Powerlink Queensland

Project Assessment Conclusions Report

25 October 2019

Maintaining power transfer capability and reliability of supply at Lilyvale

Document Purpose

For the benefit of those not familiar with the National Electricity Rules (the Rules) and the National Electricity Market (NEM), Powerlink offers the following clarifications on the purpose and intent of this document:

1. The Rules require Powerlink to carry out forward planning to identify future reliability of supply requirements and consult with interested parties on the proposed solution as part of the Regulatory Investment Test for Transmission (RIT-T). This includes replacement of network assets in addition to augmentations of the transmission network.
2. Powerlink must identify, evaluate and compare network and non-network options (including, but not limited to, generation and demand side management) to identify the '*preferred option*' which can address future network requirements at the lowest net cost to electricity consumers. This assessment compares the net present value (NPV) of all credible options to identify the option that provides the greatest economic benefits to the market.
3. This document contains the results of this evaluation, and a final recommended solution to address the condition risks arising from the ageing transformers and primary plant at Lilyvale Substation by October 2022.

Contents

Executive Summary

Lilyvale Substation, located approximately 50km from Emerald, plays a critical role in the supply of electricity to customers in Queensland's Central West region, as well as the Blackwater and Bowen Basin mining areas. Planning studies have confirmed there is a long-term requirement to continue to supply the existing electricity services provided by Lilyvale Substation supporting a diverse range of customer needs in the area.

Commissioned over 38 years ago, much of the substation's primary plant, including two of the original three 132/66 kV transformers, are reaching the end of their technical service lives and are no longer supported by the manufacturer, with limited spares available to rectify a failure if one were to occur.

The increasing likelihood of faults arising from the condition of Lilyvale's ageing and obsolete transformers and primary plant remaining in service beyond October 2022, exposes customers to the risks and consequences of an increasingly unreliable electricity supply.

There is a requirement for Powerlink to address these emerging risks. As the identified need for the proposed investment is to meet reliability and service standards specified within Powerlink's Transmission Authority and to ensure Powerlink's ongoing compliance with Schedule 5.1 of the National Electricity Rules (the Rules) and relevant jurisdictional obligations[1], it is classified as a 'reliability corrective action'[2].

This Project Assessment Conclusions Report (PACR) represents the final step in the RIT-T process prescribed under the Rules undertaken by Powerlink to address the condition risks arising from the ageing transformers and primary plant at Lilyvale Substation. It contains the results of the planning investigation and the cost-benefit analysis of credible options compared to a non-credible Base Case where the emerging risks are left to increase over time. In accordance with the RIT-T, the credible option that maximises the net present value (NPV) of economic benefit, or minimises the costs, is recommended as the preferred option.

Credible options considered

Powerlink has developed two credible network options to maintain the existing electricity services, ensuring an ongoing reliable, safe and cost effective supply to customers in the area. The options result in different substation configurations by 2027, with the existing three 132/66kV 80MVA transformers being replaced by three 100MVA transformers in Option 1 and by two 160 MVA transformers in Option 2.

By addressing the condition risks, both options presented allow Powerlink to meet the identified need and continue to meet the reliability and service standards specified within Powerlink's Transmission Authority, Schedule 5.1 of the Rules and relevant jurisdictional obligations.

Powerlink published a Project Specification Consultation Report (PSCR) in May 2019 to address the risks arising from the condition of the ageing transformers and primary plant at Lilyvale Substation.

Interest was shown by three non-network proponents in response to the PSCR, and subsequent discussions were held with two, however the proponents ultimately decided not to progress with formal submissions. As a result, no additional credible options to meet the identified need were identified as part of this RIT-T consultation.

The two credible network options, along with their net present values (NPVs) relative to the Base Case are summarised in Table 1. Option 2 is ranked first of the two credible options, with the highest NPV relative to the Base Case.

[1] Electricity Act 1994, Electrical Safety Act 2002 and Electricity Safety Regulation 2013
[2] The Rules clause 5.10.2, Definitions, reliability corrective action.

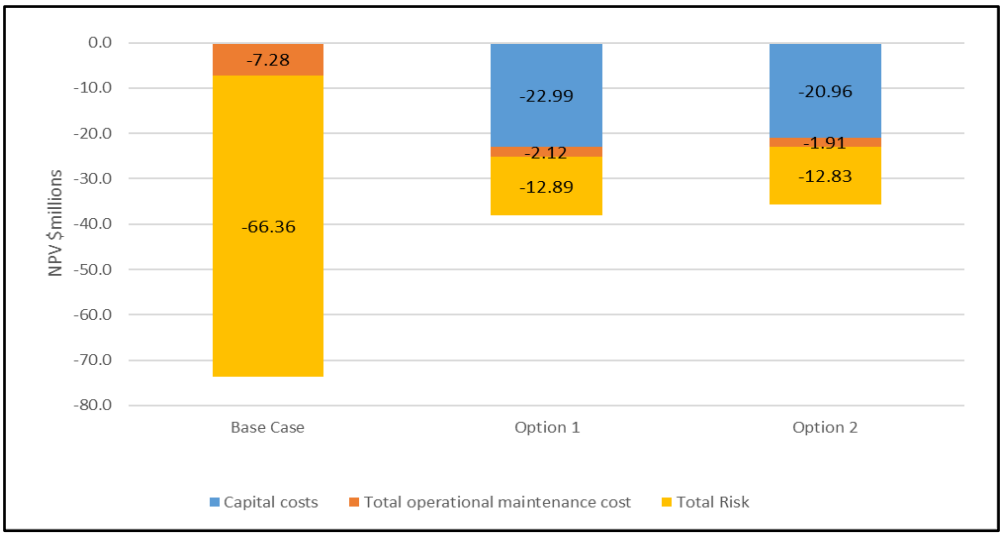
Table 1: Summary of credible RIT-T network options

Option	Description	Total Cost ($m) 2018/19	NPV relative to Base Case ($m) 2018/19	Ranking
Option 1	Replacement of two 132/66kV 80MVA transformers with two 100MVA transformers and full-bay replacement of primary plant in selected bays by October 2022.	25.39*	35.65	**2**
	Replacement of remaining 80MVA transformer with 100MVA transformer by December 2027	8.13†		
	TOTAL	**33.52**		
Option 2	Replacement of two 132/66kV 80MVA transformers with two 160MVA transformers and full-bay replacement of primary plant in selected bays by October 2022.	26.27*	37.95	**1**
	Decommissioning of remaining 80MVA transformer by December 2027	1.96†		
	TOTAL	**28.23**		

*RIT-T Project
†Future modelled projects (operational and capital).

