Appendix 5.18: Distribution – LV switchboard assembly ASP

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

evoenergy

ASSET SPECIFIC PLAN

Distribution

LV Switchboard Assembly

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ActewAGL
for you

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Reference Documents

Document
National Electricity Rules
National Electricity Law
Utilities Act (ACT)
Electricity Distribution Asset Management Policy v7.0
Asset Management Strategy v2.16
Asset Management Objectives v1.3
Asset Management System Manual
PR5017 Recovery and disposal of reclaimed network assets
SM4606 Environmental PCB Management Plan
Pole Strategy Review 2016

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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
MCCB	Moulded Case Circuit Breaker
MTBF	Mean Time Between Failures
NER	National Electricity Rules
NSP	Network Service Providers
OEM	Original Equipment Manufacturer
OPEX	Operational Expenditure
OPGW	Optical Ground Wire
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.

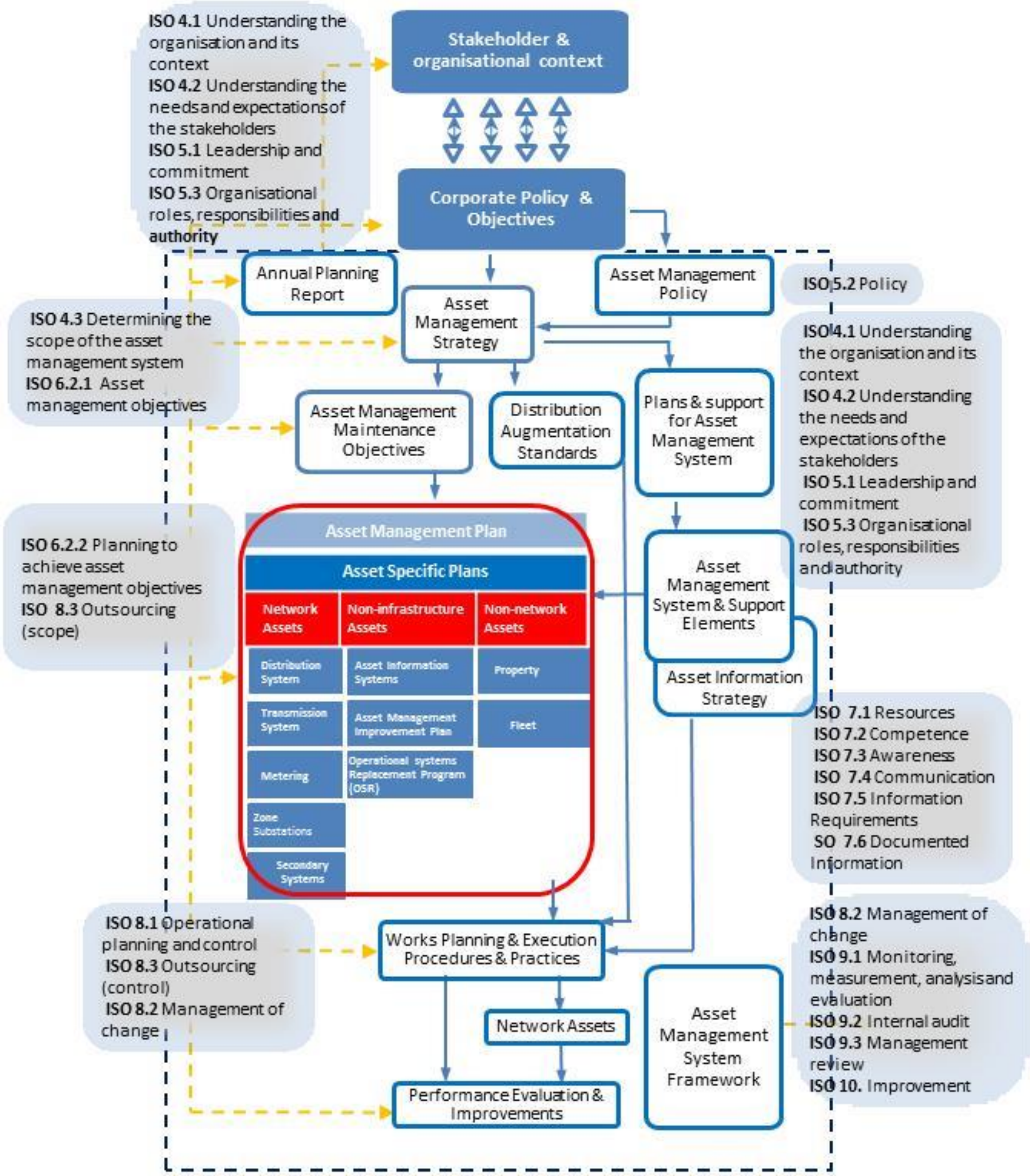

Figure 1: Asset management system structure

1 Executive Summary

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

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

Distribution LV switchboard assembly assets supply few customers and have a lower cost of failure when compared to distribution HV, zone substation and transmission network assets. Their reliable operation is fundamental to the safe and reliable operation of the LV network and their criticality rating is considered as medium.

This ASP evaluates options for the management of this asset class with a risk based approach to determine the optimal strategy that satisfies the asset class objectives. A summary of the options considered are:

- Option - 0: Reactive Strategy – effectively adopt a “run to failure” approach;
- Option - 1: Existing Strategy – routine planned maintenance and “need” or “opportunity” based replacement;
- Option - 2: Reduce Cost Strategy – reduced routine planned maintenance and reduced “need” or “opportunity” based replacement
- Option - 3 Reduce Risk Strategy – routine planned maintenance and replace before failure and “need” or “opportunity” based replacement.

The preferred option from this evaluation is option 1 – Existing strategy. This option satisfies the asset class objectives, manages risk to acceptable level and eliminates the health and safety risk of Capstan Link LV Switchboard assets by completing the replacement program by 2023/24. This option minimises lifecycle costs by replacement of assets on a “need” or “opportunity basis outlined in this plan. It includes effective planned maintenance for LV CBs which is effective in maximising the reliable and safe working life of these assets.

Key challenge: managing the safety risk presented by Capstan Link LV Switchboards. This type switchboard was installed in AADs network up to 1975 and are of very basic design with exposed live equipment on all sides. As well as exposure to live equipment this equipment has an inherent design fault with presents a severe safety risk. During switching it is possible to create a short circuit resulting in a flashover and may cause serious injury or death to personnel. There have been several health and safety incidents in AAD when switching Capstan Link Switchboards. The preferred strategy eliminates this risk in Chamber substations by targeted replacement of this type of equipment by 2023.

The estimated 2018-24 budget for CAPEX and OPEX is presented in Table 1.

Total Budget	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
CAPEX	**676,555**	**676,555**	**676,555**	**676,555**	**676,555**	**135,311**
OPEX	**425,925**	**440,698**	**440,698**	**251,266**	**574,220**	**378,873**
Planned Maintenance	405,925	420,698	420,698	231,266	554,220	358,873
Unplanned Maintenance	20,000	20,000	20,000	20,000	20,000	20,000
Condition Monitoring	0	0	0	0	0	0

Table 1: OPEX and CAPEX Optimised Program of Work Budget

This ASP presents a broad-based program of works for this asset class and applies relative considerations of CAPEX, OPEX and risk costs.

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 LV Switchboard Assembly asset class, which lies within the distribution asset portfolio. This asset class includes LV switchgear in distribution substations including chamber, padmount, kiosk and stockade substations. The basic function of this asset class is to divide and protect the supply from the LV side of distribution transformers into separate circuits in the distribution network.

Padmount and kiosk substations have one LV switchboard per substation where chamber and stockade substations have up to four. Each LV switchboard has multiple LV circuits protected by a fuse or circuit breaker on each circuit.

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

2.1 Asset Class Objectives

This ASP strategy 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 • Maintain a good reputation within the community • Minimise environmental impacts, for example bushfire mitigation • 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 • Achieve 0 catastrophic asset failures • Ensure design and acceptance for new assets complies with standards • Eliminate the health and safety risk of Capstan Link LV Switchboards in Chamber Substations
Reliable	
• Tailor maintenance and renewal programs for each asset class based on real time modelling of asset health and risk • Meet network SAIDI and SAIFI KPIs • Record failure modes of the most common asset failures in the network	• Enhance maintenance report to capture insights for asset performance • Achieve detailed understanding of asset health and incorporation into asset modelling and maintenance plans • Measure SAIDI and SAIFI contribution from this asset class • Review ASP at least every 5 years • 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 • Make prudent commercial investment decisions to manage assets at the lowest lifecycle cost • Integrate primary assets with protection and automation systems in accordance with current and future best practice industry standards • Deliver the asset class PoW within budget.	• Achieve 90% data completeness for minimum asset data requirements • Deliver PoW outlined in this plan
People	
• Proactively seek continual improvement in asset management capability and competencies of maintenance personnel.	• Promote continual improvement • Provide training for LV circuit breaker maintenance where necessary

Table 2: Asset class objectives

2.2 Asset Groups

Distribution LV switchboard assembly assets are classified by two main asset types shown in Table 3. Supporting components in the switchboard are discussed further in Section 2.3.

Asset Class	Distribution LV Switchboard Assembly
Asset Groups	Distribution LV Switchboard Distribution LV Circuit Breaker

Table 3: Asset Classification – Distribution LV Switchboard Assembly Assets

2.3 Asset Functions

Distribution LV Switchboards and their components divide and protect the supply from the LV side of distribution transformers into separate circuits in the LV distribution network. They also provide switching and isolation to allow safe access to maintain the network. The main components and their function are;

LV Switchboard

LV switchboards are enclosures which house components including busbars, circuit breakers, fuses and links. The enclosure provides mechanical, structural support and operational integrity from environmental influences such as mechanical impacts, dust and moisture. The LV switchboard enclosure also provides protection of human life against the possibility of electric shock due to contact of energised electrical equipment.

LV Busbar

LV busbars provide the medium to distribute power through the switchboard. LV 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.

