Instrument Transformers

AMS – Electricity Distribution Network

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Table of Contents

1 Executive Summary

This document is part of the suite of Asset Management Strategies relating to AusNet Services' 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 instrument transformers.

1.1 Current Transformers:

This strategy covers the 1237 current transformers installed in zone substations. Approximately 34.4% of the current transformers are located outdoor and have oil- paper insulation. The remaining population (65.6%) are solid resin insulation types mainly installed on indoor switchboards or outdoor power transformer neutrals.

Condition assessment shows approximately 71.2% of the total CT population are either in a "Very Good" condition (C1), "Good" condition (C2) or "Average" condition (C3). Approximately 28.8% of the population are either in "Poor" condition (C4, 16.7%) or "Very Poor" condition (C5, 12.1%). The majority of the "Very Poor" condition CTs are outdoor 66kV oil –paper insulation type and 22kV outdoor metering current transformers used in feeder exits in older switchyards.

The consequence of a failure was assessed based on community impact due to outages, safety, environment and collateral damage risks. Porcelain housed & oil filled current transformers pose a high risk of safety, collateral damage and environmental risk due to the inherent explosive and oil fire risk.

Using the condition assessment and consequence criticality, a risk assessment for current transformers was performed using a combined AWB / spreadsheet based quantitative analysis. This has established an economically sound replacement program for high risk current transformers during the period 2022-26.

Proactive management of current transformers 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.

1.1.1 Asset Strategies

1.1.1.1. New Assets

- Install dead tank circuit breakers with integral CT's where possible
- Where associated 66kV CB is not being replaced, install polymer housed oil –paper insulated outdoor current transformers to latest specification
- Install high quality epoxy cast resin current transformers for operating voltages at and below 22kV.

1.1.1.2. Inspection

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

1.1.1.3. Maintenance

- Continue condition monitoring through regular oil sampling and DGA analysis, as per PGI 02-01-04.

1.1.1.4. Replacement

- Replace 78 "Very Poor" condition 22kV and 66kV current transformer types: [C.I.C] [C.I.C] Products under station rebuild and asset replacement program during the EDPR period 2022-26.

1.2 Voltage Transformers:

This strategy covers the 655 voltage transformers installed in zone substation. Voltage transformers consist of Magnetic Voltage Transformers (MVTs) type, 76.5% of population, and Capacitive Voltage Transformers (CVTs), 23.5% of the population, Approximately 67.6% of the voltage transformers are located outdoor and have oil- paper insulation. The remainder of the population (32.4%) consist of solid resin insulation mainly installed on indoor switchboards or outdoor 22kV bus or transformer positions.

Condition assessment shows approximately 65.5% of the total VT population are either in a "Very Good" condition (C1), "Good" condition (C2) or "Average" condition (C3). Approximately 34.5% of the total VT population are either in "Poor" condition (C4, 14.4%) or "Very Poor" condition (C5, 20.2%). Majority of the "Very Poor" condition VTs are 66kV oil –paper insulation type bus MVTs or line CVTs.

The consequence of a failure was assessed based on community impact due to outages, safety, environment and collateral damage risks. Porcelain housed & oil filled voltage transformers pose a high risk of safety, collateral damage and environmental risk due to the inherent explosive and oil fire risk.

Using the condition assessment and consequence criticality, a risk assessment for voltage transformers was performed using a combined AWB / spreadsheet based quantitative analysis. This has established an economically sound replacement program for high risk voltage transformers during the period 2022-26.

Proactive management of voltage transformers 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.

1.2.1 Asset Strategies

1.2.1.1. New Assets

- At 66kV install polymer housed oil –paper insulated outdoor voltage transformers to latest specification
- At 22kV and below install high quality epoxy cast resin voltage transformers
- Install CVT asset monitoring system (CAMs) on all 66kV CVTs installed in the distribution system

1.2.1.2. Inspection

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

1.2.1.3. Maintenance

- Continue condition monitoring through regular oil sampling and DGA analysis of MVT

1.2.1.4. Condition Monitoring

- Install CVT asset monitoring system (CAMs) on 43 off poor condition 66kV Tyree CVTs installed in the distribution system

1.2.1.5. Replacement

- Replace 76 "Very Poor" condition 22KV and 66kV voltage transformers types: [C.I.C], [C.I.C] , under station rebuild and asset replacement program during the EDPR period 2022-26.

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 Services' 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.

2.2 Scope

This Asset Management Strategy applies to all outdoor and indoor type instrument transformers operating at 66kV, 22kV, 11kV and 6.6kV located in zone substations. It covers all types of current transformers (CT), magnetic voltage transformers (MVT) and capacitive voltage transformers (CVT). It excludes low voltage insulated current transformers integrated into power transformers and dead tank circuit breakers.

2.3 Asset Management Objectives

As stated in *AMS 01-01 Asset Management System Overview*, the high-level asset management objectives are:

- Comply with legal and contractual obligations
- Maintain safety
- Be future ready
- Maintain network performance at the lowest sustainable cost, and
- Meet customer needs.