The absolute NPVs of the Base Case and the credible options are negative, shown graphically in Figure 1. All options reduce the total risk and maintenance costs arising from the ageing and obsolete assets at Lilyvale remaining in service, with Option 2 having the largest reduction and reflecting a net economic benefit of $37.95 million compared to the Base Case.

Figure 1: NPV of Base Case and Options ($m, 2018/19)



Evaluation and Conclusion

The RIT-T requires that the proposed preferred option maximises the present value of net economic benefit, or minimises the net cost, to all those who produce, consume and transport electricity in the market.

In accordance with the expedited process for this RIT-T, the PSCR made a draft recommendation to implement Option 2, which delivers a net economic benefit of $37.95m compared to the Base Case.

The RIT-T project for Option 2 involves the replacement of two 132/66kV 80MVA transformers with two 160MVA transformers and the full bay replacement of primary plant in selected bays by October 2022. The substation's third 80MVA transformer will be decommissioned under a separate operational project by December 2027. The indicative capital cost of the RIT-T project for the preferred option is $26.27 million in 2018/19 prices.

Under Option 2, design work would commence in 2020 with the installation of the new transformers and primary plant completed by October 2022.

As the outcomes of the economic analysis contained in this PACR remain unchanged from those published in the PSCR, the draft recommendation has been adopted without change as the final recommendation, and will now be implemented.

1. Introduction

This Project Assessment Conclusions Report (PACR) represents the final step of the RIT-T process[3] prescribed under the National Electricity Rules (the Rules) undertaken by Powerlink to address the condition risks arising from the ageing and obsolete transformers and primary plant at Lilyvale Substation. It follows the publication of the Project Specification Consultation Report (PSCR) in May 2019.

The Project Specification Consultation Report (PSCR):

- described the identified need that Powerlink is seeking to address, together with the assumptions used in identifying this need
- set out the technical characteristics that a non-network option would be required to deliver in order to address the identified need
- described the credible options that Powerlink considered may address the identified need
- discussed specific categories of market benefit that in the case of this RIT-T assessment are unlikely to be material
- presented the Net Present Value (NPV) economic assessment of each of the credible options (as well as the methodologies and assumptions underlying these results) and identified the preferred option and that Powerlink was claiming an exemption from producing a Project Assessment Draft Report (PADR)
- invited submissions and comments, in response to the PSCR and the credible options presented, from Registered Participants, the Australian Energy Market Operator (AEMO), potential non-network providers and any other interested parties.

Powerlink identified Option 2, the replacement of two 132/66kV 80MVA transformers with two 160MVA transformers and the full bay replacement of primary plant in selected bays by October 2022, as the preferred option. The indicative capital cost of the RIT-T project for the preferred option is $26.27 million in 2018/19 prices.

The Rules clause 5.16.4(z1) provides for a Transmission Network Service Provider to claim exemption from producing a PADR for a particular RIT-T application if all of the following conditions are met:

- the estimated capital cost of the preferred option is less than $43 million
- the preferred option is identified in the PSCR noting exemption from publishing a PADR
- the preferred option, or other credible options, do not have a material market benefit, other than benefits associated with changes in involuntary load shedding[4]
- submissions to the PSCR did not identify additional credible options that could deliver a material market benefit.

There were no submissions received in response to the PSCR that closed for consultation on 21 August 2019. As a result, no additional credible options that could deliver a material market benefit have been identified as part of this RIT-T consultation. As the conditions for exemption are now satisfied, Powerlink has not issued a PADR for this RIT-T and is now publishing this PACR, which:

- describes the identified need and the credible options that Powerlink considers address the identified need
- discusses the consultation process followed for this RIT-T together with the reasons why Powerlink is exempt from producing a PADR

[3] This RIT-T consultation was commenced in May 2019 and has been prepared based on the following documents: National Electricity Rules, Version 121, 2 May 2019 and AER, Application guidelines, Regulatory investment test for transmission, December 2018.
[4] Section 4.3 Project assessment draft report, Exemption from preparing a draft report, AER, Application guidelines, Regulatory investment test for transmission, December 2018

- provides a quantification of costs and reasons why specific classes of market benefit are not material for the purposes of this RIT-T assessment
- provides the results of the net present value (NPV) analysis for each credible option assessed, together with accompanying explanatory statements
- identifies the preferred option for investment by Powerlink and details the technical characteristics and proposed commissioning date of the preferred option.

2. Customer and non-network engagement

Delivering electricity to almost four million Queenslanders, Powerlink recognises the importance of engaging with a diverse range of customers and stakeholders who have the potential to affect, or be affected by, Powerlink's activities and/or investments.

2.1 Powerlink takes a proactive approach to engagement

Powerlink regularly hosts a range of engagement forums and webinars, sharing information with customers and stakeholders in the broader community. These engagement activities help inform the future development of the transmission network and assist Powerlink in providing services that align with the long term interests of customers. Feedback from these activities is also incorporated into a number of publicly available reports.

2.2 Working collaboratively with Powerlink's Customer Panel

Powerlink's Customer Panel provides a face-to-face opportunity for customers and consumer representative bodies to give their input and feedback about Powerlink's decision making, processes and methodologies. It also provides Powerlink with a valuable avenue to keep customers better informed, and to receive feedback about topics of relevance, including RIT-Ts.

The Customer Panel is regularly advised on the publication of Powerlink's RIT-T documents and briefed quarterly on the status of current RIT-T consultations, as well as upcoming RIT-Ts, providing an ongoing opportunity for:

- the Customer Panel to ask questions and provide feedback to further inform RIT-Ts
- Powerlink to better understand the views of customers when undertaking the RIT-T consultation process.

2.3 Transmission Annual Planning Report (TAPR) – the initial stage of public consultation

Powerlink utilises the TAPR as a primary vehicle to engage and understand broader consumer, customer and industry views on key topics as part of the annual Transmission Network Forum (TNF) and to inform its business network and non-network planning objectives. TNF participants encompass a diverse range of stakeholders including customers, landholders, environmental groups, Traditional Owners, government agencies, and industry bodies.

