HV OVERHEAD SWITCHGEAR AIR BREAK SWITCH FAILURE RISK MITIGATION

Case for investment FY25
March 2022

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1. Executive summary

This case for investment (CFI) recommends both the proactive and reactive strategies for overhead 11kV and 22kV distribution Air Break Switches (ABS's) within the FY25-FY29 period to address the safety, reliability, and bushfire risks associated with this equipment failing in service.

Endeavour has approximately 8,400 ABS's in service operating at 11kV and 22kV in the distribution network. ABS's allow isolation and segmentation of the network for the purpose of providing access to parts of the network to carry-out asset maintenance and repairs.

ABS's are categorised into two switch types, general population (7,400) and problematic (1,000). Problematic type switches were identified during a reliability centred maintenance (RCM) analysis and include three ABS models which exhibit higher potential consequence outcomes upon failure. These problematic switches receive additional maintenance.

The possible consequences of failure for the general and problematic ABS's include the following, noting that problematic ABS's have increased chance of failure:

- Safety impacts: ABS's are typically installed on the top of a pole approximately 8 meters above ground level. As the supporting porcelain insulators deteriorate and crack over time, the insulator may fall to the ground under its own weight or become dislodged due to the physical force of operating the switch. This represents a safety risk to operators of the switch which has been detailed in Hazard Alert 08-14. Furthermore, cracks in the supporting insulators may allow current to flow down the operating rod or the pole posing a safety risk resulting in electric shock.
- Reliability impacts: broken, cracked, or fallen insulators as well as misaligned or jammed contacts can create loss of supply on overhead HV feeders and to any downstream customers. HV feeder supply is affected from ABS failures and subsequently while the network is re-configured to isolate and sectionalise the switchgear.
- Bushfire impacts: arcing of live contacts and insulation failures may create sparks and initiate a bushfire.
- No significant environmental or regulatory compliance consequences have been experienced or are anticipated for future failures of an ABS.

Due to the substantial load that each switch carries on a continual basis and its functionality (e.g. a network isolation / switching device), there are no credible non-network solutions which could replace their functionality and therefore network options should be considered to address the identified need.

Repair and refurbishment of ABS's are currently carried out as part of Endeavour Energy typical business as usual (BAU) approach. This CFI considers the following network intervention options for addressing the failure risk of ABS's in a proactive planned manner:

- Lockout of the ABS: If it is assessed that the functionality of a retired switch is no longer required, then it is locked out and removed from service.
- Replacement of the ABS: If it is assessed that the functionality of a retired switch is still required, then it is replaced by either a new ABS or with an enclosed load break switch. The enclosed load break switch may also be connected to the SCADA network for remote and/or automated operation.

ABS's are identified for proactive retirement at the time when the net present value of the intervention reaches its maximum value. Where this occurs in the period of FY25 – FY29, the retirements have been included in this program. As a result, it is proposed that 819 ABS retirements are carried out during FY25 – FY29. Based on the application of MDI0026 [1], historical replacement trends indicate 574 (70%) of these are expected to be replaced and 245 (30%) are expected to be removed from service as they would no longer be required in the network.

The net present value (NPV) of the proposed replacement option is unique to each ABS and varies from $1,901 to $257,768 with an average of $39,599 across the 819 assets for intervention during the period as proposed. The total NPV of the proposed program is $18.03 million.

The benefit to cost ratio (BCR) for each ABS varies from 1.1 to 15.2 and averages 3.3 across the 819 ABS's proposed.

The total cost for the estimated 574 ABS's is forecast to be $10.63 million (in real FY23 terms), and it is recommended that the program be approved for consideration in the FY25 Portfolio Investment Plan (PIP) for optimisation.

A further 530 ABS's are NPV positive and provide their maximum NPV across the second half of the 10-year investment period (FY30-FY34 period) and are also put forward for optimisation. Based on the application of MDI 0026, 371 (70%) of these are expected to be replaced and 159 (30%) are expected to be removed from service as they would no longer be required in the network. These 371 replacements total a further $6.88 million (in real FY23 terms) giving a total investment for optimisation of $17.51 million.

There are a further 2,177 switches that are NPV positive but do not achieve NPV maximum prior to the conclusion of the investment period (FY34) at the time of completing this assessment. Based on the application of MDI 0026, 1,523 (70%) of these are expected to be replaced and 652 (30%) are expected to be removed from service as they would no longer be required in the network. These 1,523 have an estimated replacement value of $28.22 million (in real FY23 terms). However, these assets have not been considered within this CFI for optimisation.

This recommendation is made on the basis that the preferred solution represents the highest economic value (economic benefit) compared to other credible network and non-network options.

The project cost of the credible options fall below the threshold for application of the Regulatory Investment Test for Distribution (RIT-D) (currently $6.0 million) and therefore the RIT-D is not applicable to this program.

In addition, reactive modelling for the FY25 – FY29 period has forecast a further 340 ABS's to reach a state of functional or conditional failure (e.g. found to be in a poor condition indicative of imminent failure and/or no longer capable of performing its function). Based on the application of MDI 0026, 238 (70%) are expected to be replaced and 102 (30%) are expected to be removed from service. To accommodate this eventuality, it is proposed that additional funding of $3.66 million (in real FY23) terms be made available for reactive ABS replacement during the FY25 – FY29 period. It is to be noted that the ABS's proposed for proactive retirement as part of this CFI have been excluded from the reactive modelling across this period.

2. Purpose

The purpose of this document is to seek endorsement of the case for investment (CFI) for managing the risks posed by aged ABS's throughout the distribution network.

This case for investment (CFI) recommends the proactive intervention of the identified ABS's during the FY25 – FY29 period and provision of additional capital for the reactive retirement of ABS's that may functionally or conditionally fail unexpectedly during the period.

