Asset Management Plan

High Voltage Circuit Breakers

January 2023

PowerWater

Version control

This document has been approved in accordance with the Delegation of Authority (DoA) as evidenced by signatures and dates contained herein.

Rev	Date	Description	Author	Endorsed	Approved
1	17/01/2023	Revised and moved to new template	M Van Doornik Asset Engineer	B Kaye Manager Asset Strategy and Risk	S Eassie Senior Manager Asset Management

Contents

1. Introduction

ISO 55000 defines an Asset Management Plan (AMP) as documented information that specifies the activities, resources and timescales required for an individual asset, or a grouping of assets, to achieve the organisation's asset management objective.

1.1 Purpose and context

The purpose of this Asset Management Plan (AMP) is aligned to the requirements specified in ISO 55000. This AMP:

- Defines what is included and excluded from its scope
- Describes the asset class being managed
- Defines how this asset class will contribute to achieving the Asset Management Objectives that are defined in the Strategic Asset Management Plan (SAMP)
- Identifies the challenges we are expecting to encounter over the AMP planning horizon
- Sets out the projects and programs that we will invest in to ensure we achieve the Asset Management Objectives and address the identified challenges
- Quantifies the risk posed by this asset class with and without the proposed projects and programs of work

By reviewing this AMP and reassessing asset performance on an annual basis, we will ensure that any emerging issues are identified and can be addressed prior to becoming a significant risk. The outcome of the annual review will support the annual update of the Statement of Corporate Intent (SCI) and provide input into the annual Transmission and Distribution Annual Planning Report (TDAPR).

1.2 Scope of the AMP

The AMP covers the High Voltage (HV) Circuit Breaker asset class which are typically located within zone substations. The scope is limited to the regulated assets that are regulated by the Australian Energy Regulator (AER). It covers capital expenditure (replacement and growth) and operational expenditure (inspection and maintenance).

The AMP excludes:

- Non-regulated or Indigenous Essential Services (IES) assets that are managed by Power and Water
- Power transformers, instrument transformers, surge arresters, protection relays, DC systems, SCADA, buildings, fences and other civil infrastructure within zone substations
- HV circuit breakers in the distribution network, such as Ring Main Units, for transformer protection.

1.3 Timeframe of the AMP

This AMP is focused on a 10-year planning horizon, with respect to expenditure forecasts, that aligns with the requirements of the SCI and TDAPR. However, when assessing future challenges and emerging trends we may consider longer timeframes and will comment by exception if any longer-term issues are expected to arise.

PowerWater

1.4 Asset management framework

Power and Water has developed a new Strategic Asset Management System[1] which sets out the framework for asset management and the hierarchy of documents. This provides line of sight from the corporate objectives through to the asset objectives and how management of this asset class will contribute to achieving those objectives. Figure 1 highlights how the AMP fits in with the overall asset management system.

