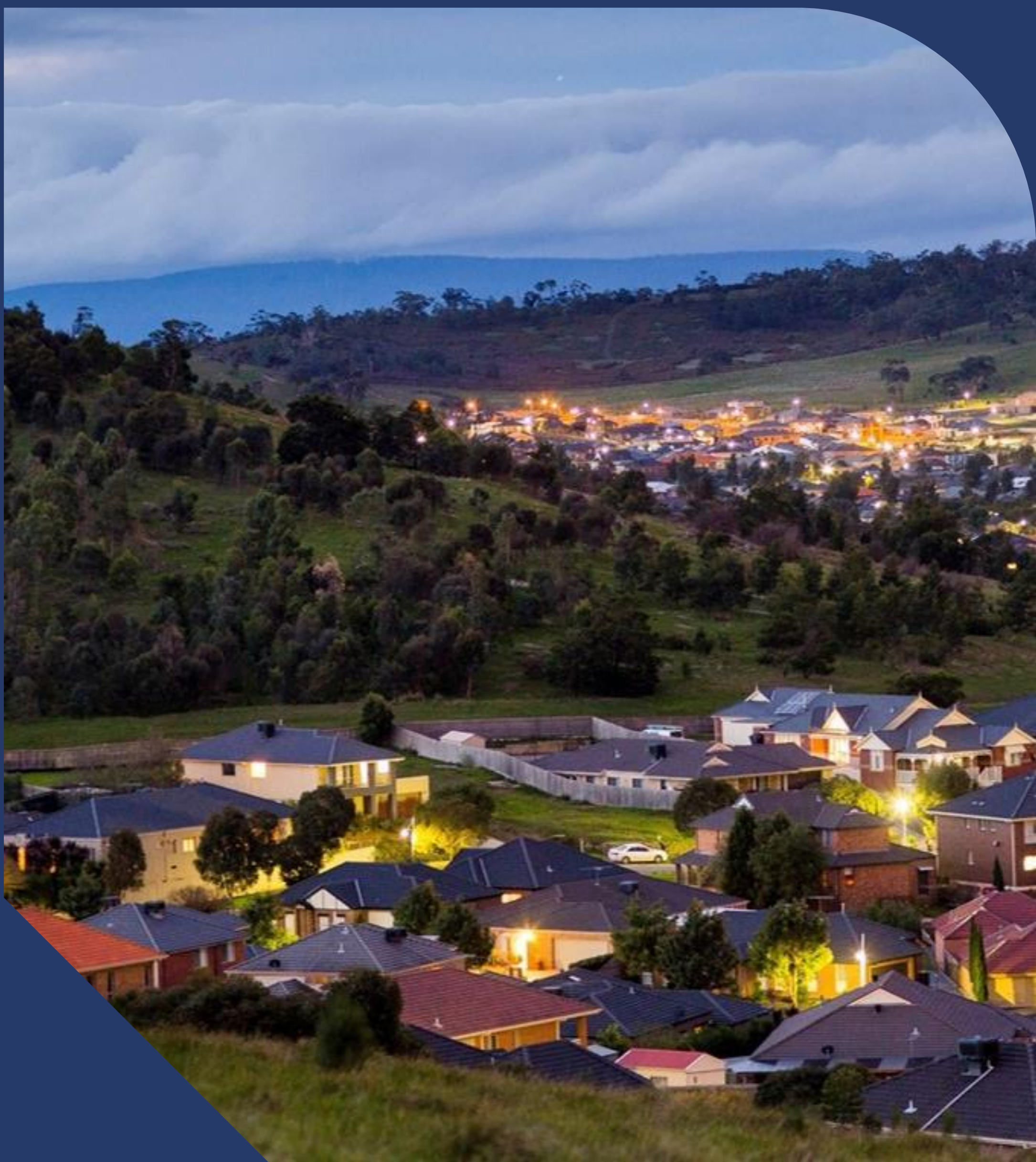
AusNet

Instrument Transformers

Asset Management Strategy



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Abbreviations and Definitions

TERM	DEFINITION
AMS	Asset Management Strategy
COF	Consequence of Failure
POF	Probability of Failure
CAMS	CVT Asset Monitoring System
CT	Current Transformer
CVD	Capacitive Voltage Divider
CVT	Capacitive Voltage Transformer
DGA	Dissolved Gas Analysis
MVT	Magnetic Voltage Transformers
OEM	Original Equipment Manufacturers
PCBs	Polychlorinated Biphenyls
VTFST	Voltage Transformer Free Standing
VT	Voltage Transformer
ZK	Work order Notifications associated with failures (unplanned power interruptions
ZA	Work order Notifications associated with corrective actions from planned inspections

1. Executive Summary

This document outlines AusNet's asset management strategy for instrument transformers within the regulated electricity transmission network. It details the approach for inspection, maintenance, replacement and monitoring activities identified for economic life cycle management of Instrument Transformers.

The strategy addressed the challenged presented by a fleet of 1288 Current Transformers (CTs) and 1442 Voltage Transformers (VTs) installed in terminal stations.

A risk-based assessment has been undertaken, focusing on the consequences of failure including community impact, safety, environmental, and market considerations. Particular attention is given to porcelain housed and oil-filled CT's and CVT's which pose heightened safety and environmental risks due to explosive and fire hazards. The assessment supports a targeted replacement program between 2027 and 2032, with priority given to obsolete models with known performance or reliability issues.

The strategy emphasises proactive management through scheduled preventative maintenance, non-invasive condition monitoring, and periodic electrical testing. Key risks include technical obsolescence, limited OEM support, and increasing failure trends among older CT's and CVT's. The plan aims to satisfy stakeholder expectations for safety, reliability, cost-effectiveness, and environmental responsibility are consistently met through ongoing maintenance, monitoring innovations, and the systematic replacement.

1.1. Asset Strategy Summary

AusNet's asset strategy for high voltage instrument transformers focuses on proactively managing risk, ensuring safety, and maintaining reliability through a targeted program of replacement and maintenance activities. The approach prioritises the replacement of higher-risk instrument transformers, including:

- 66kV [C.I.C] CTs
- 66kV [C.I.C] and [C.I.C] MVTs
- 66kV [C.I.C] CTs, CVTs and MVTs
- 220kV [C.I.C] and TRENCH CVTs
- 500kV [C.I.C] CTs (as part of the Major Station program)

To complement the replacement strategy, the continued use of non-invasive condition monitoring techniques remains a key focus. These include thermal imaging and ultrasonic testing, which allow for early detection of anomalies without the need for equipment shutdown. Condition monitoring of CTs is also maintained through regular oil sampling and Dissolved Gas Analysis (DGA), providing insights into internal degradation and incipient faults. For CVTs, online condition monitoring via the SCADA system continues to be an essential tool for real-time performance tracking and fault detection.

For new assets, where feasible, dead tank circuit breakers with integral CTs are being installed for voltage levels up to 220kV, eliminating the need for standalone CTs. In cases where the associated circuit breaker is not being replaced, polymer-housed oilpaper insulated outdoor CTs and CVTs and for 500kV applications, polymer-housed SF_6 gas-insulated outdoor CTs, polymer-housed oil filled CVT's are preferred due to their inherent safety features, and reduced maintenance requirements.

This comprehensive, risk-based asset strategy enables confidence that AusNet's instrument transformer fleet is managed in a manner that upholds stakeholder expectations for safety, reliability, cost-effectiveness, and environmental responsibility.

2. Introduction

2.1. Purpose

The purpose of this document is to outline the inspection, maintenance, replacement and monitoring activities identified for economic life cycle management of instrument transformers in AusNet's Victorian regulated electricity transmission 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.

2.2. Scope

This strategy includes:

- CTs with nominal voltage ranging from 11kV to 500kV
- MVTs, CVTs, and CVDs with nominal voltage ranging from 11kV to 500kV

The strategy excludes:

- Low voltage insulated CTs integrated into power transformer bushings and dead tank circuit breakers
- Power transformer Neutral CTs
- Instrument Transformers installed in [C.I.C] Switchgear

2.3. Asset Management Objectives

As stated in REF: AMS 01-05 Strategic Asset Management Plan, asset management objectives are:

Trusted to bring the energy today and build a cleaner tomorrow							
Strategic Pillars						Ambition	
Safely deliver our customer's energy needs today				Create the energy network of tomorrow	Enable the transition to a net zero future	Be a leader in asset management practice	
Asset Management Objectives						Enabling AMOs	
Safety: Minimise risk to our people, contractors, customers and communities AFAP across our networks	**Reliability:** Meet the reliability expectations of our customers and communities, and meet our reliability targets	**Resilience:** Improve the resilience of our network to adapt to a changing climate and energy system environment	**Compliance:** Comply with all legislation, regulations, relevant standards and industry codes	**Planning and decision-making:** Deliver valued planning and network outcomes through optimising asset lifecycle management	**Sustainability:** Build stakeholder trust and deliver social value. Reduce our environmental impact. Operate efficiently to sustain financial value creation.	**Competency and capability:** Develop asset management capability and competency in the organisation	**Continuous improvement:** Continually improve asset management maturity for effective delivery of services

3. Asset Description

3.1. Function

Instrument transformer is a general classification applied to current transformer (CT) and voltage transformer (VT) used to change currents and voltages from higher magnitude to lower to perform a metering, alarm or protection relay function for isolation of unhealthy electrical circuit.

CT are used to measure the current flowing through a high voltage electricity circuit within the Transmission network and transform this current into convenient quantities for use in protection and measurement & control relays.

VT, including Magnetic Voltage Transformers (MVT), Capacitive Voltage Dividers (CVD) and Capacitive Voltage Transformers (CVT) are used to measure the operating voltage of a high voltage electricity circuit and transform this measurement into convenient voltages for use in protection and measurement & control relays.

3.2. Population

There is a total of 1288 CTs and 1442 VTs (MVT, CVT and CVD) installed in AusNet terminal stations as of 22 Sep 2025.

CTs are single phase devices available in hairpin and inverted head post-type with oil/paper insulation and porcelain or polymer housings at all voltage levels. SF6 gas insulated inverted head post type are also used at 275kV and 500kV. There is also outdoor metal enclosed oil insulated type, indoor and outdoor epoxy encapsulated block type used up to 22kV.

CVTs and CVD are single phase devices and MVT is either single or three-phase voltage transformers. There are no CVTs installed on circuits operating below 66 kV. CVTs and CVDs are outdoor type with oil paper insulation in porcelain or polymer housings. MVTs are outdoor type with oil paper insulation in porcelain or polymer insulation. MVTs are also found with solid epoxy encapsulated block type insulation and are used in applications up to 22kV.

3.2.1. Current Transformers (CTs)

Figure 1 below provides the CT population by voltage. Approximately 75% of the total population are at 66kV and 220kV, followed by 15% at 500kV. The number of post-type high-voltage insulated CTs at 66kV and 220kV is steadily declining due to the transition to dead tank circuit breakers equipped with integral low-voltage insulated CTs. This transition offers advantages such as reduced maintenance requirements and a smaller physical footprint.

