OPTIONS EVALUATION REPORT (OER)

Strategic Investment for Renewables uptake

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Ellipse project description: Various Locations Dynamic V Support
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Approvals

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1. Need/opportunity

The Need and Opportunity Statement (NOS-1650) outlines a need for some corrective action, to address the forecast voltage stability/capacity issues due to the renewable generation hubs identified in TransGrid's NSW Connection Opportunities (CO) publication.[1]

There will be a need for some corrective action to address the forecast voltage stability/capacity issues at the renewable generation hubs listed in the CO publication. Given the uncertainty of specific timing and triggers for the exact locations it is proposed that projects will be required to facilitate the renewable uptake in NSW to meet NSW government target of 20% renewables by 2020.[2]

The following events would trigger the Need, if they occur, by 2020:

- Commitment to the connection of new renewable generation to one or more of the locations identified in Table 1.
- The level of committed renewable generation is such that voltage and control stability considerations will impede the ability of the generators to be connected and operated at full capacity.
- Positive net benefits of removing the potential constraints are confirmed through a cost-benefit analysis as outlined in the RIT-T guidelines.

Table 1: Connection Opportunities – Locations

Area	Locations considered	Generation Level Triggering the Need for Reactive Support[4]
South West	Balranald 220 kV and 22 kV Broken Hill 220 kV and 22 kV Buronga 220 kV Darlington Point 330 kV and 132 kV Griffith 132 kV and 33 kV	617 MVA (Darlington Pt 330 kV)
Central West	Parkes 132 kV and 66 kV Wellington 330 kV and 132 kV	1234 MVA (Wellington 330 kV)
North	Tamworth 330 kV and 66 kV	1649 MVA (Tamworth 330 kV)

As more renewable generators are connected to the system there will be a requirement for some action to be taken to address the voltage stability and short circuit ratio (SCR) issues. At time of writing, the most effective locations to install dynamic voltage control plant to manage the issues are assessed to be Buronga and Parkes, as outlined in OFRs 1650 A-D.

2. Related needs/opportunities

Nil.

[1] https://www.transgrid.com.au/NSWconnectionopportunities

[2] http://www.resourcesandenergy.nsw.gov.au/__data/assets/pdf_file/0010/475318/nsw-renewable-energy-action-plan.pdf

[3] Calculated based on the methodology in the Connection Opportunities report (footnote 1):

$$\textit{Available capacity due to stability limitations} = (\text{fault level at the connection point})/3.5 - \text{existing generation} + \text{local load.}$$

[4] These generation levels are based on the highest fault level in the considered area and the load at each substation.

3. Options

Base case

The base case option is not feasible. If no investment is made, the renewable generation uptake will be severely constrained and creates a barrier to implementing the state and federal government committed renewable generation in New South Wales. Furthermore, the system reliability and security to load customers will be severely compromised as under voltage stability will cause frequent load shedding to be undertaken.

The main risk cost of this option is estimated to be the market cost of unserved energy caused by a trip of a reasonable number of renewable generators in 2020, when renewables are intended to supply 20% of peak demand in NSW.

A reasonable assessment of the risk cost has been carried out using the following assumptions and calculations, based on the total number and capacity of renewable generator connection inquiries.

Due to the anticipated stability and power quality issues mentioned above, it is reasonable to assume that at least 300 MW[5] of the renewable generation capacity will not be built, or will be constrained off at two or more areas identified for potential connection opportunities.

Considering the following assumptions:

> The renewable energy source most likely to connect will be solar PV;

> The price of gas-fired generation is approximately \$98/MWh in 2020[6] and replaces 300 MW of solar PV generation shortfall;

> The price of solar PV generation is approximately \$133/MWh in 2020[6]; and

> There is a solar PV generation capacity factor of 0.3, and a gas-fired generation capacity factor of 0.83.[6]

We find that the approximate cost of constraining the renewable generation from the NEM will be:

$$[(\$98 * 0.83) - (\$133 * 0.3)]/MWh * 300\,MW * 24hrs * 365\,days = \$108.9\,million\,/\,year$$

Considering additional risks such as TransGrid's reputation, the total risk cost of this option is \$108.97 million per annum, based on the lost generation as shown in Attachment 1.

