OPTIONS EVALUATION REPORT (OER)

TL Silmalec Fitting Condition Phase 2

OER- 000000001590 revision 3.0

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Project reason: Capability - Asset Replacement for end of life condition
Project category: Prescribed - Asset Renewal Strategies

Approvals

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Change history

Revision	Date	Amendment
0	21 October 2016	Initial issue
1	8 December 2016	Update to format
2	17 January 2017	Minor change to recommendation
3	18 January 2017	Minor change to recommendation

1. Need/opportunity

Large diameter Silmalec single all aluminium alloy conductor has been installed on 330kV lines in the high altitude areas of the transmission lines connected to the Snowy Hydro scheme, in particular around Upper Tumut Switching Station (UTSS) and Lower Tumut Switching Station (LTSS). These lines were constructed between about 1957 and 1964 and play a critical role in the NEM transferring energy from Victoria/Snowy to NSW and connecting major hydroelectric generation.

In recent years, a number of issues have arisen around lines with Silmalec conductor, particularly with mid-span joints, conductor deadend fittings and vibration dampers:

- In 2003, a mid-span joint failed on 01 T/L in span 2-3 outside UTSS. Metallurgical examination of the failed fitting showed a fatigue failure, expected to have started from a compression of the joint tube adjacent to the end of one of the conductors, creating a shear crack that grew under tension to an eventual fatigue failure. In 2010, a mid-span joint failed on 01 T/L in span 38-39. Metallurgical examination of the failed fitting showed cracking that grew to an eventual fatigue failure.
- In 2015, a deadend failed on U7 T/L on Structure 1 in span 1-2. Metallurgical examination of the failed fitting showed points of stress and cracking which grew until there was an eventual fatigue failure. A further metallurgical examination of five other deadends removed from U7 following site dye penetrant testing showed that cracking they exhibited was due to stress corrosion cracking. The indication from these failures in this manner and the identification of some level of cracking on other deadends through dye penetrant is that these fittings may be reaching end of life. It is probable that bowing of the deadends (refer Attachment 1) during installation (due to difficulties associated with handling and terminating conductor of this larger size) has exacerbated the formation of cracks.
- Lines with Silmalec conductor are fitted with “Elgra” vibration dampers from the original construction. Manufactured in Sweden, these dampers consist of a number of weights resting on elastomer pads around a central rod suspended vertically. They have been discarded from service in Sweden and elsewhere because of excessive wear at the connecting rod joint. In low winds, conductors on these lines have been seen vibrating, indicating the industry findings these style of dampers are ineffective. These vibrations increase fatigue on the conductor and its associated fittings, shortening the expected life of the conductor and increasing its likelihood of failure and resultant conductor drop over time.

Transmission Line and Cables Asset Management has undertaken a review of all 330kV transmission lines installed with Silmalec conductors and identified a total of 451 original deadend fittings and 62 original mid-span joints that are potentially at risk of failure by this mode (cracking of the conductor fitting). A number of these lines, namely TL 65, 66 and the Upper Tumut Group (U1, U3, U5 and U7), have been identified as being generally strung at a higher tension (> 48kN), and are being addressed as a priority under Need 1290 (a total of 99 deadends and 57 mid-span joints). All “Elgra” vibration dampers on the aforementioned lines were also addressed under this Need.

The remaining deadends, mid-span joints and vibration dampers for lines generally strung at lower tensions (< 48kN) require rectification in the short – medium term (within the 2018-2023 Regulatory Control Period) to ensure that asset risk levels remain within an acceptable level in the longer term (a total of 352 deadends, 5 mid-span joints and vibration dampers on those lines).

2. Related Needs/opportunities

Pre-requisite

- Need 1290 – 330kV Silmalec Conductor Deadends and Mid-span Joints Phase 1

Related

- Need 1556 – TL Low Spans Stage 2
  - The project includes work on the same transmission lines and it may be possible to combine the works

Dependent

- There are no dependent Needs.

3. Options

All dollar values in this document are expressed in un-escalated 2016/17 dollars.

