2023-27
POWERLINK QUEENSLAND REVENUE PROPOSAL

Project Pack – PUBLIC

CP.02370
Tully Transformer 2 Replacement

CP.02370 – Tully Transformer 2 Replacement

Project Status: Not Approved

1. Network Need

T084 Tully Substation, approx. 150km south of Cairns, is a major 132kV network injection point for Far North Queensland and supplies Ergon Energy distribution network south of Innisfail. Tully Substation contains an aged 132/22kV, 20MVA transformer (T2). An outage on this transformer would leave up to 15MW and up to 300MWh of customer load per day at risk[2].

A Condition Assessment (CA) conducted in February 2020 identified that T2, which is 44 years old (commissioned in 1976), is approaching the end of its technical service life[1]. T2 is exhibiting the following end of life attributes: areas of Grade 4 (High) base plate corrosion likely to have affect the tank integrity, minor oil leaks, PCB contaminated oil, and control cubicles and cabling in poor condition.

Energy Queensland forecasts confirm there is an enduring need to maintain electricity supply to the Tully area. The removal or failure of T2 at Tully Substation would violate Powerlink's Transmission Authority reliability obligations (N-1-50MW / maximum 600MWh unserved energy)[2] under the credible contingency of a loss of the remaining T1 transformer.

Further decline in the T2 asset condition increases the risk of failure that may cause network outages and additional network costs to replace assets under emergency conditions. The CA recommends reinvestment in the asset 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 obligations [6].

2. Recommended Option

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

The current recommended option is to replace T2 at Tully 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.
- Decommission Transformer 2 – rejected due to non-compliance with reliability standards under the credible contingency of a loss of the remaining T1 transformer.
- 22kV Supply from El Arish – Augmentation of 23km of 22kV feeder is not considered economically feasible when compared to replacement of T2.
- Non Network Option – At this stage no viable non-network options have been identified.

Figure 2-1 shows the current recommended option reduces the forecast risk monetisation profile of Tully Substation T2 transformer to effectively $0 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 to over $65k per annum in 2030. This is predominantly due to network risks (unserved energy) associated with potential concurrent outages of T2[3].

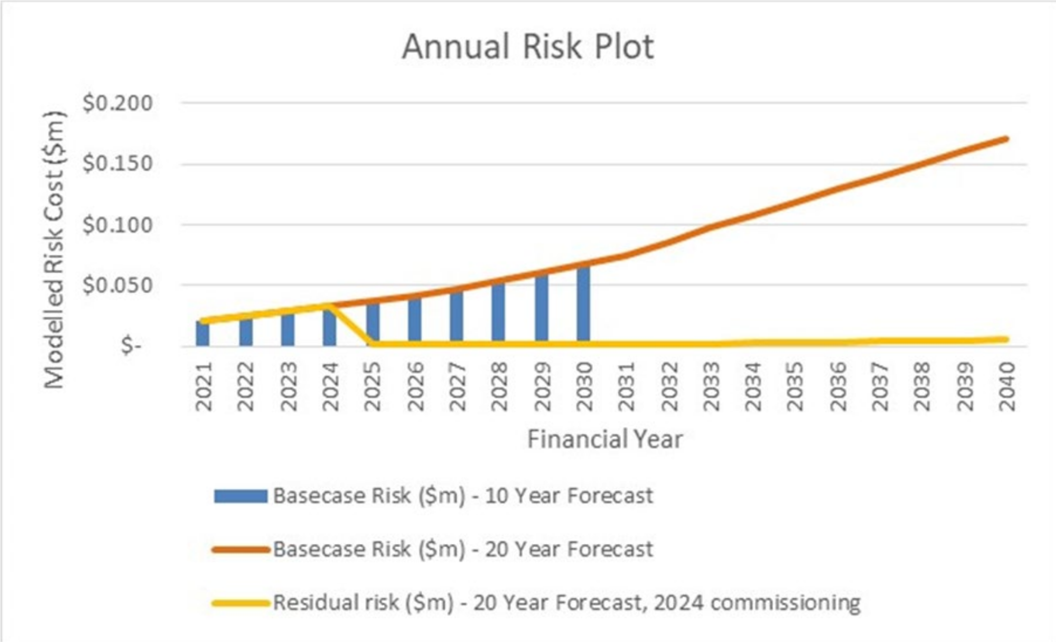

Figure 2-1 Annual Risk Monetisation Profile (Nominal)

3. Cost and Timing

The estimated cost to replace T2 at Tully substation is $5.2m ($2019/20).

Target Commissioning Date: October 2024

Note: Project staging requires the target commissioning date to been shifted to from June 2024 to October 2024 to minimise network and load at risk issues (i.e. the works have been scheduled during the 22 week sugarcane crushing season when additional local generation is available).

4. Documents in CP.02370 Project Pack

Public Documents

1. T2 Transformer Condition Assessment T048 Tully Substation
2. CP.02370 – T048 Tully Substation – Transformer T2 Replacement – Planning Statement
3. Base Case Risk and Maintenance Costs Summary Report CP.02370 Tully 132/22kV Transformer T2 Reinvestment
4. Project Scope Report CP.02370 T048 Tully No2 Transformer Replacement
5. Concept Estimate for CP.02370 – T048 Tully No 2 Transformer Replacement

Supporting Documents

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

T2 Transformer Condition Assessment T048 Tully Substation

Asset Category	Power transformers	**Author**	[redacted]	**Authorisation**	[redacted]
Activity	Condition assessment - primary substation plant, power transformers.				
Reviewed by:	[redacted]	Review Date:			
Document Type	Report	**Team**	Substation Strategies		
Issue date	20/02/2020	**Date of site visit**	05/02/2020		

Date	Version	Objective ID	Nature of Change	Author	Authorisation
27/02/2020	2.0	A3309779			
26/10/2015	1.0	A2371244			

***Note:** Where the indicator symbol ☼# is used (# referring to version number), it indicates a change / addition was introduced to that specific point in the document. If the indicator symbol ☼# is used in a section heading, it means the whole section was added / changed.*

IMPORTANT: - As this condition assessment is a snapshot in time and subject to the accuracy of the assessment methodology and ongoing in-service operating environment, the recommendations and comments in this report are valid for 3 years from the date of the site visit stated above.

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1. SUMMARY

A thorough condition assessment was performed on transformer T2 20MVA 132/22kV bulk supply transformer installed at T048 Tully Substation to determine its residual service life and any immediate issues that may need to be considered. No internal inspections nor electrical tests were performed on this in-service transformer for this assessment.

This report does not attempt to cover any detailed economic analysis of the viability of rectifying the highlighted issues associated with this transformer but provides a condition assessment of the “key” parameters for this transformer and reinvestment recommendations for the next 10 years.

Transformer T2:

Apart from having oil leaks, corrosion and poor paintwork the transformer appears to be in satisfactory condition considering its current service life of 44 years. DP values are calculated using 2-Furfurals values from oil samples and the Chengdong formula and are adjusted based on DGA, transformer maintenance and loading history. The calculated average DPv is 760, which is very good for a transformer of this age. It is reasonable to assume that minimum DPv at hot spot would be in order of 600-660, which is still indicating good condition of paper insulation and cellulose containing components inside transformer tank.

Based on this, it is forecasted that it is possible to achieve at least further 10 years of service from this transformer if the oil leaks and corrosion can be successfully addressed and confirm that all bushings are in good condition.

It is important to note that the mechanical stability of the windings cannot be confirmed without detailed transformer internal inspections and full through fault data history. However, DPv can be used as an indicator of loss of cellulose mass, which in turn has a loose correlation with residual axial winding clamping pressure. So if the calculated DPv value were used without reference to through fault history, the windings of these transformers would be considered to have a remaining service life of another 10 years.

2. INVESTIGATION:

A comprehensive on-site inspection of T2 was performed on the 5th February 2020 and the major findings which may impact its serviceability are discussed in this report. The substation Operating Diagram is shown in figure 1.

[redacted]

Figure 1: T048 Tully Substation Operating Diagram

2.1 T048 TULLY TRANSFORMER T2:

2.1.1 Identification Details:

Transformer T2 details are shown below. It was originally commissioned at Kamerunga substation in 1976 and relocated to Tully substation in 2000.

- Manufacturer - Tyree
- Contract 260/74
- YOM = 1976 (44 years)
- Commissioned 1976
- Capacity 40 ONAN
- Voltage 132 / 22 kV
- Serial No. 70762
- SAP Equipment No. 20008071
- Reinhausen OLTC model no. MII300-150/C101919W, serial no. 81671
- OLTC counter reading=181130

2.2 Onsite Inspection:

2.2.1 Anti-corrosion System:
Maintenance records show this transformer has been partially painted and corrosion issues addressed on a number of places and fittings. The coating which was applied to the main tank is badly oxidised as shown in Figures 2 & 3 and in some locations the paint is flaking off the original OEM coating.

Figure 2: Transformer T2 HV side of the main tank showing paint oxidisation

Figure 1: Transformer LV side of the main tank showing the oxidised repainted surfaces

This transformer has grade 4 corrosion on the base plate as shown in Figure 4. This corrosion is at the edges of the base plate and the extent of this towards the centre of the base could not be fully assessed. However, it is likely to have spread to the main tank underneath the transformer, which places the integrity of the tank at risk. With the loss of galvanised coating, climatic conditions and extent of grade 4 corrosion present, it is estimated that corrosion could lead to significant loss of steel cross-section of the main tank within 5-10 years.

