2023-27
POWERLINK QUEENSLAND REVENUE PROPOSAL

Project Pack – PUBLIC

CP.02814
Managing Southeast Queensland Voltages

CP.02814 – Managing SEQ Voltages

Project Status: Not Approved

1. Network Need

Falling demand, lower numbers of synchronous generators online and poor leading power factors has increased the complexity of managing voltages in South Queensland.

The continued displacement of traditional synchronous generation in Southern Queensland with rooftop PV solar and embedded renewable energy generation has significantly changed the daily load profile for Southern Queensland; producing a 'hollowing' effect throughout the middle of the day. This coupled with falling minimum demand alters the net power factor of the load, reduces the reactive power consumed by the distribution system and results in a reactive power surplus which must be absorbed by transmission connected plant.

Network studies have confirmed there is an enduring need to increase the reactive power absorption capability in Southeast Queensland. If unmanaged, Powerlink will incur potential violations of power system performance, security criteria and 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, immediate action needs to be taken. To date AEMO has been managing system limitations by switching out or de-energising feeders. This remedy is now at its operational limit.

The Planning Statement recommends the installation of three 275kV shunt reactors throughout northern, central and southern South East Queensland network. These will provide additional reactive capability to manage the high voltages and improve operability of the Southern Queensland system[1].

2. Recommended Option

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

The current recommended option is to install 275kV, 126MVAr bus shunt reactors at Blackstone, Woolooga and Greenbank Substations[3].

The following options have been identified to address the network risk:

- Do Nothing – rejected due to non-compliance with power frequency and security requirements.
- Non Network Option parameters outlined – at present no viable option has been identified, however Wivenhoe Hydro Power Station has been identified as a potential option for providing some level of reactive power absorption capacity.

Figure 2.1 shows the risk monetisation profile for SEQ voltage management is expected to exceed $3m per annum by 2030. This is expected to continue to increase due to continued uptake of rooftop PV solar, embedded renewable energy systems, and progressive installation of energy efficient devices within residential and commercial residences. All of which, drive the need for further reactive power and over-voltage management.

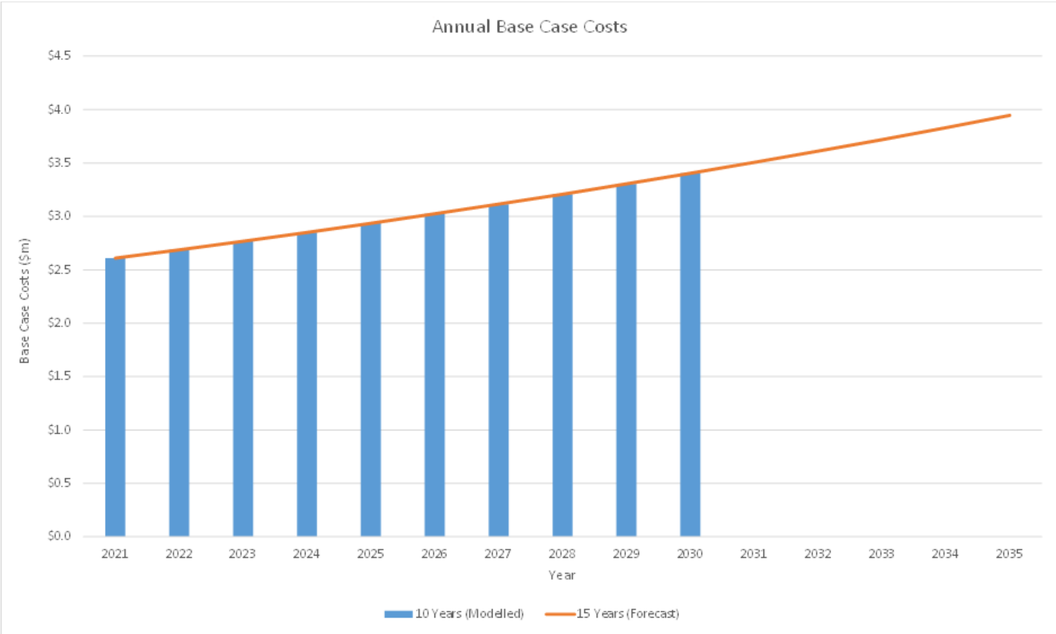

Figure 2-1 Risk Monetisation (Nominal)

3. Cost and Timing

The current recommended option is to install a 275kV, 126MVAr bus shunt reactors at Blackstone, Woolooga and Greenbank Substations is $30.3m ($2020/21 Base).

Target Commissioning Date: June 2024[5]

4. Documents in CP.02814 Project Pack

Public Documents

1. Managing Voltage Profile in South Queensland - Planning Statement
2. Base Case Benefits and Maintenance Costs Summary Report CP.02814 Managing SEQ Voltages
3. Project Scope Report CP.0214 Managing SEQ Voltages
4. Concept Estimate for CP.02814 Managing SEQ Voltages

Supporting Documents

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

Planning Statement		20/08/2020
Title	Managing Voltage Profile in South Queensland - Planning Statement [1]	
Zones	Moreton and South West	
Need Driver	Falling minimum demand and increasing reactive power import from the distribution network in south east Queensland has resulted in increasing risk of overvoltage and lack of voltage control in South Queensland.	
Network Limitation	Power system performance, security criteria and compliance with the National Electricity Rules (NER) power frequency voltage criterion (S5.1a.4) not being maintained.	
Pre-requisites	None	

Executive Summary

The emerging combination of lower demand, the lower number of synchronous generating units on-line and worsening leading power factors has led to increasingly difficult management of voltage in the South Queensland area.

In order to provide AEMO with the means to operate the power system in a secure state, there is a need to take immediate action. To date AEMO has been resorting to the switching-out, or de-energisation, of feeders. This remedy is now at its operational limit.

Planning recommends the installation of three busbar connected 275kV shunt reactors to provide reactive capability to manage the high voltages and improve operability of the South Queensland system. Given diversity in demand, these should be located in northern, central and southern South East Queensland (SEQ), e.g. Woolooga, Blackstone and Greenbank Substations.

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

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

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1 Background

The energy transformation is having a significant impact on the daily load profile and the operability of the transmission system. Historically, the daily load profile as delivered by the Powerlink transmission grid has seen daily maximum demand occur in the mid afternoon during the summer seasons, and during evening periods within the cooler winter seasons. Daily minimum demands have typically occurred during the night time (typically 4am or so) when industries and commercial premises are mostly closed and households are sleeping.

However, the installation of small scale rooftop photovoltaic solar (PV) systems and distribution connected solar farms is progressively changing the characteristics of daily demand required to be supplied by the Powerlink high voltage transmission system. The uptake of rooftop PV systems within Queensland has been one of the highest per capita rates in the world, and there are now over 700,000 installed rooftop PV systems with an aggregate state-wide capacity of more than 3,300MW.

While the cumulative effect of small scale renewable energy has reduced maximum demand and energy consumption, power produced by embedded solar installations has the effect of ‘hollowing’ the daily demand profile during the daytime period (refer to Figure 1).

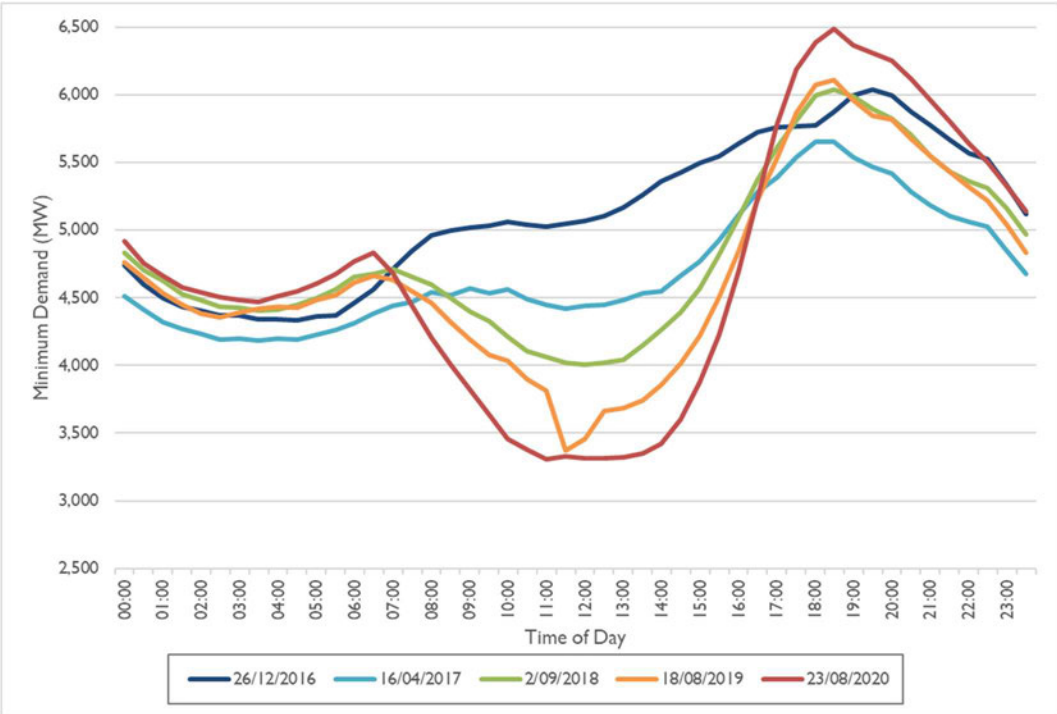

Figure 1 Transmission delivered annual minimum demand for the Queensland region

In addition to the change in daily load profile (MW) and falling minimum demand there is also a change in the net power factor of the load. As shown in Figure 2 there has been a reduction in the reactive power being consumed by the distribution system. In fact in the early hours of the morning the load has a leading power factor.