[1] CONTROL0548

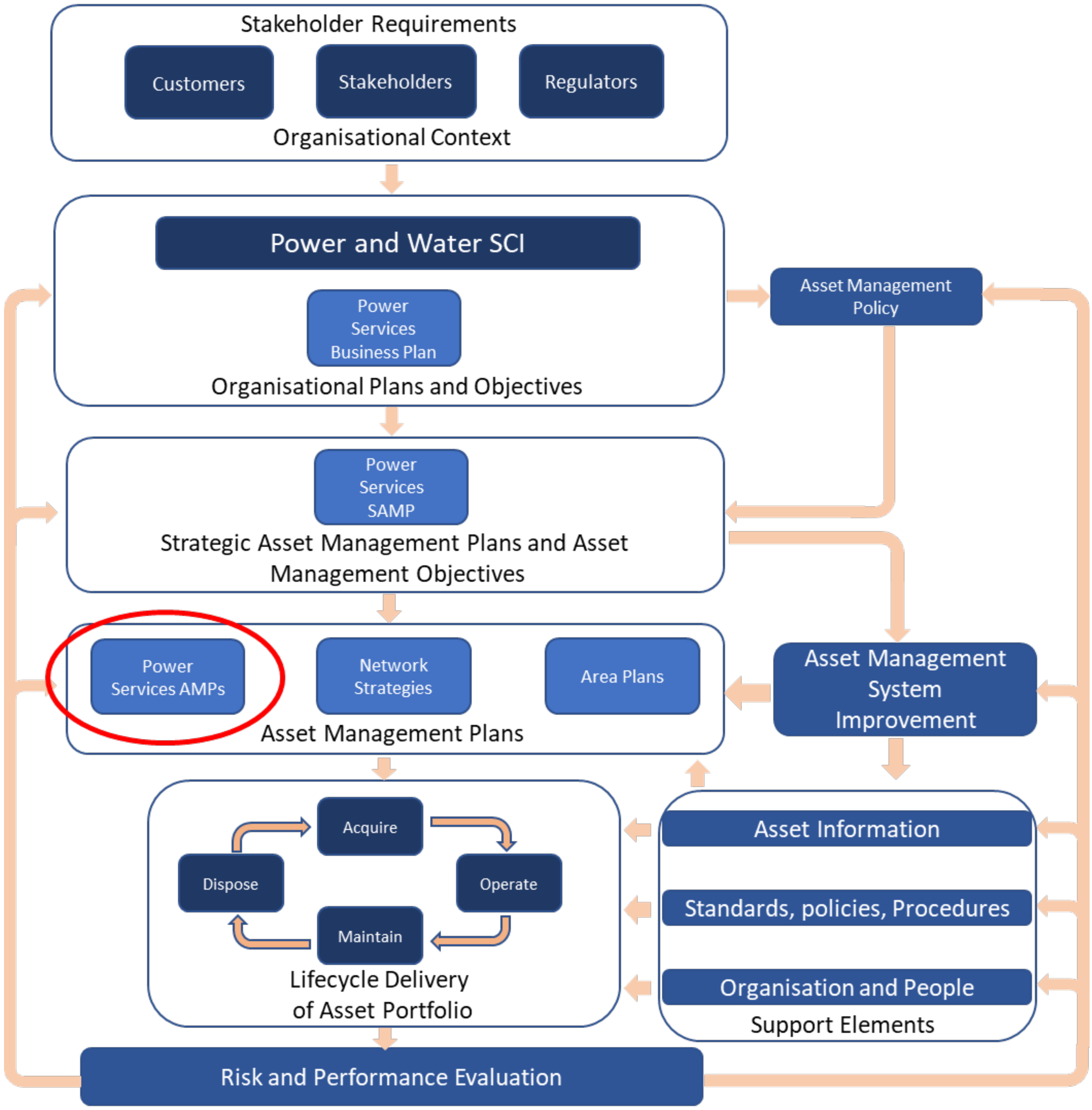

Figure 1 - The AMP within the context of the Asset Management System Diagram

1.5 Document structure

This document has been structured to align with the Power and Water Asset Management Standard and fits under the SAMP in the hierarchy of documentation. The document has been designed to be concise and provide the outcomes of detailed analysis with references, and not repeat the analysis in this document.

The purpose of each section is described below:

- **Asset profile** provides an overview of what the asset is, to provide context to the reader of the asset's role in the electricity transmission and distribution network. It provides a breakdown by asset characteristics and volume, as well as the age profile which is an important input to asset management.
- **Asset objectives and performance** sets out the asset objectives and how they apply to this asset class. Any gaps or emerging trends are identified and linked to a project or program, if relevant, to address the issue and ensure the asset objectives are achieved.
- **Asset challenges and emerging issues** outlines any existing or emerging challenges that may impact the performance of the asset class or may otherwise impact the management of, or need for, the asset class.
- **Implementation plan** sets out the projects and programs with expenditure per year for the 10-year planning horizon. This is a point in time assessment that is updated periodically so it may not align fully to the SCI and TDAPR if additional analysis has been completed subsequent to the AMP update.
- **Risk quantification and mitigation** describes the approach to risk-based investment decision-making and demonstrates the risk mitigated by the proposed implementation plan.
- **Asset lifecycle management** describes the asset management approach at each stage in the asset lifecycle.
- **Continuous Improvement** outlines the improvement plans related to the asset class.

2. Asset Profiles

HV circuit breakers are critical network components which provide network stability and reliability by rapidly de-energising sections of the network in the event of a fault. They are used at transmission and distribution voltage levels and are designed to be able to interrupt fault current up to the maximum system fault level.

HV Circuit Breakers are typically located in zone substations and each circuit breaker is dedicated to the protection of a particular assets such as feeder or power transformer.

2.1 Fleet characteristics

Power and Water owns, operates and maintains a portfolio of 534 zone substation based HV circuit breakers across the Northern Territory as shown in Table 1. Power and Water operates a Transmission network at 132kV and 66kV, and distribution network at 22kV and 11kV.

The HV circuit breaker fleet includes assets that are currently in service which were installed in 1964 through to today. This has resulted in a range of technologies, manufacturers and models.

	Voltage level (kV)				
Region	**11**	**22**	**66**	**132**	**Total**
Alice Springs	37	30	11	-	**78**
Darwin	244	31	103	29	**407**
Katherine	5	30	3	2	**40**
Tennant Creek	-	9	-	-	**9**
Total	**286**	**100**	**117**	**31**	**534**

Table 1 - HV circuit breaker volumes by region and voltage level

The average age of the HV circuit breaker fleet by type is shown in Table 2 below. The table shows that on average our circuit breaker fleet is relatively young.

Voltage Level	Quantity	Average Age	Nominal Life
Indoor Switchboard	386	16	45
GIS	52	13	45
Live Tank	44	23	45
Dead Tank	52	11	45
Total	**534**	**-**	**-**

Table 2 - HV circuit breaker volumes by region and voltage level

HV circuit breakers can be located indoors and outdoors and with interrupting media including oil, SF_6 gas and vacuum. They can be either dead or live tank arrangements. These characteristics are described below and summarised in Table 3 according to combinations of these parameters used in Power and Water's network.

