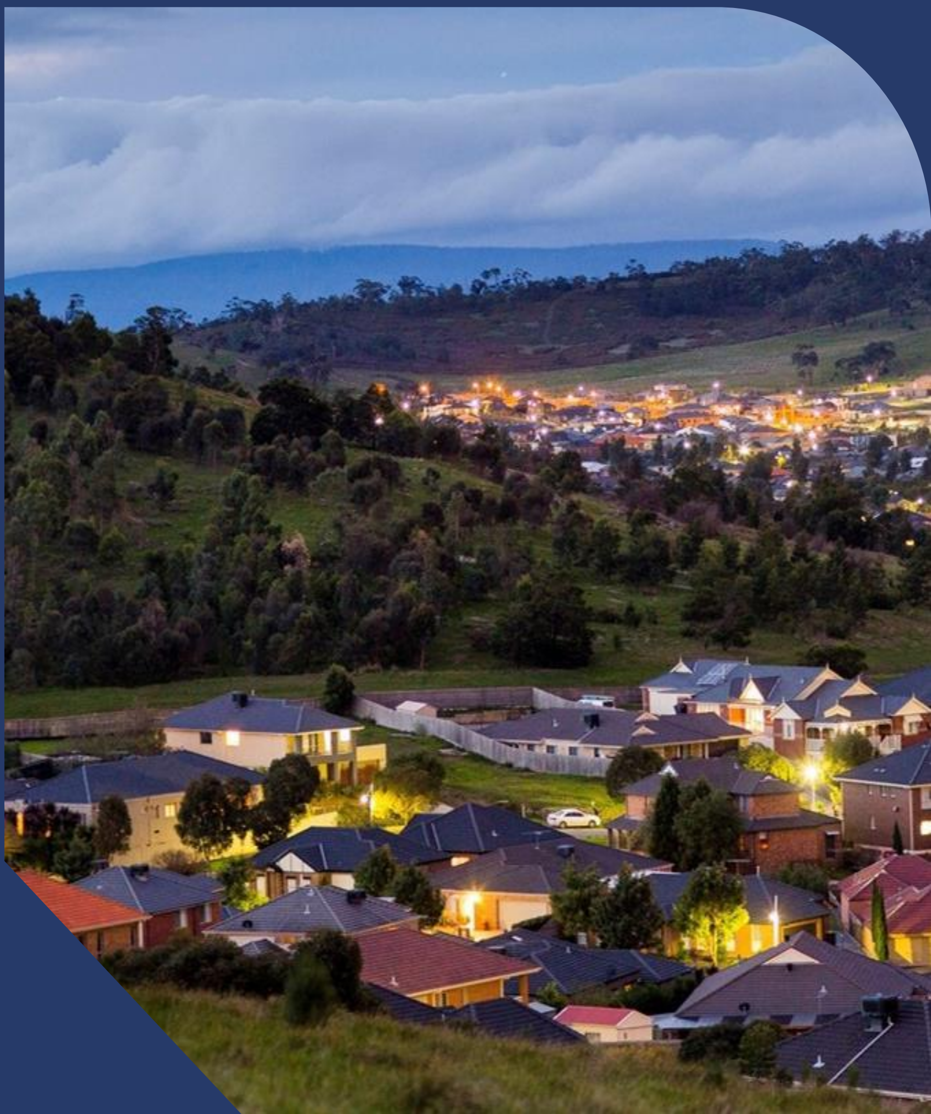
AusNet

Circuit Breakers

AMS – Electricity Distribution Network



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1. Executive Summary

This document is part of the suite of Asset Management Strategies relating to AusNet's electricity distribution network. The purpose of this strategy is to outline the inspection, maintenance, replacement and monitoring activities identified for economic life cycle management of zone substation circuit breakers (CBs).

The strategy covers 1168 circuit breakers and step switches installed in zone substations. Approximately 25% of the circuit breakers are older bulk oil circuit breakers (12%) and minimum oil circuit breakers (13%). The remaining 75% of the CB population consists of vacuum (62%) and SF6 (13%) circuit breakers. SF6 CBs are mainly installed in the 66kV network while vacuum circuit breakers are installed in 22kV indoor switchboards.

Consequence of failure is assessed based on safety, environment and collateral damage and community impacts due to outages and a quantitative risk assessment for circuit breakers has been performed to establish a prudent and risk-based replacement program for high-risk circuit breakers during the period 2026-2031.

Proactive management of circuit breakers inspection, condition monitoring and replacement practice is required to ensure that stakeholder expectations of cost, safety, reliability and environmental performance are met. The summary of proposed asset strategies is listed below.

1.1. Asset Strategies

1.1.1. New Assets

- Continue to purchase fully type tested indoor and outdoor circuit breakers to the latest specification.

1.1.2. Condition Monitoring

- Continue visual checks of circuit breakers as part of the regular zone substation inspections.
- Continue annual non-invasive condition monitoring scans including the use of radio frequency interference, ultrasonic, infra-red thermal and UV corona camera testing.
- Continue to establish the bulk oil CB's SRBP bushing condition through an electrical testing program

1.1.3. Maintenance

- Review zone substation (ZSS) Circuit Breaker Maintenance Regime in PGI 02-01-04 for 22kV Vacuum and SF6 Circuit breakers.
- Continue scheduled preventative maintenance as per specific Standard Maintenance Instructions for each circuit breaker type.

1.1.4. Spares

- Maintain strategic spares holding of circuit breakers as per spare holding policies
- Continue to salvage best parts and complete assemblies of obsolete CB to achieve per spare holdings

1.1.5. Refurbishment

- Use bushing replacements to mitigate shorter term risk until bulk oil CB replacement is possible, for very poor condition bushings found during the electrical testing condition monitoring program

1.1.6. Replacement

- Replace poor condition outdoor /Indoor circuit breakers as part of planned station rebuild projects or CB asset replacement projects for 2026-2031 period

2. Abbreviations and definitions

TERM	DEFINITION
CB	Circuit breaker
NER	Neutral earth resistor
NEC	Neutral earthing compensator
DFA	Distribution feeder automation
REFCL	Rapid Earth Fault Current Limiter
PCBs	Polychlorinated biphenyls
Pof	Probability of failure
PoF_{ML}	Probability of failure -Machine Learning
PoF_{HI}	Probability of failure -Health Index
Cof	Consequence of failure
Zk	Work order Notifications associated with failures (unplanned power interruptions)
ZA	Work order Notifications associated with corrective actions from planned inspections

3. Introduction

3.1. Purpose

The purpose of this document is to outline the inspection, maintenance, replacement, and monitoring activities identified for economic life cycle management of circuit breakers in AusNet Victorian electricity distribution network. This document is intended to be used to inform asset management decisions and communicate the basis for activities.

In addition, this document forms part of our Asset Management System for compliance with relevant standards and regulatory requirements. It is intended to demonstrate responsible asset management practices by outlining economically justified outcomes.

3.2. Scope

This Asset Management Strategy applies to all outdoor and indoor type circuit breakers operating at 66kV, 22kV, 11kV and 6.6kV located in zone substations.

Metal enclosed switchboards where indoor circuit breakers are installed are covered in AMS 20 -56.

3.3. Asset Management Objectives

The high-level asset management objectives are outlined in *AMS 01-01 Asset Management System Overview*.

The electricity distribution network objectives are stated in *AMS 20-01 Electricity Distribution Network Asset Management Strategy*.

4. Asset Description

4.1. Function

Circuit breakers (CBs) are electrical switches that, in conjunction with protection relays and supervisory control and data acquisition (SCADA) controls, operate automatically to interrupt the abnormal flow of electrical currents. In doing so, CBs protect people from injury and protect property and the electrical network equipment from damage. Circuit breakers are also used to energise and de-energise lines, feeders, busses, and electrical equipment such as transformers or capacitor banks to enable operation requirements, maintenance or augmentation works.

4.2. Population

4.2.1. Population Considerations

The population profile for Circuit Breakers is crucial for effective lifecycle management. This profile includes detailed data on the quantity, types, locations, and specifications of these assets within the electrical distribution network.

