Powerlink Queensland

Project Assessment Conclusions Report

22 February 2021

Managing voltage control in Central Queensland

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 voltage control in Central Queensland by 2023.

Contents

Executive Summary

Minimum transmission flows between Central and Northern Queensland have been decreasing over the past 5 years, with this trend forecast to continue into the future.

The main driver of this change has been the progressive displacement of traditional generation in Central Queensland with increasing amounts of large scale variable renewable energy (VRE) generation in the North, coupled with a reduction in minimum daytime demand due to the uptake of small scale rooftop PV systems. This has led to an increase in the reactive charging of 275kV lines in the Central Queensland area, resulting in a growing potential for sustained over-voltage events.

Over-voltage events can result in equipment damage, loss of supply and safety issues.

The Rules specify allowable over-voltage limits and require Powerlink to take action to ensure these limits are not exceeded in order to maintain the power system in a secure state.

Current reactive plant is at capacity and Powerlink is increasingly having to manage these limits via the switching out of feeders. This operational solution is now at its technical limit and is not considered an effective sustainable strategy. Switching out of feeders on an on-going regular basis impacts system strength and reliability of supply, while increasing transmission losses and accelerating the ageing of primary plant. With reactive plant at capacity, obtaining outages for maintenance work on the plant is also becoming increasingly problematic.

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 emerging voltage control risks in Central Queensland. 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 present value of net economic benefit, or minimises the net cost, is recommended as the preferred option.

Proposed network options to address the identified need

Powerlink developed three credible network options to maintain the existing electricity services, ensuring an ongoing reliable, safe and cost effective supply to customers in the area. The major difference between the credible options relates to the location of the reactors.

By addressing the voltage control risks, all three options allow Powerlink to meet the identified need and continue to meet the reliability and service standards specified within Powerlink's Transmission Authority and Schedule 5.1 of the Rules,.

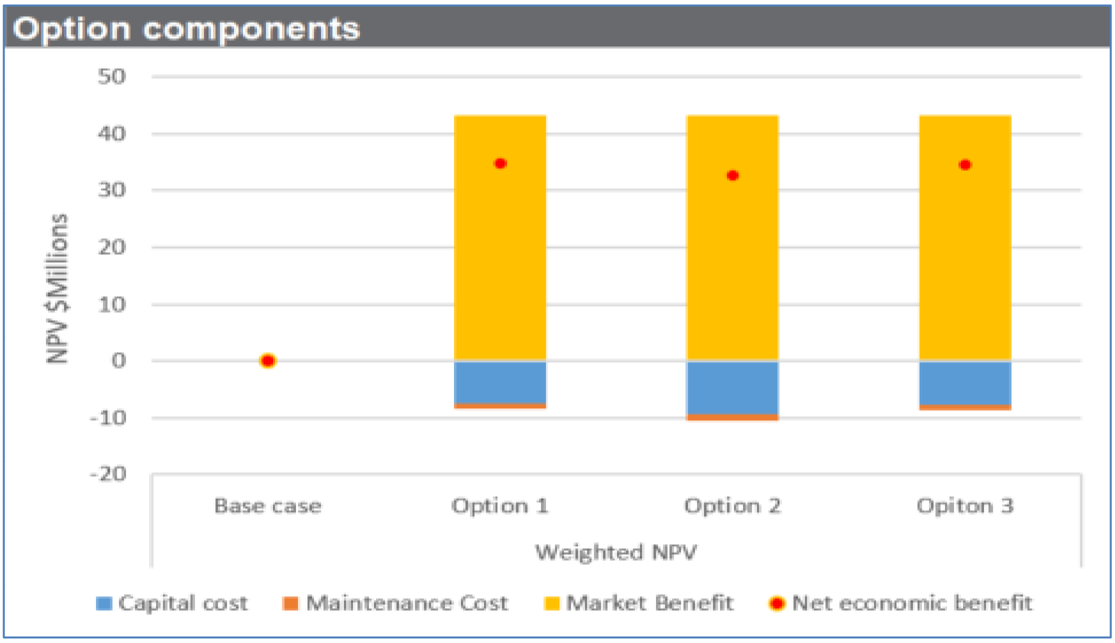
Powerlink published a Project Specification Consultation Report (PSCR) in October 2020 to address the risks of over-voltage events in Central Queensland. No formal submissions were received in response to the PSCR that closed on 8 January 2021. As a result, no additional credible options have been identified as a part of this RIT-T consultation.

The three credible network options, along with their NPVs relative to the Base Case are summarised in Table 1. Of the three credible network options, Option 1 has the greatest benefit in NPV terms.

Table 1: Summary of the credible network options

Option	Description	Total costs ($m) 2020/21	Net Economic Benefit ($m)
1	Establish 1x 150MVAr 300kV bus reactor at H020 Broadsound by June 2023	9.63	34.80
2	Establish 2x line reactors at H020 Broadsound (1x 25MVar 300kV and 1x 35MVAr 330kV) by June 2023	12.04	32.61
3	Establish 1x 150MVAr 300kV 2bus reactor at H011 Nebo by June 2023	9.89	34.48

Figure 1: NPV of Base Case and Credible Network Options



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. The economic analysis demonstrates that Option 1 provides the greatest net economic benefit in NPV terms and is therefore the preferred option.

In accordance with the expedited process for the RIT-T, the PSCR made a draft recommendation to implement Option 1, which involves the installation of a bus reactor at Broadsound Substation by June 2023. The indicative capital cost of this option is $9.63 million in 2020/21 prices. Under Option 1, initial design work will commence in early 2021, with all work completed by June 2023. Powerlink is the proponent of the proposed network project.

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 for implementation.

Dispute Resolution

In accordance with the provisions of clause 5.16B.(a) of the NER, Registered Participants, the AEMC, Connection Applicants, Intending Participants, AEMO and interested parties may, by notice to the AER, dispute conclusions in this report in relation to:

- the application of the RIT-T,
- the basis upon which the preferred option was classified as a reliability corrective action or
- the assessment of whether the preferred option has a *material inter-regional impact* or not

Notice of a dispute must be given to the AER within 30 days of the publication date of this report. Any parties raising a dispute are also required to simultaneously provide a copy of the dispute notice to the RIT-T proponent.

1 Introduction

This Project Assessment Conclusions Report (PACR) represents the final step of the RIT-T process[1] prescribed under the National Electricity Rules (the Rules) undertaken by Powerlink to address the to address the emerging voltage control risks in Central Queensland. It follows the publication of the Project Specification Consultation Report (PSCR) in October 2020.