- Indoor circuit breakers are located within a building and therefore have some protection from the climate. They are generally set up as a switchboard with each circuit breaker immediately adjacent to the next. Lower voltage circuit breakers (11kV and 22kV) are predominantly indoor installations.
- Outdoor circuit breakers are in a switchyard and are individual units separated by distance as required for electrical clearances and operational needs. Higher voltages (66kV and 132kV) are predominantly outdoor installations, except for indoor GIS switchgear which is used in higher density urban areas.
- Insulating media commonly used include vacuum, oil or SF6 gas. The insulating media enables lower clearances to earthed surfaces, reducing the size of the circuit breaker. It also controls arcing during fault or load current interruption. Oil circuit breakers are being phased out of the network with vacuum preferred for distribution voltages and SF_6 gas for transmission voltages.
- Live tank circuit breakers have the interrupting chamber at the line potential. The interrupting chamber therefore requires insulated supports and results in a high centre of gravity and maintenance is undertaken above ground level (requiring elevated work platforms).
- Dead tank circuit breakers have the interrupting chamber at ground potential. The conductors enter the interrupting chamber through insulated bushings. The interrupting chambers are at ground level, so maintenance activities are easier to conduct. 90% of all circuit breakers on Power and Water's network are dead tank, including all indoor switchboard and GIS circuit breakers.

Table 3 shows the quantity of circuit breaker assets by voltage level, interrupting medium and circuit breaker type.

Indoor / Outdoor	Tank type	Interrupting medium	11kV	22kV	66kV	132kV	Total
Indoor	Switchboard	SF_6	0	14	0	0	**14**
Indoor	Switchboard	Vac	286	86	0	0	**372**
Indoor	GIS	SF_6	0	0	38	0	**38**
Outdoor	Dead Tank	Oil	0	0	2	0	**2**
Outdoor	Dead Tank	SF_6	0	0	50	0	**50**
Outdoor	GIS	SF_6	0	0	0	14	**14**
Outdoor	Live tank	Oil	0	0	16	0	**16**
Outdoor	Live tank	SF_6	0	0	11	17	**28**
Outdoor	Live tank	Vac	0	1	0	0	**1**
Total	-	-	**286**	**101**	**117**	**31**	**535**

Table 3 - HV circuit breaker quantities by type and voltage level

2.2 Age profile

This section considers the age profile of the circuit breakers. Since assets deteriorate over time due to use, switching actions and the environment, age is a useful proxy for condition.

Figure 2 shows the age profile of the entire circuit breaker fleet by voltage level. It shows that there is a peak in quantities installed between 35 and 40 years ago. This aligns to the rebuilding post Cyclone Tracy and the expansion of the electricity network during the early 1980s.

There has been a very large number of circuit breaker assets installed in the past 20 years - nearly 80% of all circuit breakers on the network. This was due to a need to renew the old and deteriorated assets and efforts to improve network reliability after several catastrophic failures within zone substations.

The relatively new fleet of assets is reflected in the network average age. The impact of this is potentially concealing the risk associated with aged assets when looking at high level metrics.

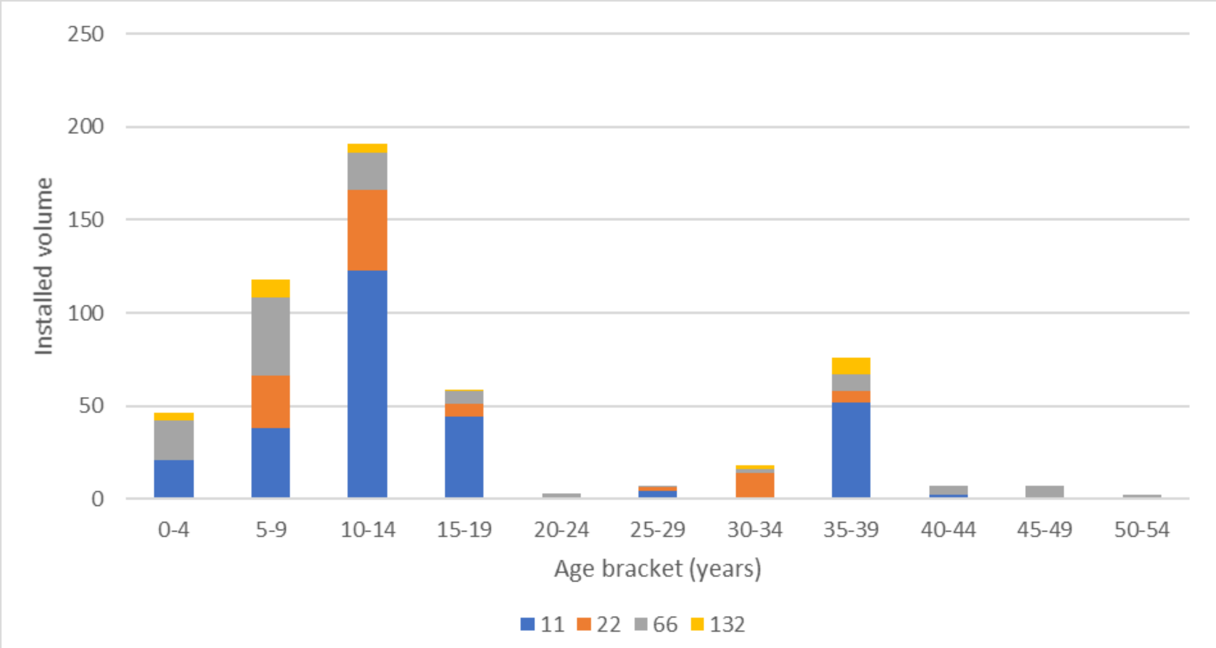

Figure 2 - Circuit breaker age profile by voltage

Since the expected serviceable life of circuit breakers is 45 years . A number of circuit breakers have already exceeded their nominal life, and many more are expected to exceed within the next 10 years. Table 4 shows the quantities of the assets.

