# Appendix 5.17: Distribution – HV switchboard assembly ASP

**Regulatory proposal for the ACT electricity distribution network 2019-24**
**January 2018**

Disclaimer: On 1 January 2018, the part of ActewAGL that looks after the electricity network changed its name to Evoenergy. This change has been brought about from a decision by the Australian Energy Regulator. Unless otherwise stated, ActewAGL Distribution branded documents provided with this regulatory proposal are Evoenergy documents.

evoenergy

# ASSET SPECIFIC PLAN

## Distribution

HV Switchboard Assembly

**Document Number: SM1132**

ActewAGL for you

**Version Control**

| Date | Version | Description | Author | Reviewed |
|---|---|---|---|---|
| 11/12/14 | 1.0 | 2014-19 Regulatory Submission | | |
| 20/04/17 | 2.0 | New template, options analysis and revised for the 2019-24 regulatory submission | | |
| 8/01/2018 | 2.1 | Updated and corrected historic CAPEX and OPEX charts | | |
| 12/01/2018 | 3.0 | Updated Table 12. | | |
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**Approval**

| | | |
|---|---|---|
| **Author** | **Primary Assets Engineer** | Signature Date |
| **Endorsed** | **Primary Assets Manager** | Signature Date |
| **Approved** | **Branch Manager Asset Strategy** | Signature Date |

**Reference Documents**

| Document |
| --- |
| National Electricity Rules |
| National Electricity Law |
| Utilities Act (ACT) |
| Electricity Distribution Asset Management Policy PO1101 |
| Asset Management Strategy SM1192 |
| Asset Management Objectives |
| Asset Management System Manual |
| PR5017 Recovery and disposal of reclaimed network assets |
| SM4606 Environmental PCB Management Plan |

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**Glossary**

| Term | Definition |
|---|---|
| AAD | ActewAGL Distribution |
| AEMC | Australia Energy Market Commission |
| AEMO | Australian Energy Market Operator |
| AER | Australian Energy Regulator |
| ASP | Asset Specific Plan |
| CAPEX | Capital Expenditure |
| CB | Circuit Breaker |
| CT | Current Transformer |
| FMEA | Failure Mode and Effects Analysis |
| HV | High Voltage |
| IED | Intelligent Electronic Device |
| kV | Kilovolt |
| LV | Low Voltage |
| MTBF | Mean Time Between Failures |
| NER | National Electricity Rules |
| NSP | Network Service Providers |
| OEM | Original Equipment Manufacturer |
| OPEX | Operational Expenditure |
| OPGW | Optical Ground Wire |
| OCB | Oil Circuit Breaker |
| VCB | Vacuum Circuit Breaker |
| PoF | Probability of Failure |
| PoW | Program of Work |
| SAIDI | System Average Interruption Duration Index |
| SAIFI | System Average Interruption Frequency Index |
| SCADA | Supervisory Control and Data Acquisition |
| STPIS | Service Target Performance Incentive Scheme |
| UFLS | Underfrequency Load Shedding |
| VT | Voltage Transformer |

NOTE

*All analysis has been undertaken using 2017/18 real dollars unless otherwise stated.*
*Budgeted expenditure for CAPEX & OPEX excludes indirect costs.*

# Document Purpose

This document is an Asset Specific Plan (ASP). This ASP provides the business case for asset management strategy selection and specifies the activities and resources, responsibilities and timescales for implementation for this specific asset class. In conjunction with the other ASPs, it forms ActewAGL's Asset Management Plan, which describes the management of operational assets of the electricity distribution system.

Asset management options are assessed in the context of the asset class' current state, condition, performance, risks, life cycle costs, trends and external environment. A recommended asset strategy is presented with associated capital expenditure and operational expenditure forecasts, including a 10 year budget forecast, for consideration by ActewAGL management.

Detailed in this document are the systematic and coordinated activities and practices whereby ActewAGL manages the asset class in an optimal and sustainable manner for the purpose of achieving the organisational strategic plan.

# Audience

This document is intended for internal use by ActewAGL management and staff. As part of legislative, regulatory and statutory compliance requirements, the audience of this document is extended to relevant staff of the ACT Technical Regulator and the Australian Energy Regulator.

# Document Hierarchy

ActewAGLs asset management system aligns with ISO 55001. This document complies with ISO 6.2.2 planning to achieve asset management objectives. Figure 1 shows the alignment of ASPs in the asset management system.

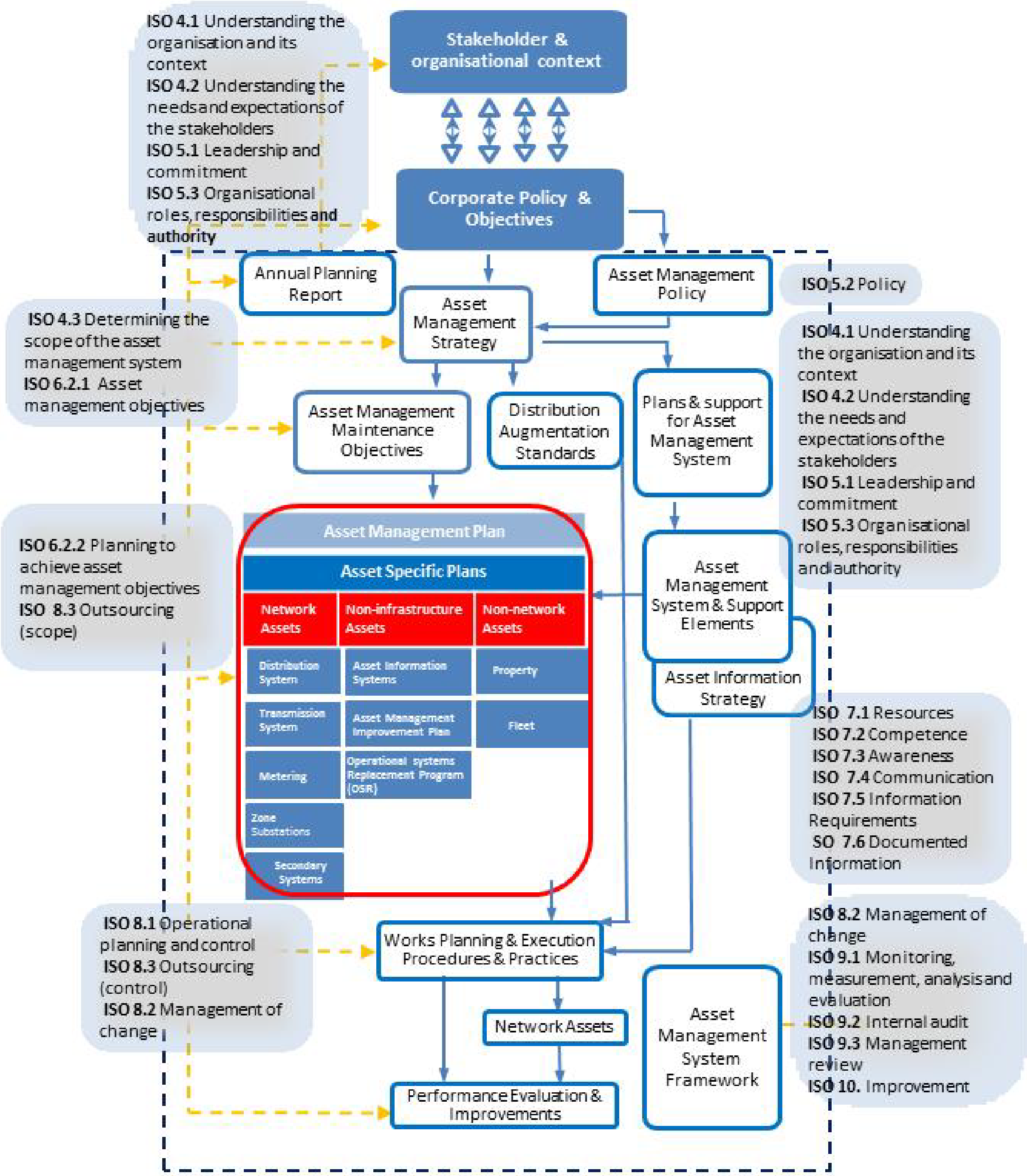


Figure 1: Asset management system structure

# 1 Executive Summary

In this ASP the Distribution High Voltage (HV) Switchboard Assembly is divided into two main functional units each comprising of electrical and mechanical components, these are HV Circuit Breakers and HV Switchboards. The HV Switchboard is also sometimes referred to as HV Board and has the some or all of the following components HV Circuit Breakers, HV fuses, HV Links and HV busbars.

The Distribution HV Switchboard assembly is one of the main components of ground mounted distribution substations. The primary role of the Distribution HV Switchboard Assembly assets is to provide electrical protection for assets, enable safe access for network maintenance, and provide switching functions for safe and reliable network operations.

The health of the high voltage distribution circuit breakers and switchboards were determined as a starting point, followed by risk-condition based scenario planning analysis for the 2019-2024 regulatory period to choose the most viable option from:

- Option 0: Reactive Strategy. This strategy was analysed in order to understand and gauge the baseline risk of this asset class with only reactive replacements undertaken.
- Option 1: Existing Strategy. The existing strategy predominantly involves five-yearly circuit breaker maintenance, thermovision to check for deterioration, as well as one targeted switchboard replacement annually.
- Option 2: reduce cost Strategy. This approach took the existing strategy and extended the circuit breaker maintenance program from five to six years. Further, the thermovision program scope was reduced to target only substations that were operating at at least 50% capacity. In order to lower CAPEX costs, the targeted switchboard replacement program was reduced from one per year to zero.
- Option 3: Reduce Risk Strategy. Risk was primarily reduced in this strategy with the introduction of an accelerated targeted switchboard replacement program, i.e. from one per year to two.

Based on the risk-condition approach, cost optimisation benefit, and the health of the assets, this plan recommends Option 1 as the strategy that provides the most optimised combination of low risk and financial benefits. The optimised program of work budget for CAPEX and OPEX is presented in Table 1.

| Total Budget | 2018/2019 | 2019/20 | 2020/21 | 2021/22 | 2022/23 | 2023/24 |
|---|---|---|---|---|---|---|
| **CAPEX** | **405,000** | **315,000** | **360,000** | **315,000** | **90,000** | **405,000** |
| **OPEX** | **86,867** | **86,867** | **86,867** | **86,867** | **86,867** | **86,867** |
| Planned Maintenance | 62,667 | 62,667 | 62,667 | 62,667 | 62,667 | 62,667 |
| Unplanned Maintenance | 12,500 | 12,500 | 12,500 | 12,500 | 12,500 | 12,500 |
| Condition Monitoring | 11,700 | 11,700 | 11,700 | 11,700 | 11,700 | 11,700 |

Table 1: OPEX and CAPEX Optimised Program of Work Budget

This ASP presents a broad-based program of work in terms of CAPEX replacements for HV switchboard assembly assets and an optimised program of work approach for maintenance. Each CAPEX replacement project is justified based on various option considerations in a separate Project Justification Report.

# 2 Asset Class Overview

This section provides an overview of the strategy and objectives specific to the asset class covered by this ASP, provides details of the assets included and their function, and explores the needs and opportunities specific to this asset class.