LV Circuit Breaker

LV 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 have integrated protection units which via electro-mechanical coupling, sends a command to open the circuit breaker under fault or overload conditions to isolate a fault.

LV circuit breakers are critical to the protection of LV distribution systems to minimise damage to equipment ensure the safety of people. LV circuit breakers in this asset class are air circuit breakers and referred to as LV CBs for in this ASP. There are two subtypes of LV CBs:

- **Moulded Case Circuit Breaker (MCCB):** This type of circuit breaker is used as a protection device with built in and adjustable protection. They have a smaller rating compared to CBs.

- **Circuit Breaker (CB):** This type of circuit breaker is used as a protection device with more configurable built in protection. They have a higher rating compared to MCCBs.

Miniature Circuit Breakers (MCB) have been excluded from this ASP.

LV Fuse

A fuse is an overcurrent protection device to isolate faults from the network and prevent overloading. Under fault or overload conditions, current flowing through a fuse element will cause it to heat and melt isolating the fault. Fuses are sacrificial devices and once a fuse has operated, it requires replacement.

Fuses are critical to the protection of LV distribution systems to minimise damage to equipment ensure the safety of people.

LV Link

LV links are non-load breaking switches which provide isolation points between transformers, switchboard and distribution circuits.

2.4 Needs and Opportunities

The opportunities for rationalisation for existing switchboards and switching devices are limited to opportunistic replacement with the current standard design. The number of switchboards in the network is governed by the number of substations and therefore possible to reduce only if the number of substations could be reduced.

All new installations are provided with standard devices and designs of LV switchboards, assisting with the long management of the asset group. Due to safety hazards, old switchboards such as Capstan Links are being replaced in a planned manner. The new switchboards are of enclosed with no exposed live parts that one could accidentally come in to contact with.

2.4.1 Needs

2.4.1.1 Capstan Link LV Switchboards

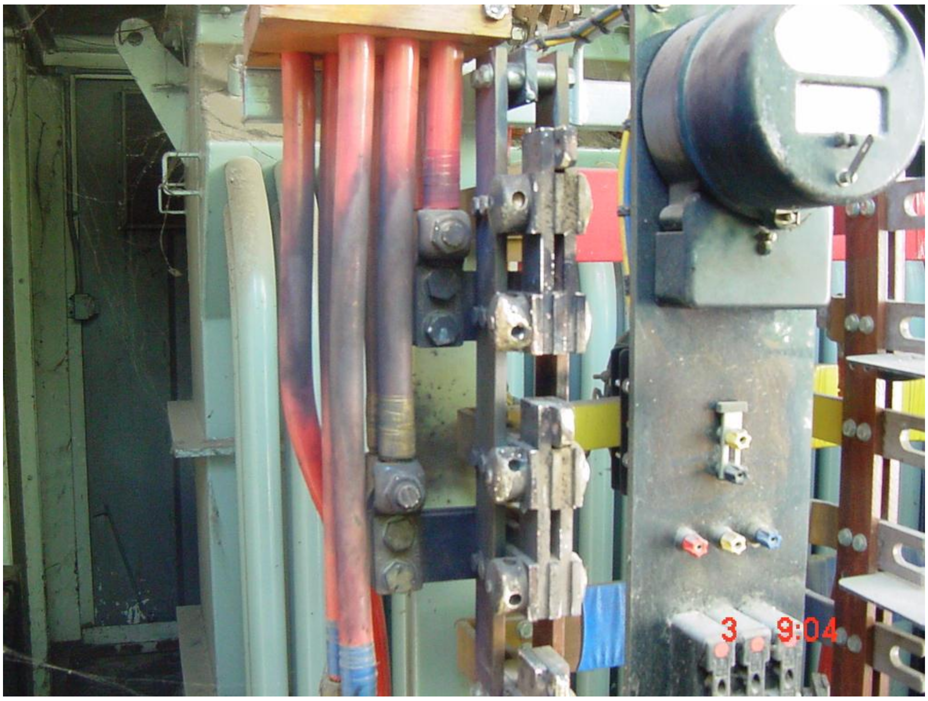

Figure 2: Capstan Links after three-phase flash over incident in 2002.

Capstan Link LV switchboards were manufactured by ActewAGL until 1975. These switchboards are known as “skeleton” LV switchboards of very basic design by current standards and have exposed live equipment on all sides (Figure 2). These switchboards use isolation links between the transformer and LV switchboard, and between bus ties in multi transformer substations. The links used in the construction of these switchboards are Capstan Links.

Capstan Links have an inherent design fault where which presents a safety risk to the operator during switching. The operator safety risk is creating a short between phases or between a phase and neutral creating a flashover. This can occur from the switching tool or the link opening past its intended operation causing the short. LV switchboards with this type of link also have exposed busbars with no mechanical barrier protection to prevent workers accidentally coming in contact with live apparatus.

There have been several incidents when switching capstan links in ActewAGL's network. These incidents occurred during operation of the links with at least 2 incidents causing flashovers resulting in serious injury to staff. An investigation in 2002 found capstan links were a high risk during operation and lead to the following actions;

- Recommendation to replace LV capstan link switchboards in chamber substations and;
- Additional operational procedures.

As a result the capstan link LV switchboard replacement program was initiated to replace all capstan link switchboards in chamber substations. Prior to this program, there were 110 capstan link LV switchboards in AADs network. To date (2017) approximately 80 units have been replaced with 30 assets remaining.

This program is planned to continue until all capstan link switchboards have been replaced in chamber substations. Asset replacement is prioritised by risk with priority given to assets which are operated most frequently. This project also creates opportunity to reduce the risk of LV Circuit Breakers containing asbestos material since they are replaced with the LV switchboard as an assembly. For details on LV Circuit Breakers containing asbestos material see Section 2.4.2.1.

The Capstan Link LV Switchboard Replacement program is forecast to be completed in 2023.

2.4.1.2 LV Circuit Breaker Trip Unit

AAD has experienced a fault with Merlin Gerin Masterpact M-type LV circuit breakers with STR58U trip units since 2010. This issue is also known industry wide where the protection nuisance trips on low and no load on trip units over ~20 years old. When the circuit breaker nuisance trips, the customer is off supply until it is reset by an operator.

The trip unit is a component of the LV circuit breaker and can be replaced separate to the circuit breaker. This is technically feasible and is significantly less cost compared to replacing the complete LV circuit breaker.

AAD has 126 Merlin Gerin Masterpact M-type LV circuit breakers in-service and to date (2017) 47 trip units have been replaced.

These trip units are replaced during planned maintenance or reactively after a nuisance trip operation. Experience with this asset is once the fault occurs once it will continue to occur until it's replaced.

2.4.2 Opportunities

2.4.2.1 Maintenance Restriction LV Circuit Breakers Containing Asbestos Material

Nilsen LV Circuit Breakers have been identified as containing asbestos material in the arc chutes. These LV Circuit Breakers cannot be maintained safely as the scope of maintenance is limited by asbestos components. Therefore, the maintenance is reduced to 'exercising' the circuit breaker and protection relay performance testing. Consequentially, poor performance has been observed due to the inefficient maintenance of these units, such as operating mechanism failures and slow or no operation to operational commands.

Opportunity to replace Nilsen LV circuit breakers containing asbestos by combining the replacement of LV Capstan Link switchboards with Nilsen LV circuit breakers. This is possible since some LV Capstan Link switchboards have this type of circuit breaker which is inherently replaced as part of the switchboard replacement.

2.4.2.2 Maintenance Restriction LV Circuit Breakers Not Supported

LV CBs manufactured by Australian GE are not supported by the manufacturer or AAD for spare parts or service. Without this support the risk of maintaining these assets is high due to the risk of not being able to repair and return the CB into service if damage occurs during maintenance.

There are only 4 Australian GE LV CBs in service (2017) and are recommended for opportunistic replacement. Substations with these CBs also have unsupported HV switchgear and therefore those substations are suitable for renewal.

2.4.2.3 LV Network Monitoring and Control

AADs Secondary Systems strategy seeks to increase the level of LV network monitoring and control in the network for reliable and efficient future operation of the network. Replacement of LV switchboards especially in chamber substations provides opportunity to install LV network monitoring and control. All LV switchboard replacements will assess the need to install SCADA and LV monitoring and control in accordance with the Secondary Systems strategy.

Historically the Capstan Link LV switchboard replacement has provided excellent opportunity to install SCADA and LV monitoring and control to realise LV network monitoring and control benefits.

2.4.2.4 Chamber Substation Asset Renewal

All LV switchboard replacements will be assessed to fit with other assets' work within the chamber substation. This will enable opportunistic LV switchboard replacements by aligning the asset renewal in chamber substations and combining works for the efficient delivery and minimisation of network outages. This chamber substation asset renewal opportunity will achieve efficiency in time and cost during asset replacements.

2.5 Associated Asset Classes

Associated asset classes are as follows:

2.5.1 Functional Relationships

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

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

2.5.2 Similar Functions

LV Switchboard Assembly assets, specifically circuit breakers, have similar functions to the following asset classes:

- Distribution HV 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 4 gives details of ActewAGL's in-service or system spare distribution LV switchboard assembly assets as at April 2017.

Asset Type	Quantity	Design Life (yrs)	Average Age (yrs)	Oldest Age (yrs)
Distribution LV Switchboard	3469	30	25	77
Distribution LV Circuit Breaker	910	50	16	71
Grand Total	**4379**			

Table 4: In-service or System Spare Assets

In this asset class there are more Distribution LV Switchboards than Distribution LV Circuit Breakers. This is because not all switchboards have LV CBs for network protection and switching. Instead of CBs, fuses and links are used in most LV switchboards for this function.

It is also more common for modern LV switchboards to have LV CBs, fuses and links which provide additional capability for protection monitoring and control. The average age of LV CBs is therefore lower than LV switchboards.

3.2 Asset Service Life Expectancy

The design life of distribution LV switchboard assembly assets is nominally 50 and 30 years for Distribution LV circuit breaker and LV switchboard respectively. In addition to expected deterioration of the asset due to aging, the actual service life expectancy of the asset is affected by other factors, such as:

- 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

The expected service life in AADs network considering local operating conditions is 50 and 60 years for Distribution LV circuit breaker and LV switchboard respectively.

