OPTIONS EVALUATION REPORT (OER)

Southern NSW - Improve voltage control

OER- 000000002145 revision 4.0

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Approvals

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Change history

Revision	Date	Amendment
1	25 August 2021	Initial issue
2	8 October 2021	Minor updates following external preliminary review comments
3	1 November 2021	Minor updates following external review comments
4	23 December 2021	Further updates following external review comments

Executive summary

AEMO's ESOO 2021 report shows that minimum demand in New South Wales will continue to decline over the next 3 - 5 years to 2025-26. The reduction in minimum demand results in high voltage issues, in particular at some switchyards where the maximum voltage rating is lower than 1.1 p.u. Also, there are locations where there are significant voltage control issues due to material load reduction from industrial plant shut downs.

Transgrid has undertaken an assessment of system voltages taking into account the ESOO's minimum demand forecasts, industrial plant shutdowns, as well as committed network augmentations (such as changes to voltage ratings due to Powering Sydney's Future project). The assessment shows over-voltage issues at Kangaroo Valley 330 switchyard and the NSW south west subsystem, specifically Darlington Point and Balranald; in particular in the event of a contingency.

Clause S5.1.4 of the National Electricity Rules (NER) requires that Transgrid plan and design the transmission network to control voltage within defined voltage limits as per clause S5.1a.4. In addition, clause 4.2.6 of the NER requires Transgrid to operate the transmission network in a secure operating state, which requires voltages to be maintained within acceptable range during normal operation and following any credible contingency event[1].

To remain compliant with NER requirements and maintain voltage levels within defined limits, it will be necessary for Transgrid to install shunt reactors at Kangaroo Valley, Darlington Point and Balranald.

The assessment of the options considered to address the need/opportunity are given in **Error! Reference source not found.**.

Table 1 - Evaluated options

Option	Description	Direct capital cost ($m)	Network and corporate overheads ($m)	Total capital cost[2] ($m)	Weighted NPV (PV, $m)	Rank
Option A.1 and A.2	Install 1 x 50 MVAr Shunt Reactor at Kangaroo Valley 330 kV Install 2 x 20 MVAr Shunt Reactors at Darlington Point 132kV and 1 x 20 MVAr Shunt Reactor at Balranald 220 kV	19.94	1.34	21.28	-17.21	1
Option B and A.2	Install 2 x 50 MVAr Shunt Reactors at Capital Wind Farm 330 kV Install 2 x 20 MVAr Shunt Reactors at Darlington Point 132kV and 1 x 20 MVAr Shunt Reactor at Balranald 220 kV	29.04	1.95	30.99	-24.96	2

[1] These requirements are set out in Clauses 4.2.6, 4.2.4 and 4.2.2(b) of the NER. The requirement for secure operation of the power system in Clause 4.2.4 requires the power system to be in a satisfactory operating state following any credible contingency event; that is, to maintain voltage within 10 per cent of normal voltage following the first credible contingency event.

[2] Total capital cost is the sum of the direct capital cost and network and corporate overheads. Total capital cost is used in this OER for all analysis.

The preferred option is Option A.1 for voltage control at Kangaroo Valley and Option A.2 for Darlington Point/ Balranald voltage control. The preferred options are selected because the combination of these options are required to meet the identified need for compliance while being technically and economically feasible.

The preferred option requires a capital expenditure of $21.28 million and the optimal commissioning year is expected to be 2026/27.

In addition to these two options, Transgrid also considered three other options involving replacement of transformers, an 11 kV supply and switching out lines during times when there are voltage issues. However, these options were not progressed as they were deemed either technically or commercially infeasible.

1. Need/opportunity

Transgrid is required by the National Electricity Rules (NER) clause S5.1.4 to plan and design the transmission network to control voltage within defined voltage limits as per clause S5.1a.4. In addition, clause 4.2.6 of the NER requires Transgrid to operate the transmission network in a secure operating state, which requires voltages to be maintained within acceptable range during normal operation and following any credible contingency event[3].

AEMO's ESOO 2021 report shows that minimum demand in New South Wales will continue to decline at a faster rate compared to the 2020 ESOO, due to an increased forecast uptake of distributed PV. The reduction in minimum demand will heighten high voltage issues already occurring in the network due to minimum demand. In addition, NSW south west subsystem is experiencing high voltage issues at times of low demand due to reduction in Wagga area load, primarily due to Norske Skog paper mill ceasing operations (about 100 MW load decrease).