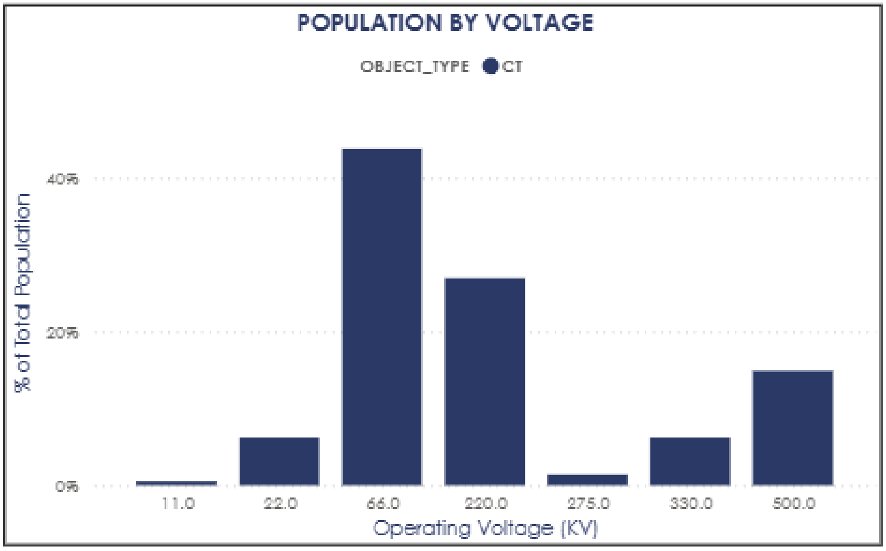

Figure 1: CT Population by voltage

Figure 2 provides the CT population by insulation medium. It is observed that approximately 75% of the population comprise of oil filled current transformers, SF6 insulated (11%), and the remaining population is solid type epoxy or cast resin type used for protection and measurements and at capacitor banks. The use of SF6 and polymer housing for 500 kV CT is a policy decision aimed at reducing potential safety risks.

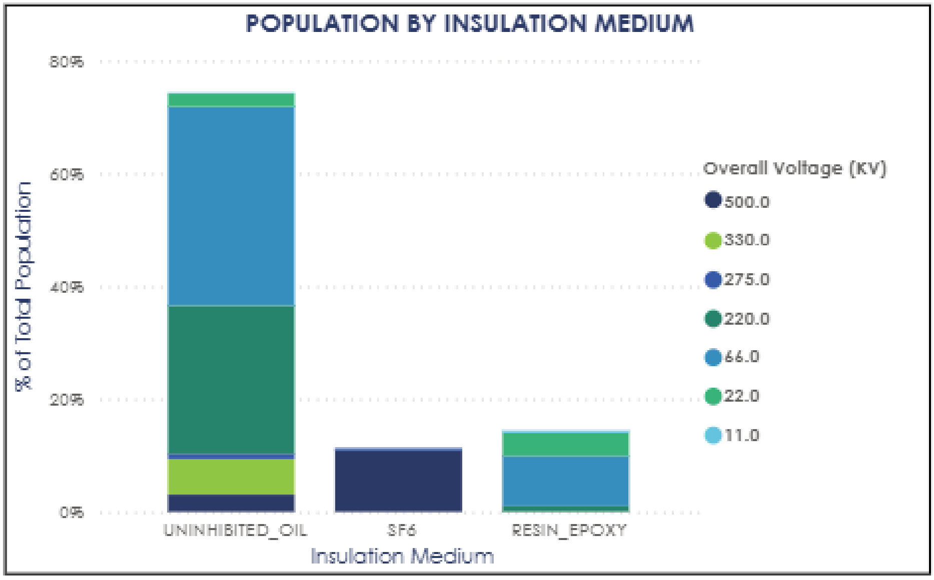

Figure 2: CT Population by Insulation Medium

Figure 3 provides percentage of top 10 current transformer population by manufacturer. The most common manufacturer is [C.I.C] that contributes to 45.2% followed by [C.I.C] (21.4%) and third [C.I.C] (7.5%) and they are generally newer types.

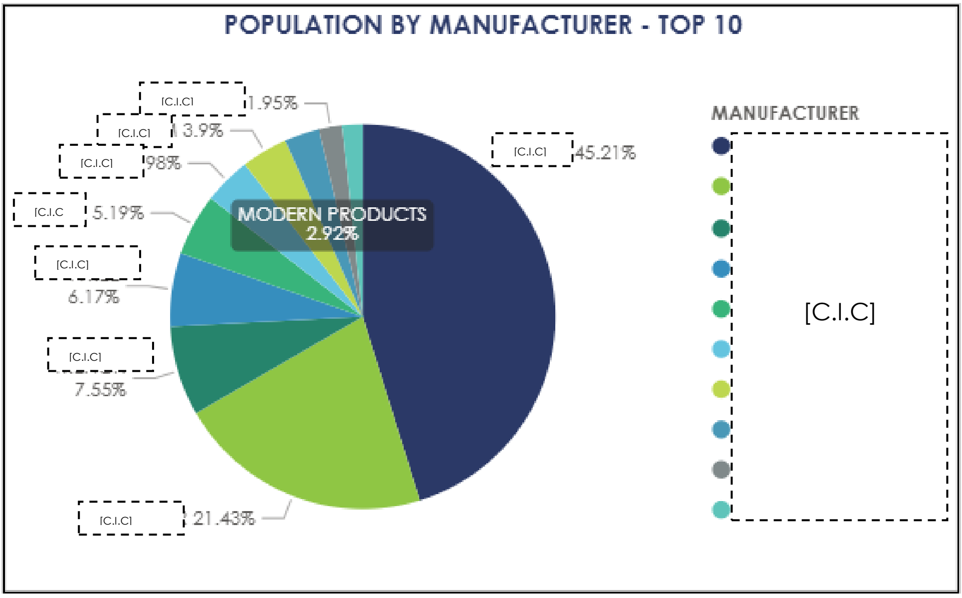

Figure 3: CT Population by Manufacturer (Top 10)

3.2.2. Voltage Transformers (MVT, CVT and CVD)

Figure 4 below provides the VT population by Object Type. Approximately 60.4% of the total 11kV - 500kV Voltage transformer population consist of CVT (56.1%) and CVDs (4.3%). CVTs are mainly at 220kV (38.5%) and 500kV (8.8%) of the total voltage transformer population. MVT and VFTST are mainly located at 66kV system (25%). Indoor types are those shown as VTSWCHBD and mainly at lower voltages.

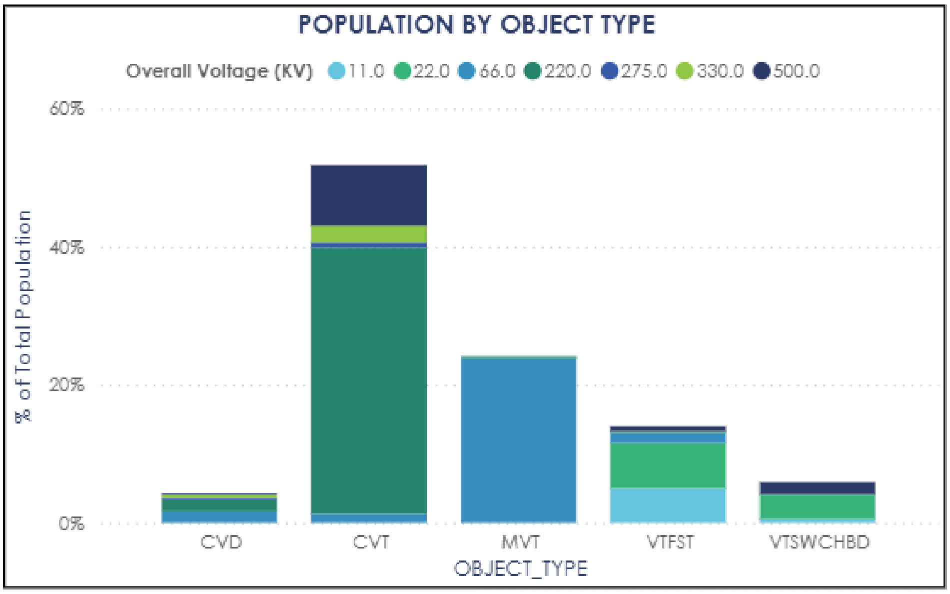

Figure 4: VT Population by Object type

Figure 5 provides the VT population by insulation type. It is observed that approximately 86% of the VT population comprise of oil insulated voltage transformers, SF6 insulated (2%) and the remaining population is solid type epoxy or cast resin type VTs used for protection and measurements.

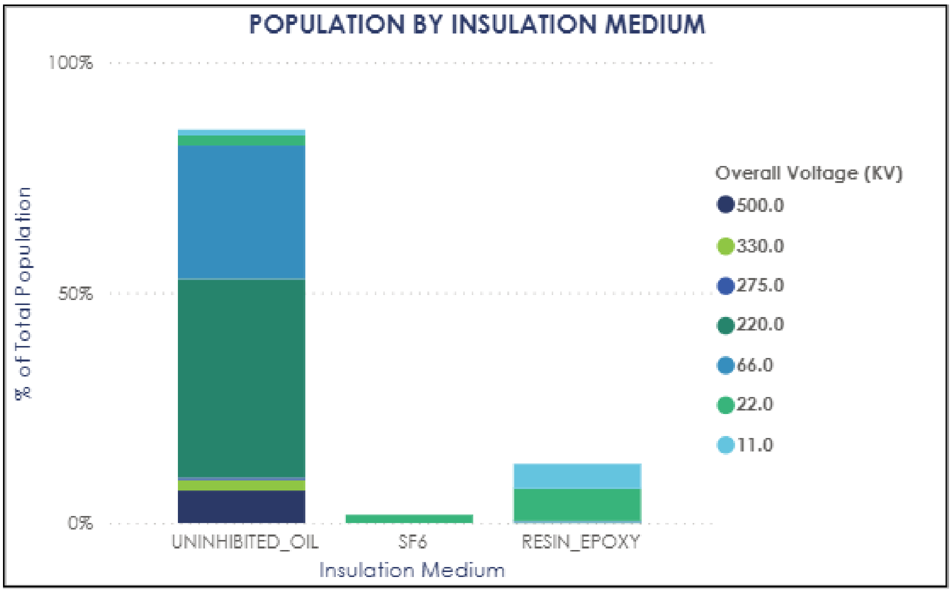

Figure 5: VT Population by Insulation Medium

Figure 6 provides percentage of top 10 voltage transformer population by manufacturer. Out of the top 10 population, [C.I.C] contributes to 35.3% followed by [C.I.C] (27.5%), [C.I.C] (15.9%) contribute to 78.7% of the top 10 population and these three are generally newer types.

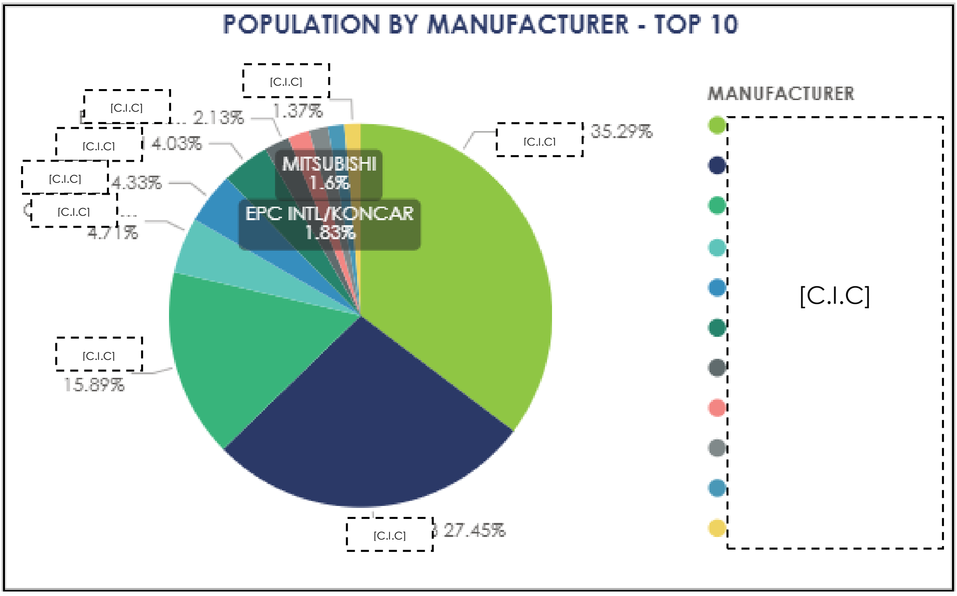

Figure 6: VT Population by Manufacturer (Top 10)

3.3. Age Profile

3.3.1. Current Transformer (CT)

The average service age of all 11kV - 500kV CTs is 19 years. Figure 7 below provides the age profile of all CTs by service voltage. It is observed that approximately 1.3% of the population are more than 45 years of age and approximately half of those are 66kV and 220kV rated. Approximately 70% of all CTs are aged 25 years or younger. The peaks in the age profile at 15 to 25 years old is in response to a number of explosive major failures between 2000 and 2010 that led to widespread CT replacement programs of certain types.