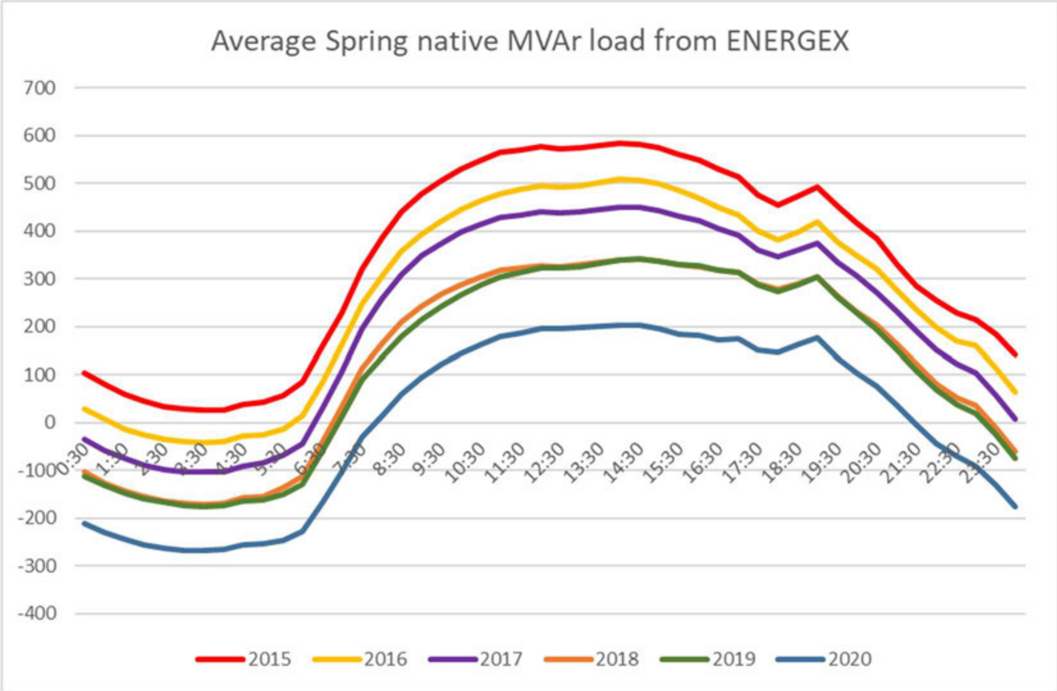

Figure 2 Average Spring MVar Load from Energex

The declining demand reduces the loading on the 275kV transmission system to well below the surge impedance loading. This, together with increasing leading power factor of the load, combine to create a reactive power surplus which must be absorbed by the transmission connected plant such as shunt reactors and dynamic reactive power devices, such as Static Var Compensators (SVCs), and generators.

The falling minimum demand also has the impact that the scheduled synchronous generators are having to reduce their output at times of low electricity demand or even de-commit. This reduces the reactive power adsorption capability of the system, particularly in the early hours of the morning when the variable renewable energy generators (solar farms) are not on-line. The combined impact can result in a voltage control/management limitation emerging in southern Queensland.

This report assesses the impact of the imbalance between the generation of surplus reactive power and the capability to absorb it on Powerlink’s obligations to provide supply to customers within the System Standards (NER S5.1a) and maintain voltage control and power system performance.

2 Constraint Forecast

Figure 3 and Figure 4 demonstrate the significant forecast reduction in minimum demand. This is highly correlated with rooftop PV installation rates which are at record levels in Queensland with expectations of continuation.

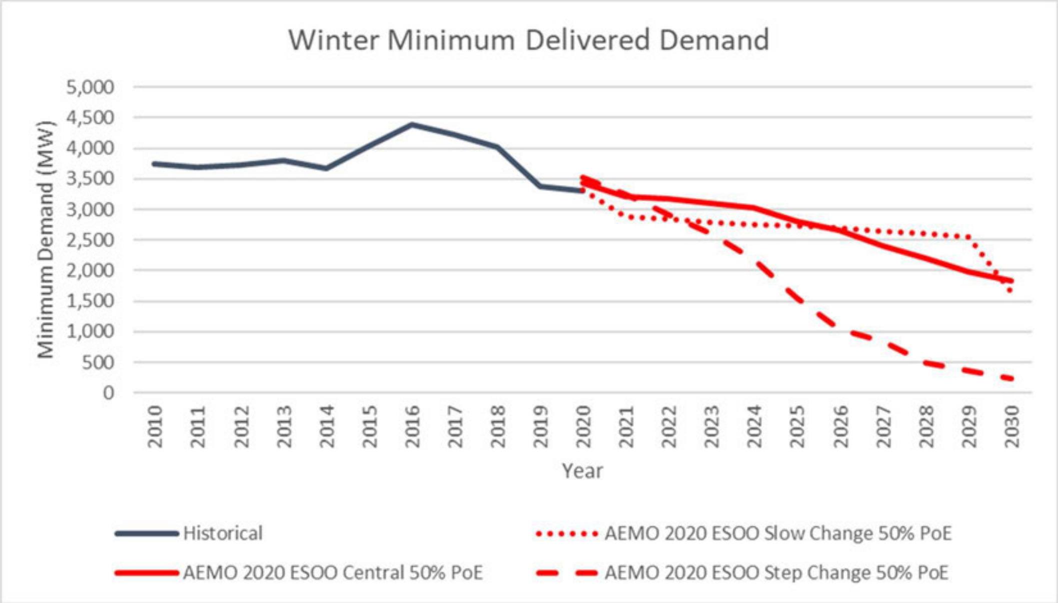

Figure 3 Winter Minimum Demand Forecast

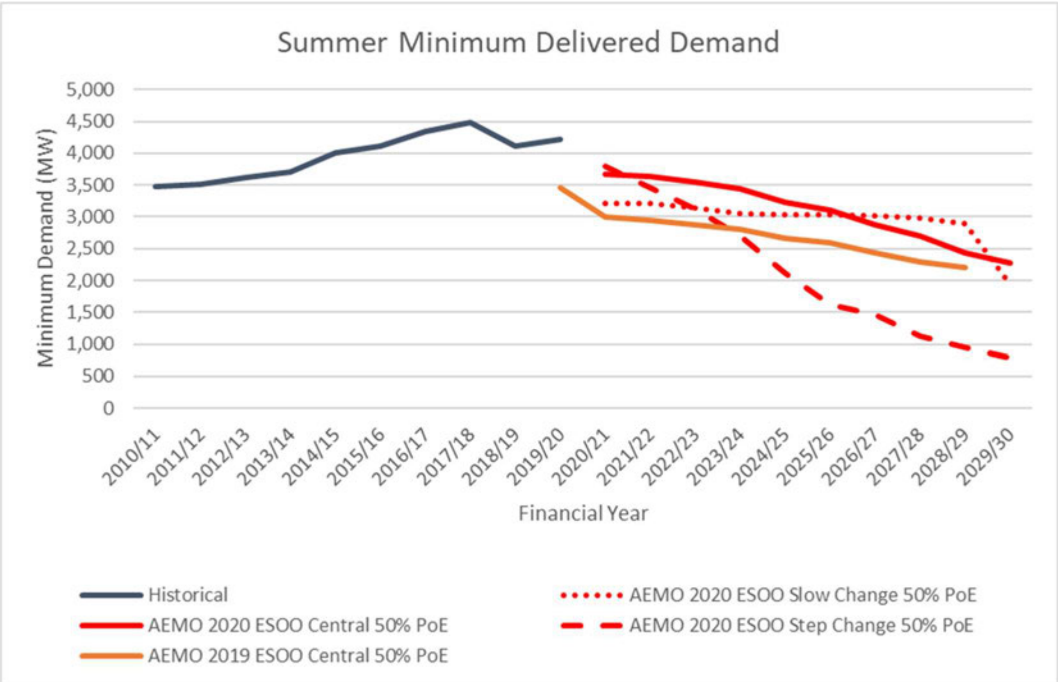

Figure 4 Summer Minimum Demand Forecast

This together with the increasing injection of reactive power from the load (refer to Figure 2) means that there are reactive power management and voltage control issues that are forecast to become increasingly difficult to manage for longer durations.

3 Power system performance lead indicators

System voltages associated with light load conditions are currently managed with existing dynamic reactive sources such as SVCs and generators.

The existing SVCs at Woolooga, South Pine and Greenbank have a dynamic range of -100 to +350MVar and the Blackwall SVC has a range of -50 to +250MVar. The SVC absorbs or supplies reactive power in the system as need arises to control the voltage.

Records from the Energy Management System show that the number of days the SVCs at Woolooga, South Pine, Greenbank and Blackwall absorb reactive power at their inductive limit is steadily increasing (refer to Figure 5). This condition is expected to escalate as the minimum load continues to decline and the load power factor becomes more leading.

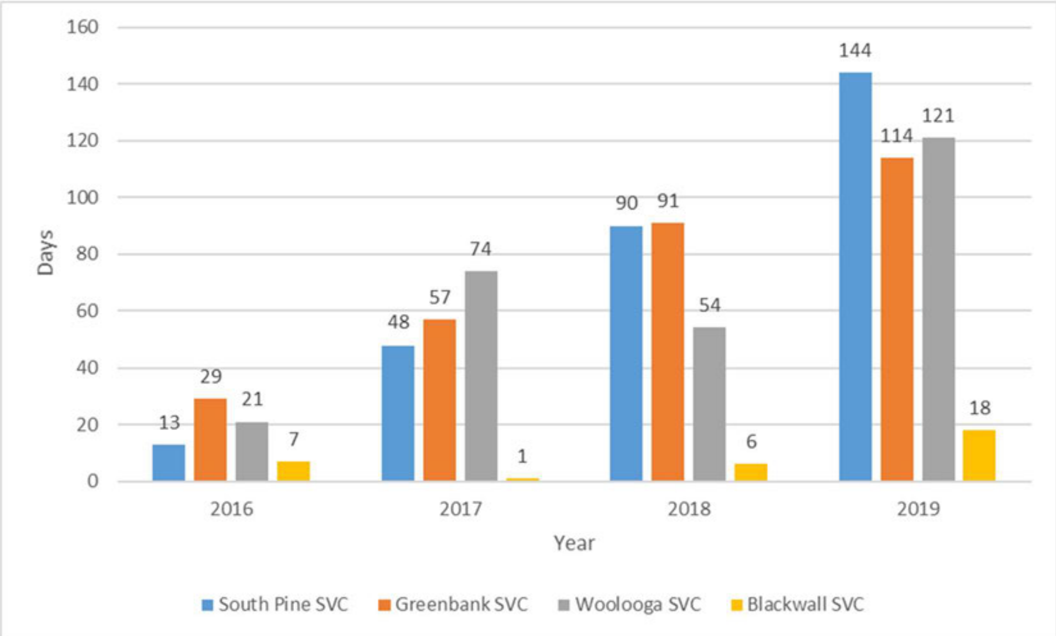

Figure 5 Number of days where SEQ SVCs have insufficient inductive range

In addition, Figure 6 and Figure 7 shows the voltage profile at Blackstone and Mudgeeraba 275kV buses respectively for the period of 1 year from July 2019 to June 2020 under normal system conditions. The figures (particularly that for Mudgeeraba 275kV bus) show that the voltage is greatest in the early hours of the morning, and has approached 298kV (1.084pu) under intact conditions on several occasions. Schedule 5.1a.4 of the NER specifies that steady state voltages are not to exceed (302.5kV) 1.1pu under system normal conditions and following credible contingency events. At 1.084pu the system would have been susceptible to violating this power system frequency voltage constraint if a reactive power contingency had have occurred.

