2023-27 POWERLINK QUEENSLAND REVENUE PROPOSAL

Project Pack – PUBLIC

CP.02765 Broadsound Bus Reactor

CP.02765 – Broadsound Bus Reactor

Project Status: Not Approved

1. Network Need

Minimum daytime power flows on the transmission system from Central Queensland to Northern Queensland (CQ-NQ) have steadily declined over the last five years, and are expected to continue to decline into the future. This is due largely to the displacement of traditional synchronous generation in Central Queensland with large scale inverter based generation in the north, together with changing market consumption patterns driven by the continued uptake of photovoltaic (PV) rooftop solar.

Network studies have confirmed that if unmanaged, the continued decline in transmission power flows will lead to high system voltages and potentially significant voltage violations that exceed the defined operating limits with risk of non-compliance with the National Energy Rules (NER) requirement s5.1a.4 Power Frequency Voltage.

In order to maintain the power system in a secure state, Powerlink's Planning Criteria establishes the need for it to take action to ensure the NER specified allowable over-voltage limits are not exceeded. To date Powerlink has managed these limits by switching out, or de-energising, transmission feeders. This remedy is now at its operational limit, with further switching likely to impact system strength and constrain inverter based generation. The reduction in system strength from switching out feeders may breach Powerlink's obligations under clauses 11.101.2 and 4.6.6 of the NER, as amended by the National Electricity Amendment (Managing power system fault levels) Rule 2017 No. 10 (Fault Levels Rule).

The Planning Report recommends the installation of a shunt reactor at Nebo or Broadsound to provide additional reactive capability to manage the high voltages and improve operability of the CQ-NQ system now and into the future[1].

2. Recommended Option

As this project is currently 'Not Approved', the project need and options will be subjected to the public Regulatory Investment Test for Transmission (RIT-T) consultation process to identify the preferred option. The first step of this process commenced in October 2020 with the publication of the Project Specification Consultation Report[5].

The current recommended option is to install a 150MVAr 300kV bus reactor at Broadsound Substation by June 2023[3].

The following options were identified to address the network risk and are described and compared in the Project Specification Consultation Report (PSCR):

- Do Nothing – this was rejected due to non-compliance with power frequency and security requirements; used as the non-credible base case in the PSCR based on the differential fuel costs if inverter based generation in the north was to be curtailed[2].
- Establish a bus shunt reactor at Broadsound 275kV Substation – described as option 1 in the PSCR; identified as the preferred option based on net economic benefits compared to the base case.
- Establish two line reactors at Broadsound 275kV Substation – described as option 2 in the PSCR; ranked third based on net economic benefits compared to the base case.
- Establish a bus shunt reactor at Nebo 275kV Substation – described as option 3 in the PSCR; ranked second based on net economic benefits compared to the base case.
- Non-Network Option parameters outlined – at present no viable option has been identified.

3. Cost and Timing

The estimated cost to install a 150MVAr 300kV bus reactor at Broadsound Substation is $9.6m ($2020/21 Base).

Target Commissioning Date: June 2023[4].

Note: Although the identified need for the bus reactor is stated as 2021 in the Project Scope Report, the target commissioning date is aligned with the earliest timing that the works can be completed based on procurement, construction and commissioning timeframes.

4. Documents in CP.02765 Project Pack

Public Documents

1. Managing Voltage Profile for Central to North Queensland – Planning Statement
2. Base Case Risk Summary Report CP.02765 Addressing Central Queensland over-voltages
3. Project Scope Report CP.02765 H020 Broadsound 275kV Bus Reactor
4. CP.02765 H020 Broadsound 275kV Bus Reactor Project Management Plan
5. Project Specification Consultation Report - Managing voltage control in Central Queensland

Supporting Documents

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

Planning Statement		10/01/2020
Title	Managing Voltage Profile for Central to North Queensland – Planning Statement [1]	
Zones	Central and North Queensland	
Need Driver	Falling minimum daytime demand and increasing asynchronous generation in north Queensland has resulted in a growing number of over-voltage events in the Central Queensland zone. With recent shortfalls in system strength declared in North Queensland, management of over voltage events by line switching now has significant constraints on variable renewable energy (VRE) generation.	
Network Limitation	Voltages exceeding defined safe operating limits and failing to comply with Powerlink's Planning Criteria, and National Electricity Rules (NER) s5.1a.4 Power Frequency Voltage.	
Pre-requisites	None	

Executive Summary

Whilst maximum transmission flows from central to northern Queensland have remained steady in recent years, minimum daytime flows 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 day time demand due to changing patterns of consumption and the uptake of rooftop PV. This has led to an increase in reactive charging of 275kV lines in the central Queensland area, resulting in a growing potential for sustained over-voltage events.

In order to maintain the power system in a secure state, Powerlink's Planning Criteria establishes the need for it to take action to ensure the Rules' specified allowable over-voltage limits are not exceeded. To date Powerlink has been managing these limits via the switching out or de-energising of feeders. This remedy is now at its operational limit, with further switching likely to impact system strength and constrain inverter connected generation.

Grid Planning recommends the installation of a shunt reactor at Nebo or Broadsound to provide additional reactive capability to manage the high voltages and improve operability of the CQ-NQ system now and into the future.

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

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

1. Contents

1. Introduction

High voltages associated with light load conditions are currently managed with existing reactive sources. However, midday power-transfer levels between Central Queensland (CQ) and North Queensland (NQ) are reducing as additional asynchronous generators are commissioned in NQ, leading to greater utilisation of voltage control plant in the CQ and NQ zones. Whilst the asynchronous generation provides additional voltage control during their operating period, they are currently located some distance away from the Broadsound to Nebo area in question, and are unable to offset the reactive charging of the 275kV transmission lines.

The additional NQ VRE generation also contributes to a displacement of the synchronous generation dispatch in CQ, further reducing the availability of voltage control equipment. As a result, voltage control is forecast to become increasingly difficult for longer durations, directly impacting Powerlink's ability to comply with the requirements of the National Electricity Rules (NER) s5.1a.4 Power Frequency Voltage, and Powerlink's agreed operating voltage limits with AEMO.

Powerlink has in the past used operational line switching to reduce voltages to within safe operating limits. Line switching can lead to reduced reliability arising from non-credible events, and more significantly, will lead to reduced system strength.

The lines required to be switched to mitigate higher operational voltages in NQ and CQ are the lines that have the largest impact on the system strength in NQ. The reduction in system strength from line switching may breach Powerlink's obligations under clauses 11.101.2 and 4.6.6 of the NER, as amended by the National Electricity Amendment (Managing power system fault levels) Rule 2017 No. 10 (Fault Levels Rule) and may result in VRE generators in NQ being constrained to ensure stability is maintained.

Powerlink has identified a need for additional reactive support, to:

- Maintain voltages within operational and design limits, and to maintain the power system in a secure operating state.
- Reduce reliability impact from the de-energisation of 275kV transmission lines.
- Reduce market constraints from the de-energisation of 275kV transmission lines.

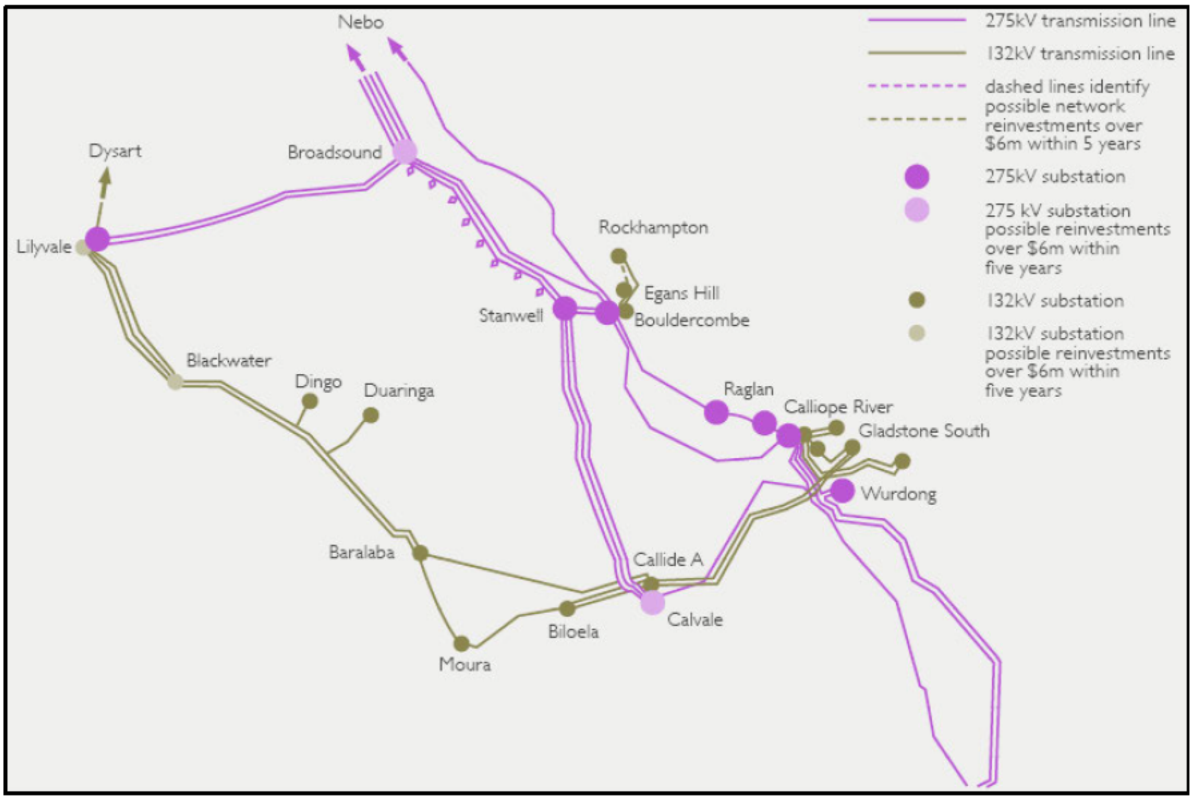


Figure 1: CQ-NQ and Gladstone grid section.

2. Grid Section Flows

The grid section flows as shown in Figure 2 demonstrates a significant reduction in the average grid section flows on CQ-NQ in 2018/19 and 2019/2020, and this trend is expected to continue with increasing VRE generation in NQ.

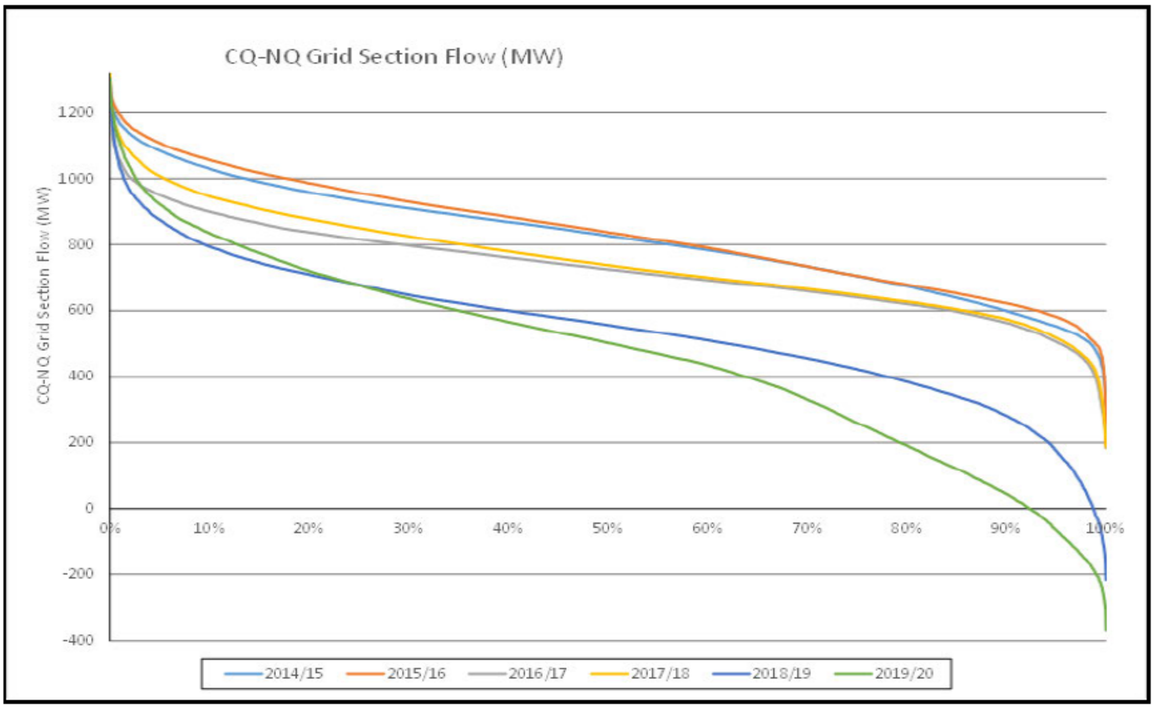


Figure 2: CQ- NQ Flows

3. Statement of Investment Need

Changing patterns of generation and demand in the area have resulted in an increasing frequency of over-voltage events that can no longer be adequately managed via line switching.

Powerlink must take action to increase the reactive capabilities within the CQ grid section to ensure ongoing compliance with its Planning Criteria and the requirements of the National Electricity Rules (NER) s5.1a.4 Power Frequency Voltage.

4. Network Risk

4.1 Study Parameters

Cases were derived from AEMO snapshots form July 2019, with central synchronous generation and northern asynchronous generation adjusted to reduce the flows on CQ-NQ to close to zero. Studies confirmed that if CQNQ flow is reduced to 200-400MW in the northerly direction, the high voltage risk exists.

To ensure that the network is able to withstand credible contingencies, generator outputs in CQ and SVC outputs in NQ were monitored to ensure that machine reactive outputs were maintained within limits.

Both system normal, as well as key plant outages, were considered. These critical contingencies include

- outage of a Nebo SVC;
- outage of the shunt reactor at Nebo; and
- outage of a line reactor at Broadsound.

4.2 A developing trend of high voltage risk

The decreasing utilisation of central and north 275kV feeders due to the shift to VRE generation dispatch in the NQ, as well as decreasing levels of generation in CQ, is elevating the voltage level on the 275kV network in CQ.

The relevant installed reactive plant for the purpose of voltage control in Central and North regions are as listed below:

- Nebo SVC, capacity: - 80MVAr to + 260MVAr,
- Nebo Shunt reactor 1, capacity: - 84MVAr
- Nebo Line reactor 821, capacity: - 35MVAr
- Nebo Line reactor 8847, capacity: - 20MVAr
- Broadsound line reactor 856, capacity: - 30MVAr
- Broadsound line reactor 820, capacity: - 20MVAr

Under system normal conditions, voltages may remain within the normal bandwidth however, the dynamic reactive plant (SVC) at Nebo is increasingly at limit under system normal, where it would become ineffective in responding to network disturbances. Records indicate that the instances of the SVC being at maximum MVAr absorption has more than doubled in 2019 (at 63 hours) when compared to 2018 (at 26 hours).

It is noted the planning high voltage limit is set at 1.1 per unit, however the operational high voltage limit is set at 1.084pu (see Table 1 below), to ensure there is sufficient dynamic capability margin to respond to network disturbances, therefore maintaining the ability to comply with the requirement of the National Electricity Rules (NER) s5.1a.4 Power

Frequency Voltage. With the SVC at Nebo increasingly at its limit, the 275kV voltage would often be nearing or at the operational limit under various key reactive plant outages.

Table 1 below summarised the operational voltage limits as agreed with AEMO.

