HV OVERHEAD SWITCHGEAR LOAD BREAK SWITCH FAILURE RISK MITIGATION

Case for investment FY23
March 2022

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Contents

Endeavour Energy

1. Executive summary

This case for investment (CFI) recommends investment into the retirement of overhead distribution Load Break Switches (LBS's) within the FY23-FY29 period to address the safety, reliability, and environmental risks associated with this equipment failing in service.

Endeavour Energy has approximately 3,200 LBS's in service operating in the HV distribution network. LBS'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. LBS's are fully enclosed pole mounted switches using SF6 gas as its arc quench medium. LBS's are able to be used to make or break 11kV and 22kV circuits under either normal or fault conditions.

LBS's are categorised into two switch ability types, manually operated on-site (2,200) and remotely operated automated/SCADA controlled (1,000). Each switch type is further categorised based on its location as either installed in an urban or coastal environment.

The possible consequences of failure for the manual and automatic LBS's include the following:

- Safety impacts: LBS's are typically installed on the top of pole approximately 8 meters above ground level. As the enclosure of the LBS degrades overtime, the sudden force on operating the switch coupled with arc quenching via a combustible gas (SF6) may cause the LBS to fail explosively causing debris to fall to the ground. Furthermore, cracks in the supporting insulator bushings may allow current to flow down the operating rod or the pole resulting in electric shock.
- Reliability impacts: broken, cracked, or fallen insulators as well as misaligned phase components can create loss of supply on overhead HV feeders and to any downstream customers. HV feeder supply is affected from LBS failures and subsequently while the network is re-configured to isolate and sectionalise the switchgear.
- Environmental impacts: SF6 gas has a global warming potential of 22,800 times that of CO2 meaning gas leakages to degrading LBS enclosures or catastrophic failures will have an environmental impact. However, currently there is no agreed value within the Australian electricity industry placed on these impacts and therefore has not been risk valued within this assessment.
- No significant bushfire or regulatory compliance consequences have been experienced or are anticipated for future failures of an LBS.

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.

LBS's are identified for proactive intervention at the time when the net present value of the intervention reaches its maximum value. The assessment conducted as part of this CFI into the proactive replacement of poles yielded no economically feasible interventions within the FY23-FY29 investment period or the following period FY30-FY34. Therefore, proactive replacement scope has not been submitted within this CFI at this time for optimisation.

There are 146 LBS's for an estimated replacement value of $2.79 million 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 economic assessment. The NPV of each of these LBS's is unique to each LBS and varies from $10 to $51,333 with an average of $6,935. The benefit to cost ratio (BCR) for each LBS range from 1.0 to 5.4 and averages 1.6. Note, these LBS's have not been considered within this CFI for inclusion in the proactive optimisation process.

Continued investment into the reactive intervention strategy of LBS's is recommended in this CFI. There are two intervention options considered once a pole has been assessed through the application of MDI 0026 [1]. These include:

- Lockout of the LBS: If it is assessed that the functionality of a retired switch is no longer required, it is locked out and removed from service. Given that LBS's are a relatively young population, this option is unlikely to be considered.

- Replacement of the LBS: If it is assessed that the functionality of a retired switch is still required, it is replaced by either a new LBS, or a new LBS which is connected to the SCADA network for remote and/or automated operation.

Reactive modelling for the FY23-FY29 period has forecast 51 LBS'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). It is expected that all 51 are expected to be replaced and 0 are expected to be removed from service as part of a reactive strategy.

To accommodate this eventuality, it is proposed that funding of $1.00 million (in real FY23 terms) be made available for reactive LBS replacement during the FY23-FY29 period. A contingency has not been proposed as the unit rates used in this forecast are based off mean values of costs accrued from Endeavour Energy's historical interventions.

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.

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.

2. Purpose

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

This case for investment (CFI) recommends reactive intervention for LBS's that that may functionally fail unexpectedly or conditionally fail during the FY23-FY29 period.

3. Identified needs and/or opportunities

3.1 Background

Endeavour Energy has approximately 3,200 LBS's in service operating in the HV distribution network. LBS'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. LBS's are fully enclosed pole mounted switches using SF6 gas as its arc quench medium. LBS's are able to be used to make or break 11kV and 22kV circuits under either normal or fault conditions.

