OPTIONS EVALUATION REPORT (OER)

Increase Capacity of 94T - DLR

OER- N2470 revision 1.0

Ellipse project no(s):
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Project category: Prescribed - NCIPAP

Approvals

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Change history

Revision	Date	Amendment
1	21 January 2021	Initial issue
2	11 October 2021	Updated as per the revised OFS and OER template

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Executive Summary

This proposal forms part of the Network Capability Incentive Parameter Action Plan (NCIPAP), for the 2023/24 to 2028/29 regulatory control period.

An opportunity has been identified to implement a Dynamic Line Rating (DLR) system on the 132kV transmission line 94T (Molong to Orange North) to optimise its thermal capacity depending on the prevailing weather conditions, and hence improve the transfer capability of this line in order to reduce the emerging constraints on low-cost renewable generation in the Central West area. The implementation of DLR as proposed in this document is expected to deliver economic benefits to the NEM before and after the implementation of the proposed major augmentation (N2162) on re-conducting the Line 94T. This is achieved by implementing the DLR system on the existing line 94T hence optimising the existing conductor thermal capacity whilst on completion of the re-conductor project, the DLR will continue optimising the upgraded conductor thermal capacity. Therefore, the two needs are to be considered complementary to each other.

The line 94T has a relatively low static thermal rating compared with other 132kV lines in the Central West subsystem. It is one of four 132 kV transmission lines which supply the Orange North switching station. Whilst the typical (static) rating for 132 kV transmission lines in the Central West is 134 MVA (summer daytime), Line 94T is currently rated at 112 MVA (summer daytime). The latest Essential Energy forecast for the Orange area projects a total peak demand of 224 MVA for summer 2021/22, which is expected to increase to approximately 250 MVA by summer 2030/31[1].

In addition, a number of new renewable generators have connected or are committed to connect to the supply network west of Molong 132/66 kV Substation. A number of solar farms with a total combined output of 170 MW are already in service, with a further 585 MW of generation in the “committed” stage of the connection application process, proposed to connect to TransGrid’s network. Further, an additional 155MW of embedded generation is committed to connect to the Essential Energy network.

The characteristics of the Central West transmission network are such that the primary direction of power flow is toward the load centre at Orange. As a consequence, the power flow direction in Line 94T is mostly from Molong Substation towards Orange North Switching Station. Due to the combined effect of the solar farms in the Central West 132kV subsystem and growing demand in Orange area very high flows are expected through the Line 94T at times of high renewable generation in the network west of Molong.

The constraint on Line 94T has already emerged into binding stage under system normal and a number of N-1 conditions and these constraints are impacting the NEM at times where Central West area has abundant solar irradiance[2]. The recent constraints reported by AEMO indicate that 94T is in the top 10 binding impact network constraint equations with a total marginal value of $717,454/MW/DI[3]. The recent generation data suggests that solar farms in Molong and Manildra have been constrained off to prevent overloading in Line 94T at a number of occasions[4].

The studies identified that with the current level of in-service and committed generation dispatched to their maximum capacities, thermal congestion of line 94T is expected to be exacerbated causing overloading up to 150% of the its normal rating under system normal network conditions Hence, the output of the renewable generators will need to be significantly constrained on regular basis to manage the loading level of 94T to contain it to below the normal (static) rating of the line. If a DLR system is implemented on Line 94T, the line rating can be optimised depending on the prevailing weather conditions, thereby reducing potential curtailment of low-cost renewable generation which would otherwise be constrained by the thermal limitation of the Line 94T. This would deliver market benefits from reducing constraints on dispatch of low-cost renewable generation from solar farms in the area as a consequence of taking advantage of the additional thermal capacity available for Line 94T.

[1] POE50 demand forecasts per Transmission Annual Planning Report (TAPR) 2021

[2] Transmission Constraints; Transgrid Transmission Annual Planning Report 2021

[3] AEMO Monthly constraint report August 2021; Marginal Value measured in $/MWDI; DI - Dispatch Intervals

[4] OPDMS generation data Aug 2021;

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This project is expected to meet the requirements of a NCIPAP project in terms of the level of capital expenditure required and the potential market benefits through network capacity increases.