Base Case

A review of all 330kV transmission lines installed with Silmalec conductors identified a total of 352 original deadend fittings and 5 original mid-span joints on lines generally strung at lower tensions (< 48kN) potentially affected by cracking failure requiring remediation. In addition, all "Elgra" vibration dampers on these lines are to be replaced in conjunction with the conductor deadends and mid-span joints. A summary of these can be found in Need/Opportunity Statement (NOS) NS 1590.

Under a Base Case 'run-to-fail' option, the associated risk cost from the issues identified in Table 1 is $1.09m per annum. A breakdown of the Base Case risk cost by category is shown in Table 1.

Table 1 – Base Case risk cost by category ($ million)

Risk Category	Annual Risk Cost
Reliability (System)	0.01
Financial	0.37
Operational/Compliance	0
People (Safety)	0.03
Environment	0.68
Reputation	0
Total	**1.09**

It can be seen from Table 1 that the category with the highest risk cost is 'environment', mainly due to the significant consequences of a bushfire event resulting from conductor drop. The other considerable contributor to the overall risk cost is the 'financial' category due to the high repair costs and market impacts associated with failures of lines in this region.

Option A — Fitting Replacement [OFR 1590A, OFS 1590A]

This option involves the replacement of deadend fittings and mid-span joints on the remaining lower tension (< 48kN) spans. Replacement of "Elgra" vibration dampers along the Silmalec conductor is also required. The scope of this option is summarised in OFR 1590A Table 1.

It is estimated that the capital expenditure associated with the fitting replacement outlined in this option is $3.62m ±25%. Details can be found in Section 6 of Option Feasibility Study (OFS) OFS 1590A.

Following the refurbishment under this option, the risk cost associated with the remediated line is $0.02m per annum. A breakdown of the Option A risk cost by category is shown in Table 2.

Table 2 – Option A Base Case risk cost by category ($ million)

Risk Category	Annual Risk Cost
Reliability (System)	0
Financial	0.01
Operational/Compliance	0
People (Safety)	0
Environment	0.01
Reputation	0
Total	**0.02**

The total projected risk reduction as a result of implementing Option A is $1.08m per annum. It can be seen from Table 3 that the largest component of the reduction is in the 'environment' category, due to the reduced likelihood of conductor drop failure. Reductions are also expected in the 'financial' category.

Option B — Fitting Reinforcement [OFR 1590B, OFS 1590B]

This option involves the reinforcement of deadend fittings and mid-span joints using clamp style devices on the remaining lower tension (< 48kN) spans. Replacement of "Elgra" vibration dampers along the Silmalec conductor is also required. The scope of this option is summarised in OFR 1590B Table 1.

It is estimated that the capital expenditure associated with the fitting reinforcement outlined in this option is $3.33m ±25%. Details can be found in Section 6 of OFS 1590B.

Following the refurbishment under this option, the risk cost associated with the remediated line is expected to be the same as that under Option A at $0.02m per annum. The total projected risk reduction as a result of implementing Option B is $1.08m per annum.

Option C — Conductor and Fitting Replacement [OFR 1590C, OFS 1590C]

This option involves replacement of the Silmalec conductor along with all associated fittings and vibration dampers on the remaining lower tension (< 48kN) spans. The scope of this option is summarised in OFR 1590C Table 1.

It is estimated that the capital expenditure associated with the conductor and fitting replacement outlined in this option is $32.69m ±25%. Details can be found in Section 6 of OFS 1590C.

Following the refurbishment under this option, the risk cost associated with the remediated line is expected to be the same as that under Options A and B at $0.02m per annum. The total projected risk reduction as a result of implementing Option C is $1.08m per annum.

All of the options mentioned in Section 3 are considered to be technically feasible[1].

[1] An option is technically feasible if TransGrid reasonably considers that there is a high likelihood that the option, if developed, will provide the relevant service while complying with all relevant laws.

4. Evaluation

4.1 Commercial evaluation

The commercial evaluation of the technically feasible options is set out in Table 4. Details of the Net Present Value (NPV) calculations for Options A, B and C are provided in Attachment 1.