Table 1 Operational Voltage limits, Planning criteria section 8.1.1

Voltage Level	Satisfactory Limit (Low)		Normal Operating Range						Satisfactory Limit (High)	
			(Low)		(Reference)		(High)			
110	99	0.900	110	1.000	115	1.045	119	1.082	121	1.100
132	119	0.900	132	1.000	138	1.045	143	1.083	145	1.100
275	248	0.900	275	1.000	292	1.060	298	1.084	303	1.100
330	297	0.900	330	1.000	350	1.060	362	1.097	363	1.100

The results from a study under system intact and various voltage control equipment outages at Nebo, Broadsound and Lilyvale substations are summarised in Table 2 below. The results demonstrate that the 275kV voltage level at Nebo and Broadsound could reach the maximum operational voltage limit during the largest reactor outage at either Nebo or Broadsound, hence the transmission dynamic voltage control effectiveness is increasingly at its limit.

Table 2: Existing Network and reactive plant N-1 steady state voltage results

Substation	Intact	Trip Nebo Reactor	Trip Broadsound Line Reactor	Trip Nebo SVC
Broadsound	1.072	1.079	1.084	1.078
Lilyvale	1.074	1.078	1.081	1.077
Nebo	1.072	1.084	1.078	1.082
Nebo SVC	-80	-80	-80	0

The following matters also emphasise the criticality of maintaining the 275kV voltage level within the max operational limit of 1.084pu.

- distribution voltage control equipment and control schemes are heavily geared towards voltage boosting (to compensate for voltage drop) hence have limited range to drop (i.e. buck) the voltage level;
- the high uptake of PV installation on the distribution network and LV network, creating further MVAr injection; and
- recent reduction of nominal low voltage level from 240V to a ‘preferred operating range’ of 230 volts +6/-2% as set out in AS 61000.3.100, resulting in a very limited upper tolerance margin of 0.017pu (i.e. what was the 1.0 pu nominal voltage has now translates to 1.043 pu).

With dynamic voltage control already at its limit, this generates frequent alarms to the control room to take pre-contingent action to mitigate the high voltage risk. With limited mitigation options available, there is a growing reliance on 275kV line switching which will inevitably result in VRE generation being constrained due to reduced system strength.

4.3 Increasing Impact of 275kV Line Switching on System Strength

In managing the high voltage risk, the switching of a single 275kV line circuit could be required. It can be demonstrated that switching off Feeder 834 between Broadsound and Nebo is the most effective for limiting excessive reactive power injection in Central and North Queensland transmission network (See Appendix A).

The switching of any 275kV feeder however will reduce the system strength that is available in North Queensland. Under AEMO's 'Notice of Queensland System Strength Requirements and Ross Fault Level Shortfall'[2], 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 (N-1). Where a prior outage is taken, the network (and connected plant) must be able to withstand the next credible contingency (hence N-1-1). As such, in order for line switching to be utilised there would be some constraints to asynchronous generation in North Queensland.

With the dynamic reactive plant more frequently reaching its limits, 275kV line switching would frequently be required to manage the high voltage risk. This in turn creates an increasing risk of system strength non-compliance at Ross, which inevitably will lead to constraining of the VRE generation in the North region.

Considering the significant impact to system strength and the flow on effect to network reliability and supply security of switching, an ongoing constraint on VRE generation could become the default mitigation strategy in lieu of 275kV line switching. Note that under some circumstances both VRE constraining and 275kV line switching could be still required.

4.4 Low CQNQ Flow Correlation with High Voltage Risk

From an operational data perspective, the high voltage risk can also be observed from the statistical correlation between CQNQ loading level and MVAr injection into Nebo as demonstrated in Figure 3 below. It is observed that MVAr injection into Nebo would often exceed 80MVAr (i.e. the SVC maximum MVAr absorption capability) when the CQNQ power flows were less than 400MW in either direction (north and south). This is with the reactors at Nebo fully operational.

At this point, the SVC at Nebo would be unable to manage the high MVAr injection under a local credible key reactive plant contingency, resulting in an elevated voltage condition on the 275kV. This is likely to result in VRE generation being constrained to bring the voltage back within the secure operational range.

[2] 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

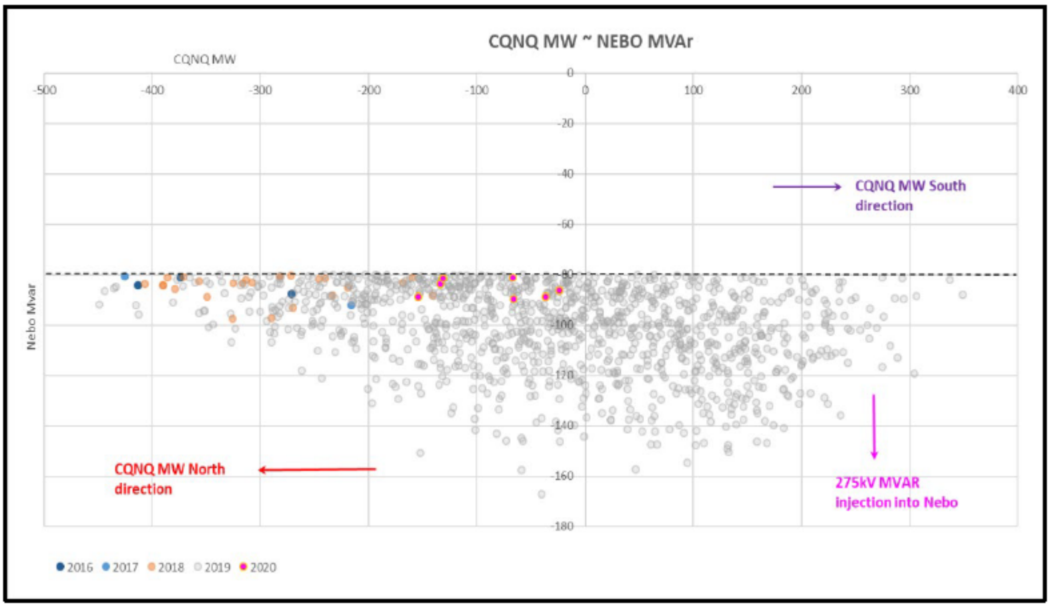


Figure 3: CQ- NQ Flows and Nebo MVAr injection.

The statistics suggest this risk could be sufficiently contained by running back the VRE generation output within the NQ region to ensure the CQNQ flow is between 200-400MW in the northerly direction. Further analysis suggests that maintaining the CQNQ flow at a minimum of 200MW (north direction) would be sufficient to contain the high voltage risk in most instances without having to resort to 275kV line switching.

Table 3 demonstrates typical voltage levels when CQNQ flow is at 200MW in the north direction with various key reactive plant outages. This loading scenario could potentially occur throughout the year and the results are derived from using the lower range of loading level and VRE generation output, which should represent the higher risk conditions.

Table 3: Voltage steady state results for 200MW CQNQ North Flow

	Intact	Trip Nebo Reactor	Trip Broadsound Line Reactor	Trip Nebo SVC
Broadsound	1.076	1.080	1.079	1.079
Lilyvale	1.073	1.075	1.075	1.074
Nebo	1.072	1.080	1.072	1.078
Nebo SVC	-58	-80	-78	0

The resulting voltage levels in Table 3 are generally lower than in Table 2 and lower than the maximum operational high voltage limit. This suggests that the CQNQ flow at 200MW (north) is a reasonable and practical limit to assess the potential market impact (at this moment). Figure 4 demonstrates the level of risk reduction at 200MW CQNQ north flow.

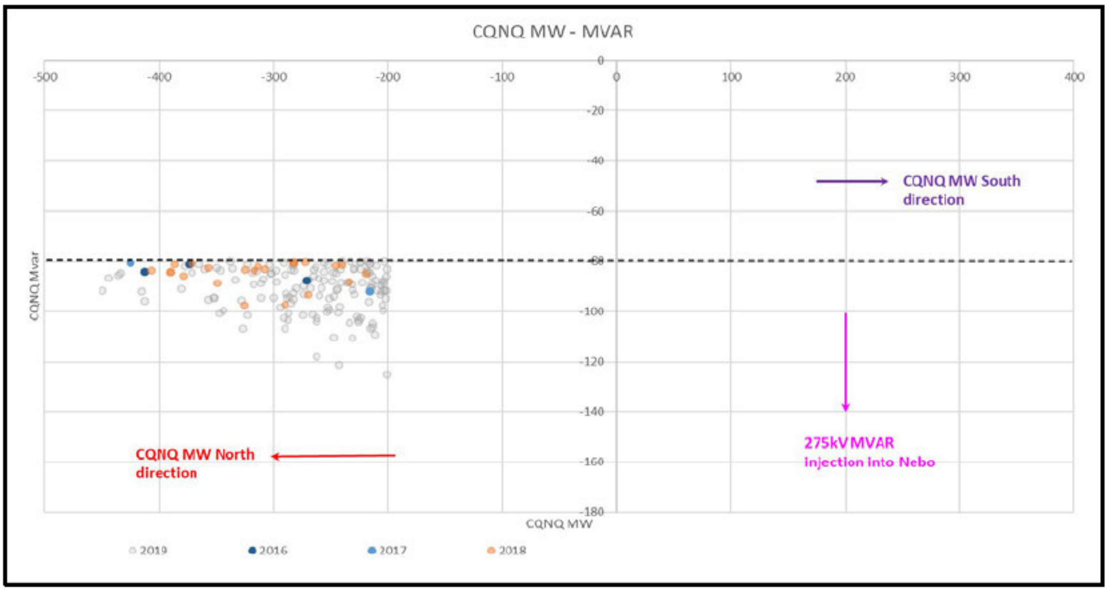


Figure 4: High voltage risk reduction with CQNQ at 200MW north

Based on the 200MW CQNQ north flow, Nebo's actionable exposure is estimated at 1050 hours (12% of the year) and the associated potential market impact was at 204GWh in the 2019 calendar year (the first year of complete data) and Table 4 below contains the 2019 monthly breakdown.

Table 4: 2019 potential market impact to maintain a minimum 200MW CQNQ north flow

Month	Potential MWh runback	Cost at $25/MWh
Jan	167	$4,175
Feb	0	$0
Mar	93	$2,325
Apr	10293	$257,325
May	15097	$377,425
Jun	27086	$677,150
Jul	37266	$931,650
Aug	20640	$516,000
Sep	48197	$1,204,925
Oct	18550	$463,750
Nov	26775	$669,375
Dec	277	$6,925
Total	**204441**	**$5,111,025**

While there is the potential to increase the number of VRE generation constraining events in the coming years, this increase is expected to quickly plateau as the available system strength in NQ is already nearing full utilisation. Therefore for assessment purpose, the market impact in the future years can reasonably be expected at a similar level as in 2019 calendar year.

4.5 NER Schedule S5.1.2.1 Compliance Impediment

As a TNSP, Powerlink must also comply with the NER relating to technical system standards during intact and contingency conditions. Schedule S5.1.2.1 of the NER specifies that:

> *Network Service Providers must plan, design, maintain and operate their transmission networks and distribution networks to allow the transfer of power from generating units to customers with all facilities or equipment associated with the power system in service*

Of particular concern is the ability to maintain and operate the network. The high voltage and system strength challenges have already impacted Powerlink's ability to efficiently schedule network outages for asset maintenance or respond to network contingencies, without substantial negative impact to the energy market and customers. This is due to the requirement to maintain network stability for the next contingency hence the need for N-1-1 assessment.

The high voltage risk associated with the N-1-1 event is probably best illustrated by the potential impact to voltage levels at Nebo and Broadsound in Table 5, which reflects the higher risk operational dataset in June 2019 hence the voltage levels are typical and will fluctuate in both directions.

Table 5: Nebo and Broadsound voltage level for N-1-1 of Key Reactive plant

N-1-1 events	Nebo pu	Broadsound pu	Lilyvale pu	Nebo SVC MVAr
Nebo shunt reactor + Nebo SVC	1.090	1.080	1.083	0
Nebo shunt reactor + Broadsound largest line reactor	1.086	1.081	1.084	-50
Nebo shunt reactor + Broadsound largest line reactor	1.081	1.078	1.082	-80

The resulting voltage levels at Nebo would often exceed the safe operation high limit of 1.084 pu and on occasions could reach 1.1 pu. As discussed in previous sections, these challenges would only worsen in the future.

On the flip side, in the warmer months (high CQNQ north flow), the same Nebo SVC is critical for mitigating the voltage collapse risk, making it virtually impossible to schedule maintenance of the CQNQ system component as it is always critical for maintaining system security.

Therefore there is a clear enduring need to improve the dynamic reactive margin of Nebo SVC to enable stable and secure day to day network operations and planned maintenance scheduling.

5. Non Network Options

5.1 System normal

Under system normal conditions, network support would need to provide voltage control equivalent to the reactor at or near Nebo or Broadsound, being 126MVAr at the 275kV bus. Reactive support would be required to be available on a continuous basis, and not be coupled to generation output

5.2 Network Outages

The network support must continue to operate as per system normal for planned and unplanned outages. Outages of the network support must be coordinated to ensure that Powerlink is able to maintain system security at all times.

6. Network Options

6.1 Establish a bus shunt reactor at Broadsound 275kV

Under this option, it is proposed to establish a 275kV bus reactor at H020 Broadsound. The reactor, which would nominally be specified as 150MVAr at 300kV (126MVAr at 275kV), would be connected to 275kV 2 bus by a dedicated reactive plant bay.

Table 7: Shunt reactor at Broadsound

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	-28.4	-80	-56.9	0

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.

6.2 Establish a bus shunt reactor at Nebo 275kV

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 275kV 2 bus by a dedicated reactive plant bay.

Table 8: Shunt reactor at Nebo

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	10.2	-47.5	-18.8	0

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.

6.3 Install line reactors at Broadsound

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)

It is expected that the reactors would both be installed at Broadsound, and that each 275kV reactor would be 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 9: Line reactors at Broadsound

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	-59.6	-80	-80	0

6.4 Establish a bus shunt reactor at Nebo utilising existing bay

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), is to be connected to C3 bay (H011-C05-583).

The proposed reactor would share the bay with the existing 275kV capacitor bank. The cap bank would be effectively mothballed on site, but available if flow forecasts were to change again i.e. high CQ-NQ flows. The Nebo capacitor banks were installed to provide limit extension ahead of the completed North Queensland 275kV reinforcement. Removal of the capacitor bank from service will reduce the CQ-NQ limit by up to 40MW for a feeder contingency and 60MW for the trip of the Townsville Power Station.

7. Options considered but not proposed

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

7.1 Do Nothing

There has been more than a doubling of instances in 2019 (63 hours) where the Nebo SVC has hit the absorption limit compared to 2018 (26 hours). This trend is expected to increase, resulting in the management of voltages in CQ becoming more problematic as the SVC at Nebo is unable to respond effectively to credible contingencies of key plant, in this case the Nebo SVC, Nebo bus reactor or Broadsound line reactors.

Declining minimum demand and CQNQ transfers will lead to an increasing requirement for upfront constraining of NQ VRE (in lieu of 275kV line switching) to keep the operational voltage levels within the agreed safe limits. As more VRE generators are connected in the NQ and FNQ regions, the scale of the upfront VRE constraining will only get larger.

As the high voltage risk becomes more frequent, the available window to schedule a planned outage will diminish. Operationally this condition also translates to a limited ability to secure and stabilise the system voltages following various network contingencies.

There is also the growing need to provide for stable maintenance window, therefore the "do nothing" is not a viable short or long term option.