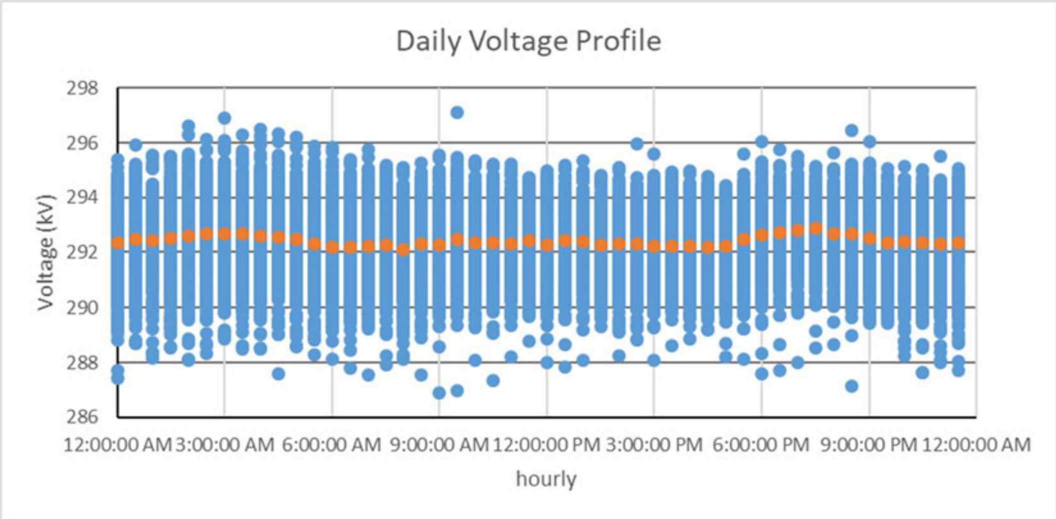

Figure 6 Daily Voltage Profile at Blackstone 275kV Bus

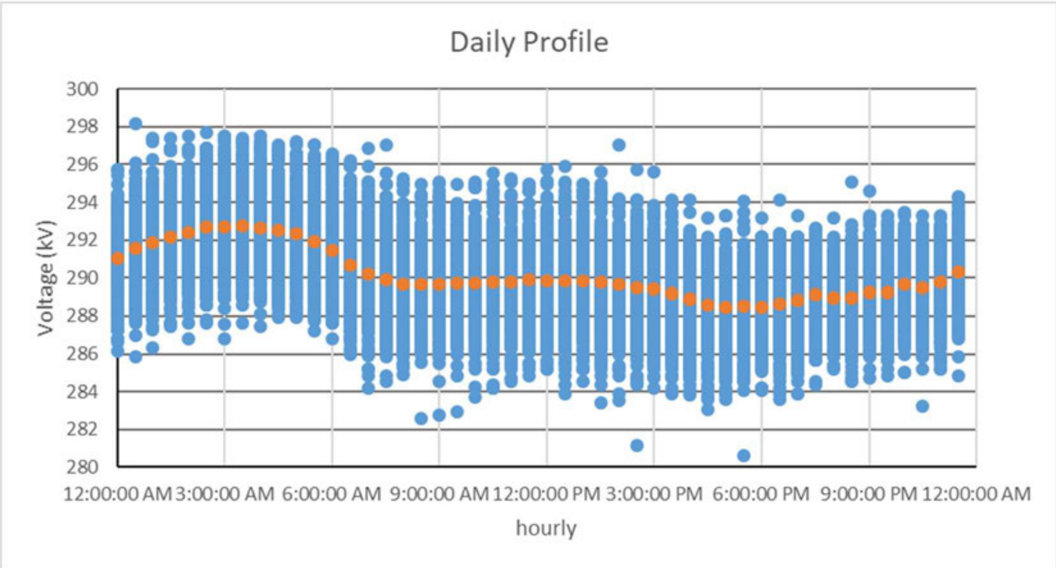

Figure 7 Daily Voltage Profile at Mudgeeraba 275kV Bus

4 Recent operational challenges

On 8 and 10 November 2020, AEMO switched out of service two 275kV transmission lines in South Queensland for voltage control during periods of low demand. Prior to switching out the Tarong to Blackwall and Middle Ridge to Greenbank 275kV lines, the Greenbank SVC was absorbing reactive power close to reactive limits and contingency analysis indicated voltages in excess of 1.1pu would occur if the Greenbank SVC tripped.

During the early morning, when these lines were switched out, the sent-out demand was between 4,750MW and 5,100MW; almost 1,000MW more than the minimum demand during the day. Five synchronous units were in service in southern Queensland and the Queensland to New South Wales interconnector was operating close to 0MW.

Although minimum demand in the early hours of the morning was not as low as during the day, challenges emerged for high voltage situations at these times because of the higher leading power factor of the load compared to daytime (refer to Figure 2) and the lower availability of generators on-line at those times.

4.1 Readjustment of operating procedures are required

The situation described above suggests that there is a clear and urgent need for additional reactive power absorption capability in southern Queensland to avoid overvoltage violations following a trip of reactive plant. Under the described conditions on 8 and 10 November, over voltages would have occurred following a single contingency even allowing for the prior switching-out of two 275kV feeders.

If this contingency were to occur, AEMO would then need to re-secure the network for the next credible contingency (e.g. an outage of another SVC in southern Queensland). This would result in a situation that was very difficult to mitigate without pre-contingent switching-out of multiple 275kV circuits. This is clearly an unacceptable situation.

However, further analysis by Powerlink has identified that there is an opportunity to operate the power system in such a way as to more appropriately pre-condition the system for such periods of low load.

During the periods analysed, the reactive power absorption capability was fully utilised and the overall voltage profile (defined by the voltage set-point of the dynamic reactive sources) was too high. Hence, because the dynamic reactive sources had no leading reactive headroom, AEMO was unable to reduce the voltage set-points or tap the generator transformers down without driving the plant against reactive limits or under-excitation limiters and losing voltage control.

The problem is one of maintaining a reactive power balance; the MVar from the load plus the net MVar charging from the transmission network must be capable of being absorbed by the reactive power sinks. This reactive power balance can be either satisfied at a high voltage (e.g. 1.08pu – as was the case on the 8 and 10 November) or at a much lower voltage. In fact if the transmission system is operated at a lower voltage profile the net MVar charging from the transmission system is lower and the overall MVar needed to be absorbed is reduced. The lower voltage profile also allows much greater voltage headroom to accommodate the reactive power contingencies (Note that at high loads, a lower voltage profile reduces the headroom to accommodate network contingencies).

In order to achieve this lower voltage profile, AEMO would need to lower the target set-points at the SVCs and via the tap positions of the generator transformers. This must be done in a co-ordinated manner such that the reactive absorption burden is shared between the reactive sources. This lowering of the voltage profile must also be done early and progressively as the load begins to reduce. This ensures that the respective target voltages are reduced whilst there is reactive absorption capability to accommodate the change in the operating point. This lowering of the voltage profile must be pre-emptive and ahead of the emergence of problems.

The process described relies on very careful tuning of transformer taps and voltage set-points. Such precise system tuning may be very challenging in a real time operating environment, given current limitations with the functionality of the automated Var Dispatch System (VDS). It may also be that the voltage profile has to be adjusted more frequently, and pre-emptively throughout the increasingly variable load profile. Further discussions between Powerlink and AEMO will be required in 2021 to determine whether these techniques can be implemented in practice.

4.2 Absorbing reactive power and voltage control planning criteria

The power system must be planned and operated such that power system performance, security criteria and compliance with the NER power frequency voltage criterion (S5.1a.4) are maintained. If AEMO operate the network as outlined in Section 4.1, additional reactive power absorption capability is only required if any of the following criteria cannot be achieved.

1. For system intact – lower the power system voltage profile maintaining at least:

    a. 1.000pu voltage at the 275kV target voltages at the generators and SVCs;
    b. one ‘buck’ tap position at the generators step-up transformers; and
    c. greater than 20MVar reactive power headroom to the individual plants inductive limits and/or under-excitation limiters.

2. For a credible single reactive power contingency (N-1) – the power system falls to a satisfactory state if:

    a. all voltages are <1.095pu;
    b. 20MVar reactive power headroom (from the under-excitation limiters) can be maintained at the synchronous generators in South Queensland and 20MVar headroom is maintained in all but one POD in South Queensland; and
    c. no post-contingent switching of transmission lines and/or change of generator tap positions is required to land at this satisfactory state.

3. For AEMO re-securing the network for the next reactive power contingency (N-1-1), where pre-contingent switching of up to two 275kV transmission lines is permitted provided no other power system security and/or reliability obligation is violated – the power system falls to a satisfactory state if:

    a. All voltages are <1.095pu;
    b. 20MVar reactive power headroom (from the under-excitation limiters) can be maintained at the synchronous generators in South Queensland and 20MVar headroom is maintained in all but one POD in South Queensland; and
    c. no post-contingent switching of transmission lines and/or change of generator tap positions is required to land at this satisfactory state.

Notes:

1. Full reactive leading capability is assumed at the Coopers Gap Wind Farm.
2. Preserving one ‘buck’ tap positions is required to accommodate unexpected loading and/or system conditions.
3. Preserving 20MVar of dynamic leading reactive capability is required to:
    a. maintain dynamic/automatic voltage control during background power system changes (e.g. load and dispatch);
    b. allow generators’ Power System Stabilisers (PSS) and SVCs’ Power Oscillation Dampers (POD) to continue to contribute damping to critical electromechanical modes of oscillation (e.g. local modes and inter and intra-area modes);
    c. the leading area of a generators capability is the least stable. Dynamic analysis may indicate that greater leading reactive headroom may be required.
4. For criteria 2 and 3, the Woolooga SVC (with no POD) and one additional SEQ SVC is allowed to saturate.