This ASP covers the Distribution HV Switchboard Assembly asset class, which lies within the distribution asset portfolio. This asset class includes HV switchboards in distribution chamber and stockade substations and indoor switching stations. The basic function of this asset class is to provide:

- The connection of distribution feeders and distribution transformer circuits
- Isolation, earthing and access to distribution feeders and distribution transformer circuits
- Network protection

Chamber and stockade substations and indoor switching stations have one HV switchboard per substation consisting of multiple HV switchboard panels depending on the number of distribution feeder and transformer circuits.

There are two types of ground mounted HV switchgear within ActewAGL's network, ring main units (RMU) and switchboards. ActewAGL's policy is to install Ring Main Units (RMU) as a first priority and then HV switchboards where required. The key drivers for HV switchboard installations are fault level and loading. For higher fault levels and higher loads the appropriate technical solution is the HV switchboard.

For details of the asset groups contained within the Distribution HV Switchboard Assembly asset class, refer to section 2.2.

## 2.1 Asset Class Objectives

The asset class strategy presented in this ASP follows the overall ActewAGL asset management strategy and asset management objectives. The asset class strategy is an integral part of the asset management strategy, with the overall objective to provide safe, reliable and cost effective supply of electricity to customers and compliance with regulatory requirements.

This ASP has been developed in alignment with the asset management strategy and seeks to meet objectives in the following categories shown in Table 2.

| Asset Management Objectives | Asset Class Objectives |
|---|---|
| **Responsible** | |
| • Achieve zero deaths or injuries to employees or the public<br>• Maintain a good reputation within the community<br>• Minimise environmental impacts, for example bushfire mitigation<br>• Meet all requirements of regulatory authorities, such as the AER as outlined in the NER, and the ACT Utilities (Technical Regulations) Act 2014. | • No death or injury to employees or the public<br>• Ensure design and acceptance for new assets complies with standards |

| Asset Management Objectives | Asset Class Objectives |
|---|---|
| **Reliable** | |
| • Tailor monitoring and replacement programs for each asset based on modelling of asset health and risk.<br>• Meet network SAIDI and SAIFI KPIs<br>• Record failure modes of the most common asset failures in the network | • Achieve detailed understanding of asset health and incorporation into asset modelling<br>• Measure SAIDI and SAIFI contribution from this asset class<br>• Review ASP at least every 5 years<br>• Record and complete asset failure investigations within 20 business days |
| **Sustainable** | |
| • Enhance asset condition and risk modelling to optimise and implement maintenance and renewal programs tailored to the assets' needs<br>• Make prudent commercial investment decisions to manage assets at the lowest lifecycle cost<br>• Deliver the asset class PoW within budget. | • Achieve 90% data completeness for minimum asset data requirements<br>• Deliver PoW outlined in this plan |
| **People** | |
| • Proactively seek continual improvement in asset management capability and competencies of maintenance personnel. | • Promote continual improvement |

**Table 2: Asset Class Objectives**

The strategy and ASP must be practical in the sense that it can be implemented, must also be flexible enough to satisfy the future requirements of the ActewAGL network, and must be cost effective and efficient with consideration of both technical and human resources.

## 2.2 Asset Groups

Distribution HV switchboard assembly assets are classified by two main asset types shown in Table 2. Supporting components in the switchboard are discussed further in Section 2.3.

| | |
|---|---|
| **Asset Class** | Distribution HV Switchboard Assembly |
| **Asset Groups** | Distribution HV Switchboard<br>Distribution HV Circuit Breaker |

**Table 3: Asset Classification – Distribution HV Switchboard Assembly Assets**

## 2.3 Asset Functions

Distribution HV Switchboards and their components enable the connection, isolation, earthing and protection of distribution feeders and transformers in distribution chamber and stockade substations and indoor switching stations. The main components and their function are;

**HV Switchboard**

HV switchboards are enclosures which house components including busbars, circuit breakers, earth switches and protection equipment. The enclosure provides structural support and operational integrity from environmental influences such as mechanical impacts, dust and moisture. The HV switchboard also provides isolation for human contact against live equipment protecting against electrical shock.

Most HV Switchboards are of single busbar configuration with some substations having double busbar switchboards. Double busbar switchboards have 2 main busbars connecting each HV switchboard panel and the incoming and outgoing circuits can be connected to either busbar for flexible network operating configurations.

**HV Busbar**

HV busbars provide the medium to distribute power through the switchboard. HV switchboards typically have a main busbar which distributes power through the switchboard. Further sections of busbar connect to the main bus connecting incoming and outgoing circuits.

**HV Circuit Breaker**

HV circuit breakers are switching devices used to protect and operate the network. Circuit breakers switch by opening and closing of moving contacts and unlike fuses they can be reset for continued use. They receive controls from protection relays to clear faults on the network, or local or remote control to operate the network.

HV circuit breakers are rackable and have insulating and arc suppression mediums including oil, vacuum and SF6 gas.

HV circuit breakers are critical to the protection of HV distribution systems to minimise damage to equipment ensure the safety of people.

**HV Instrument Transformers**

HV instrument transformers include Current Transformers (CTs) and Voltage Transformers (VTs). These devices provide means for transforming high voltages and currents down to lower levels used by protection equipment, network monitoring and metering.

## 2.4 Needs and Opportunities

Less than 2% of the ground substations have HV switchboards. This accounts for just over 10% of the chamber substation population. There are few opportunities to further rationalise the installation of HV switchboards other than standardising on make and type equipment, however there are options that can be explored to reduce asset class risk and increase safety and reliability.

### 2.4.1 Needs

#### *2.4.1.1 Unsupported Makes and Models*

Multiple switchboard and circuit breaker types that are currently in service within AADs network are unsupported by the manufacturers. This results in maintenance constraints, due to spare parts being unavailable and a lack of procedure and understanding of these assets. Further, maintenance of these assets can lead to asset failure, and is therefore generally avoided for these assets. Refer to section 6.2.3.2 for a list of makes manufacturers and their corresponding maintenance interval. The proposed solution to this issue is to systematically replace these assets with their modern counterparts.

#### *2.4.1.2 Oil insulated Switchgear*

Most of the old switchboard panels contain oil circuit breakers. They are slowly being phased out mainly due to operational risk. They are also bulky resulting in oversized switchboards. Space is getting more and more expensive and there is increasing demand on substations to be compact. ActewAGL prefers not to buy SF6 switchgear due to environmental concerns, as they contribute to 'greenhouse gas' emissions. Vacuum circuit breakers are the preferred option for the future. The ratings of circuit breakers have already been rationalized.

### 2.4.2 Opportunities

#### *2.4.2.1 Switchboard Replacement with RMUs*

Currently more than 95% of the new chamber substations are installed with RMUs. Replacement of HV switchboards with RMUs are also being considered where technically feasible and cost effective.

There exists an opportunity to accelerate the removal and replacement of this asset class with ring main units, thereby resulting in a younger, more reliable, and fully maintainable asset population.

## 2.5 Associated Asset Classes

Associated asset classes are as follows.

### 2.5.1 Functional Relationships

Distribution HV switchboard assembly assets have functional relationships with the following asset classes:

- Substation & Switching Stations
- Distribution LV Switchboard Assembly;
- Distribution Transformers;
- Distribution Earthing;
- Protection and SCADA systems;

### 2.5.2 Similar Functions

Distribution HV Switchboard assembly assets, specifically circuit breakers, have similar functions to the following asset classes:

- Distribution LV Switchboard Assembly;

# 3 Asset Base

This section provides details of ActewAGL's current asset base for assets that are a part of this asset class, including the current age and condition profiles of the assets and the projected asset count.

## 3.1 Asset Base Summary

Table 3 gives details of ActewAGL's in-service or system spare distribution HV switchboard assembly assets as at April 2017.

| Asset Type | Quantity | Design Life (yrs) | Average Age (yrs) | Oldest Age (yrs) |
|---|---|---|---|---|
| Distribution HV Switchboard | 194 | 40 | 31 | 50 |
| Distribution HV Circuit Breaker | 136 | 40 (OCB)<br>50 (VCB) | 32 | 50 |
| **Grand Total** | **330** | | | |

Table 4: In-service or System Spare Assets

## 3.2 Asset Service Life Expectancy

The design life of distribution HV switchboard assembly assets is nominally 40 years. Actual service life is affected by aging factors as follows:

- Electrical loading;
- Thermal conditions;
- Moisture/contamination ingress into the insulation system
- Exposure to overvoltage conditions (sustained or transient)
- In service duty;
- Inherent design features
- Lifetime maintenance including intervals, scope, workmanship;
- Environmental factors such as humidity and pollution

## 3.3 Asset Age Profile

Figure 1 shows the age profile of the distribution HV switchboard assembly assets.

The asset age profile shows there are a large number of assets over 20 years of age and some assets beyond the expected design life of circuit breakers and switchboards. Within the next regulatory period, an increasing numbers of assets will reach end of life condition and will require replacement.

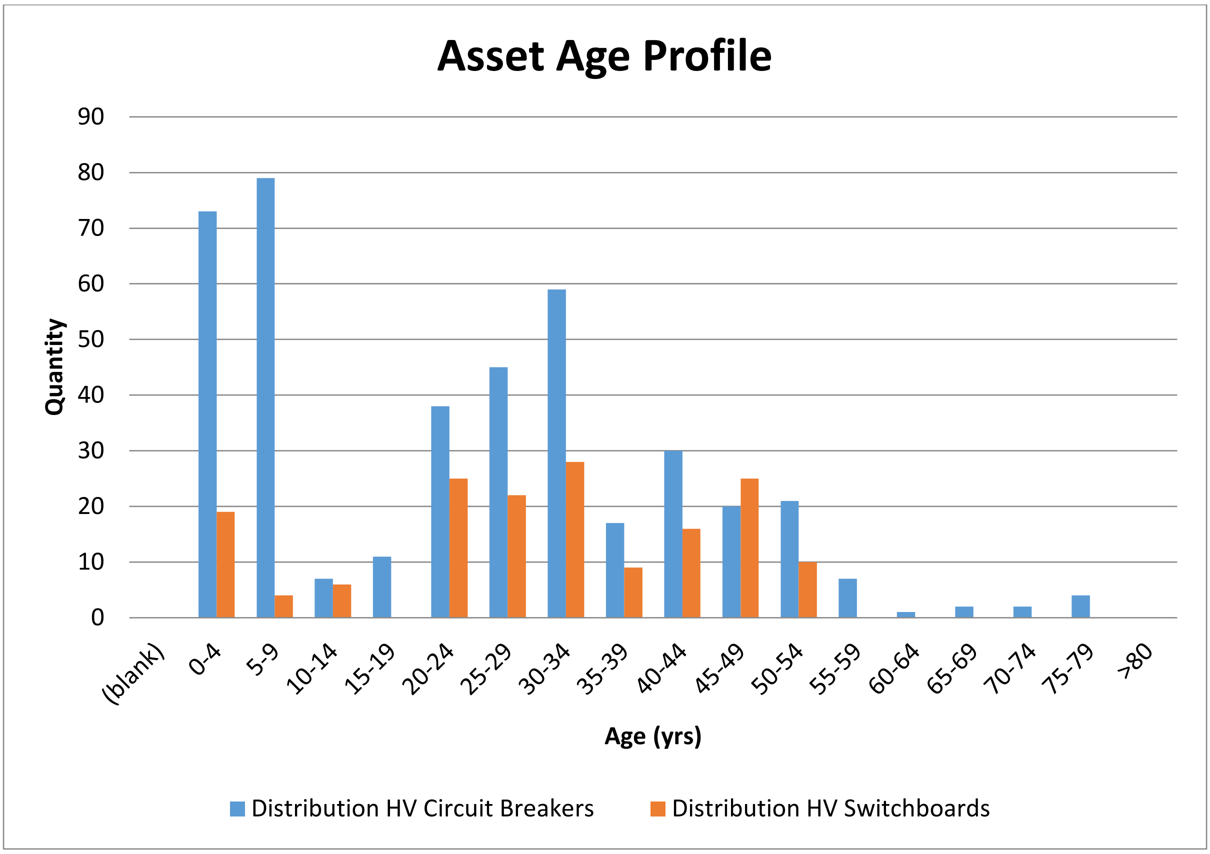


**Figure 2: Age Profile of Distribution HV Switchboard Assembly Assets**

## 3.4 Asset Condition Profile

Table 4 gives details of the current condition of the distribution HV switchboard assembly assets.