7.2 Diameter connection of reactor at Broadsound

Similar to the option to establish a bus shunt reactor at Broadsound utilising a dedicated bay, this option would see a 275kV reactor established at Broadsound in an expanded diameter (either on C500 or C504) to accommodate the reactor.

As per the bus connection described previously, the reactive plant switching bay requires that the breaker be specified as suitable for switching of reactive plant. The existing coupler breakers (in both C500 and C504) are ABB HPL300B1 CB's, and are not capable of single pole operation required to energise reactive plant.

This option, however, requires the following operational considerations

- The reactor would only be able to be energised by the CB in the new bay within the diameter
- To switch the reactor in (or out) of service, it will be necessary to open the CB in the coupler bay, open the CB in the new bay, close (or open) the motorised disconnector on the reactor, then close the CB in the new bay followed by the coupler CB.
- This switching action would be required – on average – twice a day (once in, once out)

The number of switching operations required, from both a plant and an operational perspective, are not considered acceptable for a connection of this nature, and this option was not progressed.

7.3 Dynamic reactive plant at Broadsound

Installation of dynamic reactive plant was considered, however the cost of installing dynamic reactive plant in a location where other dynamic reactive plant would be available (should the reactor be installed) would not present the least cost option.

Similarly, the installation of a synchronous condenser would be able to meet the requirement, however at a significantly higher cost than shunt reactors.

8. Recommendation

Based on the analysis carried out, planning consider that the installation of a bus shunt reactor at Nebo or Broadsound would be able to meet the requirements of the network. Either site would provide the network benefits required, and as such planning consider that the site that presents the least cost should be pursued.

9. References

1. Transmission Annual Planning Report 2019

2. Asset Planning Criteria Framework

10. Appendix A

10.1.1 Nebo-Bouldercombe 821

Switching of Nebo – Bouldercombe feeder 821 results in voltages being reduced pre and post contingent. Utilisation of the SVC in the intact system is also reduced, however post contingent the SVC is at limits.

Table 2: Feeder 821 Nebo - Bouldercombe switched

	Intact	Trip Nebo Reactor	Trip Broadsound Reactor	Trip Nebo SVC
Broadsound	1.068	1.073	1.077	1.072
Lilyvale	1.072	1.074	1.077	1.074
Nebo	1.069	1.078	1.072	1.076
Nebo SVC	-59	-80	-80	0

10.1.2 Stanwell-Bouldercombe 8831/856

Switching of Stanwell – Broadsound feeder 856 or 8831 results in voltages being reduced pre and post contingent. Utilisation of the SVC in the intact system is also reduced, however post contingent the SVC would again be at limits.

Table 3: Feeder 8831 Stanwell - Broadsound switched

	Intact	Trip Nebo Reactor	Trip Broadsound Reactor	Trip Nebo SVC
Broadsound	1.071	1.08	1.083	1.078
Lilyvale	1.073	1.078	1.081	1.077
Nebo	1.07	1.084	1.076	1.081
Nebo SVC	-78.1	-80	-80	0

10.1.3 Bouldercombe – Broadsound 820

Switching of Bouldercombe – Broadsound feeder 820 results in voltages being reduced pre and post contingent. Utilisation of the SVC in the intact system is also reduced, however post contingent the SVC is at limits.

Table 4: Feeder 820 Bouldercombe - Broadsound switched

Existing system	Intact	Trip Nebo Reactor	Trip Broadsound Reactor	Trip Nebo SVC
Broadsound	1.07	1.078	1.082	1.077
Lilyvale	1.073	1.077	1.08	1.076
Nebo	1.07	1.083	1.076	1.081
Nebo SVC	-76	-80	-80	0

10.1.4 Nebo – Broadsound 834

Switching of Nebo – Broadsound feeder 834 results in the greatest improvement in system voltages at all sites, as well as significantly decreasing the utilisation of the SVC.

Table 5: Feeder 834 Nebo - Broadsound switched

Existing system	Intact	Trip Nebo Reactor	Trip Broadsound Reactor	Trip Nebo SVC
Broadsound	1.065	1.069	1.076	1.068
Lilyvale	1.071	1.073	1.076	1.072
Nebo	1.068	1.075	1.069	1.073
Nebo SVC	-46.3	-80	-69.9	0

10.2 Market Impacts of switching

Under the scenario where line switching is utilised to address high voltages, there is an impact on system strength, and hence a constraint on the amount of VRE generation in North Queensland. Based on a likely dispatch of synchronous generation in central and north Queensland, the outcome of this is as below.

	Central	North	Gen Curtailed
8831	9	4	190
820	10	0	190
821	10	0	190
834	10	0	190

The impact on the market is that the generation constrained in North Queensland would be between $3,800 and $9,500 per hour, based on cost of fuel used to offset the renewable generation being between $20 and $50 per MWh.

11. Appendix B – Impact of reactor switching of network voltages

The sizing of the reactors at Nebo or Broadsound can be assessed in one of two ways:

- Steady state solution, with locked shunts and taps. This solution represents the impact that the network would see prior to tap adjustment or switching of any reactive plant, however allows for the response of network voltage-control plant.
- Switching solution. This solution represents the impact that the network would see immediately post switching of reactive plant.

In the past, planning has considered that the switching solution is appropriate, however where there is network voltage-control plant nearby, the impact of this switching is overstated by the switching solution. Similarly, moving to the steady state solution may understate the immediate network response of the switching.

In both cases, the limits that apply are that the voltage step should not exceed 3% for an intact system, and 5% under outage, which may include the outage of nearby network voltage-control plant.

The graphs in Figure 5 and Figure 6 highlight that Broadsound is able to switch a larger reactor, especially when assessed using the switching solution.

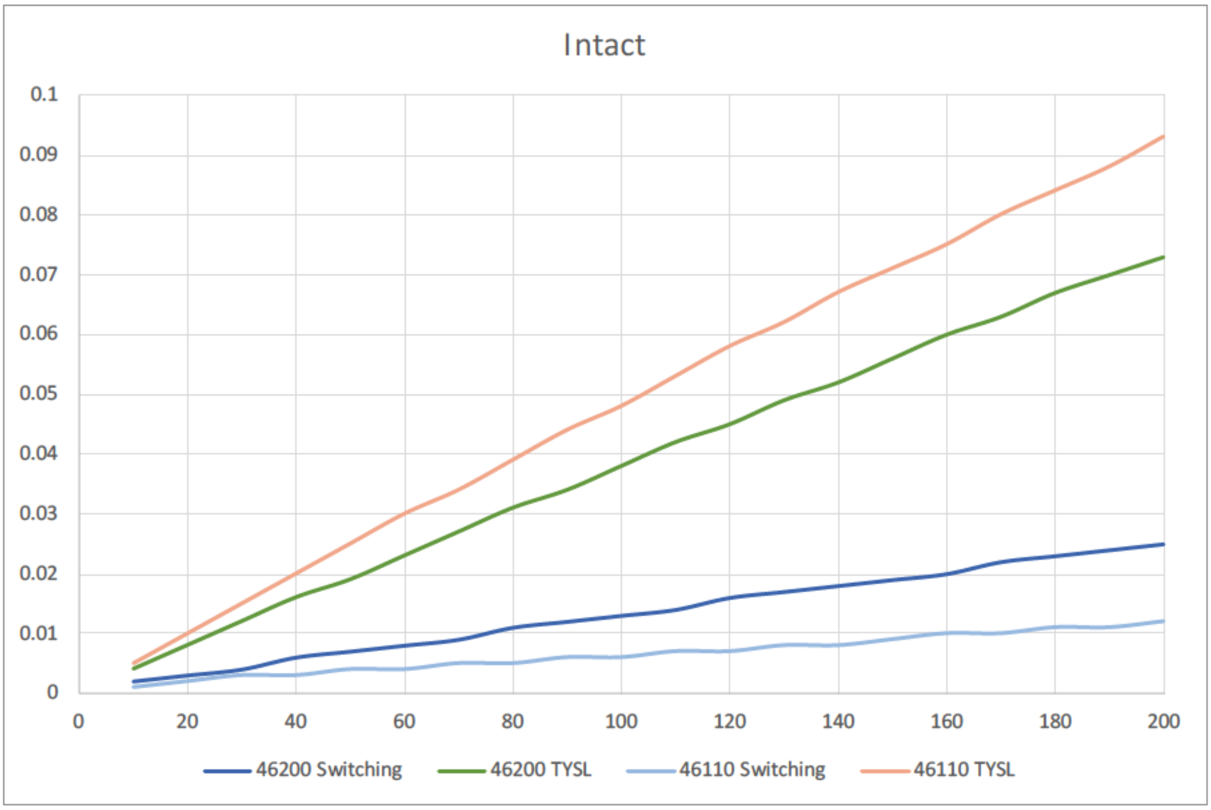


Figure 5: Nebo & Broadsound Reactor switching – Intact

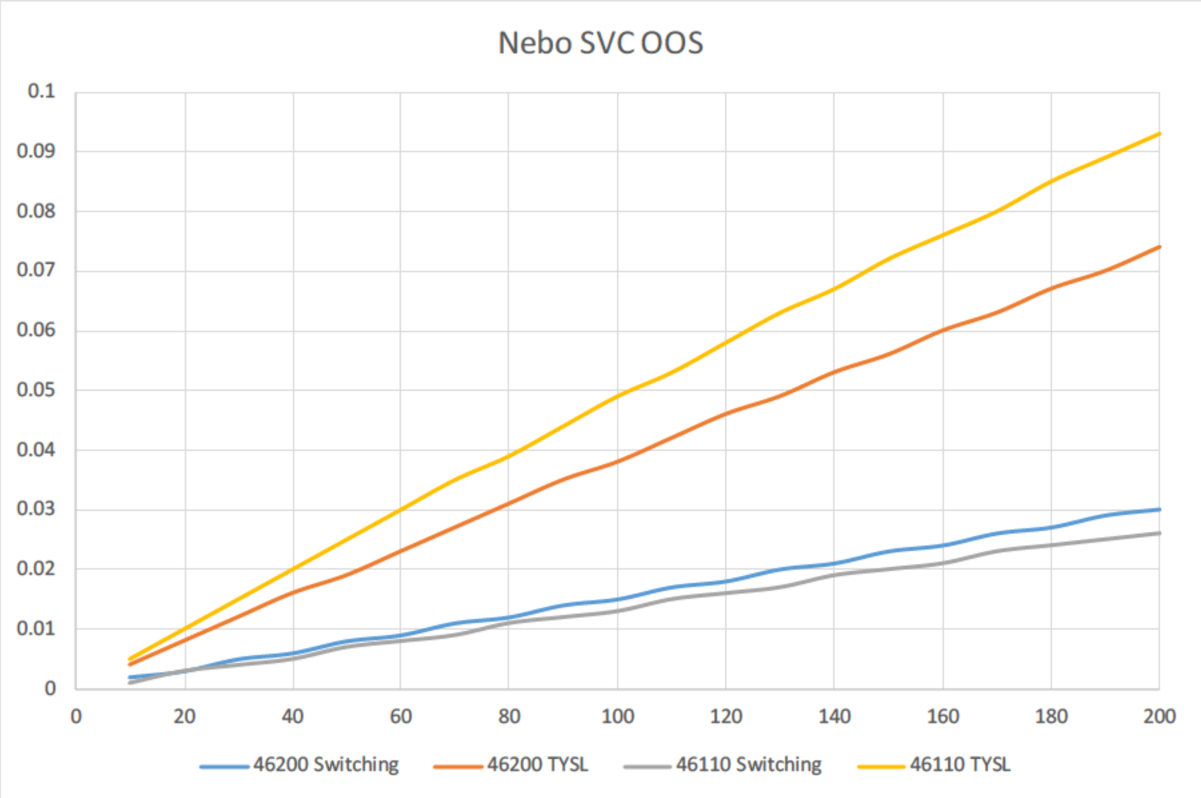


Figure 6: Nebo & Broadsound Reactor switching - Nebo SVC OoS

12. Appendix C - N-1-1 voltages with new shunt reactor installation

126MVAr shunt reactor at Broadsound

N-1-1 events	Nebo Voltage (pu)	Broadsound Voltage (pu)	Lilyvale Voltage (pu)	Nebo SVC MVAr	Broadsound new reactor MVAr
Existing Nebo shunt reactor + Nebo SVC	1.079	1.065	1.074	0	-166.4
Existing Nebo shunt reactor + Broadsound largest line reactor	1.073	1.061	1.072	-50	-142

126MVAr shunt reactor at Nebo

N-1-1 events	Nebo Voltage (pu)	Broadsound Voltage (pu)	Lilyvale Voltage (pu)	Nebo SVC MVAr	Nebo new reactor MVAr
Nebo reactor + Nebo SVC	1.071	1.072	1.078	0	-169.3
Nebo reactor + Broadsound largest line reactor	1.063	1.068	1.075	-50	-169.5

Base Case Risk Summary Report

CP.02765 Addressing Central Queensland over-voltages

Version Number	Objective ID	Date	Description
1.0	3374334	09/06/2020	Original document
2.0	3374334	17/09/2020	Minor wording corrections

1. Purpose

Powerlink is proposing to install a bus reactor at Broadsound substation, to address over-voltages in central Queensland. The purpose of this model is to quantify the base case risk costs associated with this proposed investment.

2. Background

The emerging combination of lighter demand with higher penetration of asynchronous generation in North Queensland (NQ) exacerbates the challenge of managing high voltages on the Central Queensland (CQ) – North Queensland (CQ-NQ) grid section at times of low flow on the major 275kV lines between CQ and NQ.

Whilst high voltages have been managed in the past through line switching, the lines required to be switched to mitigate higher operational voltages in CQ are the lines that have the largest impact on the system strength in NQ.

To improve operability of the CQ-NQ system now and into the future, Powerlink has identified a need for additional reactive support, to:

- Maintain voltages within operational and design limits, and to maintain the power system in a secure operating state,
- Reduce reliability impact from the de-energisation of 275kV transmission lines, and
- Reduce market constraints from the de-energisation of 275kV transmission lines.

Under CP.02765, "H020 Broadsound 275kV Bus Reactor", this additional reactive support is proposed to be installed at Broadsound substation.

As the ability to switch transmission lines reduces, and if additional reactive support is not installed, the other option to address high voltage issues is to substitute renewable generation in North Queensland with non-renewable generation sources. This will increase northerly flows and assist with management of the over voltage issue. The risk cost for the proposed investment is the differential fuel cost realised by the market if this option is utilised.

3. Base Case Risk Analysis

3.1 Risk analysis methodology

To maintain Central Queensland voltages within acceptable limits, utilising existing reactive support, network analysis identified that northerly flows have to be maintained at a minimum of 200MW. Table 1 shows the amount of renewable generation that would have been curtailed (substituted) during each month of 2019, in MWh, to achieve a minimum of 200MW northerly flow (the data for February 2019 is not available). A differential fuel cost of $25/MWh has been modelled.

3.2 Annual risk cost

Table 1 – Differential fuel costs due to renewable curtailment (2019)

Month	**Renewable curtailment (MWh)**	**Cost ($)**
January	167	4175
March	93	2325
April	10293	257325
May	15097	377425
June	27086	677150
July	37266	931650
August	20640	516000
September	48197	1204925
October	18550	463750
November	26775	669375
December	277	6925
	Total ($m):	5.1
Fuel cost ($/Mwh)	25	

There is insufficient data available to analyse curtailment requirements for 2020, and the data that has been gathered does not represent typical network flows due to the effects of coronavirus on demand. Even though a trend cannot be shown, planning advice is that the over voltage situation is unlikely to improve without intervention. Consequently, the annual risk cost will be treated as a constant for the purposes of NPV analysis.