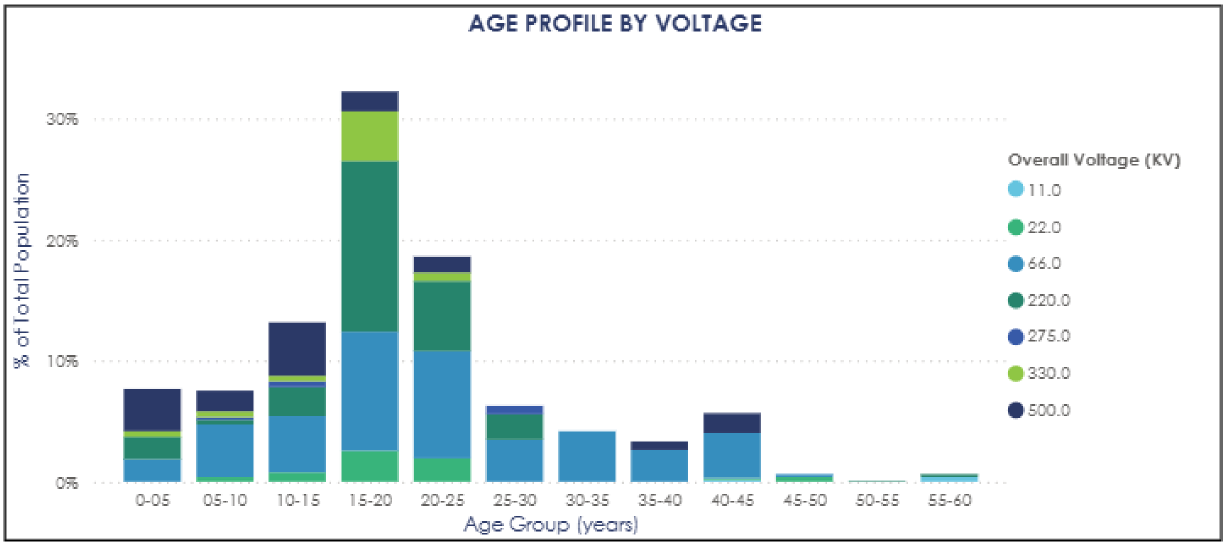

Figure 7: Current Transformer Age by Service Voltage

Figure 8 below provides the age profile of 66kV -500kV CTs by top 10 manufacturer type.

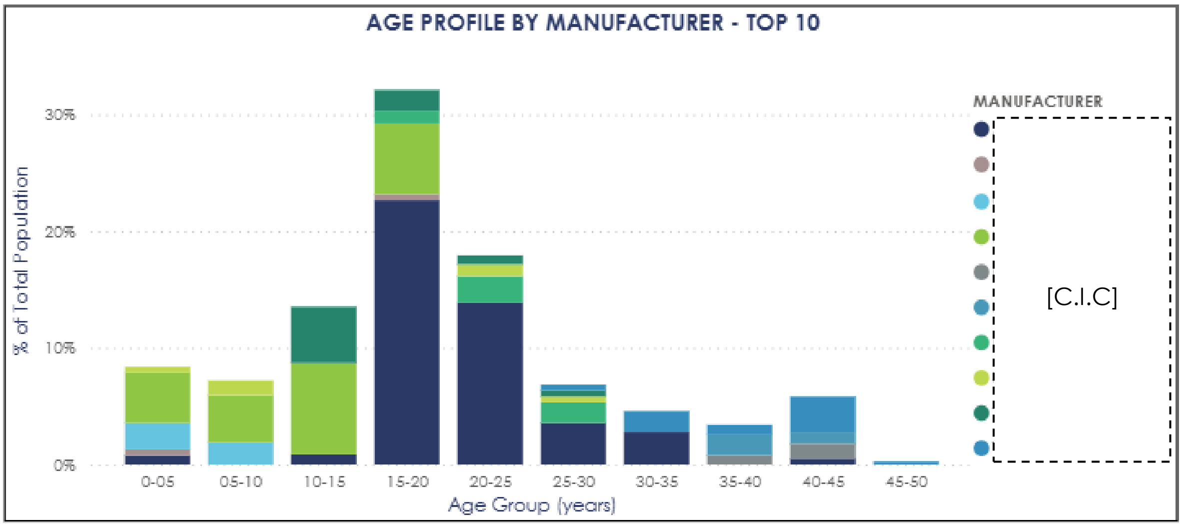

Figure 8: Age profile of 66kV - 500kV Current Transformers by Manufacturer (top 10)

3.3.2. Voltage Transformer (MVT, CVT and CVD)

The average service age of all VTs is 18 years. Figure 9 below shows the age distribution of all VTs by service voltage. It is observed that approximately 6.3% of the population are more than 45 years of age and approximately half of that (at 3%) is due to 66kV and 220kV VTs. A similar peak is observed in the CVT population, coinciding with the CT population trend. This is largely due to CVT replacement programs following catastrophic failures at Tyree types at SMTS and [C.I.C] in 2009.

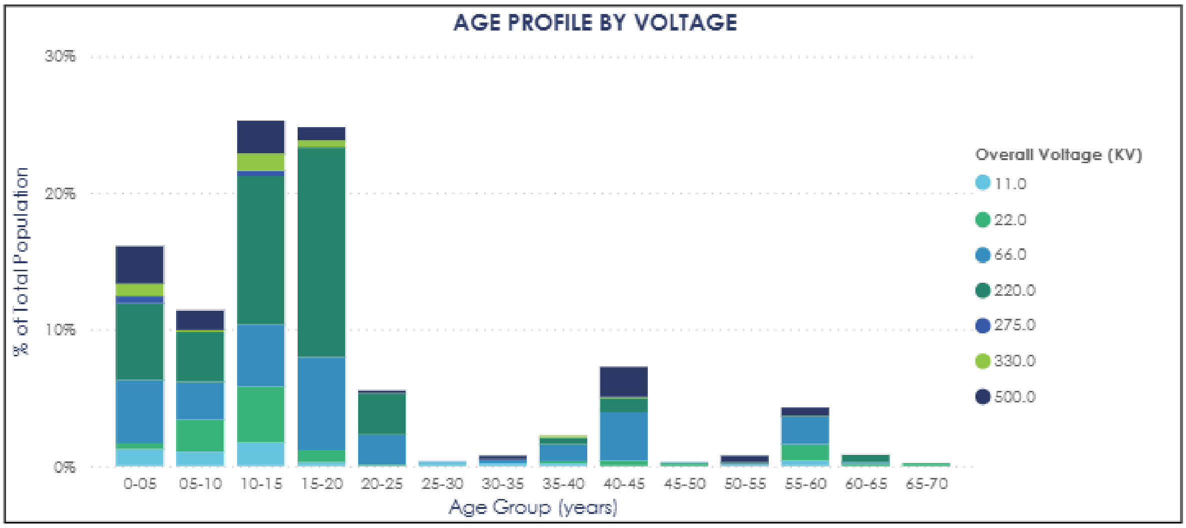

Figure 9: Voltage Transformer Age by Service Voltage

Figure 10 below provides the age profile of 66kV - 500kV VTs categorised by the top 10 manufacturer type. Endurance accounts for 1.8% and [C.I.C] accounts for 0.6% of the VT population, exceeding 45 years in service. Endurance and [C.I.C]units have been found to contain Polychlorinated Biphenyls (PCBs) in their insulating oil. Due to the associated health, safety, and environmental risks — particularly if contamination occurs — special handling procedures must be followed. As both OEMs are no longer available to provide maintenance or technical support, these VTs have been included in the TRR replacement program to mitigate operational and environmental risks and supports safe lifecycle management.

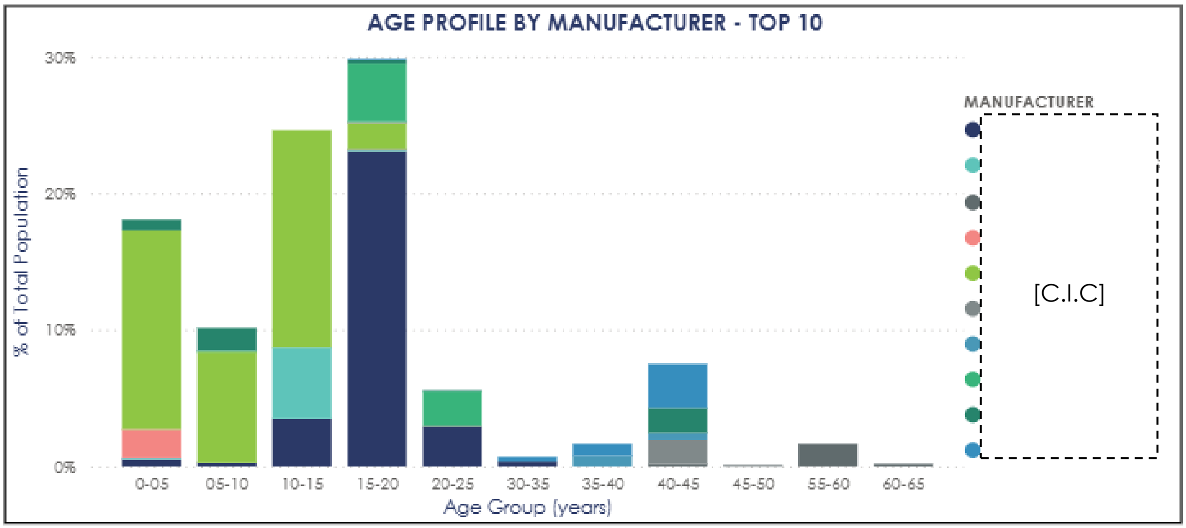

Figure 10: Age profile of 66kV - 500kV Voltage Transformers by Manufacturer (top 10)

4. Asset Performance

Life cycle management of transmission instrument transformers involve periodic routine inspections, annual non-invasive thermal and RF scanning and DGA analysis of oil. Most transmission instrument transformers are hermetically sealed, and very little corrective work can be performed economically on them.

Although instrument transformers have no moving parts, they have developed issues related to key components such as the insulation system, current path (both primary and secondary voltages), and the exterior of the earthed bottom tank. Some of the issues are due to inherent design problems with the instrument transformer which causes problems in early asset life. Other common causes of failure are environment due to pollution and corrosion, failure of seals associated with the oil/gas insulation medium, or loose capacitive grading foils in the insulating bushing. Technical obsolesce, non-availability of manufacturer support and availability of limited spares become major factors of maintaining older instrument transformers.