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 1, involving the installation of a bus reactor at Broadsound Substation by June 2023, as the preferred option to address the identified need. The indicative capital cost of this option is $9.63 million in 2020/21 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[2]
- 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 8 January 2021. 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
- provides a quantification of costs and reasons why specific classes of market benefit are not material for the purposes of this RIT-T assessment

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[1] This RIT-T consultation was commenced in October 2020 and has been prepared based on the following documents: National Electricity Rules, Version Version 148, 21 August 2020 and AER, Application Guidelines Regulatory investment test for transmission, August 2020.
[2] Section 4.3 Project assessment draft report, Exemption from preparing a draft report, AER, Application guidelines, Regulatory investment test for transmission, August 2020.

- 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

With almost five million Queenslanders and 236,000 Queensland businesses depending on Powerlink's performance, 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 activities and/or investments. Together with our industry counterparts from across the electricity and gas supply chain, Powerlink has committed to The Energy Charter.

2.1 Powerlink takes a proactive approach to engagement

Powerlink regularly hosts a range of engagement forums and webinars, sharing effective, timely and transparent information with customers and stakeholders within the broader community.

Powerlink's annual Transmission Network Forum (TNF) is a primary vehicle used to engage with the community, understand broader customer and industry views and obtain feedback on key topics.

It also provides Powerlink with an opportunity to further inform its business network and non-network planning objectives. TNF participants include customers, landholders, environmental groups, Traditional Owners, government agencies, and industry bodies.

Engagement activities such as the TNF 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 and stakeholders 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.

Powerlink will continue providing updates to and request input from the Customer Panel throughout the RIT-T consultation process.

2.3 Transparency on future network requirements

Powerlink's annual planning review findings are published in the Transmission Annual Planning Report (TAPR) and TAPR templates, providing early information and technical data to customers and stakeholders on potential transmission network needs over a 10-year outlook period. The TAPR plays an important part in planning Queensland's transmission network and helping to ensure it continues to meet the needs of Queensland electricity consumers and participants in the NEM. Powerlink undertakes engagement activities, such as a webinar and/or forum, to share with customers and stakeholders the most recent TAPR findings and respond to any questions that may arise.

In addition, beyond the defined TAPR process, Powerlink's associated engagement activities provide an opportunity for non-network alternatives to be raised, further discussed or formally submitted for consideration as options to meet transmission network needs, well in advance of

the proposed investment timings and commencement of regulatory consultations (where applicable).

2.3.1 Voltage control in Central Queensland

Powerlink identified in its 2019 and 2020 TAPR, an expectation that action would be required to address the emerging voltage control issues in Central Queensland[3].

Powerlink advised members of its Non-network Engagement Stakeholder Register (NNESR) of the publication of the TAPR.

No submissions proposing credible and genuine non-network options have been received from prospective non-network solution providers in the normal course of business, in response to the publication of the TAPR or as a result of stakeholder engagement activities.

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 that may be undertaken during the consultation process.

These activities focus on enhancing the value and outcomes of the RIT-T process for customers, stakeholders and non-network providers. Powerlink welcomes feedback from all stakeholders to help improve the RIT-T stakeholder engagement process.

2.5 The transmission component of electricity bills

Powerlink's contribution to electricity bills comprises approximately 9% of the total cost of the residential electricity bill (refer to Figure 2.1).

Figure 2.1: Components of end user bills

Detailed information on transmission pricing, including discussion on how Powerlink is actively engaging with customers and stakeholders on transmission pricing concerns, is available on Powerlink's website.

3 Identified need

This section provides an overview of the existing voltage control arrangements in Central Queensland and describes the increasing risk to Powerlink of being unable to maintain compliance with relevant standards, applicable regulatory instruments and the Rules, which are designed to ensure Powerlink's customers continue to receive safe, reliable and cost effective electricity services.

3.1 Geographical and network need

The main grid section connecting Central and Northern Queensland consists of four 275kV feeders between Nebo and Broadsound Substations, with planning studies confirming there is an enduring need for the supply of bulk electricity to Central Queensland and for the transfer of power between northern, Central and Southern Queensland[4].

The Northern and Central transmission networks are shown in Figures 3.1 and 3.1a

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[3] This relates to the standard geographic definitions (zones) identified within the TAPR.
[4] Transmission Annual Planning Report 2020, Appendix A – Compendium_ Forecast of connection point maximum demand