2.3.1 Maintaining transfer capabilities and reliability of supply at Lilyvale

- Powerlink identified in its TAPR from 2016, an expectation that action would be required at Lilyvale Substation to maintain transfer capabilities and reliability of supply to customers in the Central West transmission zone[5].
- The 2018 and 2019 TAPRs also discussed and provided technical information in relation to the identified need of this RIT-T.
- Members of Powerlink's Non-network Engagement Stakeholder Register (NNESR) were directly advised of the publication of the TAPR each year[6], including the accompanying compendium of potential non-network solution opportunities (Appendix F), which sets out

[5] This relates to the standard geographic definitions (zones) identified within the TAPR.
[6] More recently this also included the publication of a TAPR template containing detailed technical data for the connection point at Lilyvale Substation.

the indicative non-network requirements to meet the identified need at Lilyvale Substation. The NNESR were also advised of the publication of the PSCR for this RIT-T.

- The Customer Panel was advised of the upcoming RIT-T consultation for Lilyvale Substation in December 2018.

2.4 Powerlink applies a consistent approach to the RIT-T stakeholder engagement process

Powerlink undertakes a considered and consistent approach to ensure an appropriate level of stakeholder engagement is undertaken for each individual RIT-T. Please visit Powerlink's website for detailed information on the types of engagement activities, which may be undertaken during the consultation process. These activities focus on enhancing the value and outcomes of the RIT-T engagement process for customers and non-network providers. Powerlink welcomes feedback from all stakeholders to improve the RIT-T stakeholder engagement process.

3. Identified need

This section provides an overview of the existing arrangements at Lilyvale Substation and describes the increasing risk to reliability of supply to customers in the Central West transmission zone due to the assessed deteriorated condition of the transformers and selected primary plant assets at the substation.

3.1 Geographical and network need

Lilyvale Substation was established in 1980 to supply the mining load in the Bowen Basin and Blackwater Regions of Central Queensland. It connects the generation points in Central Queensland to the Blackwater and Bowen Basin mining regions, providing the main 275kV injection into western Central Queensland. This region of the network, in which Lilyvale is an integral node, also hosts a significant quantity of generation including levels of renewable and embedded generation.

Lilyvale Substation operates as a major transmission connection point supplying the Central Queensland distribution region owned and operated by Ergon Energy, mining and rail traction loads. The 66kV network fed from Lilyvale also supplies several direct connect mining customers that operate large draglines resulting in significant load fluctuations. The Central West transmission zone is shown in Figure 3.1.

Figure 3.1: Central West transmission zone

3.2 Description of asset condition and risks

Powerlink has undertaken a comprehensive condition assessment of the transformers and primary plant at Lilyvale Substation. This has identified that a significant amount of equipment is exhibiting age-related deterioration issues and reaching the end of its technical service life, with an increasing risk of failure.

This deteriorated primary plant is requiring additional maintenance and displaying reduced performance due to increased failures and an increased number of outages for repairs. The time taken for repairs is increasing significantly, as much of this plant is no longer supported by the manufacturer, with only limited spares available.

Notwithstanding the assessed condition of the asset, Powerlink's ongoing operational maintenance practices are designed to monitor plant condition and ensure any emerging safety risks are proactively managed.

Power Transformers

Commissioned over 38 years ago, the original 132/66kV transformers are all exhibiting signs of age-related deterioration, particularly by the condition of their oil and paper insulation, main tank and bushing seals as well as the corrosion of external fittings. Transformers 3 and 4 are assessed to be in a more deteriorated condition than Transformer 7 and provide an emerging risk to the reliable and safe supply of electricity to customers at Lilyvale, and more broadly into the central west transmission zone.

Protective galvanised coatings have begun to break down on several components including radiators, connecting pipework, control system cabinets, bushing mountings and flanges. The sealing integrity of numerous joints and valves has been compromised, resulting in an increased observation of oil leaks at radiators, bushings and the conservator tank.

Analysis has also shown the transformers' winding paper insulation has deteriorated and is nearing the end of its technical service life, with approximately three years of reliable operation remaining for Transformers 3 and 4. While Transformer 7 has experienced some insulating paper degradation, the measurements indicate there are approximately eight years remaining before it will reach the end of its technical service life.

The design of the winding clamping mechanism used in these older transformers also results in a loss of residual clamping pressure as the paper deteriorates, reducing the overall resilience of the transformers to through faults. The failure of transformer insulation during a through fault can have major consequences to reliability of supply, safety and the environment because of the potential for oil loss and fire.

A number of components on Transformers 3 and 4 have been repaired and/or replaced due to numerous failures.

The age and design of the transformers also means that replacements for many key components are now no longer available; hence, obsolescence has also become an issue with ongoing maintenance of the transformers.

Primary Plant

At-risk primary plant comprises circuit breakers, current and voltage transformers, isolators, earth switches and surge arrestors.

Circuit Breakers

Installed in the 1980s, the substation's ageing circuit breakers are no longer supported by their manufacturers and sourcing spare parts has become a major issue. Low air pressure in the breakers' compressor systems has resulted in a number of outages, while the wiring inside several mechanism boxes has cracked due to UV penetration through the boxes' sight glasses. SF6 gas leaks have also become a major issue on four circuit breakers procured in 1985, with the supplier no longer manufacturing HV circuit breakers.

The deteriorated state of these original circuit breakers has resulted in an increasing frequency of unplanned outages and prolonged repair times due to the lack of spares and no manufacturer support. These circuit breakers also contain friable asbestos that requires additional safety precautions when working on the units.

With limited spares available from the manufacturers, it is becoming increasingly difficult for Powerlink to service this ageing population of circuit breakers more broadly across the Powerlink transmission network.

Current and Voltage Transformers

Insulation breakdown and oil leaks pose the biggest risk to the ongoing operation of the ageing current and voltage transformers at Lilyvale Substation. The ageing process has the most significant impact on the integrity of the various seals. The deteriorated state of the aged seals has led to moisture ingress into the insulating oil causing it to breakdown. As the transformer's insulating oil breaks down, it releases a combination of combustible gases and loses its insulating properties.

The moisture migrates into the paper insulation causing its rapid degradation. The insulating paper degradation combined with continuing degradation of the oil ultimately results in the occurrence of partial discharges across insulation, which can result in arcing in the presence of highly combustible gases, leading to an increased probability of catastrophic failure. The oil is contained within porcelain housings, which can rupture when failure occurs, resulting in safety risks, reliability of supply impacts, and potential damage to adjacent equipment and plant requiring repairs and incurring financial costs.