Table 1: Evaluated options

Option	Description	Direct capital cost ($m)	Network and corporate overheads ($m)	Total capital cost[5] ($m)	Weighted NPV (PV, $m)	Rank
Option A	Implement dynamic line rating on the Line 94T	0.4	0.1	0.5	5.6	1

Preferred Option

As per Table 1, Option A, which is the only technically feasible option considered in the assessment delivers positive Net Present Values (NPV) compared to the Base Case. Hence option A has been selected as the preferred option for the identified opportunity.

Implementation of Option A allows optimised loading levels on Line 94T, and hence delivers economic (market) benefit from the provision of additional thermal capacity to facilitate the export of renewable generation from the Central West area into the wider network.

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 2023/24.

[5] 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.

1. Need/opportunity

There is an opportunity to improve the utilisation of TransGrid's 132 kV transmission line 94T from Molong to Orange North using Dynamic Line Rating (DLR) thereby improving the transfer capacity of the line to deliver market benefits as described below.

Static ratings are applied to all transmission lines in the TransGrid network and are typically determined based on the probabilistic nature of weather, line design and construction parameters and prevailing line loading conditions. The weather data used as the basis for determining the static ratings does not necessarily refer to the critical constraint spans of a transmission line, where conductor sagging and the requirement to maintain statutory ground clearance is typically the constraining issue.

In order to optimise the loading level of a given transmission line, DLR weather monitoring systems have been developed and installed on a number of transmission lines that are approaching loading limits under normal conditions, and/or where ratings may become a local network constraint under contingency conditions. The use of real-time localised data can obviate the need for applying conservative maximum line rating estimates which are typically based on assumptions and safety factors as opposed to actual loading and weather conditions. This approach can release additional network capacity in order to generate system and market benefits.

Figure 1 - Transmission network in Central West area

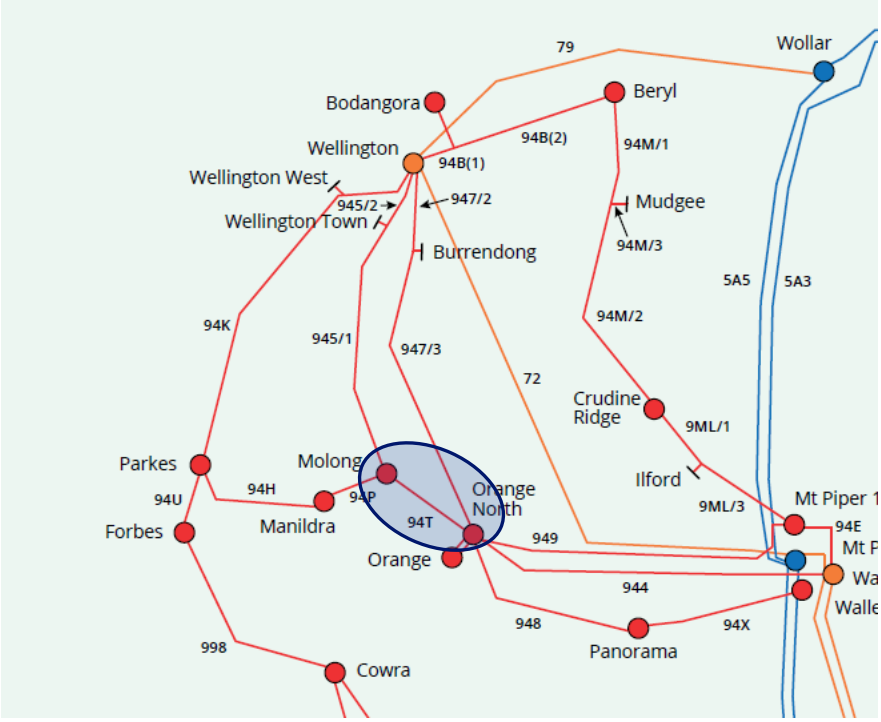

Figure 1 shows transmission network in the Central West subsystem. The 132kV transmission line 94T (Molong – Orange North) has a relatively low static thermal rating compared with other 132kV lines in the Central West subsystem. It is one of four 132 kV transmission lines which supply the Orange North switching station. Whilst the typical (static) rating for 132 kV transmission lines in the Central West is 134 MVA (summer daytime), Line 94T is currently rated at 112 MVA (summer daytime). The latest Essential Energy forecast for Orange area projects a total

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peak demand of 224 MVA for summer 2021/22, which is expected to increase approximately to 250 MVA by summer 2030/31[6].