Whilst there were signs of minor surface corrosion on some fittings, bolts, and flanges, the metal surface elsewhere appeared to be in reasonable condition.

Figure 3: Grade 4 corrosion on the base plate of the transformer

Figure 4: Corrosion on the conservator pipe work and on the base plate of A

Figure 5: Corrosion on the top of the tank

New main oil pipework has been installed in 2008 between the main tank and the cooler bank due to corrosion and oil leaks on the original pipework.

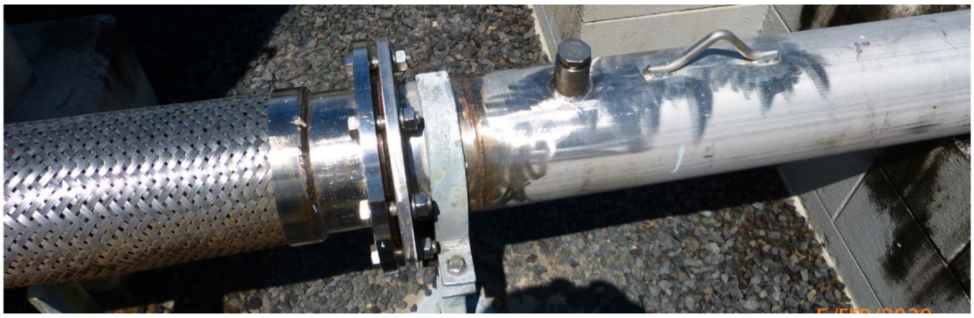


Figure 6: Main oil pipework installed in 2008.

The galvanised cooler bank is in reasonable condition with minor visible sign of surface corrosion.

Figure 7: Cooler bank on the transformer

2.2.2 Structural:

There were no signs of any structural issues associated with main supports for the cooler bank .

2.2.3 Oil Leaks:

According to the maintenance records, the repair of oil leaks (replacement of seals) was last performed in 2017 and no major oil leaks are visible at present.

Figure 9: Minor oil leak

2.2.4 Silica Gel Breather:

As with many transformers inspected in the field, it is impossible to visually inspect the condition of the oil bath on the bottom of the main conservator desiccant breather due to the design of the breather. This makes it very difficult to determine if the oil bath needs maintaining or is functioning correctly as a particulate filter.

This transformer was manufactured with the main tank oil conservator also housing the OLTC oil conservator at one end behind a partial partition. The two conservators breathe to atmosphere via a single desiccant breather.

The on-board 2 phase 22kV/110 V AC voltage transformer was fitted with a separate oil conservator and desiccant breather.

Figure 10: Main tank conservator breather showing concealed oil bath and the separate VT conservator and breather

2.3 Oil and Insulation Assessment:

A desktop assessment was performed on the oil laboratory test data for this transformer and the following information is derived.

2.3.1 Oil Quality:

When last tested for polychlorinated biphenyl (PCB) content in 2014, 2.1 mg/kg of PCB was detected in oil. Based on this, this transformer is classified as “Contaminated” and is currently being managed through operational procedures and signage.

Figure 8: Signage for PCB contamination

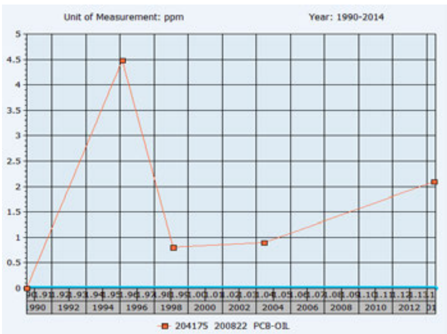


Figure 9: PCB in oil

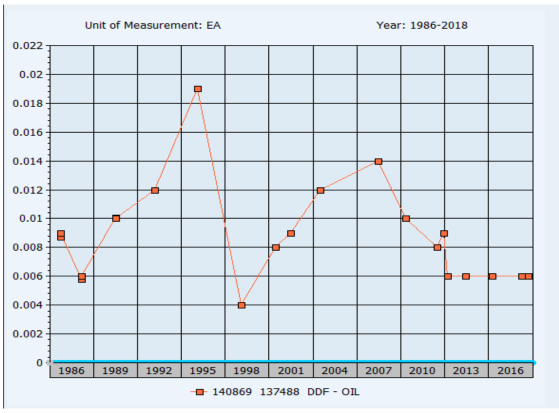


Figure 10: Oil DDF trend

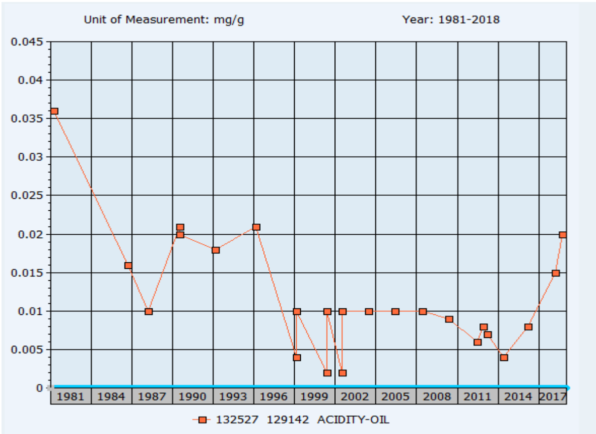


Figure 14:Oil Acidity

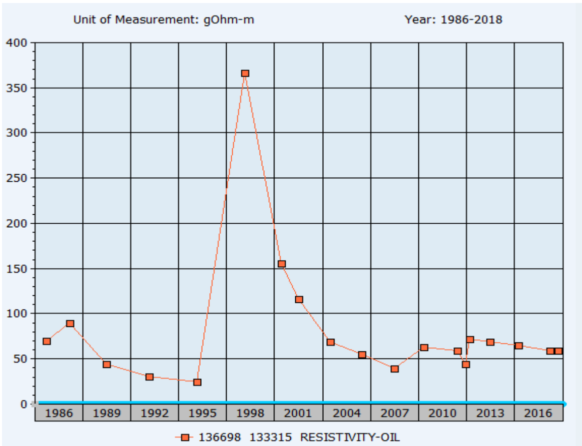


Figure 11: Oil resistivity trend

Currently the overall oil quality for this transformer looks satisfactory apart from the presence of PCB but it does appear that around 1998/99, the oil was either processed to remove dissolved PCB or replaced. This resulted in the significant improvement of the oil resistivity, dielectric loss angle and acidity and significant reduction of PCB level.

2.3.2 Transformer Loading

The peak loading in MVA on the 132kV side of this transformer over period 17/02/2018 to 13/02/2020 did not exceed 45% of the nameplate rating. The average loading over this period was 3MVA, which is 15% of the nameplate rating.

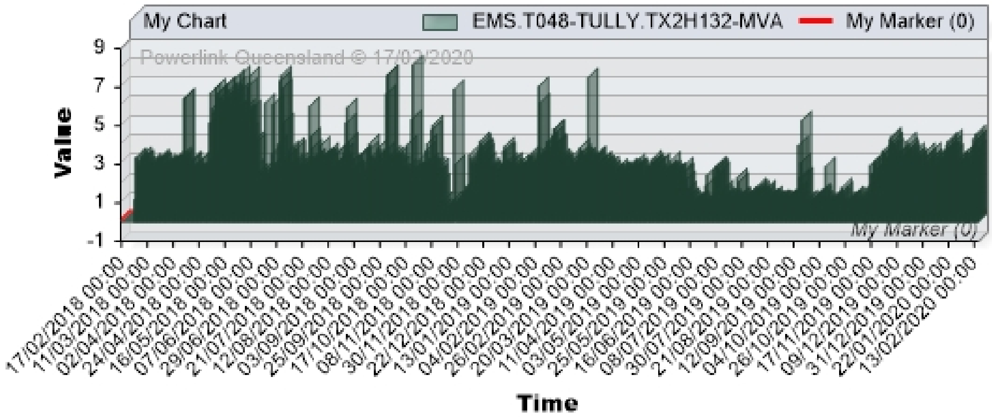


Figure 16–T2 transformer loading in MVA in period 17/02/2018 -13/02/2020 (the peak load is 9 MVA)

2.3.2 Dissolved Gas Analysis:

There are a few “stand-out” aspects to note from the oil dissolved gas analysis (DGA) test data and they are as follows;

- The insulation mass on the active part appears to have been exposed to partial discharge and high temperature in 1998. This presence of abnormal partial discharge activity was in the three 132kV high voltage (HV) transformer terminal bushings after 22 years of service. These bushings were replaced with new OIP (oil impregnated paper) bushings in 1998.