As stated in *AMS 20-01 Electricity Distribution Network Asset Management Strategy*, the electricity distribution network objectives are:

- Improve efficiency of network investments
- Maintain long-term network reliability
- Implement REFCL's within prescribed timeframes
- Reduce risks in highest bushfire risk areas
- Achieve top quartile operational efficiency
- Prepare for changing network usage

3 Asset Description

3.1 Asset Function

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

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

Voltage transformers (MVT& 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 Asset Population

There are 1,237 current transformers (CT) and 655 voltage transformers (VT) located in zone substations within the AusNet Services electricity distribution network. The total number of current transformers has decreased by 4.6% mainly due to replacement of live tank circuit breakers with dead tank circuit breakers since 2014.Number of voltage transformers had increased 7.7% since 2014.

CTs consist of hairpin and inverted head post-type with oil/paper insulation and porcelain or epoxy housings, outdoor metal enclosed oil insulated type, indoor or outdoor epoxy encapsulated block type and toroidal type constructed without HV insulation.

Capacitive Voltage Transformers (CVT) is single phase devices and Magnetic Voltage Transformer (MVT) is either single or three-phase voltage transformers. There are no capacitive VTs installed on circuits operating below 66 kV.

CVTs 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 are used in indoor or outdoor applications.

3.2.1 Current Transformers

Figure 1a below provides the current transformer population by voltage and insulation type.

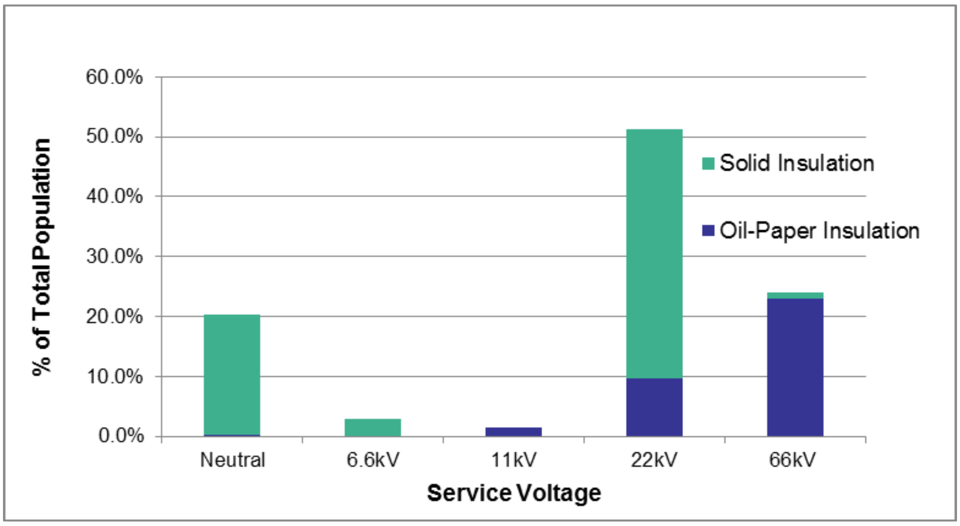

Figure 1a – Current Transformer Population by voltage and Insulation type

Figure 2a below provides the current transformer population by voltage and location by indoor or outdoor.

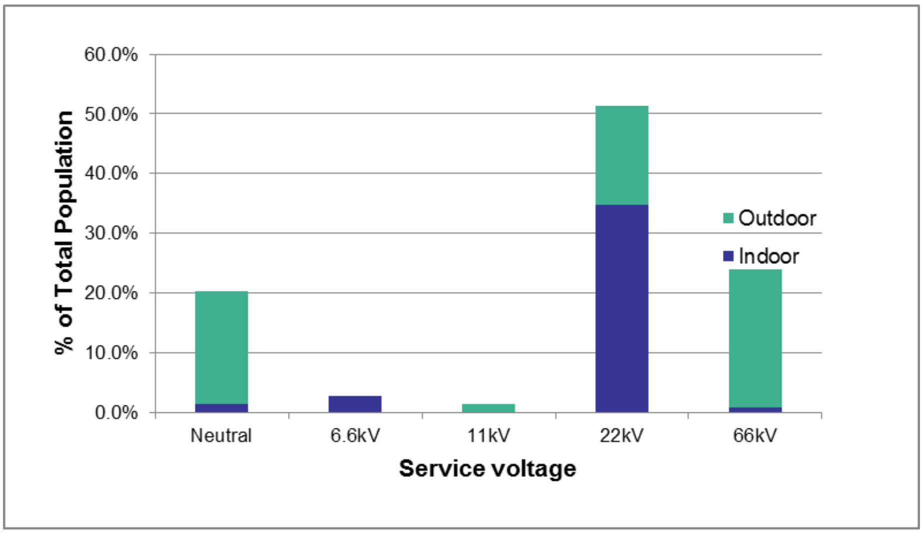

Figure 2a – Current Transformer Population by voltage and Location

It is observed that approximately 34.4% of the CT population consist of oil / paper insulation and majority are in 66kV distribution system. Approximately 92.6% of the 66kV CTs are associated with live tank circuit breakers.

Approximately 65.6% of the total current transformers consist of solid insulation (mainly epoxy cast resin) are located in indoor switchboards or in outdoor environment used as Power Transformer neutral CTs.

