Options Evaluation Report (OER)

Uprating Darlington Point 330-132kV Transformers
OER- **N2176** revision **3.0**

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Approvals

Author	Sankika Tennakoon	Senior Engineer, System Planning and Analysis
Endorsed	Kevin Hinkley	System Analysis and Planning Manager
	Debashis Dutta	Asset Analytics and Insights Manager
Approved	Kasia Kulbacka	General Manager of Network Planning
Date submitted for approval	12 October 2022	

Change history

Revision	Date	Amendment
0	19 December 2019	Initial Issue
1	4 February 2020	Revised to include the Appendix A – Summary of Preferred Option.
2	21 September 2021	Updated for the latest template; revised costs per OFS N2716A
3	12 October 2022	Updated for the revised cost for 2021/22 and new OER template Wording updated on market benefit calculation methodology

Executive summary

Darlington Point has two 280MVA 330/132/11 kV transformers (No.1 and No.2) built by Tyree (now ABB) in Moorebank. Although the design rating of these transformers is 375MVA, their rating is currently limited to 280MVA due to the limited capacity of the cooling system which consists of 18 radiators as opposed to 36 in a standard 375MVA unit.

Until the development of large-scale solar generation in the area these transformers were lightly loaded, with total area load rarely exceeding 215MVA. With the recent development of solar farms in the Darlington Point area it is expected that there will be times of high renewable generation in South-West NSW. Under these conditions very high reverse power flows through the Darlington Point 330/132kV transformers into the NSW 330 kV network is expected to occur.

This additional generation has increased the loading on the Darlington Point 330/132kV transformers, such that for loss of one Darlington Point 330/132/11kV transformer the other will be 10-25% overloaded with all other elements and committed generators in-service. The low cost renewable generation has to be curtailed via pre-contingent constraints to prevent overloading on the transformers during outage of a single unit. As such notwithstanding the failure rate of the transformers and/or probability of the planned/forced outages, curtailment of the renewable generation is required to operate the system within the safe operating conditions.

Increasing the rating of the transformers and associated equipment to their maximum design rating of 375MVA will provide an additional firm capacity of 95 MVA under N-1 conditions, with this being available to import additional renewable generation from the area into the NSW network[1].

A Need has been identified to remove the thermal limitation of the No.1 and No.2 transformers at Darlington Point transformers hence increase the transfer capability of the transformers during outage condition of a single transformer. This proposed upgrade is expected to yield market benefits.

The assessment of the options considered to address the need/opportunity appears in Table 1.

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 – Upgrade the cooler banks and associated equipment	Upgrade the cooler banks and associated equipment of the Darlington Point 330/132kV transformers to increase the transformer rating to 375MVA	3.8	0.3	4.4	49.0	1

[1] i.e. the maximum design rating of 375 MVA less the existing operating rating of 280MVA

[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.

Preferred Option

Option A — Upgrade the cooler banks and associated equipment of the Darlington Point 330/132kV transformers to increase the transformer rating to 375MVA has been selected compared to the Base Case.

The scope of the preferred option involves increasing the size of the cooler banks and related cooling equipment, and removing the associated 132kV secondary system bay rating limitations. This option also includes an assessment of the space requirements for the additional cooling equipment, and the upgrading as necessary of ancillary or secondary system equipment that would otherwise restrict the capacity of the transformers to less than the maximum design rating of 375MVA per unit.

This Option maximises the thermal capability of the Darlington Point No.1 and No. 2 330/132kV transformers, thereby increasing the transfer capability of the transformers in order to deliver low cost renewable energy to the network thereby generating market benefits.

This option has been selected as the preferred option as the increased capacity provided at Darlington Point will produce market benefits through reduced generator curtailment during N-1 conditions, and mitigate possible future curtailment in system normal situations due to growth in generation capacity connected to Darlington Point.

Further, it delivers a positive Net Present Value for all three scenarios considered compared to the Base Case, whilst being the only technically feasible option which could increase the rating of the transformers without having to replace them.

The expected commissioning date for this option is 2024/25.

Given the market benefits derived from the additional capacity thus provided, and the estimated expenditure for the upgrade being below the RIT-T investment threshold, it is proposed that these works be funded as a NCIPAP project, for implementation by no later than June 2025.