**Table 4: Current Distribution HV Switchboard Assembly Asset Condition**

| Asset Type | Manufacturer | Model | Quantity | Average Health |
|---|---|---|---|---|
| **Distribution HV Switchboard** | | | **194** | |
| | **BROWNBOVERI** | | **41** | Good |
| | | GCB | 41 | Good |
| | **GEC** | | **6** | Excellent |
| | | UNKNOWN | 6 | Excellent |
| | **HITACHI** | | **10** | Excellent |
| | | VCB | 10 | Excellent |
| | **HOLEC/HAZEMEYER** | | **23** | Excellent |
| | | (blank) | 6 | Excellent |
| | | UNKNOWN | 9 | Excellent |
| | | VCB | 8 | Excellent |
| | **NU-LEC** | | **9** | Excellent |
| | | UNKNOWN | 9 | Excellent |
| | **REYROLLE** | | **31** | Poor |
| | | UNKNOWN | 3 | Fair |
| | | OCB | 2 | Good |
| | | LMT/X6/JO | 11 | Poor |
| | | LMT/X6/QM | 10 | Poor |
| | | LMT/X31/QM | 5 | Fair |

| | | | | |
|---|---|---|---|---|
| | **SCHNEIDER** | | **17** | Excellent |
| | | AD2 | 14 | Good |
| | | DMVA | 1 | Excellent |
| | | GBCB | 1 | Excellent |
| | | IM | 1 | Excellent |
| | **SCHNEIDERMERLIN** | | **11** | Excellent |
| | | (blank) | 2 | Excellent |
| | | UNKNOWN | 1 | Excellent |
| | | DMVA | 1 | Excellent |
| | | GBCB | 1 | Excellent |
| | | IM | 4 | Excellent |
| | | IMB | 2 | Excellent |
| | **SOUTHWALES** | | **16** | Fair |
| | | OCB | 16 | Fair |
| | **UNKNOWN** | | **30** | Fair |
| | | UNKNOWN | 30 | Fair |
| **Distribution HV Circuit Breaker** | | | **136** | |
| | **BROWNBOVERI** | | **41** | Excellent |
| | | GCB | 41 | Excellent |
| | **GEC** | | **6** | Excellent |
| | | SP | 6 | Excellent |
| | **HOLEC/HAZEMEYER** | | **6** | Excellent |
| | | UNKNOWN | 3 | Excellent |
| | | VCB | 3 | Excellent |
| | **NU-LEC** | | **9** | Excellent |
| | | SP | 9 | Excellent |
| | **REYROLLE** | | **27** | Fair |
| | | UNKNOWN | 5 | Poor |
| | | OCB | 2 | Good |
| | | LMT/X6/JO | 7 | Fair |
| | | LMT/X6/QM | 8 | Fair |
| | | LMT/X31/QM | 5 | Good |
| | **SOUTHWALES** | | **15** | Fair |
| | | OCB | 15 | Fair |
| | **UNKNOWN** | | **31** | Excellent |
| | | UNKNOWN | 31 | Excellent |
| | **(blank)** | | **1** | Excellent |
| | | (blank) | 1 | Excellent |
| **Grand Total** | | | **330** | |

**Table 5: Current Distribution HV Switchboard Assembly Asset Condition**

## 3.5 Projected Asset Count

The projected asset count is an estimate of the number of HV switchboard panels by year. Note that the average switchboard assembly consists of seven panels, and each panel generally consists of one circuit breaker. The estimate includes asset additions and retirements through estimated network augmentation and asset retirements over the period. The downward trend is due to the vast majority of new substation installations containing ring main units as opposed to switchboards, as well as due to targeted replacements of in service switchboards. Refer to Figure 2 for details.

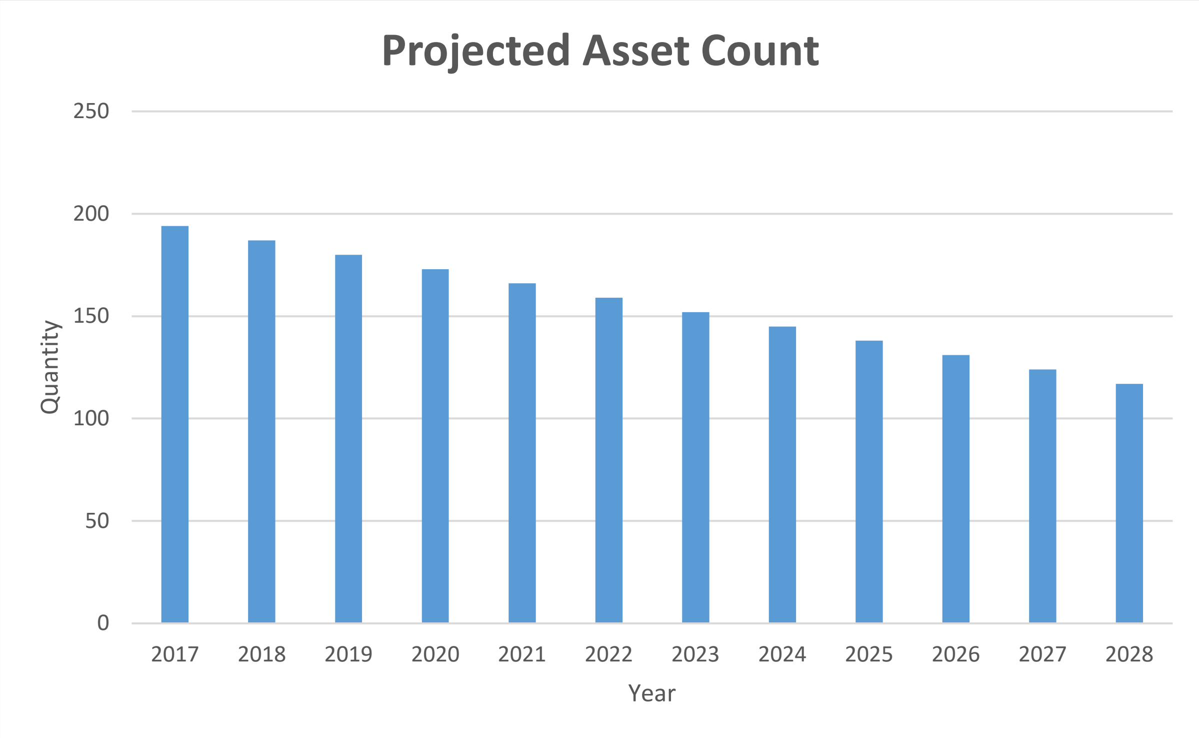


**Figure 3: Projected Asset Count of Distribution HV Switchboard Assembly Assets**

## 3.6 Data Sources

Effective asset management relies on accurate asset information. The Asset Management System uses the following data sources for asset management:

- Geospatial Information System (GIS) Including Asset Inventory – Esri GIS;
- Works Management System – Cityworks;
- Advanced Distribution Management System (ADMS) – Schneider Electric;
- Finance Management System – Oracle;
- Asset Management & Modelling System - Riva Modelling.

### 3.6.1 Data Quality

Data Completeness

- All in-service assets are included in the asset database;
- Data quality is poor for this asset class, refer to the data accuracy section below;

- All assets proposed to be installed or removed during the regulatory period are considered.

### 3.6.2 Data Accuracy

The following outlines data quality issues affecting the quality of this ASP

- Asset make and model information is inaccurate or missing;
- Not all assets which have been replaced have been processed in the database;
- Asset owner information is inaccurate or missing. This is required to define asset management responsibilities for assets connected to the network;
- Due to a blurred definition between Switchboard and Ring Main Unit, distinction and clear numbers of each asset type are poor for older assets.

Data Improvements

- Capture asset make and model for assets with missing data;
- Various data rectification works, specifically with asset manufacturer and type (i.e. ring main unit or switchboard). This can be achieved in conjunction with the routine visual substation inspection program.

# 4 Asset Performance Requirements

This section details the reliability and performance requirements of the HV switchboard assembly asset class.

## 4.1 Failure Modes

### 4.1.1 Failure Mode Effects Analysis (FMEA)

RIVA DS is the ActewAGL asset management analysis and decision support software. It has a range of functions, including a forecasting tool for most of the significant CAPEX and OPEX projections made by ActewAGL. For details on how RIVA asset data is analysed and modelled, refer to the Asset Management System Manual document.

This ASP uses a risk assessment approach based on the frequency of incidents and their severity to generate a Risk Priority Number (RPN) which is used in prioritising expenditure activities. It is a key output from the ActewAGL Failure Mode and Effects Analysis (FMEA) approach to improving reliability and reducing maintenance costs. A series of factors contributing to probability and consequence of failure for respective asset classes are identified, analysed and rated by a team of cross-functional subject matter experts. These are then utilised as inputs to Riva.

### 4.1.2 Deterioration Drivers and Common Modes of Failure

Tables in the following section will for each asset type summarise their common modes of failure. They have been configured to show the assessed effects of each failure mode in terms of severity, occurrence and detection which are the inputs to Riva. Column 6 shows the resultant Riva generated "Risk Priority Number"

The following summarises the deterioration drivers and common failure modes for the distribution switchboard assembly asset by asset type;

#### *4.1.2.1 Distribution HV Switchboard*

**Deterioration Drivers**

- Deterioration of solid insulation due to moisture ingress, heat (loading), surface contamination, erosion due to burning (arcing) and overvoltage;
- Mechanical deterioration of mechanical components from duty;
- Ingress of dust from polluted substation environment.

**Failure Modes**

| Failure Mode | Description | Severity | Occurrence | Detection | RPN |
|---|---|---|---|---|---|
| Catastrophic– Insulation breakdown failure | Failure of Switchboard insulation or housing causing a fault. | 8 | 5 | 7 | 280 |

**Table 6: Distribution HV Switchboard Modes of Failure**

#### *4.1.2.2 Distribution HV Circuit Breaker*

**Deterioration Drivers**

- Deterioration of solid insulation due to moisture ingress, heat (loading), surface contamination, erosion due to burning (arcing) and overvoltage;
- Deterioration of lubrication due to drying or contamination over time;
- Erosion of arcing contacts resulting in excessive arcing and damage to interrupter components;
- Mechanical deterioration of mechanism components from duty;
- Aging of control and protection electronics

**Failure Modes**

| Failure Mode | Description | Severity | Occurrence | Detection | RPN |
|---|---|---|---|---|---|
| Slow or no response to protection command | Potentially arising from poor connections, poor lubrication, and/or general mechanical failures. Result is failure to respond as designed to deal with switching operations or faults (make/break current). | 6 | 5 | 7 | 210 |
| Catastrophic failure of breaker | Failure of breaker causing fault/in-operation. | 7 | 5 | 7 | 245 |

Table 7: Distribution HV Circuit Breaker Modes of Failure

## 4.2 Asset Utilisation

This section details the utilisation level of the assets. Depending on the asset type, the level of utilisation will have a direct impact on asset condition and performance deterioration rates.