Voltage kV	Quantity	Qty Exceed Now	%	Qty Exceed in 10 years	%
11 kV	286	1	0.3%	55	19.2%
22 kV	100	0	0.0%	6	6.0%
66 kV	117	8	6.8%	22	18.8%
132 kV	31	0	0.0%	9	29.0%
Total	**534**	**9**	**1.7%**	**92**	**17.2%**

Table 4 - Quantities of assets that exceed their expected life now and in 10 years

This indicates that there are 9 circuit breakers (1.7% of the fleet) that are potentially high risk and are expected to require replacement soon. Further, there are 92 assets (17.2% of the fleet) which will reach the end of their nominal life within the next 10 years.

2.3 Criticality

Power and Water has established a Risk Quantification Procedure for Investment Decision Making to assess the overall risk posed by the asset fleet. However, when undertaking detailed scheduling and prioritisation of assets within the fleet for specific tasks, such as testing and inspection or replacement, we consider the localised characteristics of individual assets to account for relative criticality within the fleet.

The criticality assessment considers the diversity of the network including impact on public safety, service disruption (reliability) or environmental incidents. The location of an asset has a significant impact on the likelihood and severity of the consequences.

The criticality of an asset is an assessment of its importance to the continued operation, reliability, stability and security of the power network. Criticality is dependent on the following key attributes which are assessed at the level of a zone substation:

- The type of customer they serve
- The redundancy of the substation
- Other mitigation factors that can be implemented in the case of failure, such as transferring load to other substations
- The time required to replace the asset and the availability of spares. Circuit breakers can have longer lead times, and the ability to undertake the installation and commissioning works is limited to the dry season.

Details of the criticality assessment approach can be found in our Health and Criticality Method (D2018/72550).

3. Asset objectives and performance

The Strategic Asset Management Plan (SAMP) defines the Asset Objectives and how they support Power and Water achieving the corporate objectives. This section shows how the Asset Objectives are supported by this asset class by establishing the measures and targets to assess if the Asset Objectives are being achieved, and any gap in performance that needs to be addressed.

Table 5 states the asset management objectives from the SAMP, identifies whether they are relevant to this asset class, and defines the measures of success, targets and performance gaps. This provides a 'line of sight' between the discrete asset targets and Power and Water's corporate Key Result Areas.

The performance shown here represents the historical performance of the asset class to date. It is expected that benefits from investments proposed in the next regulatory period will manifest as benefits in these key objectives.

Objectives	Measures	Targets	Performance
Ensure appropriately skilled and qualified staff are employed to meet the current and future needs of the network. Embed a fit for purpose Asset Management System across the business that is consistent across Regulated, Non-Regulated and IES.	A capability development plan will include the requirements to ensure each asset class has defined capability requirements to enable effective management and performance. The development of our Capital and Operational Works Plan (COWP) will define capacity requirements across different capabilities to achieve asset management objectives.		
Maintain the safety of customers, community and staff demonstrated by reducing worker and public safety incidents and implementing public incident reporting metrics into asset plans.	Public injuries	0	0
	Worker injuries	0	0
	# Oil Circuit Breakers	0 by FY25	18
Reduce by 50% the number of feeders and communities exceeding performance targets by more than 100% by 2025. Enable greater visibility of planned and unplanned interruptions to customers through improved online services for all networks and improve accuracy and transparency of	SAIDI and SAIFI targets.	Target by feeder type as set by the Utilities Commission.	Targets achieved. Refer to section 3.2

reliability performance metrics for isolated remote communities.			
Implement risk quantification for all regulated network (system) capital investment decisions by Jan 2023, and extend for remote generation and networks by 2025.	Implementation of risk quantification for decision making.	Use of Risk Quantification to assess investment needs for all aspects of the asset fleet.	Achieved.
Implement by EOFY 2023 asset criticality process to support granular prioritisation of corrective works based on public safety, reliability, security and other factors, and implement in the AMS and supporting systems by 2025	A quantitative criticality assessment criterion that can be integrated into defect management processes and supported by our ICT systems to be developed for all asset classes. Circuit breaker condition information is readily available and implementation is more advanced than for other asset classes.		
Prepare our network and systems to be ready for the future, including building in flexibility for future uncertainty, maximising hosting capacity for customer DERs and enabling the energy transition to reviewable energy according to the governments targets.	Development of specific capability requirements for various asset classes is a key focus of our Future Networks Strategy to support increased utilisation of DER while maintaining safety and reliability performance.		

Table 5 - Asset Management Objectives

3.1 Reliability performance

The Utilities Commission requires Power and Water to report performance against targets for SAIDI and SAIFI, by feeder category and network region. We do not disaggregate the feeder category targets by asset class. Instead, we assess the performance of each asset class to identify trends that require further analysis, and to determine if a specific program of works is required to support achievement of our targets at the feeder category level.

From a whole of system perspective, Power and Water has continued to improve its performance, although there has been mixed performance in each feeder category and region. These trends are discussed in the SAMP and are the subject of the network reliability performance improvement strategy.

Figure 3 shows the historical and forecast performance of the HV circuit breaker asset class. Linear regression shows a decreasing trend over the past 10 years. The forecast performance is based on a rolling average of historical performance.

Since FY12 there have been 65 circuit breaker asset failures that have resulted in an outage. With the exception of FY12, the SAIDI contribution has been very low, averaging less than 1 SAIDI minute per year.