3. Identified needs and/or opportunities

3.1 Background

Endeavour has approximately 8,400 ABS's in service operating at 11kV and 22kV in the distribution network. ABS's allow isolation and segmentation of the network for the purpose of providing targeted access on other parts of the network to carry-out, asset maintenance and repairs.

ABS's are categorised into two switch types, general population (7,400) and problematic (1,000). Problematic type switches were identified during a reliability centred maintenance (RCM) analysis [2] and include three ABS models which exhibit higher potential consequence outcomes upon failure.

The switch mechanism is mounted either on the top of the pole or side mounted and is operated manually using a handle near ground level and connecting rod up to the switch, or by using an extendible link stick to operating levers located mid-way up the pole. The majority of ABS's use porcelain insulators, however in the late 2000's polymeric insulator ABS's became available and supply for these types were prioritised over the porcelain counterpart.

The most recent ongoing program is the DS405 – ABS replacement program for the replacement of defective ABS's which was initiated in FY05.

3.2 Risks and identified need

In 2014, an RCM analysis identified failure modes in these three particular types of ABS's which lead to increased safety and network risks. The failure modes identified are caused by poor insulator design and present an increased probability of failure compared to the general population of ABS's.

These three types of switches have been the focus of previous proactive replacement programs and are referred to as "problematic type ABS's". Due to the additional failure modes apparent with problematic type ABS's, they have been assigned different probability of failure characteristics in comparison to the general population. In addition, these problematic switches receive additional maintenance.

The possible consequences of failure for both general and problematic ABS's include the following, noting that problematic ABS's have increased chance of failure:

- Safety impacts: ABS's are typically installed on the top of a pole approximately 8 meters above ground level. As the supporting porcelain insulators deteriorate and crack over time, the insulator may fall to the ground under its own weight or become dislodged due to the physical force of operating the switch. This represents a safety risk to operators of the switch which has been detailed in Hazard Alert 08-14. Furthermore, cracks in the supporting insulators may allow current to flow down the operating rod or the pole posing a safety risk resulting in electric shock.
- Reliability impacts: broken, cracked, or fallen insulators as well as misaligned or jammed contacts can create loss of supply on overhead HV feeders and to any downstream customers. HV feeder supply is affected from ABS failures and subsequently while the network is re-configured to isolate and sectionalise the switchgear.
- Bushfire impacts: arcing of live contacts and insulation failures may create sparks and initiate a bushfire.
- No significant environmental or regulatory compliance consequences have been experienced or are anticipated for future failures of an ABS.

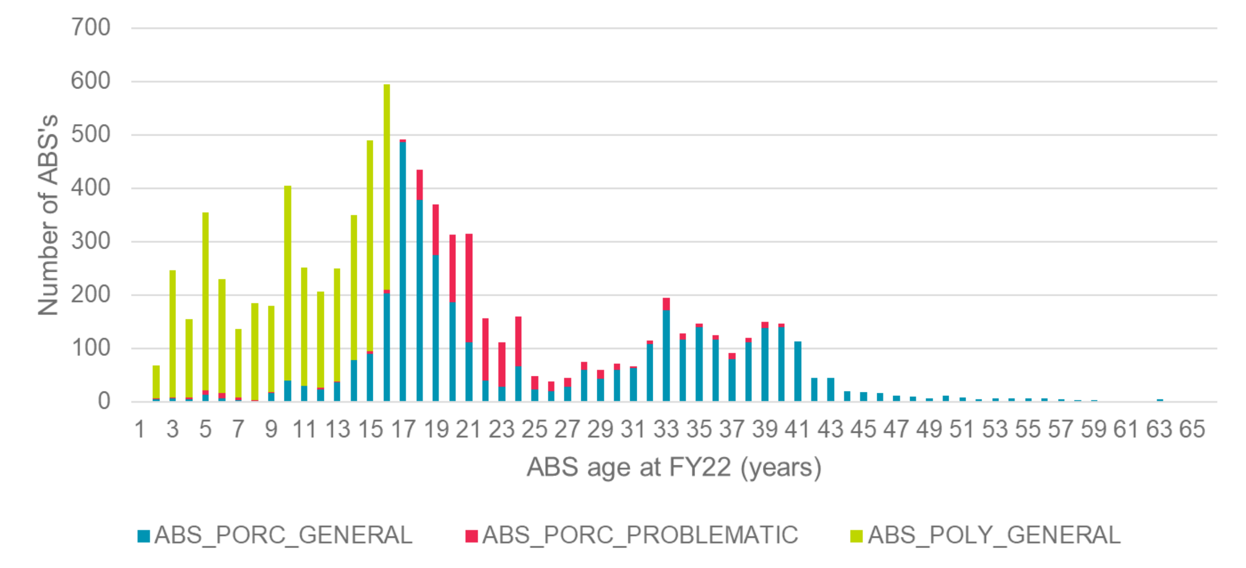
From FY13 onwards Endeavour Energy has experienced on average 29 unassisted functional failures of ABS's per year due to defective equipment and aging condition. As this asset class continues to age it is expected that with no intervention this level of failure will continue to increase over time.

Refer Appendix B for further detail of the assessed risk measures.

3.3 Asset age profile

The age profile of the fleet of 8,400 ABS's is shown in Figure 1 below.

Figure 1 – Age profile (from date of commissioning) for the fleet of ABS's



4. Consequence of nil intervention

4.1 Consequences of nil capital intervention

The nil intervention case involves not carrying out any capital works meaning ABS's would be operated until they failed and then removed from service rather than replaced. This includes the following course of action.

- Continue time-based maintenance where applicable and carry out repairs where possible after minor failures.
- Nil replacement of the ABS units after non-repairable/destructive failures.
- Switch is made safe and locked out, effectively removed from operation on the network.