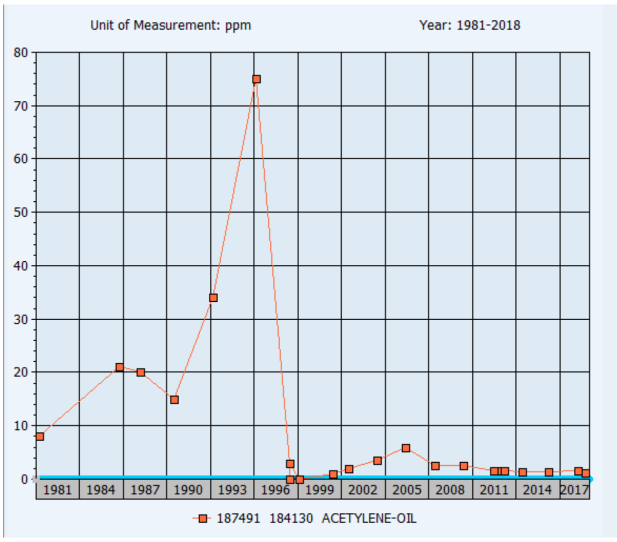


Figure 12: Acetylene levels in DGA

- There appears to be an on-going OLTC diverter switch tank oil leak into the main tank causing a mildly inflated measurement of thermal gases and traces of acetylene.

This transformer has only one cooling mode (ONAN) so it has no oil pumps nor radiator cooling fans.

2.3.3 Moisture in Insulation:

The percentage of moisture in the insulation was calculated and yielded approximately to be 2.2% by dry weight using measured moisture in oil samples. In reality, it may be best to consider the moisture level to be less than 3% but above 2%. This is still an acceptable figure for the insulation system of an unsealed transformer being in service for 44 years in wet tropical region.

2.4 Estimated Residual Life of Transformer:

2.4.1 Anti-corrosion System Life

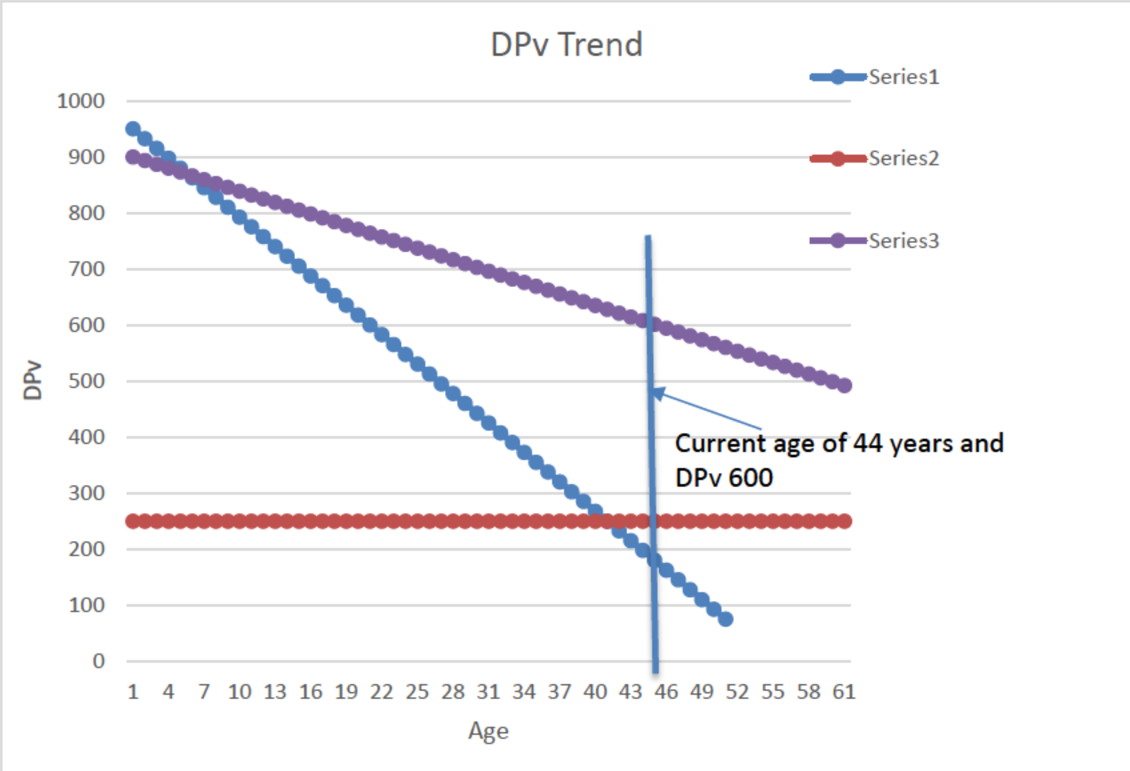
The surface paint on the main transformer tank is not in good condition and there is Grade 4 rust on the base plate. Assuming no other interventions are required for this transformer, from the anti-corrosion system condition and based on corrosion progression between 2015 and 2020 (see Figure 18 and Figure 19), it is likely that in its present state it would survive for approximately 5 years with only minor paint touch-ups.

Figure 18- Corrosion in 2020

Figure 19 – Corrosion in 2015

2.4.2 Insulation Life

Insulation age of this transformer was calculated to be approximately 15-21 years as shown below in Figure 20. This is well below its nameplate age of 44 years. This takes into account the approximate DPv at the hot spot.



Since no actual paper samples were taken from the transformer for this assessment, using the Chendong formula a paper DP value was calculated based on the dissolved furans in oil and its estimated trend is shown in Figure 20, using approximate value for hot spot considering that the furan data represents only an average of the total cellulose insulation mass. DPv of the insulating paper is very dependent on the operating conditions (temperature i.e. load and moisture).

Assuming that the current transformer operating conditions remain the same, the trend shows that the transformer has several years of remaining service life (Refer Figure 20).

As shown above, for a typical free breathing transformer the estimated service life is 40 years in n-1 operating context (operating below 50% capacity for most of time and allowing for higher ambient temperatures). The average loading of T2 transformer being only 3 MVA (only 15% of its rated capacity), the expected service life based on the paper aging only is significantly greater than theoretical design life.

2.4.3 Mechanical Life

Because there was no internal active part inspection performed, there is no way of knowing the state of the winding clamping or winding mechanical stability. There are no records available of exposure to through faults and the fault level at Tully is calculated to be just over 4kA at 132 kV voltage and just under 6 kA at 22 kV voltage level.

3.0 CONCLUSION:

3.1 Condition Assessment

Oil Leaks:
Most of the oil leaks identified on site were of a minor nature and attention is required mainly for the oil leak from top of the tank near the A phase bushing.
It is assumed this can be repaired.

External Physical Condition:
The paint system has been somewhat maintained with a number of locations evidencing flaking or corrosion.

Significant intervention is required for the corrosion of the base plate. Without significant intervention, the remaining service life is estimated to be 5 years – after this it is possible that the transformer tank can rupture and Powerlink can be found to be not complying with maintenance requirements under Electrical Safety Legislation and relevant Code of Practice.

Given the location and extent of the corrosion, it is not considered feasible to undertake appropriate remedial measures in-situ.

Insulation Residual Life:
The winding paper insulation residual life is still very good for its age and considering that the rate of chemical aging slows down exponentially as the DPv lowers, it should be possible to achieve several years of service life from the winding paper.

Winding Mechanical Stability:
Without more substantial evidence to the contrary, the mechanical stability of the windings has to be considered as questionable, due to the drying processes used in transformer manufacturing industry in times when this transformer was manufactured. It is assumed that the exposure to through faults and over-voltages would have been present due to the close proximity of insulated cables on LV side.

Figure 21 – Insulated cables connection to T2

Transformer Bushings:
It should be possible to achieve a further 5-10 years of life out of the transformer bushings provided no excessive storm activity weakens the OIP insulation over time.

Transformer Secondary Systems:
The visible condition of the secondary systems on the transformer, including external cabling, appear to require more than just normal maintenance if the transformer is to be kept for more than 5 years (Figs. 22,23,24,25). In addition, temperature indicators are also likely to require replacement

Figure 22- External cabling

Figure 23 – Internal cabling

Figure 24:OLTC Control Cubicle *Figure 25 – Temperature Indicators (OTI and WTI)*

Planning Report	**18/08/2020**
Title	CP.02370 - T048 Tully Substation - Transformer T2 Replacement [1]
Zone	Far North Queensland (FNQ)
Need Driver	Emerging operational and safety risks arising from the condition of the 132/22kV transformer.
Network Limitation	Necessary to meet Powerlink Queensland's N-1-50MW/600MWh reliability obligations. Under the scenario of a loss of a transformer, the customer loss of supply would exceed 600 MWh.
Pre-requisites	None

Executive Summary

Energy Queensland's forecasts confirm there is an enduring need to maintain electricity supply into the Tully area.

A February 2020 condition assessment of Tully T2 transformer predicts an end of technical service life in 2024.

Removal of the transformer to address emerging condition risks would result in Powerlink breaching its N-1-50MW/600MWh reliability obligations.

The preferred network solution for Powerlink to continue to meet its statutory obligations is the replacement of the at-risk transformer with a new 20/27MVA transformer by June 2024.

[1] *This report contains confidential information, which is the property of Powerlink, and the Registered Participant mentioned in the report, and has commercial value. It qualifies as Confidential Information under the National Electricity Rules (NER). The NER provides that Confidential Information:*

- *must not be disclosed to any person except as permitted by the NER;*
- *must only be used or copied for the purpose intended in this report;*
- *must not be made available to unauthorised persons*

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1. Introduction

The Tully Substation (T048) was originally established in 1976 as a 132kV injection point into Far North Queensland to supply the Ergon Energy distribution network in the region south of Innisfail. The Tully Substation has two 132/22kV 20MVA transformers (T1 and T2).