3.3 Asset Age Profile

Figure 3 shows the age profile of the distribution LV switchboard assembly assets.

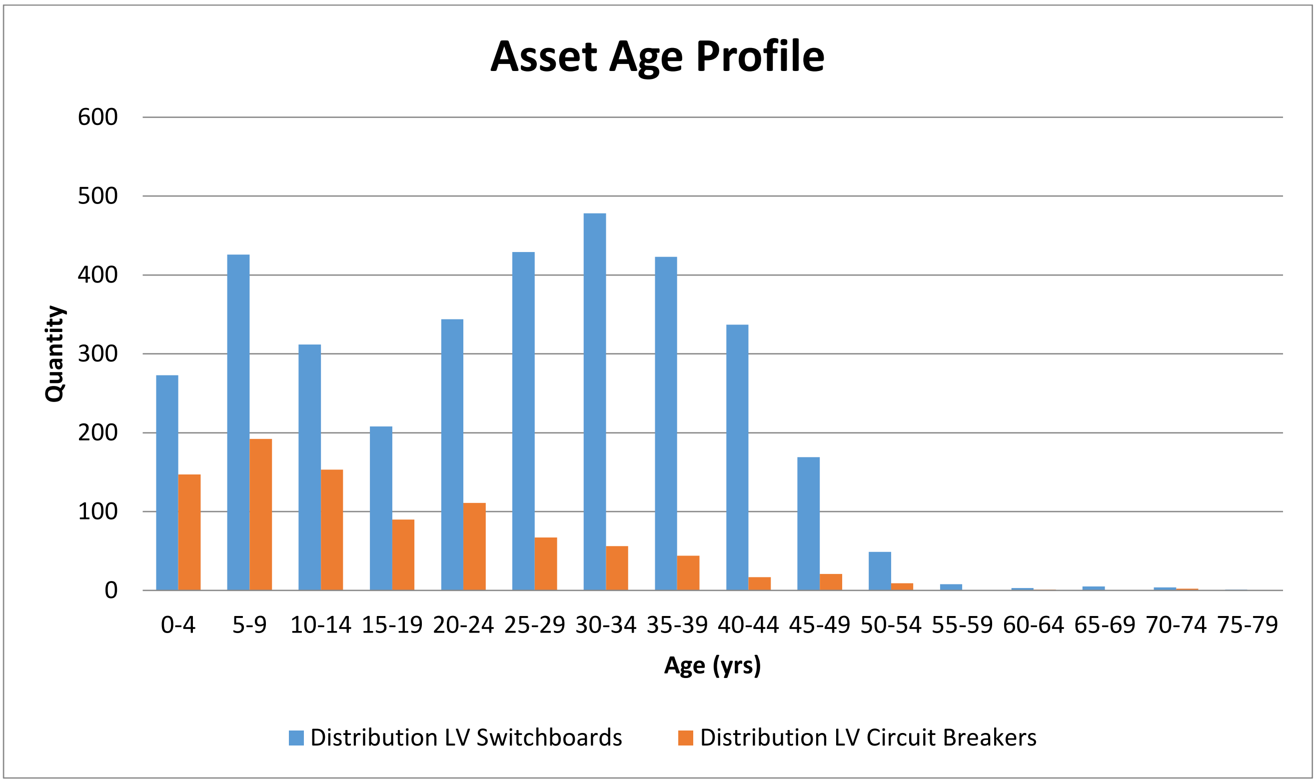

Figure 3: Age Profile of Distribution LV Switchboard Assembly Assets

In 2017 many assets beyond their design life of 50 and 30 years for Distribution LV circuit breakers and LV switchboards respectively. This is expected for an asset class with a run to fail strategy where assets are only replaced after failure or a needs or opportunity basis.

3.4 Asset Condition Profile

Table 5 gives details of the current condition of the distribution LV switchboard assembly assets.

Asset Type	Manufacturer	Asset Quantity	Asset Quantity - Critical Health 2018-24	Average Health 2017
Distribution LV Circuit Breaker		**910**	**2**	Excellent
	UNKNOWN	**76**	**0**	Excellent
	SCHNEIDER	**18**	**0**	Excellent
	NILSEN	**158**	**0**	Good
	Schneider / Merlin Gerin	**606**	**0**	Excellent
	TERASAKI	**48**	**0**	Good
	AUSTRALIANGE	**4**	**2**	Poor
Distribution LV Switchboard		**3469**	**23**	Good
	ABB	**3**	**0**	Excellent
	GEC	**3**	**1**	Fair
	UNKNOWN	**1903**	**12**	Good
	TYREE	**7**	**0**	Excellent
	ASEA	**1**	**0**	Fair
	MECHSERVICES	**37**	**0**	Fair
	WEBER	**918**	**2**	Excellent
	JEANMULLER	**51**	**3**	Good
	YORKSHIRE	**13**	**0**	Good
	SCHNEIDERMERLIN	**38**	**0**	Excellent
	COMPACT	**65**	**0**	Good
	AAD	**41**	**1**	Good
	BBC	**1**	**0**	Good
	ASEA/WEBER	**4**	**0**	Good
	OTEERMILL	**1**	**0**	Excellent
	COMPACT/ASEA	**3**	**0**	Good
	SCHNEIDER	**167**	**0**	Excellent
	ASET	**6**	**0**	Good
	WEBER/JEANMULL	**9**	**0**	Excellent
	HOLEC/HAZEMEYER	**29**	**0**	Fair
	SOUTHWALES	**2**	**0**	Fair
	HADIN	**145**	**0**	Fair
	HENLEY	**2**	**1**	Poor
	ENGLISHELECTRIC	**2**	**0**	Fair
	HAZEMEYER/HADIN	**2**	**0**	Fair
	PWA	**3**	**0**	Fair
	HAMIN	**1**	**0**	Fair
	HAYDEN	**1**	**0**	Good
	LUCY	**3**	**0**	Good
	DENNIS	**2**	**2**	Poor
	J&P	**1**	**1**	Poor
	EFEN	**2**	**0**	Excellent
	M&G	**1**	**0**	Excellent
	TP&N	**1**	**0**	Poor
	WEBER,JEAN MUL*	**1**	**0**	Excellent
Grand Total		**4379**	**25**	Good

Table 5: Asset Condition 2017

Based on the table above, less than 1% of assets are forecast to reach critical condition by the end of the 2018-24 regulatory period.

Two types of circuit breakers are no longer supported by the manufacturer or AAD. These circuit breakers are Australian GE and some Nilsen models. For these assets maintenance is restricted to exercising only and asset health is expected to deteriorate more than average. There is opportunity to manage these assets through planned Capstan Link Switchboard Replacements or decommissioning through proposed land re-development.

3.5 Projected Asset Count

The projected asset count is an estimate of the number of assets in service by year. The estimate includes asset additions and retirements through estimated network augmentation and asset retirements over the period. Refer to Figure 4 for details.

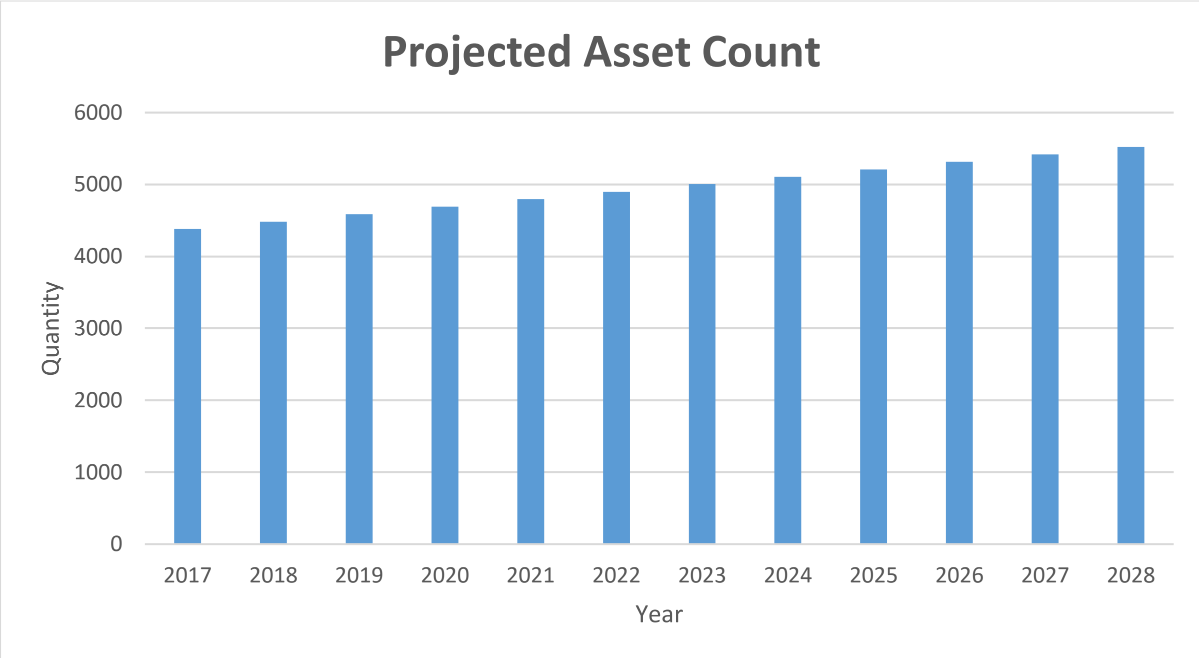

Figure 4: Projected Asset Count of Distribution LV Switchboard Assembly Assets

3.5.1 Network Augmentation and Infrastructure Development

Augmentation developments effecting this asset class include new greenfield residential and commercial estates and urban redevelopment.

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;
- Historic financial history specific to this asset class is only available from June 2014.

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;
- Specific 'type' issues are not up to date in the database. This includes the status of asbestos material in some circuit breakers.