Table 3 — Commercial evaluation ($ million)

Option	Description	Total capex	Annual opex	Annual post project risk cost	Economic NPV @10%	Financial NPV @10%	Rank
Base Case	Run-to-fail	N/A	N/A	1.09	N/A	N/A	4
A	Fitting Replacement	3.62	-	0.02	4.61	4.53	2
B	Fitting Reinforcement	3.33	-	0.02	4.83	4.74	1
C	Conductor and Fitting Replacement	32.69	-	0.02	(17.74)	(17.82)	3

The commercial evaluation is based on:

> A 10% discount rate

> A life of the investment of 20 years and a corresponding residual/terminal value

Discount rate sensitivities based on TransGrid's current AER-determined pre-tax real regulatory Weighted Average Cost of Capital (WACC) of 6.75% and 13% appear in Table 5.

Table 4 — Discount rate sensitivities ($ million)

Option	Description	Economic NPV @13%	Economic NPV @6.75%
A	Fitting Replacement	3.10	7.08
B	Fitting Reinforcement	3.32	7.29
C	Conductor and Fitting Replacement	(17.50)	(17.36)

4.2 SFAIRP/ALARP evaluation

In the context of the Network Asset Risk Assessment Methodology, the SFAIRP (So Far As Is Reasonably Practicable)/ALARP (As Low As Reasonably Practical) principle is applicable to the following Key Hazardous Events:

> Conductor drop

Options to reduce the network safety risk as per the risk treatment hierarchy have been considered in other lifecycle stages of the asset, and it has been determined that no reasonably practicable options exist to reduce the risk further than those capital investment options listed in Table 6.

Evaluation of the proposed options has been completed against the SFAIRP (So Far As Is Reasonably Practicable)/ALARP (As Low As Reasonably Practical) obligation, as required by the Electricity Supply (Safety and

Network Management) Regulation 2014 and the Work Health and Safety Act 2011. The Key Hazardous Events and the disproportionality multipliers considered in the evaluation are as follows:

- Conductor drop – 6 times the environment (bushfire) risk, 6 times the safety risk and 10% of the reliability risk (applicable to safety)

Table 5 – Feasible options ($ thousand)

Option	Description	CAPEX	Expected Life	Annualised CAPEX
Base	Run-to-fail	N/A	N/A	N/A
A	Fitting Replacement	3,619	20 years	181
B	Fitting Reinforcement	3,332	20 years	167
C	Conductor and Fitting Replacement	32,688	20 years	1,634

Table 6 – Annual risk calculations ($ thousand)

Option	Annual Residual Risk			Annual Risk Savings		
	Safety Risk	Reliability Risk	Bushfire Risk	Safety Risk	Reliability Risk	Bushfire Risk
Base	31	12	675	N/A	N/A	N/A
A	0	0	9	31	12	666
B	0	0	9	31	12	666
C	0	0	9	31	12	666

Table 7 – Reasonably practicable test ($ thousand)

Option	Network Safety Risk Reduction[2]	Annualised CAPEX	Reasonably practicable[3]?
A	4,186	181	Yes
B	4,186	167	Yes
C	4,186	1,634	Yes

From the above evaluation, it is considered that all three options A, B and C are reasonably practicable.

4.3 Preferred option

From the SFAIRP/ALARP evaluation, it is considered that all three options are reasonably practicable and are expected to provide the same level of network safety risk reduction. In order to satisfy the organisation's SFAIRP/ALARP obligations, one of these options, or a combination of them, is required to be undertaken. Of the three options, both Options A and B are both commercially viable with similar NPVs (as per the commercial evaluation), and are preferred. It is proposed that both these options be scoped in further detail to assess their feasibility, particularly around site specific constructability issues, before one option, or a combination of the two, is

[2] The Network Safety Risk Reduction is calculated as 6 x Bushfire Risk Reduction + 6 x Safety Risk Reduction + 0.1 x Reliability Risk Reduction

[3] Reasonably practicable is defined as whether the annualised CAPEX is less than the Network Safety Risk Reduction

selected to be undertaken. Due to the uncertainty surrounding the final remediation, Option A is TransGrid's preferred option for the possibility that its higher capital expenditure may be required.