Transformer T2 is approaching 40 years of age and is displaying significant condition issues typical of transformers of this age. T1 is 20 years old and still in good condition.

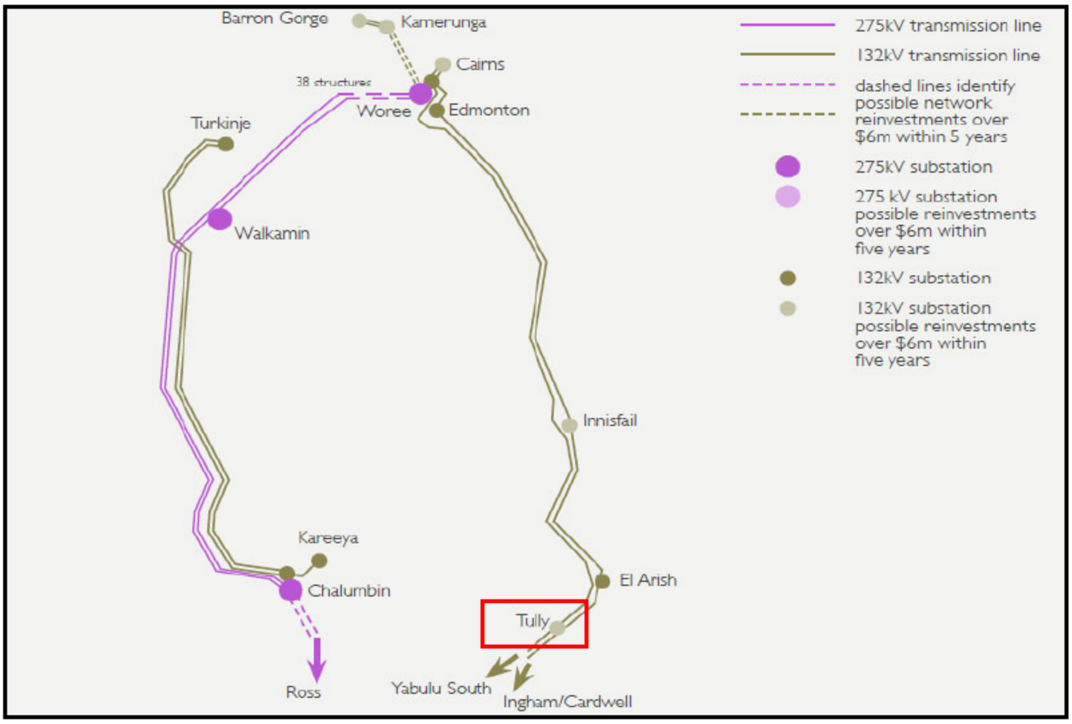

Figure 1-1: Tully Substation – Far North Queensland

Figure 1-2 shows the connections to Tully Substation in the FNQ network.

[redacted]

Figure 1-2: Single line diagram showing Tully Substation in the FNQ network

This report assesses the impact that removal of the at-risk transformer would have on the performance of the network and Powerlink's statutory obligations. It also establishes the indicative requirements of any potential alternative solutions to the current services provided by the transformer.

2. Tully Demand Forecast

The historical duration curves for the Tully Substation load are shown Figure 1-3.

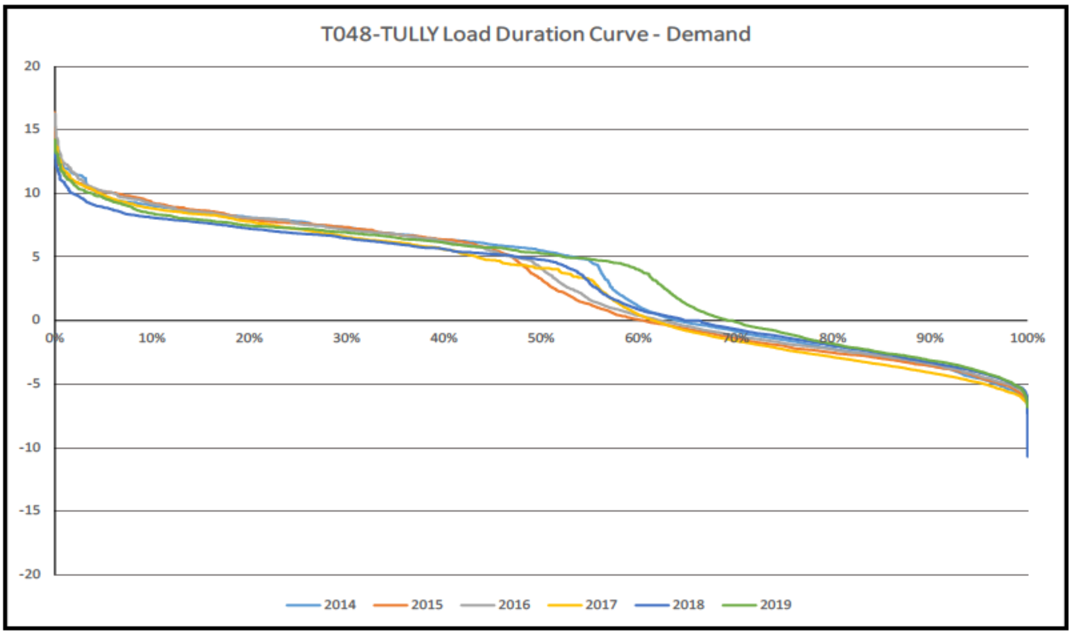

Figure 1-3: Tully load duration curves from 2014 to 2019

During the sugarcane crushing season, nominally June to November, a third party generator is capable of offsetting the load, often exporting power to the grid. However, this generator cannot run islanded from the grid, and does not operate when sugarcane is not being processed.

Peak load is not expected to change materially in coming years. The historical and forecast Tully load is shown in Figure 1-4.

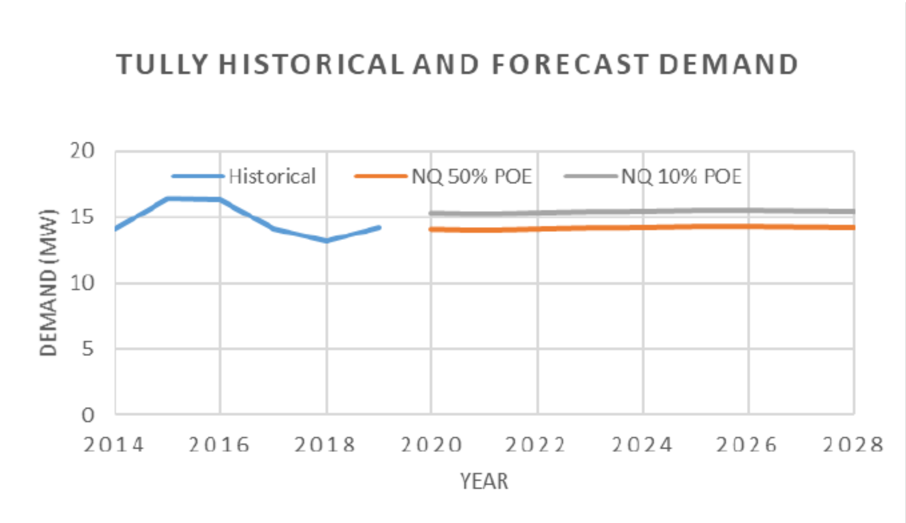

Figure 1-4: Tully Historical and Forecast Demand

3. Statement of Investment Need

Retaining Tully as a two 132/22kV transformer substation is necessary to maintain Powerlink's N-1-50MW/600MWh reliability standard.

If T2 is decommissioned, and no further investment made, then following the credible contingency loss of T1 the customer loss of supply would quickly exceed 600 MWh.

Two transformers also meets Energy Queensland's reliability standard (See Appendix A).

4. Network Risk

Table 1 summarises results of analysis to determine the maximum load at risk, as well as the energy at risk, if T2 transformer is decommissioned from service.

Table 1-1: Load at Risk

Load At Risk	Contingency Event	Quantity	2020	2030
Tully	132/22kV Transformers (1T & 2T)	Max (MW)	15	15
		Average (MW)	3	3
		24h Energy Max (MWh)	298	298
		24h Energy Average (MWh)	82	83

Given that the mean time to repair or replace a transformer is 10 to 12 weeks, the 600MWh limit of Powerlink's Transmission Authority will quickly be exceeded.

5. Non Network Options

Potential non-network solutions would need to provide supply to the 22kV network at Tully as per Table 1. That is, up to 15MW at peak and up to 300MWh per day. The non-network solution would be required for a contingency and able to operate on a continuous basis until normal supply is restored. Supply would also be required for planned outages.

In the case of loss T1:

- If the local sugar mill is crushing, and loads are light, EQL may be able to restore sufficient voltage via the 22kV network from El Arish to start the third party generator. This will not avoid the initial load, and generation loss and assumes that the third party generator will remain stable and adequately damped connected via the remote 22kV network.
- If the local sugar mill is not running, then Tully load cannot be supplied via the 22kV network from El Arish due to voltage and thermal limitations.