Figure 3.1: Northern transmission network

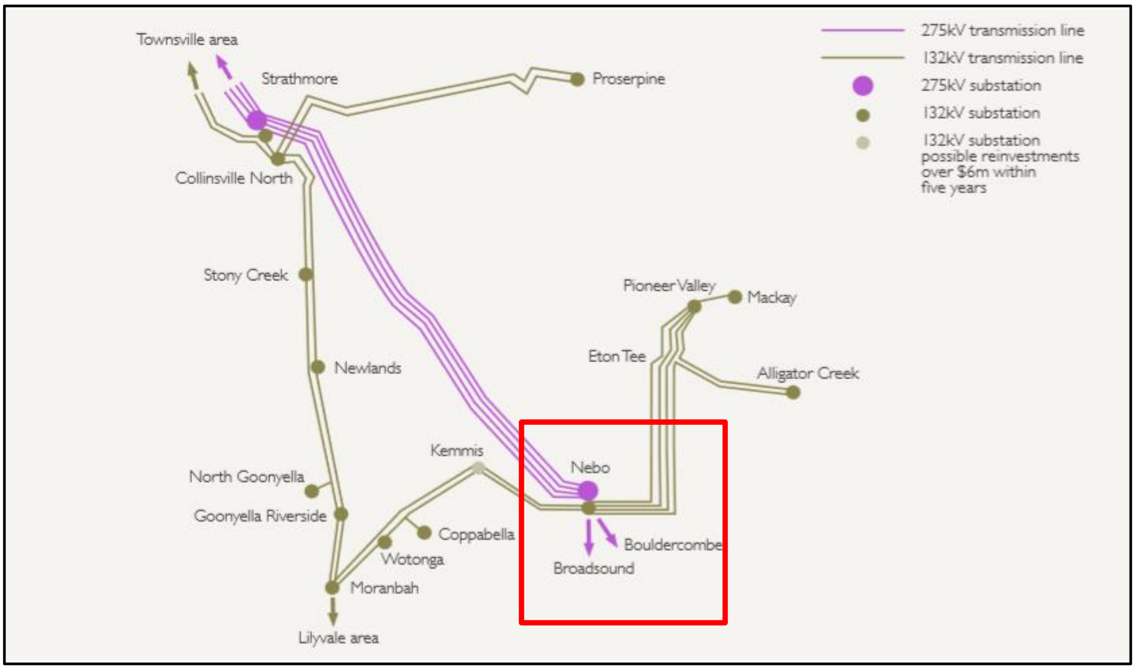
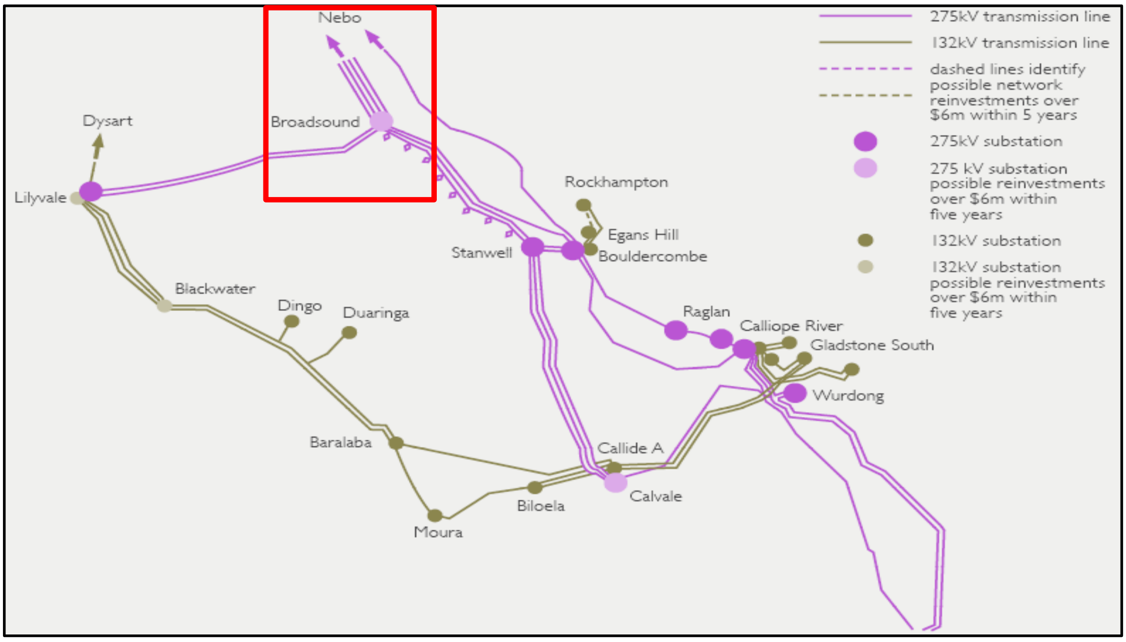


Figure 3.1a Central transmission network



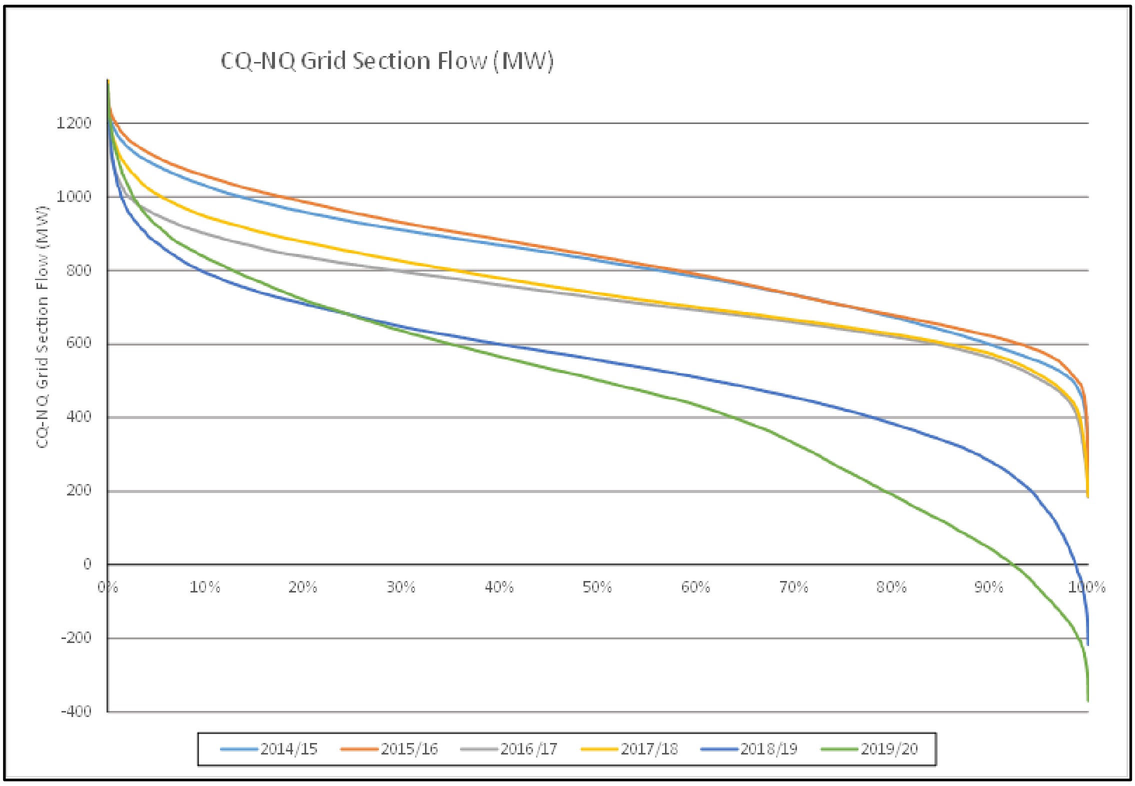
3.1.1 Increasing voltage risks associated with a rapidly transitioning energy system

An increase in the amount of large scale renewable generation in the northern zone, combined with lower minimum daytime demand, particularly since 2018/2019 has produced a declining electricity flow across the CQ-NQ grid section, (see Figure 3.2). This has resulted in an increase in the reactive charging of 275kV lines in Central Queensland, in turn producing an increase in the maximum voltages being experienced at Nebo, Broadsound and Lilyvale substations, with a sustained trend of voltages exceeding Powerlink's maximum operating voltages at Nebo.