4.1. CT Performance

The performance of CTs was assessed using a framework that is based on the following criteria.

- Dissolved gas analysis (DGA)
- Known design/construction issues
- Corrective maintenance work order analysis (notification analysis)

4.1.1. DGA for CTs

AusNet performs condition monitoring of oil in CTs where oil sampling is possible. The DGA results are a useful predictive maintenance method of determining the condition of the oil/paper insulation systems in CTs. DGA results provide understanding of the unit's serviceability. AusNet investigates all major failures. fleet issues associated with poor DGA results and trend analysis and tracks customer outages due to CT failures.

4.1.2. Factory-originated issue

A factory-originated issue refers to a defect that arises during the design or manufacturing process and is typically associated with known recurring faults linked to a specific brand or model of instrument transformer. These defects may stem from design limitations, material inconsistencies, or quality control lapses that have been previously identified and documented in similar units.

C-I-C

4.1.3. Notification Analysis

Figure 11 below, shows ZA (condition-based maintenance) and ZK (failure) notifications for CTs per year. There have on average been 16 notifications annually over the last five years. From 2020 to mid-2025, notifications at 66 kV and above show a clear trend influenced by external factors. The lower volumes during 2020–2022 were likely due to COVID-19 restrictions, which delayed inspections and maintenance activities. As a result, 2023 saw a sharp increase in notifications, reflecting the backlog of work that was deferred during the pandemic. The spike was most notable at 66 kV and 220 kV, indicating increased asset stress or failure detection. Notifications remained elevated in 2024, and while 2025 shows a decline, only mid-year data is available, so the full-year trend is yet to be confirmed.

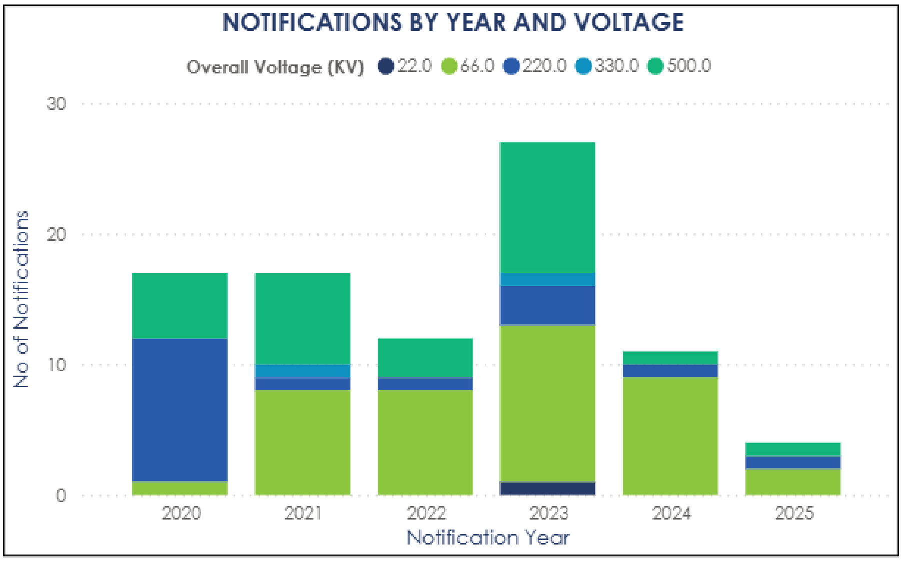

Figure 11: ZA and ZK Notifications per year and voltage 2020 - mid 2025

Figure 12 provides the Number of ZA and ZK Notifications by year and manufacturer model during the period 2020 – 2025. [C.I.C] 500kV and [C.I.C] type CT has been one of the most frequently flagged units for ZA and ZK notifications between 2020 and 2025. Approximately 90% of these notifications were related to SF6 gas leakage alarms. The [C.I.C] also had a pressure relief rupture disk replacement program, which arose out of major failure investigations prior to 2020. Corrective actions commenced in 2020 to address these known defects. The remaining oil-filled CTs with [C.I.C] (220 kV) had the next highest ZA and ZK notifications and were included in further investigation programs.

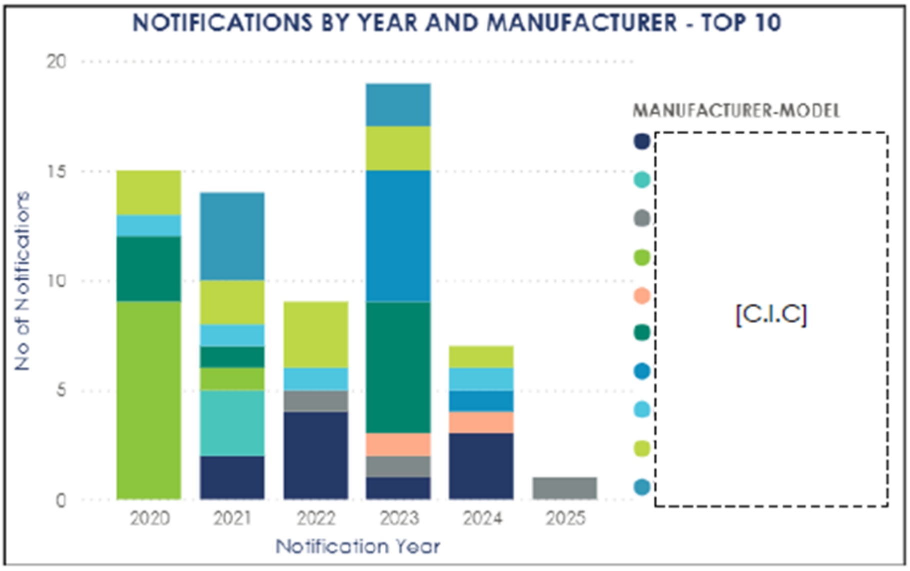

Figure 12: ZA and ZK Notifications by Year and Manufacturer 2020 - mid 2025

Figure 13 provides the CT ZA and ZK Notifications Vs Defect type (top 10) during the period 2020 – 2025. Poor oil results (DGA) requiring repeat testing contributed to 60% of the notifications during the year 2020 while low SF6 level contributed to 32% of CT ZA and ZK notifications in 2023.

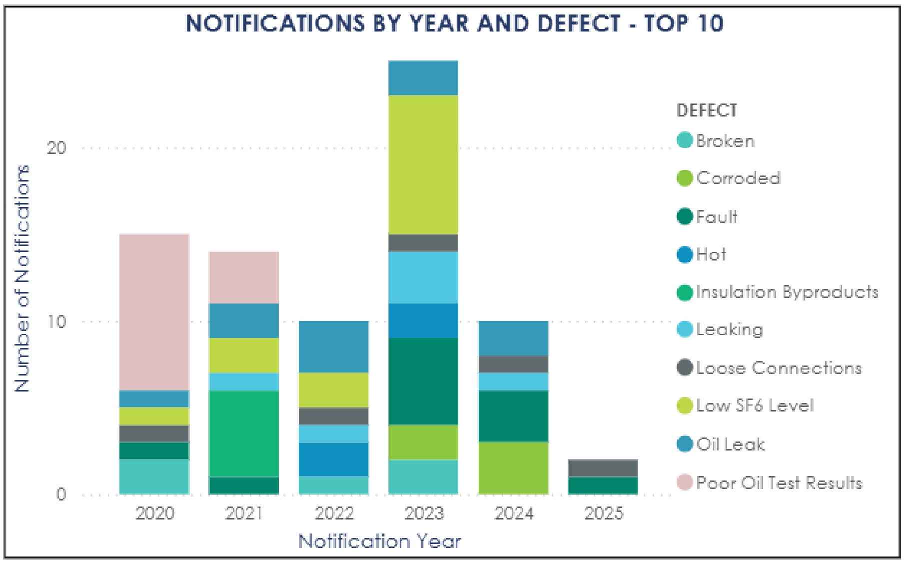

Figure 13: ZA and ZK Notifications vs Defect 2020 – mid 2025 (top 10)

Figure 14 provides the Number of CT ZA and ZK Notifications Vs Object Part for the period 2020 – 2025. Oil as the insulation medium was the key object part affected which contributed to approximately 45% of notifications in 2020 and 2021.

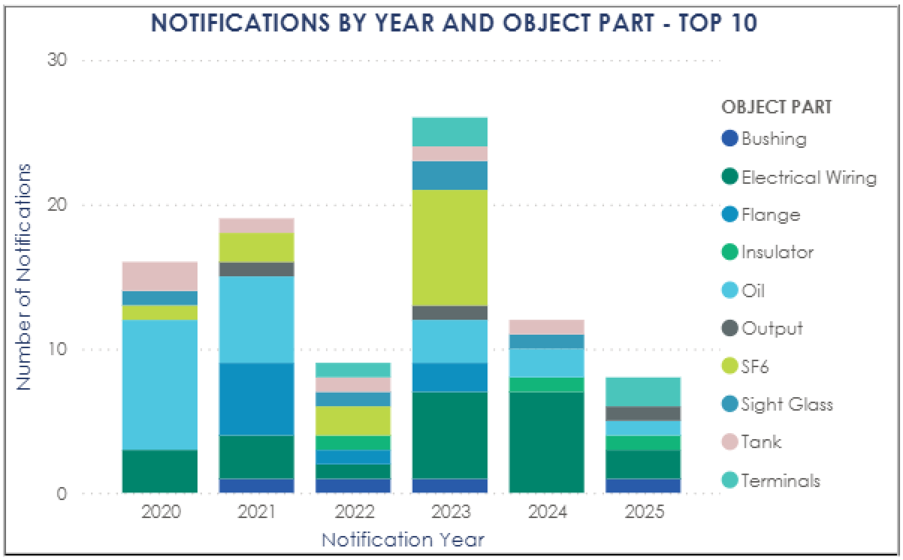

Figure 14: ZA and ZK Notifications vs Object Part affected 2020 – mid 2025 (top 10)

4.2. VT Performance

4.2.1. MVT performance

Dissolved Gas Analysis (DGA) of oil samples used to be a valuable method for assessing the condition of MVT insulation. It enables informed decisions about asset health and supports the planned removal of units that have degraded beyond acceptable limits. However, around 1995, manufacturers identified that backfilling after oil sampling could introduce moisture or air bubbles into the oil. Given the small oil volumes in MVTs, this process often caused more issues than it detected. As a result, newer designs adopted hermetically sealed units without sampling ports. Consequently, DGA is generally not applicable to MVTs manufactured in the last 30 years. In fact, more than 80% of MVTs in the transmission network are less than 30 years old, meaning DGA is increasingly limited in its practical application.

MVT with paper/oil insulation systems generally exhibit longer service life compared to similar systems in CTs. This is primarily due to lower thermal cycling demands and minimal exposure to fault currents in VTs, resulting in slower insulation degradation. However, alternative methods for MVT performance assessment are currently being explored to support long-term network reliability.

4.2.2. CVT and CVD performance

CVTs have many capacitor units (packets) connected in series, in the voltage divider stack. Generally, failure commences with the partial discharge leading to shorting of one or more packets. The step changes in capacitance allow the early stages of deterioration to be detected through the monitoring of the secondary output voltages. A continuous monitoring system called the CVT Asset Monitoring System (CAMS) has been developed for this purpose. When unexplained voltage variations in the output of CVTs are encountered the units are further investigated and removed from service before runaway failure occurs.