LBS's are categorised into two switch ability types, manually operated on-site (2,200) and remotely operated automated/SCADA controlled (1,000). Each switch type is further categorised based on its location as either installed in an urban or coastal environment.

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.

Manually operated LBS's were introduced into the network in the early 2000's with the majority supplied from Iljin and Schneider. Automated LBS's were shortly after introduced using ABB as the main supplier.

3.2 Risks and identified need

The functional failure of an LBS occurs when the LBS is unable to be operated due to either the mechanical failure of it moving parts, damaged seals resulting in not being able to hold its arc quenching medium or cracked or missing insulators.

Endeavour Energy's historical data for LBS indicate that since FY12, there have been on average 2 recorded unassisted failures per year and 6 conditional failures per year. The low number of failures may be due to the relatively young age of this subpopulation of assets.

The possible consequences of failure for LBS's include the following:

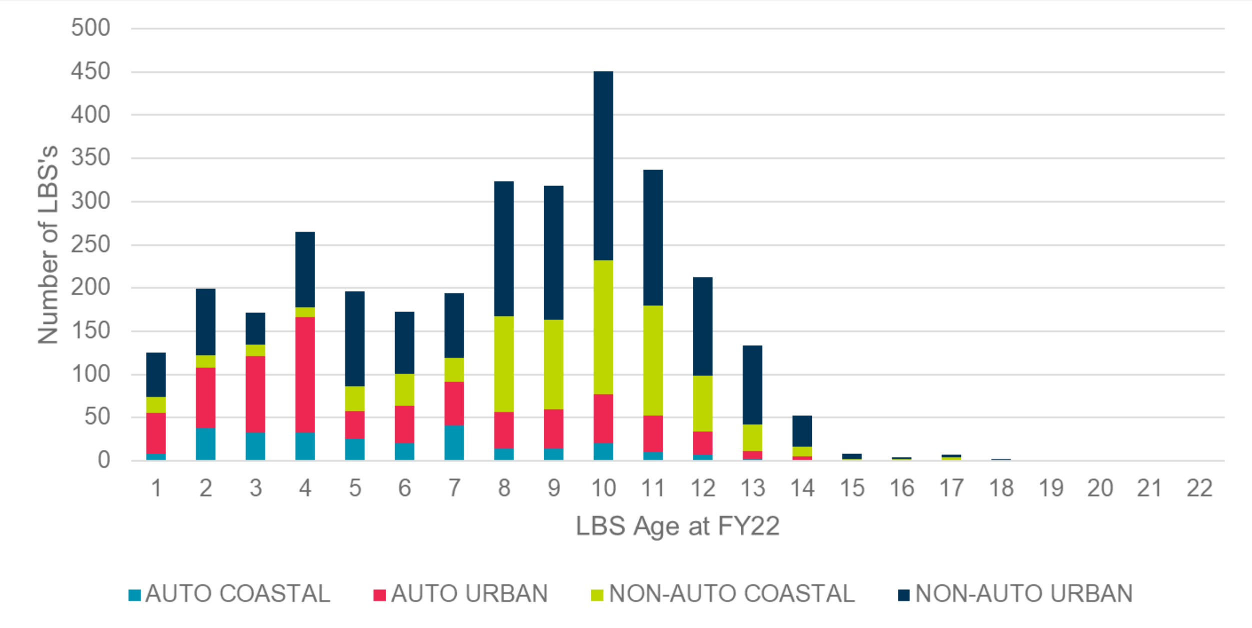
- Safety impacts: LBS's are typically installed on the top of pole approximately 8 meters above ground level. As the enclosure of the LBS degrades overtime, the sudden force on operating the switch coupled with arc quenching via a combustible gas (SF6) may cause the LBS to fail explosively causing debris to fall to the ground. Furthermore, cracks in the supporting insulator bushings may allow current to flow down the operating rod or the pole resulting in electric shock.
- Reliability impacts: broken, cracked, or fallen insulators as well as misaligned phase components can create loss of supply on overhead HV feeders and to any downstream customers. HV feeder supply is affected from LBS failures and subsequently while the network is re-configured to isolate and sectionalise the switchgear.
- Environmental impacts: SF6 gas has a global warming potential of 22,800 times that of CO2 meaning gas leakages to degrading LBS enclosures or catastrophic failures will have an environmental impact. However, currently there is no agreed value within the Australian electricity industry placed on these impacts and therefore has not been risk valued within this assessment.
- No significant bushfire or regulatory compliance consequences have been experienced or are anticipated for future failures of an LBS.