Capital and operating expenditure

The estimated capital expenditure associated with Option A is $3.62m ±25%. The estimated capital expenditure associated with Option B is $3.33m ±25%. The estimated capital expenditure associated with Option C is $32.69m ±25%. In all three instances, the vast majority of this expenditure is proposed to be carried out in 2022-2023.

It is expected that should works not occur by the Need date, under both Options A and B, an increase in corrective maintenance and subsequent operating expenditure will result.

Regulatory Investment Test

No Regulatory Investment Test for Transmission (RIT-T) analysis is required as the works are condition based.

5. Recommendation

Under both the ALARP evaluation and the commercial and technical evaluation of the available options, both Options A and B are reasonably practicable and commercially viable. It is recommended that detailed scoping for fittings replacement under Option A and fittings reinforcement under Option B be undertaken. The replacement of fittings is presently preferred over the reinforcement solution as the reinforcement option is yet to be confirmed as a feasible solution. Reinforcement concepts have been developed and assessed, however, due to the non-standard large size of the conductor a reinforcement solution is not commercially available. Due to the uncertainty of the preferred solution, along with further development of the reinforcement solution, it is recommended that a site specific constructability assessment is undertaken for each location to determine the most feasible and cost effective solution at each location.

Option A NPV calculation

Project_Option Name	Silmalec Stage 2 Option A - Fitting Replacement

1. Financial Evaluation (excludes VCR benefits)				
NPV @ standard discount rate	10.00%	$4.53m	*NPV / Capital (Ratio)*	*1.25*
NPV @ upper bound rate	13.00%	$3.04m	*Pay Back Period (Yrs)*	*0.29 Yrs*
NPV @ lower bound rate (WACC)	6.75%	$6.97m	*IRR%*	*29.15%*

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%	$4.61m	*NPV / Capital (Ratio)*	*-2.30*
NPV @ upper bound rate	13.00%	$3.10m	*Pay Back Period (Yrs)*	*3.36 Yrs*
NPV @ lower bound rate (WACC)	6.75%	$7.08m	*IRR%*	*29.48%*

Benefits					
Risk cost	As Is	To Be	Benefit	*VCR Benefit*	*$0.01m*
Systems (reliability)	*$0.01m*	*$0.00m*	*$0.01m*	*ENS Penalty*	*$0.00m*
Financial	*$0.37m*	*$0.01m*	*$0.37m*	*All other risk benefits*	*$1.07m*
Operational/compliance	*$0.00m*	*$0.00m*	*$0.00m*	Total Risk benefits	$1.08m
People (safety)	*$0.03m*	*$0.00m*	*$0.03m*		
Environment	*$0.68m*	*$0.01m*	*$0.67m*	Benefits in the financial NPV*	$1.07m
Reputation	*$0.00m*	*$0.00m*	*$0.00m*	**excludes VCR benefits*	
Total Risk benefits	$1.09m	$0.01m	$1.08m		
Cost savings and other benefits			$0.00m	Benefits in the economic NPV**	$1.08m
Total Benefits			$1.08m	***excludes ENS penalty*	

Other Financial Drivers			
Incremental opex cost pa (no depreciation)	$0.00m	Write-off cost	$0.00m
Capital - initial $m	-$3.62m	Major Asset Life (Yrs)	20.00 Yrs
Residual Value - initial investment	$0.18m	Re-investment capital	$0.00m
Capitalisation period	2.00 Yrs	Start of the re-investment period	0.00 Yrs

Option B NPV calculation

Project_Option Name	Silmalec Stage 2 Option B - Fitting Reinforcement

1. Financial Evaluation (excludes VCR benefits)				
NPV @ standard discount rate	10.00%	$4.74m	*NPV / Capital (Ratio)*	*1.42*
NPV @ upper bound rate	13.00%	$3.25m	*Pay Back Period (Yrs)*	*0.32 Yrs*
NPV @ lower bound rate (WACC)	6.75%	$7.18m	*IRR%*	*31.75%*