3.3 Consequences of Lilyvale primary plant and transformer failures

Poor asset condition increases the risk and frequency of faults, while obsolescence increases the time needed for Powerlink to undertake any necessary repairs prolonging the return to service time. The potential in-service failure of ageing and obsolete transformers and primary plant at Lilyvale presents Powerlink with a range of unacceptable safety, network and financial risks, and the inability to meet legislative obligations and customer service standards.

The condition and consequences of failure of the main at-risk items of equipment is summarised in Table 3.1.

Table 3.1: Lilyvale at-risk assets and consequences of failure

Equipment	Condition/Issue	Consequence of failure
Circuit Breakers	• Loss of pneumatic pressure • Release of SF6 gas into the atmosphere • Frequent maintenance required to add SF6 to ensure the CB remains functional • Limited availability of spares	• Failure to operate or slow clearance times resulting in safety and supply risks • Extended time to restore supply to customers due to a limited availability of spares • Potential environmental impacts • Increased maintenance resulting in less reliable and more costly supply to customers
Current Transformers	• Degraded oil and paper insulation inside porcelain housings • Oil leaks.	• Significant safety, financial, environmental and loss of supply risks • Potential for explosive failure modes leading to damage of other equipment and extended loss of supply

Equipment	Condition/Issue	Consequence of failure
Voltage Transformers	• Degraded oil and paper insulation inside porcelain housings • Oil leaks and overheating	• Significant safety, financial, environmental and loss of supply risks • Potential for explosive failure modes leading to damage of other equipment and loss of supply • Loss of protection signals resulting in disconnection of supply • Breach of metering requirements[7]
Power Transformers	• Degraded oil and paper insulation • Deteriorated cooling fans and radiators • Significant oil leaks. • Reduced clamping pressure due to clamp design • Loss of insulating paper strength • Limited availability of spares	• Increased susceptibility of power transformer failure during through faults leading to loss of supply with long return to service time. • Risk of fire and environmental damage.

Notwithstanding the assessed condition of the asset, Powerlink's ongoing operational maintenance practices are designed to monitor plant condition and ensure any emerging safety risks are proactively managed.

3.4 Description of identified need

With peak demand forecast to remain steady in the area for the next ten years[8], it is vital that Powerlink maintains supply to satisfy this demand and meet its reliability obligations under its Transmission Authority, the Electricity Act 1994 and the Rules[9].

It follows that the increasing likelihood of faults arising from the deteriorated condition of the at-risk transformers and primary plant remaining in service at Lilyvale Substation compels Powerlink to take action if it is to continue to meet its regulatory obligations and the standards for reliability of supply set out in the Rules.

Powerlink's Transmission Authority requires it to plan and develop the transmission network "in accordance with good electricity industry practice, having regard to the value that end users of electricity place on the quality and reliability of electricity services". It allows load to be interrupted during a critical single network contingency, provided the maximum load and energy will not exceed 50MW at any one time, or will not be more than 600MWh in aggregate[10].

In order to continue to meet the reliability standard within Powerlink's Transmission Authority, the services currently provided Lilyvale Substation are required for the foreseeable future to meet ongoing customer requirements.

Under the Electricity Act 1994, Powerlink is required to "operate, maintain (including repair and replace if necessary) and protect its transmission grid to ensure the adequate, economic reliable and safe transmission of electricity"[11]. The condition of the ageing assets at Lilyvale requires Powerlink to take action to either repair, replace or remove them, while taking into consideration the enduring need for the services they provide, to ensure compliance with the Electricity Act 1994.

The Electrical Safety Act 2002 also requires Powerlink to operate its network in a manner that ensures electrical risk to a person or property has been eliminated, so far as is reasonably

[7] Chapter 7, Part D, Metering Installation and Schedule 7.2 Metering Provider, AER
[8] Powerlink Transmission Annual Planning Report 2019
[9] Transmission Authority Number T01/98, as amended 30 June 2014; Electricity Act 1994; The Rules, Schedule 5.1a System Standards and Schedule 5.1.2 Network Reliability
[10] Transmission Authority No. T01/98, section 6.2(c)
[11] Electricity Act 1994, Chapter 2, Part 4, S34(1)(a)

practicable; or if it is not reasonably practicable to eliminate electrical risk to the person or property, the risk has been minimised so far as is reasonably practicable[12].

As the proposed investment is to meet reliability and service standards specified within applicable regulatory instruments, and to ensure Powerlink's ongoing compliance with its Transmission Authority and Schedule 5.1 of the Rules, it is classified as a "reliability corrective action", under the RIT-T[13].

A reliability corrective action differs from that of an increase in producer and consumer surplus (market-benefit) driven need in that the preferred option may have a negative net economic outcome because it is required to meet an externally imposed obligation on the network business.

3.5 Rules, Jurisdictional and Legislative Compliance

The consequences of Lilyvale's Transformers 3 and 4 and at-risk primary plant remaining in service beyond 2022, without corrective action, would result in Powerlink being exposed to an unacceptable risk of breaching a number of its jurisdictional network, safety, environmental and Rules' obligations - resulting in poor customer, safety and environmental outcomes.

Allowing the ageing and obsolete transformers to remain in service beyond 2022 without corrective action increases the potential risk of catastrophic failure. This would lead to a breach of Powerlink's obligations under the Electrical Safety Act 2002, the Electrical Safety Regulations 2013, Work Health and Safety Act 2011and Environmental Protection Act 1994, as well as its service standards under the Electricity Act 1994 and it's Queensland Transmission Authority[14].

Similarly, the failure of the circuit breakers to operate or clear faults in sufficient time to avoid damage to the power system could leave Powerlink unable to comply with Schedule 5.1 of the Rules[15], or meet its public safety and supply obligations to its customers. Corrective action is also required to prevent the failure of deteriorated current and voltage transformers, in order to ensure the safety of personnel, and that the plant operates as designed in accordance with the requirements of the Electrical Safety Regulations 2013 Part 1 Section 3 and Part 9 Section 198.

Removing the deteriorated assets from service will in many cases eliminate the risk of breaching these obligations. However, removing the assets from the Powerlink network without a suitable network or non-network alternative will result in Powerlink not complying with the Rules or its Transmission Authority, as discussed below.