Whilst the renewable generation in the northern zone provides additional voltage control during its operating period, its remote location relative to Broadsound and Nebo means it is unable to offset the reactive charging of the 275kV transmission lines in the area.

The rapid increase in small scale rooftop PV systems has also increased the likelihood of over-voltage events in the distribution network by reducing the minimum demand. The recent reduction of the nominal low voltage level from 240V to a 'preferred operating range' of 230 volts +6/-2% further confirms that this trend towards lower minimum demand levels will continue into the future.

Figure 3.2 CQ- NQ Flows 2014/15 – 2019/20



This combination of an increasing displacement of traditional generation, declining minimum demands and reducing transfers means the network's current ability to operate within the voltage limits prescribed in the Rules[5] is rapidly declining.

Good electricity industry practice is to maintain sufficient headroom in the system to be able to manage disturbances so that voltages do not exceed allowable safe limits. Under system normal conditions, the dynamic reactive plant (SVC) at Nebo is increasingly operating at its limit, where it would become ineffective in responding to network disturbances. The instances when the SVC is at maximum MVArs absorption have more than doubled between 2018 and 2019. With the SVC at Nebo functioning near capacity, the allowable 275kV operational voltage limits will be exceeded under key reactive plant outages.

3.2 Description of identified need

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[6].

[5] The Rules, Schedule 5.1a.4 Power frequency voltage
[6] Transmission Authority No. T01/98, section 6.2(c)

Planning studies have confirmed that in order to continue to meet the reliability standard within Powerlink's Transmission Authority, the connection points at Nebo, Broadsound and Lilyvale substations are required into the foreseeable future to meet ongoing customer requirements.

Schedule 5.1a of the Rules sets minimum standards for network service providers that:

(a) are necessary or desirable for the safe and reliable operation of the *facilities* of *Registered Participants*

(b) are necessary or desirable for the safe and reliable operation of equipment

(c) could reasonably be considered *good electricity industry practice*

S5.1a.4 states that under system normal conditions, the voltage at a connection point must not exceed 1.1 per unit. Following a credible contingency, the voltage at a connection point must be able to be restored to less than 1.1 per unit in less than 1 second. The SVC at Nebo is, in the existing system, utilised to the point that it would be unable to respond to credible network disturbances following a credible contingency, resulting in non-compliant over voltages at Nebo Substation.

S5.1.2.1 of the Rules also states "*Network Service Providers must plan, design, maintain and operate their transmission networks….to allow the transfer of power from generating units to Customers ….*" With reactive plant at capacity, obtaining outages for maintenance work is becoming increasingly difficult. Switching out lines during low load and/or low power transfer periods, to help gain access for reactive plant maintenance, reduces system strength and constrains the dispatch of renewable generation in North Queensland. Gaining access for maintenance during peak load conditions is also problematic, as these same dynamic reactive power devices are required to maintain voltage stability under high power transfer into North Queensland.

There is a need for Powerlink to address this emerging issues to ensure ongoing compliance with Schedule 5.1 of the Rules and applicable regulatory instruments, which are designed to ensure Powerlink's customers continue to receive safe, reliable and cost effective electricity services.

The proposed investment addresses the need to meet operational safety, reliability and service standards arising from Powerlink's Transmission Authority and to ensure Powerlink's ongoing compliance with Schedule 5.1 of the Rules and is categorised as 'reliability corrective action' under the Rules[7].

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.

3.3 Assumptions and requirements underpinning the identified need

Under current system normal conditions, peak operating voltages are at or near Powerlink's operational limits, while dynamic reactive plant is at its limit. Studies indicate that the current reactive capacity of the grid in this region would be unable to provide the necessary management of voltages under the forecast declines in electricity flows, resulting in over-voltages on the network following a credible contingency.

To help manage this issue, 275kV feeders in the area are increasingly being switched out for short periods, however, switching the backbone 275kV feeders to manage over voltage events in Central Queensland impacts the system strength available in North Queensland.

Under the AEMO defined minimum fault levels[8], Powerlink is obliged to maintain 1300MVA on the 275kV bus at Ross, however this is based on the intact system and loss of a critical network element. Where a prior outage is taken, the network (and connected plant) must be able to

[7] The Rules clause 5.10.2 ,Definitions, reliability corrective action
[8] [8] https://www.aemo.com.au/-/media/files/electricity/nem/security_and_reliability/system-security-market-frameworks-review/2020/2020-notice-of-queensland-system-strength-requirements-and-ross-node-fault-level-shortfall.pdf?la=en

withstand the next credible contingency. As such, in order for line switching to be utilised there would be constraints on VRE generation in North Queensland.

4 Submissions received

There were no submissions received in response to the PSCR that was open for consultation until the 8 January 2021[9]. As a result, no additional credible options that could deliver a material market benefit have been identified as part of this RIT-T consultation.

5 Credible options assessed in this RIT-T

Powerlink has developed three credible network options to address the identified need for additional voltage control capacity in the CQ-NQ grid section. All are technically and economically feasible and address the identified need in a timely manner.

Table 5.1 Summary of the credible network option

Option	Description	Total costs ($m) 2020/21	Net Economic Benefit ($m)
1	Establish 1x 150MVAr 300kV bus reactor at H020 Broadsound by June 2023	9.63	34.80
2	Establish 2x line reactors at H020 Broadsound (1x 25MVar 300kV and 1x 35MVAr 330kV) by June 2023	12.04	32.61
3	Establish 1x 150MVAr 300kV 2bus reactor at H011 Nebo by June 2023	9.89	34.48

All options are designed to:

- Maintain voltages within operational and design limits and keep the power system in a secure operating state,
- Reduce the impact on network reliability resulting from de-energising the 275kV transmission lines, and
- Reduce potential market constraints on generation resulting from de-energising the 275kV transmission lines.

None of these options have been discussed by the Australian Energy Market Operator (AEMO) in its most recent Integrated System Plan[10].

The forecast timing for implementation of the solution to address the over-voltage limitation identified in the 2020 TAPR was December 2021. Subject to the outcome of this RIT-T consultation, the earliest likely timing for the completion of works is June 2023 due to the impacts of the restrictions of the COVID-19 pandemic. The network risk associated with this limitation is being managed through a range of short-term operational measures including rescheduling of outages and the selective switching out of lines as required, until the most economical long-term solution can be implemented.

[9] Members of Powerlink's Non-network Engagement Stakeholder Register were also advised of the PSCR publication.