### 4.2.1 Capacity and Capability

The capacity of distribution HV switchboard assembly assets relates to operating parameters such rated voltage, rated (normal) current, rated short time withstand current and rated breaking current. To ensure their reliability the assets must be operated within their respective ratings.

### 4.2.2 Utilisation

Distribution HV switchboard assembly assets operate continuously and the utilisation is driven by network demand and network configuration. Assets may be exposed to short term higher loading during contingent network configurations.

ActewAGL's HV switchboards generally consist of seven HV panels. Two of these would normally be for incoming feeders, two for transformers feeders, and three for out-going feeder circuits. The incomer and transformer feeders would usually have N-1 redundancy and therefore their utilization is 50% or less of their rated (normal) current.

## 4.3 Risk and Criticality

This section details the criticality of the distribution HV switchboard assembly assets and their exposure to risk.

### 4.3.1 Asset Criticality

Asset criticality is dependent on the risk exposure to ActewAGL. Distribution HV switchboards supply residential and commercial customers, therefore the criticality for this asset class is dependent on the customer-type that it supplies. For example assets supplying commercial customers such as businesses and hospitals have a higher criticality than residential customers. The overall criticality for this asset class is categorised as medium.

In some cases in the event of an asset failure, customers can be supplied via an HV tie to restore supply until HV switchboard assets are repaired.

### 4.3.2 Geographical Criticality

Geographic criticality of HV switchboard assembly assets is affected by rural or urban location and proximity to public places. Failures with a safety or bushfire risks are higher in rural areas due to the increased likelihood of a bushfire.

Generally HV switchboard assembly assets are installed in brick/concrete buildings, known as chamber substations. These buildings are secure and the switchboards only accessible by trained personnel, therefore the risk of damage from vehicles and vandalism is low. Risk to the public is also low.

### 4.3.3 Asset Reliability

By nature of their function HV Switchboards are expected to deliver a very high level of service reliability. They are required to be in service more than 99% of the time. They are required to provide this reliability level continuously till the end of their service life which is around 40 years in the case of oil circuit breakers and 50 years for vacuum circuit breakers.

HV switchgear failures are rare but usually catastrophic.

# 5 Asset Management Strategy Options

This section outlines the options considered for the management of distribution HV switchboard assembly assets throughout their lifecycle and their assessed relative merits. It recommends an asset specific strategy that best supports the business asset management policy, strategy and objectives. It is implemented by the Asset Specific Plan as covered by this document.

## 5.1 Option Evaluation Methodology

#### *5.1.1.1 Financial Cost/Benefit Assessment*

The options are assessed in terms of their resultant OPEX, CAPEX and risk exposure costs. The option specific financial assessments are generated as outputs from the Riva system which are then factored into the options assessment process.

#### *5.1.1.2 Qualitative Risk Assessment*

Qualitative assessments of the risks and consequences inherent to each option have been undertaken utilising the standard methodology from the ActewAGL "Energy Networks Risk Assessment Tables".

## 5.2 Options - Discussion and Evaluations

Options for the asset specific strategies are evaluated against their relative cost, risk, benefits, and consider trade-offs between capital and operational expenditure to deliver the asset management objectives. The options that have been considered are as follows:

- Option 0 – Reactive Strategy;
- Option 1 – Existing Strategy;
- Option 2 – Reduce Cost;
- Option 3 – Reduce Risk.

### 5.2.1 Option 0 – Reactive Strategy

Under this option no controls such as proactive maintenance, condition assessment or planned replacement are applied. Any maintenance or asset replacement is purely reactive and is undertaken when the asset is no longer suitable for service which may be due to any of:

- A major failure that is not repairable;
- Unacceptably high incidence of defects that impact on the asset serviceability which, although repairable, are not economically or technically viable.

Thus this option incorporates:

- Reactive (corrective) maintenance;
- Reactive replacement of (failed) assets

This option delivers a drastic reduction in both OPEX and CAPEX expenditure, although simultaneously severely sacrificing risk exposure. The cost of this option is $900,000 (2017/18 – 2029/30).

#### 5.2.1.1 Risk Outcomes

As asset condition deteriorates and assets approach the end of their life, the risk exposure of this option rapidly increases. A qualitative risk assessment of this option highlights the inherent risks (no controls) of this asset class and the risk exposure. This is shown in Table 6.

| | | Inherent Risk | | | | |
|---|---|---|---|---|---|---|
| Likelihood | Almost Certain | | | | | |
| | Likely | Low<br>3 | Medium<br>1 | | | |
| | Possible | | Medium<br>6 | Medium<br>2 | | |
| | Unlikely | | Low<br>1 | | Medium<br>1 | |
| | Rare | Low<br>4 | Low<br>2 | Low<br>3 | Medium<br>1 | Medium<br>1 |
| | | Negligible | Minor | Moderate | Major | Severe |
| | | Consequence | | | | |

**Table 8: Qualitative Risk Assessment – Option 0**

A quantitative risk assessment for this option has been modelled to estimate the risk exposure and is shown in Figure 3.

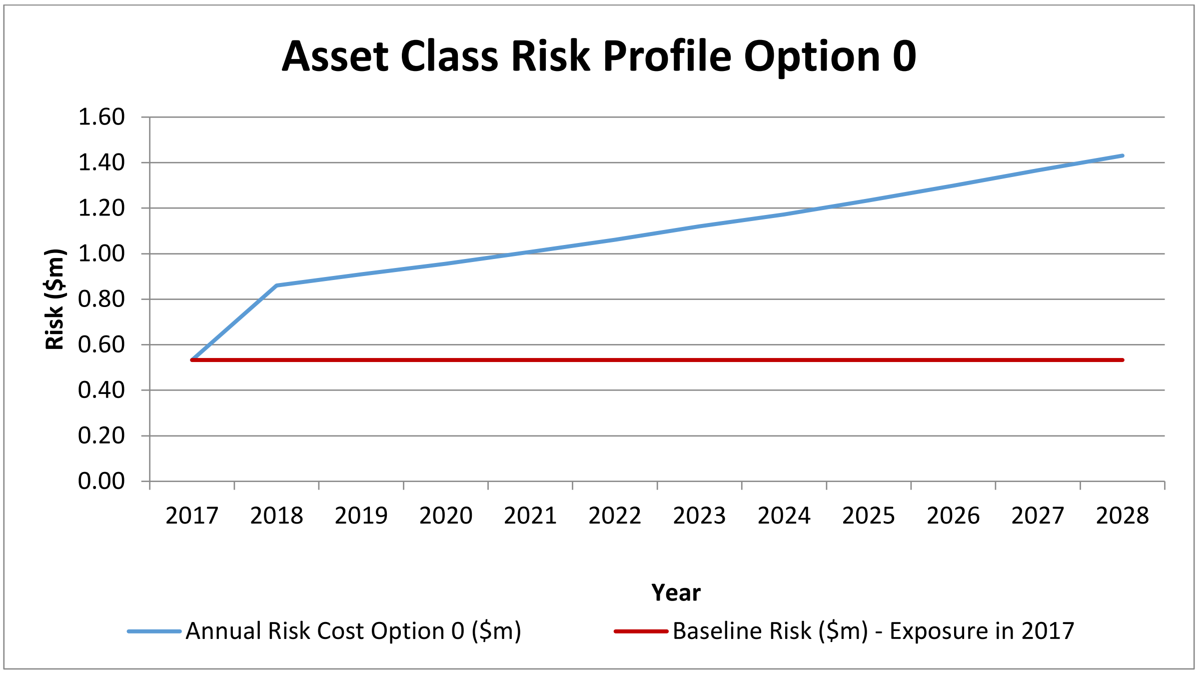


**Figure 4: Risk-Cost Analysis – Option 0**

#### 5.2.1.2 Summary of Options Benefits

This option delivers the least OPEX and CAPEX at least in the early part of the asset life. CAPEX will continue to be deferred as unplanned OPEX and risk costs escalate as the assets deteriorate through their life.

#### 5.2.1.3 Summary of Options Dis-benefits

This option delivers the following disbenefits (negative outcomes):

- Non-compliance with regulatory obligations;
- Inconsistent with contemporary industry practice and prudent asset management;
- Increased STPIS costs associated with unplanned customer outages, and increased capital expenditure for reactive asset replacements.

### 5.2.2 Option 1 – Existing Strategy at Current Expenditure Level

This option covers the existing strategy as applied to the management of the Distribution HV Switchboard Assembly assets. This strategy includes planned maintenance, planned opportunistic replacement, and reactive replacement to manage assets at their lowest lifecycle cost. This strategy looks to optimise CAPEX and OPEX costs and manage the risk presented through considered CAPEX and OPEX trade-offs which incorporate:

- Planned and unplanned maintenance of HV circuit breakers (5 year time based schedule for majority of circuit breaker types);
- 5 year substation visual inspection;
- Thermovision;
- Planned opportunistic replacement of defective assets or assets with no support for spare parts (one switchboard replaced per year);
- Repair or replace on failure for HV circuit breakers and switchboards.

This strategy uses an asset condition and risk approach to determine opportunistic planned replacements. The quantified risk provides a means for the ranking of assets relative to the risk they present and forms the basis of programs for their mitigation.

This option aims to deliver an approximate continuation in both OPEX and CAPEX expenditure, resulting in retaining risk exposure at similar or current (2017/18) levels. The cost of this option is $6,127,003 (2017/18 – 2029/30).

#### 5.2.2.1 Risk Outcomes

This option enables the risks presented by deterioration and inherent design faults to be mitigated through the combination of:

- Planned maintenance;
- Planned replacement of assets with high risk exposure from defect or operational safety constraint issues.

The exposed asset class risk ratings for this option at the end of the regulatory period (2024) are shown in Table 8.

| Likelihood | Option 1 Risk | | | | |
|---|---|---|---|---|---|
| Almost Certain | | | | | |
| Likely | Low 2 | | | | |
| Possible | Low 1 | Medium 3 | Medium 1 | | |
| Unlikely | | Low 5 | Medium 1 | | |
| Rare | Low 4 | Low 2 | Low 3 | Medium 2 | Medium 1 |
| | Negligible | Minor | Moderate | Major | Severe |
| | Consequence | | | | |

Table 9: Qualitative Risk Assessment – Option 1

A quantitative risk assessment for this option has been modelled to estimate the risk exposure and is shown in Figure 4.