In addition, a number of new renewable generators have connected or are committed to connect to the network west of Molong 132/66 kV Substation. A number of solar farms with a total combined output of 170 MW are already in service, with a further 585 MW of generation in the "committed" stage of the connection application process, proposed to connect to TransGrid's network. Further, an additional 155MW of embedded generation is committed to connect to the Essential Energy network.

The network configuration and the characteristics of the network in the Central West is such that the primary direction of power flow is toward the load centre at Orange. As a consequence, the power flow direction in Line 94T is generally from Molong Substation towards Orange North Switching Station. Due to the combined effect of the solar farms in the Central West 132kV subsystem and growing demand in Orange area, there will be very high flows through the Line 94T at times of high renewable generation in network west of Molong.

The thermal constraint associated with Line 94T has already emerged into binding stage under system normal and a number of N-1 conditions[7,8,9]. These constraints are impacting the NEM during the times where Central West area has abundant solar irradiance hence constraining off the low cost renewable generation. The recent constraints reported by AEMO indicate that 94T is in the top 10 binding impact network constraint equations with a total marginal value of $717,454/MW/DI[10].

[6] POE50 demand forecasts per Transmission Annual Planning Report (TAPR) 2021

[7] Transmission Constraints; Transgrid Transmission Annual Planning Report 2021

[8] N>>N-NIL_94T - Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil

[9] N>>N-NIL_94T_947 - Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Wellington to Orange North (947)

[10] AEMO Monthly constraint report August 2021; Marginal Value measured in $/MWDI; DI - Dispatch Intervals

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Figure 2 - Renewable generation in Central West area dispatched between 1-5 Aug 2021[11]