4. Recommendation

It is recommended that the annual risk cost for CP.02765, "H020 Broadsound 275kV Bus Reactor" is modelled as $5.1m throughout the NPV modelling period.

Project Scope Report

CP.02765 H020 Broadsound 275kV Bus Reactor

Proposal - Version 1

Document Control

Change Record

Issue Date	Responsible Person	Objective Document Name	Background
17 Jan 2020	[redacted]	Project Scope Report (Proposal) - CP.02765 H020 Broadsound 275kV Bus Reactor	Ver. 1 - Proposal initial issue

Related Documents

Issue Date	Responsible Person	Objective Document Name
10/01/20	[redacted]	Managing Voltage Profile for Central to North Queensland - Planning Statement

1. PROJECT DETAILS

1.1. Project Need

The combination of reducing demand and additional renewable generation in the Central Queensland (CQ) and North Queensland (NQ) regions is leading to periods of reduced power flow between CQ and NQ and resulting in higher operating voltages.

Network studies confirm that lower minimum demands if unmanaged can lead to high system voltages and potentially significant voltage violations that exceed defined operating limits with risk of non-compliance to National Electricity Rules (NER) requirement s5.1a.4 Power Frequency Voltage. High voltage violations are undesirable due to the risk of damage to power system plant. Reactive compensation is needed to reduce system voltage and can be achieved with the installation of additional reactive capacity in the NQ region.

Potential solutions identified at the concept stage included establishment of additional reactive plant at either Nebo or Broadsound substations. Subsequent analysis determined the least cost alternative to be the establishment of a 275kV bus connected shunt reactor at the Broadsound Substation.

The objective of the project is to ensure the transmission network maintains secure operating state during periods of minimum demand with the establishment of a 150MVAr 300kV bus shunt reactor at Broadsound substation, notionally by 31 March 2021.

1.2. Project Contacts

Project Sponsor	[redacted]	[redacted]
Strategist - HV Asset Strategies	[redacted]	[redacted]
Planner - Main/Regional Grid	[redacted]	[redacted]
Project Manager	[redacted]	[redacted]
Design Coordinator	TBC	Ext.

1.3. Project Scope

1.3.1. Original Scope

The following scope presents a functional overview of the desired outcomes of the project. The proposed solution presented in the estimate must be developed with reference to the remaining sections of this Project Scope Report, in particular *Section 1.7 Matters to Consider*.

Briefly, the project consists of establishing one 150MVAr 300kV bus shunt reactor at H020 Broadsound Substation.

1.3.2. Options - Additional reactive capacity in the NQ Region

Four credible options were identified at the concept stage to address the network need. Subsequent analysis of concept estimates identified Option 1 to be the least cost alternative and therefore the preferred option.

Table 1 summarises the options considered.

Table 1 - Options summary

Option	Description	Comm. Date
1	Establish 1x 150MVAr 300kV bus reactor at H020 Broadsound	2021
2	Establish 2x 300kV line reactors at H020 Broadsound	2021
3	Establish 1x 150MVAr 300kV 2bus reactor at H011 Nebo	2021
4	Establish 1x 150MVAr 300kV reactor with transfer bus at H011 Nebo	2021

1.3.3. Substation Works - H020 Broadsound Substation

Transmission Line Works

Not applicable

H020 Broadsound Substation Works

Design, procure, construct and commission the following works:-

- extension to the substation platform and earth grid as required to accommodate one new bus reactor bay;
- the establishment of an air-insulated primary plant bay including dead-tank POW circuit breaker suitable to connect 1x 300kV 150MVAr shunt reactor;

  Note: Connection to 2Bus is the preferred network arrangement however a 1Bus connection would also be considered a satisfactory solution if more economic.
- integration and modification to the existing oil containment system as required;
- integration and modification to the existing secondary systems as required;
- update of EMS with required changes; and
- update of SAP, CMS and drawings in SPF accordingly.

1.3.4. Key Scope Assumptions

Not applicable

1.3.5. Variations to Scope (post project approval)

Not applicable

1.4. Project Timing

1.4.1. Project Approval Date

The target approval date for the project is as soon as possible. DTS should identify any preliminary funding required to meet earliest commissioning date.

1.4.2. Site Access Date

H020 Broadsound is an existing Powerlink operational site and access is available immediately.

1.4.3. Commissioning Date

The target date for the commissioning of the new assets included in this scope is 31 March 2021.

This is a notional target commissioning date that reflects the date that the network need is defined. As part of the proposal, DTS should present a high level plan and advise of the earliest commissioning date achievable for the assets.

1.5. (Proposed) High Level Line Requirements

Not applicable

1.6. (Proposed) High Level Substation Requirements

Item	Requirement
Project Management	Existing Powerlink Standards
Civil Design	
Electrical Design	
Protection Design	
Automation Design	
Telecommunications Design	
Construction	
Commissioning	

1.7. Matters to Consider

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

- the estimate should consider the implications of relevant workplace health & safety legislation in delivering the proposed solution, and identify any alternative solutions that meet the functional requirements included in the scope whilst having the potential to facilitate improvements in safety during construction, or as built, and:
  - include such alternative solutions as a fully costed option for further investigation;
  - include an assessment of the risks associated with each option identified, after all available and applicable mitigating actions have been implemented; and

- include an allowance for any specific safety related activities required in the delivery phase of the project;

- any existing assets to be removed and disposed of as part of this scope must be identified within the estimate together with the forecast early asset write off amounts at time of disposal; and
- a high level project implementation plan including staging and outage plans (as per Section 1.10) should be considered and produced as part of the estimate.

1.8. Asset Management Requirements

Equipment shall be in accordance with Powerlink equipment strategies.

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

1.9. Asset Ownership

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

1.10. System Operation Issues

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

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

A project outage plan should be submitted in accordance with “Outage Management Process – Procedure (A463506)”, on form “Outage Plan – Projects (A523847)”. The Project Outage Plan must include both HV and Telecoms outages.

1.11. Options

Not applicable

1.12. Division of Responsibilities

Not applicable

1.13. Related Projects

No related projects

1.14. Project Drawings

[redacted]

H020 Broadsound Substation

H020 Broadsound Switchyard

2. PROPERTY & EASEMENT INFORMATION

2.1 Established Site - H020 Broadsound

2.1.1. Site Accessibility

H020 Broadsound is an established Powerlink substation and site access is available immediately.

2.1.2. Issues Regarding Site Location

Not applicable

CP.02765 H020 Broadsound 275kV Bus Reactor Project Management Plan

Record ID	A3311230	
Authored by	[redacted]	Project Manager
Reviewed by	[redacted]	Team Leader
Approved by	[redacted]	Manager Projects

Version History

Version	Date	Section(s)	Summary of amendment
1.0	10/02/2020	All	Original Concept Estimate
1.1	03/04/2020	All	Project Proposal. Class 3 Broadsound Reactor only
1.2	7/8/2020	All	Two stage approval process implemented extending the date for PC to March 2023. Added road, deleted oil tank & added oil pipe to existing tank.

Table of Contents

1. Executive Summary

Project background

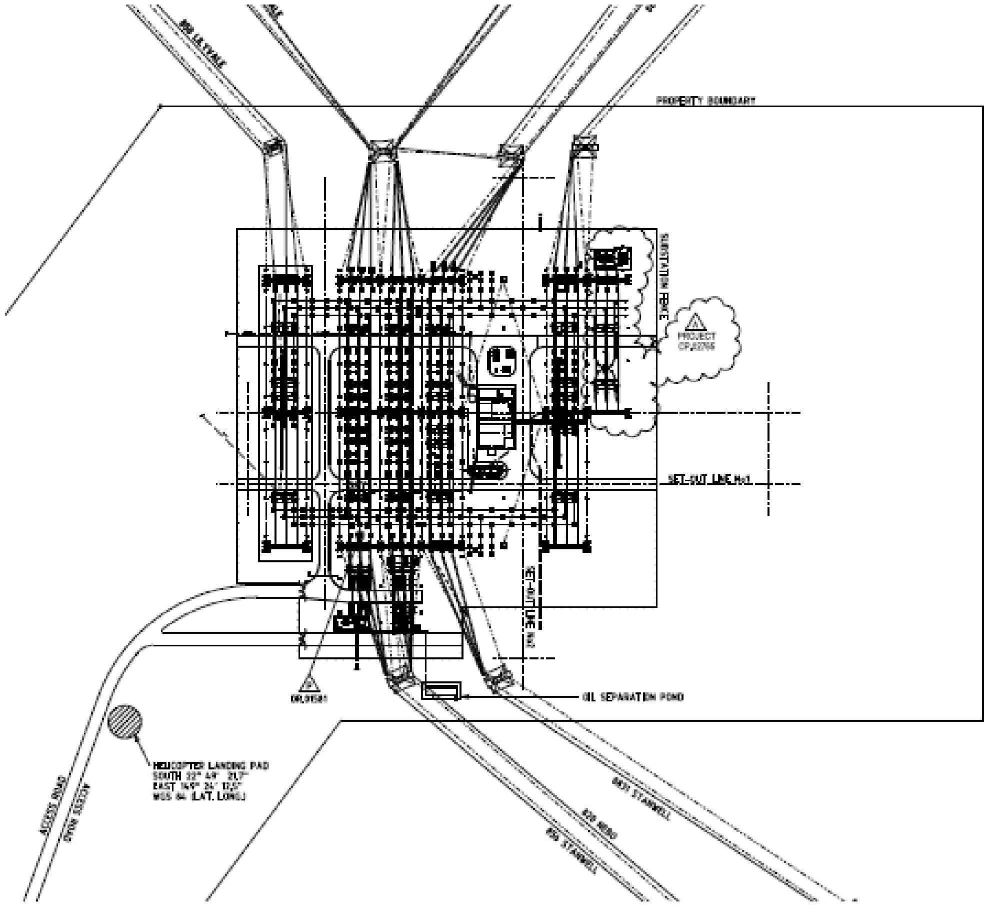
Network studies have confirmed that lower minimum demands if unmanaged lead to high system voltages and potentially significant voltage violations that exceed the defined operating limits with risk of non-compliance with the National Energy Rules (NER) requirement s5.1a.4 Power Frequency Voltage. High voltage violations are undesirable due to the risk of damage to the power system plant. Hence, reactive compensation is needed to reduce system voltage and can be achieved with the installation of additional reactive capacity in the NQ region.

Potential solutions to this issue include additional reactive plant at either Nebo or Broadsound substations. Subsequent analysis determined the least cost alternative to be the establishment of a 275kV bus connected shunt reactor at the Broadsound substation.

This proposal is based on version 1 of the CP.02765 Project Scope Report dated 17/1/2020. However with the recent introduction of two stage estimating and assuming the reactor will be approved at stage 2, the date for PC will now be 31/3/2023. With this in mind a discrete part (stage 1) for early parallel works has been created & attached in the pricing information below. This estimate is part of, not separate to, the total estimate for the project.

Project objective

The objective of the project is to ensure the transmission network maintains secure operating state during periods of minimum demand with the establishment of a 150MVAr 300kV bus shunt reactor at Broadsound substation, by 31 March 2021.



H020 Broadsound Concept General Arrangement

H020 Broadsound 275kV Bays

[redacted]

NOTE: This diagram is not intended to depict the physical layout

H020 Broadsound Switchyard

Recommended Total Project Estimate

Estimate Components			Base Cost $	Escalated $
Base Estimate (A)	Cost Estimate		8,911,886	9,416,223
	Estimate Allowance		721,902	762,731
Contingency (Unknown Risk)	(B)	[redacted]	[redacted]	[redacted]
Mitigated Risk (Known Risk)	(C)	[redacted]	[redacted]	[redacted]
Total Proposed	**(B+C)**	[redacted]	[redacted]	[redacted]
Total Proposed Approval	**(A+B+C)**		[redacted]	[redacted]

	Date
Project Scope Report (version 1) - date received	21/01/2020
Project Proposal V1.1 and Project Estimate - date submitted	17/04/2020
Project Proposal V1.2 and Project Estimate - date submitted	07/08/2020
Project Approval Advice (PAA) - date received	TBA

2. Project Definition

2.1 Project Scope

The project consists of establishing one 150MVAr 300kV bus shunt reactor at H020 Broadsound Substation.

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

2.1.1 H020 Broadsound Substation Works

Design, procure, construct and commission the following works:-

- Extension to the substation platform and earth grid as required to accommodate one new bus reactor bay;
- The establishment of an air-insulated primary plant bay including dead-tank POW circuit breaker suitable to connect 1x300kV 150MVAr shunt reactor;
  Note: Connection to 2Bus is the preferred network arrangement however a 1Bus connection would also be considered a satisfactory solution if more economic.
- Integration and modification to the existing oil containment system as required;
- Integration and modification to the existing secondary systems as required;
- Update of EMS with required changes; and
- Update of SAP, CMS and drawings in SPF accordingly.

2.1.2 Transmission Lines / Transmission Lines Refit

- Not Applicable.

2.1.3 Telecommunications

- Not Applicable.

2.1.4 Revenue Metering

The project excludes the modification/replacement of revenue metering.

2.1.5 Other Project Works

Nil.

2.2 Exclusions

Exclusions as follow:

- Allowance for unexpected ground conditions such as rock or unsuitable material;
- Non-standard foundations;
- Any work outside of normal working hours;
- Dealing with unidentified asbestos;
- Bench or application testing of new period contract relays;
- SDM9 architecture (network panels, etc.) will not be installed at H020 Broadsound;
- Changes to the Stanwell SIPS scheme, or including the new Reactor in the WAMPAC scheme; and
- Installation of noise or fire wall.

2.3 Assumptions

- Expansion of the existing substation footprint is not required;
- Outages at Broadsound are available as required;
- Availability of site access for works as required;
- Contractor and MSP resources are available as required;
- No extension to the security fence will be required;
- Internal design, contractor design and MSP resources are available as required;
- A geotechnical study has not been performed and estimates are based on standard foundations;
- Existing ground conditions are suitable for the construction of standard foundations;
- The substation platform exists and therefore detailed survey is not required;
- New equipment shall be set out relative to existing equipment;
- Contractor spoil can be spread on site adjacent the substation pad;
- Electric and magnetic field studies and calculations are not required;
- Lighting studies and calculations are not required;
- Testing of the Light levels is not required at commissioning;
- There is sufficient space in the existing control building at Broadsound for the new panels;
- All designs will be in accordance with SDM8 and subsequent Standards Updates;
- SIP Panel will not be installed at Broadsound by the time of commissioning reactor panel;
- New structure foundations are high level mass type due to the possible presence of underlying rock;
- Noise walls for the new reactor are not required however the design will include provision for the construction of future noise walls;
- 275kV lattice steel gantries are required;
- Should the available substation drawings be inadequate for the design, then additional detailed survey will be required;
- Existing drainage system is adequate to accommodate any additional trench/pit drainage in this project;
- Existing AC supplies are adequate for this project with no additional supplies or capacity required;
- Injection testing of the earth grid is not required; and

2.4 Project Interaction

OR02223 BS1140 Stanwell Broadsound Suspension Insulator Replacement – Date for PC 20/6/2022.

2.5 Project Risk

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

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

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

3. Project Financials

3.1 Project Estimate

3.1.1 Estimate Summary

Un-escalated Base Estimate Summary.

	Prescribed $	Non- Regulated $	Total $
Line Works	0	0	0
Primary Plant	7,406,205	0	7,406,205
Secondary Systems	636,066	0	636,066
Communications	0	0	0
Management & Overheads	869,614	0	869,614
Estimate Allowance	721,902	0	721,902
Total	9,633,787	0	9,633,787

3.1.2 Asset Write-Off Table

Nil.