Powerlink is not aware of any Demand Side Solutions (DSM) in the area supplied by Tully. However, Powerlink will consider any proposed solution that can contribute significantly to the requirements of ensuring that Powerlink continues to meet its required reliability of supply obligations as part of the formal RIT-T consultation process.

6. Network Options

6.1 Proposed Option to address the identified need

To address the end of life of T2 Transformer at Tully Substation, it is recommended to replace T2 transformer by June 2024.

Given the steadily slow growth load forecast, the existing transformer size is considered sufficient. The existing T2 transformer also matches the transformer size of existing T1 transformer, and the transformers at Cardwell Substation. Powerlink considers the proposed network solution will not have a material inter-network impact.

Further details of the condition assessment for the transformer can be found in Reference 1.

6.2 Option Considered but Not Proposed

This section discusses alternative options that Powerlink has investigated but does not consider technically and/or economically feasible to address the above identified issues, and thus are not considered credible options.

6.2.1 Do Nothing

“Do Nothing” would not be an acceptable option as the primary driver (transformer condition) and associated safety, reliability and compliance risks would not be resolved. Furthermore, the “Do Nothing” option would not be consistent with good industry practice and would result in Powerlink breaching their obligations with the requirements of the System Standards of the National Electricity Rules and its Transmission Authority.

6.2.2 Decommission Transformer 2

Under this option, T2 Transformer is immediately decommissioned. The mean time to repair or put a spare transformer in place is 10 to 12 weeks. This option would not meet Powerlink’s reliability obligations (N-1-50MW/600MWh) and Energy Queensland’s reliability obligations (see Appendix A) under the credible contingency of a loss of the remaining T1 Transformer.

6.2.3 22kV supply from El Arish

Augmentation of the 23 km length of 22kV feeder from El Arish to Tully is not considered economically feasible when compared with replacing T2.

7. Recommendations

Powerlink has reviewed the condition of the T2 132/22kV Transformer at Tully Substation and concludes it will reach end of technical service life by 2024. It is therefore recommended that the 132/22kV transformer T2 at Tully Substation be replaced by June 2024.

Retaining Tully as a two 132/22kV transformer substation will allow Powerlink to continue to meet its required reliability obligations (N-1-50MW/600MWh). It will also allow Energy Queensland to meet its reliability standard (See Appendix 1).

Powerlink is currently unaware of any feasible alternative options to minimise or eliminate the load at risk at Tully but will, as part of the formal RIT-T consultation process, seek non-network solutions that can contribute significantly to ensuring it continues to meet its reliability of supply obligations.

8. References

1. CP.02370 T048 Tully No2 Transformer Replacement Project Scope Report
2. Tully T2 Transformer Condition Assessment (A3309779)
3. Transmission Annual Planning Report 2020
4. Asset Planning Criteria Framework

9. Appendix A: – EQ Planning Standards

Area	Targets for restoration of supply following an N-1 Event
Regional Centre[13]	Following an N-1 Event, load not supplied must be: • Less than 20MVA (8000 customers) after 1 hour • Less than 15MVA (6000 customers) after 6 hours • Less than 5MVA (2000 customers) after 12 hours • Fully restored within 24 hours.
Rural Areas	Following an N-1 Event, load not supplied must be: • Less than 20MVA (8000 customers) after 1 hour • Less 15MVA (6000 customers) after 8 hours • Less 5MVA (2000 customers) after 18 hours • Fully restored within 48 hours.

Base Case Risk and Maintenance Costs Summary Report

CP.02370 Tully 132/22kV Transformer T2 Reinvestment

Version Number	Objective ID	Date	Description
1.0	3429469	16/09/2020	Original document
2.0	3429469	21/09/2020	Updating maintenance costs

Purpose

The purpose of this model is to quantify the base case risk cost profiles and maintenance costs for 132/22kV transformer T2 at Tully Substation which is candidate for reinvestment under CP.02370.

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

1. Key Assumptions

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

- Historical load profiles have been used when assessing the likelihood of unserved energy under concurrent failure events;
- Due to the network and substation configuration, unserved energy generally accrues under concurrent failure events and consideration has been given to potential feeder trip events within the wider transmission network supplying the substation;
- Tully Substation supplies a mixture of residential, agricultural (mainly sugar cane farming) and commercial loads. Historical load data and estimates have been used to analyse the proportion of these load types. A weighted average VCR of $32,041/MWh has been used when evaluating network risk costs; and
- The applicable VCRs published within the AER's 2019 Value of Customer Reliability Review Final Report have been used within this risk cost assessment.

2. 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. Network, safety and financial risks are considered material and have been modelled for this analysis.

3.2 Transformer analysis

This section analyses the risks presented by 132/22kV transformer T2 at Tully Substation.

Table 1 - Risks associated with at risk transformers

	Mode of failure	
Equipment	Peaceful	Explosive
Transformer	**Network risks** (unserved energy from concurrent outages). **Financial risks** to replace failed transformer(s) in an unplanned (emergency) manner.	**Network risks** (unserved energy) due to substation de-energisation to extinguish a transformer fire. **Safety risks** to personnel. **Financial risks** to replace the failed transformer in an unplanned manner, clean-up and community engagement and media liaison costs.

3.2.1 Transformer Risk Cost

The modelled and extrapolated total base case risk costs are shown in Figures 1 to 4.