Figure 3a & 4a provides percentage of current transformer population with oil paper insulation by Manufacturer for service voltage up to 22kV and 66kV respectively. It is noted that oil CTs up to 22kV consist of number of manufacturer types dominating [C.I.C] and types contributing to 53.2% of the total oil CT population. Approximately 42.1% of the 66kV oil CTs is of [C.I.C] types.

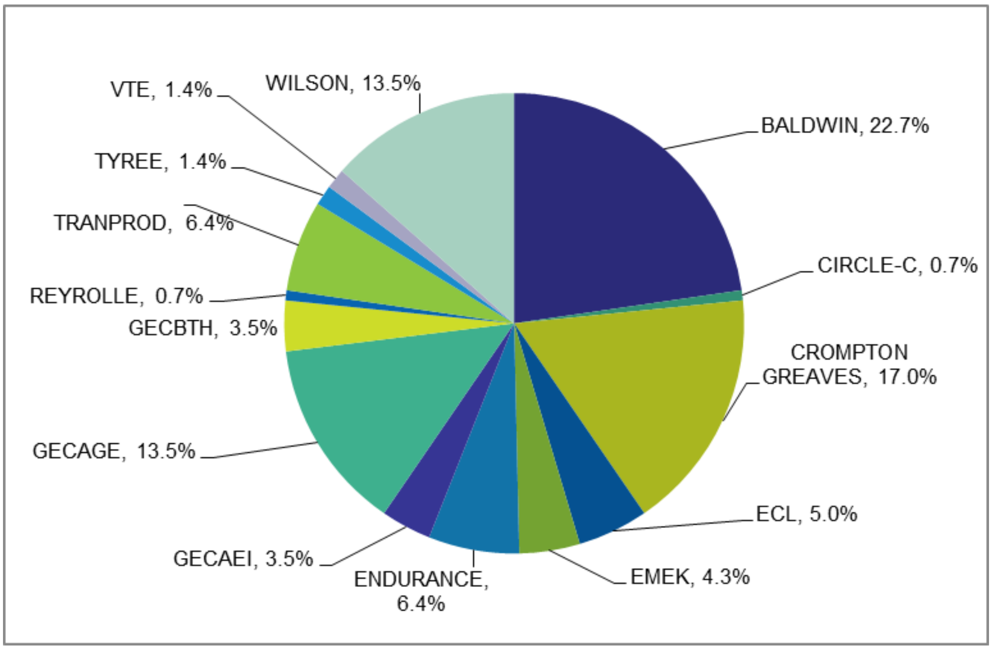

Figure 3a – Distribution Current Transformer population up to 22kV with oil paper insulation

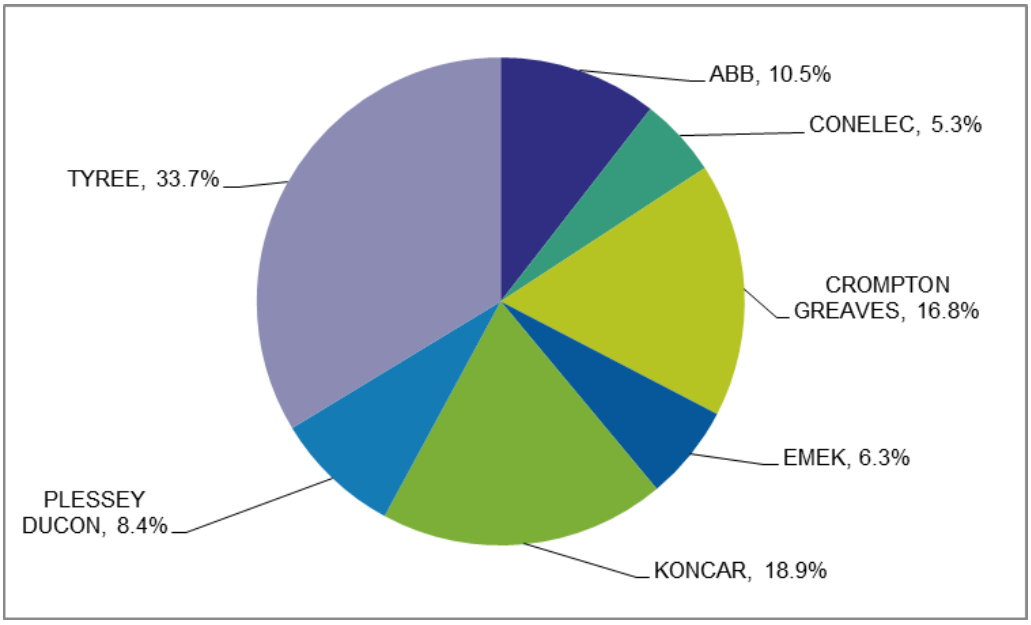

Figure 4a – 66kV Distribution Current Transformer population with oil paper insulation

3.2.2 Voltage Transformers (MVT, CVT)

Figure 1b below provides the voltage transformer population by voltage and insulation type.