5 Statement of Investment Need

The system snapshots from the 8 November 2020 provide a baseline for the assessment of reactive power absorption needs in southern Queensland. Two snapshots have been assessed; 4 am and 6 am. The South Queensland MW load was very similar in both cases. However, the reactive power load at 6am was approximately 30MVar more leading compared to 4 am. In the 6 am snapshot the PV solar farms of Oakey, Yarranlea, Susan River and Childers were all on line. The net result is that the snapshot from 4am was shown to be more onerous from a reactive power and voltage control management perspective. As such, results from the 4 am snapshot where assessed in more detail.

The synchronous dispatch in southern Queensland has been modified to align with Powerlink's minimum fault level obligation in South Queensland. This obligation can be met with four synchronous generators in southern Queensland. For the purposes of this analysis four Tarong units have been assumed to be on-line. This has only one fewer unit on-line compared to the dispatches on 8 November 2020.

Table 1 summarises the results of the steady state analysis.

Case	System Condition	Leading reactive power margin (MVar)		
		Tarong Average of units 1 to 4	South Pine, Blackwall and Greenbank SVCs	Woolooga SVC
1	Current network Intact	4 x 12	3 x 17	23
2	One additional reactor in SEQ (Greenbank) Intact	4 x 28	3 x 29	31
3	One additional reactor in SEQ (Greenbank) N-1 contingency (one reactor)	4 x 21	2 x 20	0
4	Two additional reactors in SEQ (Greenbank and Blackstone) Intact	33	62	35
5	Two additional reactors in SEQ (Greenbank and Blackstone) N-1-1 contingency (two reactors) Two 275kV feeders switched-out	4 x 26	3 x 23	20

Table 1 Summary of 4 am network analysis

Case 1 shows the reactive power headroom at the dynamic sources in South Queensland with the power system intact and with no additional static reactive devices. The reactive power margin criterion (>20 MVar at each dynamic source in the intact case) is not met. Therefore, at least one reactor is required in South Queensland to remain compliant with the criteria defined in Section 4.2. Case 2 adds a 126MVar 275kV shunt reactor at Greenbank. The reactive power margin criterion is now met in the intact case.

Case 3 summarises the reactive power margins following the critical contingency of an outage of the Greenbank reactor. With two SVCs in South Queensland at their inductive limit the voltage profile is <1.095pu and the 20MVar margin is just maintained at the remaining dynamic sources. Therefore, only one 126MVar reactor is required in South Queensland to maintain compliant system performance for N-1.

However, following the initial reactive contingency (N-1), AEMO has 30 minutes to re-secure the network. During these low load periods AEMO's main concern will be the trip of another reactive power device in South Queensland. To assist the power system in falling to a new satisfactory state the criteria allows for up to two 275kV feeders to be switched out-of-service prior to the N-1-1. With only one additional reactor in South Queensland the power system cannot fall to a satisfactory state. Therefore, a second reactor is required in South Queensland.

Case 5 summarises the compliant reactive power margins following the trip of both reactors (N-1-1) and with two 275kV circuits (Greenbank to Middle Ridge and Tarong to Blackwall) out-of-service. As shown in Case 5 there is only 73MVar of additional reactive capability above the criterion. This is not sufficient to negate the need for the second 126MVar reactor.

Therefore, based on the minimum load system conditions experienced on 8 November and assuming only four synchronous generators on-line in South Queensland there is a need for the equivalent of two 126MVar (at 275kV) reactors in South Queensland.

6 Sensitivities impacting the investment need

The number of synchronous generators on-line in South Queensland and the changing power factor of the load are two parameters that impact the required reactive power compensation needs.

6.1 Number of synchronous units on-line in South Queensland

The number of synchronous generating units on-line in South Queensland has a significant impact on the ability to balance the reactive power problem whilst preserving the required reactive power margins. On average each additional synchronous generator has the potential to negate the need for one shunt reactor.

However, this assumes that the network can be carefully tuned to share the MVar absorption burden in South Queensland. Such precise system tuning may be very challenging in a real time operating environment as discussed in Section 4.1.

In addition there is a high degree of uncertainty as to the future operating patterns of the synchronous coal-fired generators in Queensland and the speed at which dispatch patterns aligned with the minimum fault level obligations may become normal. It should be remembered that on the 8 and 10 November 2020 there was only one additional unit on-line in South Queensland above the minimum fault level obligations.

Figure 8 outlines how the number of coal-fired generation units on-line is projected to evolve under AEMO's high variable renewable energy scenario. This reflects intra-day synchronous unit withdrawal and flexible operations. By 2025/26 the number of coal units on-line could be significantly lower relative to recent history.

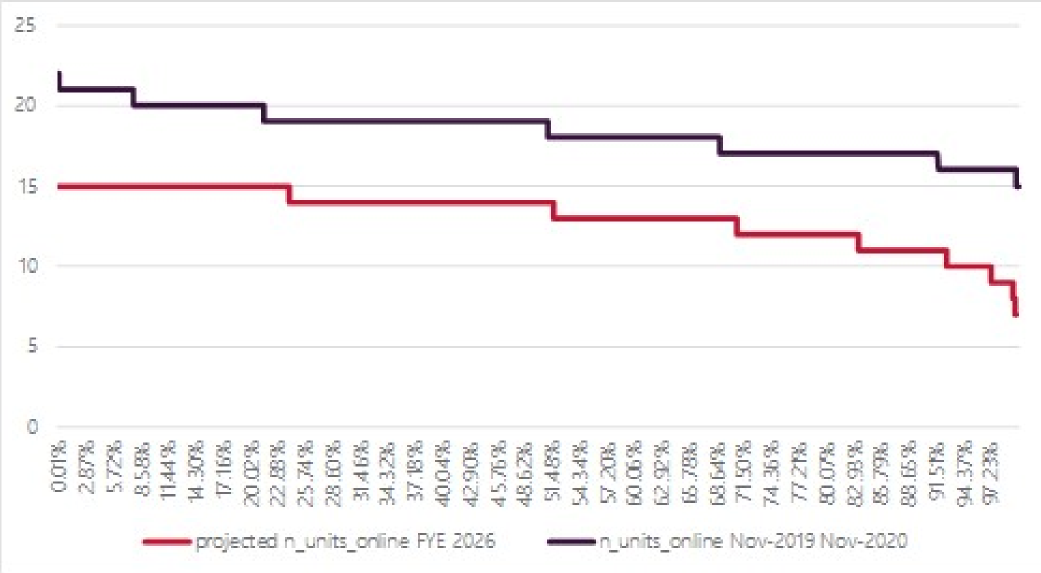

Figure 8 Number of Queensland coal-fired units on-line

Figure 8 is not specific to South Queensland but shows the emerging issue and reinforces the view that it is only a matter of time until only four units are dispatched in South Queensland. Given the lead-time in procuring reactive power absorption capability equipment, it is prudent to be proactive and define the immediate needs based on just four units in South Queensland.

6.2 Leading power factor of the SEQ load

Figure 2 and Figure 9 show the increasing leading reactive component of the load in South East Queensland. Figure 9 represents the MVar change over the past four years for each half-hour period. Two traces are shown; one is the average change in MVar for a given half-hour period and the second is the change in MVar, if the respective yearly minimums are compared for each half-hour period.

To be conservative the subsequent analysis takes into account the greatest of these changes (i.e. the average). During the early hours of the morning this change is approximately 60MVar per annum. Whereas, the change in the middle of the day (during the ‘duck curve’) is approximately 75MVar.

From Case 4 in Table 1 there is only approximately 73MVar of reactive headroom from the reactive power criterion. Based on the rates of change above, this MVar margin would be consumed in a little over 1 year, which is less than the time to install the two 126MVar reactors. Therefore, on this basis, there is a need for a third 126MVar reactor to be installed in South Queensland.

If the leading power factor continues to degrade at 60MVar per annum, the existing 73MVar headroom plus a third 126MVar reactor should ensure compliance until 2024.

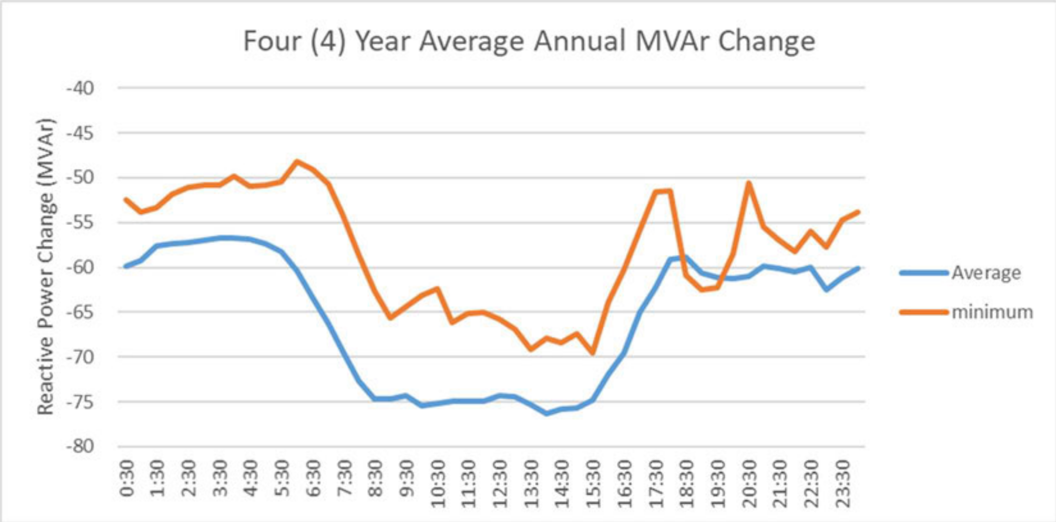

Figure 9 Increasing leading power factor of the SEQ load

6.2.1 Falling day-time demand

Figure 10 shows the variation in the reactive power component of the SEQ load during the 2020 spring period. The analysis in Section 5 was based on a SEQ reactive load consistent with the 10th percentile series in Figure 10. In addition, there is little spread between the 10th percentile and the minimum. However, there is considerably more variability in the day-time reactive demand. The greater variation being attributed to the greater variability in the day-time MW demand.