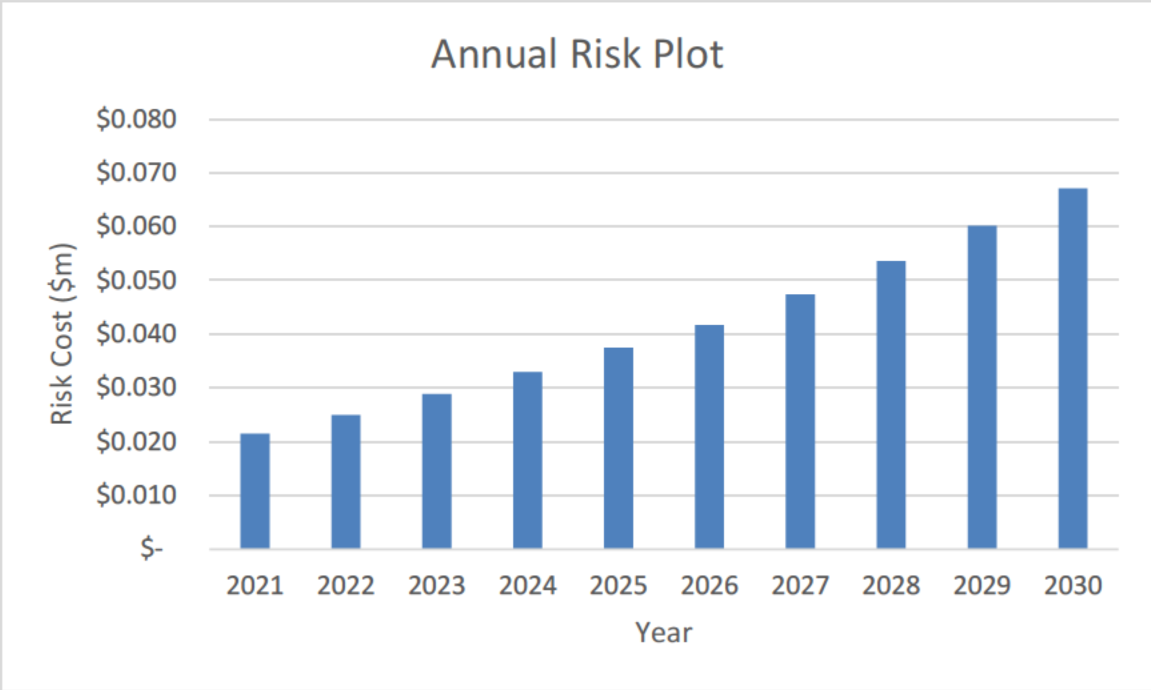

Figure 1 – Tully T2 total risk cost over time

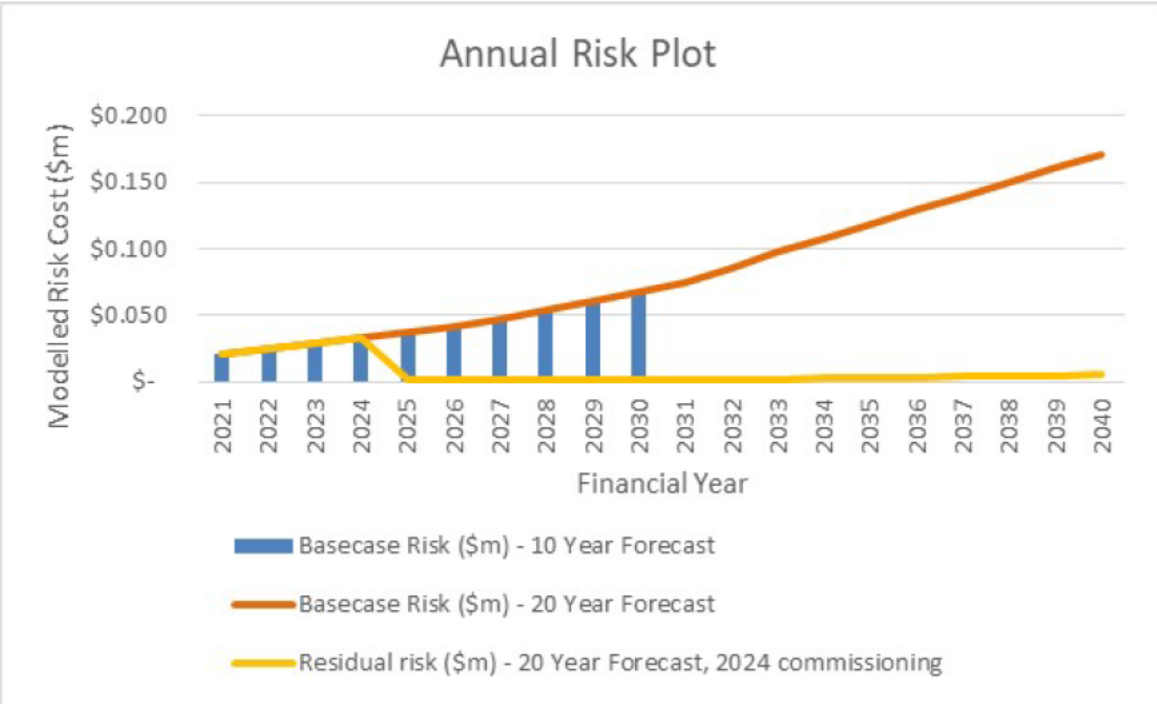

Figure 2 – Tully T2 risk cost (10 and extrapolated 20 years)

Figure 3 – Tully T2 risk cost over time by category

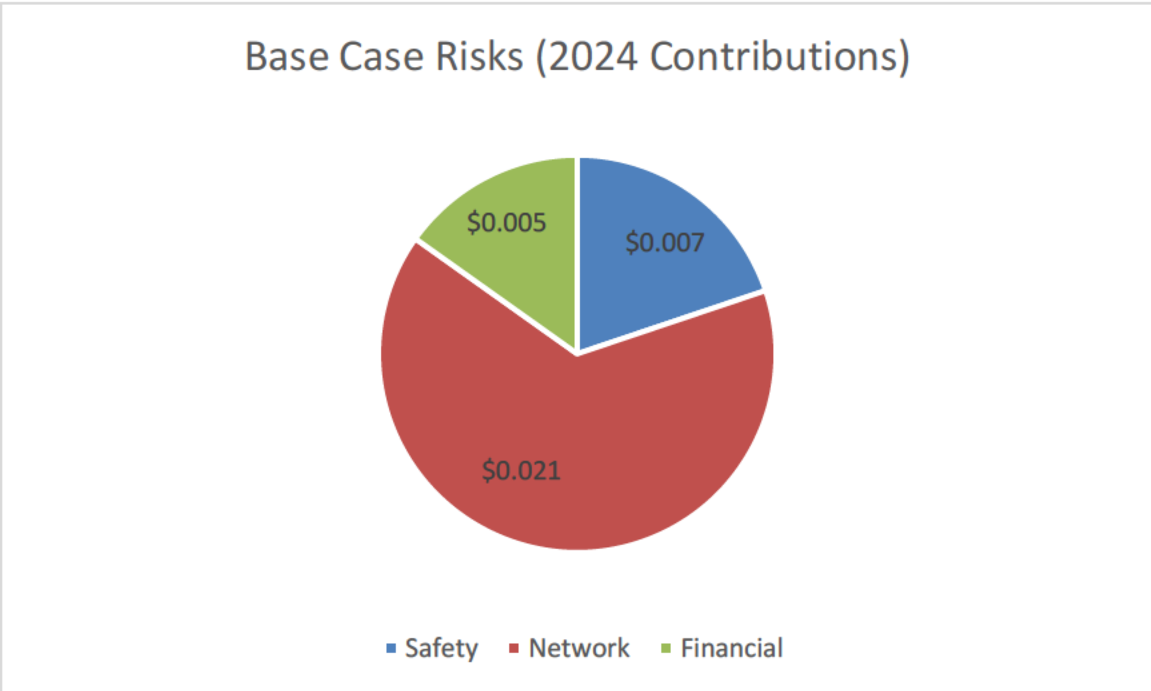

Figure 4 – Tully T2 risk cost by category (year 2024)

3.2.2 Base case risk statement

The main base case risks for 132/22kV transformer T2 at Tully Substation are network risk (unserved energy) due to concurrent outages of both 132/22kV transformers at Tully, and safety risks (injury to personnel on site) for explosive failures of the transformer.

3. 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 Figure 5 and Figure 6 below.

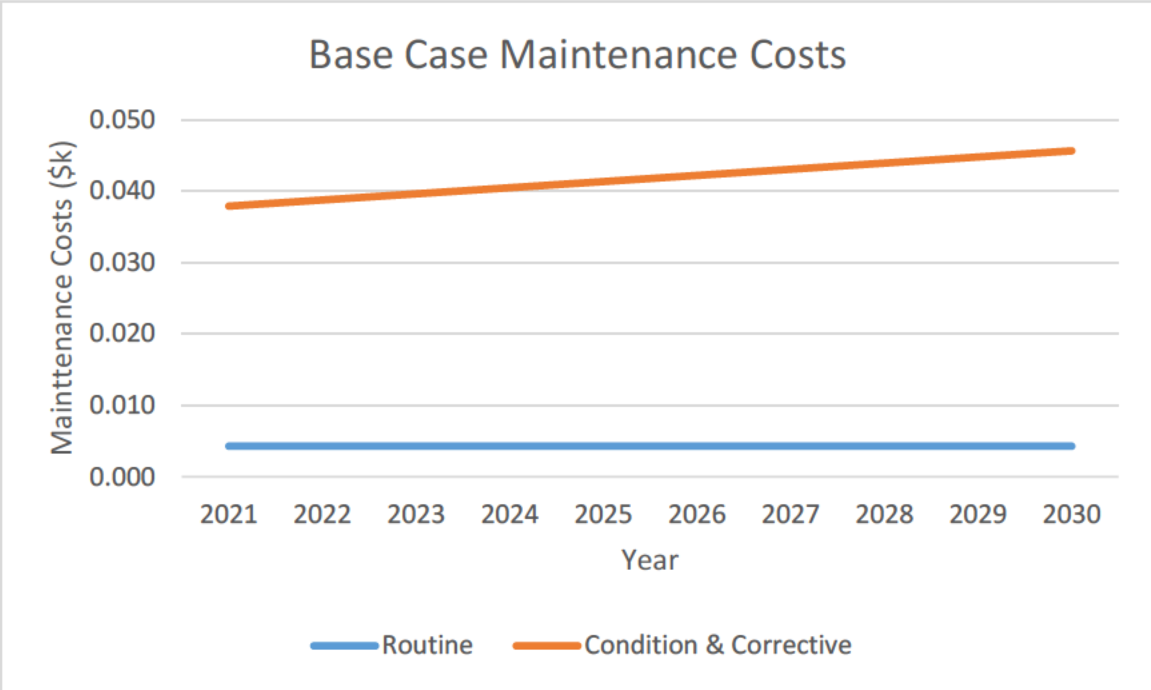

Figure 5 - Base Case Maintenance 2021 to 2030

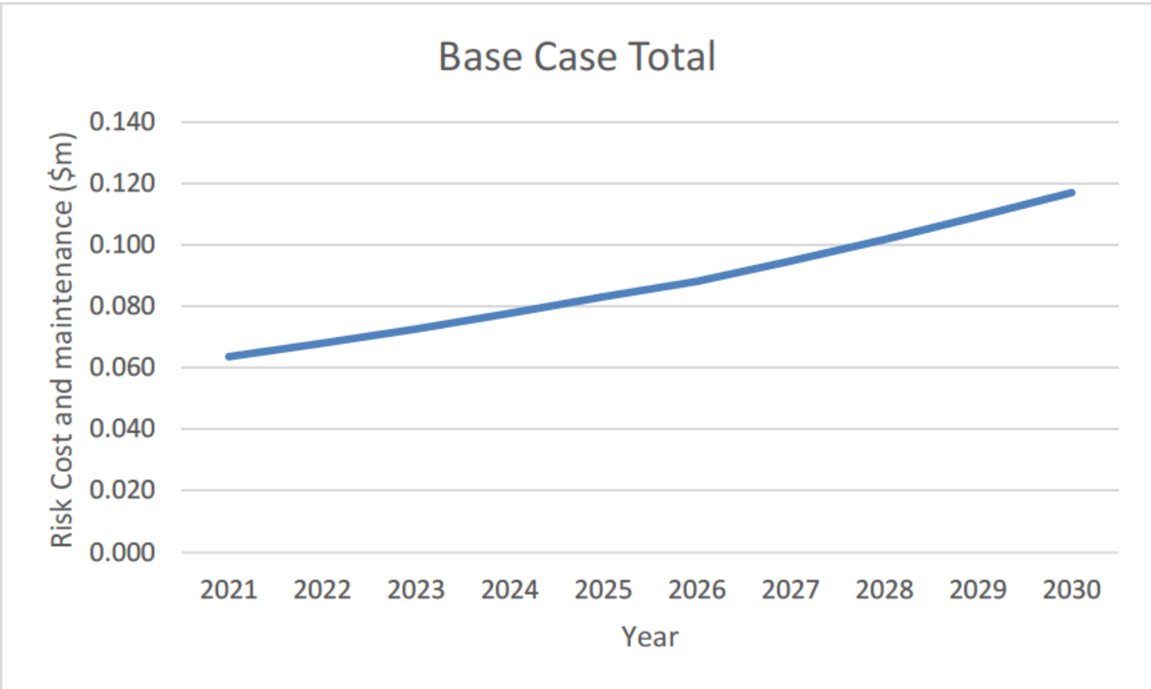

Figure 6 – Base Case Total (Risk Cost + Maintenance) 2021 to 2030

4. Input participation

Sensitivity analysis was carried out on the model to determine the participation factors for key inputs to the risk models (i.e. which inputs affect the risk calculations the most). The year analysed was 2021.