While updating this ASP, a desktop data review was undertaken to correct specific data errors however correcting all data errors was not possible through a desktop assessment. To improve data for this asset class, field data collection and verification will be integrated into planned maintenance programs.

Data Improvements

- Verify and capture asset make and model for assets with missing data;
- Verify and capture manufactures dates;
- Verify and capture asset owner information;
- Implement electronic maintenance reports in the works management system;
- Asset fault history and root cause analysis of faults;
- Financial data for this asset class will improve as asset management costs are managed specific to this asset class since June 2014.

4 Asset Performance Requirements

This section details the reliability and performance requirements for the asset class.

4.1 Failure Modes

4.1.1 Failure Mode Effects Analysis (FMEA)

This ASP uses a risk based methodology, based on 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 the overall risk cost calculations.

4.1.2 Deterioration Drivers and Common Modes of Failure

Tables in the following section 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 generated Risk Priority Number (RPN).

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

4.1.2.1 Distribution LV Switchboard

Deterioration Drivers

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

Failure Modes

Failure Mode	Description	Severity	Occurrence	Detection	RPN
Thermal failure	Loose connections of busbars and cables could generate hotspots on switchboard equipment due to accelerating insulation degradation. Effect: Hotspots could develop into faults, insulation degradation, fire or explosions causing unexpected equipment outages.	6	2	5	60
Insulation breakdown failure	Partial discharge can cause degradation and possible failure of switchboard insulation. Effect: damage to equipment, protection operates to clear fault causing an outage to customers.	6	2	4	48

Failure Mode	Description	Severity	Occurrence	Detection	RPN
Internal Arc Faults	Although this fault is of rare occurrence, when occurs it can generate internal overheating and overpressure. Fault associated with short circuit. Effect: Mechanical and thermal stresses to enclosure leading to loss of equipment. Safety hazard to operator as explosions or ignitions can occur.	9	2	5	90
External Mechanical Failure	External damage of the housing could potentially affect the integrity of the internal components. Effect: Unexpected faults can cause service delivery interruptions.	4	4	3	48
Mechanical failure of Switch (Fail to Open)	Mechanical failure of switch to break current when opened. Effect: extended isolation time or fault causing protection to operate and outage to customers.	7	4	4	112
Mechanical failure of Switch (Fail to Close)	Mechanical failure of switch to make current when closed. Effect: extended restoration time or fault causing protection to operate and outage to customers.	7	4	4	112

Table 6: Distribution LV Switchboard Modes of Failure

4.1.2.2 Distribution LV 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
Protection Failure (Fails to Open or clear faults)	Failure to open CB due to mechanical or electrical damage of CB's components. Fail to clear fault, does not respond to trip command. Failure of protection relays systems. Effect: Potential safety hazard to operators and compromise of the operability of the CB. Outages to customer. Operation of back-up protection often results in a prolonged outage.	7	4	5	140
Protection Failure (Fail to close)	Due to mechanical and control issues, CB does not close or closing time is too slow (greater than 10% over) Effect: Operational delays due to extended restoration time.	7	4	5	140
Protection Failure (Nuisance Operation)	CB opens or closes involuntarily when it should remain closed or open respectively. Effect: Inadvertent trip could cause outage to customers on LV circuit whilst inadvertent closure could be potentially dangerous to operators.	8	5	4	160
Arc Faults	Arc Faults can lead to mechanical and thermal stresses creating overheating and hotspots in the CB's components. Effect: Ignition of CB resulting to danger to the operator and customer outage.	8	2	5	80

Failure Mode	Description	Severity	Occurrence	Detection	RPN
Insulation breakdown failure	Degradation of CB insulation or housing causing a fault. Effect: damage to equipment, protection operates to clear fault and outage to customers.	7	2	5	70
Thermal Failure	Overheating can occur due to mechanical problems such as finger clusters. Effect: Heat stress of CB and switchboard. Effect: Might lead to explosions and fires. Losing its structural integrity and inoperability of CB, leading to outages. Threat to the safety of operator.	7	2	4	56

Table 7: Distribution LV 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 LV switchboard assembly assets relates to operating parameters such as 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 design ratings. LV switchgear is rated in line with the ratings of other assets within the substation (transformers and HV switchgear) so that no single component constrains the substation capacity.

4.2.2 Utilisation

Distribution LV 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.

Utilisation for this asset class is a measure of network demand on equipment capacity and the number of available spare LV circuits.

4.3 Risk and Criticality

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

4.3.1 Asset Criticality

Asset criticality is dependent on the risk exposure to ActewAGL. Distribution LV switchboards supply residential and commercial customers with an average of 41 customers per LV switchboard. Criticality is dependent on the customer type supplied by asset and its geographical location.

The combined financial, operations, reputation, safety and environmental risk cost of a complete failure of an LV switchboard is over $220,000 which is significantly above the planned replacement cost. This is lower compared to HV distribution, zone substation and transmission assets and as an asset class has medium criticality.

To reduce the reliability consequence for LV switchboard failure, in some parts of the network 'LV ties' can be used to supply customers from an alternative substation. The LV tie allows customers to be restored while LV switchboard assets are repaired.

4.3.2 Geographical Criticality

Geographic criticality of LV switchboard assembly assets is dependent on the possible consequence to environmental bushfire risk and health and safety risk. Environmental risk of these assets is dependent on the bushfire risk and assets are categorised into three environmental risk zones, urban, Bushfire Abatement Zone (BAZ) and rural. Health and safety risk cost is related to the land use zone in which the asset is located and the likelihood of a person(s) being in proximity of the asset.

4.3.3 Asset Reliability

Reliability is essential from LV Switchboards, LV CBs and its components to reliably and safety operate the LV network. The risk of LV switchboard assembly assets is lower compared to HV distribution, zone substation and transmission assets. Their reliability and or performance requirement is therefore also less.

In the past 10 years AAD has achieved zero complete failures however several partial failures have occurred.

The most common failures are:

Complete

- Insulation failure
- Circuit breaker interrupter failure

Partial

- Trip unit nuisance trip
- Circuit breaker slow operation
- Circuit breaker no operation
- Circuit breaker racking mechanical malfunction (includes busbar shutters)

5 Asset Management Strategy Options

This section outlines the options considered for the management of distribution LV 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.

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 quantitative 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 considered for the management of distribution LV switchboard assembly assets 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 unplanned maintenance;
- Reactive replacement of (failed) assets.

5.2.1.1 Risk Outcomes

The risk outcomes of this option increase over time as the condition of the assets deteriorate through the combined aging effects and as a consequence their reliability also deteriorates as they approach the end of their expected life.

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 8.

Likelihood	Option 0 Risk				
Almost Certain					
Likely			High 2		
Possible	Low 1	Medium 6	Medium 20	High 5	
Unlikely	Low 8	Low 2	Medium 6	Medium 5	
Rare	Low 7		Low 1	Medium 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 5.

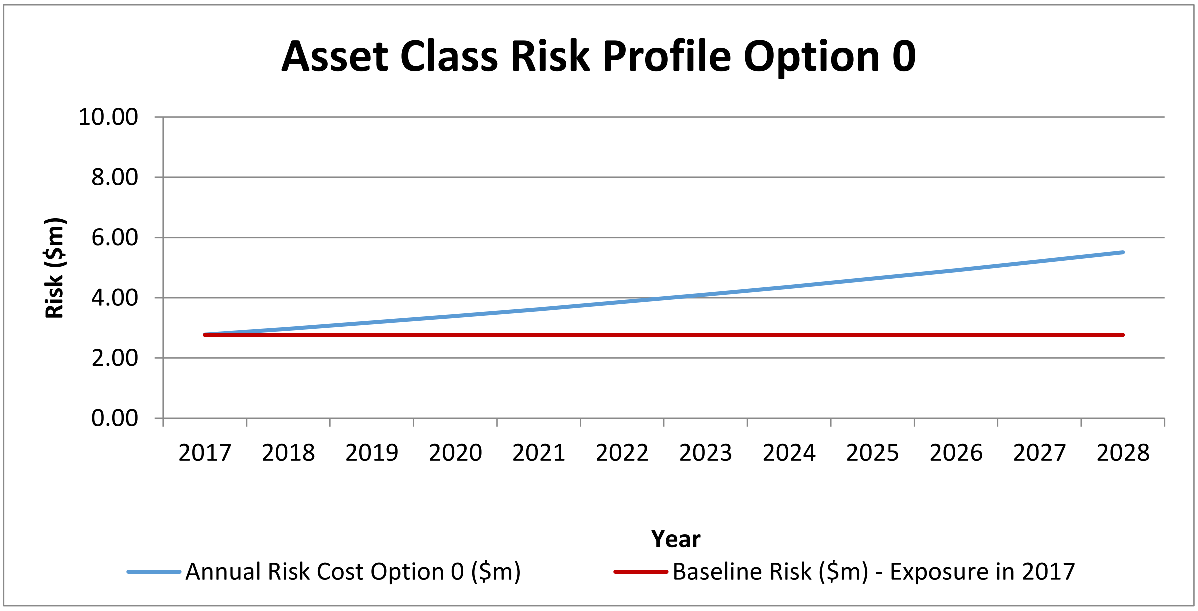

Figure 5: Risk-Cost Analysis – Option 0

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 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 dis-benefits (negative outcomes):

- Non-compliance with regulatory obligations;
- Inconsistent with contemporary industry practice and prudent asset management;
- LV circuit breakers rely on routine maintenance to operate reliability. Without maintenance they are likely to not operate causing damage to network assets, outages to more customers, environmental risks and health and safety risks.

5.2.2 Option 1 – Existing Strategy

This option covers the existing strategy as applied to the management of the Distribution LV Switchboard Assembly assets. This strategy includes planned maintenance, planned type and 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 LV circuit breakers (frequency 5 years);
- Planned 'type' replacement of Capstan Link Switchboards in Chamber Substations with high health and safety risk to staff;
- Opportunistic replacement for LV circuit breakers with asbestos arc chutes found in Capstan Links Switchboard in Chamber Substations;
- Opportunistic replacement of trip module units for Merlin Gerin Masterpact M-type LV Circuit Breakers with STR50 trip module.
- Inherent to this strategy is LV switchboard asset renewal through replacement of 'assembly' type substations. These are padmount and kiosk substations.

