good condition.
Repairs to leaking gaskets	3-5 years	3-5 years	Almost all gaskets need replacement – will require oil removal, filtering and refilling. Due to the age of transformers and bunded areas, there is an increased environmental risk.
Fault Rating	3-5 years	3-5 years	The current 275kV calculated fault level at Tarong Substation is 35.9kA – all transformers have a fault rating of 31.5kA. All transformers are underrated and will be significantly exposed when one of the paralleled transformers is out of service.

Parameter	Estimated Residual Life		Further Comments
	Transformer T1&T4 275/132kV	Transformer T2&T3 275/66kV	
Overall Residual Life	3-5 years Limited by fault rating	3-5 years Limited by fault rating	Recommended refurbishment works (within 5 years): • HV & LV bushings replacement • Oil gaskets replacement. • Re-painting of main tank, radiators & cables. However, inadequate fault current ratings cannot be addressed. These will have to be closely monitored and managed, and transformers de-energised if required for operational purposes.

Investigation of Transformers T1, T2, T3 & T4:

A comprehensive on-site inspection of the 70/90 MVA 275 /132 kV transformers T1 & T4 , 70/90 MVA 275 /66 kV transformers T2 & T3 at H018 Tarong substation was performed on the 14 August 2019 and only the major findings which may impact the serviceability of the transformers are discussed in this report.

Figure 2 -70/90 MVA 275/132kV transformer T1 at H018 Tarong substation.

Figure 1-70/90 MVA 275/66kV transformer T2 at H018 Tarong substation

Figure 3 -70/90 MVA 275/66kV transformer T3 at H018 Tarong substation.

Figure 4 -70/90 MVA 275/132 kV transformer T4 at H018 Tarong substation

[redacted]

Figure 5 - H018 Tarong substation showing the network location of T1, T2, T3 & T4 being considered in this report.

1. TRANSFORMER RATINGS AND FAULT LEVELS

When originally built H018 Tarong substation was designed, assuming the maximum fault level at this site will not exceed 31.5 kA. As network developed and more generators connected to the network, fault levels increased above 31.5 kA and major switchgear replacement projects were undertaken in 2009/2010 to ensure these are adequately rated for the increased fault levels. The analysis of fault rating adequacy for power transformers required additional data from the transformer manufacturer and by the time these were obtained and analyses undertaken, Tarong power station announced their decision to mothball one unit for several years. This temporarily reduced fault levels making the power transformer ratings suitable based on fault contributions calculations. However, in 2019 all units are generating and the calculated fault levels for 275kV L-G short circuit current is 35.83 kA and three phase 34.04 kA. All four transformers have been design assuming maximum 275 kV fault level be 31.5 kA at transformer connection point.

The design under rating of the 275/66kV T2 & T3 transformers are mitigated operationally by making sure that both the 66kV transformers are in service and the 66kV bus coupler is closed. Under contingency where one 66kV transformer is out of service, there is a potential of the remaining in-service 66kV transformer rating exceeding its current rating for close in faults on the 66kV bus. This risk is managed by ensuring no personnel is present at the yard when this network configuration is present. One option for managing fault level underrating of these four transformers considered was back-feeding Tarong from Chinchilla, but this is not registered as an active operational measure.

For the 275/132kV Transformers T1 & T4 under N and N-1 conditions, the Tarong fault level exceeds the design rating of the transformers and the risk is only managed by the fact that not all generators in the network are generating at the all times. This operating practice may be acceptable for shorter periods, however it is not a good engineering practice for long periods. In particular as all four transformers at Tarong have been subjected to a number of through faults over their service lives, which would have weakened their resilience to through faults.

To mitigate the above issues and considering the amount of through faults the transformers have been subjected to, it is recommended to replace all four transformers in 3-5 years, mainly to mitigate fault level issues if there is a long-term need for all four transformers in the network. There are no known plans for decommissioning or mothballing of any generator units in this area that may reduce or mitigate this rating issue.

2. TRANSFORMER T1

This transformer was factory tested by GEC Rocklea, Brisbane in April 1986 and SAP information indicates that transformer T1 commissioned at H018 Tarong in November 1986.

The general descriptive details of T1 transformer are shown below.

Manufacturer	GEC Rocklea
Specification	QEC Spec No. H503/84/2
Year of manufacture	1985 as stamped on transformer nameplate but April 1986 as per date on factory test report. (approx. 33 year old)
Commissioned	1986
Winding arrangement	Auto Transformer
Rating	70/90 MVA ONAN / ODAN 275 / 132 kV
Transformer Serial No.	A31R3607/1
Powerlink equipment (SAP) No.	20004912
Tap changer manufacturer	M Reinhausen model number: Type 3 MI 501-150/B-12 23 3W
Tap changer serial No.	181 019
Tap changer operations	32963 on 03/07/2019

2.1 Transformer T1 On-site Inspection:

2.1.1. Anti-corrosion System:

The cooler bank radiators are made of galvanised steel whilst all other oil circuit plumbing and main tank are made of painted steel (non galvanised).

Maintenance records do not show that the radiator bank A frame, conservator and pipework were ever repainted or treated for corrosion in full. Based on the secondary cabling and visual inspection, it is likely the main tank and secondary cabling have been either partially or fully repainted. Visible signs of major corrosion are not evident on this transformer at present. The paint system is still providing reasonable protection in the relatively dry environment at Tarong.

2.1.2. Structural:

There were no potential structural issues emerging on this transformer, apart from those associated with bunded area floor and wall cracks.

Figure 6 - H018 T1 bund condition.

2.1.3. Oil Leaks:

The lid on this transformer is not welded to the main tank and is relying on a bolted gasket between the lid and main tank steel flanges to provide sufficient sealing.
A brief summary of the oil leaks are detailed below.

- Small oil weeps from side wall hatches.
- Oil leaking from the main tank to lid gasket.
- The various gaskets are aged and maintenance records show that oil leaks are present since 2002. Many attempts were made to prevent or reduce oil leaks. This transformer was topped up with 300 litres of oil in 2017.

Figure 7. - Oil leaking from the main tank to lid gasket

Figure 8- Oil film spreading to the bund from the main tank lid gasket.

Figure 9- Oil leaks from the side wall hatch

Figure 10- Oil film spreading on radiator fins

Figure 11 - Oil leaks from a radiator bank visible on the control cables located underneath

2.1.4. Secondary Systems:

After 33 years of exposure to the elements, the external cables are set and any significant cable flexing (e.g. removal & reconnection) due to replacement of external ancillary items may create insulation damage but if left physically alone, all of the multicore cables should not fail over the next 10 years. The paint has protected them from UV to some degree.

Figure 12- Multi-core cables attach to the Main tank

2.1.5. Tap Changer (OLTC):

This transformer is fitted with an M type Maschinenfabrik Reinhausen tap changer which is performing well. The tap changer consists of a diverter switch installed into an oil compartment separate from the transformer tank and of a tap selector mounted below. The tap changer is attached to the transformer cover by means of the tap changer head, which also serves for coupling of the drive shaft and for connecting a pipe to the tap changer oil conservator.

It was impossible to see anything through the front viewing window on the tap changer compartment, likely due to contamination build-up on the inside of the sight glass. The tap changer motor drive unit door has to be opened to take the number of operations reading. Maintenance records show that during the six yearly maintenance service in 2006 and 2012 many parts of this unit were replaced and tap changer oil was also replaced. As of August 2019 the tap changer has done 32,963 number of operations.

2.1.6. Transformer Temperature Indicators:

This transformer is fitted with one top oil temperature indicator and three winding temperature indicators. The set point temperatures for each of these instruments for starting the main oil pump, triggering a top oil or winding temperature alarm or trip signals are correct. However there was a transformer trip caused by these indicators in late 2018 and therefore these and their associated wiring were replaced in late 2019.

Figure 13 - HV WTI instrument, LV WTI instrument and OTI instrument. All the viewing windows are clear enabling easy instrument reading except the OTI.

2.1.7. Oil and Insulation Assessment:

Based on oil test results, it seems that oil was either filtered or replaced in early 1988.
The most recent oil sample test data show signs of emerging thermal overheating issues similar to those seen after the transformer was installed.

A desktop assessment was performed using the full history of Oil & Insulation Testing Laboratory test data for this transformer. Signs of mild overheating (< 300 ° C) are visible in oil samples since 2008.

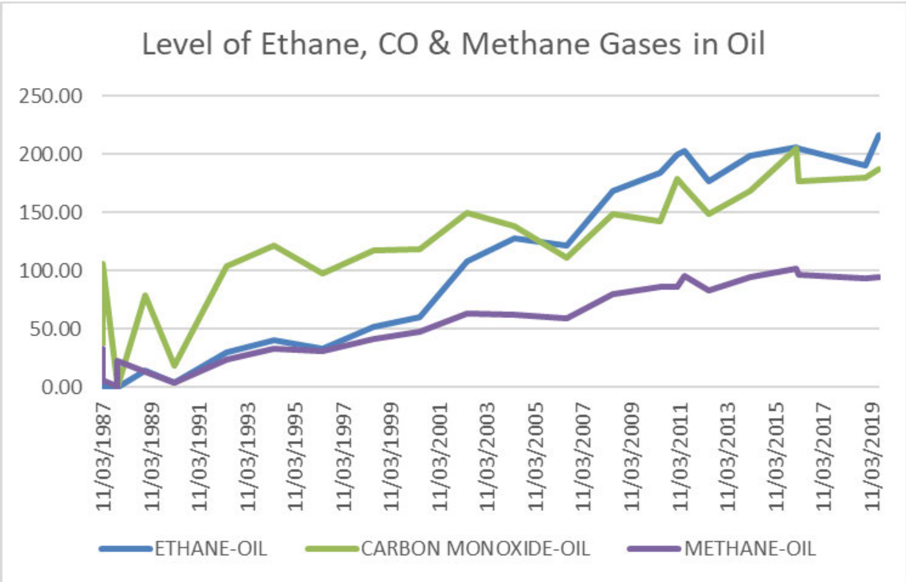

Figure 14 –Indication of overheating in transformer

Figure 14 shows the level of carbon monoxide, methane and ethane in the transformer oil. The increasing trend indicates a thermal fault at low temperature (< 300 ° C). In order to monitor this trend, the oil sampling frequency was increased to annually from 2010. The cause for this overheating is still unknown.

2.1.8. Oil Quality:

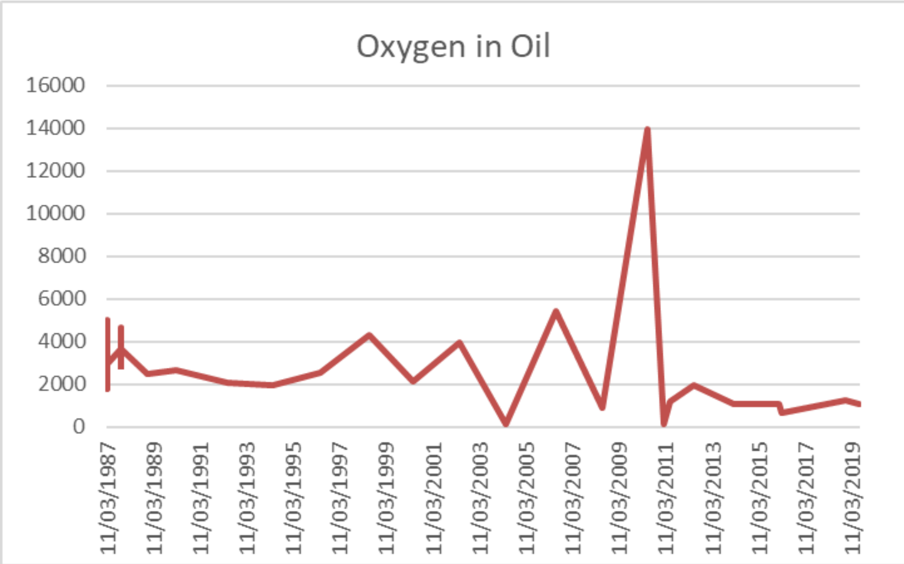

Figure 15 –Content of oxygen in oil

This GEC 90MVA 275/132kV transformer was manufactured prior to QEC introducing sealed internal HV insulation systems. The main tank conservator breathes to the atmosphere via a desiccant breather and this is obvious from the graph above showing oxygen content in oil in the main tank. The function of sealing systems is to prevent air and moisture from contaminating insulating materials within the transformer. Air contains moisture and oxygen, which causes oil to oxidize, increases oil acidity and sludging.

The graph shown in Figure 15 indicates the oxygen level in the main tank in the service history. The peak increase in oxygen level between 2008 & 2011 is likely to be linked to processes caused by mild overheating of the oil. Currently the oxygen levels are well within limits.

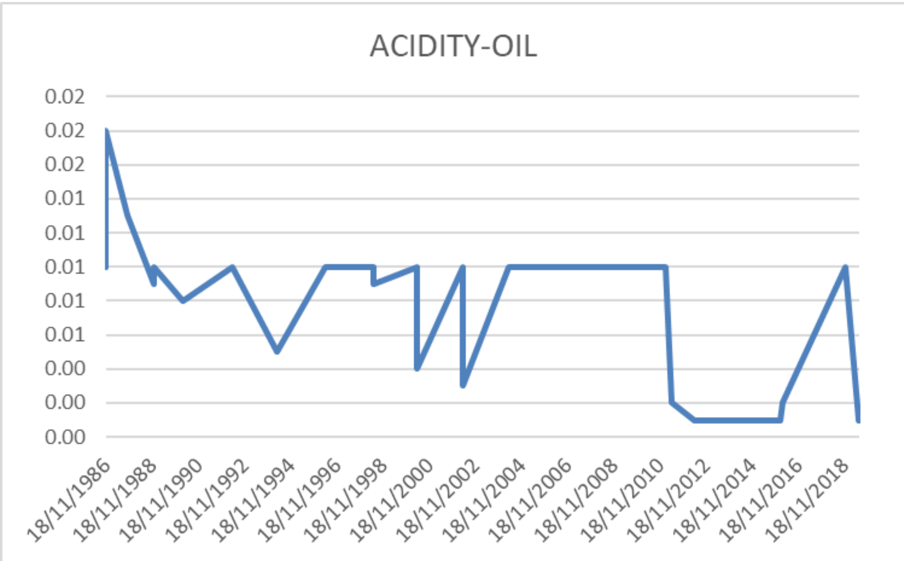

Figure 16 – Transformer T1 oil acidity

Figure 16 shows the level of acidity in the oil, which is at an acceptable level. The oil quality of this transformer has remained in reasonable condition over its life. The oil dielectric dissipation factor and dielectric strength are also within acceptable limits.

The oil in this transformer was found to be corrosive and therefore has been passivated since 2010. Oil Laboratory test data confirms that from 2010, the oil is "non-corrosive" per the IEC test method. Periodic testing and toping up of the passivator level in the oil will have to continue for the life of the transformer in order to maintain the dissolved passivator level within limits to ensure its effectiveness and prevent progression of copper corrosion.

There is no detectable PCB contamination in the oil and hence this transformer is classified as PCB free.

2.1.9. Winding Paper Quality

The dissolved furan levels in oil continue to be relatively stable and within acceptable limits (Figure 17).

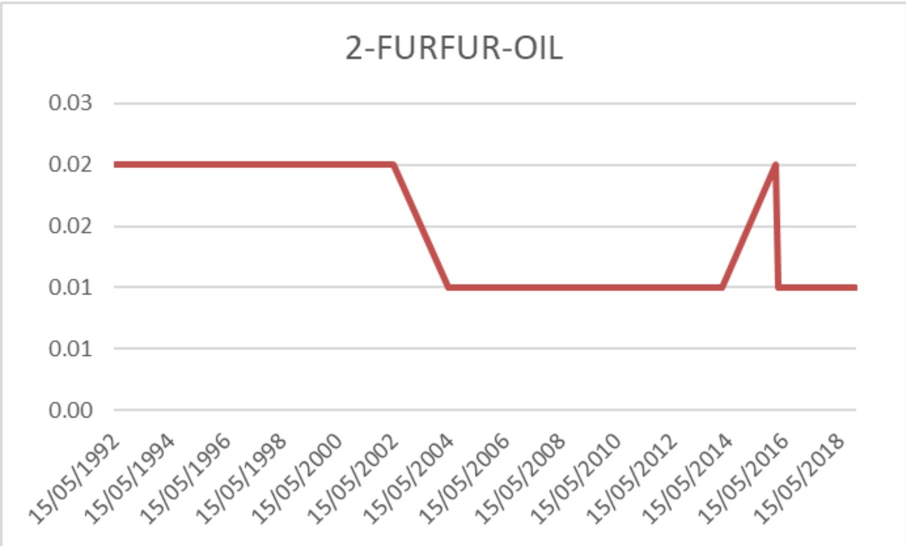

Figure 17 – T1 2 Furfurals trend

Figure 18 shows the transformer loading over the last 12 months and if this is representative of the loading over previous years, it could explain why the dissolved furan level in the oil is relatively low for a 34 years old free breathing transformer. The peak loading in MVA on the 275kV side of the transformer over the period 05/12/2018 to 05/12/2019 did not appear to exceed 40% of the nameplate ODAN rating. The average loading on the transformer for this period is 12MW.

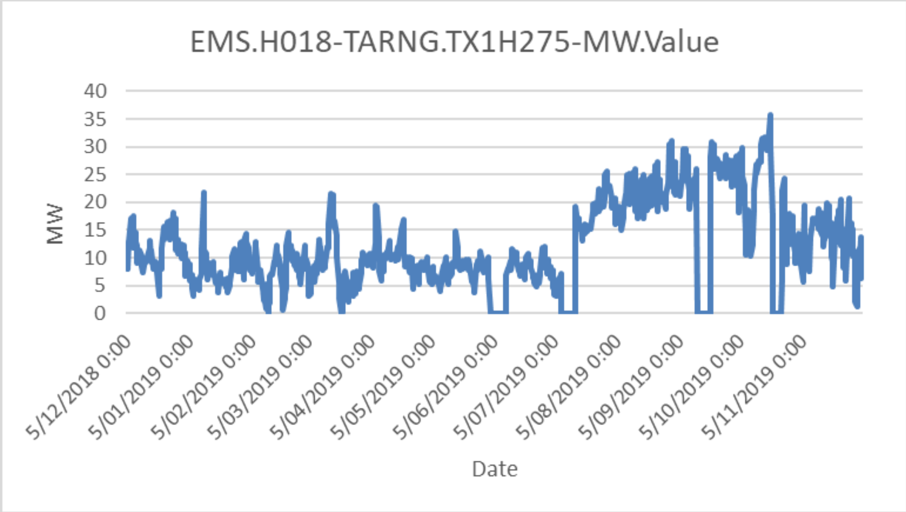

Figure 18 -T1 transformer loading in MVA in period 5/12/2018 -5/12/2019 (the highest peak load is 36 MVA i.e 40% of ODAN nameplate rating)

Because there is normally a variation in insulation temperatures throughout the transformer windings when loaded, at times fairly significant, more localised higher winding insulation temperatures will generate higher than average amounts of furans which must also be considered in the calculation of cellulose insulation age.

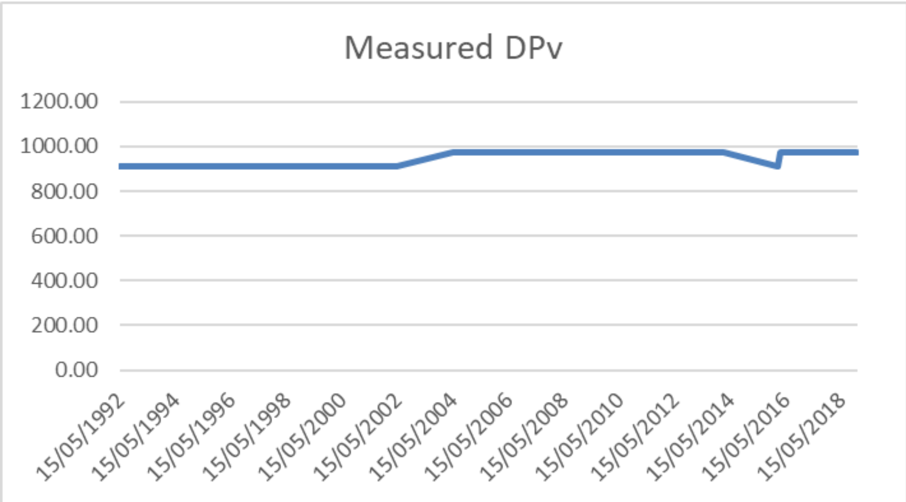

Figure 19 –T1 calculated DPv

The dissolved furan in oil test data can be used to calculate approximate and average bulk cellulose insulation DP_v and its estimated trend is shown in Figure 20. Assuming that the transformer operating conditions remain the same, the trend shows that the transformer has an estimated service life of more than 50 years (Refer Figure 20).

For a typical free breathing transformer the estimated service life is 40 years. The average loading of T1 transformer being only 12 MW (only 14% of its rated capacity), the expected service life based on the paper aging only is significantly greater than theoretical design life.

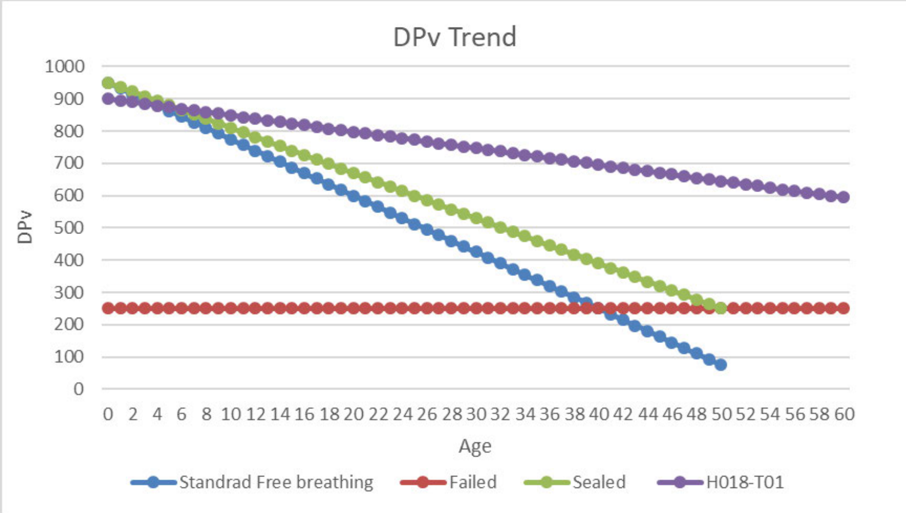

Figure 20 –T1 DPv trend, typical DPv and EOL DPv

2.1.10. Moisture in Insulation:

Figure 21 shows a plot of the measured moisture content in oil as measured in oil samples, starting from 1985. It seems to be relatively stable and being on average 4 mg/kg shows it has been managed well. It is worthwhile noting that with increasing oxygen levels and depending on silica gel quality in the breather, it can take a few years to detect increase in moisture level.