Transgrid has undertaken an assessment of system voltages taking into account the ESOO's minimum demand forecasts, industrial plant shutdowns, as well as committed network augmentations (such as changes to voltage ratings due to Powering Sydney's Future project). The assessment shows that over-voltages will occur at Kangaroo Valley 330 switchyard in the event of contingency conditions, in particular if one shunt reactor in the southern region is out of service[4]. Overvoltage also occurs at Kangaroo Valley 330 kV substation when line 18 from Dapto to Kangaroo Valley trips even with all shunt reactors in service.

In addition, the assessment shows that voltage control issues will exist in the NSW south west subsystem (in particular at Darlington Point and Balranald) at times of light demand, in the event of contingent trip of Lower Tumut – Wagga line 051.

To ensure voltage is controlled within voltage limits as prescribed by the NER, Transgrid needs to install shunt reactors at Kangaroo Valley, Darlington Point and Balranald.

2. Related needs/opportunities

N2393 – Maintain Voltage in South Western Subsystem.

3. Options

3.1 Base case

Under the base case, i.e. not facilitating network developments to address the need, overvoltage issues at Kangaroo Valley, Darlington Point and Balranald are likely to worsen as a result of decreasing minimum demand. Recent operational experience suggested that the reduction in minimum demand is worse than expected in the forecasts and can happen during most of the weekends in the shoulder period. This option is not acceptable since there is a risk of non-compliance as per NER voltage control requirements with reduction in demand.

3.2 Options evaluated for voltage control at Kangaroo Valley

Option A.1 — Install 1x 50 MVAr Shunt Reactor at KVSS 330 kV

[3] These requirements are set out in Clauses 4.2.6, 4.2.4 and 4.2.2(b) of the NER. The requirement for secure operation of the power system in Clause 4.2.4 requires the power system to be in a satisfactory operating state following any credible contingency event, that is, to maintain voltage within 10 per cent of normal voltage following the first credible contingency event.

[4] Transgrid planning criteria is to assess for system normal with one large reactive plant out of service

The following scope of works are required for the installation of one 50 MVAr Shunt Reactor at Kangaroo Valley 330 kV Switching Station:

> Construct a new 330 kV reactor foundation to the East of Bay 1G
> Remove and relocate existing drainage pipes
> Establish a new oil containment/separation facility to the West of Bay 1G
> Construct a hard stand area South of the reactor foundation to enable skating of the reactor
> Modifications to the existing roadways in the South-East corner of the switchyard
> Establish a new 330 kV gantry to the North of the reactor foundation
> Installation of a new 330 kV reactor switchbay and associated conduits including:
  - 1 x 330 kV disconnector with associated earth switch
  - 1 x 330 kV circuit breaker with POW functionality
  - 1 x 330 kV current transformers
> Earthing of all structures
> Construct 3 firewalls 8m high on the North, East and West side of the foundation
> Installation of one (1) x 362 kV 50 MVAr shunt reactor and associated bushings, pipework and surge arrestors
> Install underslung 330 kV insulators to the North of the enclosure
> Installation of the Southern firewall (8m high)
> Installation of a new combined control/protection reactor panel and associated cabling.
> Modifications to the existing substation automation system to include the new reactor.

This option will avoid overvoltages at Kangaroo Valley during system normal and in the event of a contingency above the designed rating of 346 kV.

The expected commissioning date for this option is 2026/27.The expected expenditure profile for this option is obtained using the MTWO Estimating System as given in Option Feasibility Study (OFS). The estimates in the table below have an uncertainty of ± 25% and exclude capitalised interest.

Table 2 – Option A.1 expected expenditure

	Total Project Cost ($M)	FY2024 ($M)	FY2025 ($M)	FY2026 ($M)	FY2027 ($M)
Estimated P50 cost non-escalated ($2020-21)	7.68	0.29	0.57	6.63	0.19

It is estimated that an amount up to $1m is required to progress the project from DG1 to DG2. This is to cover activities such as site visits, development of concept design, and commencement of project approvals and early procurement of long lead-time items. This amount is already included in the total project cost.

This project is expected to be completed in an estimated 39 months following the approval of DG1.