[10] 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 Integrated System Plan (ISP).

5.1 Option 1 - Establish 1x 150MVAr 300kV bus reactor at H020 Broadsound by June 2023

Under this option, a 275kV bus reactor would be establish at Broadsound Substation. The reactor, which would nominally be specified as 150MVAr at 300kV (126MVAr at 275kV), would be connected to the 275kV 2 bus by a dedicated reactive plant bay.

Table 5.2: Shunt reactor at Broadsound: Post N-1 events, per unit voltage values and SVC status

Existing system	Intact	Trip Nebo Reactor	Trip Broadsound Line Reactor	Trip Nebo SVC
Broadsound	1.055	1.058	1.064	1.057
Lilyvale	1.066	1.068	1.07	1.067
Nebo	1.066	1.071	1.068	1.07
Nebo SVC (MVArs)*	-28.4	-80	-56.9	0

*SVC Reactive Limit = -80MVars

The reactor at Broadsound has significant impacts on reducing steady state voltages at Broadsound, Nebo and Lilyvale, as well as significantly reducing the utilisation of the Nebo SVC.

5.2 Option 2 - Establish 2x 300kV line reactors at H020 Broadsound by June 2023

Line reactors would be installed on the following 275kV feeders

- Feeder 8831 Stanwell – Broadsound – 25MVAr @ 300kV (21MVAr @ 275kV)
- Feeder 834 Broadsound – Nebo – 35MVAr @ 300kV (39.4MVAr @ 275kV)

The reactors would both be installed at Broadsound with each 275kV reactor required to have a dedicated 275kV reactor circuit breaker. In order to limit resonance on the 275kV feeder, each reactor must be less than 50% of the charging of the feeder to which they are connected to, and the reactors are sized as such.

Table 5.3: Line reactors at Broadsound: Post N-1 events, per unit voltage values and SVC status

Existing system	Intact	Trip Nebo Reactor	Trip Broadsound Line Reactor	Trip Nebo SVC
Broadsound	1.064	1.07	1.082	1.069
Lilyvale	1.071	1.073	1.08	1.072
Nebo	1.069	1.078	1.076	1.076
Nebo SVC (MVARs)*	-59.6	-80	-80	0

*SVC Reactive Limit = -80MVars

5.3 Option 3 - Establish 1x 150MVAr 300kV 2bus reactor at H011 Nebo by June 2023

Under this option, it is proposed to establish a 275kV bus reactor at H011 Nebo. The reactor, which would nominally be specified as 150MVAr at 300kV (126MVAr at 275kV), would be connected to the 275kV 2 bus by a dedicated reactive plant bay.

Table 5.4: Shunt reactor at Nebo: Post N-1 events, per unit voltage values and SVC status

Existing system	Intact	Trip Nebo Reactor	Trip Broadsound Line Reactor	Trip Nebo SVC
Broadsound	1.067	1.069	1.075	1.066
Lilyvale	1.071	1.073	1.076	1.071
Nebo	1.063	1.068	1.066	1.062
Nebo SVC (MVARs)*	10.2	-47.5	-18.8	0

*SVC Reactive Limit = -80MVars

The reactor at Nebo has significant impacts on reducing steady state voltages at Broadsound and Nebo, and has a greater effect than the Broadsound reactor on reducing the utilisation of the Nebo SVC. The reactor at Nebo, however, does not have as significant an effect on the voltages at Lilyvale.

5.4 Material inter-network impact

Powerlink does not consider that the credible option under consideration will have a material inter-network impact, based on AEMO's screening criteria[11].

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 TNSP can demonstrate that a specific category is unlikely to be material to the option rankings.[12]

6.1 Market benefits modelled in this RIT-T assessment

Powerlink considers that changes in fuel costs, arising from the need to dispatch off-line generators into the market will have the potential to impact the NPV values of the options relative to the Base Case. However, this does not change the identification of the preferred option under this RIT-T as the ranking of options remains unchanged. These benefits have been quantified and included within the cost-benefit analysis.

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[13]. Other than changes in fuel costs associated with having to dispatch off-line generators, Powerlink does not consider any other category of market benefits to be material, and has 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.

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 PSCR compares the costs and benefits of the credible options developed to address the risks arising from an identified need, with a Base Case[14].

As characterised in the RIT-T Application Guidelines, the Base Case itself is not a credible option to meet the identified need. In developing the Base Case, the emerging over-voltage issues in Central Queensland are managed by reducing the output from VRE generators in north Queensland and despatching off-line synchronous generators in Central Queensland to provide the necessary reactive power in the system.

Accordingly, the Base Case provides a clear reference point in the cost-benefit analysis to compare any credible options (network or non-network).

[11] In accordance with Rules clause 5.16.4(b)(6)(ii). AEMO has published guidelines for assessing whether a credible option is likely to have a material inter-network impact.
[12] S3.6.1 Material classes of market benefits, AER, Regulatory investment test for transmission application guidelines, August 2020
[13] AER, Application guidelines, Regulatory investment test for transmission, December 2018
[14] AER, Regulatory investment test for transmission application guidelines, August 2020

7.2 Base Case assumptions

In calculating the costs required to dispatch off-line generators to address the over-voltage events, the following modelling assumptions have been made:

- To maintain Central Queensland voltages within acceptable limits, utilising existing reactive support, northerly flows would need to be maintained at a minimum of 200MW.
- historical load profiles have been used when assessing the amount of renewable generation that would need to be curtailed (substituted) in MWh, to achieve a minimum of 200MW northerly flow
- the models have used a differential 2020 fuel cost of $25/MWh.

Based upon historical load flows, the average annual cost of curtailing renewable generation in North Queensland and substituting it with suitable generation close to the over-voltage connection points, is $5.1m.

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 2020 to 2039. A 20-year period takes into account the size and complexity of the additional reactive plant.

There will be remaining asset life by 2039, at which point a terminal value[15] is calculated to account for any future benefits that would accrue over the balance of the asset's life.

8.2 Discount rate

Under the RIT-T, a commercial discount rate is applied to calculate the NPV of the costs and benefits of credible options. Powerlink has adopted a real, pre-tax commercial discount rate of 5.90%[16] 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%[17] and an upper bound discount rate of 8.33% (i.e. a symmetrical upwards adjustment).