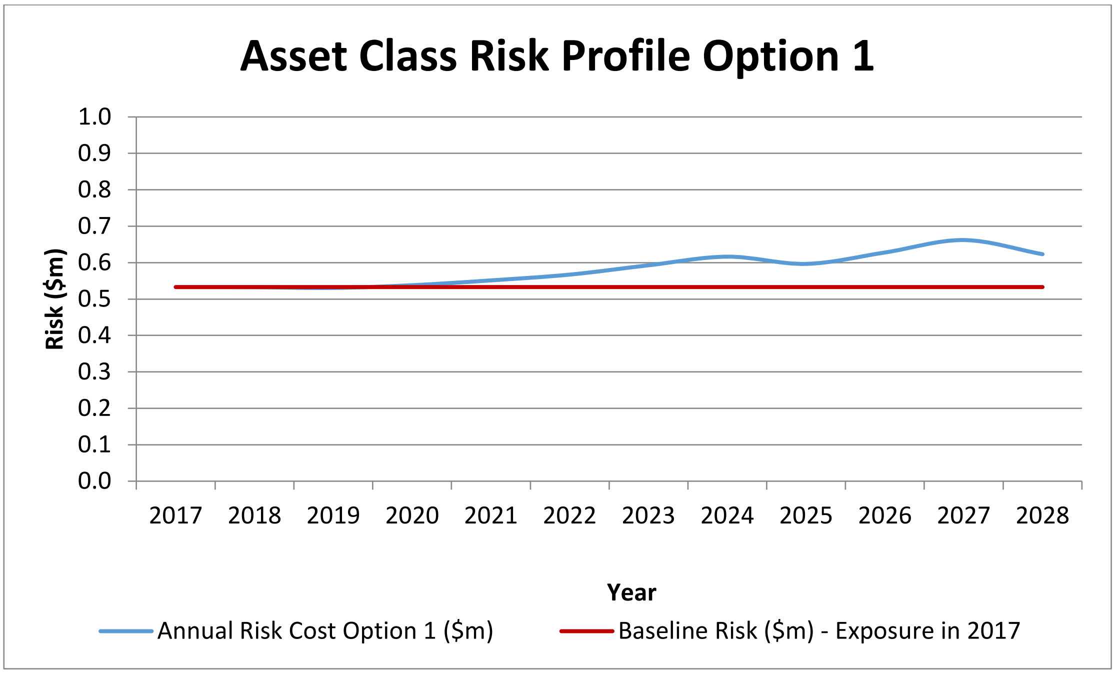


Figure 5: Risk-Cost Analysis – Option 1

### 5.2.2.2 *Summary of Options Benefits*

This option delivers the following benefits:

- Reduce the safety risk with planned low-priority replacement of switchboards with operational constraints or no spare parts support;
- Maintain HV circuit breaker performance and thus network performance.

##### 5.2.2.3 *Summary of Options Dis-benefits*

Inherent to this option is the ongoing operational costs associated with planned HV circuit breaker maintenance. If the time based maintenance interval is too low then the maintenance expenditure will be unnecessary and premature. If this interval is too high then undetected incipient failure may occur resulting in a failure of the circuit breaker.

### 5.2.3 Option 2 – Reduce Cost

This option evaluates a scenario of reduced cost of the Distribution HV Switchboard Assembly assets. Under this option the following reductions from the current strategy would be implemented:

**HV Switchboards**

- No proactive planned replacement, reactive replacement after failure only.
- Thermovision performed only on substations operating at or above 50% utilisation.

**HV Circuit Breakers**

- Extend the planned maintenance time based interval from 5 to 6 years on select HV CBs. HV CBs selected include CBs where poor operational performance is not experienced.
- Thermovision performed only on substations operating at or above 50% utilisation.

This option delivers a reduction in both OPEX and CAPEX expenditure, although it does sacrifice risk management. The cost of this option is $1,746,079 (2017/18 – 2029/30).

##### 5.2.3.1 *Risk Outcomes*

The exposed asset class risk ratings for this option are shown in Table 8.

| | | Option 2 Risk | | | | |
|---|---|---|---|---|---|---|
| Likelihood | Almost Certain | | | | | |
| | Likely | | | | | |
| | Possible | Low 5 | Medium 1 | Medium 2 | | |
| | Unlikely | Low 1 | Low 4 | | | |
| | Rare | | Low 2 | Low 5 | Medium 2 | Medium 3 |
| | | Negligible | Minor | Moderate | Major | Severe |
| | | Consequence | | | | |

**Table 10: Qualitative Risk Assessment – Option 2**

A quantitative risk assessment for this option has been modelled to estimate the risk exposure and is shown in Figure 5.

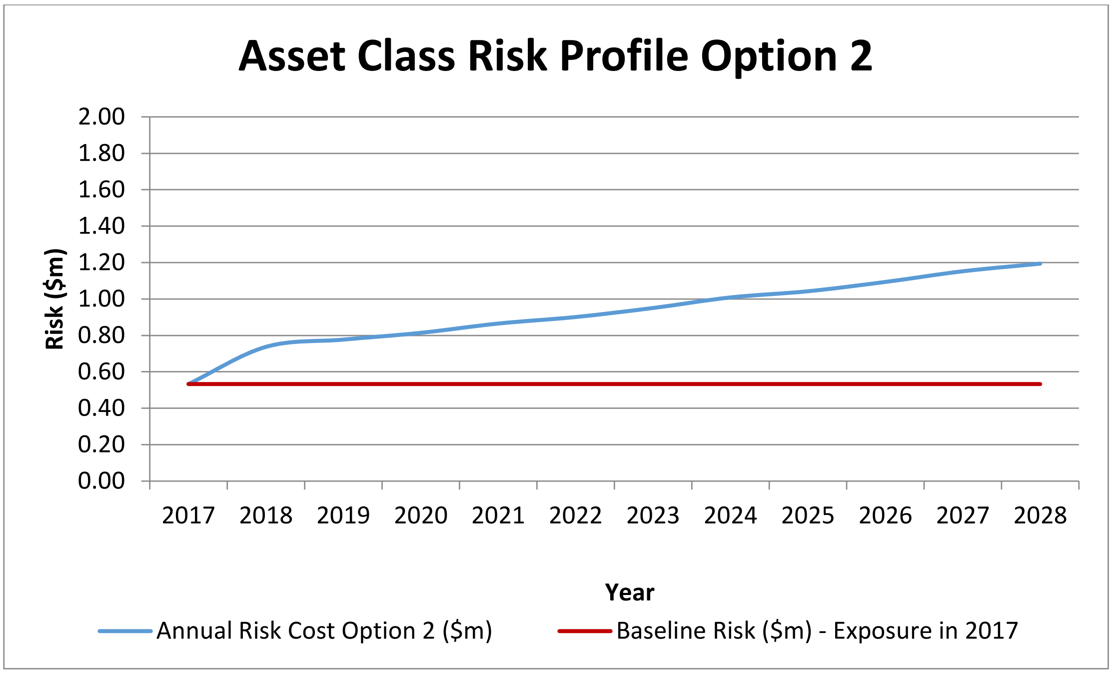


**Figure 6: Risk-Cost Analysis – Option 2**

#### *5.2.3.2 Summary of Options Benefits*

This option results in reduced operational and capital costs, particularly in the first half of the assets' lifecycle.

It has been found that thermovision of assets, in the majority of cases, is only useful if the asset is utilised to a certain level. This is because hot spots are more prevalent based on the loading of the asset. This option therefore provides lower operational costs, as well as more fruitful condition-monitoring activities.

#### *5.2.3.3 Summary of Options Dis-benefits*

This option delivers the following disbenefits (negative outcomes):

- Reduced maintenance of HV circuit breakers may result in poor HV circuit breaker performance without conducting an FMEA study on these assets
- No planned program to replace assets with defects and no support for spare parts have high safety and network reliability risk exposure

### 5.2.4 Option 3 – Reduce Risk

This option considers a scenario to reduce the risk exposure of Distribution HV Switchboard Assembly assets. For this option the following changes are made from the existing strategy:

**HV Switchboards**

- Planned opportunistic replacement of defective assets or assets with no support for spare parts – accelerated over current strategy (two replacements per year);
- Perform condition monitoring - on-line PD testing.

**HV Circuit Breakers**

- Planned opportunistic replacement of defective assets or assets with no support for spare parts – accelerated over current strategy;
- Exercise breakers which cannot be maintained (to commence FY 18/19);
- Perform condition monitoring - on-line PD testing;
- For new installations or replacements, replace Oil CBs with Vacuum or SF6 circuit breakers.

This option delivers an increase in both OPEX and CAPEX expenditure, resulting in a lowering of risk exposure as compared to historical levels. The cost of this option is $6,551,145 (2017/18 – 2029/30).

#### *5.2.4.1 Risk Outcomes*

This option reduces the risk by:

- Identify and treat insulation defects through PD testing;
- Replacement of HV switchboards and CBs with defects or no support for spare parts;
- Reduce the cost of failure of HV CBs by replacing old Oil CBs with Vacuum or SF6 insulated units.

The exposed asset class risk ratings for this option are shown in Table 11.

| | | Option 3 Risk | | | | |
|---|---|---|---|---|---|---|
| Likelihood | Almost Certain | | | | | |
| | Likely | | | | | |
| | Possible | Low 5 | Medium 1 | Medium 2 | | |
| | Unlikely | Low 1 | Low 1 | | | |
| | Rare | | Low 5 | Low 5 | Medium 2 | Medium 3 |
| | | Negligible | Minor | Moderate | Major | Severe |
| | | Consequence | | | | |

**Table 11: Qualitative Risk Assessment – Option 3**

A quantitative risk assessment for this option has been modelled to estimate the risk exposure and is shown in Figure 6.

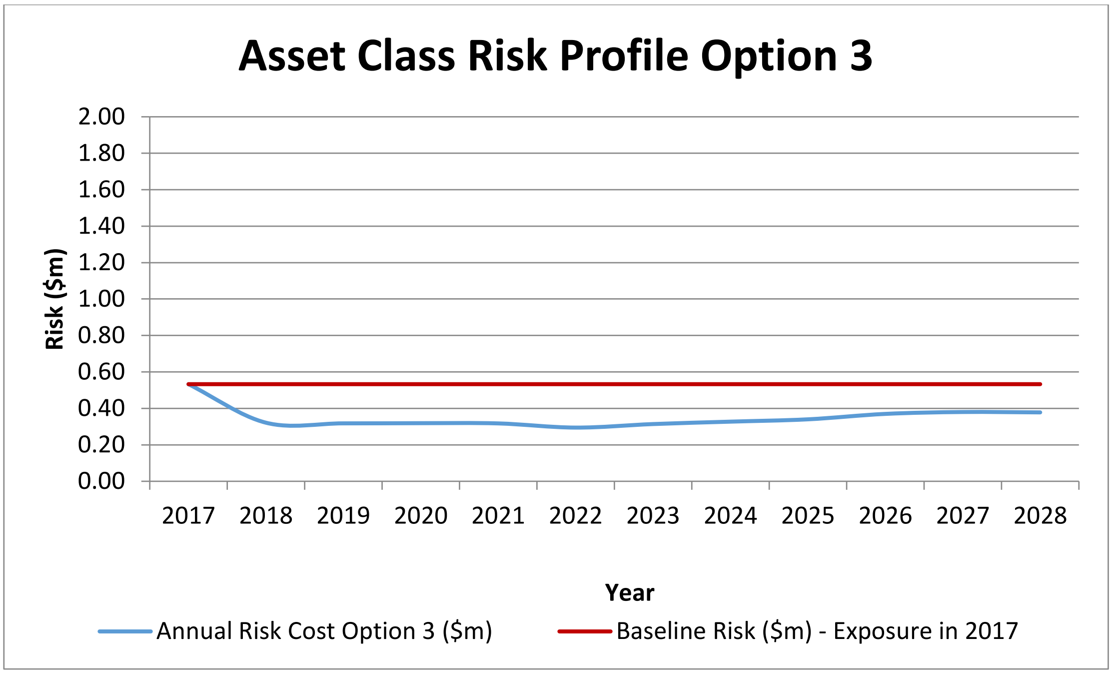


**Figure 7: Risk-Cost Analysis – Option 3**

### *5.2.4.2 Summary of Options Benefits*

This option delivers the following benefits:

- Reduced probability of asset failure with PD testing and resulting targeted replacement;
- Reduced safety risk – removal of assets with defects or cannot be maintained due to no spare parts support;
- Reduce cost of failure of HV CBs – for new installations or replacements, replace Oil CBs with Vacuum or SF6.