Figure 7 and Figure 8 below show the input values and the percentage change of the total modelled risk for a 100% change in an individual input (for example if VCR in the transformer model is doubled the calculated risk will increase by ~55%).

Equivalent cost of serious injury	1	$M
ALARP disproportionality factor	3	Ratio
VCR	32041	$/MWh
Emergency transformer replacement time without spare	12	Weeks
Time required to de-energise site during major fire	72	Hours

Figure 7 – Input values, transformer risk cost model

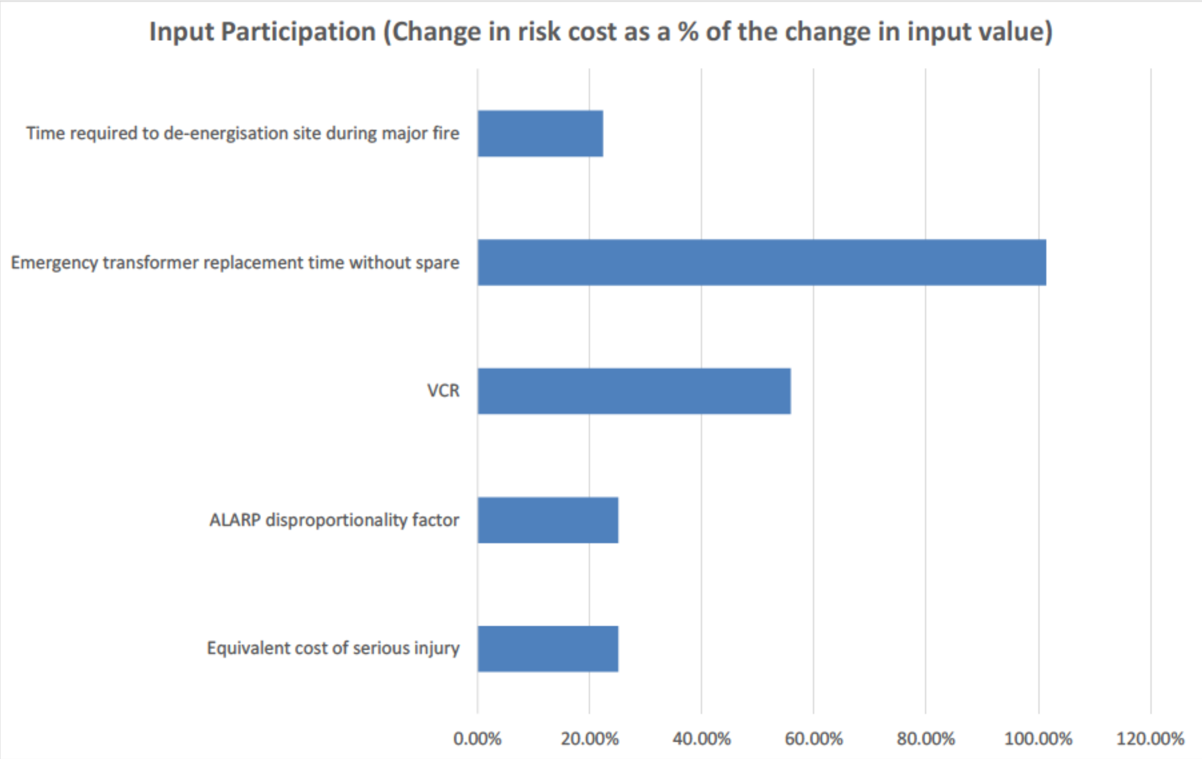

Figure 8 – Participation factors, transformer risk cost model

Project Scope Report

CP.02370

T048 Tully No2 Transformer Replacement

Concept – Version 1

Document Control

Change Record

Issue Date	Responsible Person	Objective Document Name	Background
11.02.2020	[redacted]	T048 Tully No2 Transformer Replacement	Preliminary scope

Related Documents

Issue Date	Responsible Person	Objective Document Name

Project Contacts

Project Sponsor	[redacted]	[redacted]
Connection & Development Manager	[redacted]	[redacted]
Strategist – HV/Digital Asset Strategies	[redacted]	[redacted]
Planner – Main/Regional Grid	<name>	Ext.
Manager Projects	<name>	Ext.
Project Manager	<name>	Ext.
Design Coordinator	<name>	Ext.
<delete or insert more if needed>		

Project Details

1. Project Need & Objective

T048 Tully Substation was originally established in 1976 as a 132kV injection point into Far North Queensland to supply the Ergon Energy distribution network in the region south of Innisfail. T048 Tully Substation has two 132/22kV 20MVA transformers (Tx1 & Tx2).

The transformer 2 unit is over 40 years of age and is displaying significant condition issues typical of transformers of this age.

The objective of this project is to replace transformer 2 with a new 20/27MVA transformer unit by June 2024.

2. Project Drawing

[redacted]

3. Project Scope

3.1. Original Scope

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 5 Special Considerations*.

Briefly, the project consists of replacing the existing 20MVA 132/22kV transformer 2 at T048 Tully with a new single 132/22kV 20/27MVA transformer unit.

Decommission, remove and dispose of the recovered transformer 2 unit.

3.1.1. Transmission Line Works

Not Applicable

3.1.2. T048 Tully Substation Works

Design, procure erect and commission 1 x 132/22kV 20/27MVA Star/Delta transformer, including all necessary civil works:

- procure, supply and install 1 x 132/22kV 20/27MVA Star/Delta transformer, with on load tap changer and cooling facilities;
- establish a new suitably sized earthing transformer for connection to the new transformer 2;
- review and Replace Transformer 2 foundations as required;
- review and modify transformer oil separation tank if required;
- replace existing Tx2 20MVA transformer unit with a new 1 x 132/22kV 20/27MVA Star/Delta transformer unit;
- review and upgrade as required 132 & 22kV landing spans, strung bus connections, and surge arrestors;
- review and upgrade as required associated bay plant equipment to achieve load rating compatible with new transformer ratings;
- recover and dispose of old T2 transformer unit;
- modify protection, automation and communication systems as necessary to accommodate the new transformer; and
- update SAP.

3.1.3. Telecoms Works

Not applicable

3.1.4. Easement/Land Acquisition & Permits Works

Not applicable

3.2. Key Scope Assumptions

Not Applicable

4. Project Timing

4.1. Project Approval Date

The anticipated date by which the project may be approved is December 2021.

4.2. Site Access Date

T048 Tully is an existing Powerlink owned substation, and access is available immediately.

4.3. Commissioning Date

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

5. Special Considerations

The following issues are important to consider during the implementation of this project:

- Ergon Energy also operates 22kV plant located on the site, with shared access arrangements.

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 Ergon Energy. 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.

The asset boundary with Ergon Energy will be the LV terminals of the 132/22kV transformer.

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

Not applicable.

10. Division of Responsibilities

A division of responsibilities document will be required to cover the changes to the interface boundaries with Ergon Energy. The Project Manager will be required to draft the document after project approval and consult with the Project Sponsor who will arrange sign-off between Powerlink and the relevant customer.

11. Related Projects

No related projects.

Concept Estimate for CP.02370 - T048 Tully No 2 Transformer Replacement

Record ID	A3328026	
Policy stream	Asset Management	
Authored by	[redacted]	Project Manager
Reviewed by	[redacted]	Project Manager
Reviewed by	[redacted]	Team Leader
Approved by	[redacted]	Manager Projects

Contents

1. Executive Summary

T048 Tully Substation was originally established in 1976 as a 132kV injection point into Far North Queensland to supply the Energy Queensland (EQ) distribution network in the region south of Innisfail. T048 Tully Substation has two 132/22kV 20MVA transformers (Tx1 & Tx2).

The transformer 2 unit is over 40 years of age and is displaying significant condition issues typical of transformers of this age.

As indicated in the Project Scope Report, the target commissioning date is June 2024. To minimise network and load at risk issues, the transformer outage will be scheduled during the 22 week sugarcane crushing season when additional local generation is available, generally May to September. A revised commissioning date of 30th October 2024, is proposed.

This proposal has been estimated for an 'in situ' replacement of Transformer 2.