8.3 Description of reasonable scenarios and sensitivities

The RIT-T analysis is required to incorporate a number of different reasonable scenarios, which are used to estimate market benefits and rank options. The number and choice of reasonable scenarios must be appropriate to the credible options under consideration and reflect any variables or parameters that are likely to affect the ranking of the credible options, where the identified need is reliability corrective action[18].

8.3.1 Reasonable Scenarios

The detailed market modelling of future generation and consumption patterns based upon the substitution of existing asynchronous generation with utility-scale renewables and changing consumer behaviour, represents a disproportionate cost in relation to the scale of the proposed network investment, and will not materially impact the ranking of options.

Given the specific and localised nature of the over-voltage limitation, the ISP scenarios from the most recent Input Assumptions and Scenario Report are not relevant to this RIT-T[19]. Powerlink

[15] Terminal value was calculated based on remaining asset value using straight-line depreciation over the capital asset life.
[16] This commercial discount rate on is based on AEMO's **2019** forecasting and planning scenarios, inputs, and assumptions report in accordance with AER, RIT-T, August 2020 paragraphs 18-19 .
[17] 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.
[18] AER, Regulatory investment test for transmission, August 2020, Section 23
[19] AER, Final: RIT–T, August 2020, sub-paragraph 20(b)

has chosen to present two reasonable scenarios consistent with the requirements for reasonable scenarios in the RIT-T instrument [20] and in accordance with the provisions of the RIT-T Application Guidelines[21].

Scenario 1: Powerlink has factored a 10% likelihood of additional reactive power capacity from renewable grid connections in the Central Queensland area becoming available to help address the over-voltage issue during the period of analysis.
Scenario 2: No additional reactive power from new connections in the area becomes available, resulting in higher fuel costs from the need to dispatch additional generation. This scenario was given a weighting of 90%.

Table 8.1: Reasonable scenario assumed

Key variable/parameter	Scenario 1 – Potential Renewable Generation near Broadsound	Scenario 2 – Without Potential Renewable Generation near Broadsound
Capital costs	100% of central capital cost estimate	100% of central capital cost estimate
Discount rate	5.90%	5.90%
Market Benefit from reduction in fuel consumption from generation dispatch	0	$5.1m p.a.
Weighting	10%	90%

9 Cost-benefit analysis and identification of the preferred option

9.1 NPV Analysis

Table 9.1 outlines the NPV of the credible network options relative to the Base Case.

Table 9.1: NPV of the credible network options relative to the Base Case ($m, 2020/21)

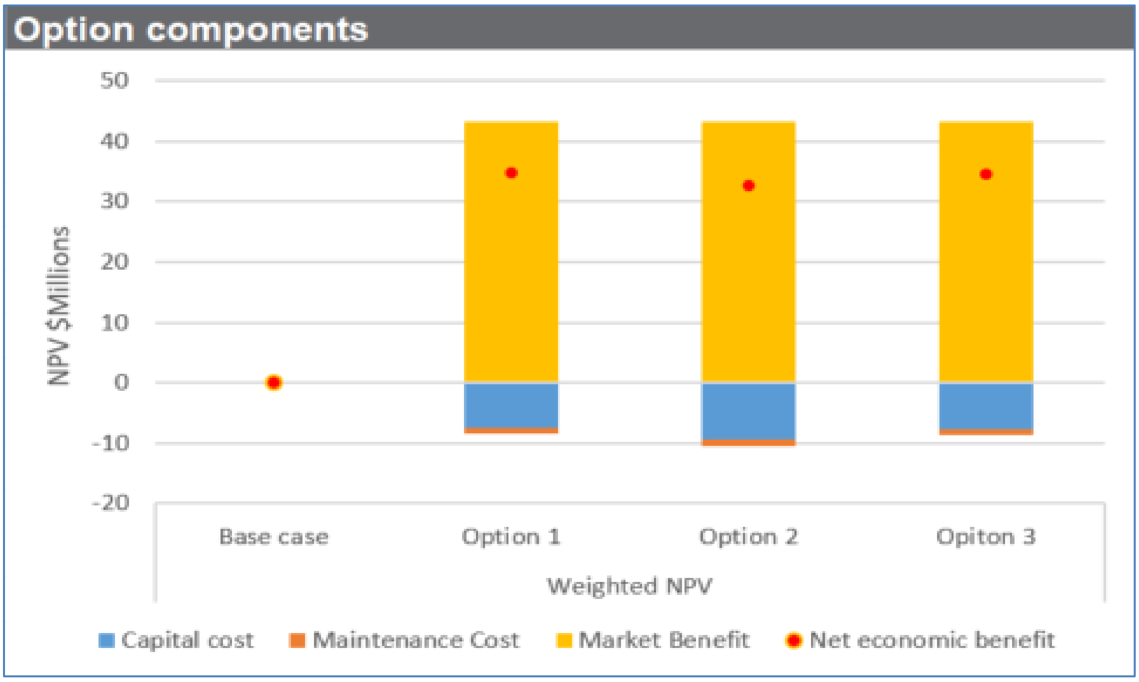
Option	Description	Net Economic Benefit ($m)	Ranking
1	Establish 1x 150MVAr 300kV bus reactor at H020 Broadsound by June 2023	34.80	1
2	Establish 2x line reactors at H020 Broadsound (1x 25MVar 300kV and 1x 35MVAr 330kV) by June 2023	32.61	3
3	Establish 1x 150MVAr 300kV 2bus reactor at H011 Nebo by June 2023	34.48	2

The credible network options address the identified need on an enduring basis by installing additional reactive capacity.

Figure 9.1 sets out the breakdown of capital cost, operational maintenance cost and market benefit of the credible options, as well as the net economic benefit in weighted NPV terms. All credible options have positive net economic benefits compared to the Base Case.

[20] AER, Final: RIT–T, August 2020, sub-paragraph 22
[21] S3.8.1 Selecting reasonable scenarios, RIT-T Application Guidelines, August 2020

Figure 9.1: NPV of the Base Case and credible option (NPV $m)



9.2 Sensitivity analysis

Sensitivity analysis was carried out to test the robustness of the analysis resulting in the preferred option and to determine if any factors would change the order of the credible options assessed:

The following sensitivities on key assumptions were investigated:

- a range from 3.47% to 8.33% discount rate
- a range from 75% to 125% of base capital expenditure estimates.
- a range from 75% to 125% of base maintenance expenditure estimates.

Figures 9.2 to 9.4 show the impacts of varying the discount rate, capital expenditure and operational maintenance expenditure on the NPV relative to the Base Case. Option 1 is the preferred option under all scenario tested.