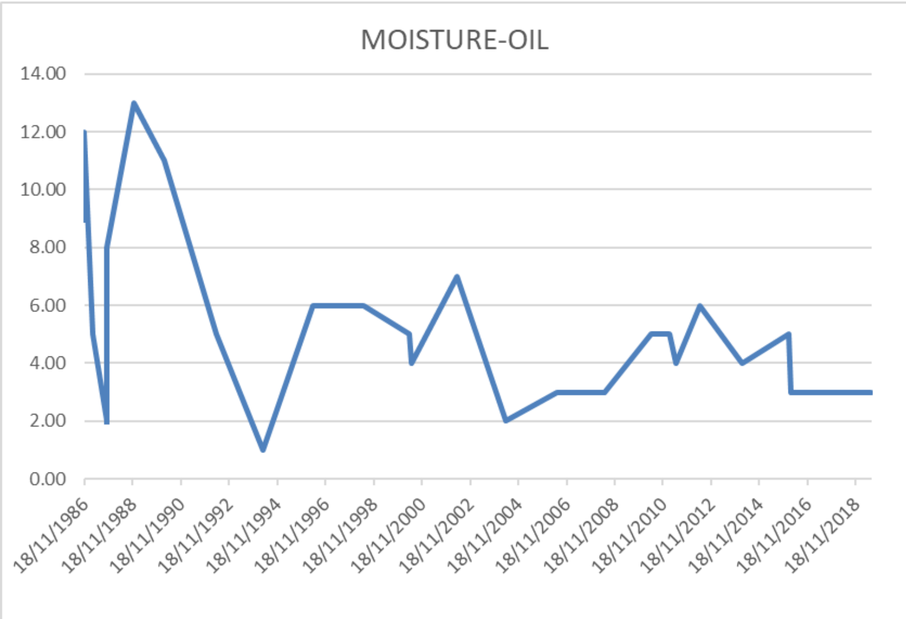

Figure 21 – Moisture in oil

The desiccant in the breather installed on the main tank conservator was in good condition as was the oil bath for particulate filtering of the incoming air.

2.1.11. Transformer Bushings:

Even though the HV & LV oil impregnated paper (OIP) bushings appear to be serviceable to date, it is recommended to have these replaced within the next 3-5 years to reduce safety risk exposure at this site, since these are of porcelain housing and insulation is aged. This is based on experience with this type of bushings as detection methods using DLA and capacitance provide late indication of failed insulation and are measured only every 6 years, due to outage constraints.

2.1.12. Transformer Secondary Systems:

The maintenance records do not show any abnormal secondary system issues emerging, however the AC control panel should be refurbished (replaced) and updated with MCBs if the transformer is to remain in service longer than 3-5 years.

2.1.13. Mechanical Life

Since there was no internal active part inspection performed, the winding clamping or winding mechanical stability is difficult to be accurately ascertained. However since the DPv values are good and with the low moisture in insulation, there should be less deterioration in these active part parameters.

Records revealed that this transformer has been subjected to a number of through faults over its service life. Whilst this type of information can't be used to accurately assess the mechanical condition of the windings, it can provide some relative understanding of the amount of mechanical stressing experienced by the transformer. The active part of this transformer should potentially last another 5-10 years, unless exposed to full fault currents at this site or exposed to more than 3-5 through faults.

2.2 Estimated Residual Life of Transformer:

Table 2 provides a summary of the estimated residual life of the “key” transformer components.

TABLE 2: Summary of Estimated Residual Life of Transformer T1 “Key” Components

Parameter	Estimated Residual Life	Further Comments
Anti-corrosion system	10 years	Surface oxidation but leaks protecting some regions.
Winding paper life	>50 years	Average insulation age of 12 years.
Winding mechanical stability	5-10 years	Questionable due to inherent manufacturing design and exposure. Subjected to many through faults.
External HV &LV bushings	3-5 years	HV & LV bushings are 34 years old, past the nominal 25 years suggested by the OEM and based on Powerlink’s experience have another max. 3-5 years.
TV bushings	5-10 years	TV bushings are hollow porcelain, as such not subject to insulation aging.
Insulating Oil	5-10 years	Good condition, acceptable moisture but increasing acidity content and low resistivity. If transformer is to be kept in service, oil replacement is recommended within next 5-10 years.
Cooler Bank / Radiators	10 years	Reasonable condition with some rusted parts and minor oil leaks.
Repairs to leaking gaskets	3-5 years	Minor leaks but oil collecting on the concrete foundation & apron. – increased environmental risk due to the poor bund and associated pipework condition.
Fault rating	3-5 years	The current 275 kV calculated fault level at Tarong substation is 35.9 kA – T1 fault rating is 31.5kA.
Overall residual life	3-5 years Limited by fault rating	Minimum refurbishment required within 5 years: • HV bushings replacement. • Gaskets replacement required and oil leaks to be fixed. • Produce metallurgic report for main tank anti-corrosive system and repaint within 5-10 years. • Oil replaced within 5-10 years. • Monitor the mild overheating trend, with annual DGA analysis. • Monitor and review the number of through fault currents. However, inadequate fault current ratings cannot be addressed. These will have to be closely monitored and managed, and transformers de-enegised if required for operational purposes.

3. TRANSFORMER T2

This transformer was factory tested by GEC Rocklea, Brisbane in April 1982 and SAP information indicates that transformer T2 was commissioned at H018 Tarong in November 1982.
The general descriptive details of transformer T2 are shown below.

Manufacturer	GEC Rocklea
Specification	QEC Spec No. 32/21
Year of manufacture	1982 (approx. 37 year old)
Commissioned	1982
Winding arrangement	Auto Transformer
Rating	70/90 MVA ONAN / ODAN 275 / 66/11kV
Transformer Serial No.	A31M3278/1
Powerlink equipment (SAP) No.	2004913
Tap changer manufacturer	M Reinhausen model number: Type M3 300 60/C 10193W
Tap changer serial No.	181401601
Tap changer operations	124777 on 14/08/2019

3.1 Transformer T2 On-site Inspection:

3.1.1. Anti-corrosion System:

The cooler bank radiators are made of galvanised steel whilst all other components are made of steel protected with multiple layers of paint. Maintenance records does not show that the radiator bank A frame, conservator and pipework were ever repainted or treated for corrosion but it is obvious the main tank has been either partially or fully repainted, as well as multicore cables. Some visible signs of minor corrosion and galvanising damage/aging are evident on some parts of this transformer. The paint system and galvanising on radiator bank still provide some protection in the relatively dry environment at Tarong.

Figure 22 – Minor corrosion & galvanisation damage

3.1.2. Structural:

There were no potential structural issues emerging on this transformer. There are cracks in the bund floor, but these were sealed (see Figure 23).

Figure 23 – Sealed cracks in bund floor

3.1.3. Oil Leaks:

The lid on this transformer is not welded to the main tank and is relying on a bolted gasket between the lid and main tank steel flanges to provide sufficient sealing.

A brief summary of the oil leaks are detailed below.

- Small oil weeps from TV bushing base.
- Oil leaking from the main tank to lid gasket.
- Many oil leaks in radiator banks.
- The various gaskets are aged and maintenance records show that oil leaks are present since 1999. Many attempts were made to prevent or reduce oil leaks. This transformer was regularly topped up with oil since 2010 with total amount of oil used being 5880 litres to date.

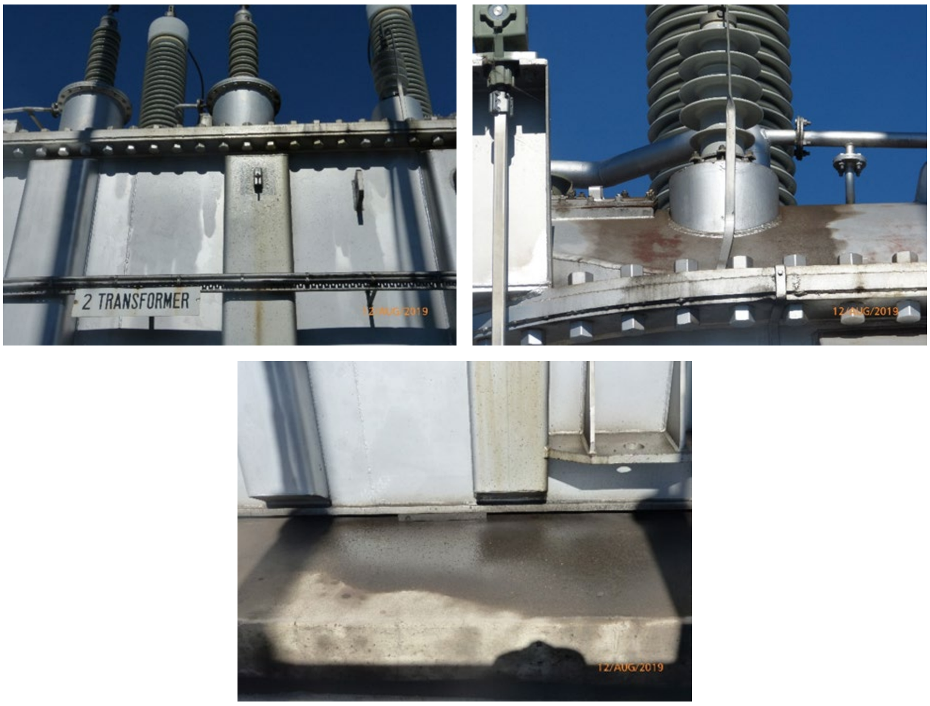

Figure 24 - Oil leaking from the main tank to lid gasket

Figure 25- Oil film leaking from the TV bushing base.

Figure 26- Oil through the cables and control box.

Figure 27- Oil leaks from the radiator banks

Figure 28- Oil leaking from HV bushing CT box

3.1.4. Secondary Systems:

After 37 years of exposure to the elements, the external cables are set and any significant cable flexing (e.g. removal & reconnection) due to replacement of external ancillary items may create some insulation damage if left physically alone, all of the multicore cables should not fail over the next 10 years.

Figure 29- Multi-core cables attach to the Main tank

3.1.5. Tap Changer (OLTC):

This transformer is fitted M type Maschinenfabrik Reinhausen tap changer which is performing satisfactorily.

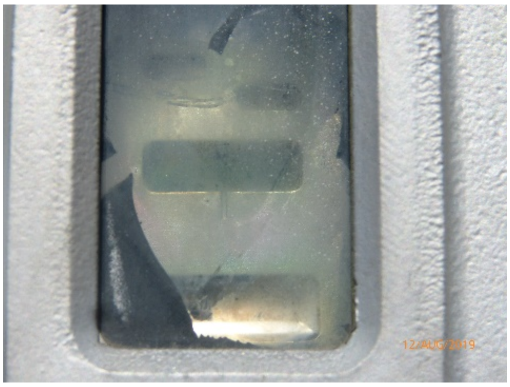

Figure 30- Tap changer sight glass

It was impossible to see anything through the front viewing window on the tap changer compartment, likely due to contamination build-up on the inside of the sight glass. The tap changer motor drive unit door has to be opened to take the number of operations reading. Maintenance records show that during the six yearly maintenance many parts of this unit were replaced and tap changer oil was also replaced. As of August 2019 the tap changer has done 124,777 operations and is in reasonable condition, apart from tap position indicator which is in a failed condition and has not been replaced – this is managed by utilising SCADA reading of the tap changer position.

3.1.6. Transformer Temperature Indicators:

This transformer is fitted with one top oil temperature indicator and three winding temperature indicators. The set point temperatures for each of these instruments for starting the main oil pump, triggering a top oil or winding temperature alarm or trip signals are correct.These are in reasonable condition considering their age and assuming routine calibrations are taking place. They are expected to provide reasonable service for next 10 to 15 years, assuming associated wiring is in good condition.

Figure 31 - HV WTI instrument, LV WTI instrument and OTI instrument.
All the viewing windows are clear enabling easy instrument reading except the OTI.

3.1.7. Oil and Insulation Assessment:

The most recent oil sample test data does not show any signs of emerging thermal or electrical overheating issues within the main tank of this transformer.

3.1.8. Oil Quality:

A desktop assessment was performed using the full history of Oil & Insulation Testing Laboratory test data for this transformer.

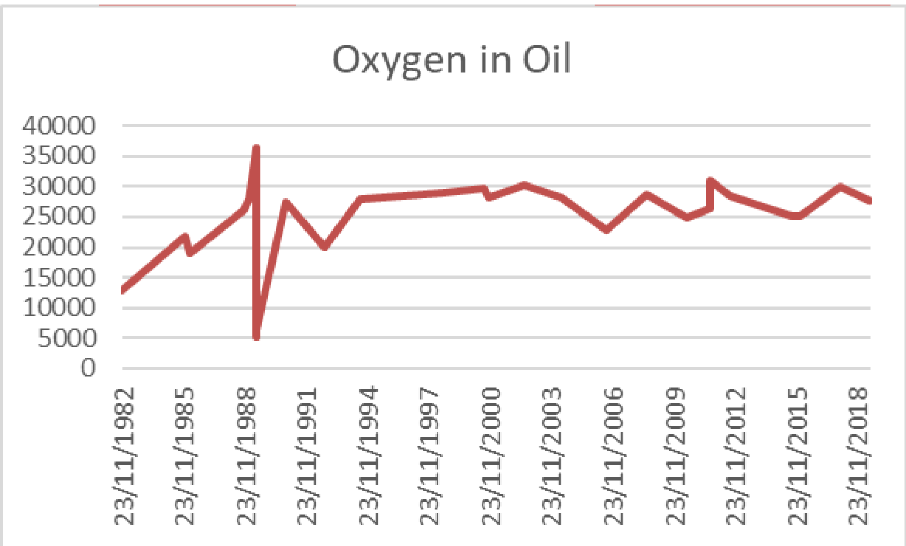

Figure 32 –Content of oxygen in oil

This GEC 90MVA 275/132kV transformer was manufactured prior to QEC introducing sealed internal HV insulation systems. The main tank conservator breathes to the atmosphere via a desiccant breather and this is obvious from the graph above showing oxygen content in oil in the main tank. The graph shown in Figure 32 indicates the oxygen level in the main tank in the service history. The level of oxygen in the oil is stable and at an acceptable level.

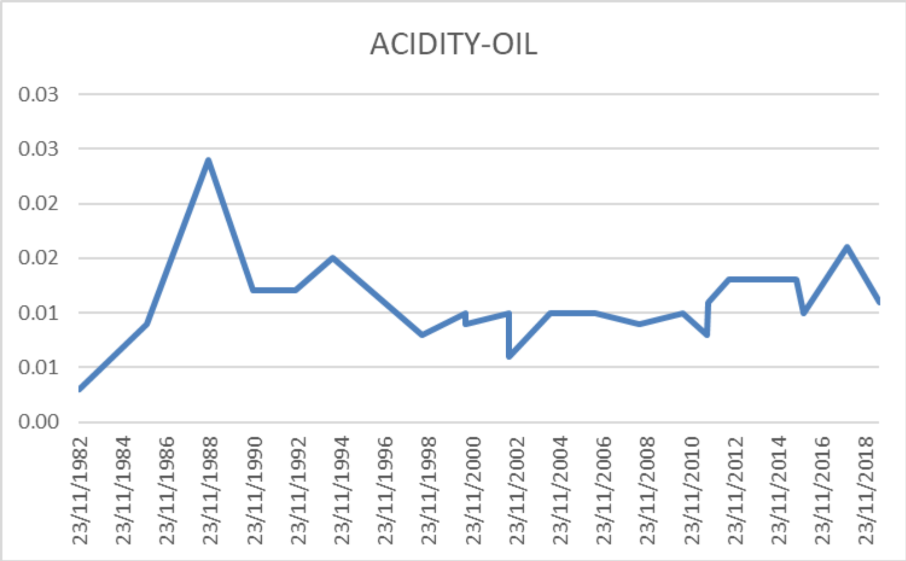

Figure 33 – Transformer T2 oil acidity

Figure 33 shows the level of acidity in the oil, which is at an acceptable level. The oil quality in this transformer has remained in reasonable condition over its life. The oil dielectric dissipation factor and dielectric strength are also within acceptable limits.

The oil was found to be corrosive and therefore the oil in this transformer was passivated in 2010. Oil Laboratory test data confirms that from 2010, the oil is "non-corrosive" per the IEC test method. Periodic testing and topping up of the passivator level in the oil will have to continue for the life of the transformer in order to maintain the dissolved passivator level within limits to ensure its effectiveness.

There is no detectable PCB contamination in the oil and hence this transformer is classified as PCB free.

3.1.9. Winding Paper Quality

The dissolved furan levels in oil continued to be relatively stable and within acceptable limits (Figure 34).

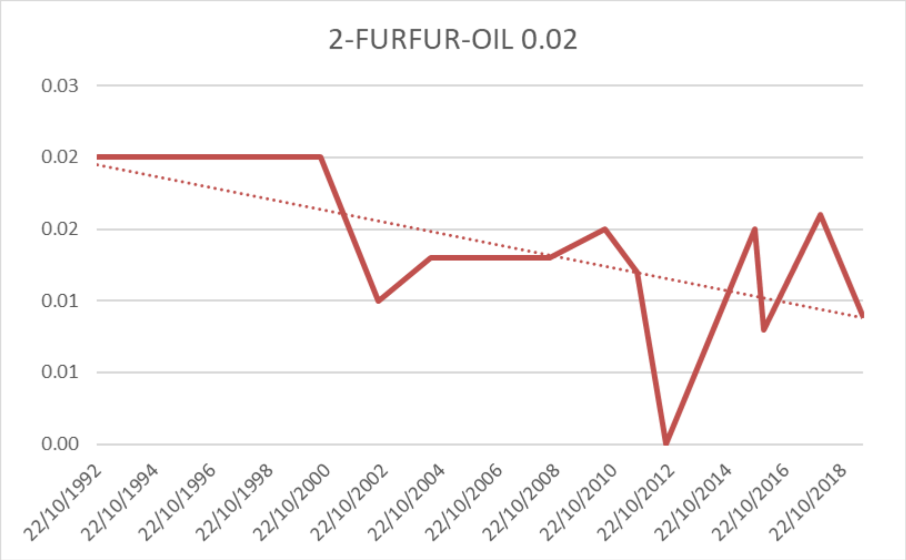

Figure 34 – T1 2 Furfurals trend

Figure 35 shows the transformer loading over the last 12 months and if this is representative of the loading over previous years, it could explain why the dissolved furan level in the oil is relatively low for a 34 years old free breathing transformer. The peak loading in MVA on the 275kV side of the transformer over period 05/12/2018 to 05/12/2019 did not appear to exceed 40% of the nameplate ODAN rating. The average loading on the transformer for this period is 16MW.

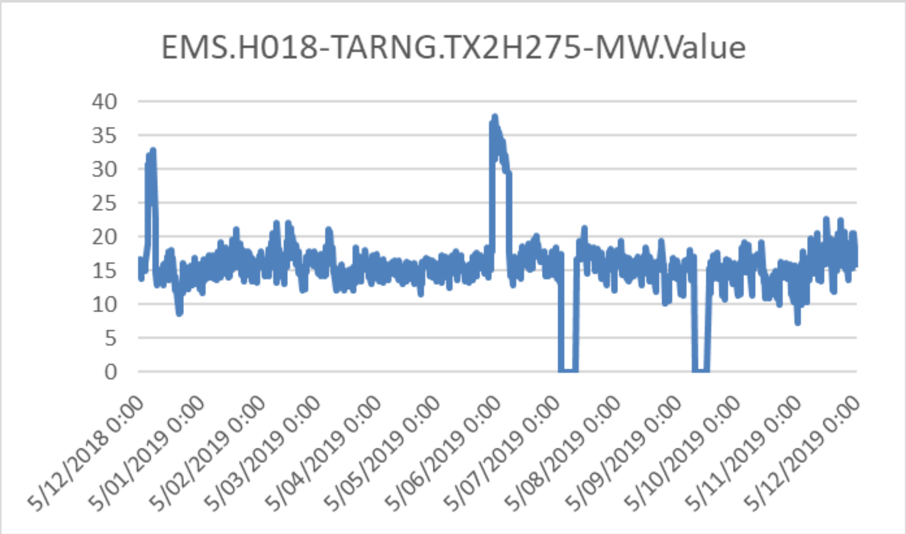

Figure 35 -T1 transformer loading in MVA in period 5/12/2018 -5/12/2019 (the highest peak load is 36 MVA i.e 40% of ODAN nameplate rating)

Because there is normally a variation in insulation temperatures throughout the transformer windings when loaded, at times fairly significant, more localised higher winding insulation temperatures will generate higher than average amounts of furan which must also be considered in the calculation of cellulose insulation age.

Even though this is a free breathing transformer the cellulose insulation system has not shown any significant deterioration from new. The measured dissolved furan levels in oil are shown in Figure 34.