3.2 Approved Released Budget

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

Estimate Components			Un-Escalated $	Escalated $
Base Estimate	Cost Estimate		8,911,886	9,416,223
	Estimate Allowance		721,902	762,731
	Total Base Estimate		9,633,787	10,178,954

3.3 Planned Costs (Forecasted Cash Flow)

	ID&TS Labour Hours	Excl. Estimate Allowances $		Incl. Estimate Allowances $	
ID&TS Labour &		Jul 2020 Base Date	Completion	Jul 2020 Base Date	Completion
To June 2021	151	407,240	407,240	440,641	440,641
To June 2022	2,143	4,857,896	5,057,070	5,251,171	5,466,469
To June 2023	1,609	3,646,750	3,951,913	3,941,975	4,271,843
Total	**3,903**	**8,911,886**	**9,416,223**	**9,633,787**	**10,178,954**

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

4. Project Planning Strategy

4.1 Milestones

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

Milestones	Planned Dates
Project Approval (issue of PAN)	01/05/2021
Design complete	20/12/2021
Site Access - to carry out investigations, inspections, etc.	Immediate
Site Possession - to carry out construction works	Immediate
Construction complete	31/01/2023
Project Commissioning Date	31/03/2023

Assuming the project is approved by 1/5/2021 the date for Practical completion will be 31/03/2023.

4.2 Project Staging

The high level project staging are as follows:

Stage	Activity/Stage Description	High Level Timing
1	Construction	May 2022 – Jan 2023
2	Broadsound SAT	Feb2023
3	Extend Bus	March 2023
4	Commissioning	March 2023

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

4.3 Project Schedule

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

4.4 Network Impacts and Outage Planning

Outages to extend the bus & commission the reactor are available with a four hour return to service.

4.5 Project Delivery Strategy

Strategy to deliver the project as follows:

Description	*Responsibility*							
	Main Site				*Remote End(s)*			
	Powerlink	*Contractor*	*MSP – O&SD*	*MSP - Ergon*	*Powerlink*	*Contractor*	*MSP – O&SD*	*MSP*
Primary Design Systems (PSD):								
Earthworks	☐	☒	☐	☐	☐	☐	☐	☐
Civil and Structural	☐	☒	☐	☐	☐	☐	☐	☐
Electrical	☐	☒	☐	☐	☐	☐	☐	☐
Secondary Systems Design (SSD):								
Protection	☒	☐	☐	☐	☐	☐	☒	☐
Automation (Circuitry and Systems Configurations)	☐	☒	☐	☐	☐	☐	☒	☐
Telecommunication System Design (TSD):								
Data Networks	☒	☐	☐	☐	☐	☐	☒	☐
Bearer Networks	☒	☐	☐	☐	☐	☐	☒	☐
Construction:								
Earthworks	☐	☒	☐	☐	☐	☐	☐	☐
Civil	☐	☒	☐	☐	☐	☐	☐	☐
Construction	☐	☒	☐	☐	☐	☐	☐	☐

Description	*Responsibility*							
	Main Site				*Remote End(s)*			
	Powerlink	*Contractor*	*MSP – O&SD*	*MSP - Ergon*	*Powerlink*	*Contractor*	*MSP – O&SD*	*MSP*
(support structures, plant and equipment installation and demolition Works)								
Secondary Systems Installation (loose panels installation, panel modification, IED replacement, etc.)	☐	☒	☐	☐	☐	☐	☒	☐
Telecommunication Construction (including fibres)	☐	☐	☒	☐	☐	☐	☒	☐
Testing and Commissioning:								
Factory Acceptance Test	☐	☐	☒	☐	☐	☐	☒	☐
Site Acceptance Test (partial)	☐	☐	☒	☐	☐	☐	☒	☐
System Cut Over and Commissioning	☐	☐	☒	☐	☐	☐	☒	☐
Other:								
Revenue Metering site works – N/A	☐	☐	☐	☐	☐	☐	☐	☐

4.6 Procurement Strategy

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

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

5. Project Execution Strategy

5.1 Project Change Control

Project changes, e.g. scope, cost and time, shall be managed using the Project Change Control process to ensure that each proposed change during a project is properly defined, considered and approved prior to implementation.

Refer to project change control register in PWA Server.

5.2 Design Management

Design shall be managed by the nominated Design Coordinator. Refer to:

- Design Schedule for timing to provide the design deliverables;
- Safety-in Design Report will be conducted during design; and
- Applicable Design Advices and supporting design documentation (refer to section 13).

5.3 Construction Management

Construction shall be managed by the Project Manager with support from nominated Construction Advisors and Construction Facilitators. Refer to Project Staging Plan (refer to section 13) for Construction strategy.

The Project Manager, with the assistance of the Project Team, shall address the following minimal requirements:

- Site Location
  - Site Address/location
  - Remoteness of work site:
  - Travel
  - Accommodation
  - Site Offices
  - Communication (mobile reception, telephone, internet, etc.)
  - Concrete batching plants
  - Contractor working roster
  - Other.
- Climate considerations:
  - Inclement weather (hot, cold, wet working conditions)
  - Weather elements wind, dust, humidity, heat stress
  - Cyclonic conditions.
- Site topography:
  - Plant and equipment access to the site and immediate areas
  - Plant and equipment working conditions on site and the immediate areas
  - Access to local infrastructure (e.g. roads / bridges) to accommodate the delivery of large plant such as transformers, control buildings and the like.
  - Crossings (Highways, roads, rivers, distribution assets, state forest, hotspots, etc.)
- Site conditions:
  - Noise constraints adjacent to neighbouring areas such as residential, retail, school and medical precincts especially outside of approved working hours.
  - Site security requirements
  - Archaeological, cultural heritage and environmental site constraints
  - Unexploded Ordinance (UXO)
  - Availability of utility services (e.g. power, telecommunication, water, gas)

  - Soil types and conditions (e.g. black soil, rock)
  - Native flora and fauna.
- Entry to 3rd party premises, sites and easements (e.g. mines, power stations, collocated telecommunications sites, local authority assets):
  - Site inductions
  - Industrial agreements.

Details of Party Holding Principal Contractor (PC) Status by Project Stage			
Project Staging	Contractor as PC	Ergon Energy as PC	Powerlink O&FS (Live Subs and Lines) as PC
Stage 1 (Construct new bay and extend Bus)	☒	☐	☐
Stage 2 (SAT of the 275kV SDM8 Control and Protection cubicle)	☐	☒	☐
Stage 3 (Bus outage to extend Bus and connect new bay)	☐	☒	☐
Stage 4 (Testing & Commissioning)	☐	☒	☐

5.4 Test and Commissioning Management

Testing and commissioning shall be managed by the nominated Project Commissioning Manager. Refer to the follow documentation:

- Project Staging plan (refer to section 13) for testing and commissioning strategy;
- Commissioning Advice; and
- Equipment to be Tested (for RFQ and ITT)
- Panels will be FAT tested at the MSP facility prior to delivery to site.

6. Project Quality Management

6.1 General

In addition to the Powerlink's Quality Management System requirements, contractors are required to have a quality system in place. Quality compliance requirement are specified in Powerlink's Quality Specification. The Contractor shall develop and submit as Quality Plan for review and acceptance by Powerlink prior to establishing on site. Verification of contractor activities occurs at various stages of the project by way of document reviews, inspections and audits.

All aspects of Design Reviews, Procurement, Construction and Test/Commissioning, shall be checked and inspected in accordance with Powerlink standards and processes, including verification, validation and record keeping processes and procedures.

All issues and defects shall be entered into Project Server and tracked until rectification is complete.

Non-conformance and corrective actions shall be entered into PQ Switch and tracked until rectification is complete.

6.2 Quality in Design

Design works shall be done in accordance with Powerlink's design manuals. *Quality of design work is monitored through d*esign reviews in accordance with Powerlink's standards and processes. Design queries raised by Contractors or Powerlink are managed by using Technical Queries (TQ) document. These TQs are logged in the TQ register.

The nominated Design Coordinator shall conduct a safety in design review.

Where Powerlink performs the design works, the designs are peer reviewed and RPEQ reviewed and approved.

Where a Contractor performs the design works, the design are reviewed by the Contractor's RPEQ and then reviewed by Powerlink in specified review meetings.

6.3 Quality in Construction

Construction works shall be performed in accordance with approved drawings and Powerlink's specifications. Quality of construction work by the contractor is monitored through the management of Inspection Test Plan (ITP). This is further verified by nominated control (surveillance, witness and hold) points through site inspections, audits, formal testing and documentation of defects and reviews of claims, variations and program.

6.4 Quality in Testing and Commissioning

Testing and commissioning works shall be performed in accordance with approved drawings and Powerlink's manuals, policies and procedures.

Quality of testing work by the contractor is monitored through the management of Inspection Test Plans (ITPs) supported by work instructions. This is verified by nominated control (surveillance, witness and hold) points during testing and commissioning works.

Quality of testing and commissioning work by the MSP is managed through the creation of Commissioning Test Plans (CTPs) by the Project Commissioning Manager and the Inspection Test Plans (ITPs) and lower order test documents produced by the secondary systems field support engineers.

Design, construction and equipment defects discovered during the testing are recorded and managed until rectified in the defect management system. Defects are also entered into PWA Server. Any outstanding defects are closed in the defect management system and project server and are recorded as P1s in SAP after the associated equipment or system is commissioned. P1s are managed in SAP until rectified.

6.5 Lessons Learnt

Lessons Learnt shall be captured in PWA Server.

7. Project Resourcing

Refer to Project Site in PWA Server for list of project team members and external contacts.

8. Project Health, Safety and Environmental (HSE) Management

Item Description	Acceptance Criteria (Measure/Benchmark/Standard/Regulation)
Project HSE Risk Assessment	Project Team shall develop Project HSE Risk Assessment prior to issue of any ITTs or RFQs. **Note**: For works in operational substations, the project team shall review works, layout, condition assessments of plant and equipment, earthing tests, RAZ zones and Partial Discharge (PD) assessments using Radio Interference and based on findings determine mitigations for working around the ageing plant at the specific location.

Item Description	Acceptance Criteria (Measure/Benchmark/Standard/Regulation)
	This may affect staging, sequence and scope of works and could include additional condition assessments, testing and/or ongoing PD assessment monitoring program. The PD assessment works shall be initiated **at least 3 months prior** to Contractor establishing on the operational substation site.
HSE Advisor	An HSE advisor shall be nominated to provide Health, Safety and Environment advice.
WHS Compliance	WHS compliance requirement shall be specified in Powerlink's WHS Specification and HIC. The Contractor shall develop and submit as WHS Plan and SWMS for review and acceptance by Powerlink prior to establishing on site.
Safety in Design (SID)	Safety in design shall be managed by Design Coordination. Refer to Safety in Design Report in Section 13. Refer to PWA Server for Safety in Design items that have not been closed out at design handover.
Hazard Identification in Construction (HIC)	Project Manager shall develop the HIC to identify all hazards applicable to the project. Refer to Hazard Identification for Construction (HIC) in Section 13.
Principal Contractor Arrangements	Principal Contractor shall be identified and appointed for every phase of the Project Work at site. If Powerlink is the engaged Principal Contractor Reference to be made to Powerlink's Safety Management Plan. If Contractor is the engaged Principal Contractor Contractor Safety Management Plan is required as per WHS specification If managing Multiple Contractor at site Where works being undertaken by Contractor X may be in the same work area (and may overlap) or under the same Project, Contractor X shall be required to work under the engaged Principal Contractor Safety Management Plan, directions and requirement. Refer to section 5.3 for Principal Contractor engagement based on project staging or contract separable portions.
Safety Work Method Statement (SWMS)	For high risk activities, Powerlink shall review SWMS prepared by the following parties: Principal Contractor Powerlink's appointed Contractor (e.g. Ergon, OSD) working under Principal Contractor Powerlink to provide Principal Contractor approval of the appointed Contractor's SWMS For works performed by MSP (OSD and Ergon) under a Principal Contractor, the MSP shall develop and submit as WHS Plan for review and acceptance by the Principal Contractor prior to commence with works.
Environmental Compliance	Environmental compliance requirements shall be specified in Powerlink's Environmental Management Specification, Environmental Annexures and Environmental Work Plan (EWP). The Contractor shall develop and submit as Environmental Management Plan for review and acceptance by Powerlink prior to establishing on site. Where applicable, the following specific plans may be required as part of the as Environmental Management Plan:

Item Description	Acceptance Criteria (Measure/Benchmark/Standard/Regulation)
	Stormwater Quality Management Plan Erosion & Sedimentation Control Plan Rehabilitation
Pre-Construction Risk Assessment Workshop	Participate in a Pre-Construction Risk Assessment workshop meeting convened by the Contractor to identify construction hazards and associated control measures to eliminate or minimise health, safety and environmental risks. For further details of the Pre-Construction Risk Assessment workshop, refer to the Specification of Construction Works – General.
HSE major issues and risk	Refer to risk register in PWA Server

9. Project Cultural Heritage Management

An assessment by the Cultural Heritage team identified no risk of harm or interference to Cultural Heritage.

Where applicable, Cultural Heritage shall be managed in accordance with Powerlink's Cultural Heritage Management – Framework with requirements specified in the following documents:

- Cultural Heritage Implement Document (CHID);
- Environmental Work Plan (EWP);
- Environmental Annexures;
- Environmental Management Plan (EMP); and
- Cultural Heritage Management Plan (CHMP).

10. Project Communications and Stakeholder Management

10.1 Communication Plan

Communication Description	Frequency and / or Date	Responsibility	Audience
Project Management Plan(PMP)	Within 8 weeks of PAN and maintained during project execution	Project Manager	Project Team and ID Management
Internal emails	ongoing	Project team	Impacted project team members

Communication Description	Frequency and / or Date	Responsibility	Audience
External emails	ongoing	Project Manager	Impacted project team members, Customers, MSP, etc.
Kick-off / Progress / Contract Meetings	Monthly	Project Manager	Project Team / Contractor / MSP
Design Progress / Review Meetings	As required	Design Coordinator	Project Team / Contractor / MSP
Officer For Local Security (OFLS) Report	Monthly	Project Manager	OFLS & MSP
Monthly Report (PM Status Update in PWA Server)	Monthly	Project Manager	Project Team, Management, Executive, Board
Close out: • Project Review Report • Final Project Report	On completion	Project Manager	Board and Executive

10.2 External Communication

Not Applicable.

11. Training

Training is not included in the project.

12. Project Finalisation and Closure

12.1 As-Built Drawings / Documents / Data

Post commissioning and as-built drawings shall be managed in accordance to with Project Drawing Control for Substation and Transmission Line System Design – Guideline (A1556191)

12.2 SAP Equipment Data

SAP data shall be managed in accordance with Management of SAP Equipment Data – Procedure (A2590157). The procedure outlines the requirements for collection of equipment data using templated spreadsheet forms.

12.3 Closure Actions / Milestones

Project closure actions and milestones shall be managed using the Milestone Checklist Spreadsheet (A1817126).

12.4 Post Project Review

A post project review meeting shall be conducted as part of project finalisation.

13. References

The following documents are applicable to this Project Management Plan.