A comprehensive understanding of the population profile allows asset managers to:

- Identify critical assets: Determine which circuit breakers are essential for maintaining the integrity and reliability of the network. For example, a 66kV circuit breaker at a major zone substation might be deemed essential and require more frequent inspections to ensure uninterrupted service.
- Allocate resources efficiently: Plan and allocate maintenance resources effectively by knowing the exact number and location of assets. For instance, knowing that a certain region has a high concentration of 22kV bulk oil circuit breakers can help in scheduling maintenance activities more efficiently.
- Risk management: Assess and manage risks associated with different assets. For example, if the population profile indicates that Bulk oil circuit breakers are located in areas with high bush fire prone areas, additional protective measures can be implemented in those areas.
- Optimise maintenance schedules: Develop optimised maintenance schedules based on the distribution and condition of assets. For instance, 66kV SF6 circuit breakers that are critical for feeder circuits from a zone substation might be scheduled for more frequent inspections and maintenance to prevent any potential failures.
- Enhance reliability and safety: Ensure that all components, circuit breakers, meet the required standards for reliability and safety. For example, if the profile reveals that certain circuit breakers are outdated and no longer meet safety standards, these can be prioritised for replacement.
- Support strategic planning: Inform long-term strategic planning and investment decisions. For instance, the population profile might show that a significant portion of 22kV circuit breakers in a rapidly developing suburban area need upgrading to support increased demand, guiding future investment in that region.

4.2.2. Geographic Impact Areas

The AusNet electrical distribution network covers a significant portion of Victoria, including Melbourne's northern and eastern suburbs, and extends across eastern and north-eastern Victoria. This region encompasses a diverse range of geographic locations, each with specific environmental impacts on circuit breakers. Understanding these impacts is essential for effective asset management within the AusNet electrical distribution network.

Notable examples include:

- High Wind Areas: High wind areas, particularly in elevated regions and open plains, subject outdoor circuit breakers to significant stress and potential mechanical damage. Example: The structural integrity of outdoor 66kV circuit breakers in the elevated regions of the Dandenong Ranges must be robust enough to withstand high wind speeds, ensuring they remain securely operational and do not fail under stress.
- Corrosive Areas: Coastal areas and industrial regions where salt and pollutants are prevalent can cause corrosion of metallic components in circuit breakers. Example: Regular maintenance and the use of corrosion-resistant materials are crucial to prolong the lifespan of these circuit breakers. Outdoor 22kV bulk oil circuit breakers in coastal towns like Wonthaggi require regular inspections and maintenance to mitigate the effects of salt-induced corrosion.
- Bushfire Areas: Bushfire-prone areas, common in many parts of Victoria, pose a risk of fire damage to circuit breaker infrastructure. Example: Fire-resistant materials and strategic vegetation management around circuit breaker installations are essential for reducing this risk. In the bushfire-prone regions of the Yarra Valley, outdoor 66kV circuit breakers must be designed to withstand high temperatures, and installations must be cleared of nearby vegetation to prevent fire spread.
- Flood-Prone Areas: Areas prone to flooding can impact the performance and integrity of indoor and outdoor circuit breakers. Example: Proper waterproofing and elevated installations are essential to protect these assets. In regions like Gippsland, where flooding is more frequent, indoor and outdoor circuit breakers must be installed with robust waterproofing measures to prevent water ingress and subsequent failures.
- Seismic Zones: Though less common, areas with potential seismic activity may require circuit breakers to be constructed with flexibility and resilience to absorb and dissipate seismic forces, reducing the risk of structural failure. Example: In areas near fault lines, circuit breakers may need to incorporate seismic-resistant features to ensure stability during earth tremors.

4.2.3. Population by Type

22kV Circuit Breakers (Bulk Oil)

Summary Explanation of Form and Function

Bulk oil circuit breakers (bulk oil) (CBBOs) use oil as both the arc extinguishing medium and the insulating medium between the current-carrying contacts. When the breaker operates, an arc forms between the contacts and the oil is vaporised, helping to quench the arc. CBBOs are one of the older technologies used in the 22kV system. They are primarily used in outdoor installations due to their robustness and the insulating properties of oil. In the network design, 22kV CBBOs serve the purpose of controlling and protecting distribution feeders, ensuring that faults are isolated to maintain system stability and prevent damage to downstream equipment. The CBBOs operate automatically or manually to interrupt abnormal electrical currents, protecting both the network and connected equipment. They are critical in preventing prolonged outages and ensuring safety by interrupting fault currents. Historical Application: Approximately 6.2% of bulk oil circuit breakers of total circuit breaker population are associated with 22kV distribution feeders. These circuit breakers have lower limits of automatic switching operations before maintenance compared to modern vacuum circuit breakers. They are technically obsolete and no longer supported by manufacturers.

22kV Circuit Breakers (Minimum Oil)

Summary Explanation of Form and Function:

Minimum oil circuit breakers (Minimum Oil) (CBMOs) use oil only around the interrupting contacts, with the rest of the insulation provided by air or other materials. This design reduces the amount of oil required, decreasing maintenance needs and fire risk. CBMOs are used for their compact size and efficiency in arc extinguishing in 22kV systems. They are often found in indoor installations due to their smaller size and lower oil volume. CBMOs control and protect distribution feeders in the 22kV network, playing a crucial role in maintaining electrical system stability and protecting downstream equipment from faults. These breakers interrupt abnormal currents using oil as the arc extinguishing medium, providing reliable operation in both normal and fault conditions. They are key in the network's fault management strategy. Historical Application: Approximately 5.1% of minimum oil circuit breakers of total circuit breaker population are associated with 22kV distribution feeders. About 95.8% of these circuit breakers are located indoors on first or second-generation switchboards. These circuit breakers have become technically obsolete and are no longer supported by the manufacturers.

22kV Circuit Breakers (Vacuum)

Summary Explanation of Form and Function:

Vacuum circuit breakers (CBVU's) use a vacuum as the arc extinguishing medium. When the contacts within the vacuum interrupter separate, the arc forms and is quickly extinguished as the metal vapours, ions, and electrons produced during the arc rapidly condense on the surface of the circuit breaker contacts within the vacuum. CBVUs are known for their longevity, low maintenance requirements, and high efficiency in arc extinguishing. They are preferred for frequent switching operations and are suitable for both indoor and outdoor installations. CBVUs protect and control distribution feeders in the 22kV network, ensuring quick and reliable fault clearance, which is essential for modern network automation and protection schemes. These circuit breakers provide reliable interruption of electrical currents during faults, with the vacuum ensuring minimal contact erosion and high operational endurance. Historical Application: Modern vacuum circuit breakers are being used to retrofit/replace older **[CIC] and [CIC]** indoor minimum oil circuit breakers, enhancing reliability and efficiency. Vacuum Circuit breakers (CBVU) are being used to replace old 22kV CBBO and CBMO technologies described above.

22kV Circuit Breakers (Dead Tank/Live Tank)

Summary Explanation of Form and Function:

Dead Tank (CBDT) and Live Tank (CBLT) circuit breakers use sulphur hexafluoride (SF_6) to extinguish the arc. The SF_6 has excellent insulating and arc-quenching properties, making it highly effective for circuit interruption. SF_6 gas is utilised for their superior arc extinguishing capabilities, compact size, and minimal maintenance needs. However, SF_6 gas circuit breakers are not used in AusNet 22kV indoor switchboards and 99.9% of them have now been phased out in 22kV outdoor stations.

66kV Circuit Breakers (Bulk Oil)

Summary Explanation of Form and Function:

Like 22kV CBBOs, 66kV CBBOs use oil for arc extinguishing and insulation. The oil surrounds the contacts and absorbs the arc energy during operation. CBBOs are robust and suitable for outdoor installations in the 66kV system. They are used for their high interrupting capacity and reliable performance under various conditions. These circuit breakers are essential for controlling and protecting the higher voltage feeders and bus sections, ensuring the stability of the 66kV network. 66kV CBBOs interrupt high fault currents to protect the network and equipment. The oil acts as the arc-quenching medium, ensuring reliable operation. Historical Application: Approximately 1.3% of bulk oil circuit breakers of total circuit breaker population are associated with the 66kV distribution network. These circuit breakers are becoming technically obsolete and are no longer supported by the manufacturers.