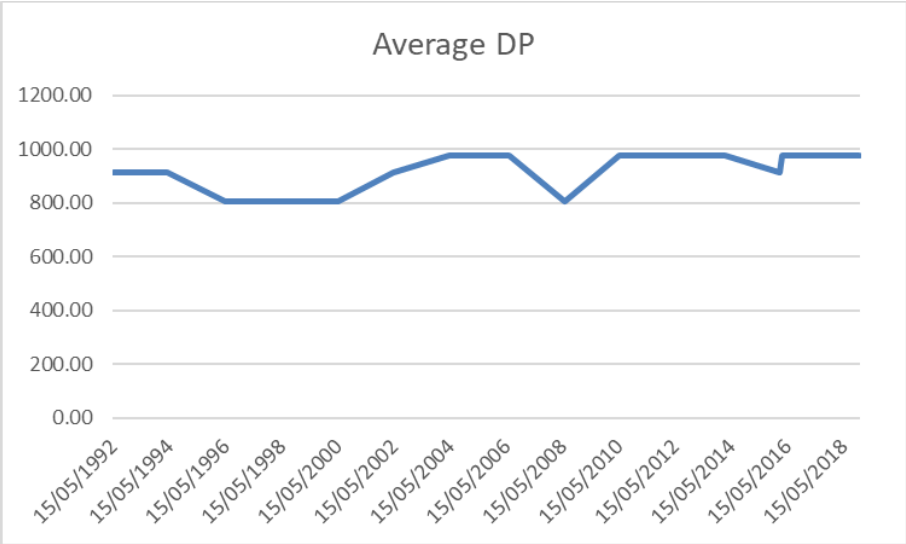

Figure 36 –T1 calculated DPv

The dissolved furan in oil test data can be used to calculate approximate and average bulk cellulose insulation DP_v and its estimated trend based on the Chendong method is shown in Figure 36. Assuming that transformer operating conditions remain the same, the trend shows that the transformer has an estimated service life of more than 50 years (Refer figure 37).
For a typical free breathing transformer the estimated service life is 40 years. The average loading of T1 transformer is only 16 MW which is 14% of its rated capacity, due to this lightly loaded operation, the expected service life of the substation power transformer is significantly greater than the design life.

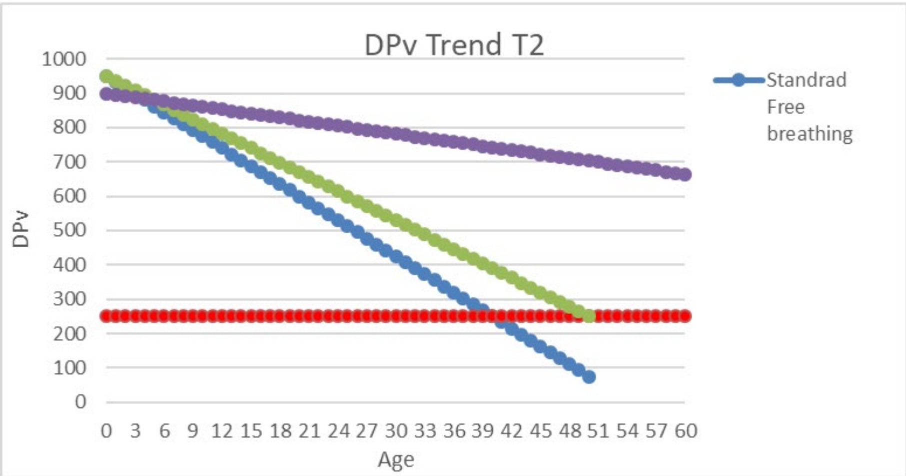

Figure 37 –T1 DPv trend, typical DPv and EOL DPv

3.1.10. Moisture in Insulation:

Figure 38 shows a plot of the measured moisture content in oil as measured in oil samples, starting from 1985. It seems to be relatively stable and being on average 5 mg/kg shows it has been managed well. It is worthwhile noting that with increasing oxygen level and depending on silica gel quality in the breather, it can take a few years to detect an increase in moisture level.

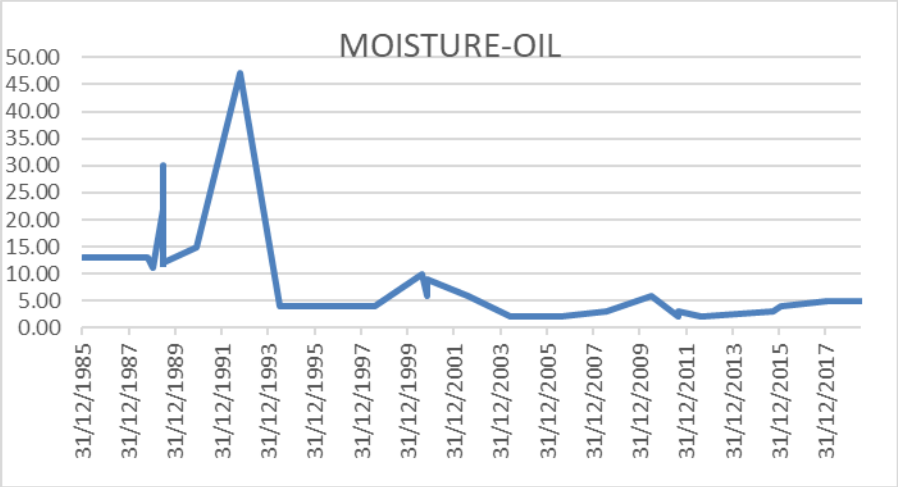

Figure 38 – Moisture in oil

The desiccant in the breather installed on the main tank conservator was in good condition, although it consisted of two paralleled units. The oil bath for particulate filtering of the incoming air was also in acceptable condition.

3.1.11. Transformer Bushings:

Even though the HV & LV oil impregnated paper (OIP) bushings appear to be serviceable to date, it is recommended to have these replaced within the next 3-5 years to reduce safety risk exposure at this site, since these are of porcelain housing and tests are only done every 6 years.

3.1.12. Transformer Secondary Systems:

The maintenance records to date do not show any abnormal secondary system issues emerging, however the AC control panel should be refurbished and updated with MCBs if the transformer is to remain in service for any longer than 3-5 years.

3.1.13. Mechanical Life

Since there was no internal active part inspection performed, the winding clamping or winding mechanical stability is difficult to accurately ascertain. However since the DPv values are good and there is an indication that moisture in insulation is low, there should be less deterioration in these active part parameters.

This transformer has been subjected to a number of through faults over its service life. Whilst this type of information can't be used to accurately assess the mechanical condition of the windings, it can provide some relative information with regard to the amount of mechanical stressing experienced by the transformer. The active part of this transformer has the potential to last another 5-10 years assuming it is not exposed to the through faults above its rating and not more than 3-5 through faults.

3.2 Estimated Residual Life of Transformer:

Table 3 provides a summary of the estimated residual life of the “key” transformer components.

TABLE 3: Summary of Estimated Residual Life of Transformer T2 “Key” Components

Parameter	Estimated Residual Life	Further Comments
Anti-corrosion system	10 years	Surface oxidation but leaks protecting some regions.
Winding paper life	>50 years	Average insulation age of 12 years.
Winding mechanical stability	5 years	Questionable due to inherent manufacturing design and exposure. Subjected to many through faults.
External HV &LV bushings	3-5 years	HV & LV bushings are 34 years old, past the nominal 25 years suggested by the OEM and based on Powerlink’s experience have another max. 3-5 years.
TV bushings	10 years	TV bushings are hollow porcelain, as such not subject to insulation aging
Insulating Oil	10 years	Good condition, acceptable moisture but increasing acidity content and low resistivity. If transformer is to be kept in service, oil replacement is recommended within next 5-10 years.
Cooler Bank / Radiators	5-10 years	Some repairs will be required to manage oil leaks and deteriorated galvanising.
Repairs to leaking gaskets	3-5 years	Major oil leaks, which were attempted to be repaired. Increasing pressure on gaskets is not effective anymore and majority if not all gaskets need to be replaced if transformer is to be kept in service for longer than 3-5 years.
Fault rating	3-5 years	The current 275 kV calculated fault level at Tarong substation is 35.9 kA – T2 fault rating is 31.5kA.
Overall residual life	3-5 years Limited by fault rating	Minimum refurbishment required within 5 years: • HV bushings replacement. • Radiator leaks repaired and radiators re-galvanised. • Gaskets replacement required and oil leaks to be fixed. • Produce metallurgic report for main tank anti-corrosive system and repaint within 5-10 years. • Oil replaced within 5-10 years. • Monitor and review the number of through fault currents. However, inadequate fault current ratings cannot be addressed. These will have to be closely monitored and managed, and transformers de-enegised if required for operational purposes.

4. TRANSFORMER T3:

This transformer was factory tested by GEC Rocklea, Brisbane in April 1982 and SAP information indicates that transformer T3 was commissioned at H018 Tarong in November 1982.

The general descriptive details of T3 transformer are shown below.

Manufacturer	GEC Rocklea
Specification	QEC Spec No. 32/21
Year of manufacture	1982 (approx. 37 year old)
Commissioned	1982
Winding arrangement	Auto Transformer
Rating	70/90 MVA ONAN / ODAN 275 / 66/11kV
Transformer Serial No.	A31M3278/1
Powerlink equipment (SAP) No.	2004913
Tap changer manufacturer	M Reinhausen model number: Type M3 300 60/C 10193W
Tap changer serial No.	181401601
Tap changer operations	119821 on 14/08/2019

4.1 Transformer T3 On-site Inspection:

4.1.1. Anti-corrosion System:

The cooler bank radiators are made of galvanised steel whilst all other components are made of steel and protected by paint. Maintenance records do not show that the radiator bank A frame, conservator and pipework were repainted or treated for corrosion, but visual inspection confirms that the main tank and multicore cabling have been either partially or fully repainted. Visible signs of major corrosion are not evident on this transformer at present. The paint system is still providing reasonable protection in the relatively dry environment at Tarong.

Figure 39 – paint on multicore cables.

4.1.2. Structural:

There were no potential structural issues emerging on this transformer. There are sealed cracks visible on the bund floor.

Figure 40 – Bund floor cracks

4.1.3. Oil Leaks:

The lid on this transformer is not welded to the main tank and is relying on a bolted gasket between the lid and main tank steel flanges to provide sufficient sealing.

A brief summary of the oil leaks are detailed below.

- Small oil weeps from TV bushing base.
- Oil leaks from the main tank to lid gasket.
- Many oil leaks in radiator banks
- The various gaskets are aged and maintenance records show that oil leaks are present since 2003. Many attempts were made to prevent or reduce oil leaks. There are no records available to confirm the quantity of oil added to this transformer over the years.

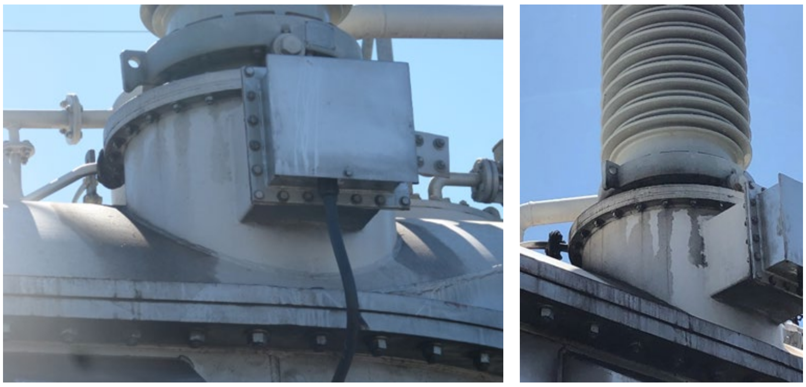

Figure 41 - Oil leaks from the A & C phase bushing turrets

Figure 42- Oil film leaking from the top of main tank.

Figure 43- Oil leaks from radiator banks.

4.1.4. Secondary Systems:

After 37 years of exposure to the elements, the external cables are set and any significant cable flexing (e.g. removal & reconnection) due to replacement of external ancillary items may create some insulation damage. If left physically alone, all of the multicore cables should not fail over the next 10 years.

Figure 44- Multi-core cables attach to the Main tank

4.1.5. Tap Changer (OLTC):

This transformer is fitted M type Maschinenfabrik Reinhausen tap changer which is performing satisfactorily.

It was impossible to see anything through the front viewing window on the tap changer compartment, likely due to contamination build-up on the inside of the sight glass. The tap changer motor drive unit door has to be opened to take the number of operations reading. Maintenance records show that during the six yearly maintenance many parts of this unit were replaced and tap changer oil was also replaced during this service. As of August 2019 the tap changer has done 119821 number of operations and Reinhausen service confirmed that this tap changer does not have a genuine Reinhausen drive but a licenced copy produced by ATL. The service at 114011 number of operations indicated that this motor drive is at the end of its service life.

This transformer has a bag-less conservator with main tank & OLTC sharing a common air space & breather with partial divider separating the oil volumes.

Maintenance records indicate there is a leak between OLTC & main tank, but it could not be confirmed if this is occurring via a leak at the diverter switch or via a perforation in the conservator barrier.

The maintenance crews are doing their best to keep this OLTC in service expecting that transformer replacement is planned to occur in 3-4 years.

4.1.6. Transformer Temperature Indicators:

This transformer is fitted with one top oil temperature indicator and three winding temperature indicators. The set point temperatures for each of these instruments for starting the main oil pump, triggering a top oil or winding temperature alarm or trip signals are correct.They are in reasonable condition considering their age and assuming rouitine calibrations are taking place, they are expected to provide reasonable service for 5 to 10 years, assuming their wiring is in good condition.

Figure 45 - HV WTI instrument, LV WTI instrument and OTI instrument.
All the viewing windows are clear enabling easy instrument reading except the OTI

4.1.7. Oil and Insulation Assessment:

The most recent oil sample test data does not show any signs of emerging thermal or electrical overheating issues within the main tank of this transformer.

4.1.8. Oil Quality:

A desktop assessment was performed using the full history of Oil & Insulation Testing Laboratory test data for this transformer.

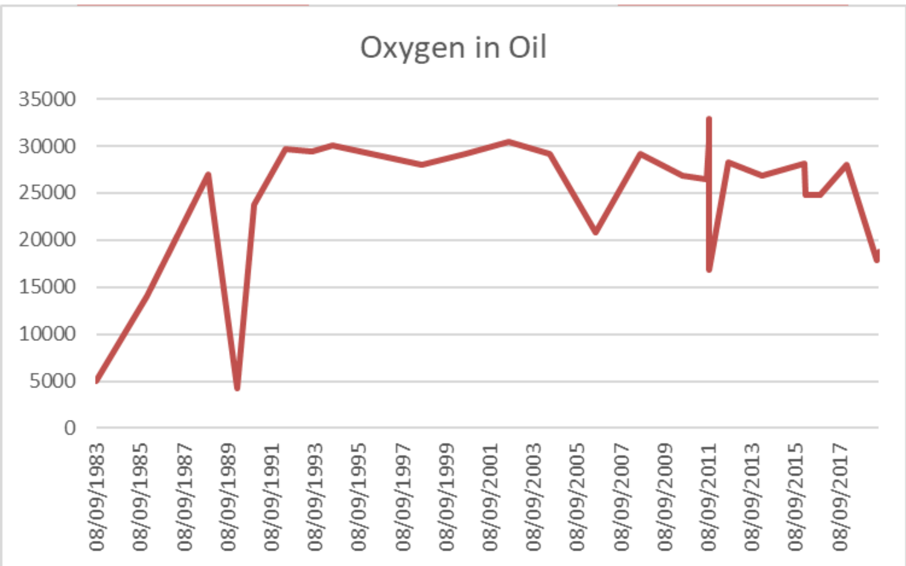

Figure 46 –Content of oxygen in oil

This GEC 90MVA 275/66kV transformer was manufactured prior to QEC introducing sealed internal HV insulation systems. The main tank conservator breathes to the atmosphere via a desiccant breather consisted of two paralleled units and this is obvious from the graph above showing oxygen content in oil in the main tank. The graph in Figure 46 shows the oxygen level in the main tank throughout its service history. The level of oxygen in the oil is stable and at an acceptable level.

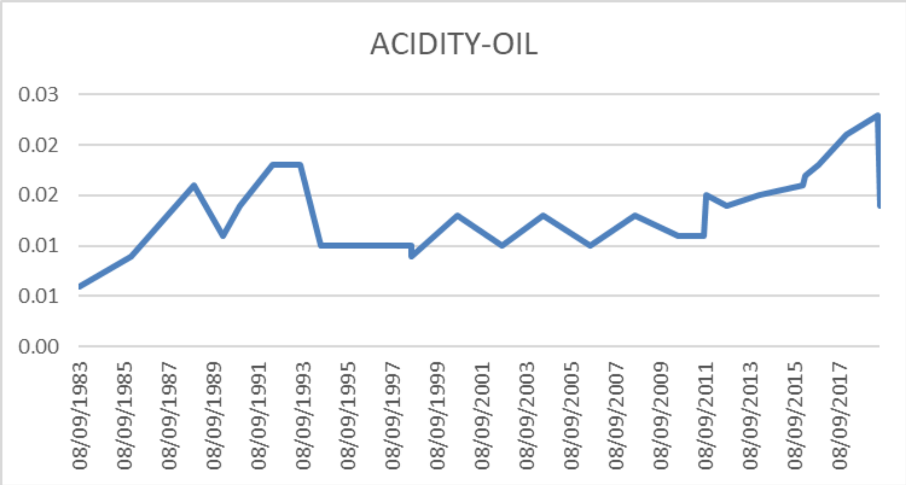

Figure 47– Transformer T3 oil acidity

Figure 47 shows the level of acidity in the oil, which is at an acceptable level. The oil quality in this transformer has remained in reasonable condition over its life. The oil dielectric dissipation factor and dielectric strength are also within acceptable limits.

The oil was found to be corrosive and therefore the oil in this transformer has been passivated since 2010 and Oil Laboratory test data confirms that from 2010, the oil is “non-corrosive” per the IEC test method. Periodic testing and toping up of the passivator level in the oil will have to continue for the life of the transformer in order to maintain the dissolved passivator level within limits to ensure its effectiveness.

There is no detectable PCB contamination in the oil and hence this transformer is classified as PCB free.

4.1.9. Winding Paper Quality

The dissolved furan levels in oil continue to be relatively stable and within acceptable limits (Figure 48).

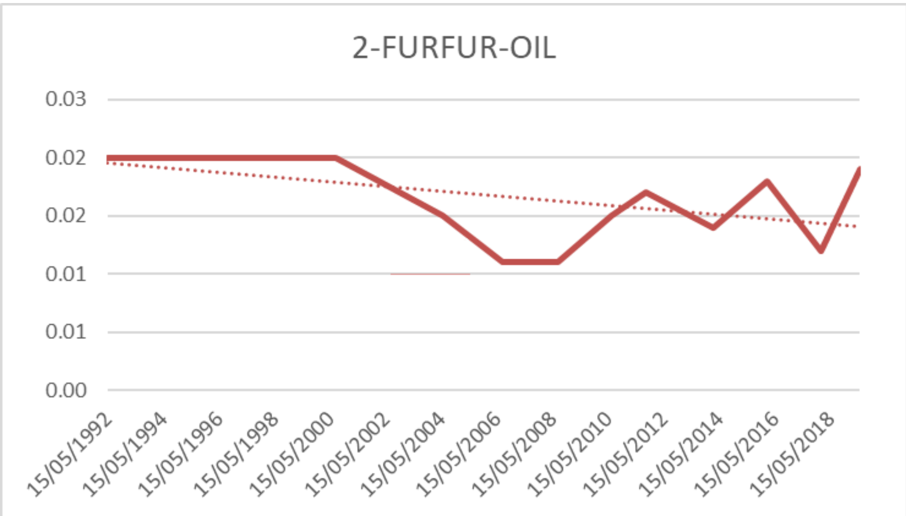

Figure 48 – T3 2 Furfurals trend

Figure 49 shows the transformer loading over the last 12 months and if this is representative of the loading over many previous years, it could explain why the dissolved furan level in the oil is relatively low for a 34 year old free breathing transformer. The peak loading in MVA on the 275kV side of the transformer over period 05/12/2018 to 05/12/2019 did not appear to exceed 40% of the nameplate ODAN rating. The average loading on the transformer for this period is 16MW.

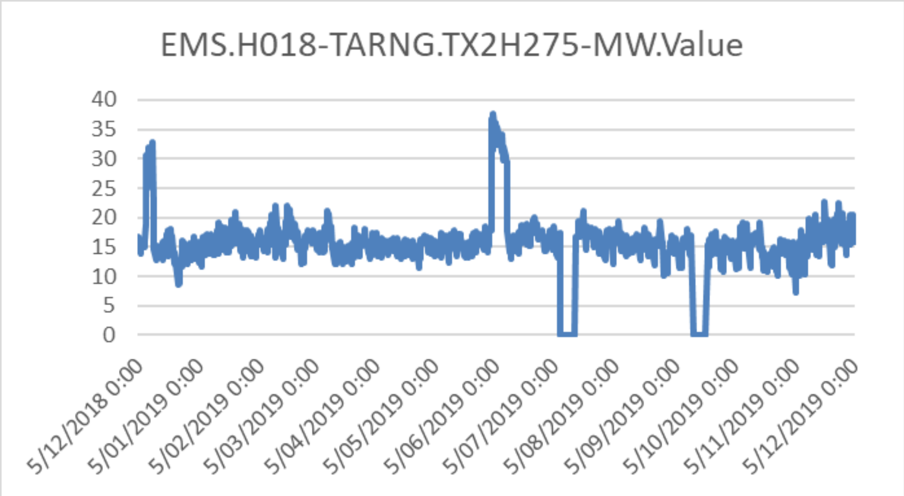

Figure 49 -T1 transformer loading in MVA in period 5/12/2018 -5/12/2019 (the highest peak load is 36 MVA i.e 40% of ODAN nameplate rating)

Because there is normally a variation in insulation temperatures throughout the transformer windings when loaded, at times fairly significant, more localised higher winding insulation temperatures will generate higher than average amounts of furan which must also be considered in the calculation of cellulose insulation age. Even though this is a free breathing transformer exposed in particular to oxygen and moisture, the cellulose insulation system has not shown any significant deterioration from new. The measured dissolved furan levels in oil are shown in Figure 48.

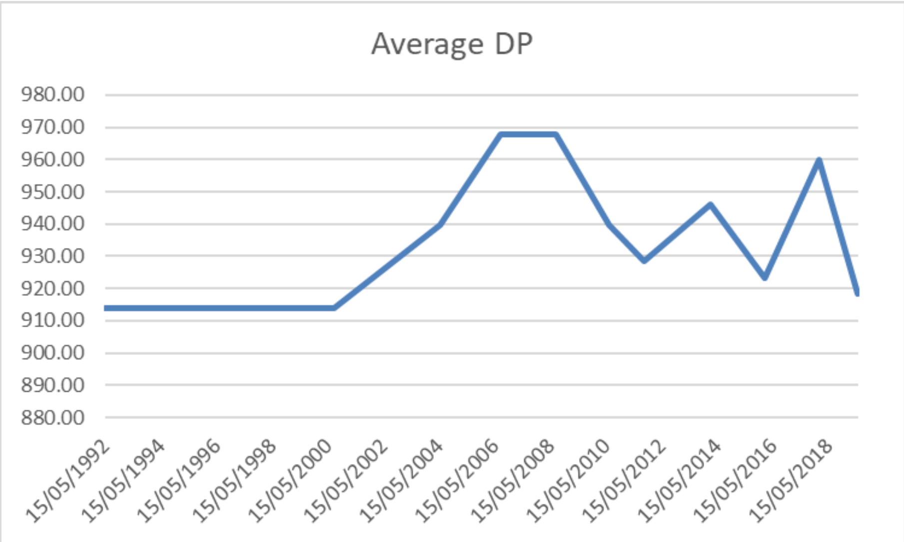

Figure 50 –T1 calculated DPv

The dissolved furan in oil test data can be used to calculate approximate and average bulk cellulose insulation DP_v and its estimated trend using the Chendong method is shown in Figure 51. Assuming that the transformer operating conditions remain the same, the trend shows that the transformer paper has potentially an estimated service life of more than 50 years.
For a typical free breathing transformer the total estimated service life is 40 years. The average loading of the T3 transformer is only 16 MW (14% of its rated capacity) being so light is the main reason for this large discrepancy.