The consequences of this would include:

- The consequences of failure for each ABS as noted in Section 3.2.
- Non-repairable failures lead to extended loss of supply while alternate arrangements are made.
- Misalignment to the network guidelines as outlined in MDI 0026.
- Loss of redundancy of neighbouring supplies and loss of network flexibility which will lead to extended customer outages during planned and unplanned work.

On this basis, the reactive retirement of ABS's which fail will be undertaken, subject to an assessment of the ongoing need for the asset, and the nil intervention case will not be considered further in this CFI.

4.2 Counterfactual (business as usual)

The business as usual (BAU) "counterfactual" scenario for ABS's includes operating the ABS until it fails and then assessing for their need for removal from service or replacement where its assigned service is maintained. Nil proactive capital intervention is carried out.

The scope of works under the BAU include:

- Maintenance including major overhaul of problematic type ABS's every 4-8 years and repairs of minor damage (limited repairs due to spare parts no longer being available).
- Reactive replacement after failure.

Currently, "failure" refers to the inability of the ABS to perform its required function as a consequence of the condition of the asset:

- Failures disruptive to the supply of electricity.
- Catastrophic failures of equipment or subcomponents such as the insulators or contacts.
- Failure of the switchgear to operate (or be operated) when required.
- Failure of the switchgear to perform its rated duty.

Conditional failures are units which are deemed defective as per MMI 0002 [3]. These could include broken or misaligned arcing horns, misaligned contacts, damaged bonds, and damaged/cracked insulators. These are typically scheduled for retirement with the appropriate intervention option selected in accordance with MDI0026 [1].

For this assessment, only costs that have occurred due to a functional failure has been considered. A summary of the risk presented by the counterfactual case is shown in Table 1 and below. All costs are in real FY23 terms and are present values (PV).

Table 1 – BAU risk cost summary

Risk category	PV of residual risk ($M)	Risk proportion (%)
Bushfire	15	7
Safety	27	13
Reliability	132	64
Reactive Replacement	34	16
Total	**208**	**100**

As noted in Table 1 above, the residual risk presented by the BAU case totals $208 million. The residual risk value presented by each ABS ranges from $2,244 to $423,408 and averages $24,698.

The higher risk values indicate the need for the higher risk ABS's to be retired to mitigate the risk. Options for intervention should be considered to provide for the continuity of service required of these ABS's.

5. Options considered

5.1 Risk treatment options

A range of options have been considered to address the risk presented by the ABS being assessed as an alternative to network investment. These approaches are summarised in Table 2 below.

Table 2 – ABS risk treatment options

Option	Assessment of effectiveness	Conclusion
Additional maintenance to extend the life of the existing asset	A maintenance program, which was initially introduced in 2005, has had negligible effect on the defect rate for ABS's. Since 2015 maintenance of general population ABS's was ceased whereas maintenance on problematic ABS's continued [2]. However, given that the primary causes of failure are age related or problematic insulator design (both of which cannot be adequately addressed with maintenance), re-introducing maintenance on the general population or funding additional maintenance on the problematic population will not be effective in managing risk.	No technically feasible solution in isolation
Reduce the load on the asset through network reconfiguration, network automation, demand management or other non-network options	The risk of failure is independent of load. A minor reduction in the consequences of failure could be achieved by transferring load from any of the distribution substations. ABS's facilitate flexibility in switching of the overhead distribution network to minimise the extent of customer outages and the duration of outages during planned and unplanned works on the network and limit the extent of outages after faults. Further, there are no practicable non-network solutions for replacing the function of ABS's.	No technically feasible solution
Implementing operational controls such as limiting access, remote switching protocols etc	Operating controls are already in place for the operation of all ABS's. These controls are in place to limit the safety risks presented by this equipment to workers, but the principal risk that drives the need for intervention is reliability, which is not affected by practicable controls.	Controls only the safety risk elements for workers
Staged retirement to maintain option value and reduce the consumer's long-term service cost	Replacement or removal of service of ABS's.	Recommended approach for further consideration.

5.2 Non-network options

Due to the substantial load that each switch carries on a continual basis and the asset's primary functionality being to isolate / switch the network, there are no credible non-network solutions which could replace their functionality and therefore network options have been considered to address the identified need.

5.3 Credible network options

When an ABS is identified for retirement, Endeavour Energy Mains Design instruction MDI 0026 [1] provides instructions for the minimum isolations requirements and sets out in detail both the location and the type of isolation points to be installed overhead 11kV and 22kV distribution network and resolves whether a switch can be:

- Lockout of the ABS: If it is assessed that the functionality of a retired switch is no longer required, then it is locked out and removed from service.
- Replacement of the ABS: If it is assessed that the functionality of a retired switch is still required, then it is replaced by either a new ABS or with an enclosed load break switch. The enclosed load break switch may also be connected to the SCADA network for remote and/or automated operation.

Historical trends indicate that 70% of switches identified for retirement require replacement with a new switch and 30% will be locked out and effectively removed from service on the network.

Table 3 – Credible network options considered for ABS's

Option	Description	Conclusion
Proactive ABS replacement	As per MDI 0026 [1], ABS intervention options are determined at time of retirement. If the switch is found to be still required, the intervention options include: • Like-for-like replacement with a polymeric ABS. • Replaced with an enclosed SF6 load break switch (LBS). • Replaced with an enclosed SF6 load break switch which is also connected to the SCADA network for remote and/or automated operation (ALBS).	Credible option considered and has progressed for further assessment.

Replacement of ABS units based on condition is considered a credible network option.

5.3.1 ABS replacement

Under this option, the intervention includes an assessment of the need for the service level of the ABS and if deemed required, the complete replacement of the ABS unit in a proactive manner.