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

3.3 Asset age profile

The age profile of the fleet of 3,200 LBS's is shown in Figure 1 below.

Figure 1 – Age profile (from date of commissioning) for the fleet of LBS'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 LBS'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 and carry out repairs where possible after minor failures.
- Nil replacement of the LBS 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 LBS 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 LBS'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 LBS’s includes operating the LBS 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 routine checks, inspections, and minor overhauls for manual and automated SF6 LBS’s [2].
- Reactive replacement after failure.

Currently, “failure” refers to the inability of the LBS 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 corroded low gas indicators, gas leakages, faulty motor control, hot joints or burnt bonds, misaligned phase components or poor contact between phases, faulty operating mechanism, and cracks on insulator bushings or surge diverters. These are typically scheduled for retirement with the appropriate intervention option selected in accordance with MDI 0026.

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 (%)
Safety	1	4
Reliability	20	72
Reactive Replacement	7	24
Total	**27**	**100**

As noted in Table 1 above, the residual risk presented by the BAU case totals $27 million. The residual risk value presented by each LBS range from $1,489 to $149,658 and averages $8,641.

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

5. Options considered

5.1 Risk treatment options

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

Table 2 – LBS risk treatment options

Option	Assessment of effectiveness	Conclusion
Additional maintenance to extend the life of the existing asset	Routine maintenance is currently performed on all SF6 LBS's (manual and automated). However, given that the primary causes of failure are age related or commissioning related (both of which cannot be adequately addressed with maintenance), further maintenance LBS's will not be effective in mitigating the risk associated with the expected reactive failure forecast of LBS's.	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. LBS'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 LBS'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 LBS'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 LBS'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 LBS is identified for retirement, Endeavour Energy Mains Design instruction MDI 0026 [1] provides instructions for the minimum isolations requirements and sets out both the location and the type of isolation points to be installed overhead distribution network and resolves whether a switch can be:

- Lockout of the LBS: If it is assessed that the functionality of a retired switch is no longer required, it is locked out and removed from service.
- Replacement of the LBS: If it is assessed that the functionality of a retired switch is still required, it is replaced by either a new LBS, or a new LBS which is connected to the SCADA network for remote and/or automated operation.

The current trend over the past two years indicates that 70% of overhead HV switches identified for retirement typically require replacement with a new switch and 30% are considered no longer required and are bonded through and locked out, effectively removed from service on the network. However, this trend seems to apply more predominantly towards air-break switches (ABS) identified for retirement rather than LBS's. This in part seems to be due to relatively low failure rate of LBSs due the young age of the asset base and the additional make and break functionality an LBS provides over of a local ABS when the switch undergoes MDI 0026 assessment. Given this 100% of LBS identified for retirement have been assessed will be replaced rather than removed from service on the network.

Table 3 – Credible network options considered for LBS's

Option	Description	Conclusion
Proactive LBS replacement	As per MDI 0026, LBS 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 another LBS. • Replaced with an LBS which is also connected to the SCADA network for remote and/or automated operation (ALBS).	Credible option considered and has progressed for further assessment.

5.4 Economic evaluation

5.4.1 Option 1 – LBS replacement

LBS's are identified for proactive intervention at the time when the net present value of the intervention reaches its maximum value. The assessment conducted as part of this CFI into the proactive replacement of poles yielded no economically feasible interventions within the FY23-FY29 investment period or the following period FY30-FY34. Therefore, proactive replacement scope has not been submitted within this CFI at this time for optimisation.

5.5 Evaluation summary

Not applicable to this CFI.

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 A for details of these assumptions.

5.7 Scenario assessment

Not applicable to this CFI.