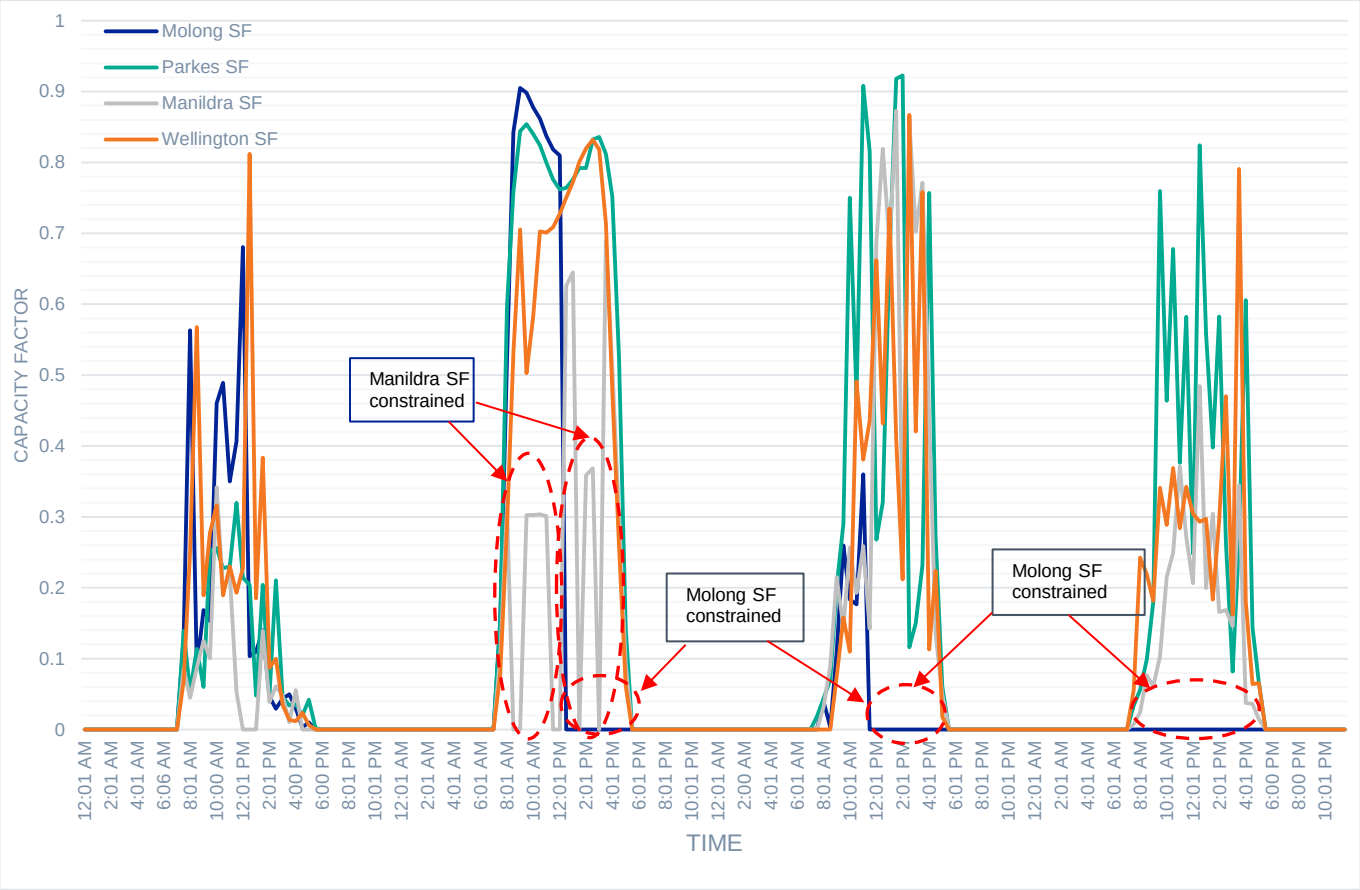

Figure 2 illustrates the generation dispatched from four different solar farms located within proximity in Central West area. The generation is plotted as a capacity factor with respect to the maximum capacity of each solar farm for a period of 4 days in August 2021. It is evident from Figure 2 that the Molong and Manildra solar farms, which have higher contribution factors to the overloading in Line 94T compared to the other solar farms in the area have been curtailed partially or fully on a regular basis during the time period considered.

The studies identified that with the current level of in-service and committed generation dispatched to their maximum capacities, thermal overloading of line 94T is expected to occur under system normal network conditions more often than is currently being experienced. The overloading could occur up to 150% of the normal rating (112MVA) of the Line 94T leading to further curtailment of the generation.

If the static ratings of the Line 94T are applied, the output of the renewable generators will need to be significantly constrained on regular basis to manage the loading level of 94T to below the normal (static) rating of the line.

If DLR is implemented on Line 94T, the line rating can be optimised depending on the prevailing weather conditions, thereby reducing potential curtailment of low cost renewable generation due to the thermal limitation of the Line 94T. This would deliver market benefits from reducing constraints on dispatch of low-cost solar farms as a consequence of taking advantage of the additional thermal capacity available for Line 94T.

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

[11] OPDMS Data for between 1/8/2021-4/8/2021

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2. Related needs/opportunities

> 2162 – Thermal limitation on Line 94T [12]

This Need has been raised to increase the thermal capacity of Line 94T as an augmentation project. The preferred option is to re-conductor the line 94T with a higher rated conductor on the existing structures. The target increased Summer Day rating of the proposed augmentation is 150MVA. The augmentation project requires larger capital investments than the low cost investment proposed in this document under N2470, and is proposed to be implemented in 2024/25.

Based on the projected renewable generation, it is anticipated that the loading level in Line 94T under system normal condition could exceed the target Summer Day rating of the new conductor in Need 2162[13]. Therefore, implementing the DLR system on the existing line 94T would optimise the existing conductor capacity and will continue optimising the upgraded conductor capacity after the re-conductor of the line occurs as per Need 2162. Hence, the DLR proposed in this document (OER N2470) is expected to deliver economic benefits both before and after the increase in thermal capacity, and so is independent of need 2162.

> 1579 – Dynamic Line Rating Monitoring Program

This Need has been raised to establish dynamic line rating system for a number of transmission lines in TransGrid's network and is in the process of being delivered by Infrastructure Delivery.