Non-Network Option

This Need is to address the addition of embedded generation into the transmission network. As such, there are no feasible non-network options identified to enable connection of the new renewable generation plant across the network.

Option A — Install 2x 150 MVAr SVC at 132 kV or 220 kV Busbar in Areas 1 & 2 <OFR-1650A, OFS-1650A>

This option considers installation of SVCs at 132 kV or 220 kV. The benefit of network controlled SVC rather than distributed at renewable generation connection point is that it is easy to deploy them as part of system security assessment as against distributed SVC. Further, renewable generation output variations installed across several vast areas will be seen as aggregated at the network bulk supply point and thus optimises the size of the installation and assists in addressing the network level voltage stability. Providing bulk, network level SVC will allow voltage at 132 kV or 220 kV to be maintained at an appropriate level to maintain voltage stability by looking at the local bus voltage magnitude and bus angle which is a simpler way to implement an effective solution.

The specific scope of this option is therefore:

> Install 1 x 150 MVAr SVC, connected to the Buronga 220 kV bus. Suitable transformers are required to be installed to connect the SVC

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[5] This is around 5% of the proposed renewable generation.

[6] Australian Government Bureau of Resources and Energy Economics 2012, *Australian Energy Technology Assessment 2012.* Assuming that natural gas will replace the renewable sources if they are not commissioned or are constrained off.

- Install 1 x 220 kV single circuit breaker (CB) switchbay
- Complete associated secondary systems modifications
- Complete any other required civil works including potential bench extension
- Same scope as above (1-4) but at 132 kV, at Parkes substation

The cost of this option is estimated in OFS-1650A to be $38.9 million in 2016-17 AUD.

This option will meet the need. With properly designed and installed facilities the risk of voltage instability will be significantly removed and no residual risk remains.

Option B — Install 300 MVAr (60x 3 MVAr) Synchronous Condensers with High Inertia at Each of the 132 kV or 220 kV Busbars in Areas 1 & 2 <OFR-1650B, OFS-1650B>

This option considers installation of high inertial synchronous condensers at 132 kV or 220 kV. The benefit of network-installed condensers is that they will increase the fault levels and thus increases the stability limit. Further, they have sufficient response time to manage reactive power support in response to the changes in load and changes in the output of generation (including renewables). Importantly, this will assist in providing sufficient Effective Short Circuit Ratio (ESCR) at the connection points for the connection of PV and or Wind Farms.

The specific scope of this option is therefore:

1. Install 3 x 50 MVAr synchronous condensers with high inertia, connected to the Buronga 220 kV busbar. Suitable transformers are required to be installed to connect the synchronous condensers
2. Install 3 x 220 kV single circuit breaker (CB) switchbays
3. Completed associated secondary systems modifications
4. Complete any other required civil works including potential bench extension
5. Same scope as above (1-4) but at 132 kV, at Parkes substation

The cost of this option is estimated in OFS-1650B to be $92.7 million in 2016-17 AUD.

This option will meet the need. With properly designed and installed facilities the risk of voltage instability will be significantly removed and no residual risk remains.

Option C — Install 50 Mvar DVAR With 5 Seconds Boost Capability of 100 MVAr, Areas 1 to 3, plus 1x 100 MVAr Fixed Capacitor, in Areas 1 & 2 <OFR-1650C, OFS-1650C>

This option addresses the need for fast reactive support to assist the voltage recovery under fault conditions. The use of DVAR allows optimising the size of the reactive power required, while the boost capability typically available from DVAR will help significant increase in fast reactive power output to support recovery of voltage. This option will not work on its own and will require additional switched shunt capacitors to be installed to allow for voltage recovery; the capacitors to be supporting voltage, while DVAR settles back to its pre fault values. The advantages are dependent on the transformer size and costs. The DVAR could be installed at 22 kV or 33 kV voltages, while the fixed shunt capacitors at 132 kV or 220 kV. Coordination with On Load Tap Changers (OLTC) will be required.