1. Need/opportunity

Darlington Point has two 280MVA 330/132/11 kV transformers. These transformers are the same fundamental design as Transgrid standard 375MVA units, but with only half the cooler banks installed. Comparison of the nameplate specifications of these transformers with 375MVA units installed at Sydney North and Dapto reveals that the 375MVA units have 36 radiators with 32 fans, whilst the Darlington Point units only have 18 radiators with 16 fans.

Until the development of large-scale solar generation in the area these transformers were lightly loaded, with total area load rarely exceeding 215MVA. A number of solar farms have recently been developed in the in the Darlington Point area including Darlington Point Solar Farm (275MW), Coleambally Solar Farm (150MW), and Griffith Solar Farm (30MW) which are currently in-service. In addition, Hillston Solar Farms (85MW), Riverina Solar Farm (30MW) and Avonlie Solar Farm (190MW) are currently under development. These generators feed into the 132 kV network in the area supplied from the Darlington Point transformers.

Figure 1 illustrates the transmission network in Darlington Point area.

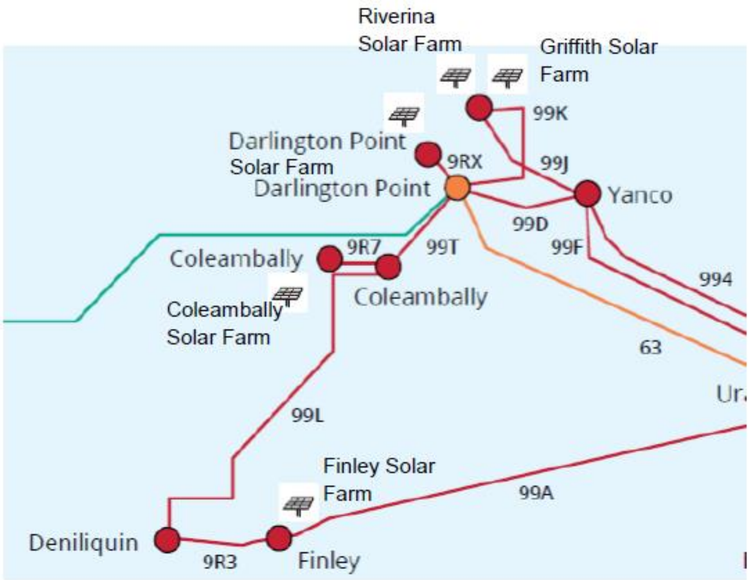

Figure 1: Transmission network in Darlington Point area

At times of high renewable generation in South-West NSW it is expected that there will be high reverse power flow through the two Darlington Point transformers into the broader NSW 330 kV network. During the day, when there is abundant solar irradiance in the area and relatively low local demand conditions, there will be excess low cost generation flowing into the main grid. This additional generation will increase the loading on Darlington Point 330/132 kV transformers, such that for loss of one Darlington Point 330/132/11kV transformer the other will be 10-25% overloaded with all committed generators in-service, depending on the local demand conditions.

The risk of the overloading of the transformers is currently managed by an overloading control scheme at Darlington Point. In the event of a transformer overload, the Darlington Point Solar Farm will run back, and for prolonged and higher overload levels the solar farm will be disconnected. With further additional generation expected due to the other solar farms currently under development, there will be even higher flows through the transformers, and hence the generation will need to be further curtailed from present levels to manage the transformer loading.

Increasing the rating of the transformers to 375MVA will provide an additional firm capacity of 95MVA[3] under N-1 conditions to facilitate the import of additional renewable generation from the area into the NSW network.

A need has been identified to remove the thermal limitation of the Darlington Point No.1 and No.2 330/132kV transformers by uprating them to their full design rating to 375MVA, thereby increasing the transfer capability from local renewable generation to the greater network.

This project is expected to meet the requirement for a NCIPAP project in terms of the level of investment required and the potential market benefits through network capacity increases.

2. Related needs/opportunities

- N2174 – Removing Limitations in Darlington Pt. Tie Transformers.

  This Need is to implement a trip scheme to increase the operating ratings of the Tie transformers from 200MVA to 250-300MVA hence remove constraints on generation on the 220kV network. N2404 – Transformer refurbishment/ replacement project at Darlington Point. The scope of this project include project refurbishment of the No.1 No.3 and No.4 transformers at Darlington Point. The proposed refurbishment works would not increase the rating of the transformers.

- 1253 – Darlington Point Secondary Systems Renewal.

  Need 1253 addresses the need for the complete in-situ renewal and upgrade of secondary systems at Darlington Point 330kV Substation.