6. Preferred option details

6.1 FY23-FY29 scope and timing

Not applicable to this CFI.

6.2 Additional scope and timing

Not applicable to this CFI.

6.3 Investment summary

6.3.1 Planned proactive works

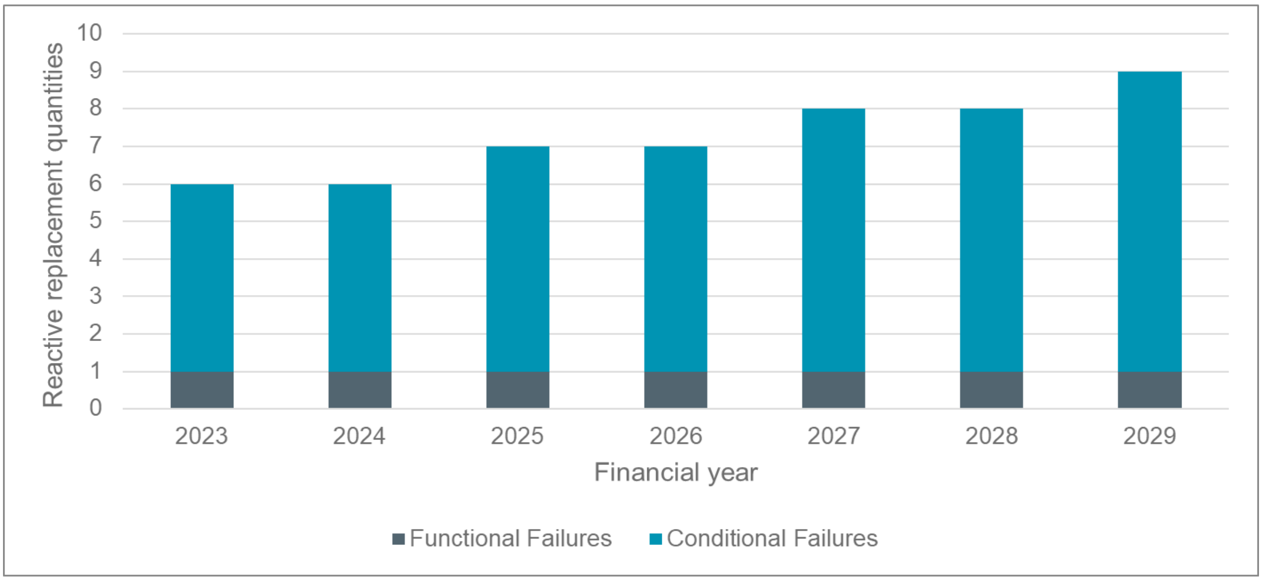
LBS's are identified for proactive intervention at the time when the net present value of the intervention reaches its maximum value. The assessment conducted as part of this CFI into the proactive replacement of poles yielded no economically feasible interventions within the FY23-FY29 investment period or the following period FY30-FY34. Therefore, proactive replacement scope has not been submitted within this CFI at this time for optimisation.

6.3.2 Reactive investment

Reactive modelling for the FY23-FY29 period has forecast a 51 LBS'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 51 (100%) of these are expected to be replaced and 0 (0%) are expected to be removed from service as they would no longer be required in the network.

Figure 2 below shows the forecast trend of reactive investment likely to be required for the retirement of failed LBS units into the future.

Figure 2 – Forecast reactive retirement quantities FY23-FY29



To accommodate this eventuality, it is proposed that additional funding of $1.00 million (in real FY23 terms) be made available for reactive replacement during the FY23-FY29 period.

Table 4 below, summarises the proposed reactive funding forecast.

All costs are in real FY23 terms.

Table 4 – Reactive replacement forecast

Description	Unit rate per reactive replacement ($)	Forecast quantity of reactive replacements		Forecast reactive replacement investment ($M)	
		FY23-FY24	FY25-FY29	FY23-FY24	FY25-FY29
Conditional Failures	19,592	10	34	0.20	0.67
Functional Failures	19,592	2	5	0.04	0.10
Sub-total		**12**	**39**	**0.24**	**0.76**
Total (FY23-FY29)		**51**		**1.00**	

6.4 Project scope of works

6.4.1 LBS 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 LBS
- Like-for-like replacement with another LBS.
- Replacement with an automated SCADA controlled LBS.