Option B — Install 2 x 50 MVAr shunt reactors at Capital Wind Farm 330 kV

The following scope of works are required for the installation of 2 x 50 MVAr shunt reactors at Capital Wind Farm 330 kV:

> Extend the existing switchyard bench by 60m x 95m
> Install 215m of perimeter fence to enclose the new bench extension

- Remove the Western fence on the existing site
- Installation of a new section of earth grid on the new bench area (60m x 95m = 5700m^2)
- Extend existing roadways by 215m to allow access for low loaders
- Construct two (2) new reactor foundations to the West with dimensions 22 x 12m and 600mm bundwalls on 3 sides
- Construct firewalls (12m long x 6m high) on each foundation on the side away from the roadways
- Establish a new oil containment system and associated pipes from the reactor bunds
- Establish two 330 kV gantries to the West of the Substation and 30m strung bus
- Extend the existing 330 kV 'A' Bus to connect, using droppers (approx. 15m), to the new Bus Section 'A'
- Establish two 330 kV gantries to the West of the Substation and 30m strung bus
- Extend the existing 330 kV 'B' Bus to connect, using droppers (approx. 15m), to the new Bus Section 'B'
- Remove existing buswork from Bay 1G to Bay 1B, and install the following equipment in its place:
  - 2 x 330 kV Disconnectors with associated Earth Switches
  - 1 x 330 kV live tank circuit breaker
  - 1 x 330 kV current transformer
  - All associated conduits
- Construct two sections of low busbar (approx. 35m each) and connect via droppers to strung bus above
- Installation of two (2) new 330 kV reactor switchbay and associated trenches and conduits including:
  - 2 x 330 kV disconnector with associated Earth Switch (one set switchbay)
  - 2 x 330 kV circuit breaker with POW functionality (one set switchbay)
  - 2 x 330 kV current transformer (one set switchbay)
  - 2 x 330 kV surge arrestors (one set per switchbay
- Earthing of all structures
- Installation of two (2) x 362 kV 50 MVAr shunt reactor and associated bushings, pipework and surge arrestors
- Installation of a third firewall (12m long x 6m high) on the foundation adjacent to the existing roadway
- Installation of two (2) new combined control/protection reactor panel and associated cabling
- Modifications to the existing substation automation system to include the new reactors.

This option will avoid overvoltages at Kangaroo Valley during system normal and in the event of a contingency above the designed rating of 346 kV.

The expected commissioning date for this option is 2026/27.The expected expenditure profile for this option is obtained using the MTWO Estimating System as given in OFS. The estimates in the table below have an uncertainty of ± 25% and exclude capitalised interest.

Table 3 – Option B expected expenditure

	Total Project Cost ($M)	FY2024 ($M)	FY2025 ($M)	FY2026 ($M)	FY2027 ($M)
Estimated P50 Cost non-escalated ($2020-21)	17.39	0.60	1.12	13.02	2.65

It is estimated that an amount up to $1.5m is required to progress the project from DG1 to DG2. This is to cover activities such as site visits, development of concept design, and commencement of project approvals and early procurement of long lead-time items. This amount is already included in the total project cost.

This project is expected to be completed in an estimated 42 months following the approval of DG1.

3.3 Options evaluated for voltage control at Darlington Point and Balranald

Option A.2 — Install 2 x 20 MVAr shunt reactors at Darlington Point 132 kV and 1 x 20 MVAr shunt reactor at Balranald 220 kV

The following scope of works are required for the installation of 2 x 20 MVAr shunt reactors at Darlington Point 132 kV and 1 x 20 MVAr shunt reactor at Balranald 220 kV:

Darlington Point:

> Construction of 2 new 132 kV reactor foundations: East of 132 kV B busbar (adjacent to bay 3D); and West of 132 kV A busbar (adjacent to Bay 3L). This requires:
  - Removal and relocation existing drainage pipes
  - Establishment of new oil containment/separation facilities and associated pipework for each new reactor bund
  - Installation of 1 firewall per reactor on the Northern side of the foundations

> Installation of 2 new 132 kV reactor switchbays and associated conduits. Each new reactor switchbay includes:
  - 1 x 132 kV disconnector with associated Earth Switch
  - 1 x 132 kV dead tank circuit breaker with POW functionality
  - 1 x 132 kV surge arrestors (for 3 phases)
  - 1 x 132 kV bus support post insulators (for 3 phases)

> Installation of 2 x 132 kV 20 MVAr shunt reactor and associated bushings and surge arrestors

> Installation of 2 new reactor combined control/protection panels and associated cabling

> Modifications to the existing substation automation system to include the 2 new reactors and associated switchbays

Balranald:

> Extension of substation bench by 10m x 74m in North Eastern direction. This also requires:
  - Extension of substation earth grid
  - Extension of palisade fencing

> Extension of new 220 kV busbar (to be installed under N2575 – Relieve X5 Voltage Stability Constraints) in North Eastern aspect of the substation. This requires the following:
  1. Extension of low busbar by 7m
  2. Installation of 12m high busbar across transformer runway
  3. Installation of additional 18m of low busbar (including one right angle bend)

> Construction of a new 220 kV reactor foundation in the North Western aspect of the substation. This requires:
  - Removal and relocation existing drainage pipes
  - Establishment of new oil containment/separation facilities and associated pipework for each new reactor bund

> Installation of a new 220 kV Reactor switchbay and associated conduits. The switchbay includes:
  - 1 x 220 kV disconnector with associated Earth Switch

  - 1 x 220 kV dead tank circuit breaker with POW functionality
  - 1 x 220 kV surge arrestors (for 3 phases)
  - 1 x 220 kV bus support post insulators (for 3 phases)

> Installation of 220 kV 20 MVAr shunt reactor and associated bushings and surge arrestors

> Installation of a new reactor combined control/protection panels and associated cabling

> Modifications to the existing substation automation system to include the new reactor and associated switchbay.