A value of $18,100 (in real FY22 terms) for replacement of the ABS has been assumed for this assessment. This value is calculated as the weighted average unit rate based on historical replacements of ABS's between FY20-FY22 where the replacement type has been either a similar polymer type ABS, SF6 load-break switch (LBS) or a load-break switch connected to the SCADA network (ALBS).

5.4 Economic evaluation

5.4.1 Option 1 – ABS replacement

This option identifies 819 ABS's whose NPV at time of proposed intervention is positive and reaches a maximum value during the FY25 – FY29 period. This option presents a residual risk of $180 million and provides a benefit of $28.04 million compared to the counterfactual case. The PV of the cost of the option is $10.01 million and the NPV overall is $18.03 million.

Table 4 below provides a summary of the residual risk presented by this option. Refer Appendix A for details of the ABS's identified for retirement during the FY25 – FY29 period under this option.

Table 4 – Option 1 residual risk summary

Risk category	PV of residual risk ($M)	Risk proportion (%)
Bushfire	13	7
Safety	24	13
Reliability	114	64
Reactive Replacement	29	16
Total	**180**	**100**

5.5 Evaluation summary

Table 5 below summarises the outcomes of the cost-benefit assessment for the ABS replacement options relative to the BAU case. The summary shows only the impact of investment of ABS's with positive maximum NPV within the FY25 - FY29 period.

Table 5 – Option economic evaluation summary

Option	Option type	Volume of inter-ventions	Residual risk ($M)	PV of benefits ($M)	PV of investment ($M)	NPV ($M)	Rank	Comments
BAU	Counter-factual	-	208	-	-	-	2	BAU
Replace ABS	Network	819	180	28.04	10.01	18.03	1	Preferred option

As shown in Table 5, ABS retirement provides a positive NPV overall and will deliver the highest overall value and is therefore the preferred option.

5.6 Economic evaluation assumptions

There are a wide range of assumptions of risk, their likelihoods, and consequences which support the cost benefit assessment associated with this project. Refer to Appendix B for details of these assumptions.

5.7 Scenario assessment

A scenario assessment has been carried out on the various elements of the risk and cost assumptions used in the economic analysis in order to test the robustness of the evaluation.

Three scenarios have been assessed:

- Scenario 1 – discourages investment with low benefits and high capital costs;
- Scenario 2 – represents the most likely central case based on estimated or established values;
- Scenario 3 – encourages investment with the high benefits with low capital costs.

The values for each of the variables used for each scenario are shown in Table 6 below.

Table 6 – Summary of scenarios investigated

Variable	Scenario 1 – low benefits, high capital costs	Scenario 2 – central values	Scenario 3 – high benefits, low capital costs
Capital cost	5% increase in the estimated network capital costs	Estimated network capital costs	5% decrease in the estimated network capital costs
Value of risk (combination of consequence of the failure risk and the likelihood of the consequence eventuating)	10% decrease in the estimated risk and benefit values	Estimated risk values	10% increase in the estimated risk and benefit values
Weibull distribution end-of-life failure characteristic	5% increase in the Weibull Scale parameter (increases the mean time to failure for the asset)	Estimated Weibull parameters based on available failure data and calibrated to observed failure rates	5% decrease in the Weibull Scale parameter (decreases the mean time to failure for the asset)

The impact on the preferred option (Option 1) NPV is shown in Table 7 below and the resultant spread of replacement years to give the maximum NPV for each of the 819 ABS's identified for replacement under the preferred option is shown in Figure 2.

Table 7 – NPV of scenario analysis for the preferred option (Option 1)

Scenario	NPV of preferred option ($M)
Scenario 1 – Low benefits, high costs	10.55
Scenario 2 – Central risks and costs	18.03
Scenario 3 – High benefits, low costs	28.30
Average	**18.96**

Each scenario reduces the risks posed by the 819 ABS's with an average NPV of $18.96 million across the three scenarios analysed.

Figure 2 – Option 1: maximum NPV replacement years for the three sensitivity scenarios