LBS'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 MMI 0002 [3] should be considered when assessing LBS's for replacement, this includes PIN defects. The defects which are likely to initiate replacement include:

- Broken or corroded low gas indicators
- Gas leakages
- Faulty motor control
- Hot joints or burnt bonds
- Misaligned phase components or poor contact between phases
- Faulty operating mechanism
- Cracks on insulator bushings or surge diverters

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 LBS replacement. However, if pole replacement is required, because of defects against the pole which are not related to the LBS 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 over the FY23-FY29 period, a condition based reactive intervention strategy is to be undertaken for LBSs within the Endeavour Energy network.

The total cost of these works has been estimated to be $1.00 million in real FY23 terms and is recommended to be included into the optimisation process within the FY23-FY29 Portfolio Investment Plan.

9. Attachments

Appendix A – Summary of key risk assessment variables and assumptions

10. References

[1] Endeavour Energy, “Mains Design Instruction MDI0026 - Location of Isolation Points on the High Voltage Network,” November 2015.

[2] Endeavour Energy, “Substation Maintenance Instruction SMI207 - HV reclosers, sectionalisers and load break switches,” 2015.

[3] Endeavour Energy, “MMI0002 - Distribiution Overhead Defect Handbook,” Asset Planning & Performance, 2021.

Appendix A – Summary of key risk assessment variables and assumptions

General variables and assumptions

Parameter	Value	Description/Justification	Source/Assumptions
Population	3,174	Number of LBS's in service (268 automated coastal) (692 automated urban) (762 non-automated coastal) (1,452 non-automated urban)	Endeavour Energy's Ellipse database
Annual conditional failures	6	The expected number of conditional LBS failures seen in a year based on a 10year period. (FY12-FY22)	Endeavour Energy's defect data via Ellipse workorders
Annual unassisted functional failures	2	The expected number of unassisted functional LBS failures seen in a year based on a 10year 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
Planned intervention cost	$19,129	The FY22 cost associated with a planned LBS intervention	Calculated as the weighted average unit rate of all available replacement options for an LBS, LBS to LBS and LBS to ALBS replacements. The following weightings have been applied based on the current population ratio of LBS's. LBS to LBS: $15,500 at 70% LBS to ALBS: $27,500 at 30%
Reactive intervention	$19,129	The FY22 cost associated with a reactive LBS intervention	Assumed to be identical to the planned intervention cost

Weibull failure probability parameters

Parameter	Value	Description/Justification	Source/Assumptions
$Shape_{functional}$	Automated Coastal: 2.70 Automated Urban: 3.20 Non-automated Coastal: 2.50 Non-automated Urban: 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
$Scale_{functional}$	Automated Coastal: 89.00 Automated Urban: 97.00 Non-automated Coastal: 93.00 Non-automated Urban: 102.00	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
$Shift_{functional}$	Automated Coastal: 0 Automated Urban: 0 Non-automated Coastal: 0 Non-automated Urban: 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
$Shape_{conditional}$	Automated Coastal: 2.00 Automated Urban: 2.10 Non-automated Coastal: 2.00 Non-automated Urban: 2.40	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
$Scale_{conditional}$	Automated Coastal: 74.00 Automated Urban: 82.00 Non-automated Coastal: 78.00 Non-automated Urban: 91.00	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
$Shift_{conditional}$	Automated Coastal: 0 Automated Urban: 0 Non-automated Coastal: 0 Non-automated Urban: 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.	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 LBS 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 LBS associated outage	Assumed additional 3 hours of travel and fault locating
LoC – Switching	Varies by asset	The annual switching frequency for each LBS	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	0.38	A multiplier to calculate the annual LBS 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	0.05	Likelihood that an LBS failure will relate to a safety risk i.e. debris falling from switch during operation. Calculated as the no. of catastrophic defects / total no. of failures	Endeavour Energy's defect data via Ellipse workorders
LoC – Injury Severity	0.05	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 60 years.
LoC – Switching	Varies by asset	The annual switching frequency for each LBS	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

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