3. Options

3.1 Base case

The Base Case is the Do Nothing case. If the network is operated with the present configuration and as per current operating protocols, a significant amount of energy will need to be constrained at times of high-generation output from renewable generation in Central West area, the west of Molong, under system normal and outage conditions in order to manage the loading of the Line 94T below its normal static rating.

Hence, an opportunity exists to optimise the increase the thermal capacity of the Line 94T by implementing dynamic line rating based on the prevailing ambient temperature and the load projections. This will reduce the constraints on the low-cost renewable generation in the Central West area to deliver market benefits.

Benefit Calculation

Economic (market) benefits are expected to accrue from the provision of additional capacity using the DLR to increase the transfer capability of the Line 94T, thereby displacing higher-cost thermal generation. These have been assessed, below:

Assumptions:

> Extra capacity available on average = 4% to 20%[14]
> Expected use of extra capacity = 7 hrs a day 50% of the year [15]

[12] Option Evaluation Report 2162 (Increase capacity for generation in the Molong to Parkes area)_ Revision 0

[13] With the existing (in service) and the committed generators dispatched to their maximum capacity could result the power flow on Line 94T up to 165 MVA.

[14] This is a conservative assumption based on the historical DLRs calculated for lines with DLRs implemented and the extra capacity thereby made available, or from associated minor circuit equipment upgrades or c.t. ratio changes

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> Generation cost advantage of renewable generation compared to thermal generation[16] = $32.04/MWh

Pre Need 2162 augmentation:

Increase in thermal capacity due to DLR based on the present day rating = (4% to 20%) x 112MVA[17]
= 4.48 MVA to 22.4 MVA

Extra renewable generation capacity available in NEM = (4.48 to 22.4) x 7 x 0.5 x 365 MWh/year
= 5,723 to 28,616 MWh/year

Expected annual market benefit prior to the Need 2162 augmentation = $ (5,723 to 28,616) x 32.04
= $ 0.18 million to 0.92 million

Post Need 2162 augmentation:

The existing (in-service) and the committed generators dispatched to their maximum MW capacity may result in the power flow on Line 94T up to 165 MVA which is approximately 10% above the new thermal capacity (150 MVA per Need 2162).

Expected maximum annual market benefit post Need 2162 augmentation = 10% x 150 x 7 x 0.5 x 365 x 32.04
= $ 0.61 million

3.2 Options evaluated

Option A — Implement Dynamic Line Rating on Line 94T

This option involves implementation of a Dynamic Line Rating (DLR) system for the Line 94T from Molong to Orange North. The DLR system will utilise a number of weather stations installed along transmission line routes to determine a maximum line rating based on actual weather conditions, thereby reducing the amount of renewable energy curtailed.

The expected commissioning date for this option is 2023/24.

The expected expenditure profile for this option has been obtained using the TransGrid's Standard Estimating System and summarised in Table 2. The estimates in Table 2 have an uncertainty of ± 25%.

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

	Total Project Base Cost	2022/23	2023/24
Estimated Cost – non-escalated ($k 2020-21)	456k	13k	443k

[15] Based on expected solar generation considering solar and/or wind generation throughout the year.

[16] 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.

[17] Normal (static) rating of the Line 94T: 112 MVA

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The scope of work associated with this option includes:

- Identify appropriate locations to measure weather data (ambient temperature, wind speed, etc.) along the transmission line;
- Erect see-saw poles within existing line easements for the identified locations and install weather stations on these poles;
- Install weather stations on existing gantries within substations;
- Install communication links between weather stations and DLR HMI[18] server;
- Modify DLR HMI server software to calculate line ratings for the identified lines;
- Integrate new ratings in TransGrid's SCADA system;
- Transfer the ratings to AEMO via TransGrid SCADA system;
- Remove the terminal equipment limitation at Molong and Orange North.

Based on the assessment, a total of two weather stations along 94T and two weather stations at Molong and Orange North are to be installed for the implementation of DLR monitoring. Further it has been assumed that the existing weather stations at Molong / Orange North (for DLR – 945 / 947) can be utilised to perform the required DLR calculations.

It is estimated that an amount up to $150k is required to progress the project from DG1 to DG2, and this is included in the costs identified in Table 2 above. 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 if required.