This strategy uses an asset condition and risk approach to determine 'type' and 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.

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 ‘type’ related issues

The exposed asset class risk ratings for this option at the end of the regulatory period (2024) are shown in Table 9.

Likelihood	Option 1 Risk	Negligible	Minor	Moderate	Major	Severe
	Almost Certain					
	Likely					
	Possible		Medium 3	Medium 3		
	Unlikely	Low 8	Low 5	Medium 24	Medium 7	
	Rare	Low 9		Low 2	Medium 3	
		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 6.

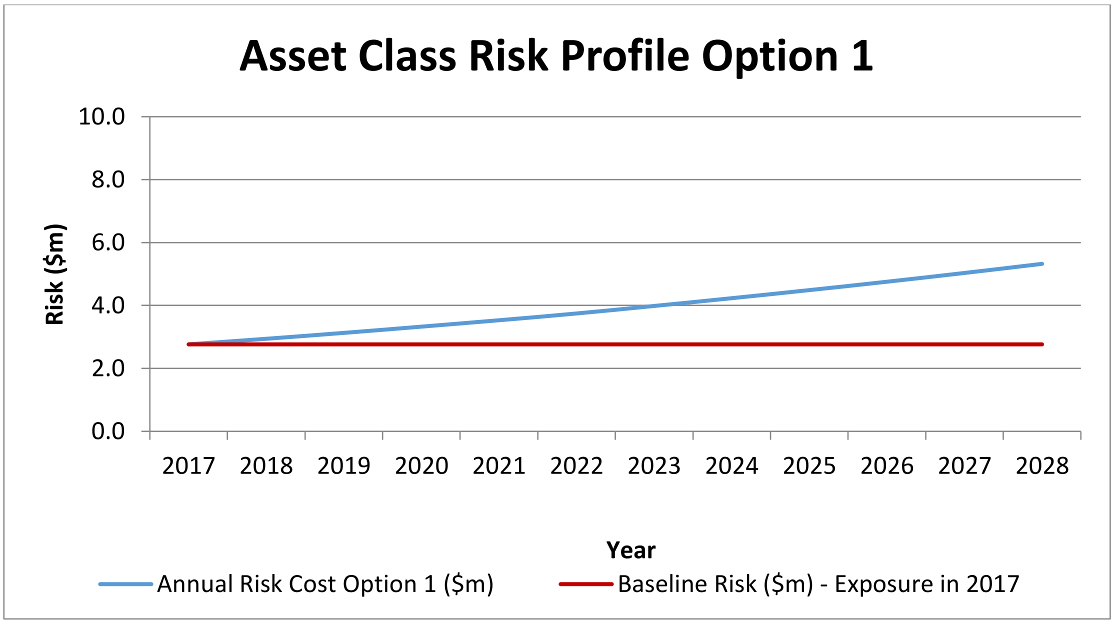

Figure 6: Risk-Cost Analysis – Option 1

5.2.2.2 Summary of Options Benefits

This option delivers the following benefits:

- Reduce health and safety risk with planned replacement of dangerous Capstan Link Switchboards;
- Reduce health and safety risk of circuit breakers containing asbestos by opportunistic replacement with Capstan Link Switchboards;
- Maintains LV circuit breaker performance and thus LV network performance;

5.2.2.3 Summary of Options Dis-benefits

Inherent to this option is the ongoing operational costs associated with planned LV 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 LV Switchboard Assembly assets. For this option the following reductions would be implemented compared to Option 1.

LV Switchboards

- Defer the replacement of Capstan Link switchboards such that the replacement program will not be completed until 2029 (2 regulatory control periods). Replacements are prioritised where the risk is the greatest, for Capstan Link switchboard replacements this is where switching is performed most frequently.

LV Circuit Breakers

- Extend the planned maintenance time based interval from 5 to 6 years on select LV CBs. Select LV CBs include CBs with good performance history and are all LV CBs except for Nilsen and A.E.I (Australian GE) CBs.

5.2.3.1 Risk Outcomes

The risk outcomes of this option primarily increases due to increased health and safety risk to staff operating Capstan Link LV switchboards as they remain in service for longer and therefore the number of switching operations on this dangerous switchgear is estimated to increase.

Less maintenance performed on LV CBs is estimated to have a marginal increase on risk for network reliability and economic costs to repair asset failures.

The exposed asset class risk ratings for this option are shown in Table 10.

		Option 2 Risk				
Likelihood	Almost Certain					
	Likely					
	Possible		Medium 2	Medium 11	High 5	
	Unlikely	Low 10	Low 6	Medium 17	Medium 4	
	Rare	Low 7		Low 1	Medium 1	
		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 7.

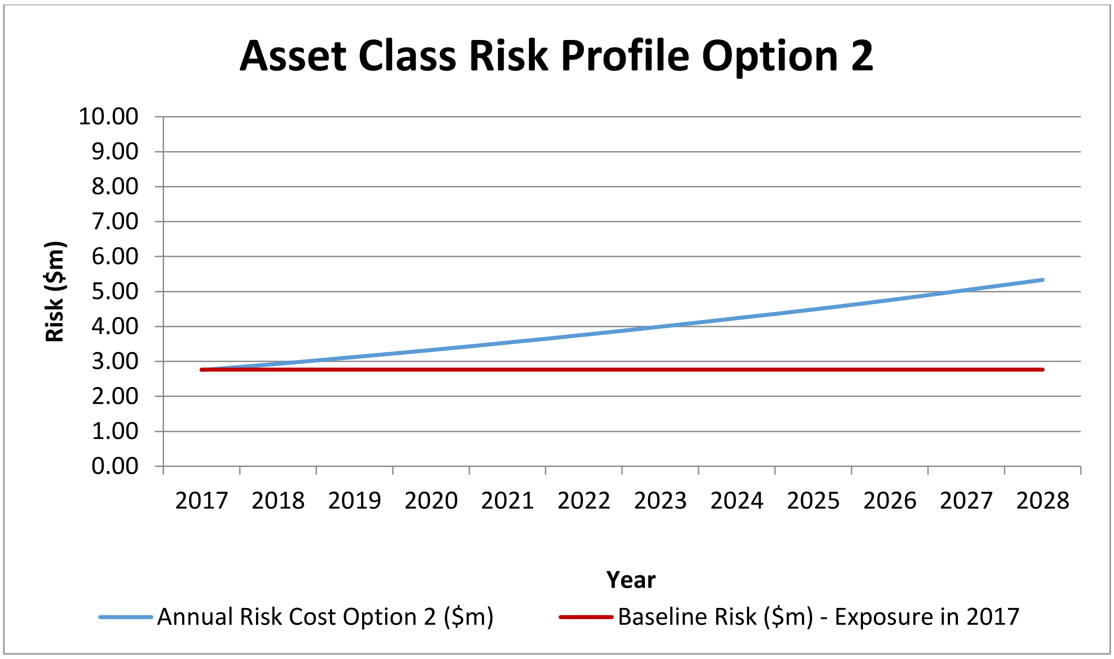

Figure 7: Risk-Cost Analysis – Option 2

5.2.3.2 Summary of Options Benefits

This option results in reduced operational and capital costs, particularly in the first half life of LV CB assets.

5.2.3.3 Summary of Options Dis-benefits

This option delivers the following dis-benefits (negative outcomes):

- LV CB maintenance is not aligned with protection relay maintenance
- Reduced maintenance of LV CBs may result in poor LV CB performance.

5.2.4 Option 3 – Reduce Risk

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

LV Switchboards

- Replace Capstan Link switchboards in Kiosk substations;
- Replace LV Switchboards Chamber substations in critical condition.

LV Circuit Breakers

- Replace LV CBs with maintenance restrictions. This includes LV CBs containing asbestos and LV CBs not supported by the manufacturer or AAD.

5.2.4.1 Risk Outcomes

This option reduces the risk of poor LV CB performance by:

- Lower the health and safety risk – maintenance restriction on certain Nilsen LV CBs is due to asbestos containing material which is unsafe to perform maintenance.
- Reduce reliability risk – maintenance restriction on Australian GE LV CBs due to no support by manufacturer or AAD.

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

		Option 3 Risk				
Likelihood	Almost Certain					
	Likely					
	Possible		Medium 4	Medium 10		
	Unlikely	Low 8	Low 3	Medium 14	Medium 6	
	Rare	Low 9	Low 1	Low 5	Medium 4	
		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.