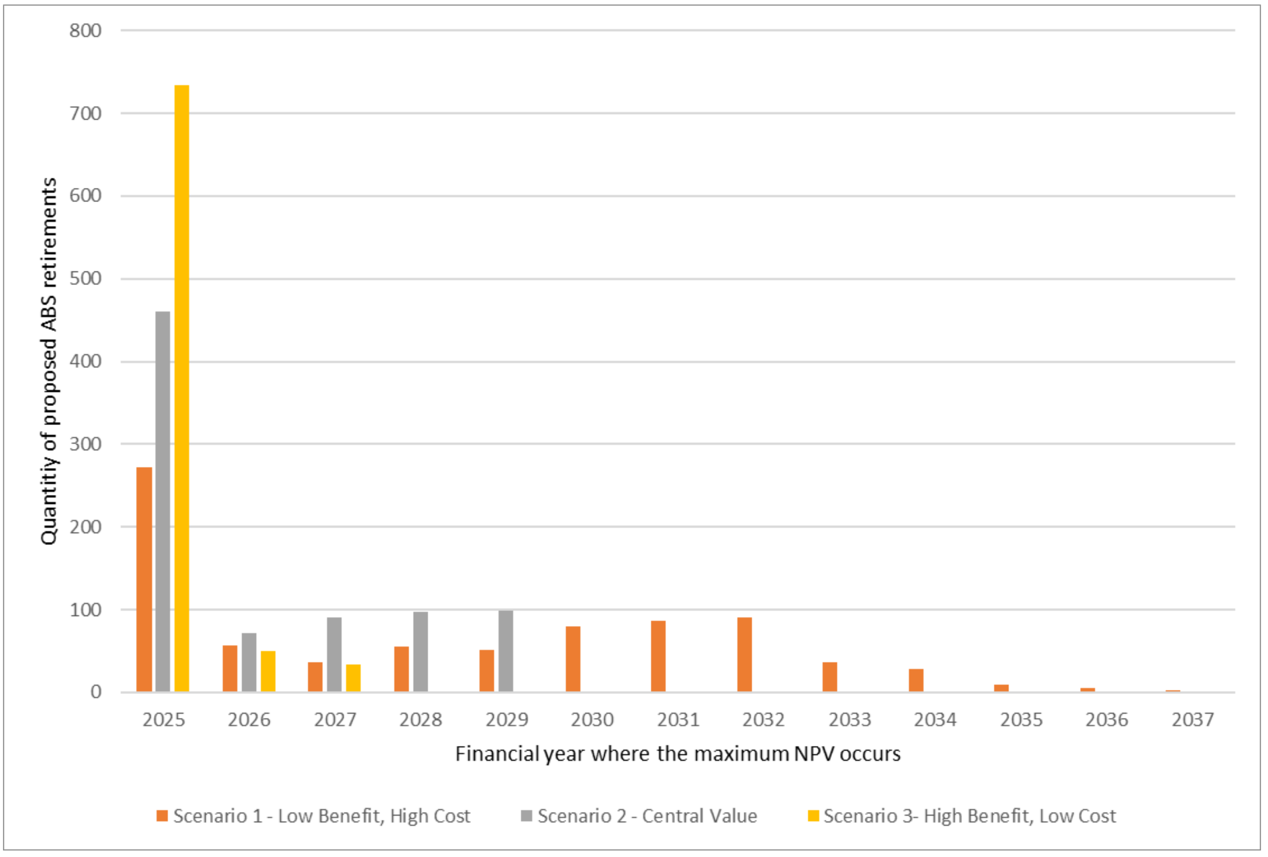


Figure 2 shows that across the three sensitivity scenarios, the timing of the maximum NPV of the recommended 819 replacements are skewed towards FY25.

All high benefit, low-cost replacement cases fall within FY25 to FY27, while the low benefit, high-cost cases are spread across FY25 – FY37. However, 98% of these occur prior to FY34.

This assessment show all of Scenario 2 and 3 where the maximum NPV occurs within the FY25 – FY29 investment period. In addition, a significant proportion of Scenario 1 cases also land within in this same timeframe suggesting an appropriate level of investment for Option 1.

6. Preferred option details

6.1 FY25 – FY29 scope and timing

The preferred option is Option 1, which includes the retirement of 819 ABS's during FY25 – FY29. Based on the application of MDI0026, historical replacement trends indicate 574 (70%) of these are expected to be replaced and 245 (30%) are expected to be removed from service as they would no longer be required in the network.

The overall cost of the proposed 574 ABS's is estimated to be $10.63 million (in real FY23 terms). Only ABS's expected to be replaced are included within this total replacement cost. A contingency is not proposed to be applied as there are multiple sites in the program and the estimated costs are based on mean values with individual site's costs evening out to the mean across the program.

6.2 Additional scope and timing

A further 530 ABS's provide are NPV positive however have their maximum NPV with the FY30-FY34 period. Based on the application of MDI0026, historical replacement trends indicate 371 (70%) of these are expected to be replaced and 159 (30%) are expected to be removed from service as they would no longer be required in the network.

These 530 investments total a further $6.88 million (in real FY23 terms) and have been identified as additional scope for inclusion in the investment portfolio optimisation process. Only ABS's expected to be replaced are included within this total replacement cost. These interventions are considered to still be providing the highest value for customers, given the uncertainties surrounding the risk assessment process.

6.3 Investment summary

6.3.1 Planned proactive works

A summary of the investment proposed to be submitted for portfolio optimisation is shown in Table 8 below. All costs are in real FY23 terms.

Table 8 – Summary of investment for optimisation

Intervention type	Unit rate ($)	Quantity of retirements	Quantity of replacements (70%	Total replacement costs ($M)
ABS Replacement (NPV Max FY25-FY29)	18,538	819	574	10.63
ABS Replacement (NPV Max FY30-FY34 – inclusion for optimisation)	18,538	530	371	6.88
Totals		**1,349**	**945**	**17.51**