The 14 SAIDI minutes in FY12 were largely the result of the slow operation of an HLC circuit breaker which caused under-frequency load shedding. Another incident in FY15 resulting in 2.4 SAIDI minutes due to a broken rod on an HLC circuit breaker. The issues surrounding HLC circuit breakers are discussed further in section 4.1.

The other major incident in FY15 was caused by a circuit breaker model which has since been removed from the network (22kV ABB VBF).

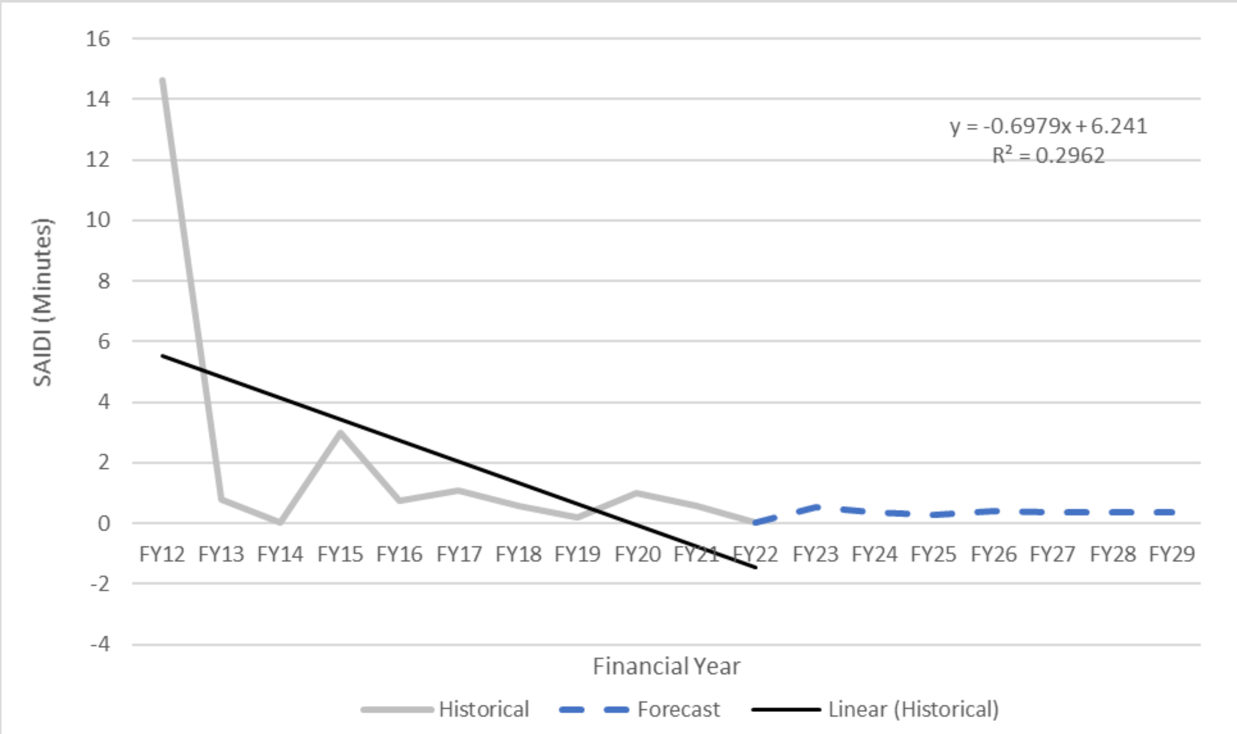

Figure 3 SAIDI performance of the HV circuit breaker asset class

While not resulting in a customer outage, the earth switches on our Simoprime switchboards have negatively impacted circuit breaker reliability. These have been inoperable on a number of occasions which has prevented other works from being undertaken. The earth switch issues are discussed further in section 4.4.

Overall, the circuit breaker asset class is very reliable, largely due to the relatively young asset fleet and the comprehensive preventative maintenance program. A review of maintenance strategy for Simoprime types is in progress to develop efficient strategy for this type given earth switch operation issues.

3.2 Safety performance

The failure rates of 66kV HLC and 22kV YSF6 circuit breakers, including multiple catastrophic failures, are our primary focus for this asset class due to safety and reliability impacts of these failures.

Another emerging issue is the lack of arc containment on older HV switchboards, and maintenance accessibility on newer switchboards.

These issues are discussed further in section 4.

Reducing manual handling hazards associated with withdrawable circuit breakers are also an area of focus. The use of fixed pattern switchboards in Zone Substations eliminates these hazards and our first installation will occur at Trevor Horman substation.

4. Asset Challenges and emerging issues

4.1 66kV ASEA HLC circuit breakers

A major type issue that is currently affecting Power and Water’s circuit breaker fleet is the 66kV ASEA HLC circuit breakers. These were manufactured by ASEA and installed on Power and Water’s network between 1972 and 1986.