The specific scope of this option is therefore:

1. Install 1 x 50 MVAr DVAR with 5 seconds boost capability of 100 MVAr, connected to the Buronga 220 kV busbar. Suitable transformers are required to be installed to connect the DVAR
2. Install 1 x 100 MVAr fixed capacitor bank connected to the Buronga 220 kV busbar
3. Install 2 x 220 kV single circuit breaker (CB) switchbays
4. Complete associated secondary systems modifications
5. Complete any other required civil works including potential bench extension
6. Same scope as above (1-5) but at 132 kV, at Parkes substation

The cost of this option is estimated in OFS-1650C to be $44.3 million in 2016-17 AUD.

This option will meet the need. With properly designed and installed facilities the risk of voltage instability will be significantly removed and no residual risk remains.

Option D — Combination of 1 x 75 MVAr Synchronous Condensers with High Inertia and 75 MVAr of SVC at Each of Areas 1 & 2 <OFR-1650D, OFS-1650D>

This option is hybrid option (Option A & B). The aim is to provide inertia boost via high inertia synchronous condensers while having SVC installed for fast response to arrest unstable operation. The benefit of network-installed condensers is that they will increase the fault levels and thus increase the stability limits. Furthermore, they have sufficient response time to manage reactive power support in response to the changes in load and the output of generation (including renewables). Importantly, this will assist in providing sufficient ESCR for the connection of PV and or Wind Farms. This will largely facilitate expected 2000 MW equivalent energy (installed capacity of 5000 MW).

The specific scope of this option is therefore:

1. Install 1 x 75 MVAr synchronous condenser with high inertia, connected to the Buronga 220 kV busbar. Suitable transformers are required to be installed to connect the synchronous condenser.
2. Install 1 x 75 MVAr SVC, connected to the Buronga 220 kV busbar. Suitable transformers are required to be installed to connect the SVC.
3. Install 2 x 220 kV single circuit breaker (CB) switchbays
4. Complete associated secondary systems modifications
5. Complete any other required civil works including potential bench extension
6. Same scope as above (1-5) but at 132 kV, at Parkes substation

The cost of this option is estimated in OFS-1650D to be $69 million in 2016-17 AUD.

This is the most robust technical option, which will assist or nullify any retirement of thermal units in NSW. Studies are required to determine the response time. Further fast acting SVC installed will assist in fast recovery of voltage and therefore avoid voltage instability.

This option will meet the need. With properly designed and installed facilities risk of voltage instability will be significantly removed and no residual risk remains.

4. Evaluation

A technical and economic evaluation of all technically feasible options has been made. The options presented here are well proven solutions for dealing with voltage stability issues as well as addressing issues with renewable energy integration to the grid[7].

Among the options presented the best technical option is Option D. This is because it not only addresses the voltage stability and assists the grid reliability of supply, but it will also address the looming reduction in inertia caused by increased renewables replacing conventional generation. However, due the significant upfront capital cost, and the fact that it addresses an additional possible system issue of reduced inertia which is not the primary Need, Option D is not preferred.

Option A is the preferred option as it addresses the Need and has the highest (least negative) financial NPV and the highest economic NPV.

The commercial evaluation of the technically feasible options is set out in Table .