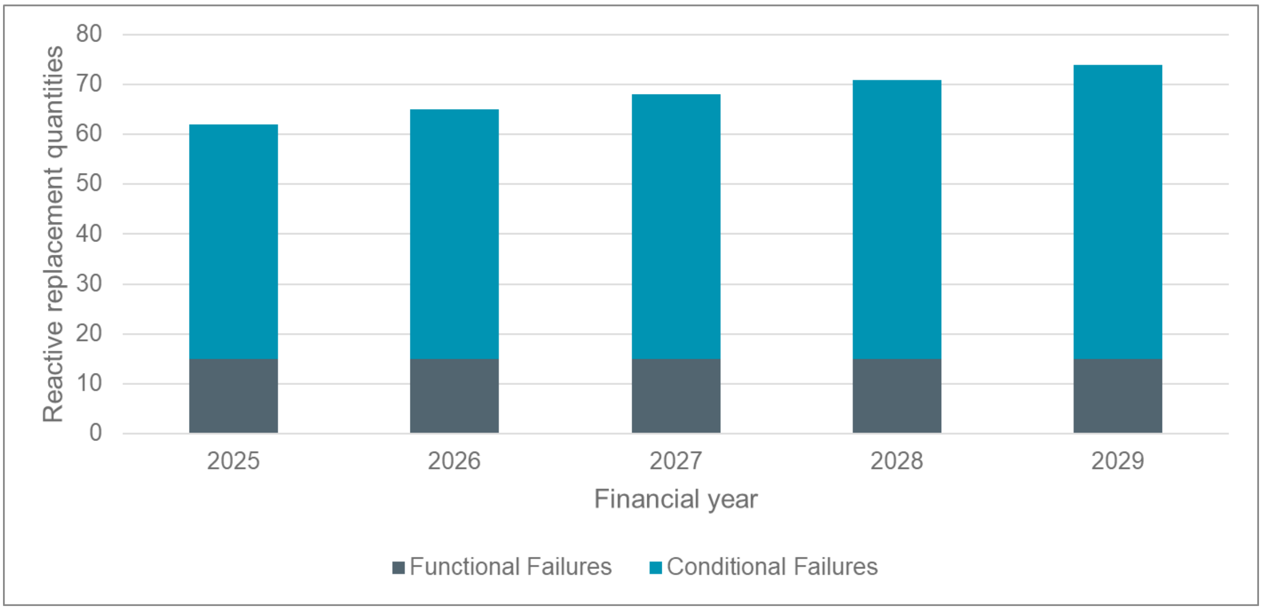
6.3.2 Reactive investment

Reactive modelling for the FY25 – FY29 period has forecast a further 340 ABS's to reach a state of conditional failure (e.g. found to be in a poor condition indicative of imminent failure and/or no longer capable of performing its function). Based on the application of MDI0026, historical replacement trends indicate 238 (70%) of these are expected to be replaced and 102 (30%) are expected to be removed from service as they would no longer be required in the network.

It is to be noted that the ABS's proposed for proactive retirement as part of this CFI have been excluded from the reactive modelling across this period.

Figure 3 below shows the forecast trend of reactive investment likely to be required for the retirement of failed ABS units into the future.

Figure 3 – Forecast reactive retirement quantities FY25-FY29



To accommodate this eventuality, it is proposed that additional funding of $3.66 million (in real FY23 terms) be made available for reactive replacement during the FY25 – FY29 period. Only ABS's expected to be replaced are included within this total replacement cost

Table 9 below, summarises the proposed reactive funding forecast.

All costs are in real FY23 terms.

Table 9 – Reactive replacement forecast

Regulatory control period (FY25-FY29)	Unit rate per reactive replacement ($)	Forecast quantity of reactive retirements	Forecast quantity of reactive replacements	Forecast reactive replacement investment ($M)
Conditional Failures	15,363	265	186	2.85
Functional Failures	15,363	75	52	0.81
Total		**340**	**238**	**3.66**

6.4 Project scope of works

6.4.1 ABS replacement

The operational need for each retired switch is assessed in accordance with MDI0026 [1] before a decision is made.

There are four proposed outcomes which include:

- Lockout of the ABS as per guidelines outlined in Technical Bulletin TB-215 The Management of Air Break Switches [4].
- Like-for-like replacement with a polymeric ABS.
- Replacement with an enclosed SF6 LBS.
- Replacement with an enclosed SF6 automated LBS.

ABS's which have failed (or after they have been maintained, remain in a poor condition indicating imminent failure), are to be defected in SAP.

The defects outlined in MMI0002 [3] should be considered when assessing air-break switches for replacement, this includes PIN defects. The defects which are likely to initiate replacement include:

- Broken or cracked supporting insulators.
- Particular types of switches which have been identified as posing a safety risk.
- Misaligned, jammed, or welded contacts.
- Faulty operating mechanism.
- The presence of tracking currents.

The proposed scope of works should include the replacement of the switch only. The replacement of the pole should not generally be required or included in the ABS replacement. However, if pole replacement is required, because of defects against the pole which are not related to the ABS replacement, the costs of the pole replacement are to be booked to the *Distribution pole replacement program.*

7. Regulatory investment test

The project cost of the credible option(s) for each site falls below the threshold for application of the Regulatory Investment Test for Distribution (RIT-D) (currently $6.0 million) and therefore the RIT-D is not applicable to this project.

8. Recommendation

It is recommended that Option 1 for the proactive replacement of ABS's where the intervention timing indicates that maximum NPV is between FY25 – FY34, be included in the PIP FY25 and to proceed to the investment portfolio optimisation stage.

With an allowance for a further $3.66 million (in real FY23 terms) within the FY25 – FY29 period for the reactive replacement of ABS's that reach a state of conditional failure (e.g. found to be in a poor condition indicative of imminent failure and/or no longer capable of performing its function).

9. Attachments

Appendix A – Details of recommended scope for optimisation

Appendix B – Risk assessment variables

10. References

[1] "Mains Design Instruction MDI0026 - Location of Isolation Points on the High Voltage Network".

[2] Endeavour Energy, "TB0215A - The Management of Air Break Switches," 9 March 2016.

[3] Endeavour Energy, "Air Break Switch Maintenance Impact Assessment," FMECA/RCM, July 2014.

[4] Endeavour Energy, "DS405 Air Break Switch Proactive Replacement - Case for Investment," Asset Planning & Performance, January 2020.

[5] Endeavour Energy, "DS405 Air Break Switch Reactive Replacement - Case for Investment," Asset Planning & Performance, January 2020.

[6] Endeavour Energy, "MMI0002 - Distribiution Overhead Defect Handbook," Asset Planning & Performance, August 2021.