### *5.2.4.3 Summary of Options Dis-benefits*

This option results in the following disbenefits (negative benefits):

- Increased, ongoing operational costs compared to the current strategy.
- Increased capital expenditure to replace assets that may not be at end of life, although are unmaintainable.

## 5.3 Option Evaluation

In order to assess the most optimal HV switchboard assembly management strategy, a condition and risk-cost based modelling approach has been conducted using the RIVA Asset Management modelling tool for the various scenarios.

This section provides a summary comparison of the evaluations of the options.

### 5.3.1 Engineering and Risk Evaluation

**Option 0 – Reactive**

Reactive strategy does not meet the asset class objectives and has no controls for high risk assets with very high consequence of failure. Assets in this class especially circuit breakers contain complex mechanical systems requiring regular maintenance to ensure they continue to operate reliably and condition monitoring is fundamental in identifying assets for replacement prior to failure.

Option 1, 2 & 3 are proactive strategies utilising planned maintenance, condition monitoring and planned asset renewal to ensure the reliable and safe operation. These strategies satisfy the asset class objectives, control risk to an acceptable level and are technically feasible.

**Option 1 - Current**

This strategy employs a historically tested strategy that satisfactorily manages circuit breaker performance and HV switchboard reliability. Routine maintenance and planned replacement of the oldest and unsupported units has resulted in acceptable levels of network performance.

This option manages assets at an acceptable risk.

**Option 2 – Reduce Cost**

Reduce cost sees the planned switchboard replacement program coming to an end, with the only replacements undertaken being a result of in-service failure or from significant terminal thermography results. Further, the maintenance strategy for circuit breakers has been extended from five years to six. The outcome of this change is hard to quantify, however given the manageable population of circuit breakers it does not result in significant OPEX savings.

This option employs a decreased frequency of condition based monitoring and planned maintenance to reduce the lifecycle cost, however at the expense of an increasing risk exposure that results in over double the current (2017/18) risk-cost experienced within the next 10 year period.

**Option 3 – Reduce Risk**

Reduce risk incorporates additional targeted replacement of old unsupported switchboards, dedicated condition monitoring in the form of online PD testing, and the cessation of oil circuit breakers being installed.

Past performance of circuit breakers has been good and benefits from additional targeted condition monitoring is estimated to be minimal. Further, online PD testing has been identified as part of the recommended strategy within the High Voltage Underground Cable asset specific plan for high voltage terminations, and will be leveraged to provide condition data for this asset class.

## 5.3.2 Financial Evaluation

Financial comparison of technically feasible and acceptable risk options are summarised in Table 12. This summary includes forecast budget CAPEX and OPEX for the period 2018-24 and for comparison the 10 year and 30 year NPC of TOTEX and risk exposure.

| Option | Budget ($m) 2018-24 | | | NPC ($m) 10 yrs | | | NPC ($m) 30 yrs | | | Average Annual Risk 30 years ($m) | Rank |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | TOTEX | CAPEX | OPEX | TOTEX | Risk | TOTEX + Risk | TOTEX | Risk | TOTEX + Risk | | |
| Option 0 | 0.00 | 0.00 | 0.00 | 0.569 | 5.939 | 6.508 | 0.57 | 20.00 | 20.57 | 1.79 | 4 |
| Option 1 | 2.18 | 1.53 | 0.65 | 3.112 | 3.258 | 6.370 | 5.39 | 7.28 | 12.67 | 0.60 | 2 |
| Option 2 | 0.39 | 0.00 | 0.39 | 1.018 | 5.234 | 6.252 | 3.81 | 11.46 | 15.26 | 0.88 | 3 |
| Option 3 | 3.83 | 3.20 | 0.63 | 4.118 | 2.052 | 6.170 | 5.59 | 4.41 | 10.00 | 0.35 | 1 |

Table 12: Cost and Risk Strategy Options Summary

The graph in Figure 8 provides an overall picture of all five risk options.

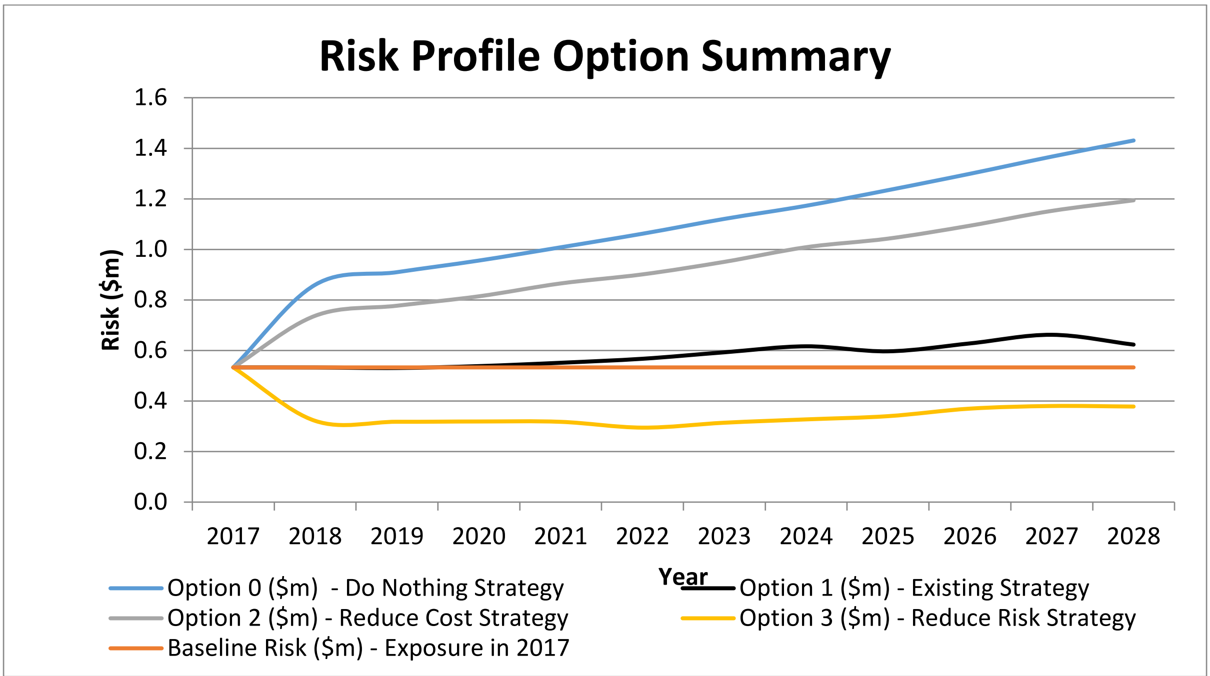


Figure 8: Risk Profile Comparison – Distribution HV Switchboard Assembly Assets

### 5.3.3 Options Assessment

The evaluated options are also compared utilising the ActewAGL corporate methodology in which qualitative assessment is made of the extent to which each option satisfies the specified criteria as shown in the following table.

| Criteria | Description and Weighting |
|---|---|
| **Cost** | This ranks the relative CAPEX and OPEX costs associated with the options. The weighting reflects the relative importance of this criterion. |
| **Risk – Safety, Environmental, Reliability, Other** | The extent to which the option provides mitigation/controls to risks identified. The weighting reflects the relative importance of this criterion. |
| **Strategic Objectives** | The extent to which the option meets the requirements of the asset management strategic objectives. The weighting reflects the relative importance of this criterion. |
| **Innovation/Benefits** | The extent to which the option provides business benefits including but not limited to information or intelligence to support innovative asset management and network operation. The weighting reflects the relative importance of this criterion. |

**Table 13: Option Evaluation Scoring Criteria**

| | Criteria | | | | Option Score |
|---|---|---|---|---|---|
| | Cost | Risk | Strategic Objectives | Innovation / Benefits | |
| **Criteria Weighting** | **30%** | **30%** | **30%** | **10%** | **100%** |
| Option 0 – Reactive Strategy | 3 | 0 | 0 | 0 | 30% |
| Option-1 – Current Strategy | 2 | 3 | 2 | 1 | 73% |
| Option 2 – Reduce Cost | 3 | 1 | 0 | 1 | 43% |
| Option 3 – Reduce Risk | 2 | 3 | 1 | 1 | 63% |

| Scoring Key | | | |
|---|---|---|---|
| 0 | Fatal flaw | 1 | Unattractive |
| 2 | Acceptable | 3 | Attractive |

**Table 14: Scoring Matrix**

## 5.4 Recommended Option

This section provides an overview of the recommended option and its outcomes for the period 2019-24.

### 5.4.1 Recommendation

The recommended option is Option 1 – Current Strategy. This option satisfies the asset class objectives, manages risk to an acceptable level and delivers the outcomes which most completely satisfy the Corporate Criteria.

With emerging disruptive technologies, uncertainty of future load, and potential for stranded assets, emphasis is given to the option which manages risk at acceptable levels at the least TOTEX cost.

Note that it has been decided that moving forward, AAD will only perform thermovision for distribution substation equipment operating at or over 50% of the rated loading due to recent findings regarding the efficacy of this practice. This is the only planned deviation from the current and recommended HV switchboard assembly management strategy, within this program.

Other program changes however do affect the HV switchboard assembly assets. Specifically, the HV UG Cable Asset Specific Plan incorporates partial discharge (PD) analysis testing on cable terminations. During this test, the HV switchboards and HV circuit breakers will be analysed for partial discharge defects.

### 5.4.2 Forecast Asset Condition

Health profile is determined by asset condition and performance history. Condition is determined by the asset's capacity to meet requirements, asset reliability and its level of obsolescence. Obsolescence will be determined by maintenance requirements and availability of support from manufacturers.

The future health profile is the asset health profile at the end of the Regulatory Period, year 2024, under the recommended option to maintain risk exposure. This forecast is based on:

- Initial health profile
- Deterioration due to aging
- Deterioration where condition monitoring identifies specific risks for certain models of equipment
- Allowance made for replacement and refurbishments.

A strategic decision is made at the start of the period on the adequacy of the asset class health, and whether the asset class health should be maintained, improved, or allowed to decline during the period. The maintenance program is adjusted to achieve the required asset class health at the end of the period.