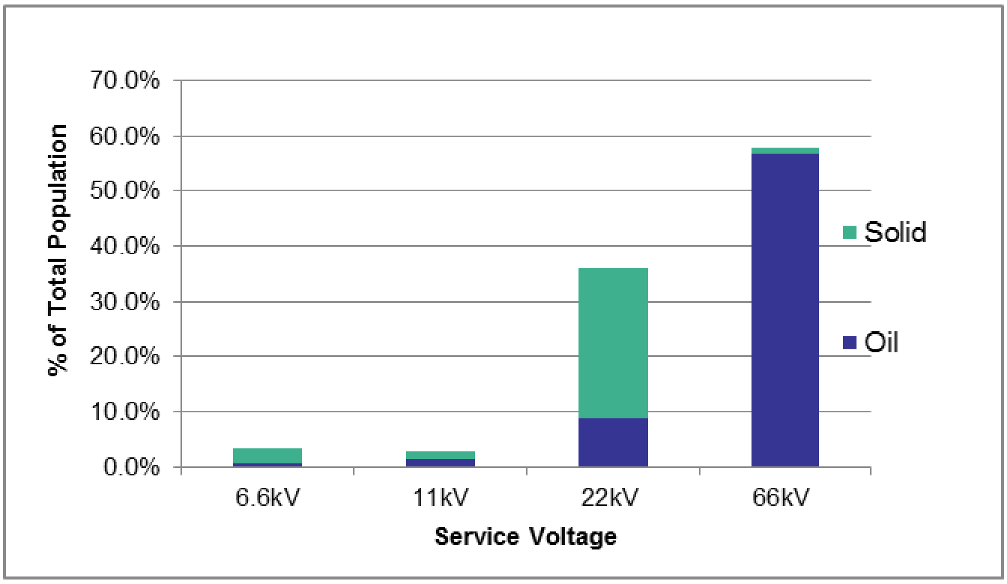

Figure 1b – Voltage Transformer Population by voltage and Insulation type

Figure 2b below provides the voltage transformer population by voltage and location by indoor or outdoor.

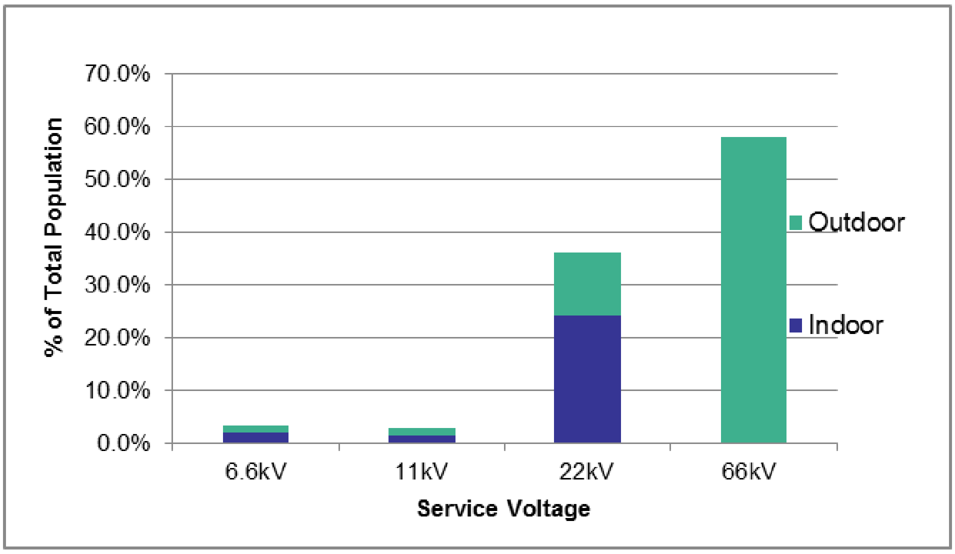

Figure 2b – Voltage Transformer Population by voltage and Location

It is observed that approximately 67.6% of the VT population consist of oil / paper insulation and they are all located in the 66kV distribution system. Approximately 73.9% of the 66kV VTs with oil paper insulation are associated with line VTs. Approximately 57.9% of the VT population are 66kV outdoor VTs. Up to 22kV VTs are either located in indoor switchboards or outdoor.

Figure 3b below provides the VT population against VT type namely (magnetic voltage transformer (MVT) and capacitive voltage transformer (CVT). It is observed All VTs up to 22kV are of MVT type. Approximately 23.5% of VT population comprise of 66kV CVTs and 34.4% of the 66kV VTs are of MVT type.