Appendix A – Details of recommended scope for optimisation

Scope with maximum NPV between FY25-FY34, shown in order of descending BCR, then descending NPV can be found in attached MS Excel spreadsheet:

Appendix A – Details of recommended scope for optimisation.xlsx

Appendix B – Summary of key risk assessment variables and assumptions

General variables and assumptions

Parameter	Value	Description/Justification	Source/Assumptions
Population	8,405	Number of ABS's in service (3,880 general porcelain) (3,574 general polymer) (1,030 problematic porcelain)	Endeavour Energy's Ellipse database
Annual conditional failures	90	The expected number of conditional ABS failures seen in a year based on a 10 year period. (FY12-FY22)	Endeavour Energy's defect data via Ellipse workorders
Annual unassisted functional failures	29	The expected number of unassisted functional ABS failures seen in a year based on a 10 year period. (FY12-FY22)	Endeavour Energy's Outage Management System
WACC	3.26%	Weighted average cost of capital	Regulated rate
Base year of investment	FY23	All investments for budgeting purposes are expressed in real FY23 dollars	For inclusion into the FY23 PIP after optimisation
Calculation horizon	175 years	The timeframe over which the cost-benefit analysis is performed	Figleaf algorithm
Maintenance costs	$2,200 $367 annualised	The cost associated with maintenance of problematic model ABS's	Based on actual costs of previously delivered works The annualised cost assumes an average between the 4 year and 8 year maintenance cycle for ABS's.
Planned intervention cost	$18,100	The FY22 cost associated with a planned ABS intervention	Calculated as the weighted average unit rate of all available replacement options for an ABS, including ABS to ABS, ABS to LBS, and ABS to ALBS replacements. The following weightings have been applied based on installation ratios which have occurred in the past. ABS to ABS: $10,500 at 41% ABS to LBS: $15,500 at 21% ABS to ALBS: $27,500 at 38%
Reactive intervention	$15,000	The cost associated with a reactive ABS intervention	Based on actual costs of previously delivered works
ABS retirement benefit factor	60%	Switches which are retired (locked out) do not completely reduce their risk post intervention. These switches are assumed to be 60% effective as retirement removes risk associated with failure during switching.	Calculated as the average benefit provided when eliminating risks associated by switching events.

ABS replacement cost factor	70%	70% of switches requiring retirement will be assessed as being required to be replaced and 30% of switches requiring retirement will be removed from service as they are no longer required. The 30% of switches which are deemed to be removed from service are not considered as capital expenditure and are therefore excluded in the costings.	Calculated using actual replacement to removed from service rates over the last two years.

Weibull failure probability parameters

Parameter	Value	Description/Justification	Source/Assumptions
$\boldsymbol{Shape_{functional}}$	Porcelain General – 3.60 Porcelain Problematic – 4.00 Polymeric General – 2.60	The shape parameter, also known as the Weibull slope, used for calculating probability of failure for proactive investment. Developed by applying asset age to failure correlation using Endeavour Energy's historical failure and asset data.	Endeavour Energy's Outage Management System
$\boldsymbol{Scale_{functional}}$	Porcelain General – 76.00 Porcelain Problematic – 57.00 Polymeric General – 80.00	The scale parameter used for calculating probability of failure for proactive investment. Developed by applying asset age to failure correlation using Endeavour Energy's historical failure and asset data.	Endeavour Energy's Outage Management System
$\boldsymbol{Shift_{functional}}$	Porcelain General – 0 Porcelain Problematic – 0 Polymeric General – 0	The location parameter used for calculating probability of failure for proactive investment. Developed by applying asset age to failure correlation using Endeavour Energy's	Endeavour Energy's Outage Management System
$\boldsymbol{Shape_{conditional}}$	Porcelain General – 2.50 Porcelain Problematic – 4.00 Polymeric General – 2.00	The shape parameter, also known as the Weibull slope, used for calculating probability of failure for reactive forecasting. Developed by applying asset age to failure correlation using Endeavour Energy's historical failure and asset data.	Endeavour Energy's Ellipse defect data
$\boldsymbol{Scale_{conditional}}$	Porcelain General – 68.00 Porcelain Problematic – 50.00 Polymeric General – 74.00	The scale parameter used for calculating probability of failure for reactive forecasting. Developed by applying asset age to failure correlation using Endeavour Energy's historical failure and asset data.	Endeavour Energy's Ellipse defect data
$\boldsymbol{Shift_{conditional}}$	Porcelain General – 0 Porcelain Problematic – 0 Polymeric General – 0	The location parameter used for calculating probability of failure for reactive forecasting. Developed by applying asset age to failure correlation using Endeavour Energy's	Endeavour Energy's Ellipse defect data