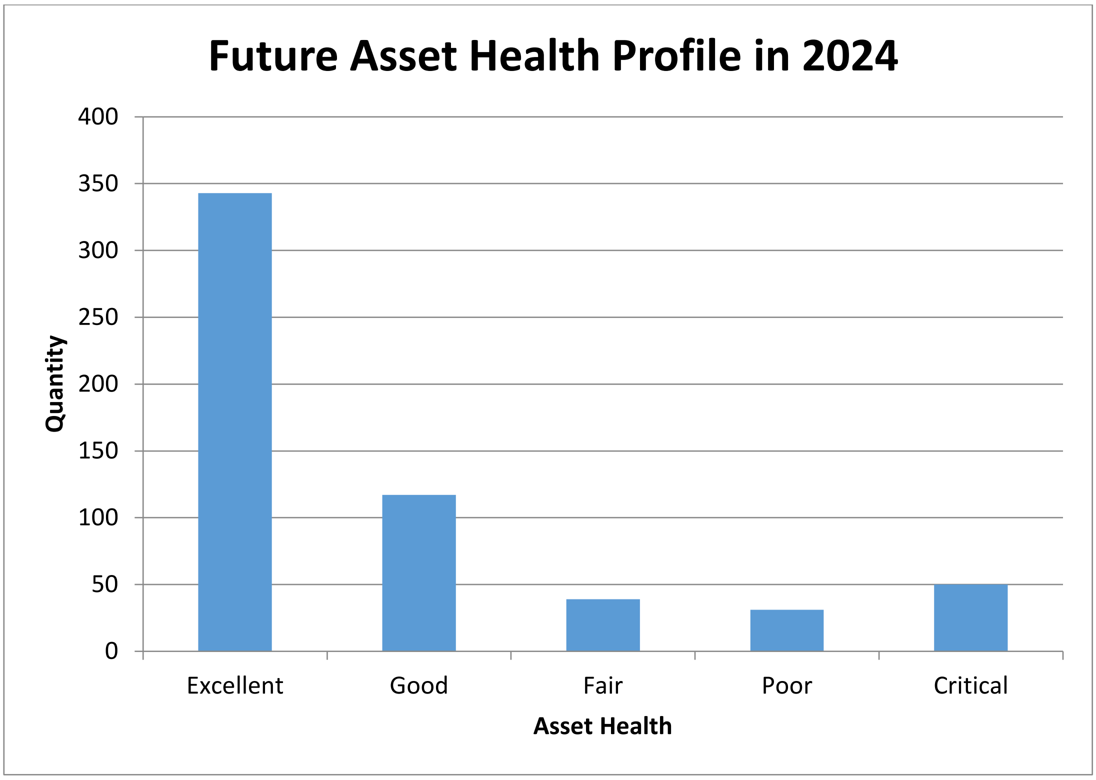


**Figure 9: Asset Future Health Profile – Distribution HV Switchboard Assembly Assets**

# 6 Implementation

This section provides implementation details for the recommended asset management strategy option.

## 6.1 Asset Creation Plan

New equipment for this asset class is purchased under period contracts with standard equipment specifications. For detailed equipment specifications refer to the equipment specifications for distribution substation HV switchgear.

HV Switchboard replacements where possible are replaced with ring main units (RMU), however in some situations this is not possible due to existing equipment interfacing requirements and/or physical size/shape restrictions.  In these cases a new HV switchboard will be commissioned.

## 6.2 Asset Maintenance Plan

The objective of this maintenance plan is to economically achieve the longest possible reliable working life of assets. This is done through condition monitoring, preventative and corrective maintenance and has been adapted to ActewAGL's assets, operating environment and conditions.

### 6.2.1 Development

The maintenance plan is designed to achieve the objectives of the asset specific strategy. The following engineering techniques were used to develop the maintenance plan:

- Failure Mode and Effects Analysis (FMEA)
- Condition monitoring
- Historic performance
- Equipment manuals

| Asset Type / Manufacturer | Maintenance Task | Maintenance Trigger |
|---|---|---|
| Distribution HV Circuit Breaker | Maintain Distribution HV Circuit Breaker | 5 years |

Table 15: Distribution HV Switchboard Assembly Protection Asset Maintenance Interval Summary

### 6.2.2 Condition Monitoring

Specific condition monitoring activities are limited to thermovision of the assets, however visual inspections are also performed during routine substation inspections.  Additionally, it is proposed under the Underground HV Cable Asset Specific Plan to perform partial discharge (PD) analysis testing on cable terminations.  During this test, the HV switchboards and HV circuit breakers will be analysed.

The combination of visual inspections, thermovision, and PD analysis will provide a sufficiently accurate indication of asset health, which will be used when considering asset replacement.

### 6.2.3 Maintenance Strategy

HV Switchboards are maintenance free and only HV circuit breakers are subject to a program of planned maintenance. The intervals and scopes are as follows:

#### *6.2.3.1 HV Circuit Breakers*

For circuit breakers planned maintenance is driven by elapsed time. For continued reliable operation, circuit breakers require periodic maintenance to clean and lubricate mechanical components, inspect for contact wear, and test for correct open and close operation. During this scheduled maintenance, protection performance testing is carried out.

#### *6.2.3.2 HV Circuit Breakers – maintenance restriction*

Certain HV circuit breakers have maintenance restrictions imposed by AAD either due to lack of ongoing manufacturer support, or in order to reduce risk. This includes health and safety risk (asbestos material, operational risk).

For these assets maintenance is limited to exercising the CB to reduce the likelihood of failure during operation. This has previously not been undertaken, however it is planned to commence FY 18/19.

| Manufacturer | Maintenance Instruction |
|---|---|
| BROWNBOVERI | Maintain |
| EMAIL | Maintain |
| GEC | Maintain |
| HAWKERSIDDELEY | Maintain |
| HOLEC/HAZEMEYER | Maintain |
| J&P | Maintenance restriction –not supported by AAD or manufacturer |
| LUCY | Maintain |
| NU-LEC | Maintain |
| REYROLLE | Maintenance restriction –not supported by AAD or manufacturer |
| SCHNEIDER | Maintain |
| SCHNEIDERMERLIN | Maintain |
| SOUTHWALES | Maintain |
| YORKSHIRE | Maintenance restriction –not supported by AAD or manufacturer |
| Unknown (blank) | Maintain |

### 6.2.4 Unplanned Maintenance

Unplanned maintenance is undertaken on a needs basis as determined from in-service failure or substation inspection. Where possible it is undertaken as a planned activity and is aligned as far as possible with activities associated with interconnected assets.

## 6.3 Asset Renewal Plan

The asset renewal plan minimises risks presented by deterioration of the assets through planned replacement of assets on a needs or opportunistic basis. As such is considers the following factors;

- Economic obsolescence (less economic to repair/refurbish than to replace with alternative product);
- Technological obsolescence (availability of spare parts and support);
- Safety risk (inherent to construction type, mode of failure etc.);
- Suitability of ratings for installed location.

## 6.4 Asset Disposal Plan

Retired assets are assessed for disposal or recovery under the ActewAGL procedure PR5017, “Recovery and Disposal of Reclaimed Network Assets”.

Those assets containing PCB contaminated oil will be disposed of in accordance with the ActewAGL manual SM4606, “Environmental PCB Management Plan”.

## 6.5 Associated Asset Management Plans

The following asset specific plans are considered within this to optimise the management of distribution substation works by alignment of maintenance and replacement activities:

- Distribution Enclosures
- Distribution Ring Main Units
- Distribution Ground Transformers
- Distribution RMUs
- Distribution LV Switchboard Assembly

Integration and alignment of these plans create a holistic view of distribution substation assets to facilitate the decision to maintain and replace assets. This approach enables efficient asset management and prudent network design by combining delivery activities and realise the full benefits of a distribution substation complete with modern equipment.

## 6.6 Asset Strategy Optimisation Plan

The asset strategy optimisation plan lists initiatives and future improvement opportunities to improve the management of this asset class. This includes:

- Further installation of HV network monitoring and control for benefit to network operations
- Verify asset data in the field to improve asset modelling and effective management

# 7 Program of Work

This section provides the Program of Work and the resulting operational and capital expenditure forecasts.

## 7.1 Maintenance Program

This section outlines the operational expenditure for preventative maintenance, corrective maintenance and condition monitoring.

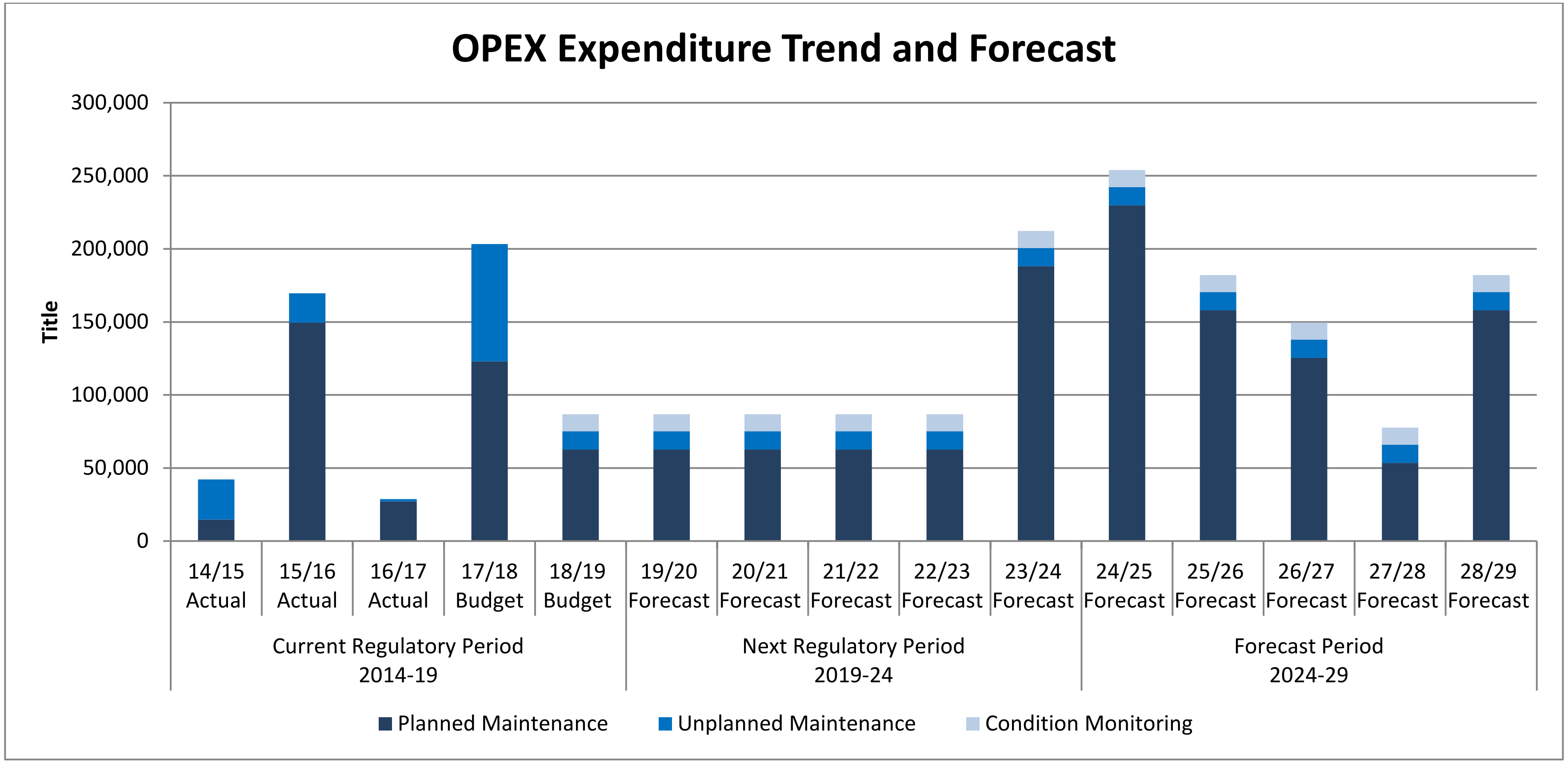


**Figure 10: OPEX for Maintenance Program of Distribution HV Switchboard Assembly Assets**

## 7.2 Capital Program

This section outlines the capital expenditure for asset replacement and refurbishment.