The factors that have identified these assets as having type issues include:

- consistently poor performance results for their functional and electrical tests, higher rates of failure and need for non-routine maintenance than experienced for other circuit breaker types
- common issues identified amongst the fleet during inspection and routine maintenance and high historical maintenance cost
- restricting access to nearby equipment for maintenance to mitigate safety hazard until repaired, delaying repairs to other assets

These circuit breakers have suffered an increasing range of problems as they approached the end of their economic lives such as:

- Water in oil – the HLC CB is a “free-breathing” design so, in the humid and wet environment of the Northern Territory, moisture enters the circuit breaker to the extent that significant volumes of ‘free’ water (i.e., water below the oil) must be drained from the circuit breaker stacks at each maintenance outage. The presence of free water increases the risk of the CB failing to break fault currents when required.
- Recent maintenance reports indicate that the water-in-oil problem is increasing (larger volumes of oil being drained) and more frequent maintenance outages than the present biennial regime are advisable.
- Contaminated insulators – extreme environmental conditions result in greater surface contamination of the insulators than is advisable, resulting in an increased risk of tracking along the insulator surface.
- Cracked insulating rods – Power and Water believes that a batch of non-OEM insulating rods was procured at some time in the past, which wear more quickly and tend to develop cracks more easily than OEM components, resulting in replacement rods being required more frequently than expected.

The majority of these assets have now been replaced. The remainder already have approved replacement projects or disposal plans and are expected to be decommissioned by 2025.

4.2 Hitachi CPFT GIS circuit breakers

The Hitachi GIS circuit breakers at Channel Island are some of the most critical circuit breaker assets in the Power and Water network, connecting the largest power station at Channel Island into the 132kV transmission network.

The 11 circuit breaker assets were installed in the mid-1980s and are due for a major midlife overhaul of the operating mechanisms. These are unique assets with no local or national expertise available to perform the maintenance, and as a result specialist from overseas are required. This has been made extremely difficult for the past several years due to Covid and the subsequent restrictions on travel.

An accelerated maintenance program is being developed to perform required maintenance and ensure reliability is maintained through to end-of-life.

4.3 Hitachi 66kV OSYGB circuit breakers (2 in fleet)

The Hitachi 66kV OSYGB oil circuit breakers exhibit a range of age-related issues such as:

- cracks in the bushing sight glasses
- air leaks in the compressed air system and operating mechanisms
- slow operating times

These circuit breakers have exceeded the estimated economic life of 45 years and are planned for decommissioning in FY23.

4.4 Simoprime HV switchboard earth switch failures

An emerging reliability issue is with performance of earth switches on our Simoprime HV switchboards. It has been found that maintenance undertaken on these switches has been inadequate, resulting in the switches being inoperable or damaged during operation. We have updated our maintenance strategies to address this issue and maintenance is expected to be completed in FY24.

4.5 YSF6 circuit breakers

YSF6 circuit breakers have historically posed a safety hazard, with multiple catastrophic failures in the last 15 years. The last remaining switchboard is installed at Sadadeen zone substation, and access to the switchroom is restricted to minimise staff exposure. The switchboard is fitted with permanent online monitoring to enable rapid detection of any change in condition. This switchboard is planned to be decommissioned in FY24.

4.6 HV Switchboard arc containment

Our older HV switchboards that were not design for arc containment during faults are a focus area for operator and maintainer safety. To mitigate this risk, we have installed arc flash protection on older switchboards which do not have high speed bus protection. In addition, we have installed a remote racking system at Berrimah zone substation so that staff can rack the circuit breakers from outside of the switchroom. We have also begun to move towards fixed pattern switchboards for new installations, which have superior arc containment and eliminate most tasks that require operators to interact directly with the switchboard for switching.

A type issues has also been identified on newer Simoprime switchboards which compromises the arc containment. We are working closely with the OEM to retrofit these switchboards and restore the full arc rating.

4.7 HV Switchboard accessibility

Several of our HV switchboards are installed with the back of the unit flush against the switchroom wall. This does not allow staff to safely access the rear of the unit to perform maintenance in the cable boxes and earth switches. We are investigating building modifications to enable safe access, and this has already been performed at Lovegrove zone substation.

4.8 8DN8 GIS Switchgear

There have been several instances of limit switches failing on our 66kV 8DN8 GIS switchgear. This has led to the isolators entering an inoperable state and requiring manual intervention and extended outages to complete switching. It appears to be caused by a manufacturing issue and is exacerbated by the how infrequently the units are switched. We have replaced the limit switches identified as faulty and developed tools and training to allow expedited recovery from any future maloperations. We are also investigating an switch exercise program to further reduce the risk of future occurrences.

5. Implementation plan

The following set of projects and programs have been developed to address the gaps in asset performance compared to the asset objectives and our long-term view to start planning for forthcoming asset challenges.

5.1 Replacement expenditure

Replacement expenditure is defined as work to replace an asset with its modern equivalent where the asset has reached the end of its useful life. Capex has a primary driver of replacement expenditure if the factor determining the expenditure is the existing asset's inability to efficiently maintain its service performance requirement.

The identified projects and programs are listed below. The indicative cost (real FY22) of the project or program for the 10-year horizon is provided and includes the entire project, not only the power transformer component:

- ZSS minor capital asset replacement program ($9.0 million)
- Replace Berrimah zone substation ($28.7 million)
- Tindal zone substation and feeder reconfiguration ($11.3 million)
- Alice Springs network reconfiguration ($4.2 million)
- Upgrade Humpty Doo Zone Substation ($2.8 million)
- Cosmo Howley Replacement ($0.6 million)
- Centre Yard Replacement ($0.8 million)

5.2 Augmentation expenditure

Augmentation expenditure is defined as work to extend the network or to increase its capacity to transmit or distribute electricity. It also includes work relating to improving the quality of supply to customers within the network, for example, to meet regulatory obligations.