Based on Figure 10 the minimum SEQ reactive load is approximately 150MVar more inductive during the day-time.

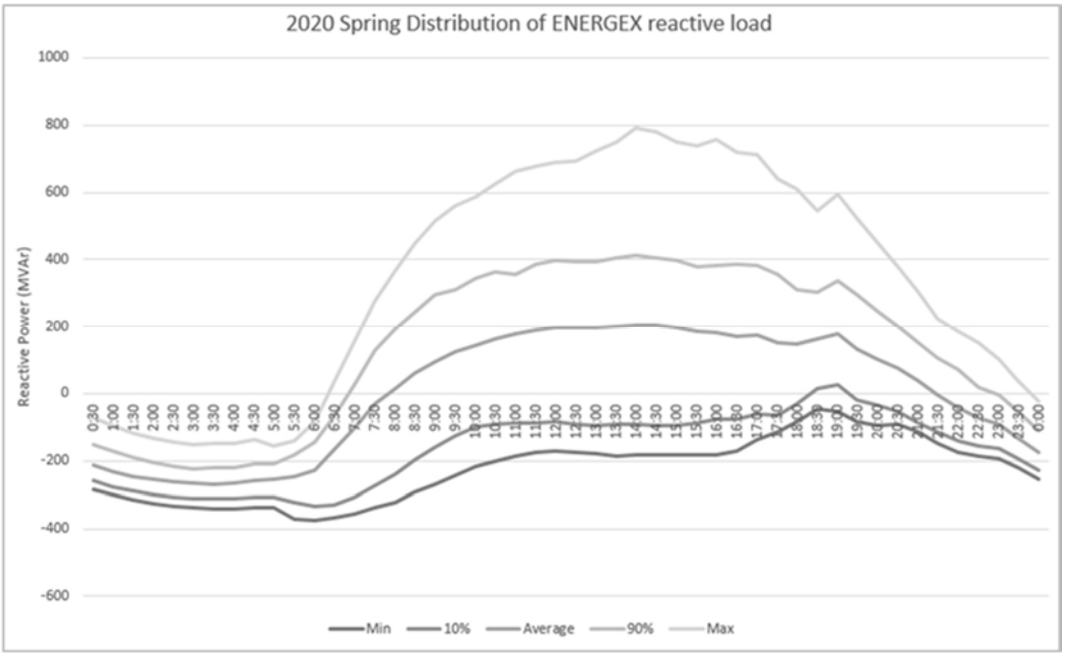

Figure 10 Distribution of Spring reactive load in SEQ

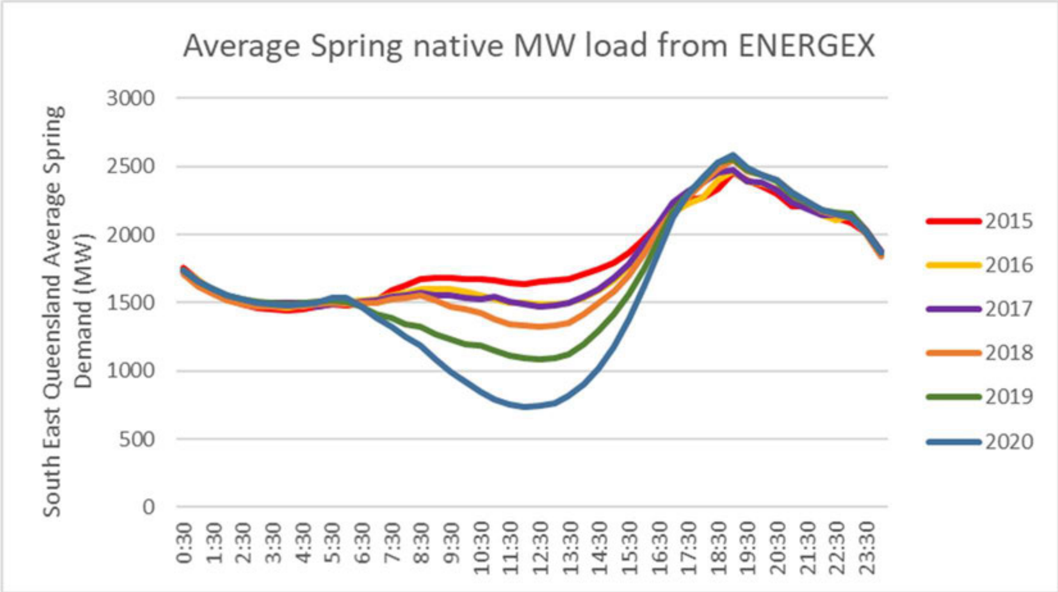

Figure 11 Average Spring MW load in SEQ

Figure 11 shows that in spring 2020 the average minimum day-time demand was approximately 750MW lower than the load during the early morning. However, the minimum gap in the MVar load between early morning and day-time is 150MVar (i.e. the early morning load is approximately 150MVar more leading than the day-time load).

Network analysis has found that a 750MW reduction in the SEQ load reduces the transmission network losses by approximately 100MVar. As the day-time minimum load continues to fall due to the increasing penetration of rooftop PV the MVar transmission losses will also decrease. However, the rate of decrease will not be linear. Already the transmission system into and within SEQ is operating below the surge impedance loading (SIL). As such, the net reactive contribution of the transmission network will eventually saturate at the capacitive limit (i.e. V^2B).

The conclusion of this assessment is as follows.

- There is currently a minimum 150MVar gap between the early morning and day-time reactive component of the load.
- The lower day-time MW demand will reduce this gap to approximately 50MVar.
- The gap between the early morning and day-time leading reactive load growth is approximately 15MVar per annum.
- During the day-time there are more reactive power sinks available, existing, committed and anticipated (large-scale solar and wind connections) to assist in balancing the reactive power flow.

Therefore, although the day-time demand is falling, the leading reactive power and voltage control management issues are currently more onerous in the early morning. However, these limitations may become more onerous during the minimum day-time load periods as this load continues to reduce. This will require further analysis as these conditions unfold. It is possible that further reactive power management solutions will be required prior to 2024.

6.3 Urgent need for action

Powerlink must take action to increase the reactive absorption capability of South Queensland to ensure ongoing compliance with its Planning Criteria and the requirements of the National Electricity Rules, specifically the power frequency voltage (S5.1a.4) and stability (S5.1.8) requirements.

There is an urgent need for the following:

1. Lowering the voltage profile during low load periods through co-ordinated adjustment of the generator transformer tap positions and the set-point voltages of the SVCs.

2. Notwithstanding the adjustment in the voltage profile there is an immediate need for one 126MVar reactor in South Queensland to land in a satisfactory state following an N-1 contingency. However, the equivalent of two 126MVar reactors are required to re-secure the system and land in a satisfactory state following an N-1-1 contingency.

3. The requirements in 2 above are based on the current leading reactive load and assume four synchronous generators on-line in South Queensland. The addition of a Tarong North, Kogan Creek or Millmerran unit would reduce this need to one reactor. Two additional units would remove the need.

4. Given a network solution (commissioning of shunt reactors) may take up to three years to deliver and due to the changing load power factor during this lapsed time, the equivalent of three 126MVar reactors are required (again assuming four synchronous units on-line).

5. If the reactive power component of the load continues to change at the current rate (60MVar per annum), then the three reactors will only maintain the required reactive power margins to 2024. Beyond this date the reactive power gap will re-emerge if there are only four synchronous units on-line in South Queensland. Therefore, the equivalent of a fourth 126MVar reactor may be required within the 2023-27 regulatory control period.

   Note: the development of additional wind farms in South Queensland with or without system strength remediation obligations may mitigate the need for a fourth reactor.

6. Based on points 1 and 2 above, there is an immediate reactive power gap of the equivalent of two 126MVar reactors, if there are four synchronous units on-line in South Queensland. Six synchronous units would need to be on-line in South Queensland for this gap to be addressed. Given that five units have already been observed (8 November 2020) it is recommended that an EOI for Network Support Services be called in the short-term until a possible network solution can be delivered.

The possibility of a non-network solution forming part (or all) of the longer-term solution will be assessed as part of the RIT-T process.

7 Non Network Options

Under system intact conditions with four synchronous generators on-line in South Queensland and low load conditions, the network support would need to provide reactive power absorption capability equivalent to two 126MVar reactors in South Queensland. The reactive support would be required to be available on-line during these conditions (refer to Case 3 in Table 1 – the N-1 criteria are only just met with one reactor with no material headroom for increasing leading MVar from the load).

Based on the expected deteriorating leading MVar from the load (60MVar per annum), the equivalent of three 126MVar reactors would be required from 2022.

Wivenhoe Hydro Power Station consists of two units that can operate as generators, pump and synchronous condensers. In all three modes of operation the units have the capability to absorb reactive power. The Generator Performance Standards specify a capability to absorb at the connection point an amount of reactive power of at least 98.75MVar. Based on the Generator's Capability Curve the capability of each unit to absorb reactive power in synchronous condenser mode is materially greater (approx. 200MVar).

8 Network Options

8.1 Preferred option to meet the identified need

The preferred network option is to establish a 275kV bus reactor at three locations across South East Queensland, i.e. Greenbank, Blackstone and Woolooga. The reactors would nominally be specified as 150MVar at 300kV (126MVar at 275kV) and connected via a 275kV reactive plant bay.

8.2 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.

8.2.1 Do Nothing

The conclusions derived from the analysis of the system conditions that occurred on 8 November, and the trends in falling demand levels and worsening leading reactive power loads in SEQ, confirm that there is an immediate and enduring need to increase the reactive power absorption capability in South Queensland. Do nothing is not a viable option if compliance with the power system performance, security criteria and NER power frequency voltage criterion (S5.1a.4) are to be maintained.

9 Recommendation

Based on the analysis the recommendation is to install 275kV, 126MVar bus shunt reactors at Blackstone, Woolooga and Greenbank substations.

Although the day-time demand is falling, the leading reactive power and voltage control management issues are currently more onerous in the early morning. However, these limitations may become more onerous during the minimum day-time load periods. This will require further analysis as these conditions unfold and it is possible that further reactive power management solutions are required prior to 2024.

10 References

1. Transmission Annual Planning Report 2020

2. Asset Planning Criteria Framework

Base Case Benefits and Maintenance Costs Summary Report

CP.02814 Managing SEQ Voltages

Version Number	Objective ID	Date	Description
1.0	A3374955	09/11/2020	Original document.