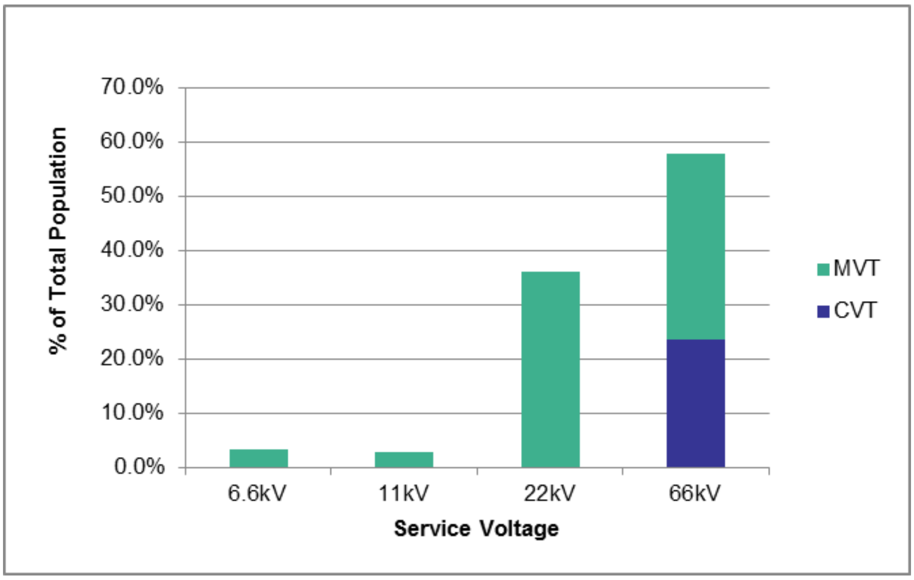

Figure 3b – Distribution VT population by type MVT and CVT

Figure 4b & 5b provides percentage of voltage transformer population with oil paper insulation by Manufacturer for service voltage up to 22kV and 66kV respectively.

It is noted that oil VTs up to 22kV consist of wide range of manufacturer types. Alstom 225L type has the highest population of 21.1%.

Approximately 39.2% of the 66kV oil VTs is of [C.I.C] types which are of CVT category. [C.I.C] older types have the tendency to fail catastrophically and experienced by Transmission system and other utilities. VTs are not repairable or can be refurbished and maintenance free. In most of the CVT types are sealed and do not have oil sampling provision for Oil condition analysis.

C.I.C

3.3 Asset Age Profile

3.3.1 Current Transformers

The average service age of all voltage transformers is 25.3 years. Figure 6 &7 below provides the age profile of all current transformers by service voltage and Insulation type respectively.

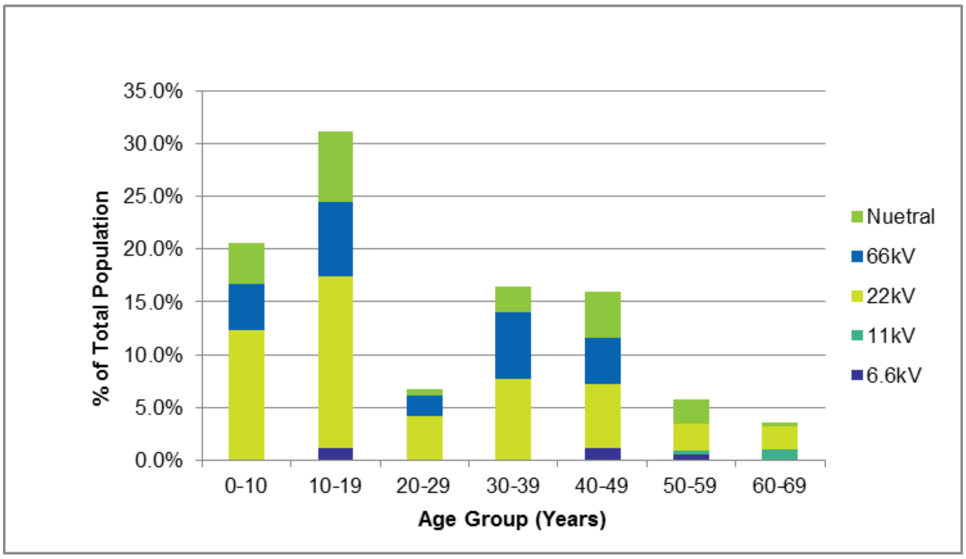

Figure 6- Current Transformer Age by Service Voltage

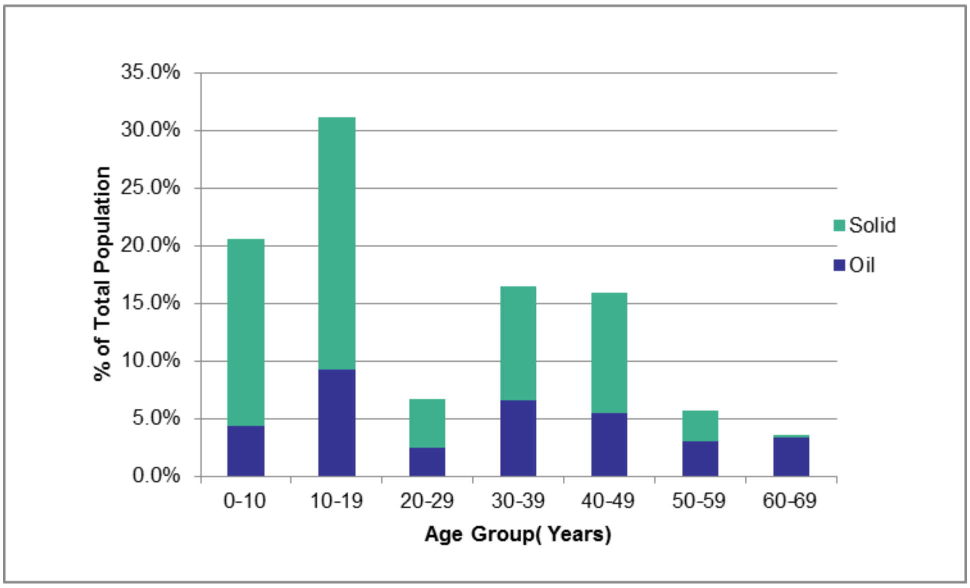

Figure 7- Current Transformer Age by Insulation Type

Majority of other older 22kV and below types have been identified under current station augmentation and REFCL projects prior to EDPR 2022-26 period.