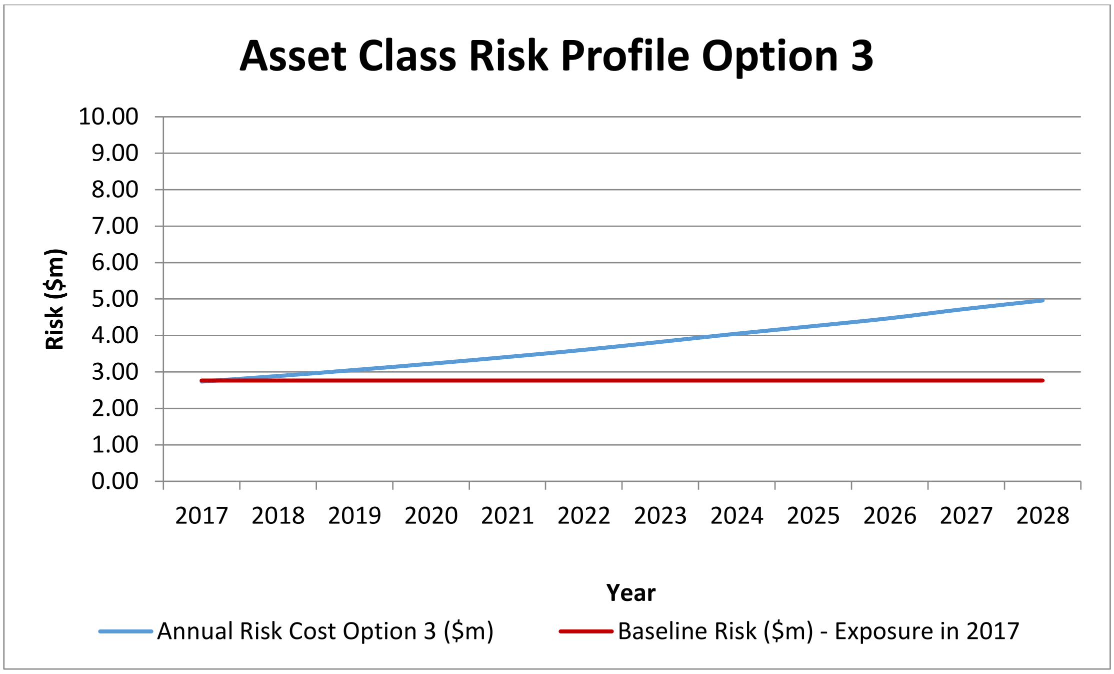

Figure 8: Risk-Cost Analysis – Option 3

5.2.4.2 Summary of Options Benefits

This option delivers the following benefits:

- Reduced safety risk – removal of assets containing asbestos
- Increased reliability and safety – LV CBs with maintenance restrictions are replaced with maintainable assets

5.2.4.3 Summary of Options Dis-benefits

This option results in the following dis-benefits:

- Highest capital expenditure
- The potential hazard of kiosk and padmount substations containing LV Capstan links is not addressed

5.3 Option Evaluation

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

5.3.1 Engineering & Risk Evaluation

The asset class criticality rating for LV Switchboard assembly assets is medium with consequence of failure exceeding $220,000. The key risk for this asset class is the health and safety risk presented by LV Capstan Link Switchboards. This type of switchboard has a live front and an inherent design fault creating a safety risk to operators during switching. Several incidents have occurred at AAD during operation and at least 2 incidents causing flashovers resulting in serious injury to staff. This risk remains in AADs network as several switchboards of this type of switchboard remains in service.

The asset class risk is increasing for all options with marginal difference between options. This is due to deteriorating asset condition and all options triggering few asset replacements for the asset base (average asset age 23 years).

Option 0

Option 0 – Reactive strategy does not meet the asset class objectives and has no controls for risk. This strategy does not eliminate the health and safety risk presented by LV Capstan Link Switchboards. Furthermore, circuit breakers contain complex mechanical systems requiring regular maintenance to ensure they continue to operate reliably which is fundamental for the protection of assets and safety in the LV network.

Option 1

Option 1 – Existing strategy utilises planned maintenance and planned replacement to eliminate key risks. CB performance is maintained throughout their life with effective planned maintenance and CBs with maintenance restrictions are targeted for planned replacement on an opportunistic basis.

This option manages the key asset class health and safety risk presented by Capstan Link Switchboards. It does so by eliminating the risk by replacement of these dangerous assets. Some Capstan Link Switchboards contain CBs with maintenance restrictions (specific Nilsen CBs containing asbestos) which are forecast to decline in performance from minimal maintenance. Replacement of Capstan Link Switchboards provides opportunity to replace these CBs with maintenance restrictions. An additional benefit of this replacement is the installation of SCADA for LV network monitoring and control.

This option replaces 5 Capstan Link Switchboards per year until all units are replaced in chamber substations. The Capstan Link Switchboard replacement program is forecast to be completed in 2023/24.

Replacing 5 units per year is achievable from an AAD works delivery perspective (demonstrated by previous PoW performance) and eliminates the health and safety risk as far as reasonably practicable.

There is not a specific program targeting Capstan Link Switchboards in Kiosk substations, however its removal is co-ordinated with that of other obsolete HV switchgear, transformer defects, and substation capacity uprating works as the opportunity arises.

This option manages assets at an acceptable risk.

Option 2

Option 2 – Reduce costs considers reducing maintenance of LV CBs and reducing the number of Capstan Link Switchboard replacements per year to 3.

This option manages the key asset class health and safety risk presented by Capstan Link Switchboard however the high risk remains in the network for longer. For this strategy these dangerous assets will not be eliminated until 2026/27.

For this option the Capstan Link Switchboard health and safety risk remains in AADs network the longest and does not eliminate the risk as far as reasonably practicable.

There is not a specific program targeting Capstan Link Switchboards in Kiosk substations, however its removal is co-ordinated with that of other obsolete HV switchgear, transformer defects, and substation capacity uprating works as the opportunity arises.

Extending the LV CB maintenance interval creates inefficiencies by misalignment of primary and secondary system equipment maintenance on common equipment. Extending the maintenance internal from 5 to 6 years results in primary system and secondary system maintenance done at separate times. The outcome is increased planned customer outages and higher overall costs by inefficient delivery of primary and secondary systems maintenance.

Option 3

Option 3 – Reduce risk includes the replacement of LV Capstan Link Switchboards in Chamber and Kiosk substations, LV Switchboards in chamber substations in critical condition and planned replacement of all LV CBs with maintenance restrictions.

Like option 1, this option manages the key health and safety risk of Captain Link Switchboards replacing these assets at a rate achievable by AADs Works Delivery Branch and eliminating the health and safety risk as far as reasonably practicable.

This option includes targeted replacement of Captain Link Switchboards in Kiosk substations to further reduce health and safety risk. No known incidents have been recorded for LV Capstan Link Switchboards in Kiosk substations however the risk is similar due to their design.

Replacement of LV CBs with maintenance restrictions increases the reliability and reduces health from assets containing asbestos material. The majority of these assets are installed in LV Capstan Link Switchboards thus replacing the remaining population has minimal benefit compared to the other options 1 and 2.

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	2.100	1.35	0.748	3.210	21.550	24.760	13.215	77.954	91.169	7.118	4
Option 1	6.030	3.518	2.512	5.544	21.053	26.598	11.166	75.020	86.186	6.823	2
Option 2	4.693	2.571	2.122	5.418	21.050	26.468	10.618	75.128	85.746	6.836	1
Option 3	8.573	5.183	3.391	9.822	20.302	30.124	20.374	70.601	90.976	6.402	3

Table 12: Cost and Risk Strategy Options Summary

The financial comparison ranks options giving more emphasis to the lowest NPC cost option.

The graph in Figure 9 provides an overview of long term risk exposure for all options. The risk outcomes for option 1 and 2 are similar and cannot be differentiated on the graph. From Table 12, it is observed that the average annual risk over a 30 year period is $6.823m and $6.836m for options 1 and 2 respectively.

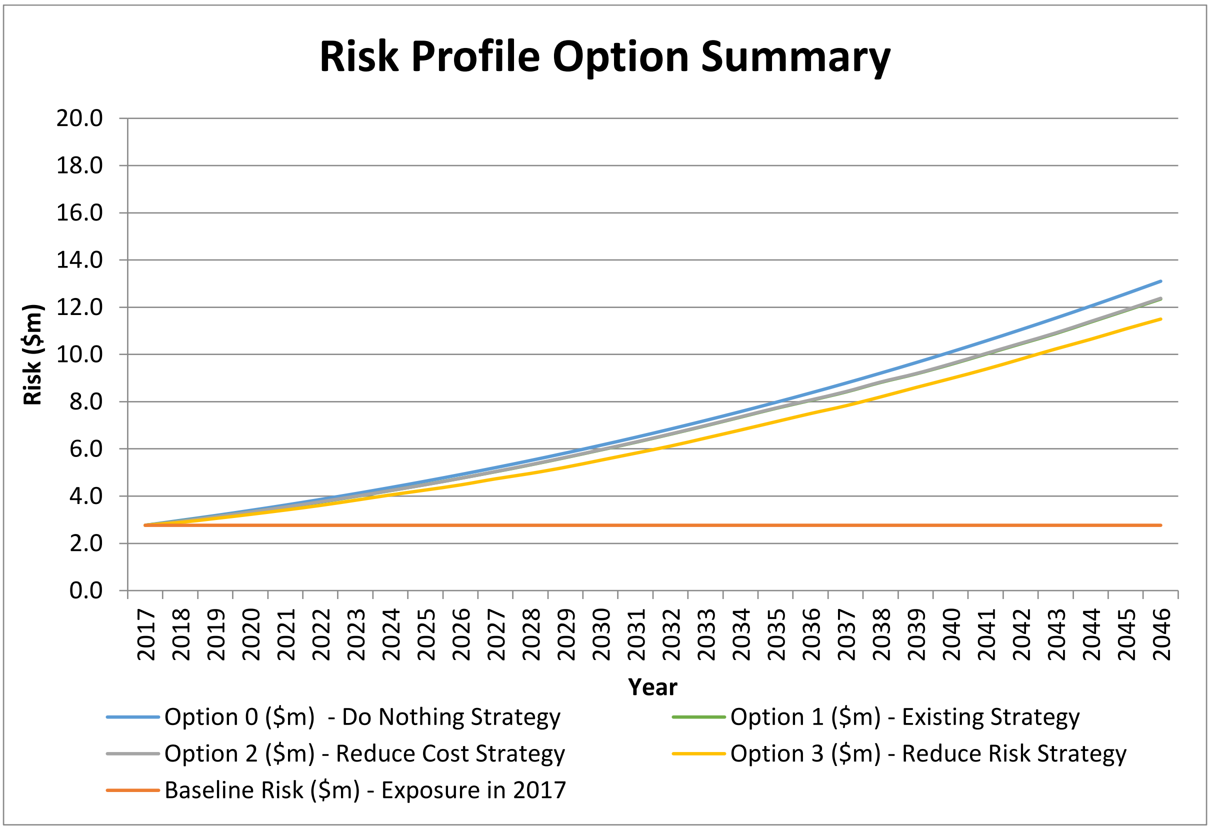

Figure 9: Risk Profile Comparison

5.3.3 Corporate Criteria Satisfaction Comparison

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 *- Do nothing Strategy*	*3*	*1*	*1*	*1*	*53%*
Option 1 *- Existing Strategy*	*2*	*3*	*3*	*2*	*87%*
Option 2 *- Reduce Cost Strategy*	*3*	*2*	*2*	*2*	*77%*
Option 3 *- Reduce Risk Strategy*	*1*	*3*	*2*	*2*	*67%*

Table 14: Scoring Matrix

Scoring Key			
0	Fatal flaw	1	Unattractive
2	Acceptable	3	Attractive

Table 15: Scoring Key Matrix

The scoring matrix in table 14, has been used as an evaluation method to compare options against weighting criteria considerations based on cost, risks, strategic objectives and innovation.