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%	$4.83m	*NPV / Capital (Ratio)*	*-2.41*
NPV @ upper bound rate	13.00%	$3.32m	*Pay Back Period (Yrs)*	*3.09 Yrs*
NPV @ lower bound rate (WACC)	6.75%	$7.29m	*IRR%*	*32.11%*

Benefits					
Risk cost	As Is	To Be	Benefit	*VCR Benefit*	*$0.01m*
Systems (reliability)	*$0.01m*	*$0.00m*	*$0.01m*	*ENS Penalty*	*$0.00m*
Financial	*$0.37m*	*$0.01m*	*$0.37m*	*All other risk benefits*	*$1.07m*
Operational/compliance	*$0.00m*	*$0.00m*	*$0.00m*	Total Risk benefits	$1.08m
People (safety)	*$0.03m*	*$0.00m*	*$0.03m*		
Environment	*$0.68m*	*$0.01m*	*$0.67m*	Benefits in the financial NPV*	$1.07m
Reputation	*$0.00m*	*$0.00m*	*$0.00m*	**excludes VCR benefits*	
Total Risk benefits	$1.09m	$0.01m	$1.08m		
Cost savings and other benefits			$0.00m	Benefits in the economic NPV**	$1.08m
Total Benefits			$1.08m	***excludes ENS penalty*	

Other Financial Drivers			
Incremental opex cost pa (no depreciation)	$0.00m	Write-off cost	$0.00m
Capital - initial $m	-$3.33m	Major Asset Life (Yrs)	20.00 Yrs
Residual Value - initial investment	$0.00m	Re-investment capital	$0.00m
Capitalisation period	2.00 Yrs	Start of the re-investment period	0.00 Yrs

Option C NPV calculation

Project_Option Name	Silmalec Stage 2 Option C - Conductor and Fitting Replacement

1. Financial Evaluation (excludes VCR benefits)				
NPV @ standard discount rate	10.00%	-$17.82m	*NPV / Capital (Ratio)*	*-0.55*
NPV @ upper bound rate	13.00%	-$17.56m	*Pay Back Period (Yrs)*	*-0.04 Yrs*
NPV @ lower bound rate (WACC)	6.75%	-$17.46m	*IRR%*	*-3.76%*

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%	-$17.74m	*NPV / Capital (Ratio)*	*5.91*
NPV @ upper bound rate	13.00%	-$17.50m	*Pay Back Period (Yrs)*	*Not measurable*
NPV @ lower bound rate (WACC)	6.75%	-$17.36m	*IRR%*	*-3.67%*

Benefits					
Risk cost	As Is	To Be	Benefit	*VCR Benefit*	*$0.01m*
Systems (reliability)	*$0.01m*	*$0.00m*	*$0.01m*	*ENS Penalty*	*$0.00m*
Financial	*$0.37m*	*$0.01m*	*$0.37m*	*All other risk benefits*	*$1.07m*
Operational/compliance	*$0.00m*	*$0.00m*	*$0.00m*	Total Risk benefits	$1.08m
People (safety)	*$0.03m*	*$0.00m*	*$0.03m*		
Environment	*$0.68m*	*$0.01m*	*$0.67m*	Benefits in the financial NPV*	$1.07m
Reputation	*$0.00m*	*$0.00m*	*$0.00m*	**excludes VCR benefits*	
Total Risk benefits	$1.09m	$0.01m	$1.08m		
Cost savings and other benefits			$0.00m	Benefits in the economic NPV**	$1.08m
Total Benefits			$1.08m	***excludes ENS penalty*	

Other Financial Drivers			
Incremental opex cost pa (no depreciation)	$0.00m	Write-off cost	$0.00m
Capital - initial $m	-$32.69m	Major Asset Life (Yrs)	20.00 Yrs
Residual Value - initial investment	$0.00m	Re-investment capital	$0.00m
Capitalisation period	3.00 Yrs	Start of the re-investment period	0.00 Yrs