Figure 8 below provides the age profile of 66kV CTs by manufacturer type. [C.I.C] CTs are the oldest of the current transformer fleet. [C.I.C] older types have the tendency to fail catastrophically and experienced by Transmission system and other utilities. They are mostly associated with live tank circuit breakers.

C.I.C

3.3.2 Voltage Transformers (MVT, CVT)

The average service age of all voltage transformers is 24.2 years. Figure 9 & 10 below provides the age profile of all voltage transformers by service voltage and Insulation type respectively. Figure 11 shows the age profile by VT type. It is observed that CVT age ranges from 30 – 59 year band and contribute to 23.1 % of the total VT population. Normally 66kV CVTs are replaced with 66kV MVTs.

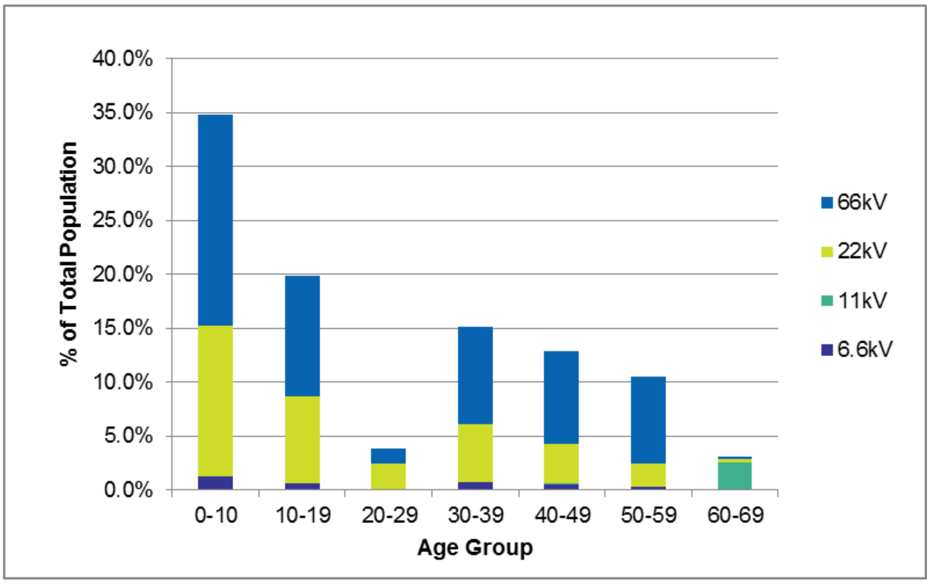

Figure 9 - Voltage transformer Age by Service Voltage

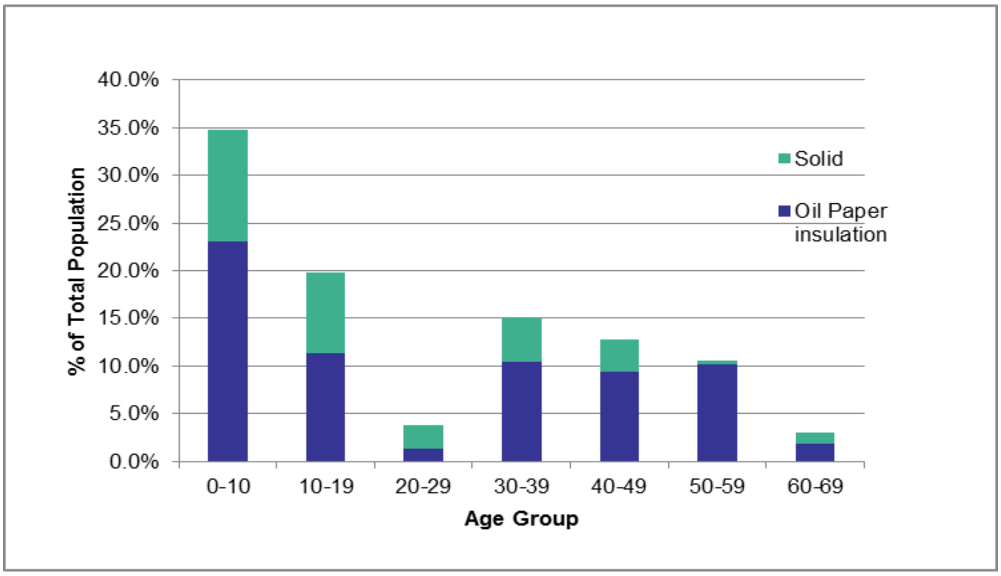

Figure 10- Voltage transformer Age by Insulation Type

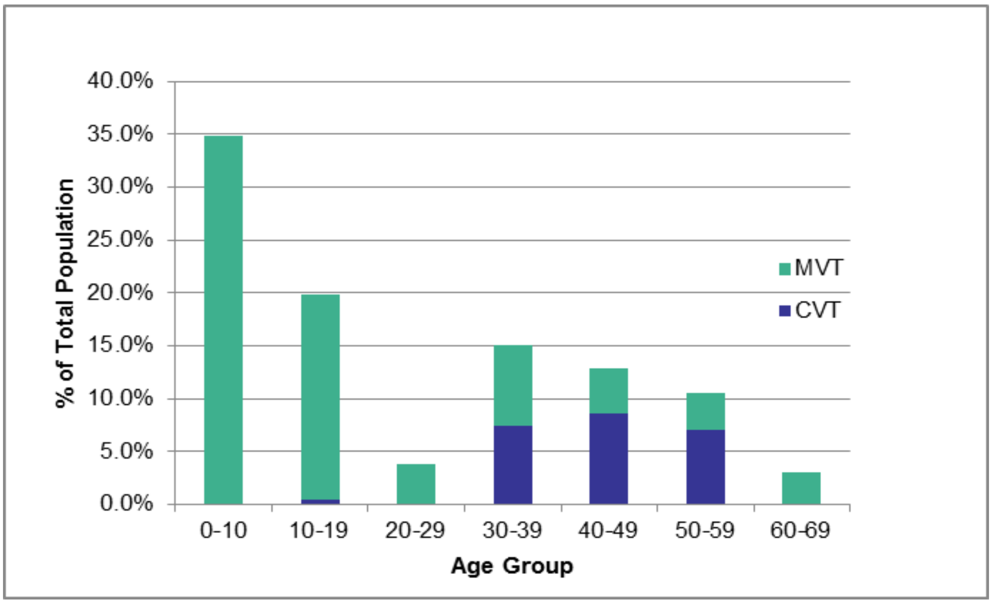

Figure 11- Voltage transformer Age by VT type

Figure 12 below provides the age profile of 66kV VTs by manufacturer type. [C.I.C] [C.I.C] VTs are the oldest of the voltage transformer fleet. Plessey Ducon and Tyree older CVT types have the tendency to fail catastrophically and experienced by Transmission system and other utilities.

C.I.C

3.4 Asset Condition

Following key factors were used to determine the health Score of Instrument transformers:

1. Oil Score based on previous oil condition history (Oil analysis).
2. Asset Score based on 80% Oil score and 20% age score.
3. Fleet Score based on failure history, technical issues and technical obsolescence.
4. Overall Health Score based on 60% asset score and 40% of fleet score.

The Table 1 provides a definition of the various condition scores and recommended action.

Table 1- Condition Score definition and recommended action