Reliability risk inputs

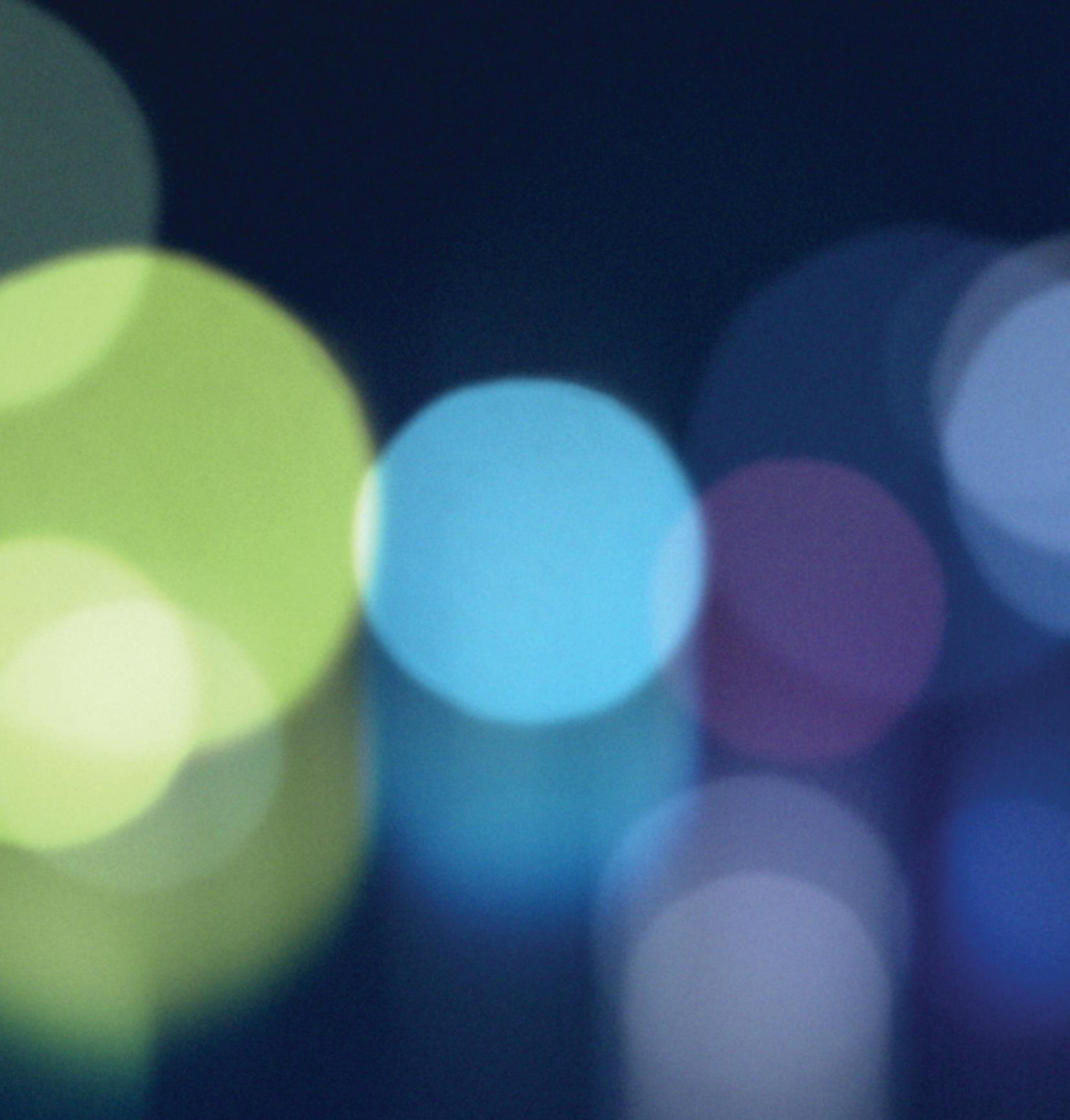
Parameter	Value	Description/Justification	Source/Assumptions
Load factor	0.7	Factor applied to maximum feeder loadings to represent the magnitude of load during a network outage Calculated using historic outage data across 2,336 events	Endeavour Energy's Outage Management System
Outage duration – (Failure on event)	2	Switching failure: Time taken to restore load. Hour 1 – 100% load loss Hour 2 – 100% load loss Calculated as the average minutes lost per customer under an ABS associated outage	Endeavour Energy's Outage Management System
Outage duration – (Failure in-service)	5	Time taken to restore load. Hour 1 – 100% load loss Hour 2 – 100% load loss Hour 3 – 100% load loss Hour 4 – 75% load loss Hour 5 – 50% load loss Calculated as the average minutes lost per customer under an ABS associated outage	Assumed additional 3 hours of travel and fault locating
LoC – Switching	Varies by asset	The annual switching frequency for each ABS	Endeavour Energy's SwitchIt database. Assumed 1 operation every 20 years for switches which were not operated in the last 10 years
LoC – In Service	0.62	A multiplier to calculate the annual ABS failures which fail in service (not during switching) Backwards calculated using the annual no. of in service failures. Indicates the ratio between number of in-service failures vs number of switching failures (on event)	Endeavour Energy's Outage Management System
VCR ($/MWh)	Varies by asset	The value customers place on having reliable electricity supplies under different conditions. Calculated as an average VCR across each LGA	PowerFactory load data
Load (MVA)	Varies by asset	The HV load distributed across each feeder at each pole.	PowerFactory load data

Safety risk inputs

Parameter	Value	Description/Justification	Source/Assumptions
LoC – Failure Mode	0.46	Likelihood that an ABS failure will relate to a safety risk i.e. insulator shatters on switching Calculated as the no. of insulator crack defects / total no. of failures	Endeavour Energy's defect data via Ellipse workorders
LoC – Injury Severity	0.24	Likelihood that a safety incident will result in an injury Calculated as the no. of injuries / no. of safety incidents	Endeavour Energy's historical Safety Incidents via MySafe database Assumed close calls are considered as an injury
LoC – Fatality Severity	0.01	Likelihood that a safety incident will result in a fatality Calculated as the no. of fatalities / no. of safety incidents	Endeavour Energy's historical Safety Incidents via MySafe database had 0 fatalities in the last 10 years. Assumed 1 fatality every 20 years.
LoC – Switching	Varies by asset	The annual switching frequency for each ABS	Endeavour Energy's SwitchIt database. Assumed 1 operation every 20 years for switches which were not operated in the last 10 years
CoC – Injury	$51,000	Cost of a single injury	Disproportionate factor used alongside CoC – Fatality and GNV979 – Quantitative Determination of Reasonably Practicable Risk Control Measures when Assessing Health and Safety Risks
CoC – Fatality	$5,100,000	Cost of a single fatality	Office of Best Practice Regulation

Bushfire Risk Inputs

Parameter	Value	Description/Justification	Source/Assumptions
LoC – Fire Start	Varies by asset	Likelihood that an ABS failure will create a fire Calculated as the annual no. of ABS related fires * LoC – In Service / annual no. of ABS bushfire related defects	Endeavour Energy's defect data via Ellipse workorders Endeavour Energy's historical fire database
LoC – Vegetation	Varies by asset	Risk reduction factor based on the asset's spatial location and its proximity to vegetation fuel sources	RFS bushfire prone land maps
CoC – Bushfire	Varies by asset	Cost of a bushfire including costs associated with fatalities, houses lost, residential contents lost, vineyards lost, plantations lost, crops lost, powerlines lost.	Ignition simulation via Phoenix software



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