The removal of the power transformers or any of the circuit breakers, or other affected primary plant, at Lilyvale will result in the need for load shedding to ensure that the system is able to be operated without breaching clause 4.2.2(d) of the Rules:

> *"all other plant forming part of or impacting on the power system is being operated within the relevant operating ratings (accounting for time dependency in the case of emergency ratings) as defined by the relevant Network Service Providers in accordance with schedule 5.1."*

The load shedding requirement under an intact system, as well as for a credible contingency, would result in breaches of Powerlink's Transmission Authority T01/98 clause 6.2 (c), where Powerlink must plan and develop its transmission network such that:

> *"the power transfer available through the power system will be such that the forecast of electricity that is not able to be supplied during the most critical single network element outage will not exceed:*
>
> *(i) 50 megawatts at any one time; or*
>
> *(ii) 600 megawatt-hours in aggregate."*

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[12] Electrical Safety Act 2002 sections 10 and 29
[13] The Rules clause 5.10.2, Definitions, reliability corrective action.
[14] *Section 29, Electrical Safety Act 2002*; P*art 1, Section 3, and Part 9, Section 198, Electrical Safety Regulations 2013; Section 19, Work Health and Safety Act 2011*; *Chapter 7, Part 1, Division1 Section 319(1), Environmental Protection Act 1994*; *Section 34 (1)a Electricity Act 1994*; Queensland Transmission Authority T01/98
[15] The Rules Schedule 5.1.9 Protection systems and fault clearance times

By addressing the risks arising from the condition of ageing and obsolete assets at Lilyvale, Powerlink is seeking to ensure it can continue to safely deliver an adequate, economic, and reliable supply of electricity to its customers into the future.

4. Submissions received

There were no formal submissions received in response to the PSCR that was open for consultation until the 21 August 2019.

Interest was shown by three non-network proponents in response to the PSCR, with subsequent discussions being held with two. However, the proponents ultimately decided not to progress with any formal submissions. As a result, no additional credible options to meet the identified need were identified as part of this RIT-T consultation.

5. Credible options assessed in this RIT-T

Powerlink has developed two credible network options to address the identified need for maintaining power transfer capabilities and reliability of supply at Lilyvale Substation. In both options, work commences for the RIT-T project in 2020, with commissioning in October 2022.

- Option 1: Replacement of two 132/66kV 80MVA transformers with 100MVA transformers and full-bay replacement of primary plant in selected bays by October 2022. Replacement of the remaining 80MVA transformer with a 100MVA transformer by December 2027. The RIT-T portion of this option would be completed by October 2022 at a cost of $25.39 million in 2018/19 prices.
- Option 2: Replacement of two 132/66kV 80MVA transformers with two 160MVA transformers and full-bay replacement of primary plant in selected bays by October 2022. Decommissioning of the remaining 80MVA transformer by December 2027. The RIT-T project component portion of this option would be completed by October 2022 at a cost of $26.27 million in 2018/19 prices.

Due to the higher rating of the new transformers installed under Option 2, Transformer 7 will not be replaced at the end of its technical service life in 2027, resulting in a configuration consisting of two, 160MVA 132/66kV transformers at Lilyvale instead of three. Option 1 however will result in a substation configuration consisting of three 132/66kV 100MVA transformers in 2027.

Table 5.1 provides a summary of the options, along with indicative capital and annual operational and maintenance costs.

Table 5.1: Summary of credible options

Option	Description	Indicative project costs ($million, 2018/19)	Indicative annual average O&M costs ($million, 2018/19)
Option 1	Replacement of 3 and 4 power transformers with two 100MVA transformers and full replacement of 132kV and 275kV primary plant in selected bays by October 2022*	25.39*	0.16
	Replacement of 7 transformer with a third 100MVA transformer and full replacement of primary plant in associated bays by December 2027†	8.13†	

Option	Description	Indicative project costs ($million, 2018/19)	Indicative annual average O&M costs ($million, 2018/19)
Option 2	Replacement of 3 and 4 power transformers with two 160MVA transformers and full replacement of 132kV and 275kV primary plant in selected bays by October 2022*	26.27*	0.14
	Decommissioning of transformer 7 by December 2027†	1.96†	

*Proposed RIT-T project
†Future modelled projects (operational and capital)

All credible options address the major risks resulting from the deteriorated condition of ageing transformers and primary plant at Lilyvale Substation and allow Powerlink to maintain compliance with obligations specified in its Transmission Authority, Schedule 5.1 of the Rules and applicable regulatory instruments. None of these options has been discussed by the Australian Energy Market Operator (AEMO) in its most recent National Transmission Network Development Plan (NTNDP)[16].

5.1 Material inter-network impact

Powerlink does not consider that any of the credible options being considered will have a material inter-network impact, based on AEMO's screening criteria[17].

6. Materiality of market benefits

The Rules require that all categories of market benefits identified in relation to a RIT-T be quantified, unless the Transmission Network Service Provider (TNSP) can demonstrate that a specific category (or categories) is unlikely to be material.

6.1 Market benefits that are material for this RIT-T assessment

Powerlink considers that changes in involuntary load shedding (i.e. the reduction in expected unserved energy) between the options, set out in this PSCR, may impact the ranking of the credible options under consideration and that this class of market benefit could be material. Consequently, these benefits have been quantified and included within the cost benefit and risk cost analysis as network risk.

6.2 Market benefits that are not material for this RIT-T assessment

The AER has recognised a number of classes of market benefits may not be material in the RIT-T assessment and so do not need to be estimated[18]. Other than market benefits associated with involuntary load shedding, Powerlink does not consider any other category of market benefits to be material, and had not estimated them as part of this RIT-T.

More information on consideration of individual classes of market benefits can be found in the PSCR.

[16] Clause 5.16.4(b) (4) of the Rules requires Powerlink to advise whether the identified need and or solutions are included in the most recent NTNDP. The 2018 NTNDP is currently the most recent NTNDP.
[17] In accordance with Rules clause 5.16.4(b) (6) (ii). AEMO has published guidelines for assessing whether a credible option is expected to have a material inter-network impact.
[18] AER, Application guidelines, Regulatory investment test for transmission, December 2018.

7. Base Case

7.1 Modelling a Base Case under the RIT-T

Consistent with the RIT-T Application Guidelines the assessment undertaken in this PACR[19] compares the costs and benefits of credible options to address the risks arising from an identified need, with a Base Case[20].

As characterised in the RIT-T Application Guidelines, the Base Case itself is not a credible option to meet the identified need. Specifically, the Base Case reflects a state of the world in which the condition of the ageing asset is only addressed through standard operational activities, with escalating safety, financial, environmental and network risks.