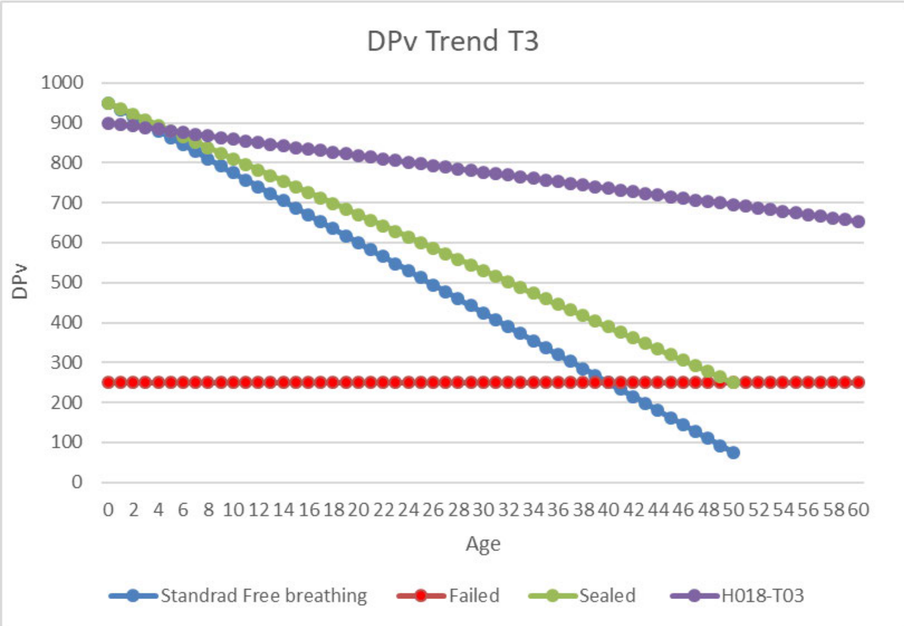

Figure 51 –T1 DPv trend, typical DPv and EOL DPv

4.1.10. Moisture in Insulation:

Figure 52 shows a plot of the measured moisture content in oil as measured in oil samples, starting from 1985. It seems to be relatively stable and being on average 4 mg/kg shows it has been managed well. It is worthwhile noting that with increasing oxygen level and depending on silica gel quality in the breather, it can take a few years to detect increase in moisture level.

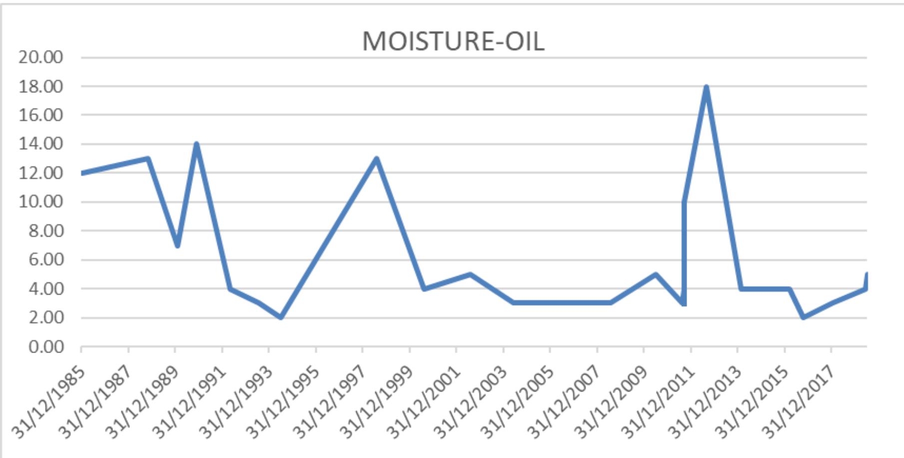

Figure 52– Moisture in oil

The desiccant in the breather installed on the main tank conservator was in good condition as was the oil bath for particulate filtering of the incoming air.

4.1.11. Transformer Bushings:

Even though the HV & LV oil impregnated paper (OIP) bushings appear to be serviceable to date with quite a few oil leaks, it is recommended to have these replaced within the next 3-5 years to reduce safety risk exposure at this site. These are tested every 6 years and considering their age and exposure to electric and magnetic fields, this may not be frequent enough to manage the risk.

4.1.12. Transformer Secondary Systems:

The maintenance records to date show a number of issues with various relays failing and the AC control panel should be refurbished and updated with MCBs if the transformer is to remain in service any longer than 3-5 years.

4.1.13. Mechanical Life

Since there was no internal active part inspection performed, the winding clamping or winding mechanical stability is difficult to accurately ascertain. However since the DPv values are good and the transformer shows low moisture in insulation, there should be less deterioration in these active part parameters.

However this transformer has been subjected to a number of through faults over its service life. Whilst this type of information cannot be used to accurately assess the mechanical condition of the windings, it provides some understanding of the potential damage caused by mechanical stress. The active part of this transformer has the potential to last another 5-10 years assuming through faults do not exceed its rating and there are no more than 3-5 through faults impacting this transformer.

4.2 Estimated Residual Life of Transformer:

Table 4 provides a summary of the estimated residual life of the "key" transformer components.

TABLE 4: Summary of Estimated Residual Life of Transformer T3 "Key" Components

Parameter	Estimated Residual Life	Further Comments
Anti-corrosion system	5-10 years	Surface oxidation but leaks protecting some regions.
Winding paper life	>50 years	Average insulation age of 12 years.
Winding mechanical stability	3-5 years	Questionable due to inherent manufacturing design and exposure. Subjected to many through faults.
External HV &LV bushings	3-5 years	HV & LV bushings are 34 years old, past the nominal 25 years suggested by the OEM and based on Powerlink's experience have another max. 3-5 years.
TV bushings	10-20 years	TV bushings are hollow porcelain, as such not subject to insulation aging.
Insulating Oil	5-10 years	Good condition, acceptable moisture but increasing acidity content and low resistivity. If transformer is to be kept in service, oil replacement is recommended within next 5-10 years.
Cooler Bank / Radiators	5-10 years	Reasonable condition but has many oil leaks.
Repairs to leaking gaskets	3-5-years	Minor leaks but oil collecting on the concrete foundation & apron – increased environmental risk.
Fault rating	3-5 years	The current 275 kV calculated fault level at Tarong substation is 35.9 kA – T3 fault rating is 31.5kA.
Overall residual life	3-5 years Limited by fault rating	Minimum refurbishment required within 5 years: • HV & LV bushings replacement. • Gaskets replacement required and oil leaks to be fixed. • Produce metallurgic report for main tank anti-corrosive system and repaint within 5-10 years. • Oil replaced within 5-10 years. • Monitor and review the number of through fault currents. However, inadequate fault current ratings cannot be addressed. These will have to be closely monitored and managed, and transformers de-enegised if required for operational purposes.

5. TRANSFORMER T4:

This transformer was factory tested by GEC Rocklea, Brisbane in April 1992 and SAP information indicates that transformer T4 was commissioned at H018 Tarong in November 1992.

The general descriptive details of T4 transformer are shown below.

Manufacturer	GEC Rocklea
Specification	QEC Spec No. H893/90/1
Year of manufacture	1992 (approx. 27 year old)
Commissioned	1992
Winding arrangement	Auto Transformer
Rating	70/90 MVA ONAN / ODAN 275 / 132 kV
Transformer Serial No.	31C3891
Powerlink equipment (SAP) No.	20012884
Tap changer manufacturer	M Reinhausen model number: 3M10601150
Tap changer serial No.	186980
Tap changer operations	31657 on 14/08/2019

5.1 Transformer T4 On-site Inspection:

5.1.1. Anti-corrosion System:

The cooler bank radiators are made of galvanised steel whilst all other components are made of steel and protected by paint. Maintenance records do not show that the radiator bank A frame, conservator and pipework were repainted or treated for corrosion, but visual inspection confirms that the main tank and multicore cabling have been either partially or fully repainted. This was evident by the overspray on the external multi-core cables which run along the side of the main tank. It was very obvious that this repainting process was not actioned correctly, with the newer paint delaminating extensively off the original main tank paint surface. Visible signs of major corrosion are not evident on this transformer at present. The paint system is still providing reasonable protection in the relatively dry environment at Tarong.

Figure 53- Flaking of paint

5.1.2. Structural:

There were no potential structural issues emerging on this transformer. However, there are some cracks in bund walls and floor (resealed).

Figure 54-Bund cracks

5.1.3. Oil Leaks:

The lid on this transformer is welded to the main tank and different to other three transformers on this site, this transformer is a fully sealed transformer. Despite its lower service age it does have oil leaks summarised below.

- Small oil weeps from main tank top.
- The various gaskets are aged and maintenance records show that minor oil leaks were present since 1999. This transformer was topped up with 1000 litres of oil in 2017 and 600 litres in 2018.

With respect to the cooler bank, there were no obvious oil leaks to note. The concrete foundation and apron immediately below the cooler bank also shows no sign of oil contamination or oil residue on its surface.

Figure 55- Oil film leaking from the top of main tank

Figure 56 - Oil leaks from Bushing Turrets

Figure 57- Oil leaks from Terminal box on tertiary bushings.

Figure 58 - Oil leaks from Terminal box on tertiary bushings

5.1.4. Secondary Systems:

After 27 years of exposure to the elements, the external cables are set and any significant cable flexing (e.g. removal & reconnection) due to replacement of external ancillary items may create some insulation damage if left physically alone, all of the multicore cables should not fail over the next several years.

Figure 59- Multi-core cables attach to the Main tank

5.1.5. Tap Changer (OLTC):

This transformer is fitted with an M type Maschinenfabrik Reinhausen tap changer which is performing satisfactorily.

It was impossible to see anything through the front viewing window on the tap changer compartment, likely due to contamination build-up on the inside of the sight glass. The tap changer motor drive unit door has to be opened to take the number of operations reading. Maintenance records show that during the six yearly maintenance many parts of this unit were replaced and tap changer oil was also replaced also during this service. Many auxiliary contactors needed to be replaced as well as contacts. No cause for contact deterioration was established. On a number of occasions the tap changer was unable to change taps. As of August 2019 the tap changer has done 31,657 number of operations.

5.1.6. Transformer Temperature Indicators:

This transformer is fitted with one top oil temperature indicator and three winding temperature indicators. The set point temperatures for each of these instruments for starting the main oil pump, triggering a top oil or winding temperature alarm or trip signals are correct.These are in reasonable condition considering their age and assuming routine calibrations are taking place, they are expected to provide reasonable service for the next 15 to 20 years.

Figure 60 - HV WTI instrument, LV WTI instrument and OTI instrument.
All the viewing windows are clear enabling easy instrument reading except the OTI

5.1.7. Oil and Insulation Assessment:

The most recent oil sample test data does not show any signs of emerging thermal or electrical overheating issues within the main tank of this transformer.

5.1.8. Oil Quality:

A desktop assessment was performed using the full history of Oil & Insulation Testing Laboratory test data for this transformer.

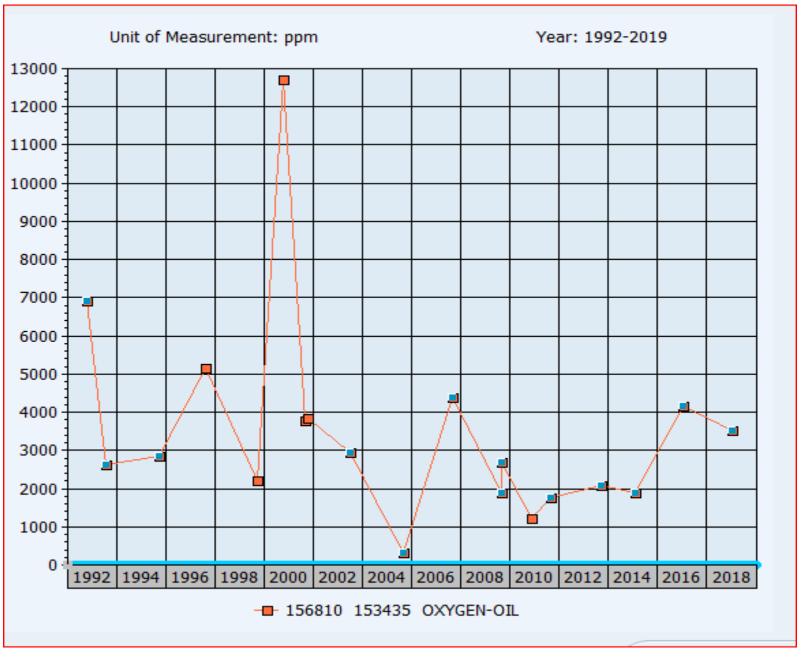

Figure 61 –Content of oxygen in oil

This GEC 90MVA 275/132kV transformer has a sealed internal HV insulation system. The graph shown on Figure 61 indicates the oxygen level in the main tank in the service history. The level of oxygen in the oil is relatively stable and at acceptable levels.

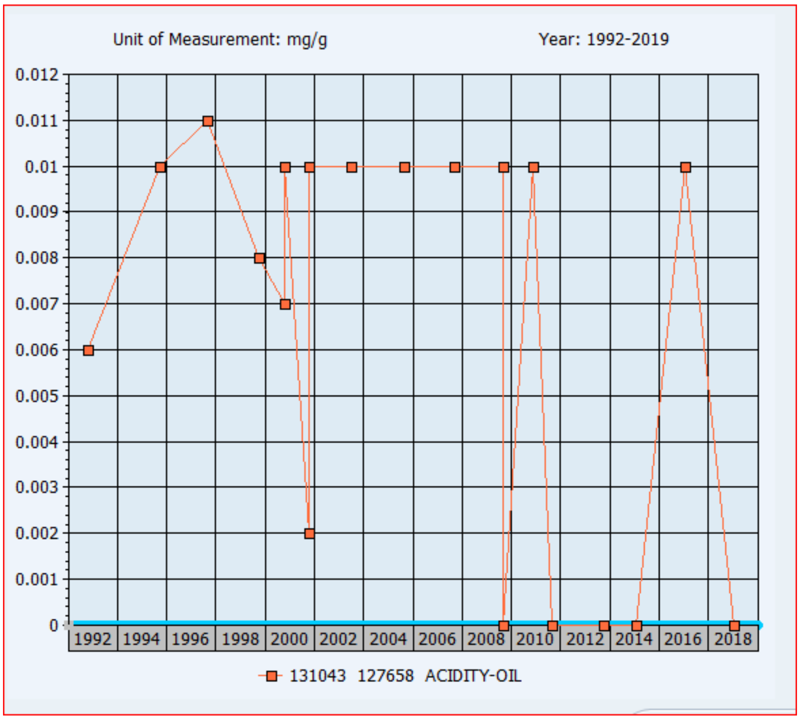

Figure 62 – Transformer T4 oil acidity

Figure 62 shows the level of acidity in the oil, which is low and at acceptable level. The oil quality in this transformer has remained in reasonable condition over its life, as expected for a transformer of this age. The oil dielectric dissipation factor and dielectric strength are also within acceptable limits.

The oil was found to be corrosive and therefore the oil in this transformer has been passivated since 2010 and Oil Laboratory test data confirms that from 2010, the oil is “non-corrosive” per the IEC test method. Periodic testing and topping up of the passivator level in the oil will have to continue for the life of the transformer in order to maintain the dissolved passivator level within limits to ensure its effectiveness.

There is no detectable PCB contamination in the oil and hence this transformer is classified as PCB free.

5.1.9. Winding Paper Quality

The dissolved furan levels in oil continued to be relatively stable (apart from an erroneous reading in 1997, repeated and confirmed to be 0.001) and within the acceptable limits (Figure 63).

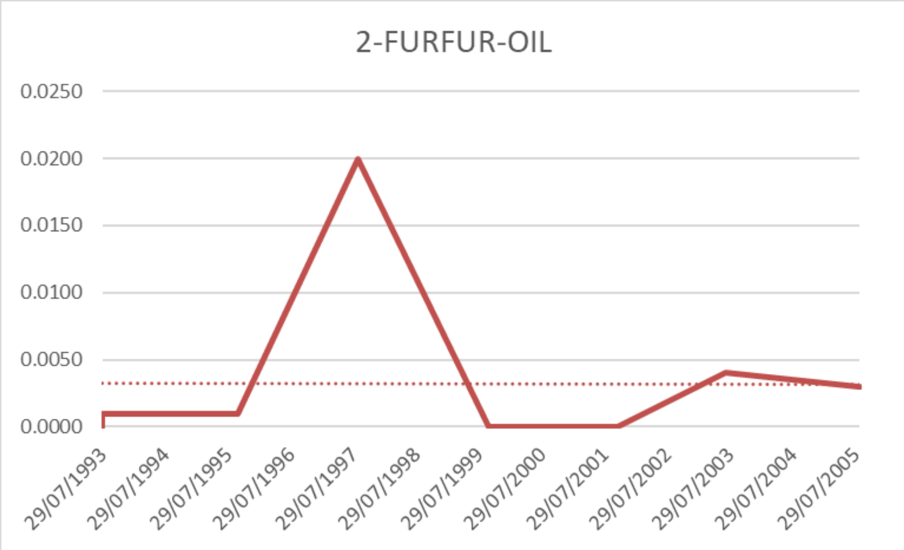

Figure 63– T4 2 Furfurals trend

Figure 64 shows the transformer loading over the last 12 months and if this is representative of the loading over many previous years, it could explain why the dissolved furan level in the oil is relatively low for a 27 years old sealed transformer. The peak loading in MVA on the 275kV side of the transformer over period 05/12/2018 to 05/12/2019 did not appear to exceed 44% of the nameplate ODAN rating. The average loading on the transformer for this period is 12MW.

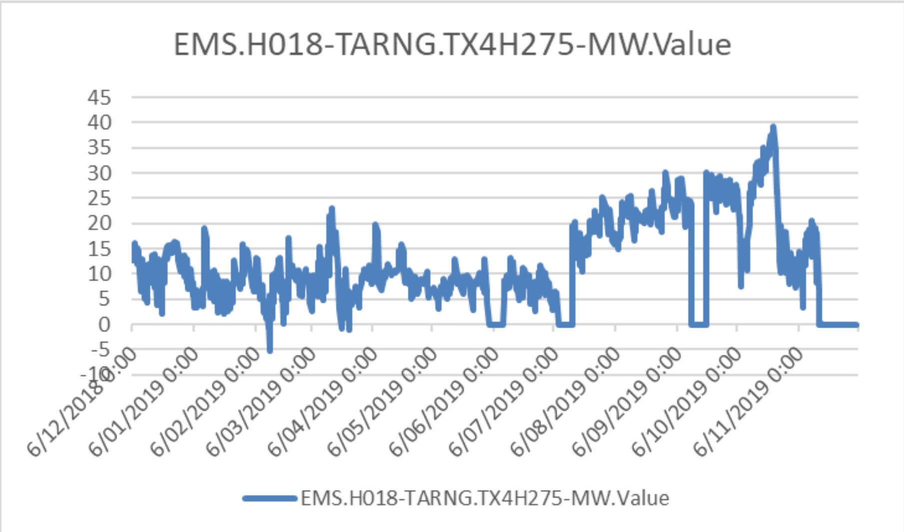

Figure 64 –T4 transformer loading in MVA in period 5/12/2018 -5/12/2019 (the highest peak load is 40 MVA i.e 44% of ODAN nameplate rating)

Because there is normally a variation in insulation temperatures throughout the transformer windings when loaded, at times fairly significant, more localised higher winding insulation temperatures will generate higher than average amounts of furans which must also be considered in the calculation of cellulose insulation age. This is a fully sealed transformer and as expected, the cellulose insulation system has not shown any significant deterioration from new. The measured dissolved furan levels in oil are shown in Figure 65.

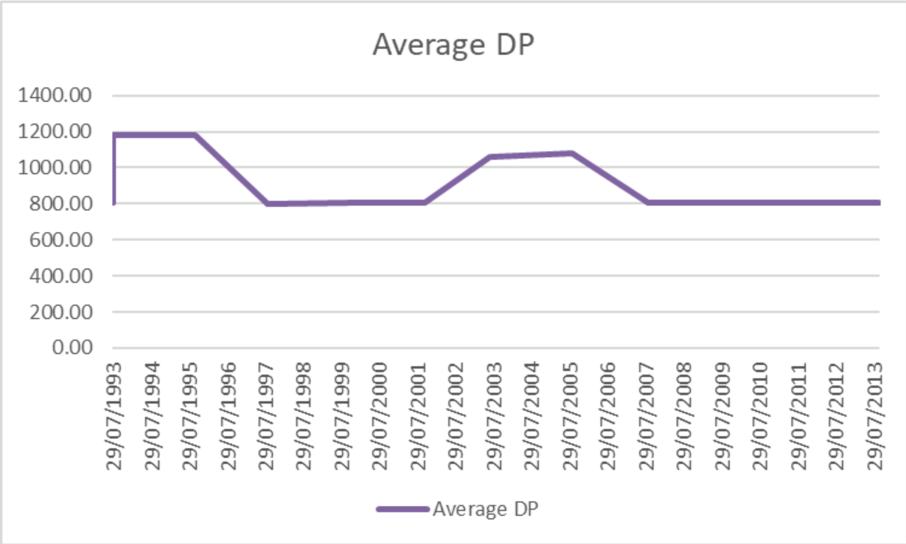

Figure 65–T4 calculated DPv

The dissolved furan in oil test data can be used to calculate approximate and average bulk cellulose insulation DP_v and its estimated trend is shown in Figure 60. Assuming that transformer operating conditions remain the same, the trend shows that the transformer has potentially an estimated service life of more than 50 years.