Table 2: Commercial Evaluation of Technically Feasible Options

Option	Description	Capex ($m)	Opex ($m)	Post project risk cost / yr ($m)	Financial NPV ($m)	Economic NPV ($m)	Rank
Base case	'Do Nothing' – no investment	-	-	73.39	-	-	-
A	Install 2x 150 MVAr SVC at 132 kV or 220 kV Busbar in Areas 1 & 2	38.9	0.778	0	(32.75)	642.40	1
B	Install 300 MVAr (60x 3 MVAr) Synchronous Condensers with High Inertia at Each of the 132 kV or 220 kV Busbars in Areas 1 & 2	92.70	1.854	0	(78.63)	596.52	4
C	Install 50 Mvar DVAR With 5 Seconds Boost Capability of 100 MVAr, Areas 1 to 3, plus 1x 100 MVAr Fixed Capacitor, in Areas 1 & 2	44.30	0.886	0	(37.35)	637.81	2
D	Combination of 1 x 75 MVAr Synchronous Condensers with High Inertia and 75 MVAr of SVC at Each of Areas 1 & 2	69.00	1.380	0	(58.41)	616.74	3

[7] Cigré report

The commercial evaluation is based on:

> a 10% discount, with sensitivities based on TransGrid's current AER-determined pre-tax real regulatory WACC of 6.75% for the lower bound and 13% for the upper bound provided in Appendix A.

> the applied sensitivities on the discount rate give the following economic NPVs for the preferred option, A:

Discount Rate (%)	Economic NPV ($m)
6.75	962.11
13.00	460.45

ALARP Evaluation

An ALARP assessment is triggered by the following hazard and the disproportionate factor:

> Unplanned outage of HV equipment → 3 times the safety risk reduction and taking 10% of the reliability risk reduction as being applicable to safety.

However, as this will only produce 30% of the benefit derived in the economic evaluation, a full ALARP evaluation will not produce an alternative preferred solution.

Preferred Option

Based on the economic and technical evaluation above, Option A is the preferred option to address the Need as it addresses the voltage stability and assists the grid reliability of supply.

Capital and operating expenditure

The yearly incremental operating expenditure of Option A is estimated to be 2% of the upfront capital cost of the option, which equates to $0.778 million, escalated at a rate of 2.9% per annum.

Regulatory Investment Test – Transmission

Option A will be subject to the RIT-T process as it has an estimated cost greater than the mandated $6 million threshold.

5. Recommendation

Based on the economic and technical evaluation above, Option A is the preferred option to address the Need as it addresses the voltage stability and assists the grid reliability of supply.

This option can assist with significant renewable uptake and is therefore recommended to proceed.

Appendix A - Financial and Economic Evaluation Reports

Project_Option Name	1650A - Various Locations Dynamic Voltage Support

1. Financial Evaluation (excludes VCR benefits)				
NPV @ standard discount rate	10.00%	-$32.75m	*NPV / Capital (Ratio)*	*-0.84*
NPV @ upper bound rate	13.00%	-$29.12m	*Pay Back Period (Yrs)*	*Not measurable*
NPV @ lower bound rate (WACC)	6.75%	-$37.57m	*IRR%*	*-9.56%*

2. Economic Evaluation (includes VCR benefits but excludes tax benefits from non-cash transactions, ENS penalty and overall tax cost)				
NPV @ standard discount rate	10.00%	$642.40m	*NPV / Capital (Ratio)*	*16.51*
NPV @ upper bound rate	13.00%	$460.45m	*Pay Back Period (Yrs)*	*Not measurable*
NPV @ lower bound rate (WACC)	6.75%	$962.11m	*IRR%*	*129.61%*

Benefits					
Risk cost	As Is	To Be	Benefit	*VCR Benefit*	*$108.90m*
Systems (reliability)	*$108.90m*	*$0.00m*	*$108.90m*	*ENS Penalty*	*$0.00m*
Financial	*$0.00m*	*$0.00m*	*$0.00m*	*All other risk benefits*	*$0.07m*
Operational/compliance	*$0.00m*	*$0.00m*	*$0.00m*	Total Risk benefits	$108.97m
People (safety)	*$0.00m*	*$0.00m*	*$0.00m*		
Environment	*$0.00m*	*$0.00m*	*$0.00m*	Benefits in the financial NPV*	$0.07m
Reputation	*$0.07m*	*$0.00m*	*$0.07m*	**excludes VCR benefits*	
Total Risk benefits	$108.97m	$0.00m	$108.97m		
Cost savings and other benefits			$0.00m	Benefits in the economic NPV**	$108.97m
Total Benefits			$108.97m	***excludes ENS penalty*	