More than 98% of CVT's are monitored and the system has proved effective in detecting CVT about to fail and avoiding catastrophic failures since it was introduced in early 2000's. Refer to Appendix 1 for three examples of emergency replacements triggered by CAMS alarms between 2015 and 2020.

CVDs installed between 2000 and 2015 for AEMO quality-of-supply monitoring are not integrated with the CAMS system, as they do not interface with SCADA. Some early CVD units have already been removed following investigations into low secondary voltage output. Given these issues, there is a growing need to explore the feasibility of an online CAMS-style monitoring system specifically for CVDs. However, CVDs are no longer being installed, with newer installations favouring low-voltage power quality (PQ) sensors that can be embedded within CVTs.

4.2.3. Specific Type Issue

Legacy VT models such as [C.I.C] are now considered technically obsolete. These units exhibit inherent design limitations and are prone to safety risks, particularly as their condition deteriorates over time. Common issues include insulation degradation, oil leaks, and compromised mechanical integrity, which can lead to unsafe operating conditions and increased risk of failure.

To address these concerns and align with modern safety and reliability standards, these older VTs are systematically replaced during station rebuild, augmentation and asset replacement programs. The replacement units are fail-safe modern VTs, typically featuring polymeric housings that offer superior insulation performance, reduced maintenance requirements, and enhanced resilience against environmental factors.

4.2.4. Notification Analysis

Figure 15 provides the Number of ZA and ZK Notifications by voltage and year during the period 2020 – 2025 Approximately 58% of the VT notifications in this period were due to 66kV and 220 kV VTs. Unlike CTs, where over 70% are older than 15 years, over 50% of VTs fleet is less than 15 years old due to a consistent replacement program. This younger asset profile contributes to a declining trend in VT-related notifications. The spike in 2023 is largely attributed to deferred inspections and maintenance during the COVID-19 pandemic, rather than a reflection of worsening asset condition. As the replacement program continues and the VT fleet remains relatively modern, notification volumes are expected to stabilise or decline further, supporting improved reliability across the network.

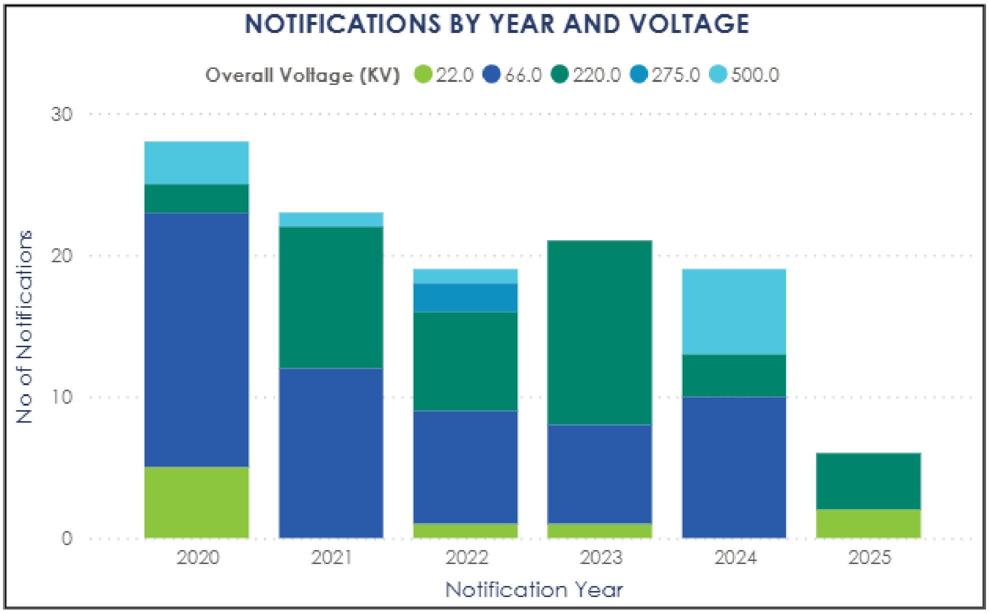

Figure 15: ZA and ZK Notifications by Voltage and Year 2020 – mid 2025

Figure 16 provides the Number of ZA and ZK Notifications per VT manufacturer model during the period 2020-2025.

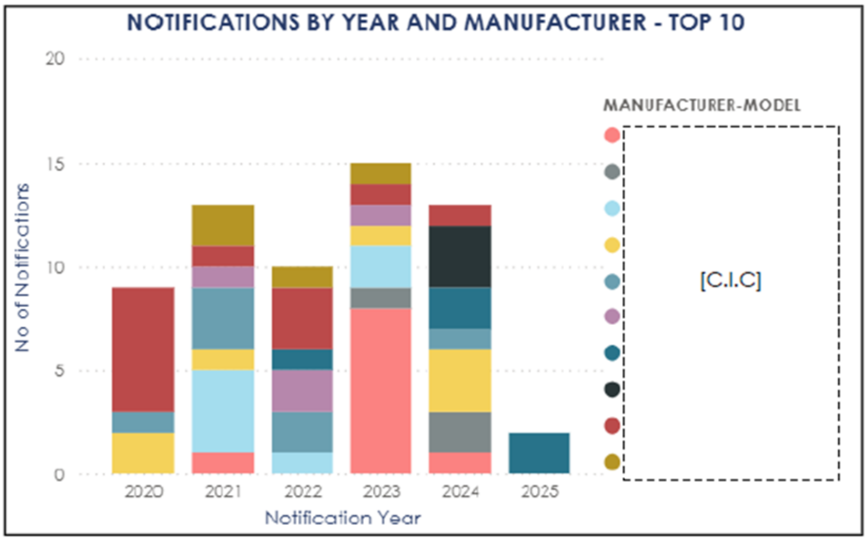

Figure 16: Number of ZA and ZK Notifications per VT Manufacturer 2020 – mid 2025 (top 10)

Figure 17 provides the Number of VT ZA and ZK Notifications Vs Defect type during the period 2020-2025. Oil leaks, parts broken and faults contributed to 43.1% of ZA and ZK notifications in the above period.

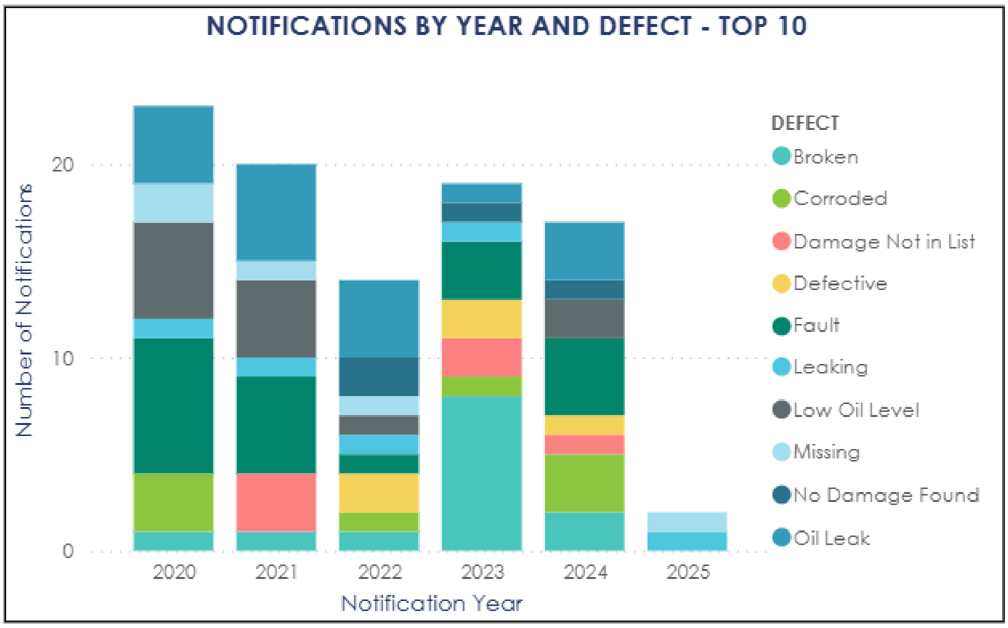

Figure 17: Number of VT ZA and ZK Notifications vs Defect 2020 – mid 2025 (top 10)

Figure 18 provides the Number of VT ZA and ZK Notifications Vs Object Part for the period 2020 - mid 2025. Issues in electrical wiring contributed to 17% of total ZA and ZK notifications during the period. Other key affected object parts are Insulator bushings (12%), tank (12%), Oil insulation medium (10%) during the last 5-year period.

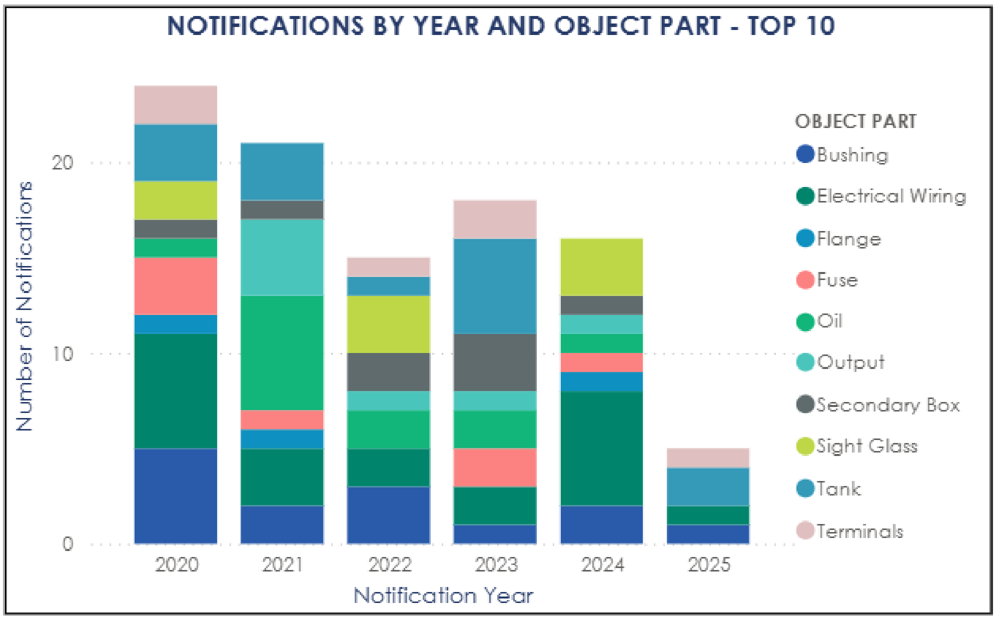

Figure 18: Number of VT ZA and ZK Notifications vs Object Part affected 2020 – mid 2025 (top 10)

4.3. Major Failures

Major failures of instrument transformers, particularly those constructed with porcelain housings, pose significant health and safety risks to personnel and can result in extensive collateral damage to adjacent plant and equipment within terminal stations. These failures are often catastrophic in nature, involving violent explosions that project porcelain fragments at high velocity, creating a serious hazard to anyone in proximity. Additionally, the presence of mineral oil in many legacy designs introduces the risk of oil fires, which can escalate rapidly and compromise the integrity of surrounding infrastructure and assets.

Over the past two decades, there have been several incidents of such major failures across the transmission network. These events have highlighted the vulnerabilities of high-risk assets and underscored the need for proactive asset management strategies.

4.3.1. CT Failures

A major explosive failure involving fire and collateral damage occurred at RTS during the rebuild construction phase in 2016. The failed asset was a 220kV [C.I.C] type CT. At the time of failure, the CT was 53 years old and was scheduled to be replaced in the RTS rebuild project by July 2017. The most probable cause of failure is due to prolonged moisture ingress into the head housing via the inspection cover, causing severe corrosion. Free breathing caused a build-up of free water in the head that migrated into the main tank via the breather pipe. The rusty water entry caused tracking between the capacitive grading foils on one side of the hairpin conductor – increasing the voltage stress on the insulation structure. Under extreme pressure, the porcelain housing eventually failed and distributed porcelain around the switchyard at extreme speeds.