The identified projects and programs are listed below. The indicative cost (real FY22) of the project or program for the 10-year horizon is provided and includes the entire project, not only the poles and towers component:

- Tindal Zone Substation Upgrade ($6.9 million)

5.3 Operational expenditure

The forecast annual expenditure on maintenance activities is outlined in Table 6 below.

Maintenance Type	All Assets	Circuit Breakers
Routine Maintenance	$7.0	$1.1
Non-Routine Maintenance	$7.7	$0.5
Emergency Response	$7.6	$0.2
Total	**$22.3**	**$1.8**

Table 6 - Forecast annual maintenance expenditure ($ Million FY22)

5.4 Delivery plan

There have been a number of challenges during the current regulatory period that have resulted in under-delivery of capital plans. We have undertaken a detailed analysis of our internal processes and activities to identify the causes and compiled a detailed plan to address this issue. The analysis and resulting plan to enable delivery of the proposed program of works is described in our Capital Delivery Plan.

6. Risk quantification and mitigation

Power and Water has established a Risk Quantification Procedure for Investment Decision Making to assess the overall risk posed by the asset fleet. Our procedure considers the asset's condition and failure modes, the likely risks of failure on safety, security and reliability of services to customers, and the relative maintenance and capital costs. In some cases, our decision making will be influenced by demand growth or customer upgrade requirements. Essentially, our decision making is based on an economic assessment of risks, costs, and benefits.

Figure 4 below shows our forecast of risk on the network that is contributed by the HV circuit breakers asset fleet. The unmitigated risk shows increasing risk cost if no actions are taken to address known issues. The mitigated risk shows the risk cost is maintained if the suite of proposed programs is implemented. The current risk level provides a reference to the current level of risk.

Overall, the risk is low as in most cases we are able to transfer load through operational switching with adjacent feeders, hence any outage is limited to switching time. We have also allowed for operational measures that limit health and safety risk, such as remote racking and switching at Berrimah ZSS.

Planned actions of replacing Berrimah ZSS and decommissioning the Ron Goodin 22kV switchboard are included and help maintain risk at the current levels. We expect that the switchgear at Palmerston ZSS and Mitchell St switching station will be replaced in 2031 and 2033, respectively, and further analysis will be undertaken to define the need, timing and cost.

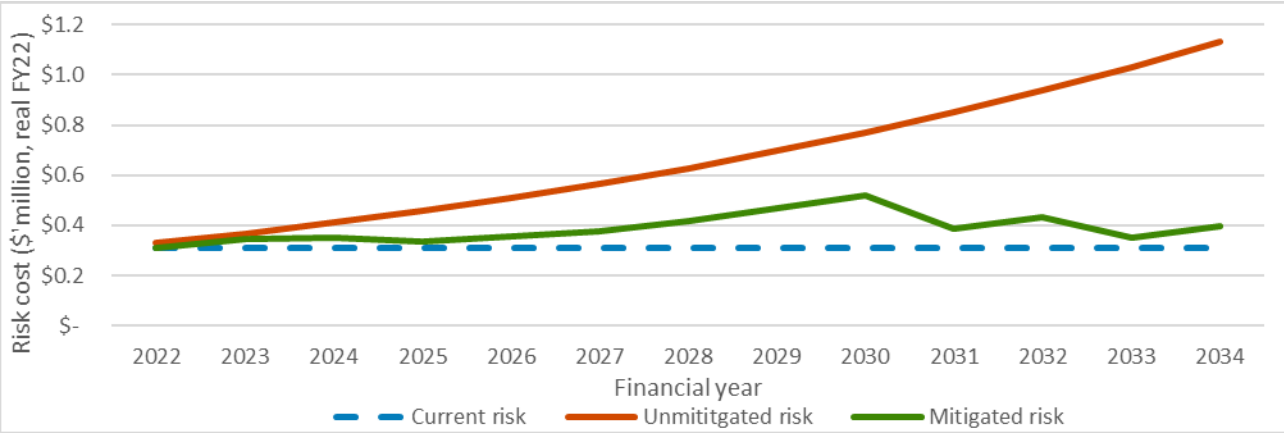

Figure 4 Forecast total unmitigated and mitigated risk compared to the current risk level

7. Asset Lifecycle Management

Power and Water's asset management approach considers the entire asset lifecycle. This approach supports prudent asset management decision making to effectively balance risk, cost and performance over the life of the asset. The intended outcomes of a lifecycle approach for Power Transformers are to:

- Maximise asset utilisation
- Minimise asset lifecycle costs
- Minimise variation to mitigate supply chain risks and minimise spares
- Keep asset risk as low as reasonably practical
- Review and continuously improve asset management practices

The following sections detail Power and Water's lifecycle management activities.

7.1 Planning

Asset planning identifies the need for an asset, outlines its functional requirements, and identifies the lowest cost solution that maintains risk within tolerable levels. Key planning inputs include asset condition, performance, criticality, and forecast demand.

The requirement for a new asset can be triggered by augmentation drivers, such as the connection of new customers or load growth on existing assets, or replacement drivers such as asset condition or performance issues.

7.2 Design

PWC develops and maintains a Substation Design Manual which defines the functional requirements for zone substation assets and allows for the standardisation of zone substation designs as far as is practicable, given the broad range of capacities and locations.