It is not anticipated at this stage that the project will have a significant impact on the environment in accordance with Section 111 of the EP&A Act. This will be reviewed as the project develops but at this stage it is anticipated that a Part 5 assessment in the form of a Summary Environmental Report (SER) only will be required.

This project is expected to be completed in an estimated 21 months following the approval of DG1.

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	4.8%	7.37%	2.23%

[18] Human - Machine Interface

Extra capacity available in Line 94T prior to Need 2162 implementation[19]	12%	4%	20%
Extra capacity available in Line 94T post Need 2162 implantation[20]	6%	2%	10%
Fuel Cost[21]	100%	70%	130%
Capital cost	100%	125%	75%
Operating expenditure	100%	125%	75%
VCR	AER Latest VCR (escalated) 100%	70%	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 commercial evaluation

Parameter	Parameter Description	Value used for this evaluation
Discount year	Year that dollar values are discounted to	2020/21
Base year	The year that dollar value outputs are expressed in real terms	2020/21 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

[19] Low and High values are based on the historical DLRs data calculated for lines with DLRs implemented and the extra capacity thereby made available, or from associated minor circuit equipment upgrades or c.t. ratio changes; Central scenario assumes the average of High and Low scenario values.

[20] High value is estimated based on the expected maximum power flow levels with the existing and committed generation in the area and the indicative valued of the new thermal capacity after the proposed augmentation per Need 2162; Low value assumed a conservative limit of 2% whereas the Central value is the average of High and Low values.

[21] 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.

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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.

The commercial evaluation for the investment period 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	0.3	0.1	4.3	0.3	13.4	5.6	1

4.3 Preferred option

The Base Case, which is the “do nothing option” is the reference case, against which the benefits and costs of technically feasible options have been assessed.

Option A has been selected as the preferred option due to the following reasons:

- It provides sufficient market benefits that are greater than the investment cost, resulting positive Net Present Values for all three scenarios considered.
- It is the only technically feasible option.

The following scope of works has been included under the preferred Option:

Installation of DLR system on the 132kV Line 94T (Molong to Orange North). The DLR system will utilise a number of weather stations installed along transmission line route to determine a maximum line rating based on actual weather conditions, reducing the amount of renewable energy curtailed.

Capital and Operating Expenditure

The preferred option requires capital expenditure of $456k. 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 per Table 2 is less than the trigger threshold of $6 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 and optimises that economic benefits by implementing project prior to the implementation of the major augmentation works as proposed in Need 2162 . The commencement year is determined based on the following required project disbursement to the meet the commissioning year based on the OFS.

The results of optimal timing analysis is:

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- Optimal commissioning year: 2023/24
- Commissioning year annual benefit: $275k
- Annualised cost: $24k

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

6. Recommendation

It is recommended that implement the dynamic rating facilities on the Line 94T from Molong to Orange North substation (Option A) by installing the monitoring equipment, communication and other minor upgrades to the secondary system equipment as identified by the scope of works to facilitate an online monitoring and a DLR system on Line 94T.

The capital expenditure of $150k 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 2023/24.

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Appendix A – Option Summaries

Table 6: Summary of Option A

Project Description	**Increase Capacity of 94T - DLR**		
Option Description	Option A – Implement dynamic line rating facilities on the Line 94T (Molong to Orange North)		
Project Summary			
Option Rank	*1*	Investment Assessment Period	*25*
Asset Life	50	NPV Year	*2020/21*
Economic Evaluation			
NPV @ Central Benefit Scenario (PV, $m)	4.3	Annualised CAPEX ($m)	*0.02*
NPV @ Lower Bound Scenario (PV, $m)	0.3	Network Safety Risk Reduction ($m)	*N/A*
NPV @ Higher Bound Scenario (PV, $m)	13.4	ALARP	*N/A*
NPV Weighted (PV, $m)	5.6	Optimal Timing	*2023/24*
Cost			
Direct Capex ($m)	0.4	*Network and Corporate Overheads ($m)*	*0.1*
Total Capex ($m)	0.5	*Cost Capex (PV,$m)*	*0.3*
Terminal Value ($m)	0.3	Terminal Value (PV,$m)	*0.1*

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