The objective of this project is to replace transformer 2, in situ, with a new 20/27MVA transformer unit by the proposed commissioning date of October 2024.

1.1 Project Estimate

Estimate Components		Base $	Escalated $
Estimate Class	5		
Estimate Accuracy	+100% / -50%		
Base Estimate		**5,171,334**	**6,039,218**
Mitigated Risk	[redacted]	[redacted]	[redacted]
Contingency Allowance	[redacted]	[redacted]	[redacted]
TOTAL		[redacted]	[redacted]

1.2 Project Financial Year Cash Flows

	June 2020 Base $	Escalated $
To June 2020	5,623	5,621
To June 2021	18,323	19,075
To June 2022	18,323	19,857
To June 2023	1,556,551	1,755,964
To June 2024	2,673,906	3,140,141
To June 2025	898,608	1,098,560
TOTAL	**5,171,334**	**6,039,218**

2. Project and Site Specific Information

2.1 Project Dependencies & Interactions

No significant dependencies and interactions have been identified.

2.2 Site Specific Issues

The T048 Tully site is located on flat terrain on the southern side of the Tully Falls road, at the junction with Sandy Creek road. It is approximately 3km south-west of the township of Tully in Far North Queensland.

Traffic control will be required to ensure safe access and egress from the T048 Tully Substation for the removal and delivery of the transformers and primary plant items.

It is expected that external stakeholder management will be required to advise Kareeya Power Station and property owners of the T048 Tully Substation work.

No works are expected at the remote end substations for the project works.

3. T048 Transformer No.2 Replacement

3.1 Definition

3.1.1 Scope

The project consists of the ‘In Situ’ replacement of the 132/22kV 20 MVA Transformer 2 with a 132/22 kV 20/27 MVA ONAN/ONAF and Neutral Earthing Transformer (NEX/NER) at T048 Tully Substation.

High Level Line Diagram included in Figure 1 below.

Figure 1 - High Level Line Diagram - Tully Substation

[redacted]

3.1.1.1 Substations Works

Replace existing 132/22kV 20MVA Star/Delta transformer, including all necessary works:

- procure 1 x 132/22kV 20/27MVA Star/Delta transformer, with on load tap changer and cooling facilities;
- procure a new suitably sized neutral earthing transformer for connection to the new Transformer 2;
- geotechnical works to confirm ground conditions;
- decommission, disassemble, remove and dispose of old T2 transformer unit;
- demolish, remove and dispose of existing Transformer 2 bund and foundations;
- construct new Transformer 2 bund and foundations;
- construct new fire wall;
- reroute 22kV cable to new secondary bushing;
- install a new 1 x 132/22kV 20/27MVA Star/Delta transformer unit;
- upgrade 132kV & 22kV surge arrestors; and
- modify protection, automation and communication systems as necessary to accommodate the new transformer.

3.1.1.2 Transmission Line Works

Not applicable.

3.1.1.3 Telecommunication Works

Not applicable.

3.1.1.4 Easement/Land Acquisition & Permit Works

Not applicable.

3.1.2 Major Scope Assumptions

It is assumed that the follow:

- The existing Oil Separation tank and general arrangement will be of sufficient capacity to accommodate the new transformer and neutral earthing transformer. This estimate includes the connection of the new transformer bund area to the existing oil separation pipes and environmental control measures.
- The reuse of the existing transformer foundations would be subject to a detailed assessment, it is anticipated that the existing foundations will not be suitable and that replacement is required as per the scope. Therefore the estimates allows for the removal of existing transformer foundations and construction of new foundations.
- The general arrangement and footprint of the new 20/27MVA transformer will be similar to existing Transformer 1 (repositioned 22kV bushings).
- That all foundations will designed and constructed as High level / Mass pour foundations due to previous geotechnical reports that have been conducted at various locations within the T048 Tully Substation.
- It has been assumed that an extended outage will be available outside the summer peak period for in-situ replacement of Transformer 2 at T048 Tully Substation. This outage is considered high risk and there would be additional costs if outages of the required duration cannot be obtained.
- That there is no need to replace the existing protection and control panels at T048 Tully as the site has recently completed a Secondary System Upgrade, so the protection relays are the current generation (SEL 487E & ABB RET 670) and these panels and relays are suitable to accommodate the new T2 transformer arrangement. Only costs for reuse of the existing relays and panels have been included in the estimate.
- Overheard earth wire above Transformer 2 can be removed for the duration of the construction and commissioning.

- Required modifications to Energy Queensland assets will be performed by Energy Queensland accordingly and within the required timeframes to avoid delaying Powerlink work.
- The existing substation platform does not require major upgrade or replacement works.
- No Energy Queensland 22kV interface works is required, as this should have been completed at the last secondary system upgrade.
- No upgrade work required for the AC Change over board and associated supply cables.
- The Metering is compliant and may only require a ratio change for compliance due to the larger Transformer.
- There may be access issues with 132kV hybrid Bays to disconnect and re-connect the 132kV High Voltage Droppers and will require Live Substation team to assist.
- The redundant Transformer 2 will not be required for network contingency support.
- This project will be delivered using Powerlink internal design, a Substation Panel Contractor under a Construct Only contract. With the Maintenance Service Provider performing the testing and commissioning resources.
- Existing road pavement and geometry is sufficient to facilitate removal of existing transformers and delivery and installation of the new transformer.
- Existing ground conditions are suitable for the construction of foundations and no allowance has been made for unexpected ground conditions such as rock, unsuitable material, contamination etc.

3.1.3 Scope Exclusions

- Replacement of oil separation tank as desktop review has determined that the capacity of the existing oil separation tank it sufficient therefore the replacement of the oil separation tank has been excluded from this concept estimate.
- Replacement of associated bay plant equipment to achieve load rating compatible with new transformer ratings. A desktop review has determined that the capacity of the existing bay plant equipment is adequate.
- All works for the contingency plan as the project outages are expected to be high risk and a detailed contingency plan will need to be prepared and agreed with Network Operations. The contingency plan may include a requirement for retention of the removed transformer on site as a spare and installation of temporary bridging outside the substation.
- Any Major upgrade or replacement works for the existing substation platform.
- All works to upgrade the existing road pavement and geometry facilitate the removal of existing transformers and delivery and installation of the new transformer.
- No allowance has been made for unexpected ground conditions such as rock, unsuitable material, contamination etc.
- Any modification works for the Transformer 2 - Circuit breaker.
- Any works to replace Energy Queensland 22kV assets.
- All additional costs for a change in the delivery strategy other than the resources identified in this concept estimate.

3.2 Project Execution

3.2.1 Project Schedule

A High Level Project Schedule should be developed and should address the following project stages:

Task	Target Completion
Project Approval	November 2022
Design Commencement	June 2022
Procurement Orders	March 2023
Procurement Deliveries	July 2024
Contract Award	February 2024
MSP works to Decommission Transformer 2	April 2024
Contractor Site Access Date	June 2024
Transformer 2 Construction	June to September 2024
Transformer 2 Commissioning	September 2024
Project Commissioned	October 2024
Project Closure	October 2025

3.2.2 Network Impacts

The proposed Transformer 2 outage is scheduled for a duration of five (5) months, that mirrors the local 'sugar cane crushing' period, as a third party generator will be in operation during this period to assist in network support, if required.

3.2.3 Project Staging

Stage	Description/Tasks
1	Geotechnical works to confirm ground conditions for design
2	MSP to isolate and decommission Transformer 2 • Transformer 2 – Secondary and primary • Disassemble, remove and dispose of redundant Transformer 2
3	Contractor to construct / supervise • Removal of Transformer 2 bund / foundations • Remove redundant secondary system cabling • Install New secondary systems cabling • Supervise New Transformer installation – Transformer contractor • Construct and install new HV droppers between the new transformer and circuit breaker • NER foundations
4	MSP to terminate HV droppers from transformer circuit breaker and 132kV bus, terminate, test and commission 22kV cable, Transformer 2 and neutral earthing transformer

3.2.4 Resourcing

- Live subs maybe required to disconnect 132kV T2 CB due to clearance and access issues.
- Resources for the project will be a combination:
  - contractor will be engaged by a Construct only contract;
  - MSP to complete decommissioning activities, removal of transformer 2, all final terminations and commissioning for the new Transformer 2 arrangement; and
  - Powerlink resources to complete the internal design, supervision and commissioning activities.

3.3 Project Estimate

Estimate Components		Base $	Escalated $
Estimate Class	5		
Estimate Accuracy	+100% / -50%		
Base Estimate		**5,171,334**	**6,039,218**
Mitigated Risk	[redacted]	[redacted]	[redacted]
Contingency Allowance	[redacted]	[redacted]	[redacted]
TOTAL		[redacted]	[redacted]

3.4 Project Financial Year Cash Flows

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To June 2024	2,673,906	3,140,141
To June 2025	898,608	1,098,560
TOTAL	**5,171,334**	**6,039,218**

3.5 Project Asset Classification

Asset Class	Asset Life	Base $	Percentage
Secondary systems	15 years	309,230	6%
Communications	15 years		
Primary plant	40 years	4,862,104	94%
Transmission lines	50 years		
TOTAL		**5,171,334**	

4. Reference

Document name	Version	Date
Project Scope Report	1.0	11/02/2020