Other Financial Drivers			
Incremental opex cost pa (no depreciation)	-$0.78m	Write-off cost	$0.00m
Capital - initial $m	-$38.90m	Major Asset Life (Yrs)	40.00 Yrs
Residual Value - initial investment	$14.59m	Re-investment capital	$0.00m
Capitalisation period	5.00 Yrs	Start of the re-investment period	0.00 Yrs

Project_Option Name	1650B - Various Locations Dynamic Voltage Support

1. Financial Evaluation (excludes VCR benefits)

NPV @ standard discount rate	10.00%	-$78.63m	*NPV / Capital (Ratio)*	*-0.85*
NPV @ upper bound rate	13.00%	-$69.81m	*Pay Back Period (Yrs)*	*Not measurable*
NPV @ lower bound rate (WACC)	6.75%	-$90.41m	*IRR%*	*-9.80%*

2. Economic Evaluation (includes VCR benefits but excludes tax benefits from non-cash transactions, ENS penalty and overall tax cost)

NPV @ standard discount rate	10.00%	$596.52m	*NPV / Capital (Ratio)*	*6.43*
NPV @ upper bound rate	13.00%	$419.77m	*Pay Back Period (Yrs)*	*Not measurable*
NPV @ lower bound rate (WACC)	6.75%	$909.28m	*IRR%*	*75.48%*

Benefits

Risk cost	As Is	To Be	Benefit		
Systems (reliability)	*$73.32m*	*$0.00m*	*$73.32m*	*VCR Benefit*	*$108.90m*
Financial	*$0.00m*	*$0.00m*	*$0.00m*	*ENS Penalty*	*$0.00m*
Operational/compliance	*$0.00m*	*$0.00m*	*$0.00m*	*All other risk benefits*	*$0.07m*
People (safety)	*$0.00m*	*$0.00m*	*$0.00m*	Total Risk benefits	$108.97m
Environment	*$0.00m*	*$0.00m*	*$0.00m*	Benefits in the financial NPV*	$0.07m
Reputation	*$0.07m*	*$0.00m*	*$0.07m*	**excludes VCR benefits*	
Total Risk benefits	$73.39m	$0.00m	$73.39m		
Cost savings and other benefits			$35.58m	Benefits in the economic NPV**	$108.97m
Total Benefits			$108.97m	***excludes ENS penalty*	

Other Financial Drivers

Incremental opex cost pa (no depreciation)	-$1.85m	Write-off cost	$0.00m
Capital - initial $m	-$92.70m	Major Asset Life (Yrs)	40.00 Yrs
Residual Value - initial investment	$34.76m	Re-investment capital	$0.00m
Capitalisation period	5.00 Yrs	Start of the re-investment period	0.00 Yrs

Project_Option Name	1650C - Various Locations Dynamic Voltage Support

1. Financial Evaluation (excludes VCR benefits)				
NPV @ standard discount rate	10.00%	-$37.35m	*NPV / Capital (Ratio)*	*-0.84*
NPV @ upper bound rate	13.00%	-$33.19m	*Pay Back Period (Yrs)*	*Not measurable*
NPV @ lower bound rate (WACC)	6.75%	-$42.86m	*IRR%*	*-9.61%*

2. Economic Evaluation (includes VCR benefits but excludes tax benefits from non-cash transactions, ENS penalty and overall tax cost)				
NPV @ standard discount rate	10.00%	$637.81m	*NPV / Capital (Ratio)*	*14.40*
NPV @ upper bound rate	13.00%	$456.38m	*Pay Back Period (Yrs)*	*Not measurable*
NPV @ lower bound rate (WACC)	6.75%	$956.82m	*IRR%*	*121.32%*