The listed scope of works will allow Transgrid to maintain voltage across Darlington Point and Balranald within prescribed limits during minimum demand period.

The expected commissioning date for this option is 2025/26.

The expected expenditure profile for this option is obtained using the MTWO Estimating System as given in OFS. The estimates in the table below have an uncertainty of ± 25% and exclude capitalised interest.

Table 4 – Option A.2 expected expenditure

	Total Project Cost ($M)	FY2024 ($M)	FY2025 ($M)	FY2026 ($M)
Estimated P50 Cost non-escalated ($2020-21)	13.60	0.60	1.45	11.55

It is estimated that an amount up to $2.0 million is required to progress the project from DG1 to DG2. This is to cover activities such as site visits, development of concept design, and commencement of project approvals and early procurement of long lead-time items. This amount is already included in the total project cost.

This project is expected to be completed in an estimated 36 months following the approval of DG1.

3.4 Options considered and not progressed

We considered three other options that were not progressed as they were considered not technically or economically feasible. These options are outlined in the table below.

Option	Reason for not progressing
Option C Replace Kangaroo Valley No. 3 and No.4 generator transformers and Bendeela No. 1 generator transformer	The cost to replace 3 generator transformers will be more than 50% higher than the cost of Option A.1 or B, and so is not considered commercially viable.
Option D 11 kV supply from Kangaroo Valley town	11 kV supply from Kangaroo Valley town will allow disconnecting Kangaroo Valley substation from 330 kV transmission network in the event of over-voltages following a transmission line trip (i.e. open line 3W from Capital to Kangaroo Valley in the event of a trip of Kangaroo Valley – Dapto line 18 resulting in over-voltages at Kangaroo Valley substation). However, the high voltage issue at Kangaroo Valley is expected to exist under system normal conditions from 2024. Hence, an additional 11 kV line from Kangaroo Valley town to supply auxiliaries during transmission outages would not resolve the issue, and so is not technically feasible.
Option E Install shunt reactors at Wagga Wagga substation	The installation of shunt reactors at Wagga Wagga instead of Darlington Point and Balranald will require a larger size of reactors due to the added distance

	from the local area experiencing the voltage issues. This will incur a higher cost than Option A.2, and thus is not considered commercially viable.
Switching out lines at times of voltage control issues	Voltage control issues are expected to happen more regularly. Using this option will cause system security issues and maintenance requirements in the long term. This option will cause an additional burden for the control room and pose an additional risk to loads and generating stations. This option will also cause additional generator constraints. This option is only acceptable as a short-term operational emergency measure.

In addition, we considered all other voltage control and NSCAS related projects included in the portfolio in order to optimise the scope, including the project N2393 Maintain Voltage in South Western Subsystem, however, found that there is no opportunity to further optimise. This is due to the local nature of the voltage issues identified to be addressed in this need.

4. Evaluation

4.1 Commercial evaluation methodology

The economic assessment undertaken for this project includes three scenarios that reflect a central set of assumptions based on current information that is most likely to eventuate (central scenario), a set of assumptions that give rise to a lower bound for net benefits (lower bound scenario), and a set of assumptions that give rise to an upper bound on benefits (higher bound scenario).

Assumptions for each scenario are set out in the table below.

Parameter	Central scenario	Lower bound scenario	Higher bound scenario
Discount rate	4.8%	7.37%	2.23%
Demand Growth	Medium (POE50)	Low (POE90)	High (POE10)
Capital cost	100%	125%	75%
Operating expenditure	100%	125%	75%
VCR	AER Latest VCR (escalated) 100%	70%	130%
Fuel Cost	100%	70%	130%
Scenario weighting	**50%**	**25%**	**25%**

Since the central scenario represents the most likely scenario to occur, this has been weighted at 50 per cent. The other two scenarios reflect extreme combinations of assumptions designed to stress test the results. Accordingly, these scenarios are weighted at 25 per cent each.