66kV Circuit Breakers (Minimum Oil)

Summary Explanation of Form and Function:

CBMOs at 66kV operate similarly to their 22kV counterparts, using oil around the interrupting contacts with additional insulation provided by air or other materials. These circuit breakers are preferred for their reduced oil volume, making them safer and easier to maintain compared to bulk oil types. CBMOs protect and control 66kV feeders, playing a vital role in fault management and ensuring the continuity of power supply. By interrupting fault currents, these circuit breakers protect the network and equipment from damage, ensuring reliable operation. Historical Application: Approximately 4.4% of minimum oil circuit breakers of total circuit breaker population are associated with the 66kV distribution network. These circuit breakers are becoming technically obsolete and are no longer supported by the manufacturers.

66kV Circuit Breakers (Dead Tank/Live Tank)

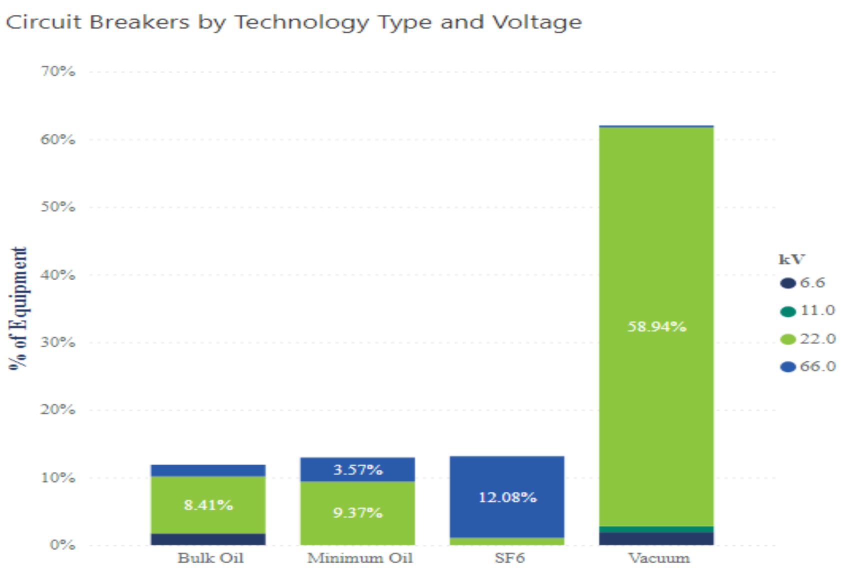
Summary Explanation of Form and Function:

Dead Tank (CBDT) and Live Tank (CBLT) circuit breakers use SF6 for arc extinguishing. SF6 provides excellent insulation and arc-quenching properties, making these circuit breakers highly efficient. SF6 gas is used for their high reliability, low maintenance needs, and effective arc quenching. These circuit breakers are critical for protecting and controlling the 66kV network, ensuring quick fault clearance and maintaining system stability. The SF6 quenches the arc during operation, providing reliable interruption of fault currents and preventing equipment damage and these circuit breaker types are being used to replace old CBBO and CBMO technologies described above. Historical Application: A current project is in progress to replace the **[CIC]** circuit breaker (CBMO) population during the 2018 FY with SF6 insulated dead tank circuit breakers. (CBDT)

Population Profile

AusNet has a total of 1168 CBs installed in the electricity distribution network. Included in this number are capacitor bank CBs and step switches, Neutral earth resistor (NER) bypass CBs, Neutral bus CBs used in REFCL operated stations and neutral earthing compensator (NEC) CBs. A summary of the distribution circuit breaker population by voltage class and technology type is shown in figure 1.

Figure 1: Circuit breaker population by technology type and voltage



4.2.3.1. 22kV Circuit Breakers

Bulk oil and minimum oil circuit breaker types have lower limits of automatic switching operations before maintenance compared to modern vacuum circuit breakers. They are technically obsolete and no longer supported by the manufacturers. With the application of new technology in 22kV network; distribution feeder automation (DFA) and Rapid Earth Fault Current Limiter technology (REFCL), demands a very reliable and efficient circuit breaker with frequent auto reclosing. Life cycle management of these older CBs, especially 22kV minimum oil indoor circuit breakers is becoming difficult.

Population of 22kV oil insulated circuit breakers is dominated by only a few types. Top five (5) Manufacturer /Models of 22kV bulk oil (CBBO) and minimum oil (CBMO) circuit breakers contribute to approximately 84.8% of the oil filled circuit breaker population.

[CIC] (22.83%)

[CIC] (22.29%)

[CIC] (15.22%)

[CIC] (13.04%)

[CIC] (11.41%)

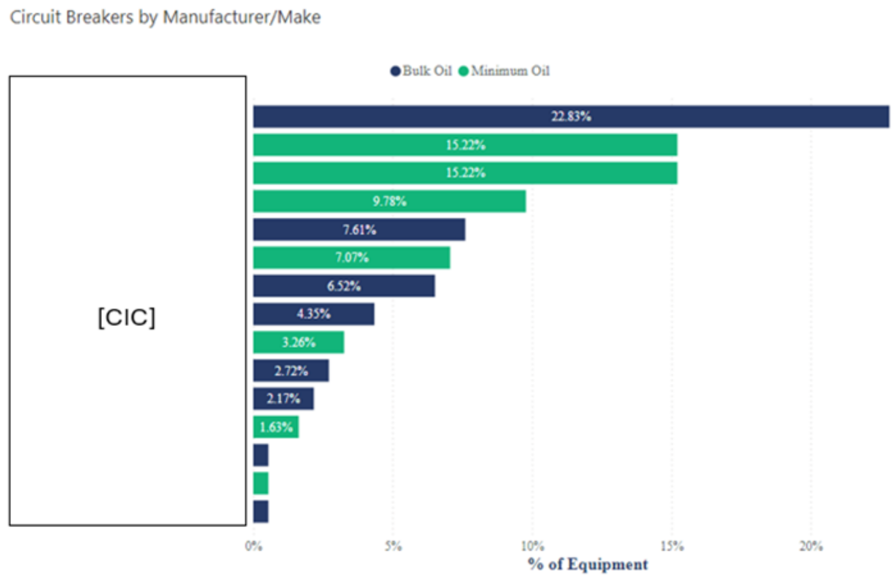


Figure 2: 22kV minimum oil and bulk oil circuit breakers by manufacturer/make.

It should be noted that 22kV minimum oil circuit breakers are mainly located in second generation indoor switchboards are reaching end of life, mainly **[CIC]**, **[CIC]** and **[CIC]** types.

4.2.3.2. 66kV Circuit Breakers

66kV bulk oil and minimum oil circuit breaker types have lower limits of automatic switching operations before maintenance compared to modern SF6 circuit breakers. These circuit breakers are becoming technically obsolete and no longer supported by the manufacturers. Life cycle management of these older CBs, especially 66kV minimum oil circuit breakers is becoming difficult.

Population of 66kV oil insulated circuit breakers comprised of few types of Manufacturer /Models of 66kV bulk oil (CBBO) and minimum oil (CBMO) Circuit breakers. They are, **[CIC]**, **[CIC]**, **[CIC]**, **[CIC]** circuit breakers as shown in figure 3.