A higher score has been provided to Option 1 as this option delivers a more attractive risk mitigation while satisfying the long term strategy objectives of AAD.

5.4 Recommended Option

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

5.4.1 Recommendation

Based on the analysis of the asset management strategy options, the **Option 1 – existing strategy** has been recommended. This option satisfies the asset class objectives, manages risk to an acceptable level and delivers the outcomes that most completely satisfy the corporate criteria.

In the financial comparison, options 1, 2 and 3 manage risks to an acceptable level in both short and long term forecasts, while option 0 provides with the least controls for risk mitigation resulting in higher long term cost increments. Disruptive technologies are not expected to result in stranded assets in this asset class as capacity and functionality in the LV network will be required in the modern electricity network. With this in mind, consideration is given to the long term NPC evaluations of 30 years.

The NPC TOTEX and Risk Cost for Options 1 and 2 are almost equal considering the financial comparison. Option 1 is preferred as it provides the greatest health and safety benefits through the replacement of all chamber substation LV Capstan Link Switchboards by 2023/24, eliminating the risk as far as reasonably practicable. Timely replacement of these assets also provides additional benefits from the installation of SCADA and substation LV monitoring and control which will play a vital role in the efficient, reliable and safe operation of future LV networks.

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.

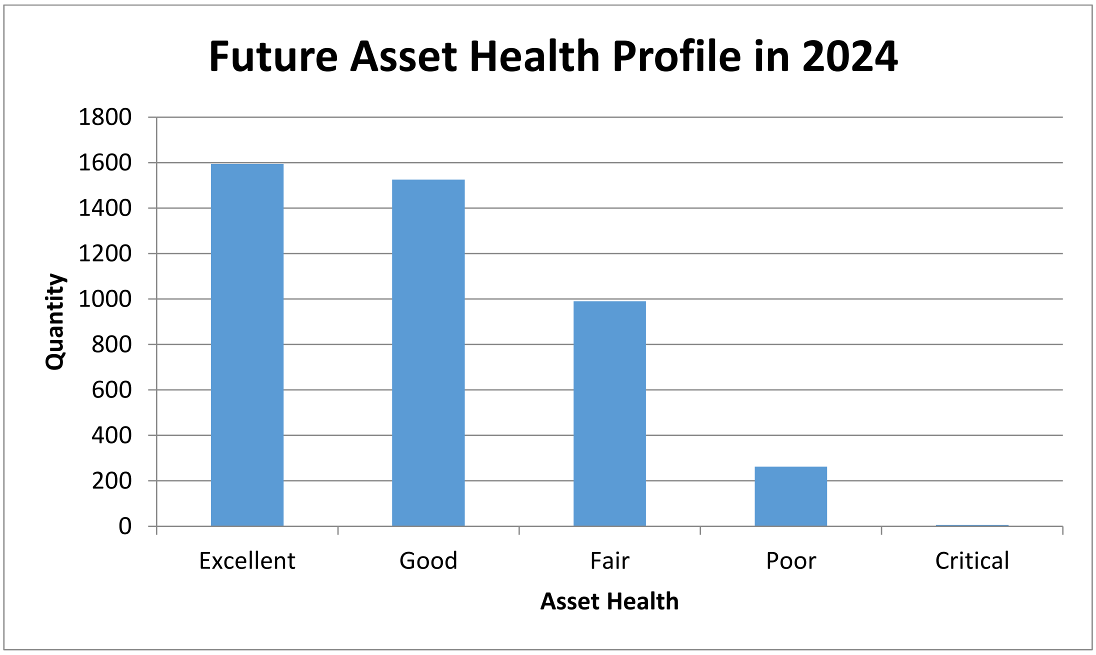

Figure 10: Asset Future Health Profile

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 LV switchgear.

Some LV Switchboard replacements may require special manufacturing to fit within existing substations. For these installations AAD has the opportunity to manufacture LV switchboards in house using components such as LV circuit breakers from the standard equipment specification list.

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
- Continuous review of asset performance and fine-tuning of maintenance triggers.

Asset Type	Maintenance Task	Maintenance Trigger
Distribution LV Circuit Breaker	Maintain Distribution LV Circuit Breaker	5 years
Distribution LV Circuit Breaker (with maintenance restriction)	Exercise Distribution LV Circuit Breaker	5 years

Table 16: LV Switchboard Assembly Asset Maintenance Interval Summary

6.2.2 Condition Monitoring

Specific condition monitoring activities are not performed on these assets however visual inspections are performed during substation inspections and prior to manual switching operations.

6.2.3 Maintenance Strategy

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

6.2.3.1 LV 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 LV Circuit Breakers – maintenance restriction

Maintenance of LV circuit breakers with maintenance restrictions is reduced to manage risks which these circuit breakers introduce. This includes health and safety risks (asbestos material) and units not supported by AAD or the manufacture.

For these assets maintenance is limited to exercising the CB to reduce the likelihood of failure during operation.

Manufacturer	Model	Maintenance Frequency
AUSTRALIANGE	**N/A**	Exercise only Maintenance restriction –not supported by AAD or manufacturer
NILSEN	**AB-10**	Exercise only Maintenance restriction – (contains asbestos)
	AB5/16	Exercise only Maintenance restriction – (contains asbestos)
	AB7/16/0	Exercise only Maintenance restriction – (contains asbestos)
	D-PRO	Maintain
	D-PRO203	Maintain
	M5694	Maintain
	NAB1/16	Maintain **If serial number <6000** Exercise only Maintenance restriction – (contains asbestos)
	NAB1/20	Maintain **If serial number <6000** Exercise only Maintenance restriction – (contains asbestos)
	NAB1/200	Maintain **If serial number <6000** Exercise only Maintenance restriction – (contains asbestos)
	NAB1/20D	Maintain **If serial number <6000**

		Exercise only Maintenance restriction – (contains asbestos)
	NAB1/31D	Maintain **If serial number <6000** Exercise only Maintenance restriction – (contains asbestos)
	UNKNOWN	Maintain
SCHNEIDER	N/A	Maintain
SCHNEIDERMERLIN	N/A	Maintain
TERASAKI	N/A	Maintain
UNKNOWN	N/A	Maintain

Table 17: Circuit breaker maintenance frequency according to models.

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 asbestos will be disposed of in accordance with the ActewAGL procedure PR4614, “Management of Asbestos and Synthetic Mineral Fibres Procedure”.

6.5 Associated Asset Management Plans

This section outlines related asset classes which are considered in this ASP. Planning and alignment with associated asset classes is important to provide the best technical and economic option which may integrate with other asset classes.

6.5.1 Distribution HV Switchboard Assembly

Distribution HV Switchboard Assembly assets are considered in this plan to optimise the management of distribution substation works by alignment of maintenance and replacement activities.

6.5.2 Distribution Ring Main Units

Distribution Ring Main Units (RMU) are considered in this plan to optimise the management of distribution substation works by alignment of maintenance and replacement activities.

6.5.3 Distribution Ground Transformers

Distribution ground transformers are considered in this plan to optimise the management of distribution substation works by alignment of maintenance and replacement activities.

6.5.4 Distribution Ground Substations

Distribution ground substations are considered in this plan to optimise the management of distribution substation works by alignment of maintenance and replacement activities. The need to replace LV Switchboard assembly assets will also consider the needs of other substation components and the opportunity to replace all components as an assembly, e.g. padmount substation.

6.5.5 Distribution Protection

Distribution protection is considered in this plan to optimise the management of distribution substation works by alignment of maintenance and replacement activities.

6.5.6 Distribution SCADA

Distribution SCADA is considered in this plan to optimise the management of distribution substation works by alignment of maintenance and replacement activities. This plan also aligns the rollout of LV network monitoring and control in line with LV Switchboard replacement projects.

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:

- Installation of LV network monitoring and control for benefit to network operations
- Enhanced condition monitoring of circuit breakers during maintenance activities
- Verify asset data in the field to improve asset modelling

7 Program of Work

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

8

8.1 Maintenance Program

This section outlines the operational expenditure for planned maintenance, unplanned maintenance and condition monitoring.