Condition Score	Condition Description	Summary of Details of Condition Score	Remaining Service Potential %
C1	Very Good	Instrument transformers are typically new, with no oil leaks or defects.	95%
C2	Good	Instrument transformers have typically been in service for a number of years. Typically very few minor defects and no history of any major failures and oil condition is satisfactory.	70%
C3	Average	Advancing deterioration. Occasional oil leaks but typically no history of any major failures or urgent replacements. Instrument transformers are still fully serviceable but more attention is to be paid to deterioration rates. Oil condition is satisfactory.	45%
C4	Poor	Advanced aging. Oil leaks and failure of rubber sealing bellows may be becoming more evident. Some units may have been replaced. Autopsies and laboratory testing of suspect types are planned to better understand the deterioration mechanisms. Major failures may have occurred requiring enhanced monitoring. The risk of individual failures is tending upwards. Spares parts such as replacement bellows increasingly scarce and have to be salvaged from removed units. Oil condition is becoming poor and need DGA monitoring more than normally required.	25%
C5	Very Poor	These units have reached end of life and high risk of failure. Failure mechanisms may be known through autopsies and laboratory investigations from removed units. Major failures may have occurred and there will be a history of replacements. Enhanced monitoring, such as oil dissolved gas analysis (DGA) or RF scanning may be scheduled. There may be high enough safety concerns over the risk of major failure that site access restrictions are implemented. There are no longer like spares available.	15%

3.4.1 Current Transformers

Condition profile of distribution current transformers by voltage is shown in Figure 13.