For a typical sealed transformer the estimated service life is 50 years. Considering the average loading of the T4 transformer being only 12 MW so far, the expected service life of this transformer is greater than the design life.

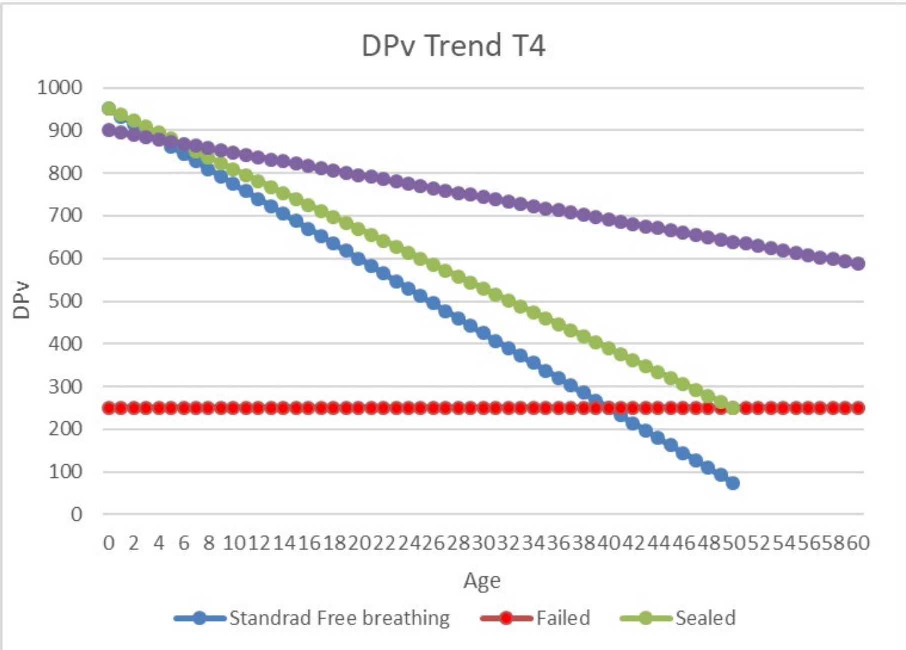

Figure 66 –T4 DPv trend, typical DPv and EOL DPv

5.1.10. Moisture in Insulation:

Figure 67 shows a plot of the measured moisture content in oil as measured in oil samples, starting from 1992. It is relatively stable, being on average 4 mg/kg showing it has been managed well. It is worthwhile noting that with increasing oxygen level and depending on silica gel quality in the breather, it can take a few years to detect increase in moisture level.

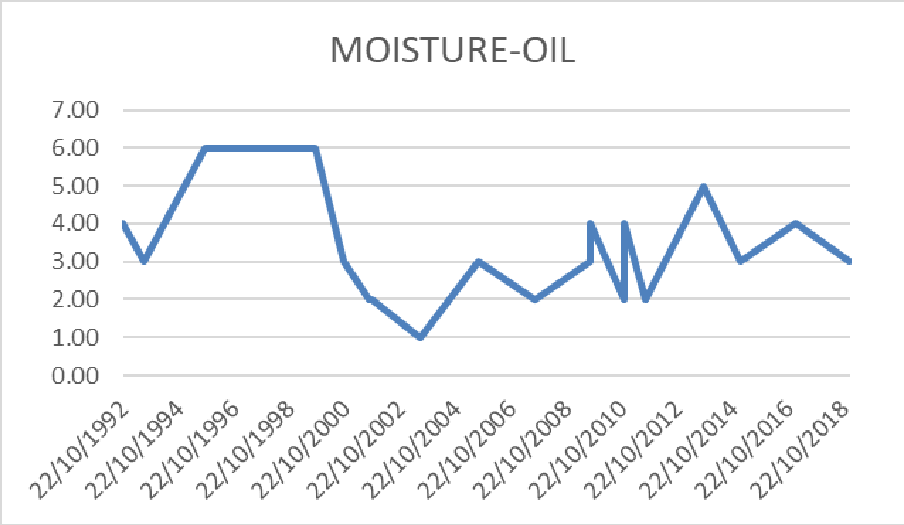

Figure 67 – Moisture in oil

The desiccant in the breather installed on the main tank conservator was in good condition as was the oil bath for particulate filtering of the incoming air.

5.1.11. Transformer Bushings:

Even though the HV & LV oil impregnated paper (OIP) bushings in porcelain housing appear to be serviceable, it is recommended to have these replaced within the next 10-15 years to reduce safety risk exposure at this site, especially as leaks have been present for a few years.

5.1.12. Transformer Secondary Systems:

Maintenance records to date do not show any abnormal secondary system issues emerging, however the AC control panel should be refurbished and updated with MCBs if the transformer is to remain in service for another 15-20 years.

5.1.13. Mechanical Life:

Since there was no internal active part inspection performed it is difficult to accurately ascertain the winding clamping or winding mechanical stability. However since the DP values are good and there is low moisture in insulation, there should be less deterioration in these active part parameters.

This transformer has been subjected to a number of through faults over its service life. Whilst this type of information cannot be used to accurately assess the mechanical condition of the windings, it provides some relative feeling for mechanical stressing experienced by the transformer. The active part of this transformer should have the potential of lasting another 10 years.

5.2 Estimated Residual Life of Transformer:

Table 5 provides a summary of the estimated residual life of the “key” transformer components.

TABLE 5: Summary of Estimated Residual Life of Transformer T4 “Key” Components

Parameter	Estimated Residual Life	Further Comments
Anti-corrosion system	10 years	Surface oxidation but leaks protecting some regions.
Winding paper life	>50 years	Average insulation age of mzn5 years.
Winding mechanical stability	5-10 years	Questionable due to inherent manufacturing design and exposure. Subjected to many through faults.
External HV &LV bushings	5-10 years	HV & LV bushings are 27 years old and only just past the nominal 25 years suggested by the OEM. Based on Powerlink’s experience considering the oil leaks they have another max. 5-10 years.
TV bushings	10-20 years	TV bushings are hollow porcelain, as such not subject to insulation aging.
Insulating Oil	10-15 years	Good condition, acceptable moisture but increasing acidity content and low resistivity. If transformer is to be kept in service, oil replacement is recommended within next 10-15 years.
Cooler Bank / Radiators	10-15 years	Good condition no oil leaks.
Repairs to leaking gaskets	5-10 years	Minor leaks but oil collecting on the concrete foundation & apron. – increased environmental risk.
Fault rating	3-5 years	The current 275 kV calculated fault level at Tarong substation is 35.9 kA – T4 fault rating is 31.5kA.
Overall residual life	3-5 years Limited by fault rating	Minimum refurbishment required within 5 years: • HV bushings replacement. • Gaskets replacement required and oil leaks to be fixed. • Produce metallurgic report for main tank anti-corrosive system and repaint within 5-10 years. • Monitor and review the number of through fault currents. However, inadequate fault current ratings cannot be addressed. These will have to be closely monitored and managed, and transformers de-enegised if required for operational purposes.

Technology and Planning – Network Planning

October 2018

Tarong Transformer Planning Report

Prepared by: Grid Planning
Report Number: T18/24

Table of Contents

1 Executive Summary

A Condition Assessment (CA) of the four 90MVA 275kV transformers at H018 Tarong Substation identified transformers T1-T4, which have been in service for 26-36 years, as requiring reinvestment. The CA recommended replacement of all four transformers due to insufficient fault rating and limited life extension that could be achieved (reference 1). This planning report assesses the ongoing need of all four transformers, and proposes solutions to address the network driven requirements. These transfomers consist of:

- T1, T4: 90MVA 275/132/19.1 kV supplies the Chinchilla feeder and its local load. Age, 32 and 26 years respectively.

- T2, T3: 90 MVA 275/66/11 kV supports the 66kV Tarong load (Energy Queenlsand, Tarong Energy, Pacific coal, Caboonbah, Kingaroy) as well the 11kV auxillary supply. Age, 36 and 35 years respectively.

Planning studies have determined that T2 and T3 have an ongoing need to meet the supply requirements of Tarong 66kV and provide operational flexibility in the Tarong area. Transformer T1 and T4 are no longer critical to the network to meet the reliability obligations in the area, however their presence provides greater operational flexibility and assist with fault level control at Tarong. If T2 and T3 are replaced/uprated to a 40kA rating and T1 and T4 are removed, the current fault level control required at Tarong is void. There is a potential to radialise the Chinchilla load, as it can be fully supplied by Columboola and its 275kV network. Hence radialising Chinchilla from Columboola substation can be facilitated by the removal of the 132kV double circuit feeders between Chinchilla and Tarong. Grid Planning have investigated several alternative options, but they are not considered to be credible options from a technical and economic point of view.

There is potential to use non-network support for the 66kV load, which includes Energy Queensland (EQ) and Tarong Power Station auxiliary supply, by supplying up to 40MW and up to 850MWh per day to meet the planning criteria. The Chinchilla load can be supplied from Columboola and hence a non-network solution for the T1 and T4 transformers has not been considered.

2 Background

Tarong Substation is located in the South West Queensland transmission network and is a critical part of the 275kV network supplying South East Queensland. Tarong Substation links all the 275kV transmission circuits from the central and south west parts of the Queensland into the South East Queensland load centre and ensures power transfer capability to the load. Tarong substation is also the connection point for the Tarong and Tarong North base load coal fired power stations, and step down transformation point to supply local rural and mining loads.

The Tarong Substation was established in conjunction with the Tarong Power Station in 1982. The substation consists of one switchyard of 275 kV operating voltage and one switchyard of 132 kV and 66 kV operating voltages. Powerlink owns the 275kV, 132kV and 66kV assets on site (refer to Figure 3). Transformer T2 and T3 275/66/11 kV were commissioned in 1982 and 1983 respectively; these transformers support the supply to the 66kV network. In terms of the voltage ratio, these transformers are unique in Powerlink’s network. T1 275/132/19.1 kV was commissioned in 1986 and T4 275/132/19.1 kV was commissioned in 1992 to support the Chinchilla load off two 132kV feeders.

Tarong area historically had higher forecasted loads than are currently being experienced in the area. Hence the substation itself has increased operational flexibility for outages and maintenance outages. It has multiple feeder pathways, which facilitate flows from the South West, QNI, Bulli, Surat, North, and Central West. This generation supplies the loads off Tarong and is the critical power transfer node in supplying South East Queensland (Moreton area) loads. The strength of the network at Tarong can now be used to support interest in renewable generation in the area.

Since the commissioning of the 275kV network in the South West and Surat, F7168 and F7183 between Tarong and Chinchilla are no longer critical to meet reliability in the area. However, having this 132kV connectivity provides diversity of supply and operational flexibility to manage Tarong Substations 275kV fault level.

2.1 Geographical Overview

Figure 1 shows a geographical view of Tarong substations location within the South West area. The figure shows the existing 275kV and 132kV transmission networks in the area but omits the 66kV distribution networks.

[redacted]

Figure 1: Geographical view of the South West area transmission network

2.2 Existing Supply Arrangements

The 275 kV switchyard at Tarong consists of two 275 kV busbars and is configured as breaker and half, with transformers T3/T4 and T1/T2 connected to 1 and 2 bus respectively. It consists of nine 275 kV diameters with twenty nine active bays, of which nine are coupler bays, fifteen feeder bays, and one capacitor bank bay. There are two spare feeder bays. All four power transformers are connected directly to the bus via two transformer bays (refer Figure 2 and 3).

The 132kV and 66kV switchyards at Tarong Substation provide bulk supply for mining and Energy Queensland loads in the Kingaroy, Caboonbah areas of South West Queensland. These also provide the auxiliary supply to Tarong power station. The switchyard is comprised of two 132kV feeder bays, six 66kV feeder bays, two 66kV transformer bays and 66kV bus section breaker.

Figure 2: Aerial view of Tarong Substation

[redacted]

Figure 3: Single line diagram of Tarong Substation

3 Load Forecast and Future Supply Requirements

The Tarong Substation supplies the 66kV loads at Tarong via two 275/66/11kV transformers T3 and T2 (rated at 90 MVA each). Tarong Substation also supplies the Chinchilla load via two 275/132/19.1 kV transformer T1 and T4 (rated at 90 MVA each). The 132 kV feeders between Chinchilla and Tarong, F7168 and F7183, are currently lightly loaded due to the strength of the surrounding 275kV network. Tarong Substation itself facilities the power flow from the South West and Central West areas to South East Queensland loads.

Figure 4 shows Tarong load duration curves between 2013 and 2018. The curves indicate that the peak load at Tarong is experience approximately 1% of the year, and for the majority of the year the load is approximately 35MW. This graph depicts both the 66kV load at Tarong and the Chinchilla load off feeders 7168 and 7183. Figure 5 and Figure 6 shows the load duration curves for Chinchilla and 66kV loads separately, and highlights the peak loads are experienced approximately 1-2% of the year.

Figure 7 shows the summer maximum demand forecast at the Tarong Substation and indicates a steady flat demand out to 2026. Both the 66kV EQ and Chinchilla load are represented, with future loads being ~40MW and ~20MW respectively. The load forecast for the 66kV network and Chinchilla is relatively flat for the 10 year period. There are no major additional loads proposed or committed in the Tarong region. Figure 7, shows the historical maximum demand peak was 66MW in 2016/17 and the lowest maximum demand was 36MW in 2010/11.

The 66kV supplies to Tarong Power Station provide the auxiliary loads to the power station, with up to 38MVA required during machine start-ups. This is additional to the load forecast and needs to be considered for the proposed sizing of any new transformer.

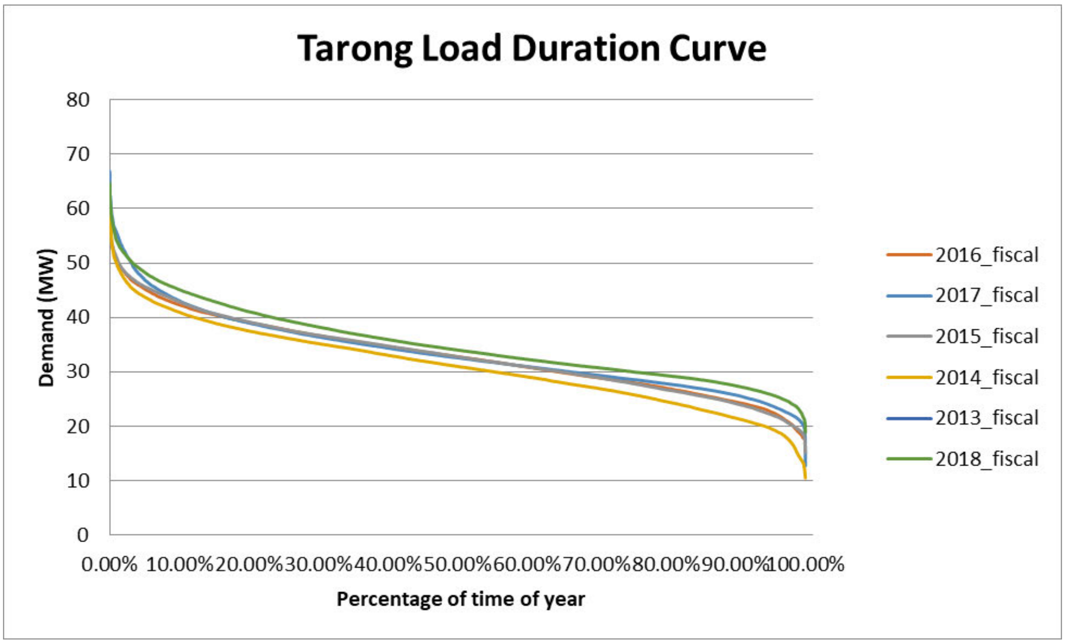

Figure 4: Load Duration Curve for Tarong Substation includes both 66kV and Chinchilla load

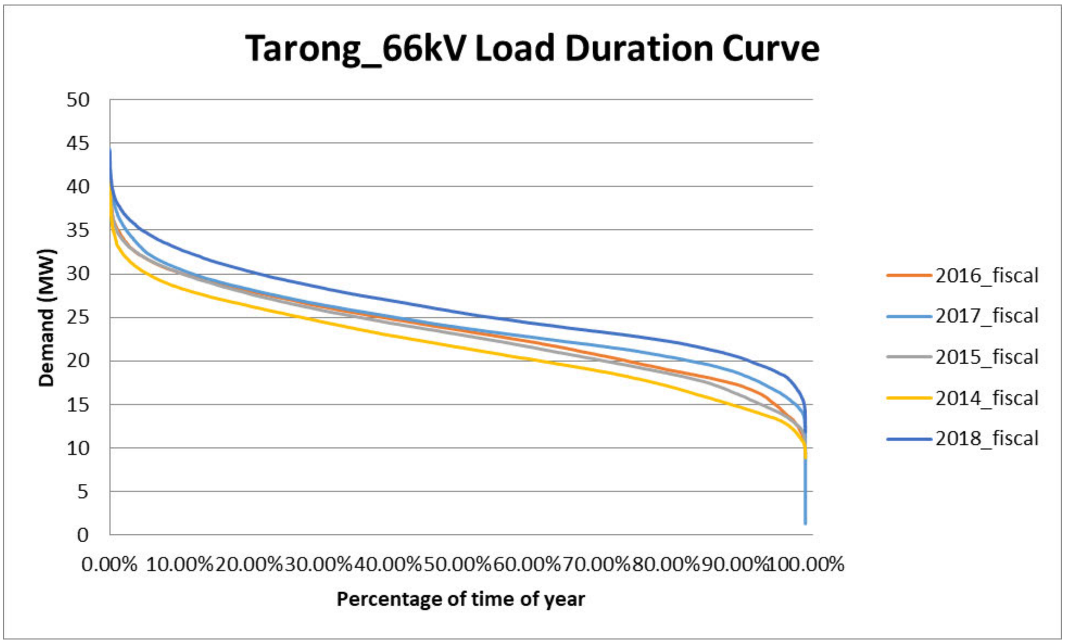

Figure 5: 66kV Load Curve for Tarong Substation

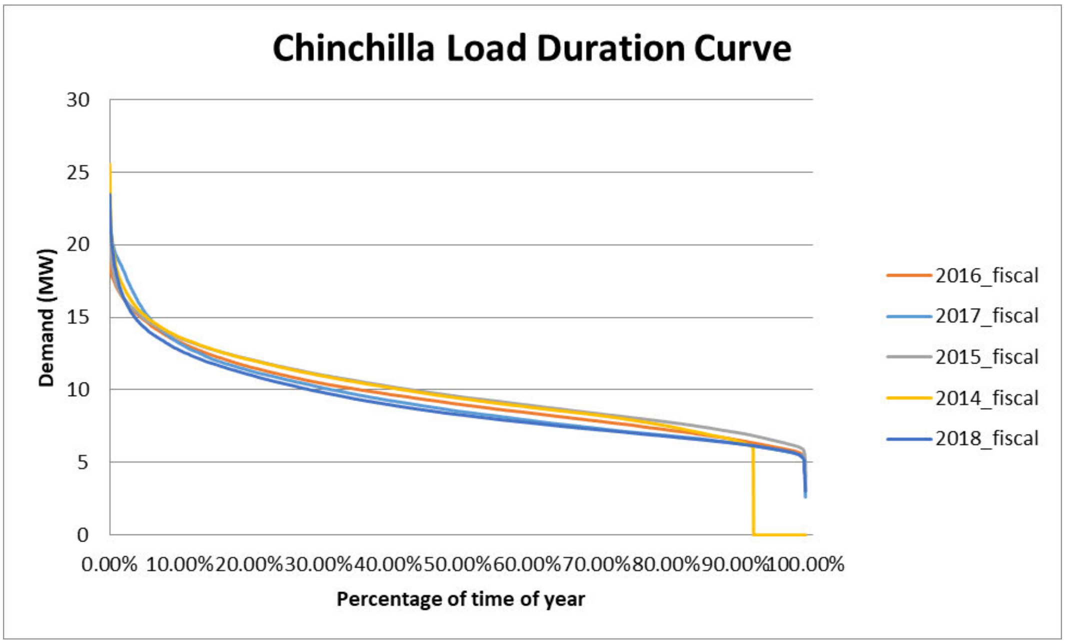

Figure 6: Chinchilla Load Curve for Tarong Substation

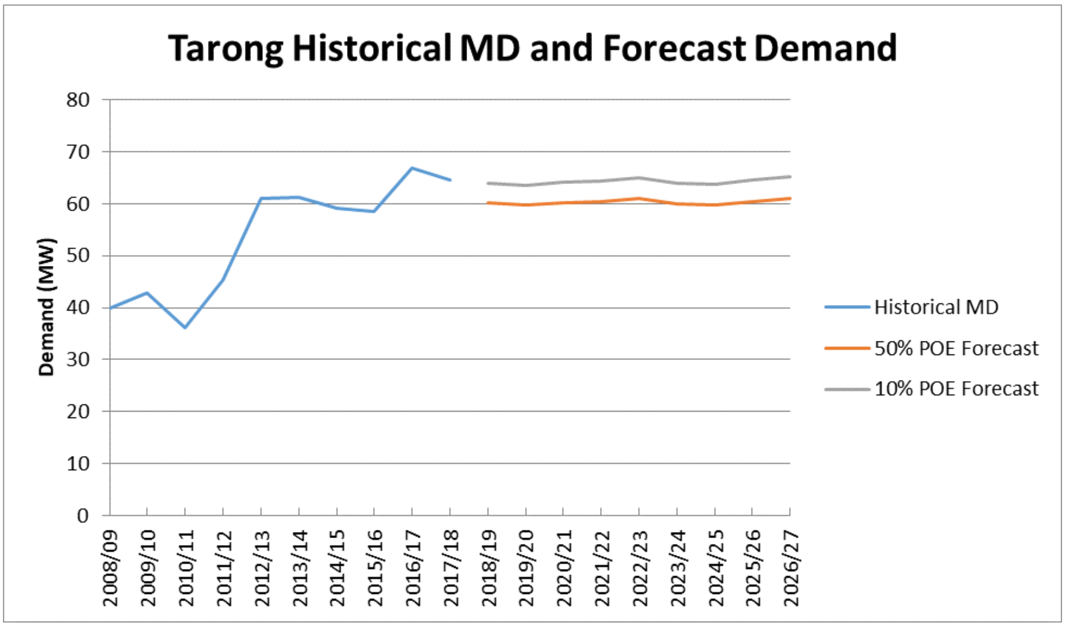

Figure 7: Maximum demand forecast for Tarong Substation includes both 66kV and Chinchilla load

4 Transformer Rating and Fault level

The four transformers at H018 Tarong Substation have a short circuit fault design rating of 31.5kA, the maximum sustained current that the equipment can withstand, which is consistent with all primary plant originally installed at Tarong. However, subsequent replacement of primary plant has increased the short circuit fault design rating to 40kA. In 2019/20, the 275kV L-G short circuit current at Tarong was calculated to be in excess of 35.0kA, which exceeds the fault rating of the transformers. This is currently managed operationally for each pair of transformers as follows.