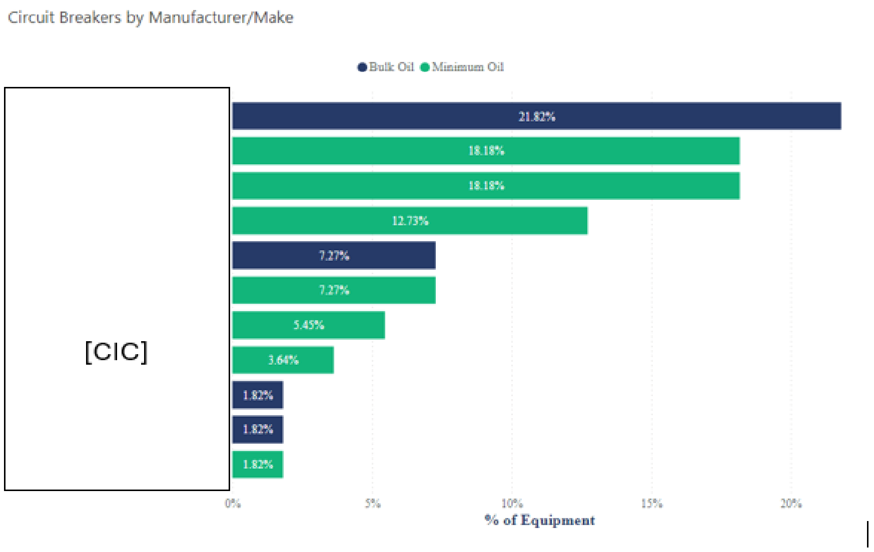


Figure 3: 66kV minimum oil and bulk oil circuit breakers by manufacturer/make.

4.3. Age

Age Considerations

An informed understanding of the age profile of circuit breakers is crucial for effective asset management and lifecycle planning. Knowing the age distribution of these assets helps in predicting their remaining useful life and planning maintenance, upgrades, or replacements accordingly.

Age Profile of Circuit Breakers

22kV Circuit Breakers

Bulk Oil Circuit Breakers (CBBOs)

- **Overview**: CBBOs are generally older assets, often nearing or exceeding their expected operational life.
- **Statistics**: Approximately 80.5% of the bulk oil CBs comprise **[CIC]**, **[CIC]** and **[CIC]** types, mostly over 40 years old and reaching end of life.
- **Issues**: Age-related issues include oil degradation, contact wear, and reduced reliability.
- **Mitigation**: Regular oil testing and replacement can prevent unexpected failures and extend service life.
- **Spares and Reliability**: Some spares are available from retired circuit breakers, but overall reliability is becoming poor.

Minimum Oil Circuit Breakers (CBMOs)

- **Overview**: CBMOs tend to be older, with many in the 35–45-year age band.

- **Statistics**: Approximately 95.7% of Minimum oil CBs comprise, **[CIC]**, **[CIC]**, **[CIC]**, **[CIC]** mostly over 40 years old and reaching end of life.
- **Issues**: These circuit breakers are technically obsolete and no longer supported by manufacturers. Age-related issues include oil leakage, insulation breakdown, and mechanical wear.
- **Mitigation**: Refurbishing or replacing ageing indoor CBMOs can enhance network reliability and safety.

Vacuum Circuit Breakers (CBVU)

- **Overview**: Generally newer compared to oil types but require targeted condition monitoring as they age.
- **Issues**: Potential issues include vacuum interrupter wear and control circuit failures.
- **Retrofit Programmes**: Modern VCBs are being used to retrofit older **[CIC]** and **[CIC]** type indoor CBMOs. However, retrofit program was delayed due to safety issues and other options of replacing with new indoor switchboards is being considered as an option.
- **Mitigation**: Replacing or refurbishing ageing VCBs ensures reliable operation and supports modern automation and protection schemes and target high risk stations for switchboard replacement.

SF6 Circuit Breakers (DTCB/LTCB)

- **Overview**: Among the newer types in the 22kV system, using SF6. Only a very small population exists at 22kV.
- **Issues**: Age-related challenges include SF6 leakage and mechanical component wear.
- **Mitigation**: Regular SF6 analysis and equipment servicing can prevent failures and maintain operational efficiency.

66kV Circuit Breakers

Bulk Oil Circuit Breakers (CBBOs)

- **Overview**: Typically older, often over 50 years old, and nearing the end of their service life.
- **Statistics**: The population comprises mainly of **[CIC]** types.
- **Issues**: Age-related issues include oil degradation, insulation failure, and contact erosion.
- **Mitigation**: Proactive oil testing and refurbishment can prevent unexpected failures and prolong operational life.

Minimum Oil Circuit Breakers (CBMOs)

- **Overview**: Most are more than 31 years old, with the oldest being 61 years.
- **Statistics**: Comprise **[CIC]**, **[CIC]**, and **[CIC]** types.
- **Issues**: Can suffer from oil degradation, insulation breakdown, and mechanical wear.
- **Mitigation**: Replacing or refurbishing ageing CBMOs can enhance network reliability and reduce outage risks.

SF6 Circuit Breakers (DTCB/LTCB)

- **Overview**: Relatively newer but still require monitoring as they age.
- **Issues**: Potential issues include SF6 leakage and mechanical wear.
- **Mitigation**: Regular SF6 analysis and servicing maintain reliability and operational efficiency.
- **Projects**: A project is in progress to replace the **[CIC]** circuit breaker population with SF6 insulated dead tank circuit breakers.

Age Profile

Summary Data

The average service age of all distribution circuit breaker population is 22.8 years. The average age of 6.6 kV and 11kV circuit breakers are 34.4 and 3 years. Average age of circuit breakers is shown in figure 4.

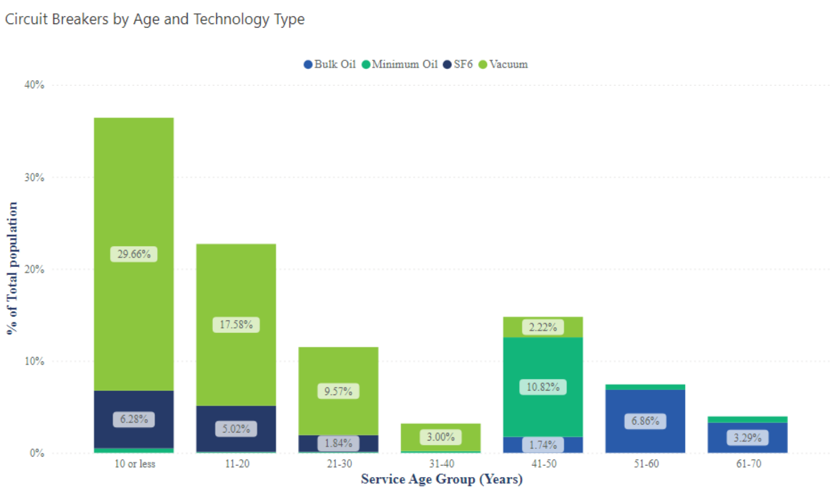
Figure 4: Circuit Breaker average age group by technology type

Average service age of distribution circuit br...

Nominal Voltage pp (kV)	Avg Service Age (Years)	% CB Population
22.0	**22.3**	**77.8%**
Vacuum	14.1	58.9%
Minimum Oil	43.5	9.4%
Bulk Oil	58.1	8.4%
SF6	6.8	1.1%
66.0	**24.0**	**17.7%**
SF6	12.4	12.1%
Minimum Oil	48.0	3.6%
Bulk Oil	59.0	1.7%
Vacuum	0.0	0.3%
6.6	**34.4**	**3.7%**
Vacuum	15.2	1.9%
Bulk Oil	55.7	1.7%
11.0	**3.0**	**0.9%**
Vacuum	3.0	0.9%
Total	**22.8**	**100.0%**

Figure 5 shows the average age of circuit breaker population by technology type. Circuit Breakers with Vacuum and SF6 insulating medium are relatively new and, are introduced to replace older bulk oil and minimum oil circuit breakers. Bulk oil and minimum oil circuit breakers are more than 40 years old. Approximately 61.5% of circuit breakers are less than 20 years old.

Figure 5: Circuit Breaker age group by technology type



22kV Circuit Breakers

22kV **[CIC]**, **[CIC]** and **[CIC]** make minimum oil circuit breakers located in second generation indoor switchboards are reaching end of life. Managing these CBs are becoming difficult due to scarcity of original spares. Their average age of minimum oil CBs is 43.5 years. (Figure 4).