To develop the Base Case, the existing condition issues associated with an asset are managed by undertaking operational maintenance only, which results in an increase in risk levels as the condition of the asset deteriorates over time. These increasing risk levels are assigned a monetary value that is used to evaluate the credible options designed to offset or mitigate these risk costs.

The Base Case therefore includes the costs of work associated with operational maintenance (i.e. routine, condition-based and corrective maintenance) and the risk costs associated with the irreparable failure of the asset. The costs associated with irreparable failures are modelled in the risk cost analysis and are not included in the corrective maintenance costs.

The Base Case acts as a benchmark and provides a clear reference point in the cost benefit analysis to compare and rank the credible options against, over the same timeframe.

7.2 Lilyvale Base Case risk costs

Powerlink has developed a risk modelling methodology consistent with the RIT-T Application Guidelines. An overview document of the methodology is available on Powerlink's website[21] and this has been used to calculate the risk costs of the Lilyvale Base Case. The document includes the modelling methodology and general assumptions underpinning the analysis.

7.2.1 Base Case assumptions

In calculating the potential unserved energy (USE) arising from a failure of the ageing and obsolete transformers and primary plant at Lilyvale, the following modelling assumptions specific to the Lilyvale network configuration have been made:

- A suitable spare transformer is available as an emergency replacement in the event of non-repairable failure of one of the aged transformers.
- The downstream Ergon Energy 66kV distribution network supplying the greater Lilyvale and Blackwater area is available to provide a level of backup supply in the event of equipment failure.
- Embedded generation within the area operates while Lilyvale Substation remains energised to reduce the impacts of unserved energy in the event of equipment failures.
- Historical load profiles and embedded generation patterns have been used when assessing the likelihood of unserved energy under concurrent failure events.
- Peak demand for the greater Lilyvale load area consistent with medium demand forecasts published within Powerlink's 2018 Transmission Annual Planning Report have been used[22].
- Unserved energy generally accrues under concurrent failure events, and consideration has been given to potential feeder trip events within the wider Lilyvale area.
- The Lilyvale load comprises of a mix of load types, including open cut mining, underground mining, traction loads, and residential township. The network risk cost models have used

[19] The economic assessment was also presented in the PSCR.
[20] AER, Application guidelines, Regulatory investment test for transmission, December 2018.
[21] The risk costs are calculated using the principles set out in the Powerlink document, Overview of Asset Risk Cost Methodology, May 2019.
[22] The forecast remains unchanged in the 2019 TAPR.

the Queensland regional Value of Customer Reliability (VCR) published within AEMO 2014 Value of Customer Reliability Review Final Report ($39,710/MWh).

- Powerlink's business response to mitigating unserved energy under prolonged supply outage events has been incorporated within the risk cost modelling.

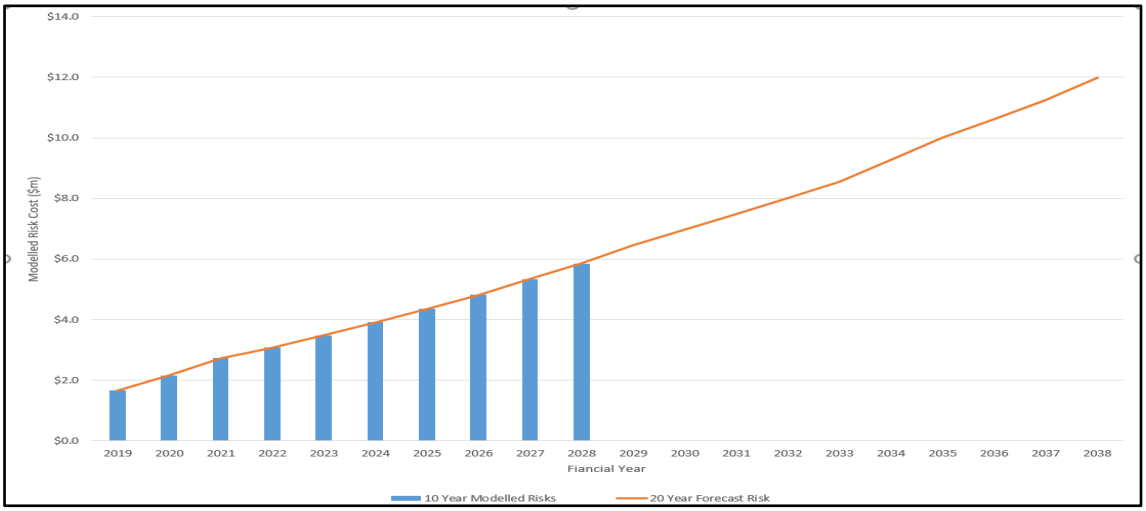
7.2.2 Base Case risk costs

The main areas of risk cost are network risks that involve reliability of supply through the failure of the deteriorated primary plant and transformers modelled as probability weighted unserved energy[23], financial risk costs associated mostly with the replacement of failed assets in an emergency and safety risks. These risks increase over time as the condition of assets further deteriorates and the likelihood of failure rises.

Based upon the assessed condition of the ageing transformers and primary plant at Lilyvale, the total risk costs are projected to increase from $1.67 million in 2019 to $11.9 million in 2038.

The 20-year forecast of risk costs for the Base Case is shown in Figure 7.1.

Figure 7.1: Modelled Base Case risk costs



7.3 Modelling of Risk in Options

Each option is specifically scoped to mitigate the major risks arising in the Base Case in order to maintain compliance with all statutory requirements. The residual risk is calculated for each option based upon the individual implementation strategy of the option. This is included with the capital and operational maintenance cost of each option to develop the NPV inputs.

8. General modelling approach adopted for net benefit analysis

8.1 Analysis period

The RIT-T analysis has been undertaken over a 20-year period, from 2019 to 2038. A 20-year period takes into account the size and complexity of the replacement primary plant and transformer investment.

For all options, there will be remaining asset life by 2038, at which point a terminal value is calculated to account for capital costs under each credible option.

[23] Unserved Energy is modelled using a Value of Customer Reliability (VCR) consistent with that published by AEMO in their *Value of Customer Reliability Review, Final Report*, September 2014.

8.2 Discount rate

Under the RIT-T, a commercial discount rate is applied to calculate the NPV of costs and benefits of credible options. Powerlink has adopted a real, pre-tax commercial discount rate of 5.90%[24] as the central assumption for the NPV analysis presented in this report.