Standardisation enables consistent application of best industry practise and continuous improvement in safety, reliability, operability, and maintainability. It establishes technical commonality that allows for an off-the-shelf, best practice, and fit-for-purpose approach to engineering solutions. It also allows for interchangeability and reduced spares holdings that provides operations and asset management benefits.

Asset failures, feedback from maintainers and information from industry working groups may trigger updates and improvements to our design standards. For example, the maintenance-induced failures, safety incidents and defects experienced with withdrawable switchgear have undergone detailed analysis, resulting in a decision to move to fixed pattern (non-withdrawable) switchboards.

7.3 Maintenance

Asset maintenance involves the upkeep of assets to ensure they will function to their required capability in a safe and reliable manner from their commissioning through to their disposal. Maintenance requirements can evolve as the condition and performance requirements of the assets change throughout its life.

Maintenance activities can be classified into three distinct areas: preventative (routine) maintenance, corrective (non-routine) maintenance, and unplanned maintenance (emergency response).

7.3.1 Preventative Maintenance

Preventative maintenance requirements are documented in our Asset Strategies Procedures. For circuit breakers we perform the following preventative maintenance activities:

- Circuit breakers undergo an online visual inspection, Partial Discharge (PD) scan and thermal scan as part of our regular zone substation inspections
- Functional maintenance is an offline inspection and operational check of the mechanical components to confirm that the circuit breaker operating mechanism is functioning correctly
- Diagnostic maintenance involves offline electrical testing of the conducting and insulating components of circuit breaker to ensure that they are within specification
- Intrusive maintenance involves the inspection and testing of internal components of the circuit breaker. Intrusive maintenance is highly technical, time-consuming and carries a higher risk of maintenance-induced failure. For gas insulated switchgear we would typically use external support to undertake this maintenance due to the risks involved and the specialised nature of the work
- Oil testing and dissolved gas analysis is performed on oil circuit breakers. This testing can identify emerging internal issues such as oil quality, water ingress, turbulator damage and slow operation. This is typically performed during diagnostic maintenance but may be done at higher frequency if warranted by prior results
- SF_6 gas testing is performed on gas circuit breakers to detect the presence of moisture and other contaminants that may affect the integrity of the circuit breaker insulation. This is typically performed during diagnostic maintenance but may be done at higher frequency if warranted by prior results

7.3.2 Corrective Maintenance

Corrective maintenance involves planned activities to repair defects or restore asset condition. Defects are typically identified during preventative maintenance and are prioritised for rectification based on the risk they pose to the network.

Common defects on HV circuit breakers include

- Oil or SF_6 gas leaks
- Racking alignment issues, affecting interlocks and operation
- Failure of switchboard auxiliary components such as earth switches and voltage transformers
- Issues with the operating mechanisms such as dashpot failure, trip coil failure, lubrication of moving parts and failed position switches
- Moisture or compromised insulation

7.3.3 Unplanned Maintenance

Unplanned maintenance involves activities to immediately restore supply or make a site safe in response to asset functional failure.

7.4 Renewal

Asset renewal is the establishment of a new asset in response to an existing asset's condition, or the extension of life of an existing asset. The need for asset renewal is typically identified during maintenance and is verified in the asset planning stage. Asset renewal aims to optimise the utilisation of an asset whilst managing the safety and reliability risk associated with the failure of the asset.

Section 5 outlines the implementation plans.

7.5 Disposal

Assets are assessed for potential reuse prior to disposal. Where it is economical to do so, assets may be retained as essential spares or components of the asset salvaged for spare parts. This is particularly the case for legacy assets since like-for-like replacements may not be available. Assets with remaining value are offered for sale prior to disposal.

Power and Water ensures that all assets identified for disposal are disposed of in an environmentally responsible manner. Older circuit breaker assets have the potential for PCB contamination in the insulating oil, so assets are tested prior to disposal. Assets that contain SF_6 gas must have the gas evacuated prior to disposal or sent back to the OEM for gas recovery and disposal. Recovered SF_6 gas is captured and sent to a recycling facility.

8. Continuous improvement

Table 7 below outlines the improvement plans related to the asset class.

Improvement Area	Today	Tomorrow / In Development	Future
SF_6 gas handling	Limited internal capability and reliance on key staff. Sealed equipment is transported for disposal at excessive cost	Improve capability by training field staff, procuring gas handling equipment. Capability to extract gas from sealed equipment to enable local disposal or recycling and significant cost saving.	Improve SF6 analysis capability to extend asset lives and maintenance Move away from SF6 to reduce handling costs.
Condition monitoring	Point in time measurements of limited condition variables	Testing of dynamic response and performance based maintenance Offline PD to extend asset lives and maintenance intervals	Online monitoring of performance during fault operation Continuous online PD measurement, predictive failure systems.
Maintenance strategy	Aligned with industry best practice	Optimise strategy to ensure appropriate balance of risk and cost for each make / model.	Leverage ongoing technology improvements to optimise maintenance frequency and cost.
Environment	Predominantly use SF_6, a potent greenhouse gas, transmission circuit breakers	Investigate emerging technologies with lower environmental impact	Standardise on an SF_6 alternative

Table 7 - Asset improvement plan

PowerWater

Power and Water Corporation

Senior Manager Asset Management
Power Services
Phone 1800 245 092

powerwater.com.au