66kV Circuit Breakers

66kV minimum oil circuit breakers comprise of **[CIC]**, **[CIC]** (Figure 3). Their average age is 48 years. **[CIC]** types are the oldest of the minimum oil circuit breaker fleet (61 years). Some spares sourced from retired CBs are available but the reliability of these CBs becoming poor.

66kV bulk oil circuit breaker population comprises of **[CIC]**, **[CIC]** and **[CIC]** circuit breakers and has a smaller population compared to 66kV minimum oil circuit breakers and are all over 50 years old. Some spares sourced from retired CBs are available but the reliability of these CBs becoming poor.

5. Risk

AusNet maintains a risk management system designed in accordance with AS ISO 31000 Risk Management – Guidelines to ensure risks are effectively managed to provide greater certainty for the owners, employees, customers, suppliers, and the communities in which we operate.

The risk of each asset is calculated as the multiplication of probably of failure (PoF) of the asset and the consequence of failure (CoF). The risk is then extrapolated into the future accounting for forecast changes in PoF and CoF.

In the distribution network, AusNet aims to maintain risk. Risk treatments required to achieve this over time include replacement, refurbishment, and maintenance activities, and are developed based on current risk and extrapolated risk.

The overall approach to quantified asset risk management is detailed in AMS -01-09. Section 5.1. 5.2. 5.3. of this document describe the considerations and methodologies to determine PoF, Cof, and risk treatments that are unique to CBs.

5.1. Probability of failure

An asset is deemed to have failed when it does not meet the functional requirements for which it was acquired. Both quantitative and qualitative analysis is used to assess the condition of the asset to determine the probability of failure and to estimate the remaining useful life. AMS 01-09 describes the detail methodologies used in calculating and deriving the probability of a failure considering the four key factors; asset life, asset utilization, location and physical condition.

5.1.1. Failure Modes

General

On signal from an operator or a protection system circuit breakers are required to break load current or fault current. They are required to operate with sufficient speed to break and extinguish an electrical arc and clear faults within tolerable time frames require to protect people and equipment, usually within 2 to 3 cycles at 50Hz. They are also required to maintain sufficient dielectric strength to prevent insulation breakdown at all times.

The interrupters are designed control electrical arcs as well as maintain insulation of live components. The mechanisms are designed to store and rapidly discharge large amounts of mechanical energy. Both are controlled by auxiliary systems within the mechanism box.

The key ways circuit breakers fail to meet functional requirements are:

- Failure to clear an arc. This can be caused by contaminated extinguishing medium or insufficient arc extinguishing mechanics due slow mechanical drive, worn arcing contacts, or interrupters that fail to fully travel.
- Failure to operate on command. This can be caused by a breakage in the mechanism drive chain, insufficient mechanism energy storage, failure to receive electrical command.
- Insulation flashover. Caused by insufficient insulation medium (ie a leak), contamination of the internal insulation medium, or external contamination (ie pollution).

Failure Modes by Asset Type

Bulk Oil Circuit Breakers (CBBO)

- Insulation Breakdown: The oil used in these breakers can degrade over time due to moisture ingress and associated contamination, as well as metallic particles resulting from contact wear, reducing its effectiveness in arc extinguishing and suppression capability. Example: Proactive oil testing and replacement can help maintain the breaker's performance.

- Wear of interrupters: Cumulative fault operation leads to wear of arcing contacts. This will eventually result in the failure of interrupters to clear an arc. Cumulative fault current density is required to be monitored with contacts replaced when the threshold is exceeded.
- Mechanical Wear: Components such as springs and hinge mechanisms can suffer from wear and fatigue, affecting the device’s ability to operate correctly. Example: Frequent operations may wear down the mechanical components, leading to slower or incomplete disconnection during faults.
- Moisture Ingress: Over a long period, moisture ingress can cause the internal metal parts to corrode and seize the operating mechanism, resulting in hang-ups. Example: AusNet has experienced warping of the Permali (resin impregnated densified wood) drive rods preventing correct interrupter travel.

Minimum Oil Circuit Breakers (CBMO)

- Insulation Breakdown: The oil can become contaminated, reducing its effectiveness in arc suppression. Example: Regular oil testing and replacement can help maintain performance.
- Mechanical Wear: Components can wear down over time, affecting the breaker's ability to operate correctly. Example: Proactive maintenance can prevent mechanical failures and extend the breaker's life.
- Wear of interrupters: Cumulative fault operation leads to wear of arcing contacts. This will eventually result in the failure of interrupter to clear an arc. Cumulative fault current density is required to be monitored with contacts replaced when the threshold is exceeded.
- Environmental Degradation: Exposure to harsh environments, such as coastal areas, can lead to corrosion of the metal components, compromising the unit’s structural integrity. Example: External rotating insulators have seized prevent correct travel of the drive train.

Live Tank SF6 Circuit Breakers (CBLT)

- SF6 Leakage: SF6 can leak, reducing the breaker's insulation and arc-quenching effectiveness. Example: Addressing root cause of SF6 alarms can prevent failures.
- Component Fatigue: Repeated fault clearing can cause fatigue in the mechanical components such as cams, springs, and dash pots, reducing their effectiveness over time. Example: Regular inspections and maintenance can ensure continued reliability and performance.
- Wear of interrupters: Cumulative fault operation can lead to wear of arcing contacts. SF6 circuit breakers are more resilient than oil CBs, are often required to be replaced during mid-life refurbishment works.

Dead Tank SF6 Circuit Breakers (CBDT)

- SF6 Leakage: SF6 can leak, reducing the breaker's insulation and arc-quenching effectiveness. Example: Addressing root cause of SF6 alarms can prevent failures.
- Component Fatigue: Repeated fault clearing can cause fatigue in the mechanical components such as cams, springs, and dash pots, reducing their effectiveness over time. Example: Regular inspections and maintenance can ensure continued reliability and performance.
- SF6 contamination: Design clearance of modern CBDTs mean there is very little tolerance for solid metallic components. Example: AusNet had experienced internal flash overs due to partial discharge of from metal shavings resulting from the onsite fitting of bushings. Pre-commissioning acoustic partial discharge tests have reduced these instances.
- Wear of interrupters: Cumulative fault operation can lead to wear of arcing contacts. It should be noted however that CBDTs are most resilient to this type of wear – often designed to withstand a minimum of 20 full faults – eg more that would be expected over the life of the breaker.

Vacuum Circuit Breakers (CBVU)

- Component Fatigue: Repeated fault clearing can cause fatigue of the mechanism.
- Failure of Vacuum: Leak in vacuum bottle can cause insulation breaker. This is very repaid failure, so detection of the external condition of the bottle can be observed, better still, vacuum breaker should be in weather resistant enclosures.

- Racking misalignment: The majority of vacuum circuit breakers are contained within metal clad switchboard with rackable isolation, misaligned operating of the racking system may result in damage the fixed contacts or shutters, leading to insulation failures.

5.1.2. Probability of Failure Assessments

In recent years AusNet has refined the probability of failure (PoF) methodology to make use of big data analytics and statistical analysis to make more effective use of available data. This allows each asset to be assigned a unique probability of failure and future extrapolation of probability of failure. Whereas assets were previously assigned a condition score (i.e. C1 to C5), they have now been assigned a value in the continuum between 0 and 1 then placed into a probability of failure bucket for visualisation.

As per the methods of calculation described in AMS 01-09, the conditional PoF for circuit breakers is a combination of machine learning and health score. Circuit breakers are broken into four subsystems – Insulation, Mechanism, Auxiliary and Bushings. The first three utilise machine learning, whilst bushings utilise HV electrical tests with rules applied in line with the transformer bushing algorithm to develop the health score.

Overall Pof (Pof $_{overall}$) is calculated by combining the machine learning Pof (Pof$_{ML}$) and health score Pof (PoF$_{HI}$) using the Equation 1.

$$PoF_{Overall} = 1 - (1 - PoF_{ML})(1 - PoF_{HI})$$

Equation 1- Overall CB Pof

5.2. Consequence

Failure of a circuit breaker has the potential of resulting in failing to supply customers with energy. There is also a possibility the failed asset injures an employee or member of the public or affect the environment.