Powerlink has tested the sensitivity of the results to changes in this discount rate assumption, and specifically to the adoption of a lower bound discount rate of 3.47%[25] and an upper bound discount rate of 8.33% (i.e. a symmetrical upwards adjustment).

8.3 Description of reasonable scenarios

The RIT-T analysis is required to incorporate a number of different reasonable scenarios, which are used to estimate market benefits. The number and choice of reasonable scenarios must be appropriate to the credible options under consideration.

The choice of reasonable scenarios must reflect any variables or parameters likely to affect the ranking of the credible options, where the identified need is reliability corrective action[26].

Powerlink has considered capital costs and discount rate sensitivities individually and in combination and found that these variables do not affect the relative rankings of credible options or identification of the preferred option. As sensitivities (both individually and in combination) do not affect ranking results, Powerlink has elected to present one central scenario in Table 8.1.

Table 8.1: Reasonable scenario assumed

Key variable/parameter	Central scenario
Capital costs	100% of central capital cost estimate
Discount rate	5.90%

9. Cost benefit analysis and identification of the preferred option

9.1 NPV Analysis

Table 9.1 outlines the net present value for each credible option and the corresponding ranking of each credible option, relative to the Base Case.

Table 9.1: NPV of credible options ($m, 2018/19)

Option	Central Scenario NPV relative to Base Case ($m)	Ranking
Option 1 Replacement of two 132/66kV 80MVA transformers with two 100MVA transformers and full-bay replacement of primary plant in selected bays by October 2022. Replacement of remaining 80MVA transformer with 100MVA transformer by December 2027	35.65	2

[24] This indicative commercial discount rate has been calculated on the assumptions that a private investment in the electricity sector would hold an investment grade credit rating and have a return on equity equal to an average firm on the Australian stock exchange, as well as a debt gearing ratio equal to an average firm on the Australian stock exchange.
[25] A discount rate of 3.47% is based on the AER's Final Decision for Powerlink's 2017-2022 transmission determination, which allowed a nominal vanilla WACC of 6.0% and forecast inflation of 2.45% that implies a real discount rate of 3.47%. See AER, *Final Decision: Powerlink transmission determination 2017-2022 | Attachment 3 – Rate of return*, April 2017, p 9.
[26] AER, *Final Regulatory Investment Test for Transmission*, June 2010, version 1, paragraph 16, p. 7

Option	Central Scenario NPV relative to Base Case ($m)	Ranking
Option 2 Replacement of two 132/66kV 80MVA transformers with two 160MVA transformers and full-bay replacement of primary plant in selected bays by October 2022. Decommissioning of remaining 80MVA transformer by December 2027	37.95	1

Both credible options will address the identified need on an enduring basis. Option 2 is ranked first, with Option 1 being $2.3 million more expensive compared to Option 2 in NPV terms.

Option 2 is identified as the preferred option as it maximises the net economic benefit relative to the Base Case.

Figure 9.1: NPV of Base Case and Options ($m, 2018/19)

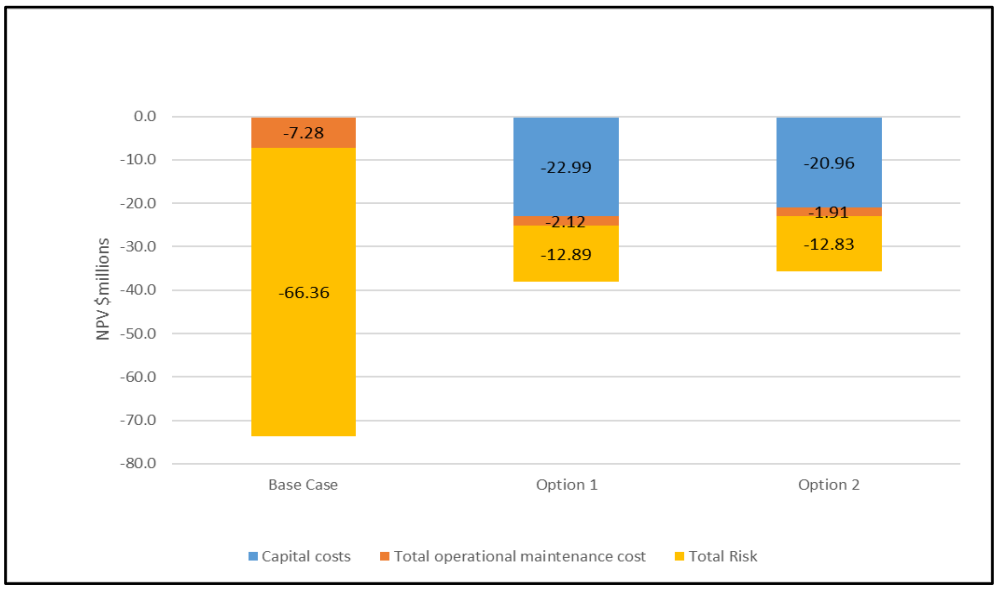


Figure 9.1 sets out the breakdown of capital cost, operational maintenance cost and total risk cost for each option in NPV terms under the central scenario. It illustrates that the capital investment for the two credible options, that address risks arising from the transformers and primary plant at Lilyvale Substation, will result in benefits from a reduction in risk costs, as well as a reduction in operational maintenance costs when compared to the Base Case. Note that the non-credible Base Case consists of operational maintenance and total risk costs and does not include any capital expenditure.

The reduction in operational maintenance costs is similar for both Option 1 and Option 2, though there is a greater reduction in Option 2, as the ultimate configuration for Option 2 results in only two 132/66kV transformers from 2027 instead of three as for Option 1.

Similarly, the reduction in risk costs is comparable between the options, resulting in a slightly greater reduction in Option 2; mostly due to less financial and safety risks associated with the ultimate two 132/66 kV transformer configuration.

9.2 Sensitivity analysis

Powerlink has investigated the following sensitivities on key assumptions:

- a range from 3.47% to 8.33% for discount rate
- a range from 75% to 125% for capital expenditure estimates
- a range from 75% to 125% for operational maintenance expenditure estimates
- a range from 75% to 125% for total risk cost estimates.