On 09 July 2023, a trip occurred on the 500kV transmission line between MOPS and BGS, triggered by a phase-to-earth fault on the blue phase of the 500kV MOPS–BGS line. Both X and Y protection schemes operated correctly in response to the fault, isolating the affected circuit. Following the incident, SF6 gas sampling was conducted on the associated CT – GE SKF-500. The gas analysis confirmed the presence of decomposition by-products, indicating an internal flashover had occurred within the CT. This internal fault is consistent with high-energy arcing, which can compromise the CT's insulation integrity and operational reliability.

Predictive replacement of two 66kV current transformers was carried out due to unsatisfactory DGA results, which indicated internal degradation and an elevated risk of failure. A [C.I.C] CT was urgently replaced in 2010, followed by a Modern Product CT in 2017, both based on diagnostic findings that revealed fault gases consistent with insulation breakdown or internal arcing. These proactive interventions were undertaken to mitigate the risk of in-service failures, maintain operational reliability. The cases demonstrate the effectiveness of DGA as a critical diagnostic tool for identifying latent faults and guiding timely asset replacement decisions.

4.3.2. VT Failures

During a three-day period in January 2009, when daily maximum temperatures exceeded 43°C, AusNet experienced two catastrophic CVT failures ([C.I.C] and [C.I.C]) and one near-catastrophic ([C.I.C]) event. Additional partial failures were also observed throughout that summer. Beyond the 2009 incidents, near-catastrophic CVT failures were recorded in 2006 and 2003 ([C.I.C]). Subsequent investigations revealed that CVT stages with significant insulation degradation are highly susceptible to thermal runaway under extreme ambient temperatures. Furthermore, circuit-specific transient switching voltages may accelerate the degradation of CVT packets.

On 31 December 2022, a fault occurred on the 66kV FDR line at Lilydale Zone Substation (LDL), leading to the failure of a [C.I.C] CVT (see Figure 19 below) that was, at the time, not included in the CAMS scheme. The failure led to the catastrophic rupture of the CVT's porcelain insulator, causing porcelain fragments to be dispersed across an approximate 10-meter radius. The incident was further compounded by an accompanying fire, which caused localized damage to nearby assets situated within a five-meter vicinity of the failed unit. The nature of the failure highlights the inherent risks associated with aging porcelain-housed instrument transformers, particularly under fault conditions.

The historic instrument transformer major failure record is shown in Appendix 1.

Note after removal of CVTs in response to CAMS (Condition Assessment Monitoring System) alarms, internal inspections have all revealed signs of failure. Specifically: 220kV and 500KV CVT units from [C.I.C] have been stripped down, and found internal shorting and blackened insulation, indicating imminent internal electrical failure.

Figure 19: [C.I.C] **CVT failure in 2022**

5. Asset Health

The asset health condition is illustrated by the likelihood of failure profile derived from the data and insights presented in Section 4 Asset Performance of this document, specifically within the performance analysis. The following graphs illustrate the likelihood of failure profiles from multiple perspectives, including object type, voltage level, and asset age, and the likelihood score reflects the probability of failure, with 1 being the least likely and 5 being the most. REF: AMS 01-09 for detail. By examining these dimensions, we can obtain a comprehensive view of the asset health condition and the associated program of work proposed.

LIKELIHOOD SCORE	LIKELIHOOD SCALE
5	Very Likely
4	Likely
3	Possible
2	Unlikely
1	Very Unlikely

Table 1: Likelihood Scale

5.1. CT Likelihood of Failure Score

Figure 20 and 21 below provides a view of the distribution of failure likelihood scores across the current transformer fleet. The majority have a Likelihood Score of 1, which corresponds to a very low probability of failure. There a few at the higher probability of failure score 4 and 5, these types are discussed further below.

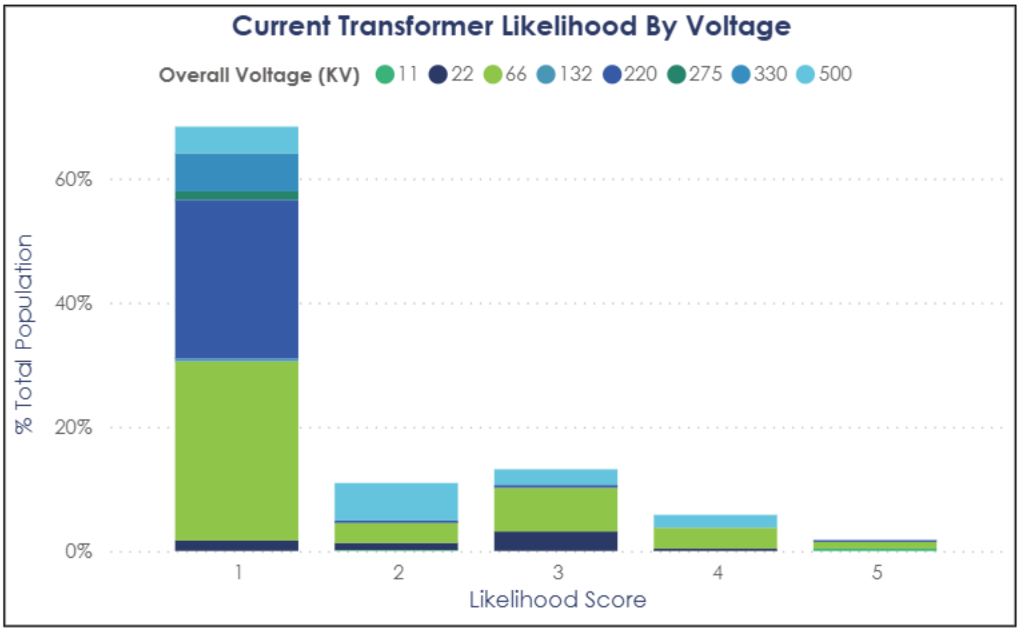

Figure 20: Current Transformers Likelihood Score by Voltage Class

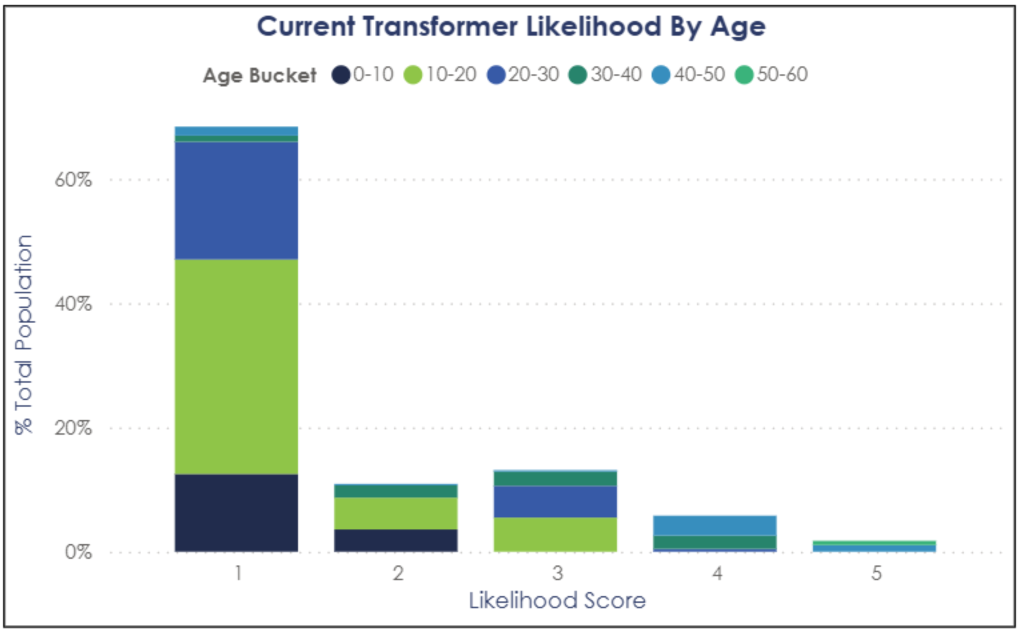

Figure 21: Current Transformers Likelihood Score by Age Profile

Key Findings on CT Health Conditions Derived from Figures 19 and 20:

- [C.I.C] 500 kV CTs have been assigned a likelihood score of 3 or 4, indicating a moderate to high probability of failure. These units have been in service for an average of approximately 40 years. Recent DGA results show that acetylene is still present in around 25% of the remaining fleet, suggesting high energy electrical arcing issue within the units. As this is the last batch of this CT type in the transmission network, their replacement will eliminate the need to retain any units for spare parts salvage.
- [C.I.C] 500kV CTs have been assigned a likelihood score of 4. These CTs were manufactured using the original TYREE design, following [C.I.C] acquisition of the [C.I.C] factory, and were subsequently branded as [C.I.C]. Investigations into [C.I.C] CTs operating at 220kV to 500kV have identified a design / manufacturing deficiency in the capacitive voltage grading structure of the insulation and the earth screen grounding connection. As a result, all 220kV and 330kV [C.I.C] CTs have been removed from the transmission network. On the 66kV network, several [C.I.C] CTs at FBTS have shown acetylene levels between 1 to 2 ppm, indicating potential high energy arcing activity. In response, AusNet plans to progressively remove the remaining 36 units over the next decade as part of a long-term asset management strategy, commencing in the TRR 2027-32 period.
- 66kV [C.I.C] CTs have been assigned a likelihood score of 3 - 5, indicating a moderate to high risk of failure. DGA results has identified insulation degradation in several units, primarily driven by elevated moisture levels within the oil system. This condition is attributed to ineffective sealing and negative internal pressure under certain atmospheric and loading conditions. Of the remaining units, 9 are scheduled for replacement with standalone CTs, while the other 18 units and their associated circuit breakers will be replaced with dead tank circuit breakers incorporating integral CTs during the TRR 2027–32 period.

5.2 VT Likelihood of Failure Score

Figure 22 and 23 below provides a view of the distribution of failure likelihood scores across the voltage transformer fleet. The fleet's 'likelihood' scores are relatively evenly spread across the bands 1 to 4. The types included in band 4 and 5, the highest probability of failure 'likelihood' band are discussed further below.