Following three key consequences of circuit breaker failure effects have been considered viewed through three lenses.

1. Safety impact,
2. Community impact due to outages (unserved energy)
3. Environment

The detail methodology of the consequence assessment is described in AMS -01-09.

5.3. Risk Treatment

Risk mitigation activities, or treatments, are required to maintain risk by targeting reduction of PoF or CoF depending on the nature of the risk. Mitigation measures include asset replacement, asset refurbishment, inspections, testing or system redesign, and are achieved through capital projects or operational expenditure. Risk treatment options are described in the section on "Risk Treatment' in AMS 01-09.

Capital replacement is a major component of asset risk management. The prerequisites for replacing assets:

- replacement of an asset will result in a material risk reduction
- risks can't be feasibly managed through maintenance or refurbishment
- monetised risk exceeds the replacement cost – ie replacement is economic.

6. Performance

6.1.1. Performance Analysis

In the context of asset management for circuit breakers, assessing asset performance is a vital tool for effective lifecycle management. Performance information provides a comprehensive understanding of how these assets behave under various conditions, enabling asset managers to make informed decisions that enhance the reliability, safety, and efficiency of the electrical distribution network.

Performance data helps identify trends and patterns in asset behaviour, which are crucial for making strategic decisions regarding maintenance, upgrades, and replacements. Understanding how assets perform over time allows for proactive management, reducing the risk of unexpected failures. The assessment employed by AusNet involves analysing failure trends and any significant impacts resulting from failure, which provides valuable insights into the health and reliability of the assets.

6.1.2. Performance Profile

Figure 6 and Fig 7 show the Zk notifications during the period 2020 - 2024 against operating voltage and technology type.

Figure 6 Zk notifications during the period 2020 - 2024 by service voltage

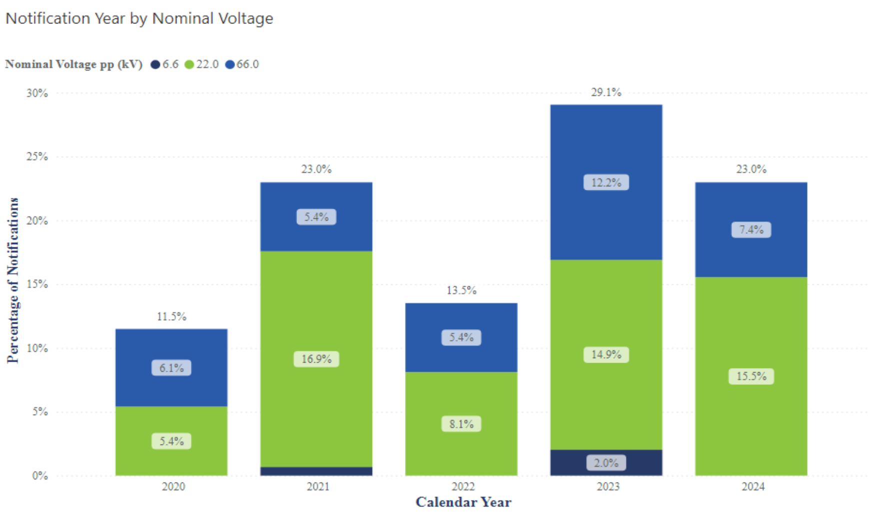


Figure 7: Zk notifications during the period 2020 - 2024 by technology type

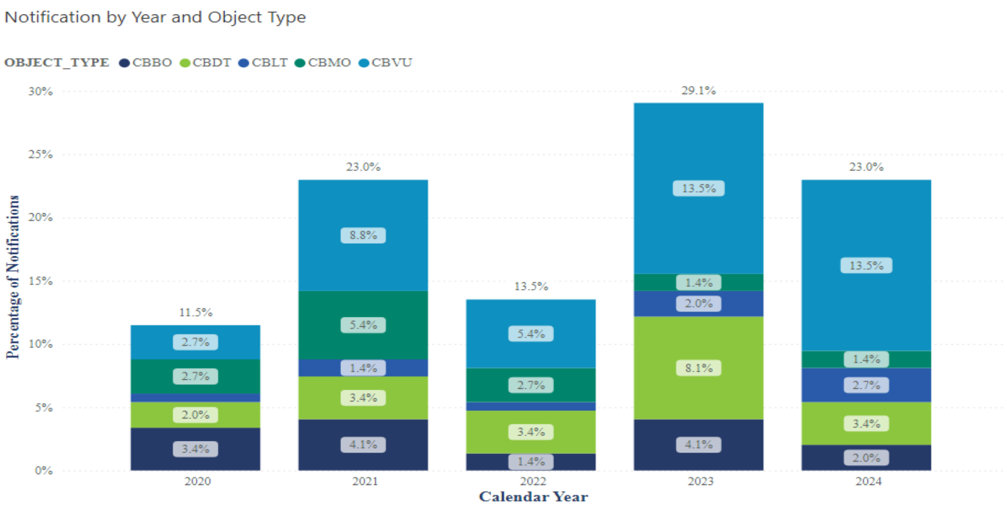


Figure 8 show the Zk notifications during the period 2020 - 2024 by age group.

Figure 8: Zk notifications during the period 2020 - 2024 by age group

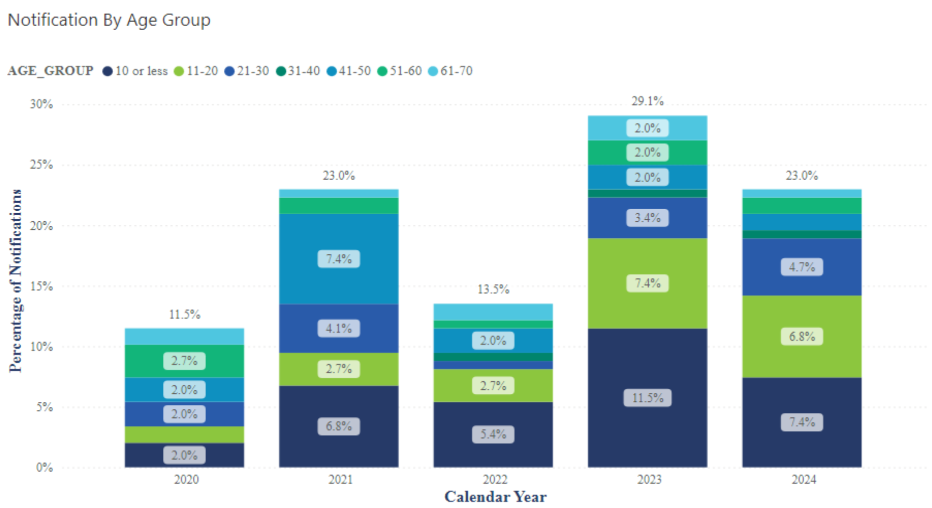
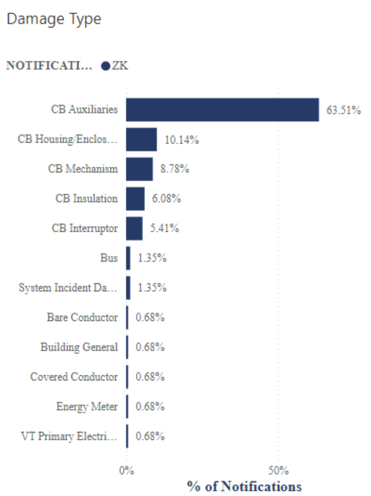


Figure 9 and Figure 10 shows the Zk notification rate per year during the period 2020 -2024 by technology and Damamge type.

Figure 9 : Zk notification rate during the period 2020 -2024 by technology

OBJECT_TYPE	Total Number of CBs	Percentage of ZK Notifications per year / CB Object type Population	Percentage of ZK Notifications per year / Total CB Population
CBVU	642	0.0222	0.0137
CBMO	134	0.0314	0.0041
CBBO	123	0.0358	0.0043
CBDT	100	0.0600	0.0058
CBLT	36	0.0612	0.0021

Figure 10 : Zk failure notification damage type



CB Notification analysis revealed following issues.