1 Purpose

The purpose of this model is to quantify the base case benefits and costs for voltage control within the South East Queensland (SEQ) load area.

The proposed reinvestment comprises of installation of bus reactors at three locations within the greater South East Queensland area under project CP.02814. The reactors are currently proposed for installation at Woolooga, Blackstone and Greenbank 275kV substations.

The base case costs have been estimated across a 15 year time frame.

2 Background

Powerlink has identified emerging voltage control and management requirements across the greater South East Queensland area.

These emerging voltage control limitations are caused by a combination of factors including:

- Falling minimum demand due to the continuing growth of roof-top solar and embedded photovoltaic systems;
- Improving load power factor arising from more efficient energy devices (e.g. inverter based air-conditioners); and
- Increased number of underground cables within the distribution network leading to higher levels of charging relative to overhead lines.

High voltage levels can cause damage to plant both within the network and downstream customer equipment, and result in accelerated degradation of insulation.

The requirement to manage voltages is prescribed within Schedule 5.1 of the National Electricity Rules. The criteria for assessing whether the transmission network is compliant with these requirements is outlined within Powerlink's Asset Planning Criteria.

Powerlink has to date managed over-voltages within the transmission network by a number of measures including switching transmission feeders out of service. The switching of lightly loaded transmission circuits removes the capacitive charging of the feeder and increases the reactive loading of the network thereby reducing voltage levels.

Switching circuits out of service as a mechanism to manage voltages has impacts on the reliability and security of supply. Switching feeders may also place limitations on project work and planned maintenance, and accelerate ageing of circuit breakers and current transformers due to voltage spikes and wear.

Accordingly the on-going switching of feeders to manage over-voltages is not considered an effective and sustainable strategy. This strategy has been included within the base case for the purposes of establishing a base line for comparison of credible options.

3 Base Case Analysis

The base case scenario includes a number of measures which would be required for the continued management of over-voltages on Powerlink's transmission network. These measures are detailed below:

Generator Ancillary Services

In order to manage voltage levels under light load conditions, generating units within the greater south east Queensland network will need to absorb reactive power to ensure that voltages remain within prescribed limits under contingency conditions.

During these circumstances, generating units may need to operate as synchronous condensor mode or dispatched out of market order at minimum power output levels.

An estimate of costs associated with generating units located within the greater south east Queensland area operating in these modes has been incorporated within the base case.

Feeder Switching

The switching of feeders out of service is an operational measure that can be used to reduce voltage levels. Power system studies have indicated that switching both Middle Ridge to Greenbank 275kV circuits out of service during light load conditions will be required to manage over-voltages.

An analysis of daily load profiles across the year has indicated that switching out of these feeders will be required on a daily basis for a significant proportion of the year (almost 50% of the year).

The switching of feeders accelerates the operating life of primary plant equipment including circuit breakers and instrument transformers. The switching of circuits also places increasing restrictions on the ability for Powerlink to conduct project and planned maintenance activities, and places load at risk for subsequent contingency events. The switching of feeders also increases transmission losses within the network relative to intact system conditions.

The costs associated with switching of feeders as a strategy to manage over-voltages has been estimated within the base case.

Increase in Costs over Time

The requirement to manage over-voltages is likely to progress over time with the continued uptake of roof-top PV systems, embedded renewable energy systems, and progressive installation of energy efficient devices within residential and commercial premises.

The change in costs over time within the base case has been estimated by assuming that the use of measures required to manage over-voltages will increase. These measures include generating units increasingly required to absorb reactive power to manage over-voltages, and the on-going switching of network feeders out of service.

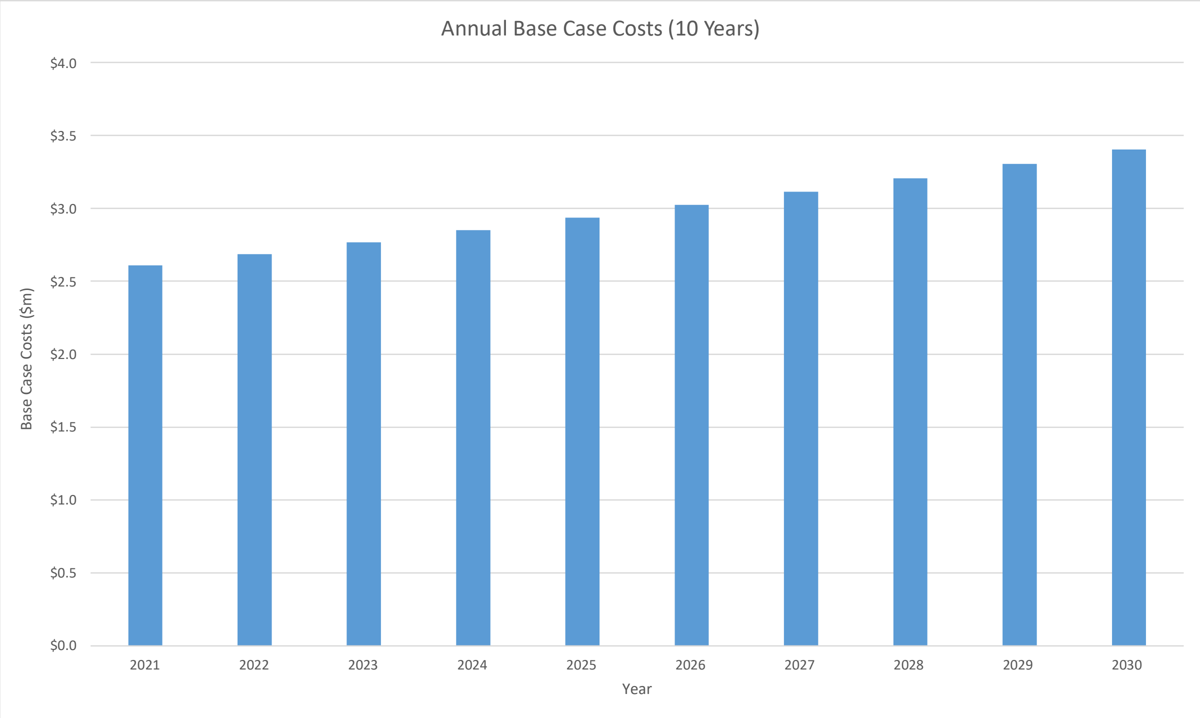

Figure 1 – Base Case Costs (10 Years)

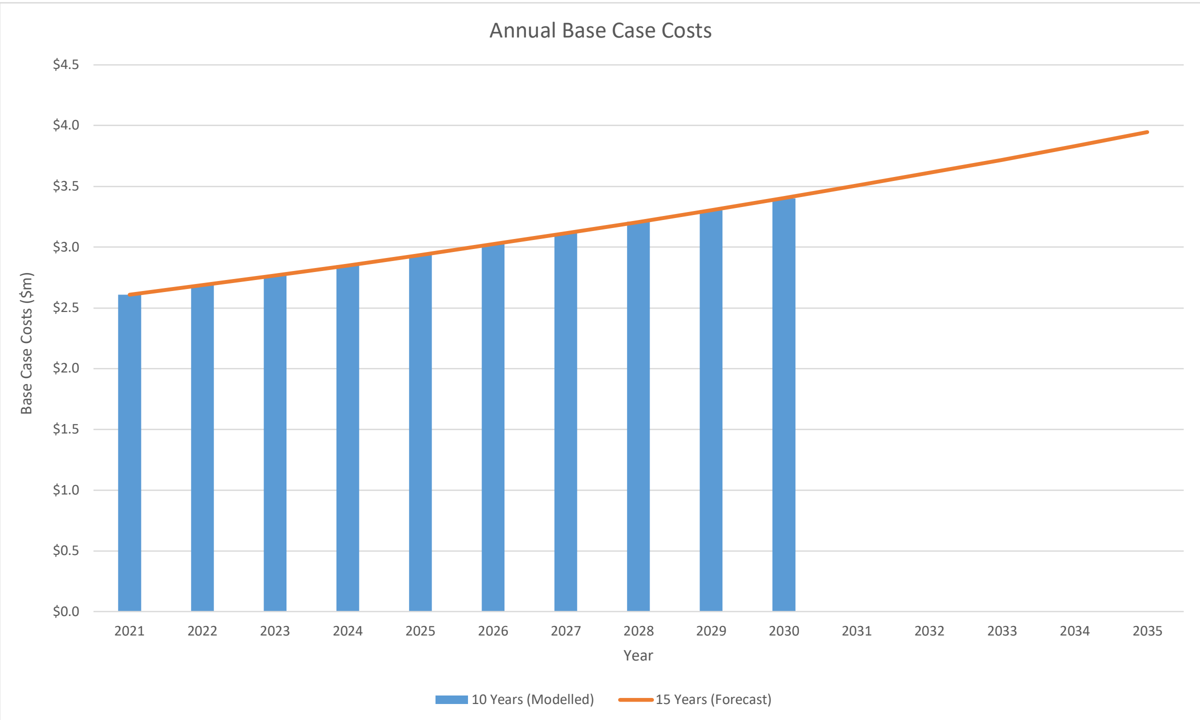

Figure 2 – Base Case Costs (10 years modelled, 15 years forecast)

4 Maintenance Costs

The operational and maintenance costs associated with new reactors proposed for installation within south east Queensland are estimated to be 1.5% of the capital cost of the equipment.