1. 275/66kV Transformers T2 & T3:

   a. Intact, the design rating of the 275/66kV transformers is mitigated provided that both 66kV transformers are in service and the 66kV bus coupler is closed. Under a contingency event where one 66kV transformer is out of service however, there is a potential that the remaining in-service 66kV transformer rating will be exceeded for close in faults on the 66kV bus. This risk may be managed operationally by isolating the 275kV Tarong switchyard and back-feeding via the Chinchilla 132kV feeders (reference 2).

2. 275/132kV Transformer T1 & T4

   a. Under N and N-1 condition, the Tarong fault level exceeds the design rating of the transformer. As there is no 132kV bus at Tarong, the coupling point is 130km away at Chinchilla, which is over 130km from Tarong, and a close in fault to the 132kV side of the transformer may be exposed to a through fault current higher than its rating. Under N condition, the transformer affected will see the full fault current as the contribution from the other transformer is over 130km away.

5 Transformer Asset Condition

The Condition Assessment report (reference 1) has assessed the 275/132kV and 275/66kV transformers at Tarong in 2014 and the following findings are based on condition and age of the asset.

All four transformers at Tarong, T1 and T4 275/132kV and T2 and T3 275/66kV, were found to have condition based drivers indicating a need for reinvestment in the next 5 years. Any life extension of the transformers would be constrained by the winding mechanical stability, which is not able to be addressed as part of any refurbishment.

Catastrophic power transformer failure may cause financial costs, loss of supply, impact on safety of personnel and public and impact on the environment (fire, gasses, oil disposal, etc.). Furthermore, in the case of transformers with unique voltage ratios such as 275/66/11kV (T2 and T3), spare replacement units may not be available and replacement of a failed unit may take up to 18 months to obtain.

6 Other Considerations

6.1 Renewable Connections

A high number of renewable connection enquiries have been received in the area between Tarong, Chinchilla and Columboola. Should any of these projects proceed, there may be an economic and stakeholder consumer benefit to retain the Tarong to Chinchilla feeders, as well as reviewing the need for T1 and T4. There is also the potential to connect as a radial from either Tarong or Chinchilla substation, depending on the connection location. Currently there is no committed connections onto the Powerlink network in this area.

6.2 Interaction with Chinchilla Projects

Chinchilla's primary plant and secondary systems has been identified as requiring reinvestment with the drivers being condition based, while the secondary systems have obsolescence based drivers for reinvestment. A potential reinvestment option is to reconfigure Chinchilla such that the transformers at Chinchilla are radially connected to Columboola, i.e. 'transformer ended'. The needs date for the primary plant is 2024 and secondary systems needs date is 2026. The Chinchilla projects will directly impact and can act upon the need for the feeders between Chinchilla and Tarong, and the associated transformers T1 and T4. At this stage it is expected that the 132kV feeders between Chinchilla – Tarong would be mothballed.

7 Options Considered

This section highlights options considered to address the above identified condition based issues and having the potential to meet the required reliability obligations to supply the Tarong load:

1. Do nothing
2. Extend transformer life (on site refurbishment)
3. Replace four transformers in current configuration
4. Replace T2 and T3 and decommission T1 and T4
5. Three transformer arrangement (existing connections)
6. Three transformer arrangement (132kV switchyard connection)
7. Non-Network options

A combination of the options may be a sustainable approach to benefit from the transformers useful life.

7.1 Do Nothing

Under Queensland legislation, Powerlink has the responsibility to plan for Queensland's future transmission needs, including the interconnection with other networks. These planning obligations are prescribed by Queensland's Electricity Act 1994 (the Act), the National Electricity Rules (NER) and Powerlink's Transmission Authority, issued by the Queensland Government.

The Transmission Authority requires that Powerlink plans and develops the transmission grid in accordance with good electricity practice, with regard to the value end users of electricity place on the quality and reliability of electricity services.

The 'Do Nothing' is not an acceptable option as the primary drivers (asset age and condition) and associated safety, reliability and compliance risks would not be addressed. It is not consistent with good industry practice and Powerlink's obligations to comply with the requirements of the Technical Rules of the NER and the Electricity Networks Access Code.

The various legislative and regulatory instruments place obligations on Powerlink as a Transmission Network Service Provider (TNSP). The "Do Nothing" option over the long term would result in breaching those obligations and is thus unacceptable.

7.2 Extend Transformer Life (On Site Refurbishment)

The Condition Assessment report (reference 1) details methodology to address the issues identified on each transformer. One option is to undertake on site refurbishment, including painting and repair, to extend the life of each transformer for up to 10 years.

Under this option all assets at Chinchilla, including primary plant, would require reinvestment. T1 and T4 life extension would align with the decommissioning of the Tarong – Chinchilla 132kV feeders, and hence can be removed simultaneously, while the Chinchilla load would be supplied from the 132kV feeders from Columboola.

This option does not address the inadequate design fault rating of the 275/132kV and 275/66kV transformers. Whilst it would facilitate the operational management of the Tarong fault level by back-feeding the 66kV load from Chinchilla until the feeders and associated transformers are decommissioned (reference 2), if there were any significant fault level injection then the fault rating may not be managed in the longer term. Also, the Condition Assessment identifies that the extent of any life extension is uncertain due to the inherent design of the winding clamping arrangement.

Further consideration would also be required as to the configuration of Chinchilla, where it would be necessary to maintain a switched configuration to facilitate this option.

7.3 Replace Four Transformers in Current Configuration

This option replaces all four transformers at Tarong in a ‘like for like’ approach.

There is an enduring need to maintain and facilitate the loads off the 66kV network, and for the next 10-15 years the Chinchilla loads. The forecast load at Chinchilla is approximately 20MW and the forecast 66kV load at Tarong is approximately 40MW, with minimal growth forecast for the next 10 years. The 132kV feeders to Chinchilla are a back-up to two 132kV feeders from Columboola to Chinchilla and are lightly loaded or are switched out to manage fault level at Tarong.

Notwithstanding, Powerlink’s Planning Criteria specifies that the maximum load at risk must not exceed 50MW and no more than 600MWh of energy is to be lost at one time following a credible contingency event. To meet these criteria, there is a need for two transformers to support the 66kV load and two transformers to support the 132kV Chinchilla load.

The current transformer arrangement is T1 and T4 275/132kV 90MVA connected to T2 and T3 275/66/11kV 90MVA at 275kV. The transformers are then connected via circuit breakers 5432 and 5422 to the rest of the 275kV yard. The design rating of any new transformers should match the Tarong Substation design rating of 40kA.

This option is not currently justified, due to the lack of consistent load on the Tarong-Chinchilla 132kV feeders, as Powerlink’s reliability of supply obligations at Chinchilla may be satisfied by the two 132kV feeders from Columboola.

7.4 Replace T2 and T3 and Decommission T1 and T4

This option considers the replacement of T1 and T4 to meet ongoing 66kV reliability obligations, while decommissioning T2 and T3.

The feeders between Tarong and Chinchilla support the load at Chinchilla, of approximately 20MW. The 132kV feeders between Tarong and Chinchilla, F7168 and F7183, are proposed to be decommissioned in approximately 10-15 years and may be mothballed ahead of decommissioning. These feeders are typically switched out to manage fault level at Tarong.

By moth-balling or decommissioning the Tarong-Chinchilla 132kV feeders, Chinchilla Substation would be supplied radially from Columboola Substation and its strong 275kV network. From a planning perspective, if this scenario is implemented, there is no requirement for T1 and T4 transformers, and Chinchilla substation could be reduced to a transformer ended configuration.

T2 and T3 66kV 90MVA transformers would be replaced with new transformers to comply with the Tarong Substation design fault rating of 40kA.

7.5 Three Transformer Arrangement (Existing Connections)

This option considers the removal of one 275/132/19.1kV transformer, and the retention of the remaining three transformers.

[redacted]

Figure 8. Tarong proposed arrangement with 3 transformers

The Chinchilla load can be supplied from Columboola substation; hence the planning criteria that no more than 600MWh of energy be lost at any one time will not be affected during the time of maintenance or outage of the 275/132/19.1kV transformer. This option has minimal changes to the existing substation arrangement, but requires reinvestment in three 275kV connected transformers and works to parallel the existing 132kV feeders between Tarong and Chinchilla.

By paralleling F7168 and F7183 between Tarong and Chinchilla, rather than removal of these feeders, this option allows for operational flexibility to manage fault level issues at Tarong 66kV switchyard. Further consideration would be required as to the configuration of Chinchilla, where it would be necessary to maintain a switched configuration to facilitate this option.

This option exceeds Powerlink’s reliability obligations at both Tarong and Chinchilla and requires additional reinvestment over and above option 4.

7.6 Three Transformer Arrangement (132kV Switchyard Connection)

This option proposes the retention and reinvestment in three transformers at Tarong, and reconfiguration of Tarong Substation to include a 132kV switchyard.

[redacted]

Figure 9. Tarong 132kV substation arrangement with 3 transformers

The network configuration comprises of one 275/132kV minimum 250MVA rated transformer, which is required to support a 132kV Tarong switchyard. From the 132kV switchyard, two 132/66/11kV, minimum 90MVA, transformers are required to supply the 66kV switchyard and load, including auxiliary supply to Tarong Power Station.

For an outage of the proposed 275/132kV single transformer, which would isolate the 275kV switchyard from the 66kV, the 66kV load would be supplied by the 132kV Chinchilla feeders through the 132/66kV transformers. All transformer ratings should match the Tarong Substation design fault rating of 40kA.

This option exceeds Powerlink's reliability obligations at both Tarong and Chinchilla and requires additional reinvestment over and above option 4.

7.7 Non-Network options

Tarong Substation is the sole point of supply for the 66kV loads. It also supplies the 132kV Chinchilla load but this load can be fully supplied by Columboola Substation, hence a non-network solution to avoid the reinvestment in the 275/132kV Transformer T1 and T4 has not been considered.

Non-network T2 and T3 275/66/11kV options are:

1. No transformers – the full 66kV load supplied by a non-network solution
2. Existing single transformer at 90MVA capacity – with a non-network solution
3. New single transformer with reduced capacity – with a non-network solution
4. Existing arrangement with adequate rating

A non-network option that avoids replacement of the 275/66KV transformers T2 and/or T3 would need to replicate the existing functionality, capacity and reliability on an enduring basis at a cost that is lower than the network options currently under consideration. A non-network solution to supply the 66kV load would need to ensure the load is supplied, specifically by considering the transformer size and configuration, such as complete non-network support or a transformer configuration to supply the 66kV yard and non-network support.

With no transformers to supply the 66kV load, the non-network solution must provide up to 40MW and up to 850MWh per day on an ongoing basis to meet the Powerlink's planning criteria. Powerlink has an obligation to supply Tarong auxiliary, up to 38MVA, and supply would need to be available to accommodate this.

For the options where a single transformer is considered, the requirement for a non-network solution is up to 40MW and up to 850MWh per day for the duration of any (planned or unplanned) outage. Any generation solution would require to be online within 6 hours of any outage occurring to comply with Powerlink's planning criteria. The obligation to supply Tarong auxiliary power of up to 38MVA would also require a non-network solution.

8 Conclusion

This planning report has investigated the enduring need for Tarong Substation 275kV transformers. This study was undertaken in response to a Condition Assessment that identified that reinvestment was required in the four transformers at Tarong, to either life extend or replace the transformers.

Planning studies found that there is a need for the transformers at Tarong to supply the 66kV load to ensure that Powerlink continues to meet its reliability and security obligations. The load at Chinchilla Substation can be fed through the 132kV network from Columboola, and hence when T1 and T4 reach end of life, they can be removed with the feeders between Tarong and Chinchilla moth-balled.

This report assessed the need for each transformer, options of retaining the existing transformers, options of replacement of the transformers and non-network support options by reviewing multiple scenarios and how best to support the Tarong loads.

Consequently, this report recommends the replacement of T3 and T4, and the decommissioning and removal of T1 and T4. This option satisfies Powerlink's ongoing reliability and security obligations whilst minimising work at Tarong Substation and facilitating the reconfiguration of Chinchilla Substation to a transformer end connection, hence reducing the replacement requirements at Chinchilla Substation.

9 References

1. "Tarong Transformers Condition Assessment Report", Powerlink, A1943068, 2014.
2. "Options to Mitigate the impact of increased Fault levels on the 275/66kV and 275/32kV Transformers at H018 Tarong Substation ", Powerlink, A1499449
3. Transmission Annual Planning Report 2018

Base Case Risk and Maintenance Costs Summary Report for Reset

CP.02584 Tarong Transformers Replacement

Version Number	Objective ID	Date	Description
1.0	A3372262	03/06/2020	Original document.

1 Purpose

The purpose of this model is to quantify the base case risk cost profiles and maintenance costs for 275/132kV transformers 1T and 4T, and 275/66/11kV transformers 2T and 3T at Tarong substation. These transformers are candidates for reinvestment under CP.02584.

Base case risk costs and maintenance costs have been analysed over a ten year study horizon.

2 Key Assumptions

In calculating the potential unserved energy (USE) arising from a failure of the ageing transformers at Tarong, the following modelling assumptions have been made:

- historical load profiles have been used when assessing the likelihood of unserved energy under concurrent failure events;
- unserved energy generally accrues under concurrent failure events, and consideration has been given to potential feeder trip events within the greater Tarong area; and
- Tarong substation supplies a mixture of residential, agricultural and commercial load types. Historical load data has been used to assess the proportion of load associated with each of the load types. The weighted VCR used for network risk cost assessments is $25,315/MWh. The most relevant residential and commercial VCR values published within the AER's 2019 Value of Customer Reliability Review Final Report have been used to determine this VCR.

3 Base Case Risk Analysis

3.1 Risk Categories

Four main categories of risk are assessed within Powerlink's risk approach; safety, network, financial and environmental.

3.2 Transformer Analysis

This section analyses the risks presented by the relevant transformers at Tarong substation, these include network, financial and safety risks.

Table 1 – Risks associated with at risk transformers

	Mode of failure	
Equipment	**Peaceful**	**Explosive**
Transformer	Network risks (unserved energy). Financial risks to attend site and replace failed transformer(s).	Network risks (unserved energy) primarily due to substation de-energisation in the event of transformer fire. Safety risks to on-site personnel. Financial risks to respond to unplanned failure events in an emergency manner.

3.2.1 Transformers – Risk Cost by Year

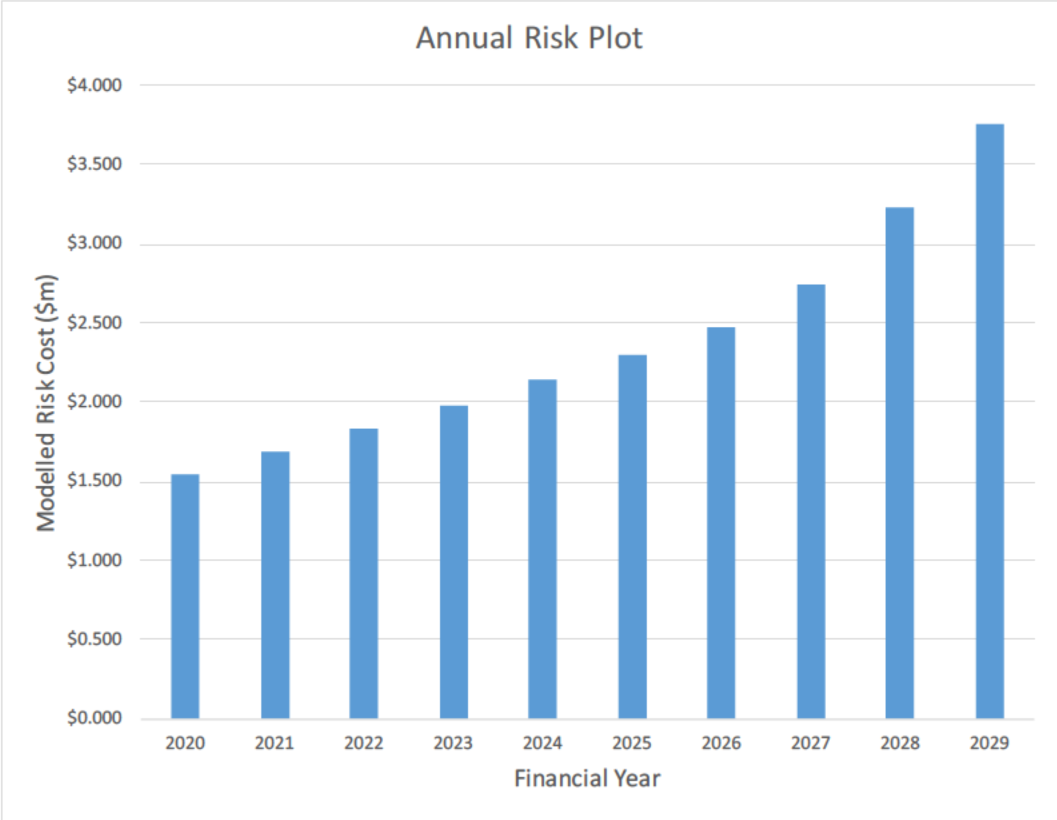

Figure 1 – Transformer risk (10 years)

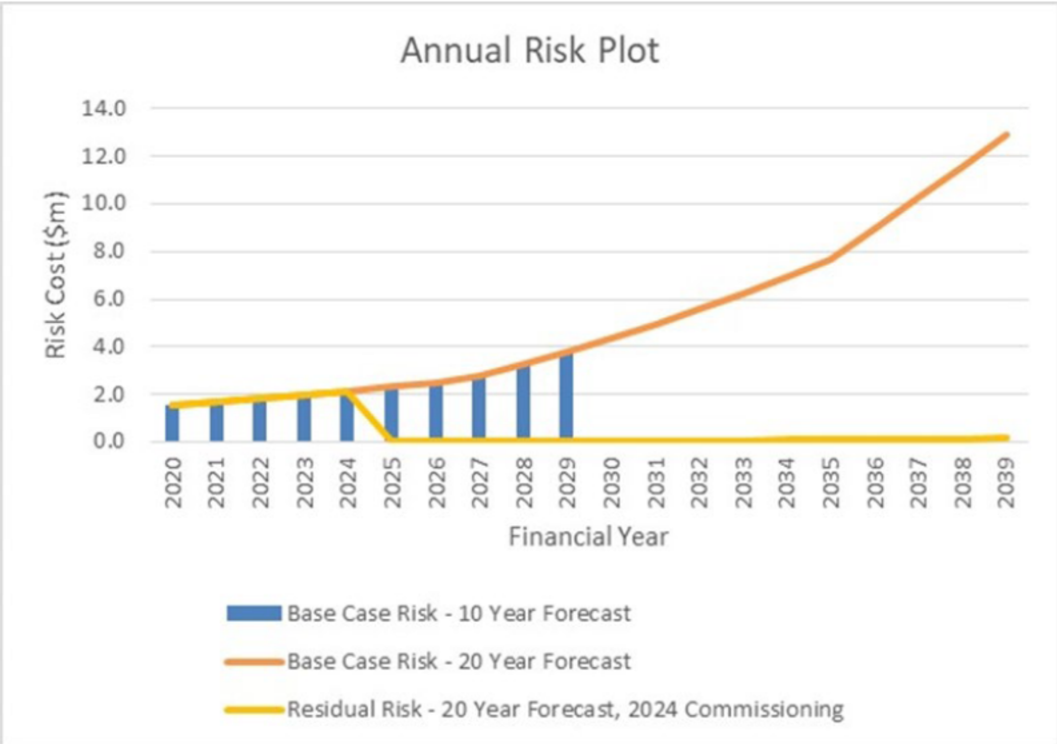

Figure 2 – Transformer risk (10 and 20 years)

3.2.2 Transformers – Risk Breakdown by Risk Category

Figure 3 – Transformer risk by category

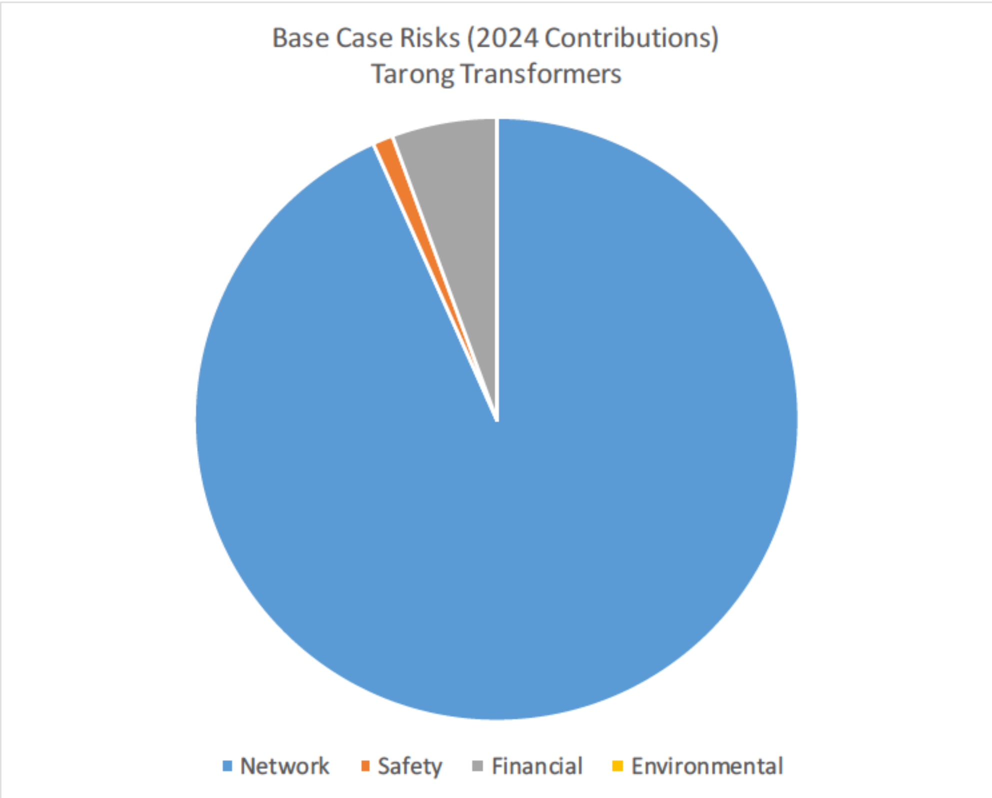

Figure 4 –Transformer risk in 2024 by category

3.3 Base case risk statement

The main base case risks for the Tarong transformer replacement project are related to network risks (unserved energy) due to failed transformers. There is also a component of financial risk associated with replacement of damaged equipment and safety risks to personnel.