1. It is observed the Zk failure notifications had increased over the period 2020 -24 and mostly reported from 22kV vacuum and 66kV SF6 circuit breakers. (refer Figure 6 & 7)
2. It is also noted that most Zk failure notifications are reported from circuit breakers that are less than 20 years of age. (refer Figure 8)
3. Vacuum CBs recorded lowest Zk failure notification rate/year compared to other technologies while SF6 circuit breakers (CBLT & CBDT) recorded the highest. (refer figure 9) Although the Zk notification rate was the lowest in vacuum circuit breakers due to the highest population of this technology type (62%) was the key factor for increasing number of Zk failure notifications.
4. It is noted Zk failures were mostly associated with CB auxiliary systems (63.51%) (refer Figure 10)

Above observations indicate the necessity of reviewing the planned maintenance regime of 22kV vacuum and 66kV SF6 circuit breaker population as increased failure notifications are coming from younger (<20 years) circuit breakers in service. Refer section 8.3.

6.1.2.1. Catastrophic Failures

There were two bulk oil circuit breaker major failures reported in 2014 and 2016 at YPS 11kV switchyard due to bushing failures, one incident resulted in a catastrophic porcelain bushing failure. Circuit breakers at this site are of **[CIC]**; **[CIC]** which are the oldest population of outdoor circuit breakers in Zone Substations.

Safety gram IMS 225933 was issued in 2016 restricting access to the YPS 11kV switchyard. YPS 11kV switchyard was included in station access restriction document SOP35-01 after carrying out further bushing tests of the circuit breakers at this site. YPS 11kV switchyard has now been replaced with a new indoor switchboard. No catastrophic failures reported in the current period in zone substations.

7. Related Matters

7.1. Regulatory Framework

7.1.1. Compliance Factors

No compliance consideration for station circuit breakers involved.

Regulatory and Legislative Reference

Effectively managing compliance obligations specific to legislation and policies is a core element of Asset Class Planning and supports the sustainable operation and management of Network Assets. Ensuring adherence to relevant laws, policies and codes helps prevent legal and regulatory breaches, which can lead to significant penalties, operational disruptions, and reputational damage.

Refer to Section 9 for detailed guidance notes and references, supplied to support the assessment of this factor and the ways it impacts and influences the management of this Asset Class.

Technical Standards and Procedures

Effectively managing compliance with technical standards and operational procedures is an important element of Asset Class Planning. Adhering to these standards ensures that the assets are designed, constructed, maintained, and operated in a manner that meets industry best practices, enhances safety, and ensures reliability. Compliance with technical standards helps prevent asset failures, reduces risks, and ensures interoperability within the electrical distribution network. For example, ensuring that all components of various asset types are installed and maintained according to Australian Standards can prevent unplanned failure and operational faults, enhancing network reliability.

Refer to Station Design Manual for detailed guidance notes and references, supplied to support the assessment of this factor and the ways it impacts and influences the management of this Asset Class.

7.2. External Factors

7.2.1. Technical Factors

Not applicable.

7.2.2. Environmental Factors

Under the new Environment Protection Authority (EPA) regulation 2020, requires a prevention-based approach underpinned by general environment duty (GED) to minimise pollution impacts identifying and managing the risk by taking reasonable steps to eliminate them or minimise them. This involves management of oil pollution and SF6 gas leaks form SF6 CBs. Management of SF6 leaks and National greenhouse and energy reporting (NGERS) of SF6 emissions from SF6 CBs to Clean Energy regulator on a yearly basis is required.

Environmental Management

Effectively managing obligations specific to environmental management is a core element of Asset Class Planning and supports the sustainable operation and management of Civil Infrastructure. Ensuring adherence to relevant environmental laws and standards helps prevent legal and regulatory breaches, which can lead to significant penalties, operational disruptions, and reputational damage.

7.2.3. Stakeholder/ Social Factors

Social Factors

Understanding social factors is essential for the effective management of critical network infrastructure assets. Social factors, including community expectations, public safety, and environmental impacts, play a significant role in shaping asset management strategies. Ensuring that these social considerations are addressed helps build public trust, maintain social license to operate, and enhance the organisation's reputation. For instance, ensuring that maintenance activities for Civil Infrastructure do not disrupt local communities or pose safety risks is crucial for maintaining public support and compliance with social responsibilities.

Stakeholder Factors

Understanding the requirements of stakeholders with a direct interest in the assets associated with the [Civil Infrastructure] asset class is an important aspect of effective asset management. Key stakeholders, including customers, regulatory bodies, and industry partners, have specific expectations that influence asset management strategies and operational decisions. Ensuring clear communication and alignment with these requirements helps maintain regulatory compliance, enhance service reliability, and build robust partnerships. For example, customers expect reliable infrastructure and timely responses to issues, which requires minimal disruption during maintenance activities of Civil Infrastructure. Similarly, regulatory bodies impose standards that must be adhered to, such as safety requirements for buildings and environmental systems, to avoid legal penalties and ensure operational legitimacy.

7.3. Internal Factors

7.3.1. Training and Competency Factors

Effective training and competency development is a core element of asset class. Ensuring that asset managers, engineers, operational staff, and field personnel possess the necessary skills and knowledge is crucial for maintaining the reliability, safety, and efficiency of the asset network. Competent staff can effectively perform inspections, maintenance, and repairs, preventing asset failures and minimising downtime. Continuous training helps in keeping up with technological advancements, regulatory changes, and best practices, thereby enhancing overall asset management performance.

7.3.2. Resource Management Factors

Resource Management is a core element of asset class planning for Network Assets. Proper oversight ensures that the management of AusNet's resource bases meets stringent quality and performance standards, which is essential for preventing asset failures, managing risks, and maintaining compliance with regulatory requirements. Effective resource management contributes to cost efficiency via activities such as leveraging the expertise of specialised in-house skills and contractors while avoiding hidden costs associated with inefficiencies and non-compliance.

There are three sub-categories of consideration for this factor, which are:

- Resourcing strategies
- Outsourcing
- Supply Chain Management

7.3.3. Economic Factors

Economic factors significantly influence the lifecycle management of network assets, impacting financial stability, investment decisions, and overall network performance. Major contracts being tendered, such as those for infrastructure development, maintenance, and technology upgrades, can materially affect asset management. These contracts involve substantial investments, requiring rigorous management to align with long-term asset goals, mitigate risks, and control costs. Effective contract management ensures that service providers deliver value, supporting the network's reliability and performance while maintaining financial health.

Material developments and significant commercial agreements also play pivotal roles in the economic landscape of asset management. Commercial agreements, including customer service agreements, dictate service levels, performance metrics, and penalties, impacting operational priorities. Regular reviews of these agreements ensure adaptability to changing economic conditions, customer expectations, and regulatory landscapes. Additionally, planned renewal programmes and changes to asset types and purchasing strategies must be evaluated for their financial impact to ensure efficient resource allocation. By addressing these economic factors, AusNet can manage financial risks, optimise investments, and support robust lifecycle models, aligning financial planning with operational goals and regulatory requirements.

7.3.4. Safety Factors

Safety is a paramount concern in the management of electricity distribution network assets, as outlined in **ESMS 20-01**. Effective asset management planning and activities are crucial for protecting employees, contractors, the public, and the environment from potential hazards associated with electrical infrastructure. Ensuring adherence to safety regulations and standards through diligent asset management helps prevent accidents, minimise risks, and maintain the integrity of the network.

Targeted asset management activities include conducting regular safety audits and risk assessments, maintaining a robust Bushfire Mitigation Plan, providing ongoing safety training and competency assessments, regularly reviewing and updating emergency response plans, engaging with the community to raise awareness about electrical safety, and adopting new technologies and practices to enhance network safety. By integrating these safety-focused activities into asset management planning, AusNet can effectively minimise safety risks "as far as practicable," as outlined in the Electricity Safety Act 1998 and reflected in **ESMS 20-01**.