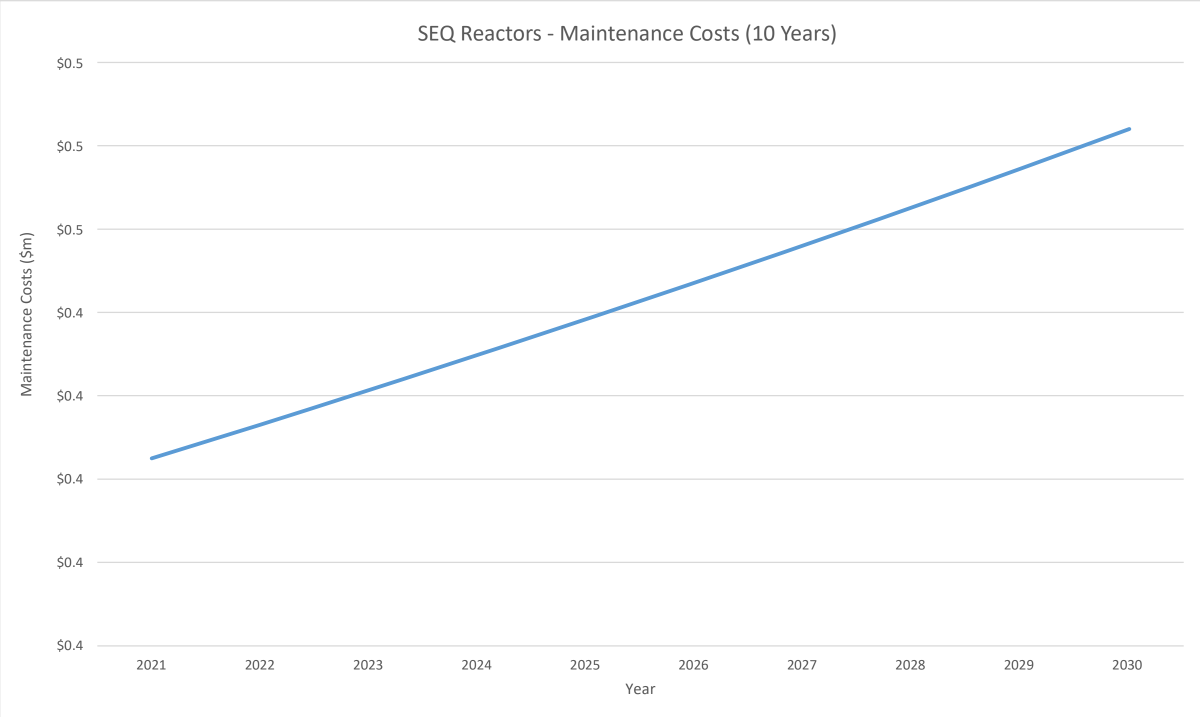

Figure 3 – SEQ Reactors Maintenance Costs (10 years)

Project Scope Report

CP.02814

Managing SEQ Voltages

Concept – Version 1

Document Control

Change Record

Issue Date	Responsible Person	Objective Document Name	Background
18/06/2020	[redacted]	Project Scope Report CP.02814 Managing SEQ Voltages	Initial Issue

Related Documents

Issue Date	Responsible Person	Objective Document Name

Project Contacts

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

Project Details

1. Project Need & Objective

The challenge of managing high power system voltage levels due to the falling minimum demand and the changing power transfer patterns on Powerlink's network is leading to higher operating voltages.

Network studies confirm that the lower minimum demands can lead to high system voltages and potentially significant voltage violations that exceed defined operating limits with the risk of non-compliance to the National Electricity Rules (NER) requirements of 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 SEQ region.

Planning studies recommend that establishment of three 275kV bus connected shunt reactors at Blackstone, Woolooga and Greenbank substations to address the voltage issues.

The objective of the project is to establish one 150MVAr 300kV bus shunt reactor at each of Blackstone, Woolooga and Greenbank substations by June 2024.

2. Project Drawing

[redacted]

Figure 1: Geographical location of Woolooga, Blackstone and Greenbank

3. Project Scope

3.1. Original Scope

The following scope presents a functional overview of the desired outcomes of the project. The proposed solution presented in the estimate must be developed with reference to the remaining sections of this Project Scope Report, in particular *Section 5 Special Considerations*.

Briefly, the project consists of the establishment of a 275kV bus connected shunt reactor at each of Blackstone, Woolooga and Greenbank substations.

3.1.1. Transmission Line Works

Not applicable

3.1.2. H072 Blackstone Substation Works

Design, procure, construct and commission 1 x 150MVA (@300kV) bus connected shunt reactor:

- Extend the substation 275kV Bus 1 to accommodate one new bus reactor bay;
- Connect the reactor into the existing oil containment system and modify as required;
- Establish an AIS primary plant bay including dead-tank POW circuit breaker suitable to connect 1x 300kV 150MVAr shunt reactor;
- Establish the secondary systems for the new reactor bay and integrate into the existing secondary systems as required;
- Update of EMS with required changes; and
- Update SAP, CMS and drawings in SPF accordingly.

3.1.3. S003 Greenbank Substation Works

Design, procure, construct and commission 1 x 150MVA (@300kV) bus connected shunt reactor:

- Relocate Cap 8 to Bay =C09 including modifications to the existing bay as required;
- Establish the bus reactor bay in the ex C8 capacitor bank bay =C16. The new bay shall include AIS primary plant including dead-tank POW circuit breaker suitable to connect 1x 300kV 150MVAr shunt reactor;
- Connect the reactor into the existing oil containment system and modify as required;
- Establish secondary system for the new reactor bay and integrate into the existing secondary systems as required;
- Update of EMS with required changes; and

- Update SAP, CMS and drawings in SPF accordingly.

3.1.4. H005 Woolooga Substation Works

Design, procure, construct and commission 1 x 150MVA (@300kV) bus connected shunt reactor:

- Establish the new reactor in Bay =C05. Assess the suitability of the existing primary equipment, alternately replace the existing bay with an AIS primary plant bay including dead-tank POW circuit breaker suitable to connect 1x 300kV 150MVAr shunt reactor connected to the 275kV 1 Bus;
- Connect the reactor into the existing oil containment system and modify as required;
- Modify/establish secondary system as necessary for the new reactor bay and integrate into the existing secondary systems as required;
- Update of EMS with required changes; and
- Update SAP, CMS and drawings in SPF accordingly.

3.1.5. Telecoms Works

Not applicable

3.1.6. Easement/Land Acquisition & Permits Works

Not applicable

3.2. Key Scope Assumptions

Not applicable

3.3. Variations to Scope (post project approval)

Not applicable

4. Project Timing

4.1. Project Approval Date

The anticipated date for approvals is Stage 1 by 28 February 2021, and full approval by 30 November 2021 upon satisfactory conclusion of the RIT-T.

4.2. Site Access Date

The sites are existing Powerlink sites. Site access is already available.

4.3. Commissioning Date

The latest date for the commissioning of the new assets included in this scope is 30 June 2022.

5. Special Considerations

Reactors preferably furnished with polymer housed bushings.

6. Asset Management Requirements

Equipment shall be in accordance with Powerlink equipment strategies.

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

Business Development will provide any necessary primary customer interface. The Project Sponsor should be kept informed of any discussions with any customer.

7. Asset Ownership

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

8. System Operation Issues

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

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

9. Options

Not applicable

10. Division of Responsibilities

Not applicable

11. Related Projects

None

Concept Estimate for CP.02814 Managing SEQ Voltages

Record ID	A3428134	
Policy stream	Asset Management	
Authored by	Project Manager	[redacted]
Reviewed by	Senior Project Manager	[redacted]
Reviewed by	Team Leader	[redacted]
Approved by	Manager Projects	[redacted]

Table of Contents

1. Executive Summary

The challenge of managing high power system voltage levels due to the falling minimum demand and the changing power transfer patterns on Powerlink's network is leading to higher operating voltages.

Network studies confirm that the lower minimum demands can lead to high system voltages and potentially significant voltage violations that exceed defined operating limits with the risk of non-compliance to the National Electricity Rules (NER) requirements of 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 SEQ region.

Planning studies recommend that establishment of 275kV bus connected shunt reactors at Blackstone, Greenbank and Woolooga Substations to address the voltage issues.

The objective of the project is to establish one 150MVAr 300kV bus shunt reactor at each of Blackstone, Greenbank and Woolooga substations by June 2024.

[redacted]

Figure 1 H072 Blackstone Operation Diagram

1.1 Project Estimate

Estimate Components		Base $	Escalated $
Estimate Class	3		
Estimate Accuracy	30% / -20%		
Base Estimate		30,293,828	33,543,816
Mitigated Risk	[redacted]	[redacted]	[redacted]
Contingency Allowance	[redacted]	[redacted]	[redacted]
TOTAL		[redacted]	[redacted]

1.2 Project Financial Year Cash Flows

	July 2020 Base $	Escalated $
To June 2021	3,029,383	3,029,383
To June 2022	9,088,148	9,652,759
To June 2023	9,088,148	10,048,523
To June 2024	9,088,149	10,813,152
TOTAL	**30,293,828**	**33,543,817**

2. Project and Site Specific Information

2.1 Project Dependencies & Interactions

Not applicable.

2.2 Site Specific Issues

[redacted]

Figure 2 H072 Operation diagram (yellow shaded area represent new Reactor bay location)

Figure 3 H072 Aerial Photo

[redacted]

Figure 4 S003 Operation Diagram (yellow shaded area represent relocated Cap bank bay location, orange area indicates the new reactor bay location)

Figure 5 S003 Aerial Photo

[redacted]

Figure 6 H005 Operation Diagram (yellow shaded area represent new Reactor bay location)

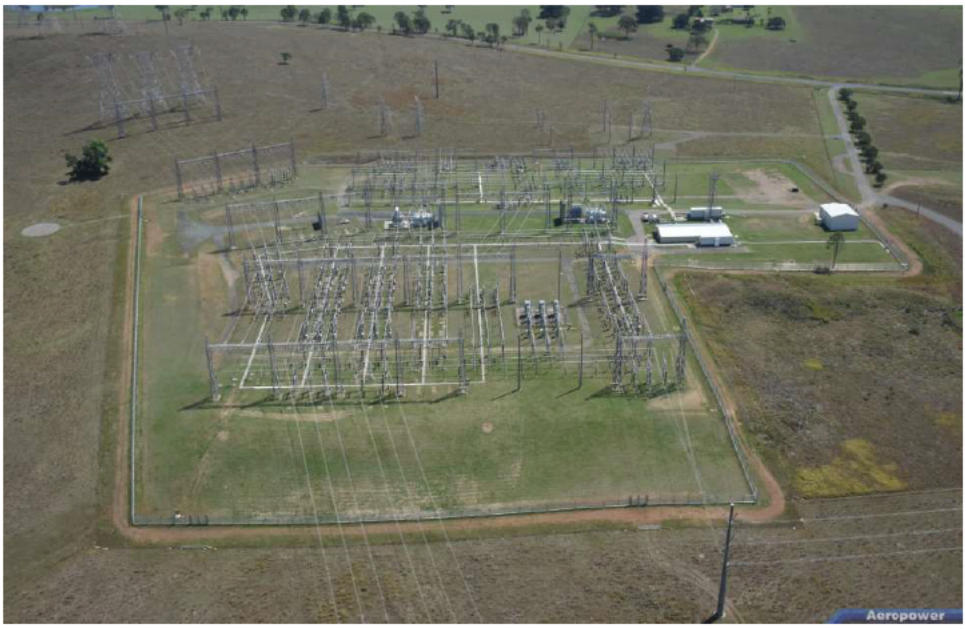

Figure 7 H005 Aerial Photo

3. Project Definition – Install Three 275kV Bus Connected Shunt Reactors in SEQ

3.1 H005 Woolooga

3.1.1 Scope

The project consists of establishing three 150MVAr 300kV bus shunt reactor at H072 Blackstone, S003 Greenbank and H005 Woolooga Substation.