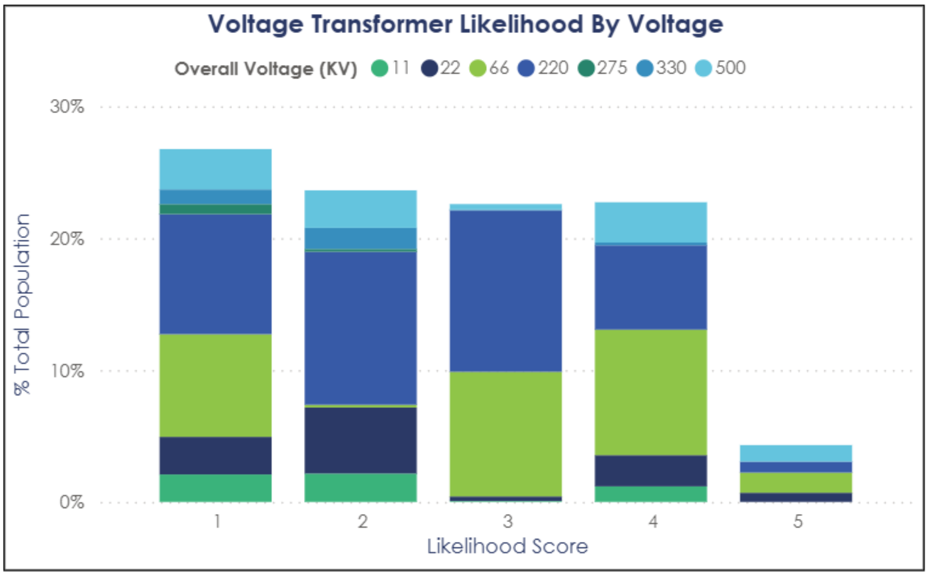

Figure 22: Voltage Transformers Likelihood Score by Voltage Class

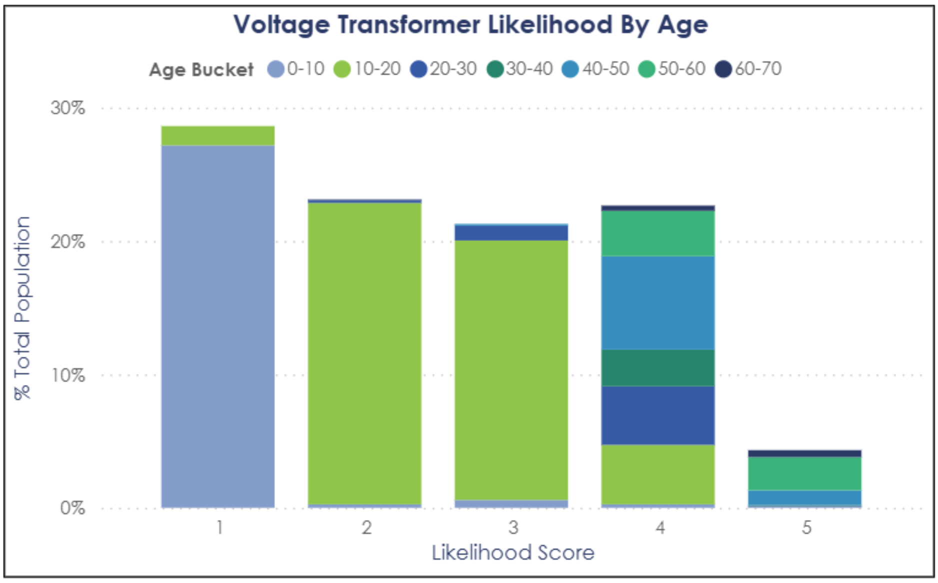

Figure 23: Voltage Transformers Likelihood Score by Age Profile

Key Findings on VT Health Conditions Derived from the Figures 21 and 22:

- The [C.I.C] VTs, including 66kV and 220kV CVTs and 66kV MVTs, which are over 40 years old, exhibit a tendency for oil leaks. Strip-down inspections have revealed general deterioration, including signs of mild overheating. Additionally, spares for these assets are no longer commercially available and can only be sourced from retired plants. Due to these factors, they have been assigned a likelihood score of 4 or 5.
- The [C.I.C] 220kV CVTs are over 40 years old, exhibit a tendency for oil leaks due to bellow failure. Strip-down inspections of units removed due to CAMS alarms have revealed internal packet deterioration, and

partial discharge. Additionally, spares for these assets are no longer available and can only be sourced from retired plants. Due to these factors, they have been assigned a likelihood score of 4 or 5.

- The 66kV [C.I.C] CVT, with an average age of 56 years, are experiencing widespread insulation degradation and are now considered technically obsolete, with no OEM support available. Due to the limited number of units remaining in the network, sourcing spare parts has become increasingly difficult. These VTs have been assigned a likelihood score of 4 or 5, reflecting a high risk of failure.

All of the above are the main types proposed for replacement in the TRR 2027-32 period.

6. Related Matters

6.1. PCB in Oilpaper insulated instrument transformers

Older oil filled instrument transformers such as [C.I.C] and [C.I.C] have been found to contain Polychlorinated Biphenyls (PCBs) in oil which requires special handling procedures to be followed during their life cycle management, due to health and safety and environment concerns if contaminated.

6.2. Asbestos in Instrument Transformers

Asbestos material has the potential to cause harm to the safety and health of people, equipment, or the environment. Certain control measures must be adopted when it is required to modify or removing asbestos as per HSP-05-05-1 guideline. Black Asbestos containing material is found only in some older instrument transformer electrical backing boards in older stations. However, no asbestos containing material has been found in secondary terminal boards.

6.3. Technical Obsolescence /Spares Management

Manufacturers usually cease officially supporting instrument transformers after 30 years. While serviceability can be enhanced during the asset's operational life by increasing spare parts inventory, once the original equipment manufacturer stops production, store inventories will eventually decrease. As a result, salvaging older instrument transformers and parts in usable condition becomes the primary method to support a fleet of CTs or VTs.

All the types identified in the proposed replacement program are technically obsolete, no longer supported and the supplier or manufacturing plant no longer exists.

6.4. CVT online health monitoring

CVT online monitoring is available through a 'CAMS' system built into the network SCADA system and providing alarms when output varies beyond normal levels, in excess of 98% of CVTs are monitored and the system has proved effective in detecting CVT about to fail and avoiding catastrophic failures since it was introduced in early 2000's.

CVD introduced between 2000 to 2015 for AEMO quality of supply monitoring are not monitored by the CAMS system as they do not feed into SCADA. There has been some early CVD under investigation removed due to low voltage output. There is growing need to investigate an online CAMS system for CVDs

CVD are no longer installed, being replaced by low voltage PQ sensors that can be fitted within CVTs

6.5. Dead tank CB CT

At 66kV and 220kV voltages the preferred CB type, for safety and economic reasons, is dead tank type with integral low voltage type CTs. This removes the need for outdoor post type CT with HV insulation. As such an integrated approach to CT and CB replacement is required.

7. Proposed Program of Work

7.1. Approach

7.1.1. Risk

AusNet's asset management decisions within the transmission network are guided by a risk-based approach, ensuring alignment with our organisational risk appetite. For instrument transformers, risk treatment required to achieve this over time involves replacement & maintenance activities. Justification for these projects are developed based on current risk and extrapolated risk.

The risk of each asset is calculated as the product of Probably of Failure (PoF) of the asset and the Consequence of Failure (CoF). This risk is then extrapolated into the future accounting for forecast changes in PoF and CoF.

AusNet's approach to asset risk management is detailed in REF: AMS 01-09 Asset Risk Assessment Overview.

7.1.1.1. Asset Risk Quantification Methods

Current Transformer PoF Model

The PoF for CTs is calculated using a health score model for oil filled CTs and aged based Weibull method is used for SF6 and Epoxy type CTs, as described in AMS - 01-09. The health score approach employs existing historical data from insulating oil chemical tests, the associated DGA and consideration of the asset design characteristics to evaluate the risk of failure over the next 12 months.

The health score model evaluates breathing and heating conditions using available diagnostic data for oil filled CTs. The Probability of Failure (PoF) is derived by integrating assessments from both free-breathing and heating indicators.

Free-breathing status, or seal failure, is determined by nitrogen concentration. CTs with levels at or above 45,000 ppm are categorised as saturated, while those below are unsaturated and each category is assessed using relevant gas concentrations and rates of change. Seal failure will result in moisture build up within the CTs.

Heating gas analysis will be done by analysing the five key gases: Hydrogen, Methane, Ethane, Acetylene and Ethylene. Duval Triangle method has been used to identify heating gas events within CTs. The Duval Triangle uses three of the heating gases (Methane, Acetylene and Ethylene) to classify a CT into heating event classifications. Unlike the IEC method, the Duval Triangle is a closed system, meaning all assets will be classified.

The overall PoF for CT is determined by integrating the breathing and heating PoF components, as illustrated in the block diagram below. The model also estimates the asset's biological age based on conditional PoF. Future PoF projections are calculated using a Weibull distribution model, in accordance with the methodology outlined in AMS 01-09.

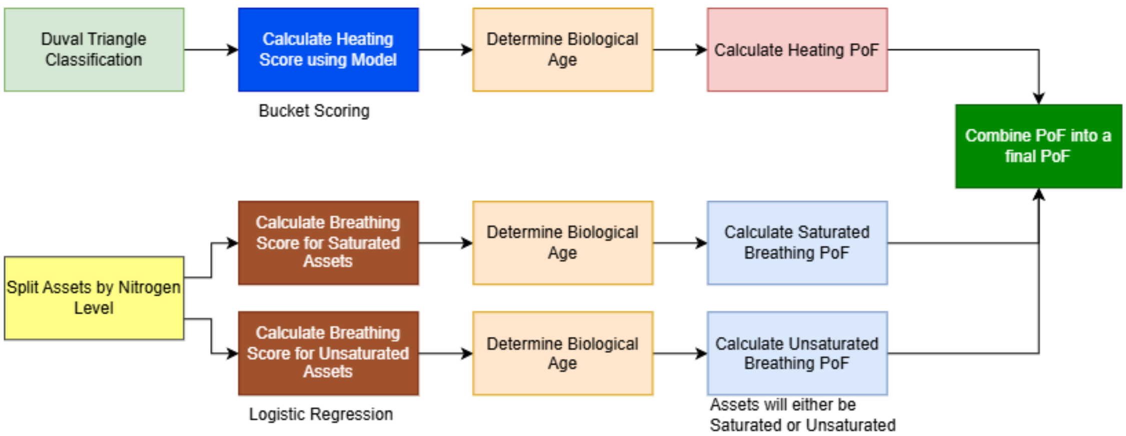

Figure 24 - Block Diagram for Combined Probability of Failure

Voltage Transformer PoF Model

As per the methods of calculation described in AMS - 01-09 the conditional PoF for VT follows a Health Score methodology. This is driven by the relatively large amount of historical data, including four key parameters: asset life, asset utilisation (or duty factor), location factor, and physical condition.

Each parameter is evaluated and assigned an index from 1 to 5 (where 1 represents optimal health and 5 indicates poor health), based on diagnostic data and condition assessments, as well as empirical experience and subject matter expertise. The highest index for each parameter is selected and used as input for the health score calculation. The probability of failure for the voltage transformer is then determined using the health score over the next 12 months, with forecasts PoF calculated through Weibull distribution models.

Consequence of Failure (CoF)

AusNet assigns a monetised value to CoF which provides an economic basis of calculating potential consequence.

The cost of failure for instrument transformers is assessed through key lenses: Safety, Environment, Customer / Market Impact and Financial consequences. These lenses provide a structured view of the potential impacts resulting loss of energy supply, injury to employees or contractors, or environmental hazards. Table 2 summarises the focus of each lens.

CONSEQUENCE LENSES	DESCRIPTION
Safety	Threat to health and safety of people
Environment	Fire/smoke damage Oil Spills SF6 Leak
Customer / Market	Loss of Supply to Customers Impact on energy market
Financial	Asset/Component replacement costs Collateral damage Emergency response repairs/replacements

Table 2: Consequence lens description

7.2. Economic Viability

Asset Management use the calculated risk based on PoF and CoF outputs to identify optimal intervention years, balancing technical feasibility with economic efficiency. These outputs are incorporated into an economic model. The economic model demonstrates the year when the calculated annualised risk is higher than the annualised replacement cost, and as such when the asset becomes economically viable to replace. The concept is shown visually in Figure 25 below.