Parameters used in this commercial evaluation:

Parameter	Parameter Description	Value used for this evaluation
Discount year	Year that dollar values are discounted to	FY2020/21

Base year	The year that dollar value outputs are expressed in real terms	FY2020/21 dollars
Period of analysis	Number of years included in economic analysis with remaining capital value included as terminal value at the end of the analysis period.	25 years

The capex figures in this OER do not include any real cost escalation.

4.2 Commercial evaluation results

The commercial evaluation of the technically feasible options is set out in Table 5. Details appear in Appendix A.

Table 5 - Commercial evaluation (PV, $ million)

Option	Capital Cost PV	OPEX Cost PV	Central scenario NPV	Lower bound scenario NPV	Higher bound scenario NPV	Weighted NPV	Ranking
Option A.1 + A.2	16.97	4.14	-17.48[5]	-20.09	-13.80	-17.21	1
Option B + A.2	24.61	6.02	-25.35[6]	-29.08	-20.06	-24.96	2

4.3 Preferred option

The preferred option is a combination of Option A.1 and A.2. Under this option, the following investments will be undertaken:

- Install 1 x 50 MVAr Shunt Reactor at Kangaroo Valley 330 kV
- Install 2 x 20 MVAr Shunt Reactors at Darlington Point 132 kV and 1 x 20 MVAr Shunt Reactor at Balranald 220kV.

The preferred option was selected because this is the option that meets the identified need for compliance at the highest Net Present Value.

Capital and Operating Expenditure

The preferred option requires capital expenditure of $21.28 million. No additional operating expenditure has been identified for this option.

The base case requires no capital or operating expenditure.

Regulatory Investment Test

As the estimated cost of the project is above the Regulatory Investment Test (RIT-T) threshold of $6 million, a RIT-T will be required.

[5] This NPV takes into account the terminal value of the asset beyond the evaluation period.

[6] This NPV takes into account the terminal value of the asset beyond the evaluation period.

5. Optimal Timing

Since this is a compliance project, the optimal timing is deemed to be as early as possible. The practical delivery date is FY 2026/27. The annualised cost is $1.2 million for both Option A.1 and Option A.2.

Based on the optimal timing, the project is expected to commence in the 2023-2028 Regulatory Period.

6. Recommendation

The recommendation is to progress with a combination of Option A.1 and A.2. This option is expected to incur a capital cost of approximately $21.28m in P50 non-escalated 2020/21 dollars.

Appendix A – Option Summaries

Project Description	Southern NSW - Improve voltage control		
Option Description	Option A.1 – Install 1x 50 MVAr Shunt Reactor at KVSS 330kV and Option A.2 – Install 2 x 20 MVAr shunt reactors at Darlington Point 132kV and 1 x 20 MVAr shunt reactor at Balranald 220kV		
Project Summary			
Option Rank	1	Investment Assessment Period	25
Asset Life	40	NPV Year	2021
Economic Evaluation			
NPV @ Central Benefit Scenario (PV, $m)	-17.48	Annualised CAPEX ($m)	1.21
NPV @ Lower Bound Scenario (PV, $m)	-20.09	Network Safety Risk Reduction ($m)	n/a
NPV @ Higher Bound Scenario (PV, $m)	-13.80	ALARP	n/a
NPV Weighted (PV, $m)	-17.21	Optimal Timing	FY 2026/27
Cost			
Direct Capex ($m)	19.94	Network and Corporate Overheads ($m)	1.34
Total Capex ($m)	21.28	Cost Capex (PV,$m)	16.97
Terminal Value ($m)	11.17	Terminal Value (PV,$m)	3.63

Project Description	Southern NSW - Improve voltage control		
Option Description	Option B – Install 2 x 50 MVAr Shunt Reactors at Capital Wind Farm 330 kV and Option A.2 – Install 2 x 20 MVAr shunt reactors at Darlington Point 132kV and 1 x 20 MVAr shunt reactor at Balranald 220kV		
Project Summary			
Option Rank	1	Investment Assessment Period	25
Asset Life	40	NPV Year	2021
Economic Evaluation			
NPV @ Central Benefit Scenario (PV, $m)	-25.35	Annualised CAPEX ($m)	1.76
NPV @ Lower Bound Scenario (PV, $m)	-29.08	Network Safety Risk Reduction ($m)	n/a
NPV @ Higher Bound Scenario (PV, $m)	-20.06	ALARP	n/a
NPV Weighted (PV, $m)	-24.96	Optimal Timing	FY 2026/27
Cost			
Direct Capex ($m)	29.04	Network and Corporate Overheads ($m)	1.95
Total Capex ($m)	30.99	Cost Capex (PV,$m)	24.61
Terminal Value ($m)	16.27	Terminal Value (PV,$m)	5.28