Document name and hyperlink	Version	Date
Project Definition		
Project Scope Report	**1**	**17/01/20**
Project Staging and Outage Plan		
Project Staging Plan	**0**	**14/02/20**
Project Outage Plan		
Project Schedule		
Project Schedule		
Project Financial		
Budget/Plan/Actual		
Design		
Electrical Design Advice	**1**	**05/02820**
Civil Design Advice	**1.0**	**04/03/20**
Secondary Systems Design Advice	**1.0**	**28/02/20**
Testing and Commissioning		
Commissioning Advice	**1**	**20/02/20**
Equipment to be Tested	**N/A**	
Quality		
Nominated Control (Surveillance, Witness and Hold) Points for ITPs - Construction		
Nominated Control (Surveillance, Witness and Hold) Points for ITPs - Testing		
Risk Management/Issues and Defects		
Risk Register		
Issues and Defects Register		
Project Resourcing		
Project Team and External Contacts		

Powerlink Queensland

Project Specification Consultation Report

8 October 2020

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[1] 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. More information on the RIT-T process and how it is applied to ensure that safe, reliable and cost effective solutions are implemented to deliver better outcomes to customers is available on Powerlink's website.
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 customers.
3. The main purpose of this document is to provide details of the identified need, credible options, technical characteristics of non-network options, and categories of market benefits addressed in the assessment. In particular, it encourages submissions from potential proponents of feasible non-network options to address the identified need.

[1] Such requirements include, but are not limited to, addressing any emerging reliability of supply issues or relevant *ISP actionable projects* identified in the Australian Energy Market Operator's (AEMO) latest Integrated System Plan (ISP), for which Powerlink has responsibility as the relevant Transmission Network Service Provider (TNSP).

Contents

Executive Summary

Changing electricity generation and consumption patterns in Central and Northern Queensland require Powerlink to take action

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.

Insufficient reactive capacity in the Central Queensland section of the grid is also making it increasingly difficult to obtain outages for maintenance purposes, increasing the likelihood of Powerlink breaching its responsibilities as a Transmission Network Service Provider (TNSP) under the Rules, as well as its Transmission Authority reliability and service standards.

Powerlink is required to apply the RIT-T to this investment

The identified need to manage voltages within allowable limits requires Powerlink to apply the RIT-T.

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 Rules, and is classified as a 'reliability corrective action'[2].

As the identified need is not discussed in the most recent Integrated System Plan (ISP), it is subject to the application and consultation process for RIT-T projects not defined as *actionable ISP projects*[3].

Powerlink has presented three credible network options in this Project Specification Consultation Report (PSCR) to maintain the existing electricity services, ensuring an ongoing reliable, safe and cost effective supply to customers in the area.

All options presented are below $43 million, with the only material market benefit being changes in fuel costs, which are identical for each option. As there are no market benefits that change the ranking of the options, Powerlink has adopted the expedited process for non-ISP projects for this RIT-T[4]. The changes in fuel costs have been included in the economic analysis of the options.

A non-credible Base Case has been developed against which to compare the credible options

Consistent with the Australian Energy Regulator's (AER's) RIT-T Application Guidelines for non-ISP projects, the assessment undertaken in this PSCR compares the net present value (NPV) of the credible network options identified to address the emerging risk-costs of a "do-nothing" Base Case.

[2] The Rules clause 5.10.2, Definitions, reliability corrective action.
[3] Refer to Clause 5.16.2 of the NER.
[4] In accordance with clause 5.16.4(z1) of the Rules and S4.1 AER Regulatory investment test for transition application guidelines, August 2020

The Base Case is modelled as a **non-credible** option where the emerging issue of non-compliant over voltage events is managed via the despatching of off-line generators to provide voltage support to the network. The additional fuel costs of despatching these generators forms the market costs of the "do nothing" Base Case.

Proposed network options to address the identified need

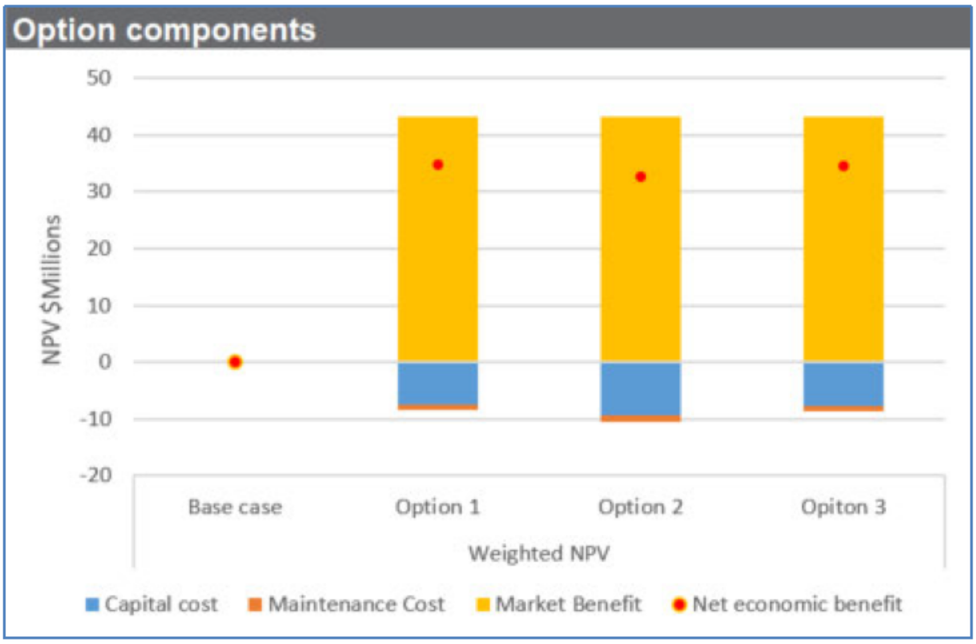
The credible network options, along with their NPVs relative to the Base Case are summarised in Table 1. The absolute NPVs of the Base Case and the credible network options are shown in Figure 1.

Table 1 illustrates that the three credible network options have a net economic benefit relative to the non-credible Base Case.

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 300kV line reactors at H020 Broadsound 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



The Base Case is not a credible option, in that it does not allow Powerlink to continue to maintain compliance with the requirements of relevant regulatory instruments and the Rules. As the investment is classified as a 'reliability corrective action' under the Rules, the purpose of the RIT-T is to identify the credible option that minimises the total cost to customers.

Taking into account capital, operational maintenance and market benefits, Option 1 delivers the greatest net economic benefit, providing a $34.80 million net economic benefit in NPV terms when compared to the Base Case over the 20-year analysis period.

Option 1 has been identified as the preferred network option

The preferred network option involves establishment of a 275kV bus connected shunt reactor at the Broadsound Substation by June 2023. Powerlink is the proponent of this network option.

Under this option, installation and commissioning of the reactor will be completed by June 2023.

Powerlink welcomes the potential for non-network options to form part or all of the solution

Powerlink welcomes submissions, from proponents who consider they could offer a potential non-network solution by January 2021.

A non-network option that avoids the proposed installation of the new shunt reactor would need to replicate, in part or full, the support that the reactor delivers to the network in the Central Queensland area, on a cost effective and ongoing basis.

Lodging a submission with Powerlink

Powerlink is seeking written submissions on this Project Specification Consultation Report on or before Friday, 8 January 2021, particularly on the credible option presented[5].

Please address submissions to:

Sarah Huang
Acting Manager Network and Alternate Solutions
Powerlink Queensland
PO Box 1193
VIRGINIA QLD 4014
Tel: (07) 3860 2328

Submissions can be emailed to: networkassessments@powerlink.com.au

[5] Powerlink's website has 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.

1 Introduction

1.1 Powerlink Asset Management and Obligations

Powerlink Queensland is a Transmission Network Service Provider (TNSP) in the National Electricity Market (NEM) that owns, develops, operates and maintains Queensland's high-voltage electricity transmission network. This network transfers bulk power from Queensland generators to electricity distributors Energex and Ergon Energy (part of the Energy Queensland Group), and to a range of large industrial customers.

Powerlink's approach to asset management includes a commitment to sustainable asset management practices that ensure Powerlink provides valued transmission services to its customers by managing risk[6], optimising performance and efficiently managing assets through the whole of asset life cycle[7].

Planning studies have confirmed there is a long-term requirement to continue to supply electricity services to customers in Central and Northern Queensland.

Declining transmission flows between Central and Northern Queensland, the progressive displacement of traditional synchronous generation[8] with asynchronous or VRE generation[9], and declining minimum demand, are increasing the likelihood of non-compliant over-voltage events. The current strategy of switching out selected feeders to ensure ongoing compliance with the Rules' "*voltage* of *supply* at a *connection point*"[10], is at the limit of its technical effectiveness. Continued reliance on increasingly onerous reconfigurations of the network will result in higher market costs, reduced system resilience, and compromised system security, and is not an effective sustainable strategy.

Powerlink must therefore take action to ensure compliance with management of voltages in its transmission network.

As the proposed credible options to address the identified need include a potential investment in excess of $6 million, Powerlink must assess these options under the RIT-T.

When developing the credible options, Powerlink has focussed on implementing cost effective solutions that ensure a reliable supply, delivering positive outcomes for customers.

1.2 RIT-T Overview

The identified need referred to in this RIT-T, managing the over voltage risks in Central Queensland, is not discussed in the most recent Integrated System Plan (ISP). As such, it is subject to the application and consultation process for RIT-T projects not defined as *actionable ISP projects*[11].

This Project Specification Consultation Report (PSCR) is the first step in the RIT-T process[12]. It:

- describes the reasons why Powerlink has determined that investment is necessary (the 'identified need'), together with the assumptions used in identifying this need
- provides potential proponents of non-network options with information on the technical characteristics that a non-network solution would need to deliver, in order to assist proponents in considering whether they could offer an alternative solution
- describes the credible option that Powerlink currently considers may address the identified need

[6] Risk assessments are underpinned by Powerlink's corporate risk management framework and the application of a range of risk assessment methodologies set out in AS/NZS ISO31000:2018 Risk Management Guidelines.
[7] Powerlink aligns asset management processes and practices with AS ISO55000:2014 Asset Management – Overview, principles and terminology to ensure a consistent approach is applied throughout the life cycle of assets
[8] For example hydro, thermal coal and thermal gas generation
[9] Such as wind turbine and solar generation.
[10] National Electricity Rules, Version 148, 21 August 2020, Schedule 5.1a.4 Power frequency voltage
[11] Refer to Clause 5.16.2 of the NER.
[12] This RIT-T consultation has been prepared based on the following documents: National Electricity Rules, Version 148, 21 August 2020 and AER, Regulatory investment test for transmission application guidelines, August 2020.

- discusses why Powerlink does not expect specific categories of market benefit to be material for this RIT-T[13]
- presents the NPV assessment of the credible option compared to a Base Case (as well as the methodologies and assumptions underlying these results)
- identifies and provides a detailed description of the credible option that satisfies the RIT-T, and is therefore the preferred option
- describes how customers and stakeholders have been engaged with regarding the identified need
- provides stakeholders with the opportunity to comment on this assessment so that Powerlink can refine the analysis (if required)

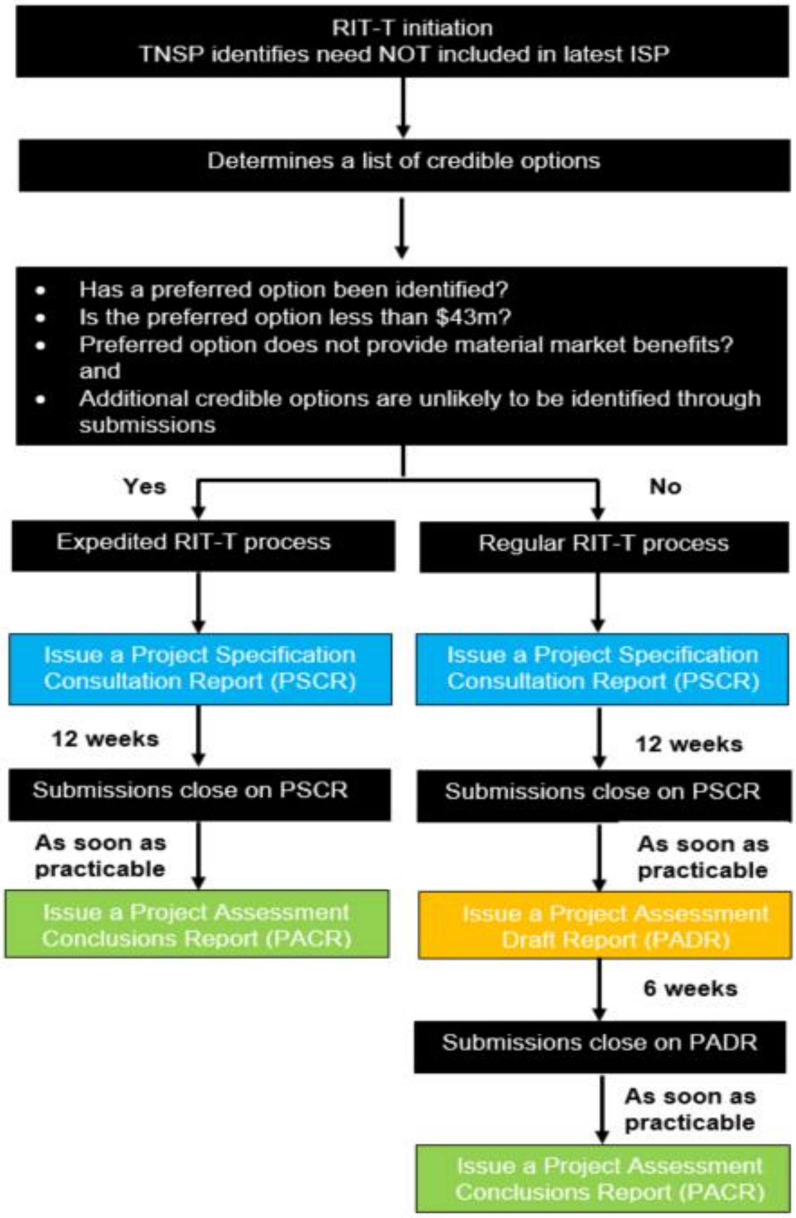
Powerlink has adopted the expedited process for this RIT-T, as allowed for under the Rules for investments of this nature[14]. Specifically, Powerlink will publish a PACR following public consultation on this PSCR and apply the exemption from publishing a Project Assessment Draft Report (PADR) as:

- the preferred option has an estimated capital cost of less than $43 million
- market benefits arising from the credible options do not impact the ranking of options or the selection of the preferred option[15]
- Powerlink has identified its preferred option in this PSCR (together with the supporting quantitative cost-benefit analysis)
- Powerlink is currently not aware of any non-network options that could be adopted. This PSCR provides a further opportunity for providers of feasible non-network options to submit details of their proposals for consideration.

Powerlink will however publish a PADR if submissions to this PSCR identify other credible options that have not yet been considered and which could provide a material market benefit.

[13] As required by clause 5.16.1(c)(iv) of the Rules.
[14] In accordance with clause 5.16.4(z1) of the Rules
[15] Section 4.3 Project assessment draft report, Exemption from preparing a draft report, AER, Regulatory investment test for transmission application guidelines, August 2020

Figure 1.1: RIT-T Process Overview for projects that are not *actionable ISP Projects*



2 Customer and non-network engagement

With 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 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 TAPR, an expectation that action would be required to address the emerging voltage control issues in Central Queensland[16].

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.

[16] This relates to the standard geographic definitions (zones) identified within the TAPR.

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 further improve the RIT-T stakeholder engagement process.

2.5 The transmission component of electricity bills

Powerlink's contribution to electricity bills reduced by a third from July 2017 and comprises approximately 8% of the total cost of the residential electricity bill (refer to Figure 2.1).