- N2363 – Improve Stability in south-western NSW

  This Need/Opportunity statement documents the triggers, limitations, needs and potential options to upgrade the transmission network in south-western New South Wales (NSW).

3. Options

3.1. Base case

The base case is to not undertake any capital investment to increase the transformer capacity, and hence retain the existing capacity of 280MVA for No. 1 and No.2 330/132/kV transformers at Darlington Point.

Under the base case, it is expected to result in curtailment of renewable energy generation to ensure each 330/132 kV transformer at Darlington Point is not overloaded in the event of a contingent trip of one of the

[3] i.e. the maximum design rating of 375 MVA less the existing operating rating of 280MVA

units. Further, as more renewable energy generation comes on line it may be necessary to curtail the large proportions of renewable generation output to prevent overloading of the transformers even under system normal conditions. The total energy to be curtailed also depends on the local demand level in Darlington Point and Griffith area as illustrated in Figure 2.

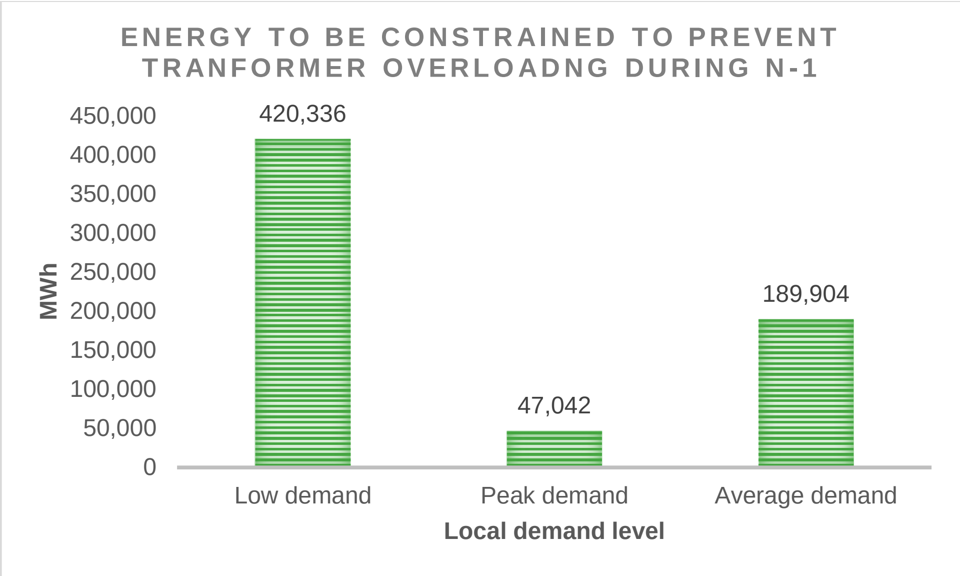

Figure 2: The estimated energy to be curtailed in a year to manage the transformer overloading at Darlington Point

As per Figure 2, at minimum there will be approximately 47GWh to be constrained per year to ensure the transformers are not overloaded.

3.2. Options evaluated

Option A — Upgrade the cooler banks and associated equipment of the Darlington Point 330/132kV transformers to increase the transformer rating to 375MVA.

This involves increasing the size of the cooler banks and related cooling equipment.

This option includes an assessment of the space requirements for the additional cooling equipment, and the upgrading as necessary of ancillary or secondary system equipment that would otherwise restrict the capacity of the transformers to less than the maximum design rating of 375MVA per unit.

The option has been assessed by relevant equipment suppliers. The supplier has confirmed that the uprating of the transformers to attain a rating of 375MVA can be achieved by doubling the cooling capacity on each transformer. This can be completed by utilising the existing radiator banks and fans on one transformer to uprate the other, while procuring a new cooling system for the other. As such, this option is based off the following staging:

Stage 1: Uprate the existing No.2 330/132/11kV Transformer

Stage 2: Uprate the existing No.1 330/132/11kV Transformer

Site conditions and ancillary electrical equipment specifications have also been assessed. Modifications required to be undertaken include:

- Primary electrical connections
- Spill oil tank
- Bunds/Blast walls
- Secondary systems upgrades including transformer control cubicle

This is the only technical feasible option being considered to maximise the thermal capability of the Darlington Point 330/132kV transformers.

Table 2: Option A expected expenditure (non-escalated)

	Total Project Base Cost [$M]	2023/24	2024/25
Estimated Cost – non-escalated ($m 2021-22)	4.4	0.6	3.8

It is estimated that this option would cost $4.4m ± 25% ($2021-22).