The economic model is producing a structured approach for each asset in the fleet. The economic model for the justified replacement program is available in asset class economic model: REF: ANT - TRR 2027-32 Asset Replacement Economic Model - Instrument Transformer - Final

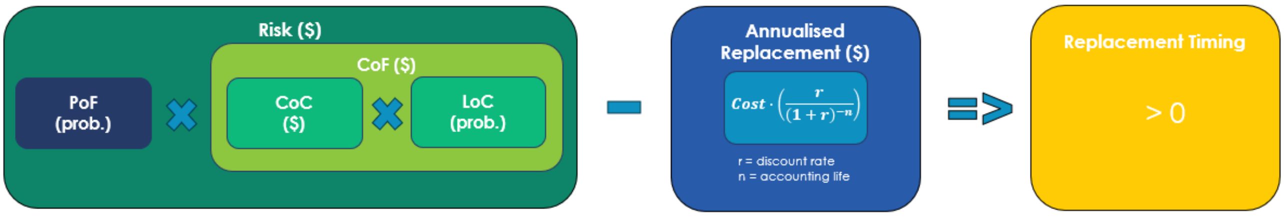

Figure 25: Concept of Economic Model

7.3. Engineering Validation

Following the generation of asset health models and Weibull forecasts, a structured validation process is undertaken by SME. his step is intended to support the interpretation of model outputs in the context of engineering interventions, operational insights, and current asset condition

Assessments as to whether the model's recommendations such as, asset replacement, refurbishment or no action are reasonably practicable. This involves verifying condition data, evaluating operational priorities, and considering strategic timing of interventions. Where appropriate recommendations for alternative actions based on professional assessment maybe implemented.

This validation process complements the use of economic model forecasts by integrating predictive outputs with expert knowledge. It supports a balanced and accountable approach to asset management, one that upholds technical integrity while remaining responsive to operational realities.

7.4. Proposed Program

The AusNet modelling process transforms instrument transformer performance and health analysis into economic assessment. The confluence of this in conjunction with risk models promotes a limited number of instrument transformers for prioritised replacement.

In general, the most significant asset types requiring replacement through TRR 2027-32 are:

a. 66kV [C.I.C] CTs
b. 66kV [C.I.C] MVTs
c. 66kV [C.I.C] CTs, CVTs and MVTs
d. 220kV [C.I.C] CVTs
e. 500kV [C.I.C] CTs (as part of the Major Station projects)

The above program removes many remaining poor condition CVT and CT types, whose fleet replacement has been progressing on a prioritised basis over last 10 to 15 years.

In addition, AusNet overall station strategy considers the condition of standalone current transformers and associated circuit breakers. For example, dead tank circuit breakers with integral CTs where possible up to 220kV will replace both high-risk circuit breaker and its associated CTs.

8. Asset Strategies

8.1. CT Strategies

8.1.1. New Installations

- Install dead tank circuit breakers with integral CTs where possible up to 220kV operating voltage level
- Where associated CB is not being replaced or a live tank type, install polymer housed oilpaper insulated outdoor current transformers to latest specification for 66 to 330kV, and polymer housed SF6 gas insulated outdoor current transformer for 500kV
- Install high quality epoxy cast resin current transformers for operating voltages at and below 22kV.

8.1.2. Inspection

- Continue visual inspection during regular station inspections
- Continue annual non-invasive thermal and RF scanning

8.1.3. Maintenance

- Continue condition monitoring through regular oil sampling and DGA analysis, as per SMI.
- Continue to establish enhanced sampling oil DGA sampling regime for approaching end of life CTs
- Establish improved tracking of overdue oil DGA sampling
- Continue to monitor closely gassing trends in the [C.I.C] polymer housed CTs

8.1.4. Asset Replacement

- Replace 9 off identified high risk 66kV Current Transformers: [C.I.C] 82/579 type
- Replace 3 off identified high risk 66kV Current Transformers: [C.I.C] type

8.2. VT Strategies

8.2.1. New Installations

- Install polymer housed oilpaper insulated outdoor inductive voltage transformers to latest specification up to 66kV operating voltage
- Install polymer housed oilpaper insulated outdoor capacitive voltage transformers to latest specification for higher than 66kV operating voltage
- At 22kV and below, install high quality epoxy cast resin VTs
- Install CVT asset monitoring system (CAMs) on all CVTs installed in the transmission network

8.2.2. Inspection

- Continue visual inspection during regular station inspections
- Continue annual non-invasive thermal and RF scanning

8.2.3. Maintenance

- Maintain CAMS to provide 100% functional coverage for CVT
- Explore alternative methods for MVT performance assessment

8.2.4. Asset Replacement

- Replace 3 off identified remaining higher risk 66kV CVTs: [C.I.C] type
- Replace 2 off identified remaining higher risk 66kV MVTs: [C.I.C]
- Replace 8 off identified remaining higher 220kV CVTs: [C.I.C] type and [C.I.C] type

9. Resource Reference

NO.	TITLE
1	AMS 01-05 Strategic Asset Management Plan
2	AMS 01-09 Asset Risk Assessment Overview
3	ANT – TRR 2027-32 Asset Replacement Economic Model – Instrument Transformer – Final

10. Schedule of Revisions

ISSUE NO.	DATE	DESCRIPTION	AUTHOR	APPROVED BY
5	22/11/06	Editorial review.	[C.I.C]	[C.I.C]
6	23/02/07	Review and update.	[C.I.C]	[C.I.C]
7	17/03/07	Editorial review.	[C.I.C]	[C.I.C]
8	24/10/07	Updated to include reference to [C.I.C] 500 kV CT Life Analysis document.	[C.I.C]	[C.I.C]
9	18/01/13	Revised Structure and General Update	[C.I.C]	[C.I.C]
10	14/08/15	Review and update.	[C.I.C]	[C.I.C]
11	28/07/2020	Review and update	[C.I.C]	[C.I.C]
12	30/08/2025	Review and update	[C.I.C]	[C.I.C]

Disclaimer

Contact

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Appendices

Appendix 1 – Instrument Transformer Failures

INCIDENT DATE	STATION	KV	MANUF.	CT/VT	TECHNOLOGY	NATURE OF FAILURE	NOTE
2002	MLTS	500	[C.I.C]	CT	Oil filled	Explosive failure	
2004	JLTS	220	[C.I.C]	CT	Oil filled	Explosive failure	
2005	MLTS	500	[C.I.C]	CT	Oil filled	Explosive failure	
2006	TGTS	66	[C.I.C]	CT	Oil filled	Explosive failure	
2006	BATS	66	[C.I.C]	CT	Oil filled	Explosive failure	
2007	DDTS	220	[C.I.C]	CT	Oil filled	DGA failed	Forced outage - Predictive Replacement
2009	SMTS	500	[C.I.C]	CVT	Oil filled	CAMS alarm	Emergency removal from service
2009	SMTS	500	[C.I.C]	CVT	Oil filled	Explosive failure	
2009	JLGS	220	[C.I.C]	CVT	Oil filled	Explosive failure	
2010	FBTS	66	[C.I.C]	CT	Oil filled	DGA failed	Forced outage - Predictive Replacement
2013	YPS	220	[C.I.C]	CVT	Oil filled	CAMS Alarm	Emergency Replacement
2014	HWPS	220	[C.I.C]	CT	Oil filled	Coupling Unit failed	
2014	KTS	500	[C.I.C]	CT	SF6	Failed rupture disk	
2015	MOPS	500	[C.I.C]	CVD	Oil filled	Visible oil leak	Predictive Replacement
2015	YPS	220	[C.I.C]	CVT	Oil filled	CAMS Alarm	Emergency Replacement
2016	RTS	220	[C.I.C]	CT	Oil filled	Explosive failure	
2017	MLTS	500	[C.I.C]	CVT	Oil filled	CAMS Alarm	Emergency Replacement
2017	WMTS	66	[C.I.C]	CT	Oil filled	DGA failed	Predictive Replacement
2018	TBTS	220	[C.I.C]	CVT	Oil filled	CAMS Alarm	Emergency Replacement
2018	ERTS	220	[C.I.C]	CVT	Oil filled	CAMS Alarm	Emergency Replacement
2018	ROTS	500	[C.I.C]	CT	SF6	Failed rupture disk	
2020	BETS	66	[C.I.C]	MVT	Oil filled	Internal fault	
2022	LDL ZSS	66	[C.I.C]	CVT	Oil filled	Explosive failure	Distribution Asset NO CAMS installed
2023	MOPS	500	[C.I.C]	CT	SF6	Internal fault	Unregulated Asset

Appendix 2 – Program of Works

FLOC DESCRIPTION	OBJECT TYPE	START-UP DATE	VOLTAGE	MANUFACTURER	MODEL	STATION
WPD 66KV FDR CB CT W/PH	CT	16/06/1983	66	[C.I.C]	06/72/37	GTS
WPD 66KV FDR CB CT R/PH	CT	16/06/1983	66	[C.I.C]	06/72/37	GTS
WPD 66KV FDR CB CT B/PH	CT	16/06/1983	66	[C.I.C]	06/72/37	GTS
DMA 66KV FDR CB CT W/PH	CT	30/06/1986	66	[C.I.C]	82/579	TBTS
HGS 2 66KV FDR CB CT W/PH	CT	30/06/1986	66	[C.I.C]	82/579	TBTS
DMA 66KV FDR CB CT B/PH	CT	30/06/1986	66	[C.I.C]	82/579	TBTS
HGS 2 66KV FDR CB CT R/PH	CT	30/06/1986	66	[C.I.C]	82/579	TBTS
HGS 1 66KV FDR CB CT W/PH	CT	30/06/1986	66	[C.I.C]	82/579	TBTS
DMA 66KV FDR CB CT R/PH	CT	30/06/1986	66	[C.I.C]	82/579	TBTS
HGS 2 66KV FDR CB CT B/PH	CT	30/06/1986	66	[C.I.C]	82/579	TBTS
HGS 1 66KV FDR CB CT R/PH	CT	30/06/1986	66	[C.I.C]	82/579	TBTS
HGS 1 66KV FDR CB CT B/PH	CT	30/06/1986	66	[C.I.C]	82/579	TBTS
4 66KV BUS CVT R/PH	CVT	01/01/1980	66	[C.I.C]	04/72/3	BETS
4 66KV BUS CVT B/PH	CVT	01/01/1980	66	[C.I.C]	04/72/3	BETS
4 66KV BUS CVT W/PH	CVT	01/01/1980	66	[C.I.C]	04/72/3	BETS
1 66KV BUS VT	MVT	30/06/1968	66	[C.I.C]	N/A	FTS
2 66KV BUS VT	MVT	30/06/1968	66	[C.I.C]	N/A	FTS
1 220KV BUS CVT R/PH	CVT	01/01/1985	220	[C.I.C]	04/245/8	JLTS
1 220KV BUS CVT B/PH	CVT	01/01/1981	220	[C.I.C]	TEHM 230H	JLTS
CBTS 1 220KV L CVT B/PH	CVT	01/01/1985	220	[C.I.C]	04/245/8	TBTS
CBTS 1 220KV L CVT W/PH	CVT	01/01/1985	220	[C.I.C]	04/245/8	TBTS
CBTS 1 220KV L CVT R/PH	CVT	01/01/1985	220	[C.I.C]	04/245/8	TBTS
CBTS 2 220KV L CVT B/PH	CVT	01/01/1985	220	[C.I.C]	04/245/8	TBTS
CBTS 2 220KV L CVT W/PH	CVT	01/01/1985	220	[C.I.C]	04/245/8	TBTS
CBTS 2 220KV L CVT R/PH	CVT	01/01/1985	220	[C.I.C]	04/245/	TBTS

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