Figure 9.2: Discount Rate Sensitivity

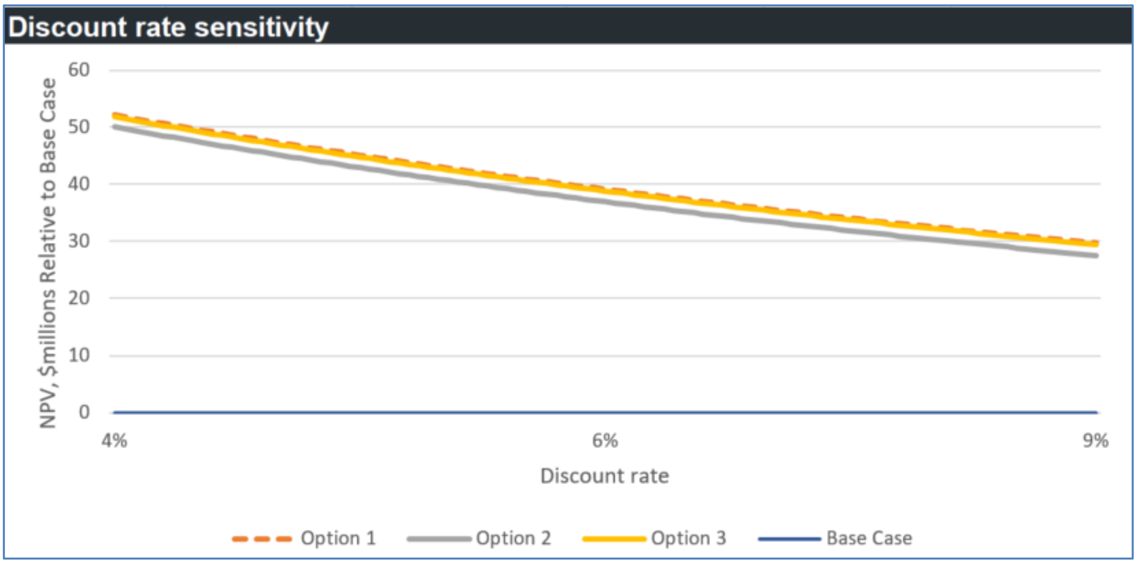


Figure 9.3: Capital Cost Sensitivity

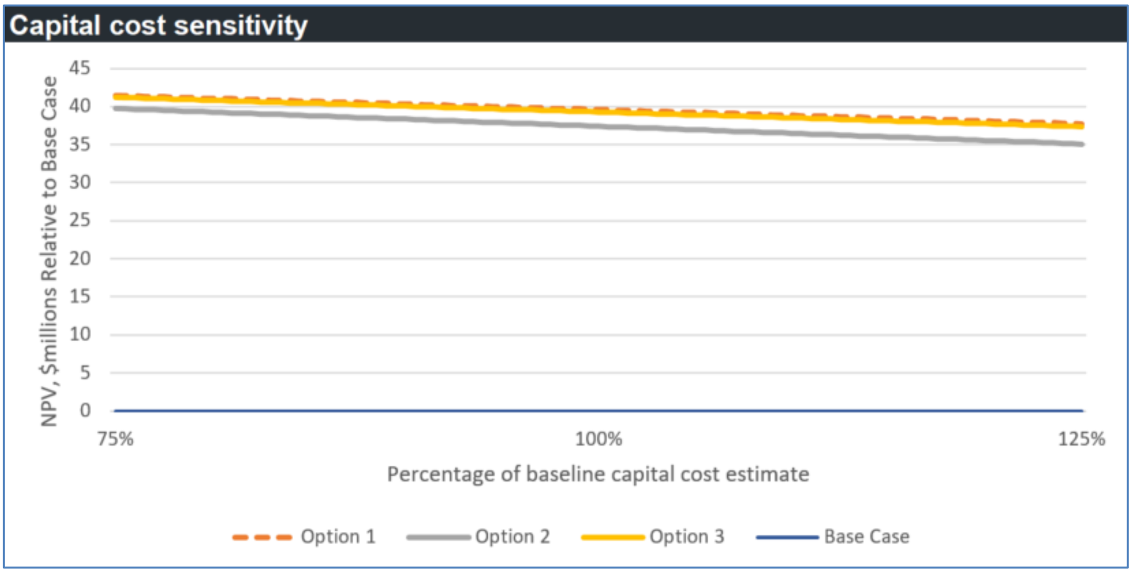
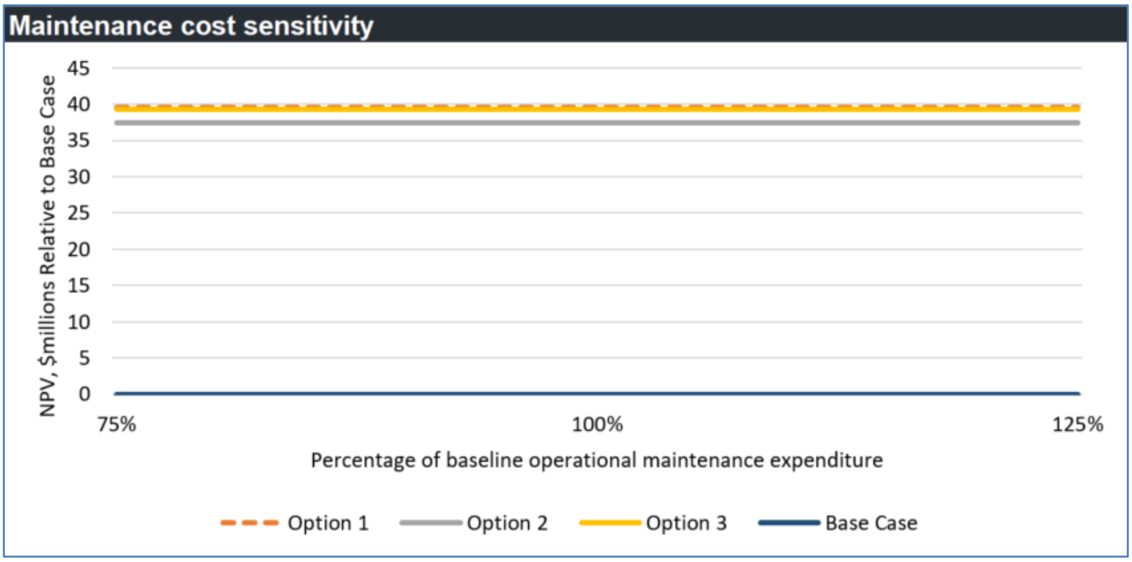