The expected commissioning date for this option is 2024/25.

It is estimated that an amount up to $500k is required to progress the project from DG1 to DG2 and this cost has been included in the expenditure listed in Table 2. This is to cover activities such as site assessments, the development of concept designs, the commencement of project approvals and the early procurement of long lead-time items.

This project is expected to be completed in an estimated 23 months following the approval of DG1.

3.3. Options considered and not progressed

No other options were considered.

4. Evaluation

4.1. Commercial evaluation methodology

The economic assessment undertaken for this project includes three scenarios that reflect a central set 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.

Table 3: Assumptions used in commercial evaluation

Parameter	Central scenario	Lower bound scenario	Higher bound scenario
Discount rate	5.5%	7.5%	2.3%
Demand Growth	Medium (POE50)	Low (POE90)	High (POE10)
Fuel Cost[4]	100%	70%	130%
Capital cost	100%	125%	75%
Operating expenditure	100%	125%	75%
VCR	AER Latest VCR (escalated) 100%	AER Latest VCR (escalated) 70%	AER Latest VCR (escalated) 130%
Scenario weighting	50%	25%	25%

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

Table 4: Parameters used in this commercial evaluation

Parameter	Parameter Description	Value used for this evaluation
Discount year	Year that dollar values are discounted to	2021/22
Base year	The year that dollar value outputs are expressed in real terms	2021/22 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 substations

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

4.2. Commercial evaluation results

This is a relative comparison, with the Do Nothing case used as the reference point. As such, the costs and benefits are given with respect to the Base Case and thus have not been costed for the Do Nothing option. The OPEX costs for the identified option are not expected to vary significantly from existing transformer O&M costs, and are therefore not shown for the assessed option.

The inputs used in the commercial evaluation in addition to those listed in Table 3 are:

- An investment life of 13 years[5], which is in line with the remaining asset life of the older unit amongst the two transformers (from the completion year of transformer upgrade); and
- Economic (market) benefits from removing the constraint on exporting the renewable generation thereby displacing higher-cost thermal generation is calculated based on the estimated total generation to be curtailed by the existing Overload Control Scheme as below.

[4] Fuel Cost used for the market benefit calculation is based on the average Short Run Marginal Cost (SRMC) of the NSW Coal-fired Generators excluding Liddell Reference: AEMO's Electricity Statement of Opportunities ESOO 2020.

[5] Assumed that the transformer asset of 50 years. No.1 transformer natural age 39 (effective age 35); No. 2 Transformer natural age 34 years (effective age: 28 years)

- Half hourly solar traces of Darlington Point Solar Farm[6] (used forecast data from AEMO generation for year 2024[7]);
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The expected additional renewable energy to be transferred through the uprated transformers per year is equal to the total renewable generation to be constrained to prevent overloading of the transformer during N-1 in a year.

Therefore, in order to ensure each transformer is not overloaded during a contingent trip of a single unit, generation will need to be curtailed pre-contingent via a constraint equation(s). As such notwithstanding the failure rate of the transformers and/or probability of the planned/forced outages, curtailment of the renewable generation is required to operate the system within the safe operating conditions. Hence, the calculation of the expected market benefits is carried out based on pre-contingent curtailment of generation as opposed to a probabilistic estimation of planned and unplanned outages.

This has been calculated as follows:

Table 5: Estimation of annual market benefit

Parameter	Quantity
Total generation to be constrained[8] on an average day with medium level of local demand	68MW
No. of hours of generation to be constrained per year[9]	2158 hrs
Fuel cost difference (for Central Scenario)	$32.05/MWh
Expected annual market benefit	=Total renewable generation to be curtailed x Fuel cost difference = 68 MW x 2158 hrs x $32.04/MWh = $ 6.02million

The commercial evaluation for the investment period of the technically feasible options is set out in Table 6. Details appear in Table 6.

Table 6: 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	3.6	1.0	45.0	24.1	81.7	49.0	1

[6] Darlington Point Solar Farm used as it has the highest contribution to the overloading of the No.1 and No.2 transformers and the being the largest solar farm in the area.
[7] ESOO Solar and Wind Trances 2020 – Darlington Point Solar Farm Reference Year 2024
[8] Typical maximum day time demand which is approximately 60% of the peak demand.
[9] Estimated based on the projected solar traces. Reference: AEMO ESOO 2020 Assumptions and workbook

This project is being proposed on the basis of market benefit impacts only, expected to be funded as a NCIPAP project. As such, only an economic evaluation of the technically feasible option has been carried out, summarised below.