4 Maintenance costs

Two categories of maintenance costs are included in Powerlink's base case approach; routine maintenance and corrective / condition based maintenance.

The routine and corrective / condition based maintenance costs and total base case costs (maintenance plus risk) are shown in figures below.

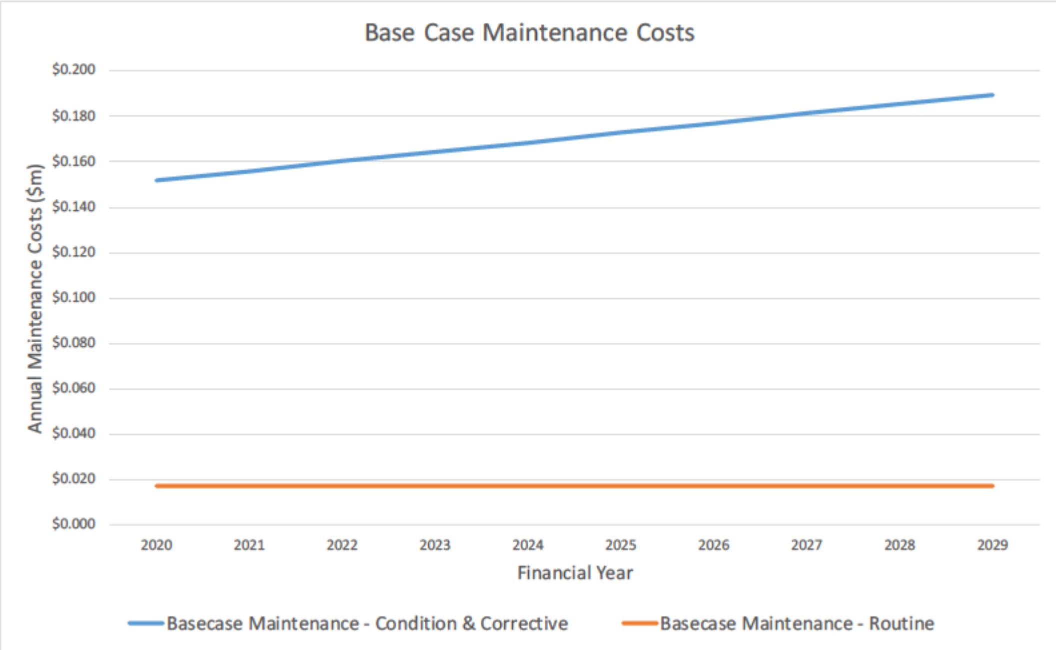

Figure 5 - Base Case maintenance Costs 2020 – 2029

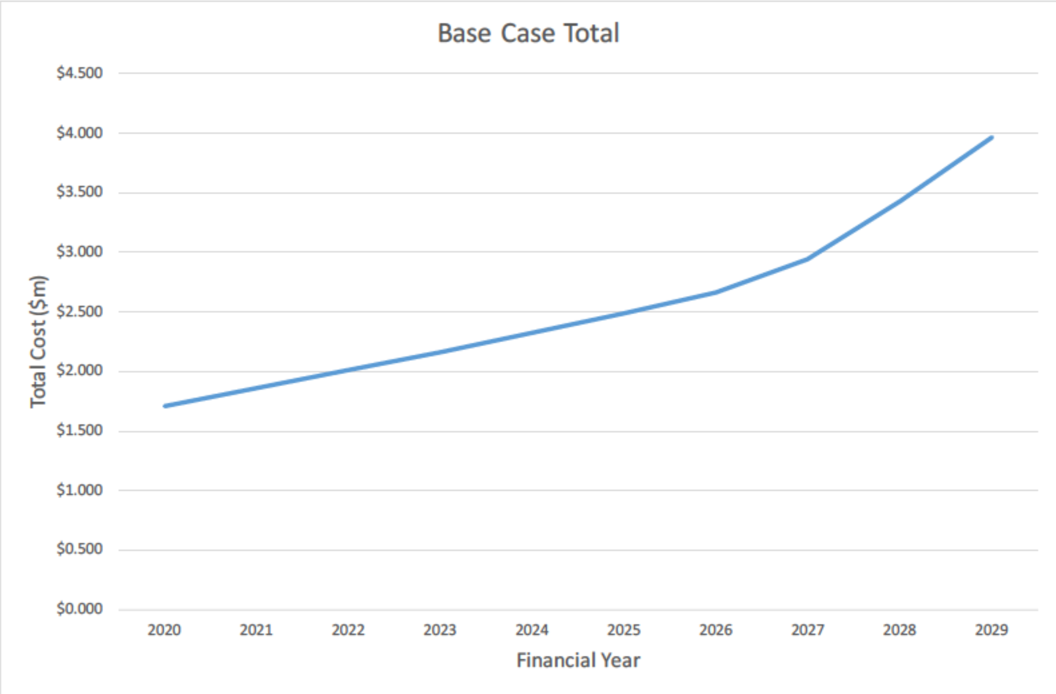

Figure 6 - Base case Total (Risk Cost + Maintenance) 2020 to 2029

5 Input participation

A sensitivity analysis was carried out to determine the participation factors for key inputs to the risk models (i.e. which inputs affect the risk cost the most).

The sensitivity analysis shows the impact of changing an input value on the modelled risk cost. For example, if VCR is increased by 10%, the total risk cost will increase by around 92.4% of this change (i.e. 9.24%).

Table 2: Input values, transformer model

Item	Value	Unit
Probability of personnel within substation	0.4	Ratio
Probability of personnel adjacent to transformer	0.9	Ratio
Equivalent cost of serious injury	1	$M
ALARP disproportionality factor (substation personnel)	3	Ratio
VCR	25,315	$/MWh
Time to switch isolators (T4 & T2, T3 & T1 contingencies)	8	hours
Emergency transformer replacement time without spare (T2 & T3)	12	Weeks
Likelihood of major fire given transformer explosion	0.2	Ratio
Time required to de-energisation site during major fire	72	Hours
Emergency transformer/bushing replacement labour/switching cost	0.5	$M
Media and communication costs	0.3	$M

Figure 7 illustrates that the VCR and the emergency replacement of a failed transformer with no available spares have the most significant impact on the risk cost modelled.

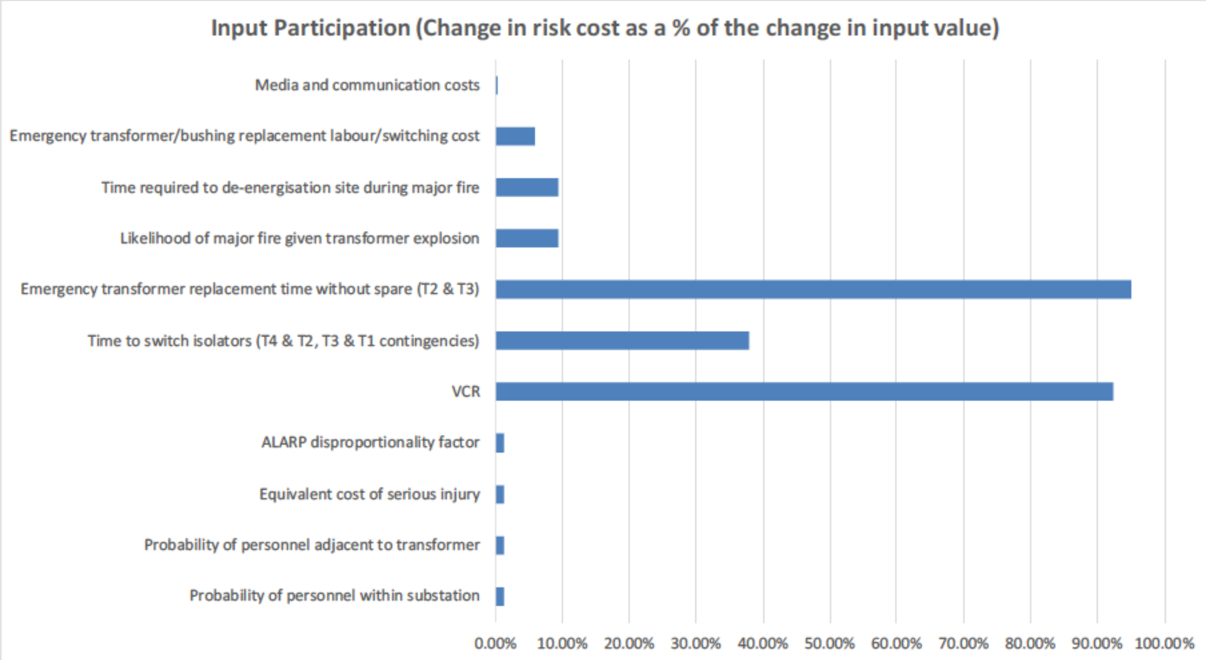

Figure 7 - Participation factors, transformer model

6 Option Risk and Maintenance Costs

6.1 Option Summary

Two reinvestment options are being considered to address the condition issues of transformers at Tarong substation:

- Option 1 – replace all four transformers by 2024
- Option 2 – replace the 275/66/11kV transformers, and retire the 275/132kV transformers by 2024.

6.2 Option Analysis

The total risk and maintenance costs for each option are shown in the tables below. The full set of figures are available within the spreadsheet with Objective ID A3371351.

Table 3 - Option 1 (Retain four transformers)

	2020	2021	2022	2023	2024	2025	…	2029	…	2039
Annual Risk ($m)	$1.543	$1.611	$1.680	$1.749	$1.818	$0.070		$0.121		$0.404
Annual Maintenance ($m)	$0.169	$0.173	$0.177	$0.181	$0.186	$0.038		$0.055		$0.097
Total ($m)	$1.711	$1.784	$1.858	$1.931	$2.004	$0.109		$0.176		$0.502

Table 4 – Option 2 (Retain 2 x 275/66/11kV transformers only)

	2020	2021	2022	2023	2024	2025	…	2029	…	2039
Annual Risk ($m)	$1.543	$1.611	$1.680	$1.749	$1.818	$0.022		$0.035		$0.143
Annual Maintenance ($m)	$0.169	$0.173	$0.177	$0.181	$0.186	$0.019		$0.028		$0.049
Total ($m)	$1.711	$1.784	$1.858	$1.931	$2.004	$0.041		$0.062		$0.191

If Option 2 is implemented, there is a minor increase in the load at risk in the Surat region during N-2 contingency events within the 275kV network in the vicinity of Columboola. The annual risk within Table 4 captures this additional network risk cost. However there is an overall reduction in risk cost if Option 2 is implemented due to the removal of risks associated with 275/132kV T1 & T4 at the substation.

Project Scope Report

CP.02584

Tarong Transformers Replacement

Concept – Version 1

Document Control

Change Record

Issue Date	Responsible Person	Objective Document Name	Background
24/01/2020	[redacted]	Project Scope Report CP.02584 Tarong Transformers Replacement	Initial Issue

Related Documents

Issue Date	Responsible Person	Objective Document Name
31/12/2019	[redacted]	H018 Tarong Transformer Condition Assessment Report

Project Contacts

Project Sponsor	[redacted]	[redacted]
Connection & Development Manager	[redacted]	[redacted]
Strategist – HV/Digital Asset Strategies	[redacted]	[redacted]
Planner – Main/Regional Grid	[redacted]	[redacted]
Manager Projects	tba	Ext.
Project Manager	tba	Ext.
Design Coordinator	tba	Ext.

Project Details

1. Project Need & Objective

Tarong Substation is a 275/132/66kV substation in the Surat Basin North West Area, approximately 90km north of Toowoomba. The substation was built in 1982. A condition assessment recommends replacement of the 275/66kV and 275/132kV transformers

The Tarong Area Plan Strategy proposes to convert Chinchilla Substation to a transformer ended substation supplied from Columboola. Under this network toplogy, the 275/132kV transformers and associated bays at Tarong will be decommissioned. Estimates for options to replace the transformers with and without the Tarong to Chinchilla 132kV transmission line in service is required to inform an economic analysis for the Tarong Area RIT-T.

The objective of this project is to replace the Transformers at Tarong Substation by 2024.

2. Project Drawing

[redacted]

Figure 1: Geographic location of Tarong Substation

[redacted]

Figure 2: H018 Tarong single line diagram

3. Project Scope

Two credible options have been identified to address the project need and are detailed below. Estimates are required for each option to inform the feasibility of the project that will form the basis for external consultation under the Regulatory Investment Test for Transmission (RIT-T).

Table 1 – Option Summary

Option	Description	Commission Date
1	Replace T1, T2, T3 and T4 – Existing Arrangement	2024
2	Replace T2 and T3 only – Chinchilla Transformer Ended	2024

3.1. Option 1 – Existing Arrangement

The following scope presents a functional overview of the desired outcomes of the project. The proposed solution presented in the estimate must be developed with reference to the remaining sections of this Project Scope Report, in particular *Section 6 Special Considerations*.

Briefly, the project consists of the replacement of T1, T2, T3 and T4 275kV transformers per the existing arrangement.

3.1.1. H018 Tarong Substation Works

Design, procure, construct and commission replacement of T1, T2, T3 and T4 275kV transformers as follows:

- Replace transformers T2 and T3 with new 275/66/11kV transformers rated at 100 MVA and capable of withstanding fault current of 40 to 50kA on 275kV bus bar.

  Note: 100MVA transformers have been specified for all options to align with Powerlink standards and minimise spares holdings.

- Connect 5T and 6T Station Transformers to the tertiary bushing of the new T2 and T3 275/66/11kV transformers.
- Replace transformers T1 and T4 with two new 275/132kV power transformers rated at 100 MVA and capable of withstanding fault current of 40 to 50kA on 275kV bus bar.
- Review and update the following equipment associated with the transformer bays as required:
  - transformer foundations and enclosures;
  - oil containment system;
  - overhead earth wire rating and shielding;
  - earth mat and portable earthing attachment points; and
  - strung bus and dropper conductors including performed terminations.

- Decommission and recover all redundant equipment, and update drawing records and SAP records accordingly.

3.1.2. Telecoms Works

Not applicable

3.1.3. Easement/Land Acquisition & Permits Works

Easement rights and approvals must be considered with the Property team.

3.2. Option 2 – Chinchilla Transformer Ended

The following scope presents a functional overview of the desired outcomes of the project. The proposed solution presented in the estimate must be developed with reference to the remaining sections of this Project Scope Report, in particular *Section 6 Special Considerations*.

Briefly, the project consists of the replacement of transformers T2 and T3 per the existing arrangement. Transformers T1 and T4 will be decommissioned and dismantled under a separate operational project.

3.2.1. H018 Tarong Substation Works

Design, procure, construct and commission replacement of T2 and T3 275kV transformers as follows:

- Replace transformers T2 and T3 with new 275/66/11kV transformers rated at 100 MVA and capable of withstanding fault current of 40 to 50kA on 275kV bus bar.
- Connect 5T and 6T Station Transformers to the tertiary bushing of the new T2 and T3 275/66/11kV transformers.
- Review and update the following equipment associated with the transformer bays as required:
    - transformer foundations and enclosures;
    - oil containment system;
    - overhead earth wire rating and shielding;
    - earth mat and portable earthing attachment points; and
    - strung bus and dropper conductors including performed terminations.
- Decommission and recover all redundant equipment, and update drawing records and SAP records accordingly.

3.2.2. Telecoms Works

Not applicable

3.2.3. Easement/Land Acquisition & Permits Works

Easement rights and approvals must be considered with the Property team.

3.3. Key Scope Assumptions

The following assumptions should be included in the estimating of this scope:

- The decommissioning of Tarong –Chinchilla 132kV feeders 7183 and 7168 is the subject of project CP.0 2170 Chinchilla Substation Replacement for the initial mothballing of this line and subsequently OR.02412 Tarong Chinchilla 132kV Decommissioning.

3.4. Variations to Scope (post project approval)

Not applicable

4. Project Timing

4.1. Project Approval Date

The anticipated date by which the project will be approved is 30 June 2021.

4.2. Site Access Date

Tarong Substation is an existing Powerlink site. Access is already available.

4.3. Commissioning Date

The latest date for the commissioning of the new assets included in this scope <u>and</u> the decommissioning and removal of redundant assets, where applicable, is 30 June 2024.

5. Special Considerations

Not applicable

6. Asset Management Requirements

Equipment shall be in accordance with Powerlink equipment strategies.

Unless otherwise advised [redacted] will be the Project Sponsor for this project. The Project Sponsor must be included in any discussions with any other areas of Investment & Planning.

[redacted] will provide the primary customer interface with Energy Queensland. The Project Sponsor should be kept informed of any discussions with the customer.

7. Asset Ownership

The works detailed in this project will be Powerlink Queensland assets.

8. System Operation Issues

Operational issues that should be considered as part of the scope and estimate include:

- interaction of project outage plan with other outage requirements;
- likely impact of project outages upon grid support arrangements; and
- likely impact of project outages upon the optical fibre network.

9. Options

Any options proposed in the Concept/Proposal in response to this Project Scope Report must be fully costed with information detailing the reason for the option being proposed, and commentary on resource and outage impacts during implementation.

10. Division of Responsibilities

A division of responsibilities document will not be required for this project.

11. Related Projects

Project No.	Project Description	Planned Comm Date	Comment
Pre-requisite Projects			
Co-requisite Projects			
CP.02170	Chinchilla Substation Replacement	2024	
CP.02801	Tarong Selected Primary Plant Replacement	2025	
OR.02325	H018 Tarong 1T and 4T Transformer Decommissioning	2024	
Other Related Projects			

CP.02584 Tarong Transformer Replacement Project Management Plan

Record ID	A3311222	
Authored by	[redacted]	Project Manager
Reviewed by	[redacted]	Team Leader
Approved by	[redacted]	Manager Projects

Version History

Version	Date	Section(s)	Summary of amendment
1.0	1/05/2020	All	Original
1.1	30/07/2020	All	Escalated for a new completion date of 30/6/2024

Table of Contents

1. Executive Summary

- *Project background*

A condition assessment of the 275/132/66kV Tarong Substation recommends the replacement of the 275/66kV and 275/132kV transformers.

Since the Tarong Area Plan Strategy proposes to convert Chinchilla Substation to a transformer ended substation supplied from Columboola, the 275/132kV transformers and associated bays will be decommissioned. This leads to two main options for this project. Either Powerlink retains the existing arrangement (replacing T1, T2, T3 and T4) or the Chinchilla Substation is transformer ended (replacing T2 and T3).

This Project Management Plan will be used initially as the Project Proposal document. As a result of this, some information is not yet known and will be marked as 'TBD' (To Be Determined) throughout the proposal stage.

- *Project objective*

The objective of this project is to replace the Transformers at Tarong Substation by 30/06/2024.

[redacted]

[redacted]

Option 1

Version 3 - Revised Completion 30 June 2024 (was 7 Feb 2023)

Estimate Components -Reset 2023-27 Project CP.02584- Option 1 (B2) V2			Un-Escalated $	Escalated $
Base Estimate	Cost Estimate		20,965,963	22,534,911
	Estimate Allowance		1,048,300	1,127,242
	Total Base Estimate		22,014,263	23,662,153
Contingency (Unknown Risk) (A)		[redacted]	[redacted]	[redacted]
Mitigated Risk (Known Risk) (B)		[redacted]	[redacted]	[redacted]
Contingency Total Proposed (A+B)		[redacted]	[redacted]	[redacted]
Total Proposed Approval			[redacted]	[redacted]

Option 2

Version 3 - Revised Completion 30 June 2024 (was 7 Feb 2023)

Estimate Components -Reset 2023-27 Project CP.02584 - Option 2 (C3)			Un-Escalated $	Escalated $
Base Estimate	Cost Estimate		13,427,793	15,122,976
	Estimate Allowance		671,400	757,850
	Total Base Estimate		14,099,193	15,880,826
Contingency (Unknown Risk) (A)		[redacted]	[redacted]	[redacted]
Mitigated Risk (Known Risk) (B)		[redacted]	[redacted]	[redacted]
Contingency Total Proposed (A+B)		[redacted]	[redacted]	[redacted]
Total Proposed Approval			[redacted]	[redacted]

Option 1 V3 Cash Flow Table	Unescalated Apr 2020 Base Date	Escalated Completion
To June 2020	100,000	100,000
To June 2021	321,669	334,857
To June 2022	7,190,964	7,792,711
To June 2023	7,190,964	8,112,212
To June 2024	7,210,666	8,467,950
Total	**22,014,263**	**23,662,153**

Option 2 V3 Cash Flow Table	Unescalated Apr 2020 Base Date	Escalated Completion
To June 2020	100,000	100,000
To June 2021	238,314	248,085
To June 2022	4,582,774	4,966,266
To June 2023	4,582,774	5,169,882
To June 2024	4,595,330	5,396,592
Total	**14,099,193**	**15,880,826**

	Date
Project Scope Report - date received	3/2/2020
Project Proposal and Project Estimate 1.0 - date submitted	1/5/2020
Project Proposal and Project Estimate 1.1 - date submitted	30/7/2020
Project Approval Advice (PAA) - date expected	TBA.

2. Option 1 – Retain Existing Arrangement

2.1 Project Description

2.1.1 Project Scope

This project consists of the replacement of T1, T2, T3 and T4 transformers per existing arrangement.

The works detailed in this project will be Powerlink Queensland assets.