Benefits					
Risk cost	As Is	To Be	Benefit	*VCR Benefit*	*$108.90m*
Systems (reliability)	*$73.32m*	*$0.00m*	*$73.32m*	*ENS Penalty*	*$0.00m*
Financial	*$0.00m*	*$0.00m*	*$0.00m*	*All other risk benefits*	*$0.07m*
Operational/compliance	*$0.00m*	*$0.00m*	*$0.00m*	Total Risk benefits	$108.97m
People (safety)	*$0.00m*	*$0.00m*	*$0.00m*		
Environment	*$0.00m*	*$0.00m*	*$0.00m*	Benefits in the financial NPV*	$0.07m
Reputation	*$0.07m*	*$0.00m*	*$0.07m*	**excludes VCR benefits*	
Total Risk benefits	$73.39m	$0.00m	$73.39m		
Cost savings and other benefits			$35.58m	Benefits in the economic NPV**	$108.97m
Total Benefits			$108.97m	***excludes ENS penalty*	

Other Financial Drivers			
Incremental opex cost pa (no depreciation)	-$0.89m	Write-off cost	$0.00m
Capital - initial $m	-$44.30m	Major Asset Life (Yrs)	40.00 Yrs
Residual Value - initial investment	$16.61m	Re-investment capital	$0.00m
Capitalisation period	5.00 Yrs	Start of the re-investment period	0.00 Yrs

Project_Option Name	1650D - Various Locations Dynamic Voltage Support

1. Financial Evaluation (excludes VCR benefits)

NPV @ standard discount rate	10.00%	-$58.41m	*NPV / Capital (Ratio)*	*-0.85*
NPV @ upper bound rate	13.00%	-$51.87m	*Pay Back Period (Yrs)*	*Not measurable*
NPV @ lower bound rate (WACC)	6.75%	-$67.12m	*IRR%*	*-9.74%*

2. Economic Evaluation (includes VCR benefits but excludes tax benefits from non-cash transactions, ENS penalty and overall tax cost)

NPV @ standard discount rate	10.00%	$616.74m	*NPV / Capital (Ratio)*	*8.94*
NPV @ upper bound rate	13.00%	$437.71m	*Pay Back Period (Yrs)*	*Not measurable*
NPV @ lower bound rate (WACC)	6.75%	$932.56m	*IRR%*	*92.34%*

Benefits

Risk cost	As Is	To Be	Benefit
Systems (reliability)	*$108.90m*	*$0.00m*	*$108.90m*
Financial	*$0.00m*	*$0.00m*	*$0.00m*
Operational/compliance	*$0.00m*	*$0.00m*	*$0.00m*
People (safety)	*$0.00m*	*$0.00m*	*$0.00m*
Environment	*$0.00m*	*$0.00m*	*$0.00m*
Reputation	*$0.07m*	*$0.00m*	*$0.07m*
Total Risk benefits	$108.97m	$0.00m	$108.97m
Cost savings and other benefits			$0.00m
Total Benefits			$108.97m

VCR Benefit	*$108.90m*
ENS Penalty	*$0.00m*
All other risk benefits	*$0.07m*
Total Risk benefits	$108.97m
Benefits in the financial NPV* **excludes VCR benefits*	$0.07m
Benefits in the economic NPV** ***excludes ENS penalty*	$108.97m

Other Financial Drivers

Incremental opex cost pa (no depreciation)	-$1.38m	Write-off cost	$0.00m
Capital - initial $m	-$69.00m	Major Asset Life (Yrs)	40.00 Yrs
Residual Value - initial investment	$25.88m	Re-investment capital	$0.00m
Capitalisation period	5.00 Yrs	Start of the re-investment period	0.00 Yrs