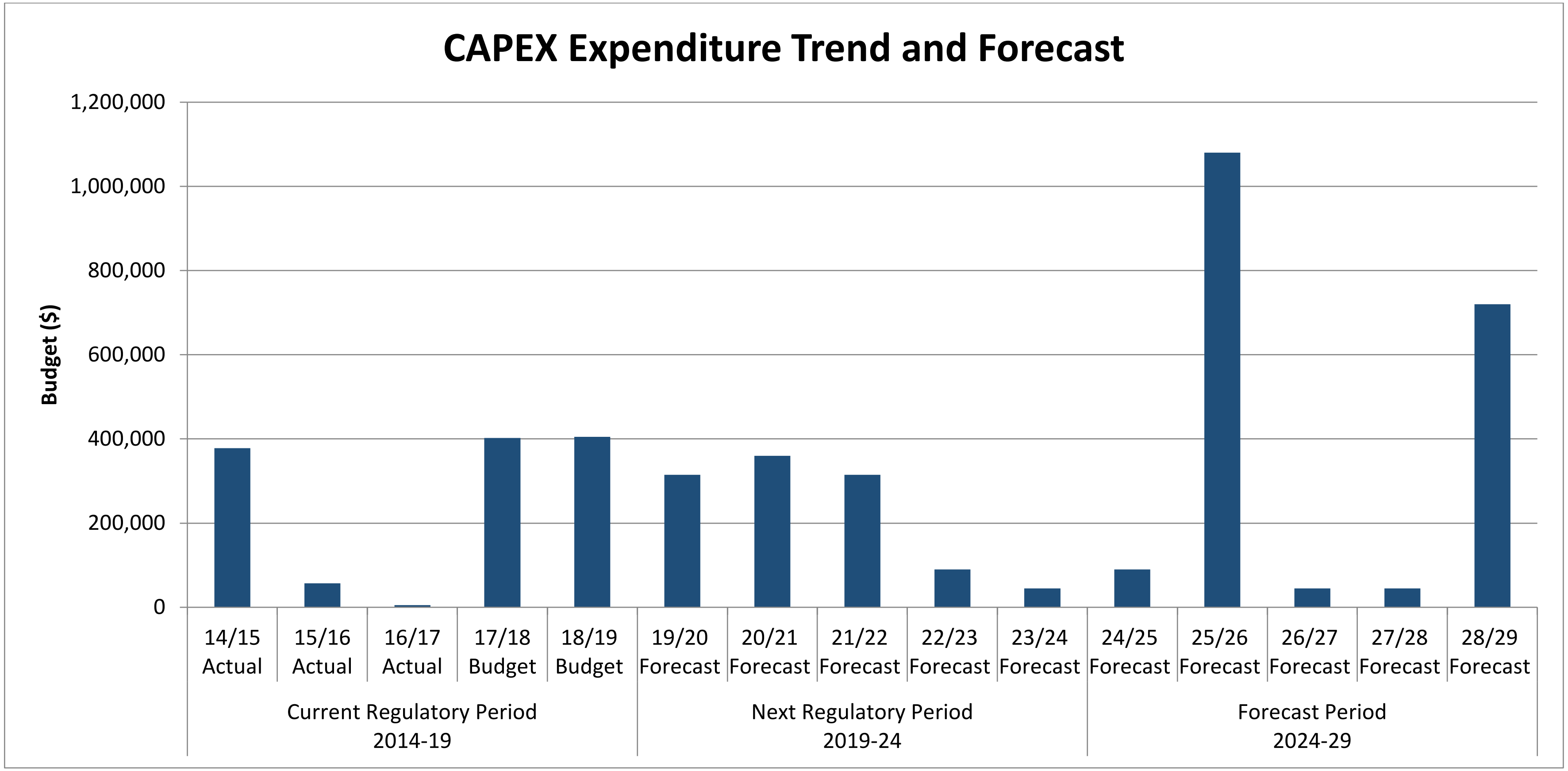


**Figure 11: CAPEX Program for Distribution HV Switchboard Assembly Assets**

## 7.3 Budget Forecast

This section provides a 10 year forecast for the CAPEX & OPEX budgets.

| Total Budget | 2018/19 | 2019/20 | 2020/21 | 2021/22 | 2022/23 | 2023/24 | 2024/25 | 2025/26 | 2026/27 | 2027/28 | 2028/29 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **CAPEX** | **405,000** | **315,000** | **360,000** | **315,000** | **90,000** | **45,000** | **90,000** | **1,080,000** | **45,000** | **45,000** | **720,000** |
| **OPEX** | **86,867** | **86,867** | **86,867** | **86,867** | **86,867** | **212,201** | **253,979** | **182,028** | **149,534** | **77,583** | **182,028** |
| Planned Maintenance | 62,667 | 62,667 | 62,667 | 62,667 | 62,667 | 188,001 | 229,779 | 157,828 | 125,334 | 53,383 | 157,828 |
| Unplanned Maintenance | 12,500 | 12,500 | 12,500 | 12,500 | 12,500 | 12,500 | 12,500 | 12,500 | 12,500 | 12,500 | 12,500 |
| Condition Monitoring | 11,700 | 11,700 | 11,700 | 11,700 | 11,700 | 11,700 | 11,700 | 11,700 | 11,700 | 11,700 | 11,700 |

**Table 16: CAPEX & OPEX 10 Year Budget Forecast**

The replacement projects have been confirmed through an individual Project Justification Report.

## 7.4 Program of Work Summary

| Year | 2018/19 | | 2019/20 | | 2020/21 | |
|---|---|---|---|---|---|---|
| Tasks | Units | Budget ($) | Units | Budget ($) | Units | |
| **CAPEX** | **2** | **402,500** | **2** | **402,500** | **2** | |
| Replace Distribution 11kV Switchboard | 2 | 402,500 | 2 | 402,500 | 2 | |
| **OPEX** | | | | | | |
| Maintain HV Distribution Circuit Breaker | **24** | **50,760** | **54** | **114,210** | **184** | |
| Repair Distribution 11kV Switchboard (Jamming) | 10 | 11,360 | 10 | 11,360 | 10 | |
| Repair Distribution 11kV Switchboard (Minor) | 25 | 56,950 | 25 | 56,950 | 25 | |
| Repair Distribution 11kV Switchgear Insulation | **5** | **12,910** | **5** | **12,910** | **5** | |
| **Grand Total** | 66 | 534,480 | 96 | 597,930 | 226 | |

Table 17: Program of Work Summary

# Appendix A Maintenance Plan Details

Appendix A provides additional details of the data used in evaluation of the asset management strategy options, including the costing and budget forecasting.

## A.1 Asset Management Tasks Unit Costs

Unit costs for this asset class have been estimated and are summarised below.

### A.1.1 Planned Maintenance Tasks

| Asset Type | Task | Unit Cost ($) |
|---|---|---|
| **Distribution HV Circuit Breakers** | Five year routine maintenance | 2,350 |

Table 18: Planned Maintenance Task Unit Costs

### A.1.2 Unplanned Maintenance Tasks

| Asset Type | Task | Unit Cost ($) |
|---|---|---|
| **Distribution HV Circuit Breakers** | Repair slow/no operation issues | 2,500 |

Table 19: Unplanned Maintenance Task Unit Costs

### A.1.3 Condition Monitoring Tasks

| Asset Type | Task | Unit Cost ($) |
|---|---|---|
| **Distribution HV Switchboard** | Thermovision inspection to check for hot spots | 300 |
| **Distribution HV Circuit Breakers** | Thermovision inspection to check for hot spots | 300 |

Table 20: Unplanned Maintenance Task Unit Costs

### A.1.4 Replacement and Refurbishment Tasks

| Asset Type | Task | Unit Cost ($) |
|---|---|---|
| **Distribution HV Panel**[1] | Replace HV Panel | 45,000 |
| **Distribution HV Circuit Breakers** | Replace HV circuit Breaker | 45,000 |

Table 21: Replacement and Refurbishment Task Unit Costs

[1] HV Switchboards are comprised of a number of HV panels – typically between 2-10 depending on the size and function of the substation.

# Appendix B Risk Definitions

Appendix B provides reference information detailing how the severity of an effect, the probability of failure and the likelihood of detection are defined and ranked for the analysis of risk.

## B.1 Severity

| Effect | SEVERITY of Effect | Ranking |
|---|---|---|
| Catastrophic | Hazardous-without warning. Very high severity ranking, potential failure mode affects safety, noncompliance with policy and without warning. | 10 |
| Extreme | Hazardous-with warning. Very high severity ranking, potential failure mode affects safety, noncompliance with policy with warning. | 9 |
| Very High | Item inoperable, with loss of primary function | 8 |
| High | Item operable, but primary function at reduced level of performance | 7 |
| Moderate | Equipment operable, but with some functions inhibited | 6 |
| Low | Operable at reduced level of performance | 5 |
| Very Low | Does not conform. Defect obvious. | 4 |
| Minor | Defect noticed by routine inspection | 3 |
| Very Minor | Defect noticed by close inspection | 2 |
| None | No effect | 1 |

## B.2 Occurrence

| PROBABILITY of Failure | Failure Probability | Failure rate Lamda "λ" | Ranking |
|---|---|---|---|
| Very High: Failure is almost inevitable | Very High: Failure is almost inevitable. Possible Failure Rate >= 1 every week. | 0.1429 | 10 |
| | Very High: Failure is almost inevitable. Possible Failure Rate >= 1 every month. | 0.0333 | 9 |
| High: Repeated failures | High: Repeated failures. Possible Failure Rate >= 1 every 3 months. | 0.0111 | 8 |
| | High: Repeated failures. Possible Failure Rate >= 1 every 6 months. | 0.0056 | 7 |
| Moderate: Occasional failures | Moderate: Occasional failures. Possible Failure Rate >= 1 every year. | 0.0027 | 6 |
| | Moderate: Occasional failures. Possible Failure Rate >= 1 every 3 years. | 0.0009 | 5 |
| | Moderate: Occasional failures. Possible Failure Rate >= 1 every 5 years. | 0.0005 | 4 |
| Low: Relatively few failures | Low: Relatively few failures. Possible Failure Rate >= 1 every 8 years. | 0.0003 | 3 |
| | Low: Relatively few failures. Possible Failure Rate >= 1 every 15 years. | 0.0002 | 2 |
| Remote: Failure is unlikely | Remote: Failure is unlikely. Possible Failure Rate >= 1 every 20 years. | 0.0001 | 1 |

## B.3 Detection

| Detection | Likelihood of DETECTION | Ranking |
|---|---|---|
| Absolute Uncertainty | Control cannot prevent / detect potential cause/mechanism and subsequent failure mode | 10 |
| Very Remote | Very remote chance the control will prevent / detect potential cause/mechanism and subsequent failure mode | 9 |
| Remote | Remote chance the control will prevent / detect potential cause/mechanism and subsequent failure mode | 8 |
| Very Low | Very low chance the control will prevent / detect potential cause/mechanism and subsequent failure mode | 7 |
| Low | Low chance the control will prevent / detect potential cause/mechanism and subsequent failure mode | 6 |
| Moderate | Moderate chance the control will prevent / detect potential cause/mechanism and subsequent failure mode | 5 |
| Moderately High | Moderately High chance the control will prevent / detect potential cause/mechanism and subsequent failure mode | 4 |
| High | High chance the control will prevent / detect potential cause/mechanism and subsequent failure mode | 3 |
| Very High | Very high chance the control will prevent / detect potential cause/mechanism and subsequent failure mode | 2 |
| Almost Certain | Control will prevent / detect potential cause/mechanism and subsequent failure mode | 1 |