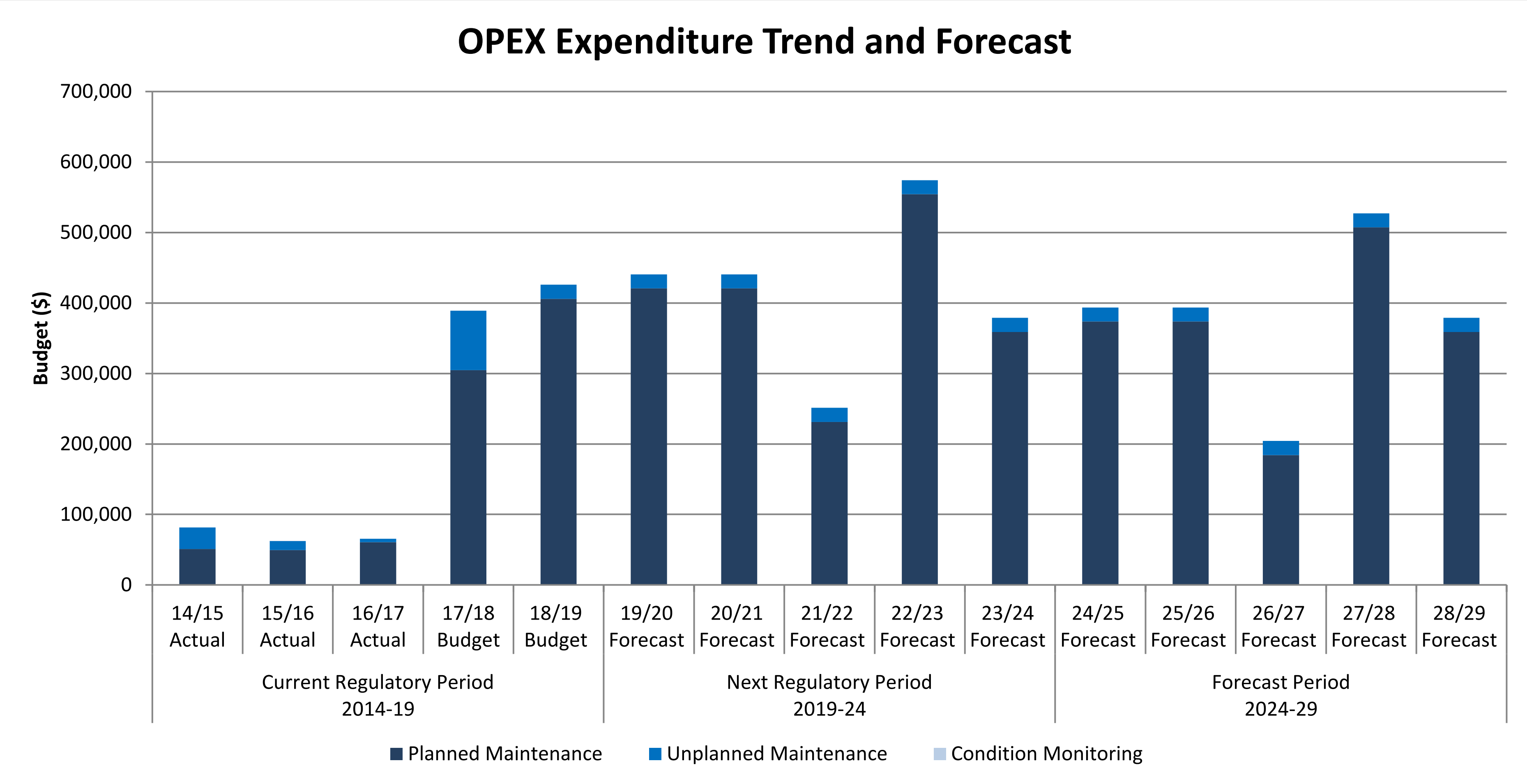

Figure 11: OPEX for Maintenance Program

8.2 Capital Program

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

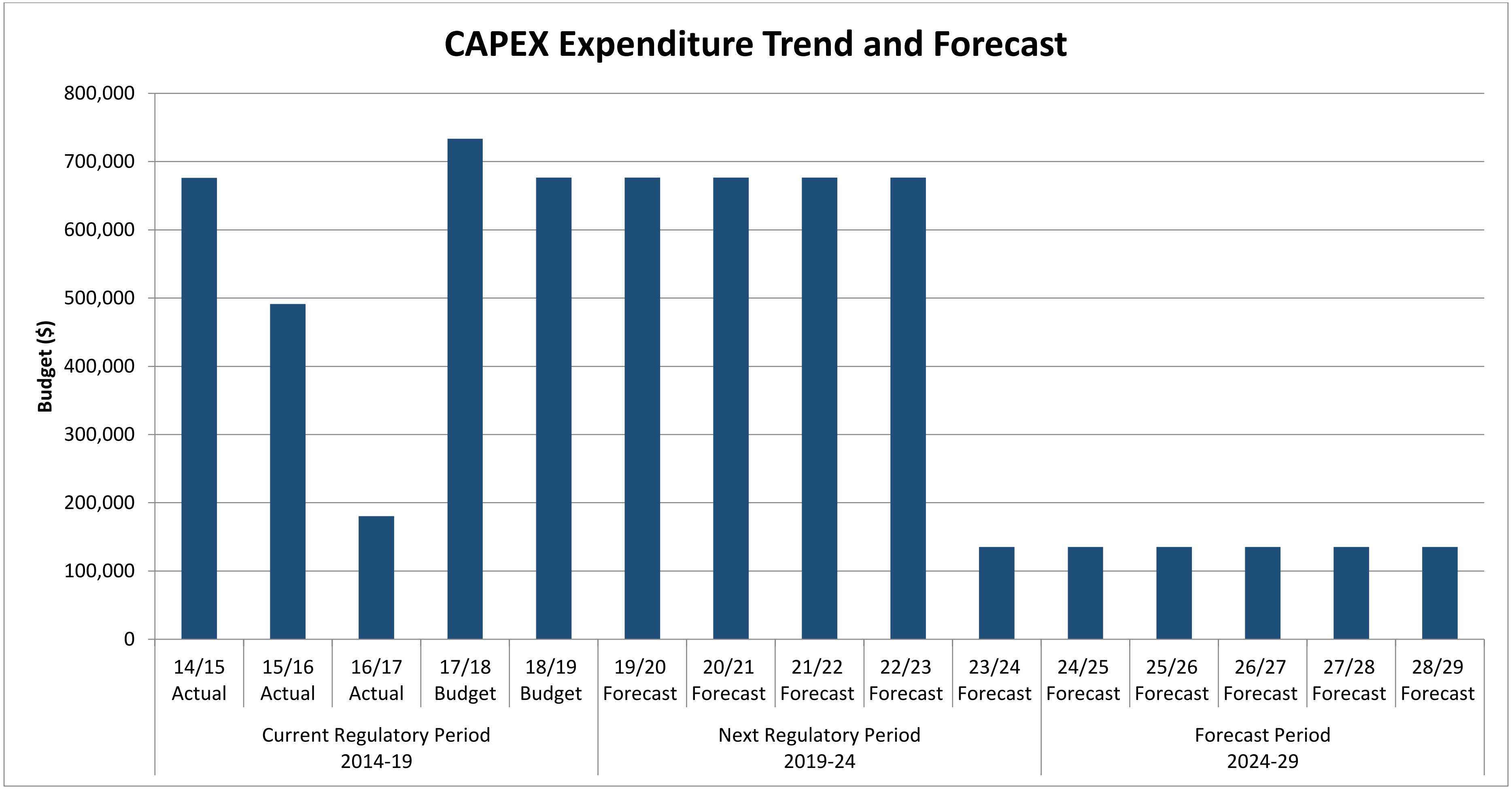

Figure 12: CAPEX Program

8.3 Budget Forecast

This section provides a 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	**676,555**	**676,555**	**676,555**	**676,555**	**676,555**	**135,311**	**135,311**	**135,311**	**135,311**	**135,311**	**135,311**
OPEX	**425,925**	**440,698**	**440,698**	**251,266**	**574,220**	**378,873**	**393,646**	**393,646**	**204,214**	**527,168**	**378,873**
Planned Maintenance	405,925	420,698	420,698	231,266	554,220	358,873	373,646	373,646	184,214	507,168	358,873
Unplanned Maintenance	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000
Condition Monitoring	0	0	0	0	0	0	0	0	0	0	0

Table 18: CAPEX & OPEX Budget Forecast

8.4 Program of Work Summary

The program of work for summary for 2018-24 is shown in Table 19.

Year	2018/19		2019/20		2020/21		2021/22		2022/23		2023/24	
Tasks	Units	Budget ($)	Units	Budget ($)	Units	Budget ($)	Units	Budget ($)	Units	Budget ($)	Units	Budget ($)
CAPEX	**5**	**676,555**	**5**	**676,555**	**5**	**676,555**	**5**	**676,555**	**5**	**676,555**	**1**	**135,311**
Replacement	**5**	**676,555**	**5**	**676,555**	**5**	**676,555**	**5**	**676,555**	**5**	**676,555**	**1**	**135,311**
Replace LV Distribution Switchboard	5	676,555	5	676,555	5	676,555	5	676,555	5	676,555	1	135,311
OPEX	**198**	**425,925**	**198**	**440,698**	**198**	**440,698**	**109**	**251,266**	**265**	**574,220**	**186**	**378,873**
Planned Maintenance	**194**	**405,925**	**194**	**420,698**	**194**	**420,698**	**105**	**231,266**	**261**	**554,220**	**182**	**358,873**
Replace LV Circuit Breaker Trip Module	12	47,052	12	47,052	12	47,052	12	47,052	12	47,052	0	0
Maintain LV Distribution Circuit Breaker	171	351,063	182	373,646	182	373,646	88	180,664	246	505,038	171	351,063
Exercise LV Distribution Circuit Breaker	11	7,810	0	0	0	0	5	3,550	3	2,130	11	7,810
Unplanned Maintenance	**4**	**20,000**	**4**	**20,000**	**4**	**20,000**	**4**	**20,000**	**4**	**20,000**	**4**	**20,000**
Maintain LV Circuit Breaker	4	20,000	4	20,000	4	20,000	4	20,000	4	20,000	4	20,000
Grand Total	**203**	**1,102,480**	**203**	**1,117,253**	**203**	**1,117,253**	**114**	**927,821**	**270**	**1,250,775**	**187**	**514,184**

Table 19: Program or 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 LV Circuit Breakers	Replace LV Circuit Breaker Trip Module	3,921
	Maintain LV Distribution Circuit Breaker	2,053
	Exercise LV Distribution Circuit Breaker	710

Table 20: Planned Maintenance Task Unit Costs

A.1.2 Unplanned Maintenance Tasks

Asset Type	Task	Unit Cost ($)
Distribution LV Circuit Breakers	Maintain LV Circuit Breaker	5,000

Table 21: Unplanned Maintenance Task Unit Costs

A.1.3 Condition Monitoring Tasks

Not applicable to this asset class.

A.1.4 Replacement and Refurbishment Tasks

Asset Type	Task	Unit Cost ($)
Distribution LV Switchboards	Replace LV Distribution Switchboard	135,311
Distribution LV Circuit Breakers	Replace LV Distribution Circuit Breaker	10,973

Table 22: Replacement and Refurbishment Task Unit Costs

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