Figure 9.4: Maintenance Cost Sensitivity

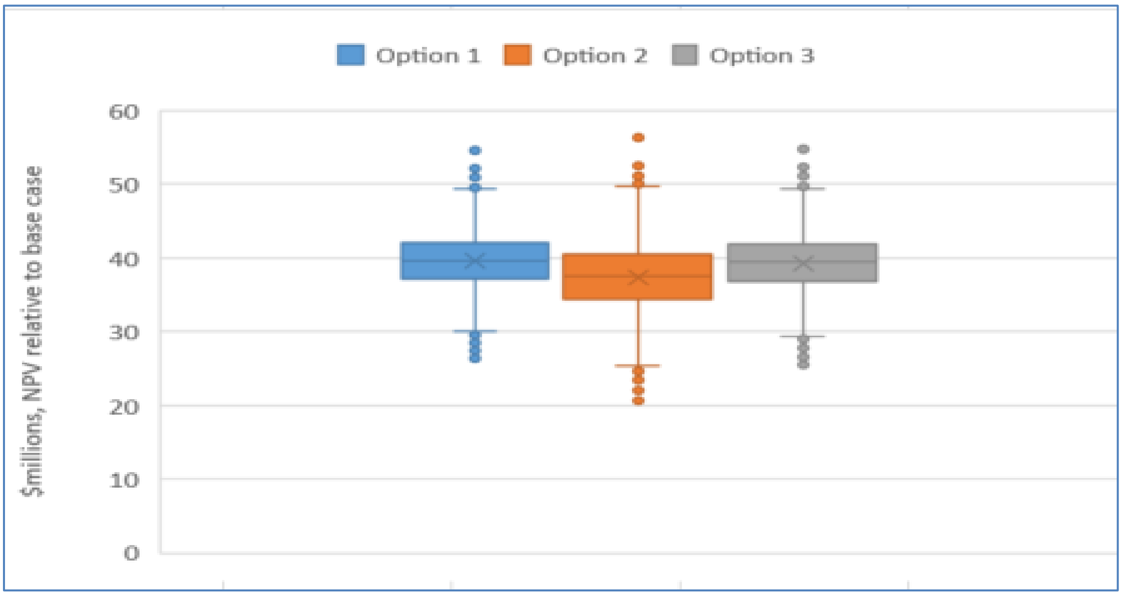


9.3 Sensitivity to multiple parameters

A Monte Carlo simulation was performed with multiple input parameters (including capital cost, discount rate, operational maintenance cost) generated for the calculation of the NPV for the credible network option. This process is repeated over 5000 iterations, each time using a different set of random variables from the probability function. The sensitivity analysis output is presented as a distribution of possible NPVs for the credible option, as illustrated in Figure 9.5.

The Monte Carlo simulation results identify that Option 1 has less statistical dispersion in comparison to Options 2 and 3 and has a higher mean compared to these Options. This confirms that the preferred option, Option 1, is robust over a range of input parameters in combination.

Figure 9.5: NPV sensitivity analysis of multiple key assumptions relative to the Base Case



10 Preferred option

Based on the conclusions drawn from the economic analysis and the Rules requirements relating to the proposed replacement of transmission network assets, it is recommended that Option 1 be implemented to address the risks arising from the emerging over-voltage risks in Central Queensland. Implementing this option will also ensure ongoing compliance with relevant standards, applicable regulatory instruments and the Rules.

The result of the economic analysis indicates that Option 1 is the credible option with highest net economic benefit, in NPV terms, over the 20-year analysis period. Sensitivity testing shows the analysis is robust to variations in the capital cost, operational maintenance cost, risk cost and discount rate assumptions.

Option 1 is therefore considered to satisfy the requirement 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 emerging over-voltage risks in Central Queensland as requiring action.
- S5.1a.4 of the NER states that under system normal conditions, the voltage at a connection point must not exceed 1.1 per unit. Following a credible contingency, the voltage at a connection point must be able to be restored to less than 1.1 per unit in less than 1 second. The SVC at Nebo is, in the existing system, utilised to the point that it would be unable to respond to credible network disturbances following a credible contingency, resulting in non-compliant over voltages at Nebo Substation.
- S5.1.2.1 of the Rules also states "*Network Service Providers must plan, design, maintain and operate their transmission networks….to allow the transfer of power from generating units to Customers ….*" With reactive plant at capacity, obtaining outages for maintenance work is becoming increasingly difficult. Switching out lines during low load and/or low power transfer periods, to help gain access for reactive plant maintenance, reduces system strength and constrains the dispatch of renewable generation in North Queensland. Gaining access for maintenance during peak load conditions is also problematic, as these same dynamic reactive power devices are required to maintain voltage stability under high power transfer into North Queensland.

- Studies were undertaken to evaluate three credible options. All three options were evaluated in accordance with the AER's RIT-T.
- Powerlink published a PSCR in October 2020 requesting submissions from Registered Participants, AEMO and interested parties on the credible options presented, including alternative credible non-network options, which could address the over-voltage risks in Central Queensland.
- 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 submissions received in response to the PSCR, which was open for consultation until 8 January 2021. 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 1 provides the greatest net 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 costs assumptions. As a result, Option 1 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.

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 1 be implemented to address the emerging over-voltage risks in Central Queensland. Option 1 allows Powerlink to continue to maintain compliance with relevant, Powerlink's Transmission Authority and Schedule 5.1 of the Rules. Powerlink is the proponent of this option.

Option 1 involves installing a bus reactor at Broadsound Substation by June 2023 at an indicative capital cost of $9.63 million in 2020/21 prices. Design and procurement activities will commence in early 2021, with all work completed by June 2023.

13 Dispute Resolution

In accordance with the provisions of clause 5.16B.(a) of the NER, Registered Participants, the AEMC, Connection Applicants, Intending Participants, AEMO and interested parties may, by notice to the AER, dispute conclusions in this report in relation to:

- the application of the RIT-T,
- the basis upon which the preferred option was classified as a reliability corrective action or
- the assessment of whether the preferred option has a *material inter-regional impact* or not

Notice of a dispute must be given to the AER within 30 days of the publication date of this report. Any parties raising a dispute are also required to simultaneously provide a copy of the dispute notice to the RIT-T proponent.

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