2.1.1.1 H018 Tarong Substation Works

Design, procure, construct and commission replacement of T1, T2, T3 and T4 275kV transformers as follows:

- Transformers T2 and T3 with new 275/66/11kV transformers rated at 100MVA and capable of withstanding fault current of 40 to 50kA on 275kV bus bar.
- Connect 5T and 6T Station Transformers to the tertiary bushing of the new T2 and T3 275/66/11kV transformers.
- Review and update the following equipment associated with transformer bays as required:
  - Transformer foundations and enclosures
  - Oil containment system
  - Overhead earth wire rating and shielding
  - Earth mat and portable earthing attachment points
  - String bus and dropper conductors including performed terminations
- Decommission and recover all redundant equipment, and update drawing records and SAP records accordingly.

2.1.1.2 Transmission Lines / Transmission Lines Refit

- Not Applicable

2.1.1.3 Telecommunications

- Not Applicable

2.1.1.4 Revenue Metering

The project excludes the modification/replacement of revenue metering.

2.1.1.5 Easement/Land Acquisition & Permit Works

- Not Applicable

2.1.1.6 Other Project Works

- Not Applicable

2.1.2 Exclusions

Exclusions as follow:

- The design of any modification to existing roads and gates to provide access suitable for the removal and replacement of the transformers;
- The design of noise and fire walls.
- Allowance for unexpected ground conditions such as rock or unsuitable material;
- Non-standard foundations;
- Any work outside of normal working hours;
- Dealing with unidentified asbestos;

2.1.3 Assumptions

Assumptions as follow:

- The project pricing assumes an exchange rate of AUD $0.65 : USD $1.
- Availability of site access for works as required;
- Internal design, contractor design and MSP resources are available as required;
- Existing ground conditions are suitable for the construction of standard foundations;
- Contractor spoil can be spread on site adjacent the substation pad;
- The decommissioning of Tarong – Chinchilla 132kV feeders 7183 and 7168 is the subject of project CP.02170 Chinchilla Substation Replacement for the initial mothballing of this line and subsequently OR.02412 Tarong Chinchilla 132kV Decommissioning;
- The final set of transformer drawings and final specifications for the transformers are available to Civil Design prior to commencing any design;
- New concrete foundations will be required for the new transformers;
- A suitable location for the new Spel Oil Separation tanks can be found in close proximity to the new transformers and within the existing fenced yard. It is assumed that no extra platform area or fencing is required;
- The existing roads, gates, access, etc. are suitable for the removal and replacement of all of the transformers;
- It is assumed that no new site survey is required. All equipment will be set out relative to existing equipment;
- A geotechnical investigation will be required to determine soil design parameters for the design of the transformer foundations. Additional geotechnical investigation may be required after demolition of the existing foundations to confirm properties;
- Civil Design has allowed in the estimate for only 6 site visits during design/construction;
- Transformers 1, 2, 3 and 4 shall be replaced in-situ for Option 1.
- Existing cabling to transformers cooler control boxes shall require replacing.
- Existing station service transformers will not be physically moved under Option 1;
- Suitable Protection class VTs are used where VT replacements are required;
- Replacement breakers will be a dead tank arrangement with toroidal CTs on either side; and
- Where CTs are replaced with DTCBs, equivalent ratios are available and of suitable specification.

2.1.4 Project Interaction

Interactions with other projects and Engineering Task Request (ETRs) as follow:

Project Number and Description	Interaction (Pre-requisite/Co-requisite/dependent/Related)	Planned Commissioning Date	Comment
CP.02170 Chinchilla Substation Replacement	Co-requisite	2023	To be completed prior to this project commencing
CP.02801 Tarong Selected Primary Plant Replacement	Co-requisite	2025	To be completed after this project.
OR.02325 H018 Tarong 1T and 4T Transformer Decommissioning	Co-requisite	2022	Will be carried out in parallel with this project.

2.1.5 Project Risk

Project risks identified during <u>Project Proposal</u> phase are as follows:

Option 1

Risk type	Risk Cost Estimate (Pessimistic - no factoring applied)	Risk Cost Estimate (after Likelihood factoring applied)	Impact To Project (UNTREATED)	Risk Treatment Cost (Additional cost to administer Risk)	Mitigated Risk (Known Risk)	Project Cost -direct transfer to estimate (Estimate Allowance)	Impact To Project (AFTER RISK TREATMENT)
Commercial & Legal	[redacted]	[redacted]	Minor	[redacted]	[redacted]	[redacted]	Minor
Finance & Economic	[redacted]	[redacted]	Significant	[redacted]	[redacted]	[redacted]	Significant
People / Human Resources	[redacted]	[redacted]	No impact	[redacted]	[redacted]	[redacted]	No impact
Natural Events	[redacted]	[redacted]	Minor	[redacted]	[redacted]	[redacted]	Minor
Environmental	[redacted]	[redacted]	No impact	[redacted]	[redacted]	[redacted]	No impact
Health & Safety	[redacted]	[redacted]	No impact	[redacted]	[redacted]	[redacted]	No impact
Project Management	[redacted]	[redacted]	No impact	[redacted]	[redacted]	[redacted]	No impact
Interfacing Management	[redacted]	[redacted]	No impact	[redacted]	[redacted]	[redacted]	No impact
Community Issues	[redacted]	[redacted]	No impact	[redacted]	[redacted]	[redacted]	No impact
Design	[redacted]	[redacted]	Minor	[redacted]	[redacted]	[redacted]	Minor
Delivery	[redacted]	[redacted]	Moderate	[redacted]	[redacted]	[redacted]	Moderate
Completion	[redacted]	[redacted]	No impact	[redacted]	[redacted]	[redacted]	No impact
TOTAL	[redacted]	[redacted]		[redacted]	[redacted]	[redacted]	

During Project Execution, project risks are recorded managed in PWA Server.

2.2 Project Financials

2.2.1 Project Estimate

2.2.1.1 Estimate Summary

Estimate Components -Reset 2023-27 Project CP.02584- Option 1 (B2) V2			Un-Escalated $	Escalated $
Base Estimate	**Cost Estimate**		**20,965,963**	**22,534,911**
	Estimate Allowance		**1,048,300**	**1,127,242**
	Total Base Estimate		**22,014,263**	**23,662,153**
Contingency (Unknown Risk) (A)		[redacted]	[redacted]	[redacted]
Mitigated Risk (Known Risk) (B)		[redacted]	[redacted]	[redacted]
Contingency Total Proposed (A+B)		[redacted]	[redacted]	[redacted]
Total Proposed Approval			[redacted]	[redacted]

2.2.1.2 Asset Write-Off Table

Option 1

CP.02584 Asset Write-off. Values current at 30th June 2020 Option1							
Functional Location	Description	Asset	Sub number	Book val.	Write-off %	Write-off Value	Currency
H018-T01-1TRF	1 TRANSF	105155	0	472,879.46	100%	$ 472,879.46	AUD
H018-T02-2TRF	2 TRANSF	105156	0	199,637.32	100%	$ 199,637.32	AUD
H018-T03-3TRF	3 TRANSF	105157	0	199,637.32	100%	$ 199,637.32	AUD
H018-T04-4TRF	4 TRANSF	105158	0	852,266.04	100%	$ 852,266.04	AUD
					Total	$ 1,724,420.14	AUD

2.2.2 Approved Released Budget

The approved release budget to execute the project is as follows:

Option 1

Estimate Components -Reset 2023-27 Project CP.02584- Option 1 (B2) V2			Un-Escalated $	Escalated $
Base Estimate	Cost Estimate		20,965,963	22,534,911
	Estimate Allowance		1,048,300	1,127,242
	Total Base Estimate		22,014,263	23,662,153

2.2.3 Planned Costs (Forecasted Cash Flow)

Option 1 V3 Cash Flow Table	Unescalated Apr 2020 Base Date	Escalated Completion
To June 2020	100,000	100,000
To June 2021	321,669	334,857
To June 2022	7,190,964	7,792,711
To June 2023	7,190,964	8,112,212
To June 2024	7,210,666	8,467,950
Total	**22,014,263**	**23,662,153**

ASSET CLASS TABLE Option 1 V2)			
Asset Life	Asset Class	Base $	Base %
40 Years	Primary Plant	20,869,566	94.8%
15Years	Secondary Systems	1,144,697	5.2%
TOTAL		22,014,263	100.0%

During Project Execution, project planned cost are managed in SAP.

3. Option 2 – Chinchilla Transformer Ended

3.1 Project Description

3.1.1 Project Scope

This project consists of the replacement of transformer T2 and T3 per existing arrangement.

The works detailed in this project will be Powerlink Queensland assets.

3.1.1.1 H018 Tarong Substation Works

Design, procure, construct and commission replacement of T2 and T3 275kV transformers as follows:

- Transformers T2 and T3 with new 275/66/11kV transformers rated at 100MVA and capable of withstanding fault current of 40 to 50kA on 275kV bus bar.
- Connect 5T and 6T Station Transformers to the tertiary bushing of the new T2 and T3 275/66/11kV transformers.
- Review and update the following equipment associated with the transformer bays as required:
  - Transformer foundations and enclosures
  - Oil containment system
  - Overhead earth wire rating and shielding
  - Earth mat and portable earthing attachment points
  - Strung bus and dropper conductors including performed terminations.
- Decommission and recover all redundant equipment, and update drawing records and SAP records accordingly.

3.1.1.2 Transmission Lines / Transmission Lines Refit

- Not Applicable

3.1.1.3 Telecommunications

- Not Applicable

3.1.1.4 Revenue Metering

The project excludes the modification/replacement of revenue metering.

3.1.1.5 Easement/Land Acquisition & Permit Works

- Not Applicable

3.1.1.6 Other Project Works

Other categories of project works as follow:

- Nil.

3.1.2 Exclusions

Exclusions as follow:

- The design of any modification to existing roads and gates to provide access suitable for the removal and replacement of the transformers;
- The design of noise and fire walls.
- Allowance for unexpected ground conditions such as rock or unsuitable material;
- Non-standard foundations;
- Any work outside of normal working hours;
- Dealing with unidentified asbestos;
- The decommissioning of Tarong – Chinchilla 132kV feeders 7183 and 7168 – initial mothballing included in project CP.02170 Chinchilla Substation Replacement and decommissioning subsequently in OR.02412 Tarong Chinchilla 132kV Decommissioning; and
- The decommissioning and removal of T1 and T4 – these to be included in separate operational project.

3.1.3 Assumptions

The following assumptions should be included in the estimating of this scope:

- The project pricing assumes an exchange rate of AUD $0.65 : USD $1.
- Availability of site access for works as required;
- Internal design, contractor design and MSP resources are available as required;
- Existing ground conditions are suitable for the construction of standard foundations;
- Contractor spoil can be spread on site adjacent the substation pad;
- The final set of transformer drawings and final specifications for the transformers are available to Civil Design prior to commencing any design;
- New concrete foundations will be required for the new transformers;
- A suitable location for the new Spel Oil Separation tanks can be found in close proximity to the new transformers and within the existing fenced yard. It is assumed that no extra platform area or fencing is required;
- The existing roads, gates, access, etc. are suitable for the removal and replacement of all of the transformers;
- It is assumed that no new site survey is required. All equipment will be set out relative to existing equipment;
- A geotechnical investigation will be required to determine soil design parameters for the design of the transformer foundations. Additional geotechnical investigation may be required after demolition of the existing foundations to confirm properties;
- Civil Design has allowed in the estimate for only 6 site visits during design/construction;
- Transformers 3 and 4 shall be replaced in-situ for Option 1.
- Existing cabling to transformers cooler control boxes shall require replacing.
- Existing station service transformers will not be physically moved under Option 1;
- Suitable Protection class VTs are used where VT replacements are required;
- Replacement breakers will be a dead tank arrangement with toroidal CTs on either side; and
- Where CTs are replaced with DTCBs, equivalent ratios are available and of suitable specification.

3.1.4 Project Interaction

Interactions with other projects and Engineering Task Request (ETRs) as follow:

Project Number and Description	Interaction (Pre-requisite/Co-requisite/dependent/Related)	Planned Commissioning Date	Comment
CP.02170 Chinchilla Substation Replacement	Co-requisite	2023	To be completed prior to this project commencing
CP.02801 Tarong Selected Primary Plant Replacement	Co-requisite	2025	To be completed after this project.
OR.02325 H018 Tarong 1T and 4T Transformer Decommissioning	Co-requisite	2022	Will be carried out in parallel with this project.

3.1.5 Project Risk

Project risks identified during <u>Project Proposal</u> phase are as follows:

Option 2

Risk type	Risk Cost Estimate (Pessimistic - no factoring applied)	Risk Cost Estimate (after Likelihood factoring applied)	Impact To Project (UNTREATED)	Risk Treatment Cost (Additional cost to administer Risk)	Mitigated Risk (Known Risk)	Project Cost -direct transfer to estimate (Estimate Allowance)	Impact To Project (AFTER RISK TREATMENT)
Commercial & Legal	[redacted]	[redacted]	Moderate	[redacted]	[redacted]	[redacted]	Moderate
Finance & Economic	[redacted]	[redacted]	Significant	[redacted]	[redacted]	[redacted]	Significant
People / Human Resources	[redacted]	[redacted]	No impact	[redacted]	[redacted]	[redacted]	No impact
Natural Events	[redacted]	[redacted]	Minor	[redacted]	[redacted]	[redacted]	Minor
Environmental	[redacted]	[redacted]	No impact	[redacted]	[redacted]	[redacted]	No impact
Health & Safety	[redacted]	[redacted]	No impact	[redacted]	[redacted]	[redacted]	No impact
Project Management	[redacted]	[redacted]	No impact	[redacted]	[redacted]	[redacted]	No impact
Interfacing Management	[redacted]	[redacted]	No impact	[redacted]	[redacted]	[redacted]	No impact
Community issues	[redacted]	[redacted]	No impact	[redacted]	[redacted]	[redacted]	No impact
Design	[redacted]	[redacted]	Minor	[redacted]	[redacted]	[redacted]	Minor
Delivery	[redacted]	[redacted]	Moderate	[redacted]	[redacted]	[redacted]	Moderate
Completion	[redacted]	[redacted]	No impact	[redacted]	[redacted]	[redacted]	No impact
TOTAL	[redacted]	[redacted]		[redacted]	[redacted]	[redacted]	

During Project Execution, project risks are recorded managed in PWA Server.

3.2 Project Financials

3.2.1 Project Estimate

3.2.1.1 Estimate Summary

Estimate Components -Reset 2023-27 Project CP.02584 - Option 2 (C3)			Un-Escalated $	Escalated $
Base Estimate	**Cost Estimate**		**13,427,793**	**15,122,976**
	Estimate Allowance		**671,400**	**757,850**
	Total Base Estimate		**14,099,193**	**15,880,826**
Contingency (Unknown Risk) (A)		[redacted]	[redacted]	[redacted]
Mitigated Risk (Known Risk) (B)		[redacted]	[redacted]	[redacted]
Contingency Total Proposed (A+B)		[redacted]	[redacted]	[redacted]
Total Proposed Approval			[redacted]	[redacted]

3.2.1.2 Asset Write-Off Table

CP.02584 Asset Write-off. Values current at 30th June 2020 Option 2							
Functional Location	Description	Asset	Sub number	Book val.	Write-off %	Write-off Value	Currency
H018-T01-1TRF	1 TRANSF	105155	0	472,879.46	0%	$ -	AUD
H018-T02-2TRF	2 TRANSF	105156	0	199,637.32	100%	$ 199,637.32	AUD
H018-T03-3TRF	3 TRANSF	105157	0	199,637.32	100%	$ 199,637.32	AUD
H018-T04-4TRF	4 TRANSF	105158	0	852,266.04	0%	$ -	AUD
					Total	$ 399,274.64	AUD

3.2.2 Approved Released Budget

The approved release budget to execute the project is as follows:

Estimate Components -Reset 2023-27 Project CP.02584 - Option 2 (C3)			Un-Escalated $	Escalated $
Base Estimate	Cost Estimate		13,427,793	15,122,976
	Estimate Allowance		671,400	757,850
	Total Base Estimate		14,099,193	15,880,826

3.2.3 Planned Costs (Forecasted Cash Flow)

Option 2 V3	Unescalated	Escalated
Cash Flow Table	Apr 2020 Base Date	Completion
To June 2020	100,000	100,000
To June 2021	238,314	248,085
To June 2022	4,582,774	4,966,266
To June 2023	4,582,774	5,169,882
To June 2024	4,595,330	5,396,592
Total	**14,099,193**	**15,880,826**

ASSET CLASS TABLE Option 2 (V2)			
Asset Life	Asset Class	Base $	Base %
40 Years	Primary Plant	13,279,824	94.2%
15Years	Secondary Systems	819,369	5.8%
TOTAL		14,099,193	100.0%

During Project Execution, project planned cost are managed in SAP.

4. Project Planning Strategy

4.1 Milestones

The following milestones are required by the project team to deliver the project:

Option 1

Milestones	Planned Dates
Project Approval (issue of PAN)	30/06/2021
Design Available	30/11/2021
Site Access - to carry out investigations, inspections, etc.	Immediate
Site Possession - to carry out construction works	28/06/2022
Project Commissioning Date	30/06/2024

Option 2

Milestones	Planned Dates
Project Approval (issue of PAN)	30/06/2021
Design Available	30/11/2021
Site Access - to carry out investigations, inspections, etc.	Immediate
Site Possession - to carry out construction works	28/06/2022
Project Commissioning Date	30/06/2024

4.2 Project Staging

The high level project staging are as follows:

Option 1

Stage	Activity/Stage Description	High Level Timing
Not applicable	Design and Procurement	Sept 21– Jan 23
SPA DC 1	Remove redundant 2Transformer and 3Transformer	Feb 23 – March 23
1	SPA DC of 1Transformer replacement at H018	April 23
2	Commission 1Transformer replacement at H018	May 23
SPA DC 2	SPA DC of 4Transformer replacement at H018	June 23- July 23
3	SAT 4Transformer replacement at H018	Aug 23
4	Commission 4Transformer replacement at H018	Sep 23
SPA DC 3	SPA DC of 2Transformer replacement at H018	Oct 23-Nov23
5	SAT 2Transformer replacement at H018	Dec 23
6	Commission 2Transformer replacement at H018	Feb 24
SPA DC 4	SPA DC of 3Transformer replacement at H018	March 23-April 24
7	SAT 3Transformer replacement at H018	May 24
8	Commission 3Transformer replacement at H018	30 June 24

Option 2

Stage	Activity/Stage Description	High Level Timing
Not applicable	Design and Procurement	Sept 21 – Jan 23
SPA DC 1	Remove redundant 2Transformer and 3Transformer	Feb 23 – March 23
SPA DC 2	SPA DC of 1Transformer and 2Transformer replacement at H018	April 23 – Oct 23
1	SAT 2Transformer replacement at H018	Nov 23
2	Commission 2Transformer replacement at H018	Dec 23
3	SAT 3Transformer replacement at H018	Jan 24
4	Commission 3Transformer replacement at H018	28 Feb 24

For detail staging, refer to the Project Staging Plan (refer to section 13).

4.3 Project Schedule

Project timing shall be managed using a Project Schedule. Refer to the Project Schedule (refer to section 13) in PWA Server.

4.4 Network Impacts and Outage Planning

An Outage Plan (refer to section 13) will be included in the project schedule on the likelihood of the outages required for this project. This outage has been discussed with Network Operations. Network Operations have advised of the following known outage restrictions:

- It is unlikely that outages for the duration required for option 1 (the in-situ replacement of all four transformers) will be available & if not this option will require a different construction methodology requiring additional transformer moves & additional outages.
- It is likely that outages for option 2 will be available.

The Project Team is investigating the above restrictions.

4.5 Project Delivery Strategy

Description	*Responsibility*							
	Main Site				*Remote End(s)*			
	Powerlink	*Contractor*	*MSP – O&SD*	*MSP - Ergon*	*Powerlink*	*Contractor*	*MSP – O&SD*	*MSP*
Primary Design Systems (PSD):								
Civil and Structural	☐	☒	☐	☐	☐	☐	☐	☐
Electrical	☐	☒	☐	☐	☐	☐	☐	☐
Secondary Systems Design (SSD):								
Protection	☒	☐	☐	☐	☒	☐	☐	☐
Automation (Circuitry and Systems Configurations)	☐	☒	☐	☐	☒	☐	☐	☐
Construction:								
Civil	☐	☒	☐	☐	☐	☐	☐	☐
Construction (support structures, plant and equipment installation and demolition Works)	☐	☒	☐	☐	☐	☐	☐	☐
Secondary Systems Installation (loose panels installation, panel modification, IED replacement, etc.)	☐	☐	☒	☐	☐	☐	☐	☒
Testing and Commissioning:								
Site Acceptance Test (partial)	☐	☐	☒	☐	☐	☐	☐	☒
System Cut Over and Commissioning	☐	☐	☒	☐	☐	☐	☐	☒

4.6 Procurement Strategy

The procurement strategy for services and selected items are listed below. All other services and items shall be procured in accordance with Powerlink's Procurement Standard.

Description	Procurement Method
Services:	
SPA DCT	ITT - Substation Panel Arrangement (SPA)
Optical Fibre System	Shortform ITT – Standing Offer arrangement with preferred/preapproved suppliers
MSP – OSD	RFQ
Primary Plant and Equipment:	
HV Plant and Equipment	Period Contractors
Structures	ITT – Standing Offer arrangement with preferred/preapproved suppliers
Hardware and fittings	ITT – Standing Offer arrangement with preferred/preapproved suppliers
Secondary Systems Equipment:	
IEDs	Period Contract
Panels, Kiosks, Boards and building fit-out	Shortform ITT – Standing Offer arrangement with preferred/preapproved suppliers

5. References

The following documents are applicable to this Project Management Plan.

Document name and hyperlink	Version	Date
Project Scope Report	1	24/1/20
Project Approval Advice	TBA	
Project Change Request Register	TBA	
Project Staging Plan	1	6/3/20
Electrical Design Advice Option 1	1	15/4/20
Electrical Design Advice Option 2	1	15/4/20
Civil Design Advice Option 1	1	6/4/20
Civil Design Advice Option 2	1	3/4/20
Protection Design Advice	1	22/4/20
Automation Design Advice	1	22/4/20
Equipment to be Tested Option 2	1	27/3/20
Equipment to be Tested Option 1	1	27/3/20
Nominated Control (Surveillance, Witness and Hold) Points for ITPs - Construction	TBA	
Nominated Control (Surveillance, Witness and Hold) Points for ITPs - Testing	TBA	