Figure 2.1: Components of end user bills

Generator Charges (41%) + Transmission Charges (8%) + Distribution Charges (36%) + Retail Charges (5%) + Green Policies (5 %) = 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

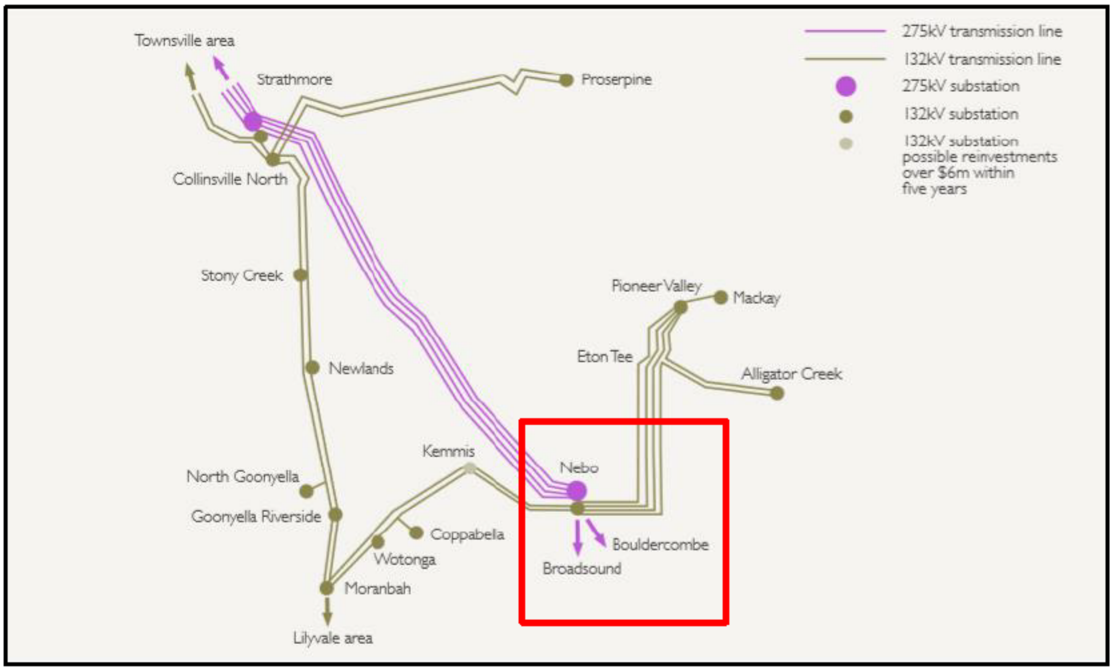
This section provides an overview of the existing voltage control arrangements in Central Queensland and describes the increasing risk to Powerlink of being unable to maintain compliance with relevant standards, applicable regulatory instruments and the Rules, which are designed to ensure Powerlink's 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[17].

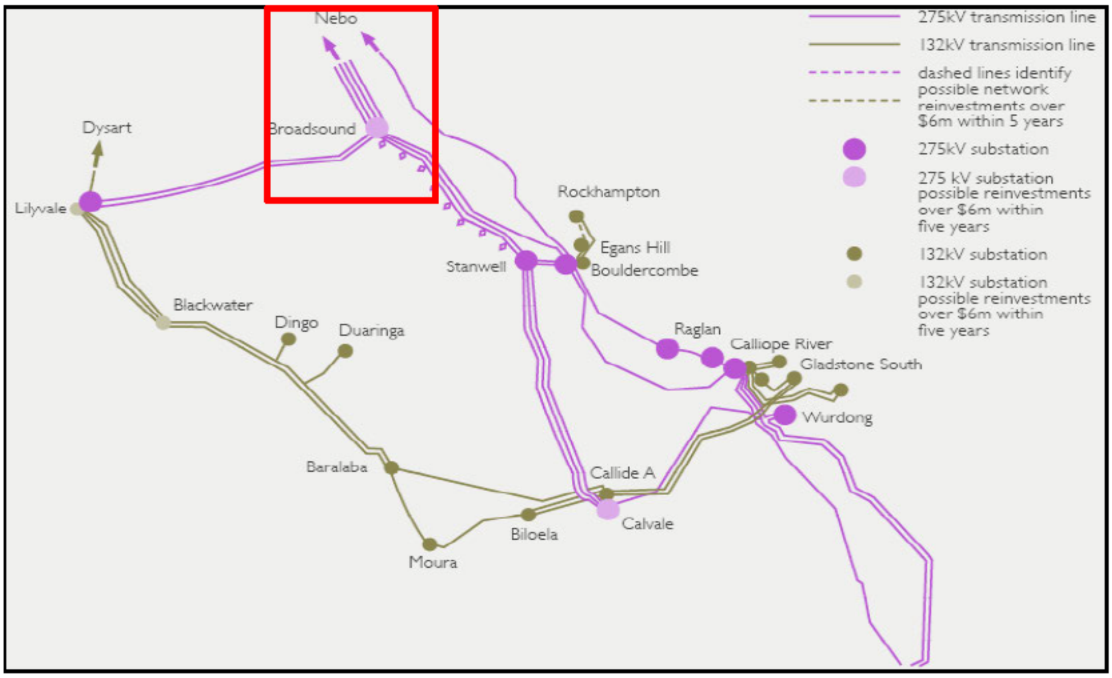
The Northern and Central transmission networks are shown in Figures 3.1 and 3.1a

Figure 3.1: Northern transmission network



[17] Transmission Annual Planning Report 2019, Appendix A – Compendium Forecast of connection point maximum demand

Figure 3.1a Central transmission network



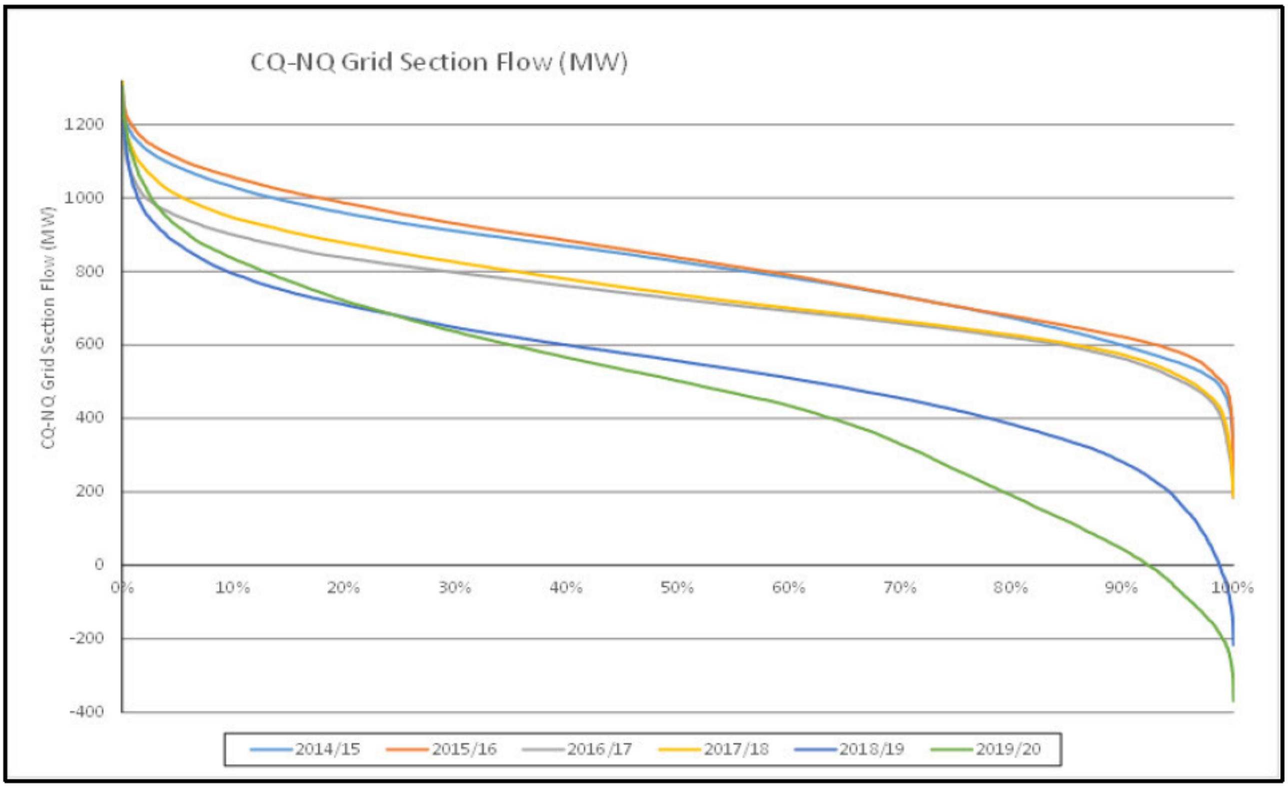
3.1.1 Increasing voltage risks associated with a rapidly transitioning energy system

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[18] 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[19].

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.

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

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[20].

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[21], 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 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.

[20] The Rules clause 5.10.2 ,Definitions, reliability corrective action

[21] [21] 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

4 Required technical characteristics for non-network options

The information provided in this section is intended to enable interested parties to formulate and propose genuine and practicable non-network solutions such as, but not limited to, local generation and Demand Side Management (DSM) initiatives.

This PSCR provides a further opportunity for providers of feasible non-network options to submit details of their proposals for consideration.

4.1 Criteria for proposed network support services

Under system normal conditions, network support would need to provide voltage control equivalent to the proposed reactor at or near Nebo or Broadsound substations, being 126MVAr at the 275kV bus. Reactive support would be required to be available on a continuous basis, and not be coupled to generation output.

The network support must continue to operate as per system normal for planned and unplanned outages. Outages of the network support must be coordinated to ensure that Powerlink is able to maintain system security at all times.

The location(s) of any proposed non-network solution will determine the exact levels of support required and will be considered on a case by case basis.

Powerlink has identified the following common criteria that must be satisfied if proposed network support services are to meet supply requirements[22].

Size and location

- Proposed solutions must be large enough, individually or collectively, to provide the size of injection or demand response set out above. However, the level of support is dependent on the location, type of network support and load forecasts.
- Due to the bulk nature of the transmission network, aggregation of sub 10MW non-network solutions will be the sole responsibility of the non-network provider.
- Notwithstanding the location of any solution, each proposal would require assessment in relation to technical constraints pertinent to the network connection, such as impacts on intra-regional transfer limits, fault level, system strength, maintaining network operability and quality of supply.

Operation

- A non-network option would need to be capable of operating continuously 24 hours per day over a period of years.
- If a generation service is proposed (either standalone or in conjunction with other services), such operation will be required regardless of the market price[23].
- Proponents of generation services are advised that network support payments are intended for output that can be demonstrated to be additional to the plant's normal operation in the NEM.
- Where there are network costs associated with a proposed non-network option, including asset decommissioning, these costs will form part of the option economic assessment.

Reliability

- Proposed services must be capable of reliably meeting electricity demand under a range of conditions and, if a generator must meet all relevant National Electricity Rules requirements related to grid connection.
- Powerlink has obligations under the National Electricity Rules, its Transmission Authority and connection agreements to ensure supply reliability is maintained to its customers.

[22] Powerlink's Network Support Contracting Framework has been developed as a general guide to assist potential non-network solution providers. This framework outlines the key contracting principles that are likely to appear in any non-network support agreement.
[23] The National Electricity Rules prevent a generator that is providing network support from setting the market price.

Failure to meet these obligations may give rise to liability. Proponents of non-network options must also be willing to accept any liability that may arise from its contribution to a reliability of supply failure.

Timeframe and certainty

- Proposed services must be able to be implemented in sufficient time to meet the identified need, using proven technology and, where not already in operation, provision of information in relation to development status such as financial funding and development timeline to support delivery within the required timeframe must be provided.

Duration

- The agreement duration for any proposed service will provide sufficient flexibility to ensure that Powerlink is pursuing the most economic long run investment to address the voltage control issues in Central Queensland.

Powerlink welcomes submissions from potential proponents who consider that they could offer a credible non-network option that is both economically and technically feasible.

5 Potential credible network options to address the identified need

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 300kV line reactors at H020 Broadsound 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.

The forecast timing for implementation of the solution to address the over-voltage limitation identified in the 2019 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 solution can be implemented.

Additional options that have been considered but not progressed, for technical or economic reasons, are listed in Appendix 1.

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 1: 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[24].

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.[25]

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.

A discussion of each market benefit under the RIT-T that is considered not material is presented below:

- **changes in voluntary and involuntary load curtailment:** while the installation of additional reactive power plant will mitigate against the need to de-energise lines, the impact is not considered material to the selection of the preferred option
- **changes in costs for parties, other than the RIT-T proponent**: All three credible network options result in the same fuel cost savings, with the start-up, operating and maintenance costs arising from delivering the savings immaterial to the quantum of the savings and therefore the ranking and sign of the options
- **differences in the timing of expenditure**: As all three options offer a substantially similar outcome, any potential transmission investment at a future date for the purposes of voltage control will not change the ranking of the options
- **changes in network losses**: The proposed credible options will have only a marginal impact on network losses. Additionally all three options have the same impact and so there is no material influence on selection of the preferred option from network losses
- **changes in ancillary services cost**: there are no Frequency Control Ancillary Services (FCAS), Network Control Ancillary Services (NCAS), or System Restart Ancillary Services (SRAS) contracts in place to address the over-voltage issue therefore changes in these costs are not material to the outcome of the RIT-T assessment
- **competition benefits:** Due to the localised nature of the voltage issues**,** Powerlink does not consider that any of the credible options will materially affect competition between generators, and generators' bidding behaviour and, consequently, considers that the techniques required to capture any changes in such behaviour would involve a disproportionate level of effort compared to the additional insight it would provide

[24] 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.
[25] S3.6.1 Material classes of market benefits, AER, Regulatory investment test for transmission application guidelines, August 2020

- **option value**: The estimation of any option value benefit over and above that already captured via the scenario analysis in the RIT-T would require significant modelling, which would be disproportionate to any additional option value benefit that may be identified. No additional option value has therefore been estimated for this RIT-T
- the negative of **any penalty** paid or payable: Powerlink does not consider the reactive plant proposed will in any material way impact its obligation to meet any relevant government-imposed instruments

6.3 Consideration of market benefits for non-network options

Powerlink notes that non-network options may impact the wholesale electricity market (for example by displacing generation output). Accordingly, it is possible that several of the above classes of market benefits will be material where there are credible non-network options, depending on the specific form of the option.

Where credible non-network options are identified as part of the consultation process on this PSCR, Powerlink will assess the materiality of market benefits associated with these options. Where the market benefits are considered material, these will be quantified as part of the RIT-T assessment of these options.

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[26].

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).

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.

[26] AER, Regulatory investment test for transmission application guidelines, August 2020

There will be remaining asset life by 2039, at which point a terminal value[27] 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%[28] 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%[29] 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[30].

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[31]. Powerlink has chosen to present two reasonable scenarios consistent with the requirements for reasonable scenarios in the RIT-T instrument [32] and in accordance with the provisions of the RIT-T Application Guidelines[33].

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%.

[27] Terminal value was calculated based on remaining asset value using straight-line depreciation over the capital asset life.
[28] 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 .
[29] 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.
[30] AER, Regulatory investment test for transmission, August 2020, Section 23
[31] AER, Final: RIT–T, August 2020, sub-paragraph 20(b)
[32] AER, Final: RIT–T, August 2020, sub-paragraph 22
[33] S3.8.1 Selecting reasonable scenarios, RIT-T Application Guidelines, August 2020

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.