3.1.1.1 Substations Works

Design, procure, construct and commission the following necessary assets to facilitate the connection of a shunt reactor onto the 275kV bus at H005 Woolooga Substation:

- Establish the new reactor in Bay =C05. Assess the suitability of the existing primary equipment, alternately replace the existing bay with an AIS primary plant bay including dead-tank POW circuit breaker suitable to connect 1x 300kV 150MVAr shunt reactor connected to the 275kV 1 Bus;
- Connect the reactor into the existing oil containment system and modify as required;
- Installation of noise enclosure is required;
- All designs will be in accordance with SDM8 and subsequent Standards Updates (SUs);
- Decommission the existing =C05 coupler protection and control panel;
- Installation of a new reactor protection and control panel into building +2;
- Integration of new equipment into existing secondary system;
- Update of EMS with required changes; and
- Update of SAP, CMS and drawings in SPF accordingly.

3.1.1.2 Transmission Line Works

Not applicable.

3.1.1.3 Telecommunication Works

Not applicable.

3.1.1.4 Easement/Land Acquisition & Permit Works

Not applicable.

3.1.2 Major Scope Assumptions

- New structure foundations, excluding circuit breaker and reactor, are bored piers;
- Existing cable trenches have sufficient capacity to cater for new cables required for the new reactor and associated bay;
- The existing transformer fire walls are sufficient in size to suit the proposed reactor;
- The existing oil separation tank has sufficient capacity to cater for the new reactor and no augmentation works are required. Allowance has been made for the provision of a second stage treatment to meet current PLQ standards;
- Outages at H005 are available as required;
- Testing of the noise levels is required prior to construction starting and at commissioning;
- The condition of existing panels, marshalling kiosks and cables at H005 Woolooga makes them suitable for reuse under this project.
- Modifications to the SVC control systems at H005 will be undertaken by OSD. Secondary systems design scope includes wiring to the existing interface kiosk only.

3.2 H072 Blackstone

3.2.1 Scope

The project consists of establishing three 150MVAr 300kV bus shunt reactor at H072 Blackstone, S003 Greenbank and H005 Woolooga Substation.

3.2.1.1 Substations Works

Design, procure, construct and commission the following necessary assets to facilitate the connection of a shunt reactor onto the 275kV bus at H072 Blackstone Substation:

- Extend the substation 275kV Bus 1 to accommodate one new bus reactor bay;
- Connect the reactor into the existing oil containment system and modify as required;
- Establish an AIS primary plant bay including dead-tank POW circuit breaker suitable to connect 1x 300kV 150MVAr shunt reactor;
- All designs will be in accordance with SDM9 and subsequent Standards Updates (SUs);
- Installation of a new reactor protection and control panel into the existing building;
- Installation of noise enclosure is required;
- Installation of new AC, DC and bay marshalling kiosks into the switchyard;
- Integration of new equipment into existing secondary systems;
- Update of EMS with required changes; and
- Update SAP, CMS and drawings in SPF accordingly.

3.2.1.2 Transmission Line Works

Not applicable.

3.2.1.3 Telecommunication Works

Not applicable.

3.2.1.4 Easement/Land Acquisition & Permit Works

Not applicable.

3.2.2 Major Scope Assumptions

- New structure foundations, excluding circuit breaker and reactor, are bored piers as per the existing construction;
- Existing cable trenches have sufficient capacity to cater for new cables required for the new reactor and associated bay;
- The existing substation access from Swanbank Coal Road will be sufficient for the reactor delivery. However is noted the horizontal geometry is tight. The road design drawing detailing the constructed road will be provided to reactor transport contractor for confirmation;
- Outages at H072 are available as required;
- Testing of the noise levels is required prior to construction starting and at commissioning; and
- Allowance has been made in Protection Estimate for consolidation of ABB Project files at Blackstone. It is assumed that 200 hours will be sufficient to complete this.

3.3 S003 Greenbank

3.3.1 Scope

The project consists of establishing three 150MVAr 300kV bus shunt reactor at H072 Blackstone, S003 Greenbank and H005 Woolooga Substation.

3.3.1.1 Substations Works

Design, procure, construct and commission the following necessary assets to facilitate the connection of a shunt reactor onto the 275kV bus at S003 Greenbank Substation:

- Relocate Cap 8 to Bay =C09 including modifications to the existing bay as required;
- Connect the reactor into the existing oil containment system and modify as required;
- Establish the bus reactor bay in the ex C8 capacitor bay =C16. The new bay shall include AIS primary plant including dead-tank POW circuit breaker suitable to connect 1x 300kV 150MVAr shunt reactor;
- Installation of noise enclosure is required;
- Provision of an external access road to the substation to enable delivery of the Reactor to site;
- All designs will be in accordance with SDM8 and subsequent Standards Updates (Sus);
- Modification of the existing =C16 protection and control panel and marshalling kiosks to suit new reactor;
- Installation of a new capacitor protection and control panel into building +5;
- Installation of new AC, DC and bay marshalling kiosks for new bay =C09 into the switchyard;
- CT links and terminals will be updated as per SU0030 and SU0020 respectively
- Integration of new equipment into existing secondary systems;
- Update of EMS with required changes; and
- Update SAP, CMS and drawings in SPF accordingly.

3.3.1.2 Transmission Line Works

Not applicable.

3.3.1.3 Telecommunication Works

Not applicable.

3.3.1.4 Easement/Land Acquisition & Permit Works

Not applicable.

3.3.2 Major Scope Assumptions

- New structure foundations, excluding circuit breaker and reactor, are bored piers;
- Existing cable trenches have sufficient capacity to cater for new cables required for the new reactor and associated bay;
- The existing substation access road is sufficient for the delivery of the Reactor. The road design drawings detailing the constructed road will be provided to reactor transport contractor for confirmation;
- An extension to the security fence will be required for the new Reactor bay at S003;
- Outages at S003 are available as required;
- Testing of the noise levels is required prior to construction starting and at commissioning.
- The condition of existing panels, marshalling kiosks and cables at S003 Greenbank are suitable for reuse;
- Modifications to the SVC control systems at S003 will be undertaken by OSD. Secondary systems design scope includes wiring to the existing interface kiosk only.

3.4 Scope 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;
- The substation platform exists and therefore detailed survey is not required;
- New equipment shall be set out relative to existing equipment;
- The information in existing geotechnical investigation is insufficient for the design; and
- Fire wall is not needed for the new reactor.

4. Project Execution

4.1 Project Schedule

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

Task	Target Completion
Reactor Procurement(18months lead times)	December 2021
Stage 2 approval(post RIT-T)	November 2021
Award ITT	December 2021
SPA construction	April 2022
Commissioning H072	August 2023
Commissioning S003	December 2023
Commissioning H005	June 2024
Project Commissioning Date	June 2024

Assuming the project is approved by November 2020 the date for Practical completion will be May 2023

4.2 Network Impacts

Based on conversations with Net-Ops team, there will be outages for extend the bus & commission the reactor are available with a four hour return to service.

4.3 Project Staging

The high level project staging are as follows:

Stage	Description/Tasks
1	Stage 1 approval Prepare ITT
2	Stage 2 approval(post RIT-T) Reactor Procurement(18months lead times) Award ITT SPA Design and Procurement MSP FAT and pre-commissioning work on site SPA Construction(3 sites) Commissioning (3 sites) Practical Completion

4.4 Resourcing

Not applicable.

4.5 Project Risks

Project risks identified during Project estimating are as follows:

H072 Blackstone Risk Sheet

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

S003Greenbank Risk sheet

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

H005 Woolooga Risk Sheet

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]	Moderate	[redacted]	[redacted]	[redacted]	Moderate
People / Human Resources	[redacted]	[redacted]	Minor	[redacted]	[redacted]	[redacted]	Minor
Natural Events	[redacted]	[redacted]	Minor	[redacted]	[redacted]	[redacted]	Minor
Environmental	[redacted]	[redacted]	Minor	[redacted]	[redacted]	[redacted]	Minor
Health & Safety	[redacted]	[redacted]	No impact	[redacted]	[redacted]	[redacted]	No impact
Project Management	[redacted]	[redacted]	Moderate	[redacted]	[redacted]	[redacted]	Moderate
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]	Moderate	[redacted]	[redacted]	[redacted]	Moderate
Completion	[redacted]	[redacted]	Minor	[redacted]	[redacted]	[redacted]	Minor
TOTAL	[redacted]	[redacted]		[redacted]	[redacted]	[redacted]	

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

5. Total Project Cost Breakdown

5.1 Project Estimate

Estimate Components		Base $	Escalated $
Estimate Class	3		
Estimate Accuracy	30% / -20%		
Base Estimate		30,293,828	33,543,816
Mitigated Risk	[redacted]	[redacted]	[redacted]
Contingency Allowance	[redacted]	[redacted]	[redacted]
TOTAL		[redacted]	[redacted]

5.2 Project Financial Year Cash Flows

	July 2020 Base $	Escalated $
To June 2021	3,029,383	3,029,383
To June 2022	9,088,148	9,652,759
To June 2023	9,088,148	10,048,523
To June 2024	9,088,149	10,813,152
TOTAL	**30,293,828**	**33,543,817**

5.3 Project Asset Classification

Asset Class	Asset Life	Base $	Percentage
Secondary systems	15 years	2,150,166	7%
Communications	15 years	2,356,450	8%
Transmission line refit			
Primary plant	40 years	25,787,212	85%
Transmission lines	50 years		
TOTAL		**30,293,828**	

6. References

Document name	Version	Date
Project Scope Report	1.0	05/11/2020