7.4. Future Developments

7.4.1. Technology and Innovation Factors

Effectively managing the process of tracking future technology developments and innovations is a core element of asset class planning. Staying informed about technological advancements ensures that asset management practices remain up-to-date, efficient, and competitive. Innovations can lead to improved materials, better monitoring systems, and enhanced maintenance techniques that increase the reliability, safety, and longevity of critical infrastructure. For example, advancements in diagnostic tools for detecting early signs of wear and the development of advanced materials for asset components can significantly enhance their performance and maintenance. **For technology and innovation, this is a process that looks to existing technologies, processes, or practices that have been proven in the market and have already been taken to market**.

7.4.2. Research and Development Factors

Effectively managing the process of investing in research and development (R&D) and seeking funds for R&D activities is a core element of asset class planning. R&D investment ensures that the organisation stays at the forefront of technological advancements, develops innovative solutions to emerging challenges, and enhances the reliability, safety, and efficiency of its assets. For example, developing new materials with improved structural properties for buildings or advanced monitoring systems for environmental systems can significantly extend their lifespan and reduce maintenance costs. **Research and development is the process of researching and investing in an idea, process, practice, or technology that has not been realised in the market yet; it is a step before tracking innovation and technology because the investment to build and take the item to market still needs to be proven**.

7.4.3. Continuous Improvement

Continuous Improvement (CIP) is a critical lynchpin process in the overall application of asset management, particularly for managing Distribution Assets. CIP ensures that asset management practices remain effective, efficient, and adaptive to changing conditions and emerging challenges. By consistently seeking ways to enhance processes, technologies, and strategies, organisations can maintain high levels of performance, reliability, and safety. For example, regularly updating maintenance protocols for buildings, environmental systems, and security fences based on feedback and new insights can prevent issues before they become major problems, thereby extending the lifespan of critical infrastructure.

Best practice asset management promotes a culture of continuous improvement, encouraging organisations to regularly evaluate their asset management systems, identify areas for enhancement, and implement changes. This iterative process involves monitoring performance, analysing data, and applying lessons learned to refine practices. By focusing on CIP, organisations can ensure that their asset management activities remain dynamic, resilient, and aligned with best practices and strategic objectives. This approach not only enhances the overall efficiency and effectiveness of asset management but also supports long-term sustainability and success. **CIP differs from technology and innovation as well as R&D because it involves the ongoing enhancement of existing processes and practices based on real-world feedback and performance data, rather than the development and introduction of new technologies or the exploration of unproven ideas**.

8. Asset Strategies

8.1. New Assets

New Asset Considerations

A strategic asset strategy for the introduction of new assets provides high-level guiding principles and overarching goals for asset management, focusing on long-term planning and sustainability. This strategy outlines the aspects of asset upgrades or changes, detailing the conditions under which new assets may be introduced into the network. This is not a like-for-like replacement but rather a strategic change or upgrade to a different type of asset to enhance reliability, improve efficiency, and incorporate advanced technologies. It serves as a roadmap that is ideal to follow if possible, guiding the decision-making process for integrating new assets into the AusNet network.

REF	DETAILS OF MATERIAL CONSIDERATIONS
01	Continue to purchase fully type tested indoor and outdoor circuit breakers to the latest specification.

8.2. Inspections and Monitoring

A strategic plan for inspections and monitoring provides high-level guiding principles and overarching goals for asset management, focusing on long-term planning and sustainability. This strategy outlines the ideal framework and objectives for conducting inspections and monitoring activities, such as enhancing reliability, improving efficiency, and incorporating advanced technologies. It serves as a roadmap that is ideal to follow if possible, guiding the decision-making process for establishing comprehensive inspection and monitoring protocols within the AusNet network.

REF	DETAILS OF MATERIAL CONSIDERATIONS
01	Continue visual checks of circuit breakers as part of the regular zone substation inspections.
02	Continue annual non-invasive condition monitoring scans including the use of radio frequency interference, ultrasonic, infra-red thermal and UV corona camera testing.
03	Continue to establish the bulk oil CB's SRBP bushing condition through an electrical testing program

8.3. Maintenance Planning

A strategic plan for maintenance provides high-level guiding principles and overarching goals for asset management, focusing on long-term planning and sustainability. This strategy outlines the ideal framework and objectives for conducting maintenance activities, such as enhancing reliability, improving efficiency, and incorporating advanced technologies. It serves as a roadmap that guides the decision-making process for establishing comprehensive maintenance protocols within the AusNet network. This involves creating a structured approach to regular maintenance activities to ensure optimal performance and longevity.

Targeted Activities (Inspection and Monitoring Strategies)

Refer section 6.1.2 observations based on performance analysis observations which require maintenance regime review of ZSS circuit breakers.

REF	DETAILS OF MATERIAL CONSIDERATIONS
01	Review ZSS Circuit Breaker Maintenance Regime in PGI 02-01-04 for 22kV Vacuum and SF6 Circuit breakers.
02	Continue scheduled preventative maintenance as per specific Standard Maintenance Instructions for each circuit breaker type.

8.4. Renewals Planning

A strategic asset strategy for renewals and replacements provides high-level guiding principles and overarching goals for asset management, focusing on long-term planning and sustainability. This strategy outlines the aspects of asset refurbishments or like-for-like replacements, detailing the conditions under which existing assets may be renewed or replaced within the network. This process ensures continued reliability and efficiency, manages obsolescence, and maintains adequate spares. It serves as a roadmap that is ideal to follow if possible, guiding the decision-making process for renewing or replacing assets within the AusNet network.

REF	DETAILS OF MATERIAL CONSIDERATIONS
01	Replace poor condition outdoor /Indoor circuit breakers as part of planned station rebuild projects or CB asset replacement projects for 2026-2031 period
02	Use bushing replacements to mitigate shorter term risk until bulk oil CB replacement is possible, for very poor condition bushings found during electrical testing condition monitoring program

8.5. Decommissioning

A strategic asset strategy for decommissioning provides high-level guiding principles and overarching goals for asset management, focusing on long-term planning and sustainability. This strategy outlines the aspects of safely and efficiently removing assets from service, detailing the conditions under which decommissioning may occur. It ensures that the process is conducted in a way that minimises disruption, manages environmental impacts, and complies with regulatory requirements. It serves as a roadmap that is ideal to follow if possible, guiding the decision-making process for decommissioning assets from within the AusNet network.

9. Legislative Reference

STATE	REGULATOR	REFERENCE
VIC	WorkSafe Victoria	Occupational Health and Safety Act 2004
National	Clean Energy Regulator	Clause 19 - National Greenhouse and Energy Reporting Act 2007 – 1
National	Clean Energy Regulator	National Greenhouse and Energy reporting -Regulation 2008
VIC	Environment Protection Authority	Section 25 -General environment Duty: Environment protection Act -2017

10. References

NO.	TITLE	DOCUMENT TITLE
1	QMS 20-04	Documented information Control
2	AMS 01-09	Asset Risk Assessment Overview
3	AS ISO 31000	Risk Management – Guidelines
4	AMS 01-01	Asset Management System Overview
5	AMS 20-01	Electricity Distribution Network Asset Management Strategy
6	PGI 02-01-04	Summary of Maintenance Intervals – Distribution Plant Guidance and Information
7	SDM	Station Design Manual

11. Schedule of revisions

ISSUE	DATE	AUTHOR	DETAILS OF CHANGE	APPROVED BY
1	17/04/2008	G Lukies A Thomaidis	Initial issue	G Towns
2	13/06/2008	S Dick A Thomaidis	Updated from review by NDD	G Towns
3	20/06/2008	R Purcell M Nevins T Hitchens	Updated from review by NSG	G Towns
4	15/04/2009	G Lukies S Dick	Review and Update	G Towns
5	18/09/2009	G Lukies	Review and Update	G Towns
6	10/11//2009	D Postlethwaite G Lukies	Editorial and risk modelling update	G Towns
7	24/11/2009	G Lukies D Postlethwaite	Review and update	G Towns
8	20/02/2015	P Seneviratne D Platt	Review and update	J Bridge
9	13/06/2019	N Boteju	Review and update	P Ascione
10	22/01/2025	N Boteju	Review and update	

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