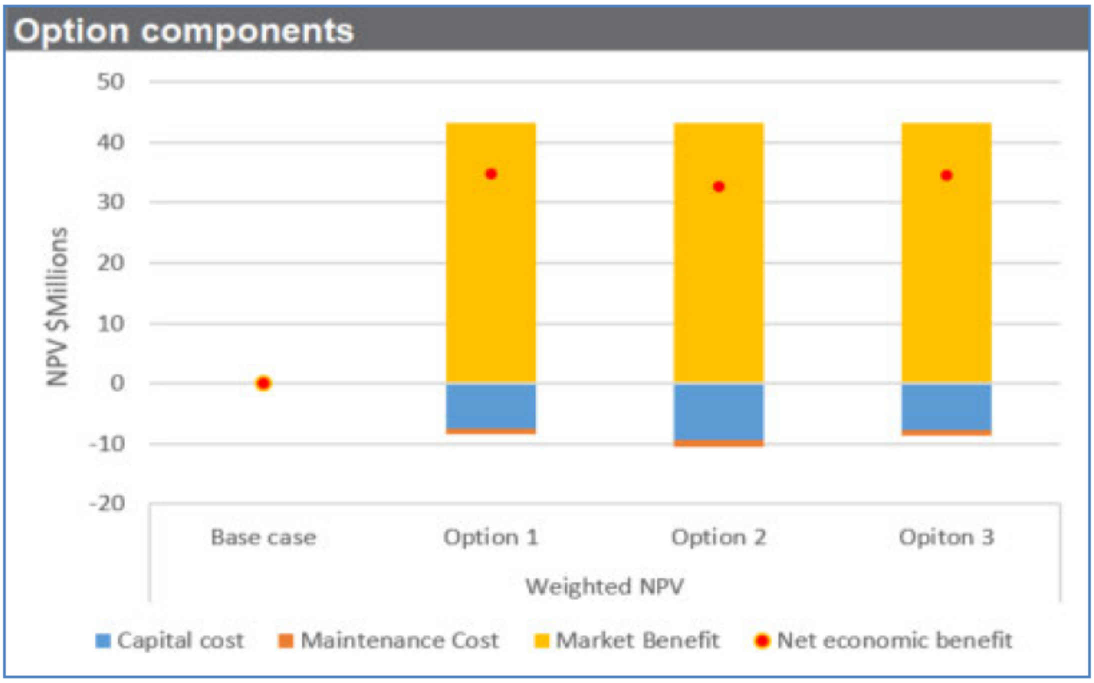
Table 9.1: NPV of the credible network options relative to the Base Case ($m, 2020/21)

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 300kV line reactors at H020 Broadsound 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.

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 9.5 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

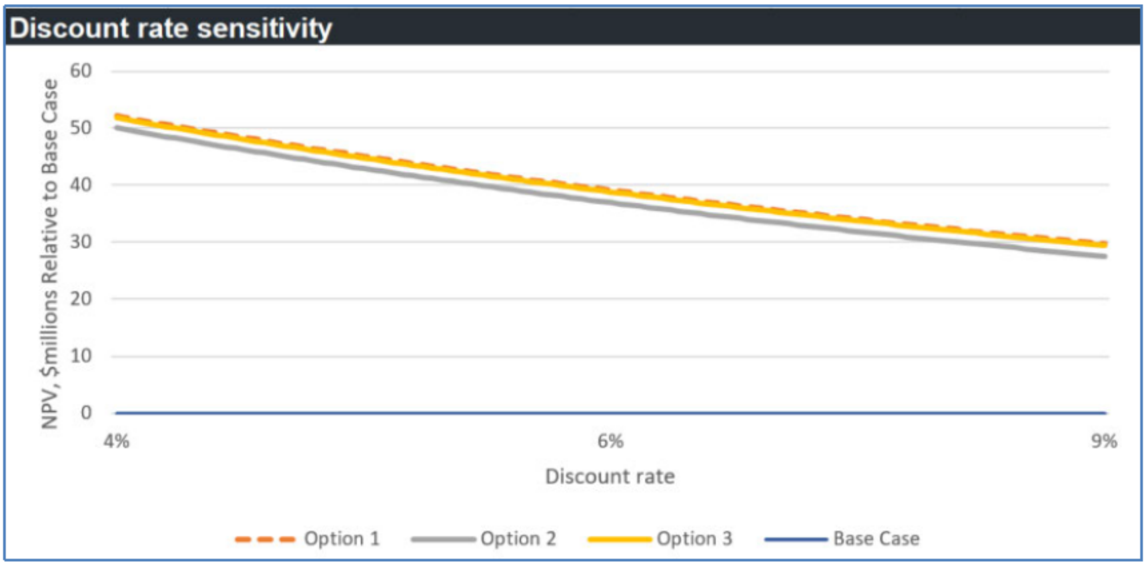


Figure 9.3: Capital Cost Sensitivity

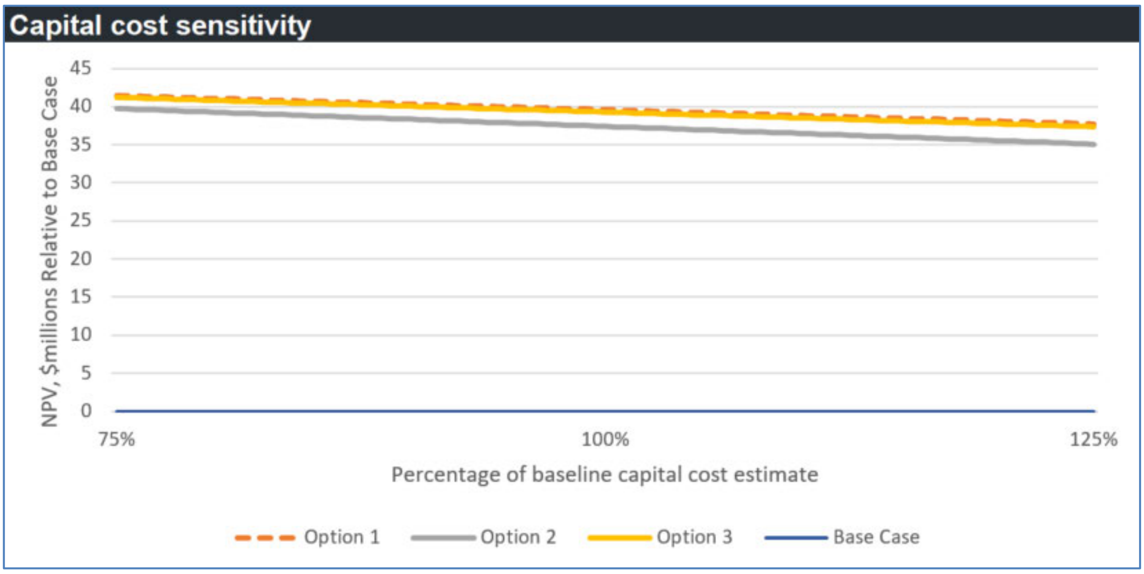
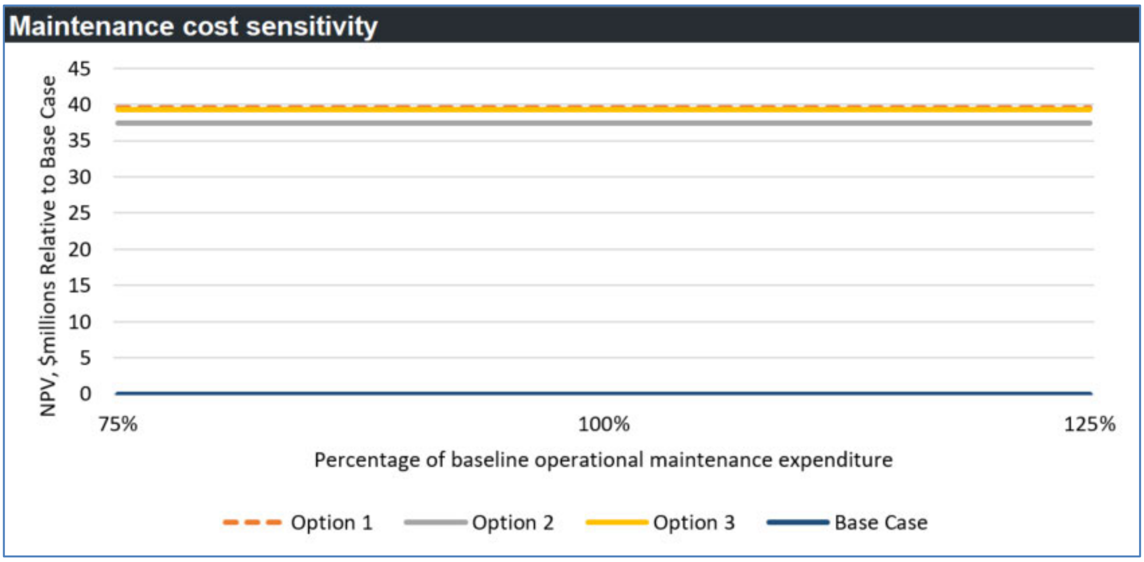


Figure 9.5: Maintenance Cost Sensitivity



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 9.6.

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.

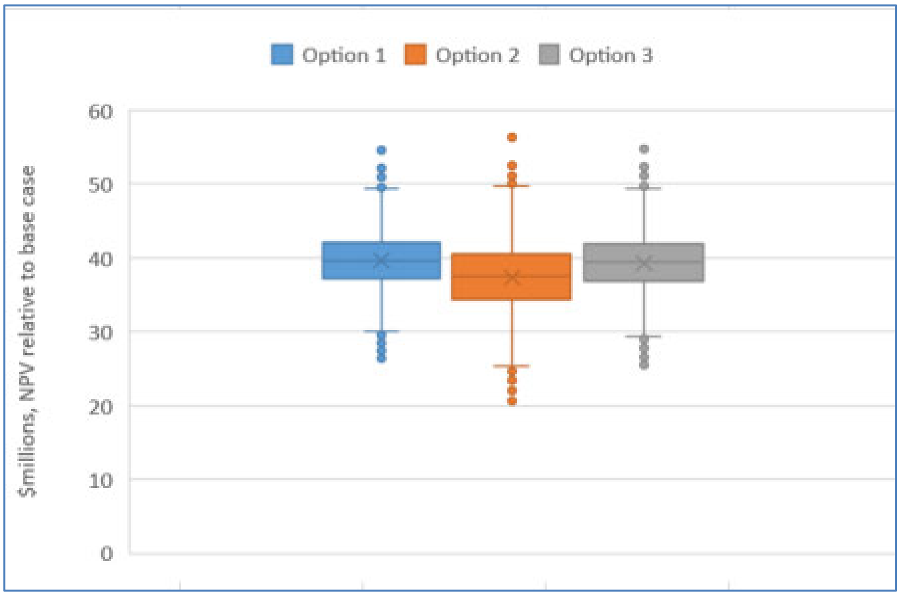


Figure 9.6: NPV sensitivity analysis of multiple key assumptions relative to the Base Case

9.4 Conclusion

The Base Case is not a credible option, in that it does not allow Powerlink to continue to maintain compliance with relevant standards, applicable regulatory instruments and the Rules. As the investment is classified as a 'reliability corrective action' under the Rules, the purpose of the RIT-T is to identify the credible option that minimises the total cost to customers.

Installing a 150MVAr 300kV bus reactor at Broadsound Substation presents the highest net economic benefit to customers and is considered to satisfy the RIT-T.

10 Draft recommendation

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 proposed network Option 1 be implemented to address over-voltage issues in Central Queensland. Implementing this option will also ensure ongoing compliance with relevant standards, applicable regulatory instruments and the Rules.

Option 1 involves the installation of a 150MVAr 300kV bus reactor at Broadsound Substation at an indicative capital cost of $9.63 million in 2020/21 prices.

Under this option, installation and commissioning of the reactor will be completed by June 2023.

11 Submissions requirements

Powerlink invites submissions and comments in response to this PSCR from Registered Participants, AEMO, potential non-network providers and any other interested parties.

Submissions should be presented in a written form and should clearly identify the author of the submission, including contact details for subsequent follow-up if required. If parties prefer, they may request to meet with Powerlink ahead of providing a written response.

11.1 Submissions from non-network providers

This is not a tender process – submissions are requested so that Powerlink can fulfil its regulatory obligations to analyse non-network options. In the event that a non-network option appears to be a genuine and practicable alternative that could satisfy the RIT-T, Powerlink will engage with that proponent or proponents to clarify cost inputs and commercial terms.

Submissions from potential non-network providers should contain the following information:

- details of the party making the submission (or proposing the service)
- technical details of the project (capacity, proposed connection point if relevant, etc.) to allow an assessment of the likely impacts on future supply capability
- sufficient information to allow the costs and benefits of the proposed service to be incorporated in a comparison in accordance with AER RIT-T guidelines for non-ISP projects
- an assessment of the ability of the proposed service to meet the technical requirements of the Rules
- timing of the availability of the proposed service
- other material that would be relevant in the assessment of the proposed service.

As the submissions will be made public, any commercially sensitive material, or material that the party making the submission does not want to be made public, should be clearly identified. It should be noted that Powerlink is required to publish the outcomes of the RIT-T analysis. If parties making submissions elect not to provide specific project cost data for commercial-in-confidence reasons, Powerlink may rely on cost estimates from independent specialist sources.

11.2 Assessment and decision process

Powerlink intends to carry out the following process to assess what action, if any, should be taken to address future voltage management requirements:

Part 1	PSCR Publication	8 October 2020
Part 2	Submissions due on the PSCR Have your say on the credible options and propose potential non-network options.	8 January 2021
Part 3	Publication of the PACR Powerlink's response to any further submissions received and final recommendation on the preferred option for implementation.	May 2021

Powerlink reserves the right to amend the timetable at any time. Amendments to the timetable will be made available on the Powerlink website (www.powerlink.com.au).

12 Appendix 1: Options considered but not progressed

Table A1: Options considered but not progressed

Option description	Reason for not progressing option
Establish 1x 150MVAr 300kV reactor with transfer bus at H011 Nebo	Extensive on site construction and testing made this option economically unviable. The 120MVAr Cap 3 will have to be moved back 3m to allow for the replacement of the independent earth switch to be replace with an isolator. A purpose-built special custom beam will have to be designed and fitted from the old rack structures to the new with different attachment heights for the beam, different offsets and different size to either of the existing units. A firewall to T6 and T2 will be required. A noise wall will be required. Outages of T6 and T2 will be required together to install these beams and strung bus and quite possibly for the delivery of the reactor. Cap 3 cannot be replaced with the reactor as it would have to be lifted over the =C6 strung bus at 20m high. Additional works by SIEMENS to modify SVC Q-Opt logic to 'inform' SVC if CB5832 is currently controlling a 'reactor' or 'cap bank'. Consideration of control system philosophy (two panels controlling one bay) e.g. interlocking. The Q optimiser logic will be unique and require extensive testing.
Establish 1x 150MVAr 300kV reactor at H020 Broadsound using an existing diameter by 2023	The reactor would only be able to be energised by the CB in the new bay within the diameter To switch the reactor in (or out) of service, it will be necessary to open the CB in the coupler bay, open the CB in the new bay, close (or open) the motorised disconnector on the reactor, then close the CB in the new bay followed by the coupler CB. This switching action would be required – on average – twice a day (once in, once out) The number switching operations required from both a plant and an operational perspective, are too high for a connection of this nature.
Establish a synchronous condenser at Broadsound	Capable of meeting voltage control requirements, however at a significantly higher cost than shunt reactors.

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