4.3. Preferred option

Option A has been selected as the preferred option based on the following reasons:

> Option A provides market benefits that are larger than the investment cost, resulting in a positive NPV for all three scenarios considered.

> Option A is the only technically feasible option.

> The base case do nothing option is the reference case, against which the benefits and costs of Option A have been assessed.

The following scope of works has been included:

For No.2 Transformer:

- Extend the existing No.2 Transformer compound and upgrade the existing waster stops
- Replace all existing masonry walls with reinforced concrete walls
- Drain oil
- Remove the existing radiators on the No.2 Transformer
- Supply and install 36 x new radiators and 24 x new fans for the No.2 Transformer
- Install a new Transformer control cubicle and associated cabling
- Supply and install WTI (Winding Temperature Indicator) and associated cables from control cubicle to the new fans
- Refill oil
- Commissioning and testing of new fans
- Installation of a new No.2 Transformer nameplate
- Perform functional testing

For No.1 Transformer:

- Construct two (2) new free standing firewalls around the No.1 Transformer compound
- Replace all existing masonry walls with reinforced concrete walls
- Drain oil
- Install the radiators taken from No.2 Transformer
- Supply and install 24 x new fans for the No.1 Transformer
- Install a new Transformer control cubicle and associated cabling
- Supply and install WTI (Winding Temperature Indicator) and associated cables from control cubicle to the new fans
- Refill oil
- Commissioning and testing of new fans
- Installation of a new No.1 Transformer nameplate

- Perform functional testing

Capital and Operating Expenditure

The preferred option requires capital expenditure of $4.4m. For the NPV analysis an annual operating expenditure of 2% of the capital cost has been identified for this option.

Regulatory Investment Test

As the expected cost of the project as per Table 2 is less than the trigger threshold of $7 million, the Regulatory Investment Test – Transmission (RIT-T) is not required for this project.

Further, as this project is below the RIT-T investment threshold and yields significant market benefit through the provision of additional market capacity, it is proposed that this project be funded as a NCIPAP project.

5. Optimal Timing

The test for optimal timing of the preferred option has been undertaken. The approach taken is to identify the optimal commissioning year for the preferred option where net benefits (including avoided costs and safety disproportionality tests) of the preferred option exceeds the annualised costs of the option. The commencement year is determined based on the following:

Required project disbursement to the meet the commissioning year based on the OFS.

Remaining asset life of the Darlington Point No.1 and No 2. 330/132/11kV transformers.

The results of optimal timing analysis is:

- Optimal commissioning year: 2024/25
- Commissioning year annual benefit: $3.0m
- Annualised cost: $485k

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

6. Recommendation

It is therefore recommended that the two Darlington Point 330/132kV Transformers be uprated from 280 MVA to 375 MVA capacity through the Option A- augmentation of the existing transformer cooling systems, and that additional works to connections and secondary systems equipment be undertaken.

The capital expenditure of $500k is required to progress the project to Decision Gate 2 (DG2).

Given the market benefits derived from the additional capacity thus provided, and the estimated expenditure for the upgrade being below the RIT-T investment threshold, it is proposed that these works be funded as a NCIPAP project, for implementation by no later than year 2024/25.

Appendix A – Summary of Preferred Option

Project Description	**Uprating DNT 330-132kV Transformers**		
Option Description	**Option A – Upgrade the cooler banks and associated equipment**		
Project Summary			
Option Rank	1	Investment Assessment Period	25
Asset Life	13	NPV Year	2021/22
Economic Evaluation			
NPV @ Central Benefit Scenario (PV, $m)	45.0	Annualised CAPEX ($m)	0.5
NPV @ Lower Bound Scenario (PV, $m)	24.1	Network Safety Risk Reduction ($m)	N/A
NPV @ Higher Bound Scenario (PV, $m)	81.7	ALARP	N/A
NPV Weighted (PV, $m)	49.0	Optimal Timing	2024/25
Cost			
Direct Capex ($m)	4.0	Network and Corporate Overheads ($m)	0.4
Total Capex ($m)	4.4	Cost Capex (PV,$m)	3.8
Terminal Value ($m)	0.0	Terminal Value (PV,$m)	0.0