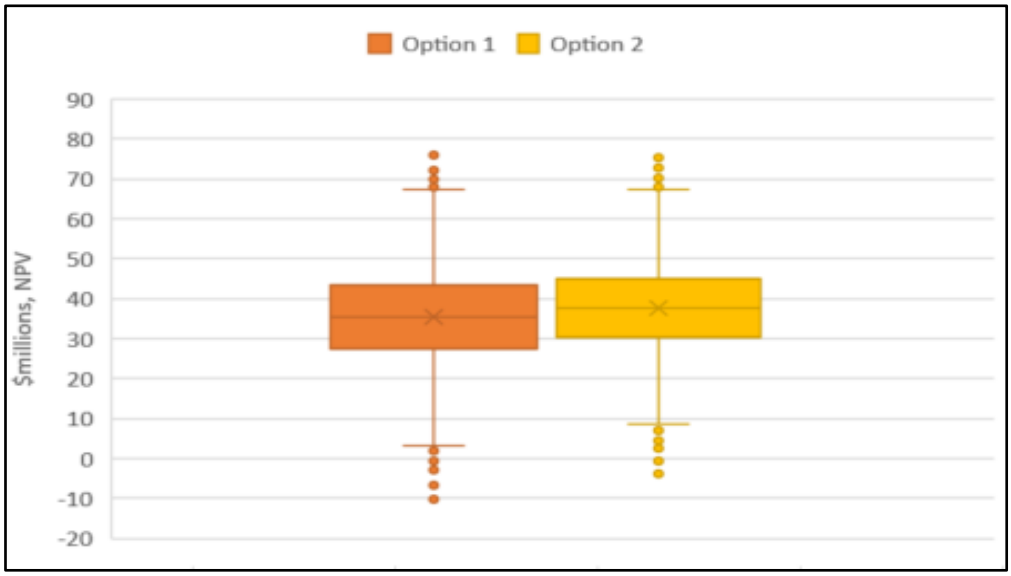
Sensitivity analysis for the NPV relative to the Base Case shows that varying the discount rate, capital expenditure, operational maintenance expenditure and total risk costs has no impact on option rank, and hence which is the preferred option.

9.3 Sensitivity to multiple key assumptions

A Monte Carlo Simulation was performed with multiple input parameters (including capital cost, discount rate, operational maintenance cost, corrective maintenance cost and total risk costs) generated for the calculation of NPV for each option. This process is repeated over 5000 iterations, each time using a different set of random variable from the probability function. The sensitivity analysis output is presented as a distribution of possible NPVs for each option, as illustrated in Figure 9.2.

The Monte Carlo simulation results identify that Option 2 has slightly less statistical dispersion in comparison with Option 1 and its mean and median is the higher of the two options. This confirms Option 2 as the preferred option and shows it to be robust over a range of input parameters in combination.

Figure 9.2: NPV sensitivity analysis of multiple key assumptions relative to the Base Case



10. Preferred option

Based on the conclusions drawn from the NPV analysis and the Rules requirements relating to the proposed replacement of transmission network assets, it is recommended that Option 2 be implemented to address the risks arising from the deteriorated condition of the ageing transformers and primary plant at Lilyvale Substation. Implementing this option will provide an ongoing safe and reliable electricity supply to customers in the area and ensure continued compliance with applicable regulatory instruments and the Rules.

The result of the cost benefit analysis indicates that Option 2 has the highest net economic benefit over the 20-year analysis period. Sensitivity testing shows that the analysis is robust to variations in the capital cost, operational maintenance cost, discount rate and risk cost assumptions. Option 2 is therefore considered to satisfy the requirements of the RIT-T and is the preferred option.

11. Conclusions

The following conclusions have been drawn from the analysis presented in this report:

- Powerlink has identified condition risks arising from the ageing transformers and primary plant at Lilyvale Substation.
- TNSPs must maintain (including repair and replace if necessary) their transmission network to ensure the adequate, economic, reliable and safe transmission of electricity, including the ability to meet peak demand if a major element of the network was to fail.

- The increasing likelihood of faults arising from the condition of the ageing transformers and primary plant compels Powerlink to undertake reliability corrective actions at Lilyvale Substation if it is to continue meeting the reliability standards set out in its Transmission Authority and to ensure ongoing compliance with the Rules and relevant jurisdictional obligations.
- Studies were undertaken to evaluate two credible options. The two credible options were evaluated in accordance with the AER's RIT-T.
- Powerlink published a PSCR in May 2019 requesting submissions from Registered Participants, AEMO and interested parties on the credible options presented, including alternative credible non-network options, which could address the condition risks arising from the transformers and primary plant at Lilyvale Substation.
- The PSCR also identified the preferred option and that Powerlink was adopting the expedited process for this RIT-T, claiming exemption from producing a PADR as allowed for under the Rules Clause 5.16.4(z1) for investments of this nature.
- There were no formal submissions received in response to the PSCR, which was open for consultation until 21 August 2019. As a result, no additional credible options that could deliver a material market benefit have been identified as part of this RIT-T consultation. The conditions specified under the Rules for exemption have now been fulfilled.
- The result of the cost benefit analysis under the RIT-T identified that Option 2 is the least cost solution, providing the greatest economic benefit, over the 20 year analysis period. Sensitivity testing showed the analysis is robust to variations in discount rate, capital expenditure, operational maintenance expenditure and risk cost assumptions. As a result, Option 2 is considered to satisfy the RIT-T.
- The outcomes of the economic analysis contained in this PACR remain unchanged from those published in the PSCR. Consequently, the draft recommendation has been adopted without change as the final recommendation and will now be implemented.

12. Final Recommendation

Based on the conclusions drawn from the NPV analysis and the Rules requirements relating to the proposed replacement of transmission network assets, it is recommended that Option 2 be implemented to address the risks arising from the condition of the ageing transformers and primary plant at Lilyvale Substation. Option 2 allows Powerlink to continue to maintain compliance with its Transmission Authority, Schedule 5.1 of the Rules and other applicable regulatory instruments, while delivering a net economic benefit of $37.95m compared to the Base Case.

Option 2 involves the replacement of two 132/66kV 80MVA transformers with two 160MVA transformers and the full bay replacement of primary plant in selected bays by October 2022. The substation's third 80MVA transformer will be decommissioned by December 2027 under a separate operational project.

The indicative capital cost of the RIT-T project for the preferred option is $26.27 million in 2018/19 prices. Powerlink is the proponent of this network solution.

Under Option 2, design work would commence in 2020 with the installation of the new transformers and primary plant completed by October 2022.

Powerlink will now proceed with the necessary processes to implement this recommendation.

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