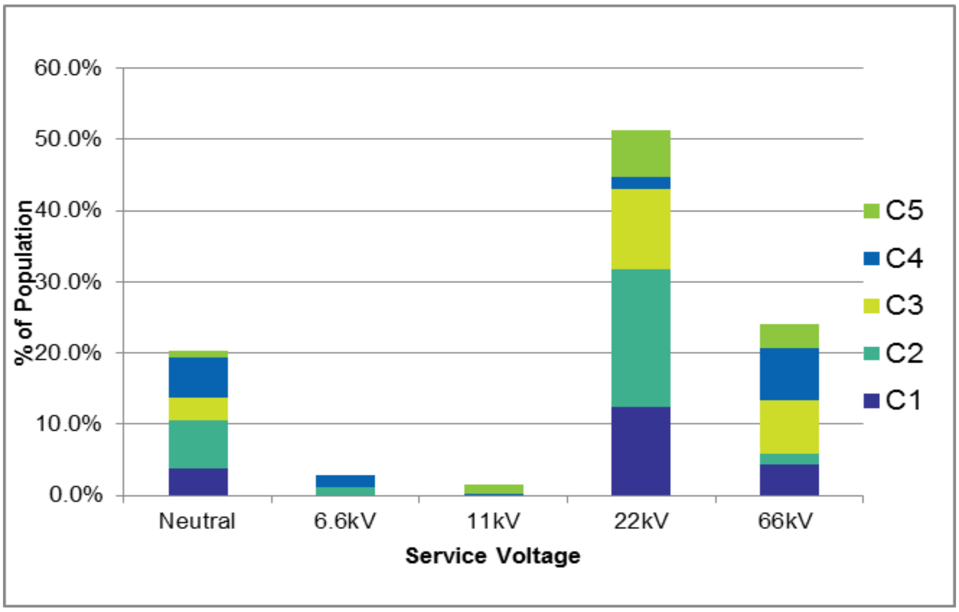

Figure 13 - Condition Profile of Distribution Current Transformers by Voltage Class

Distribution current transformer asset condition score vs age profile is shown in Figure 14.

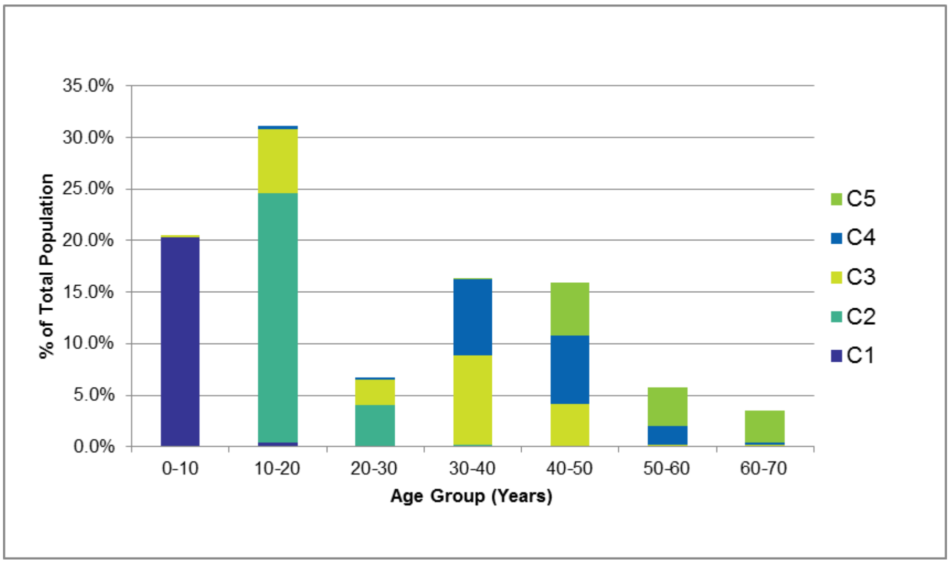

Figure 14 – CT Asset Condition vs Age

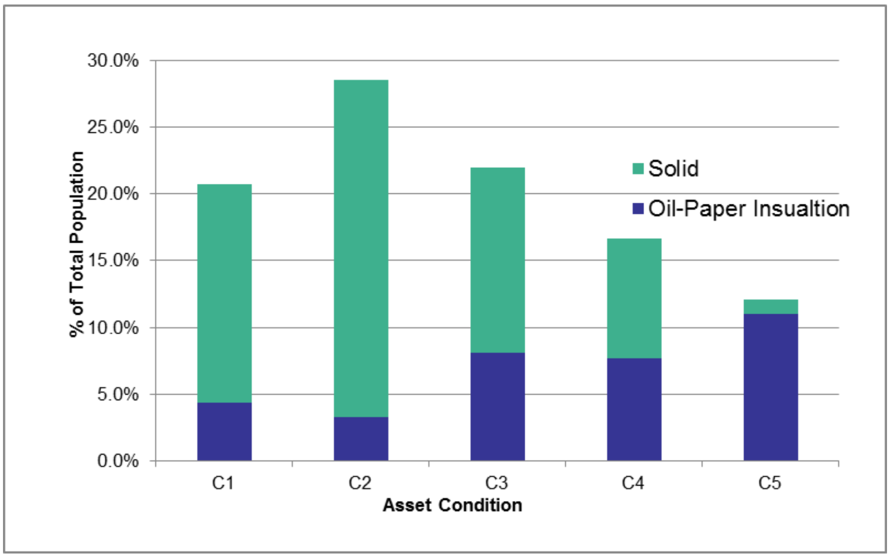

Figure 15 – CT Asset Condition vs Insulation type

66kV [C.I.C] are found to be in "Very Poor" asset condition (C5).

22kV [C.I.C] are also found to be in "Very Poor" condition (C5). "Poor" condition 22kV and below types are being replaced under current station augmentation projects and REFCL projects.

3.4.2 Voltage Transformers (MVT, CVT)

Condition profile of distribution voltage transformers by voltage is shown in Figure 16.

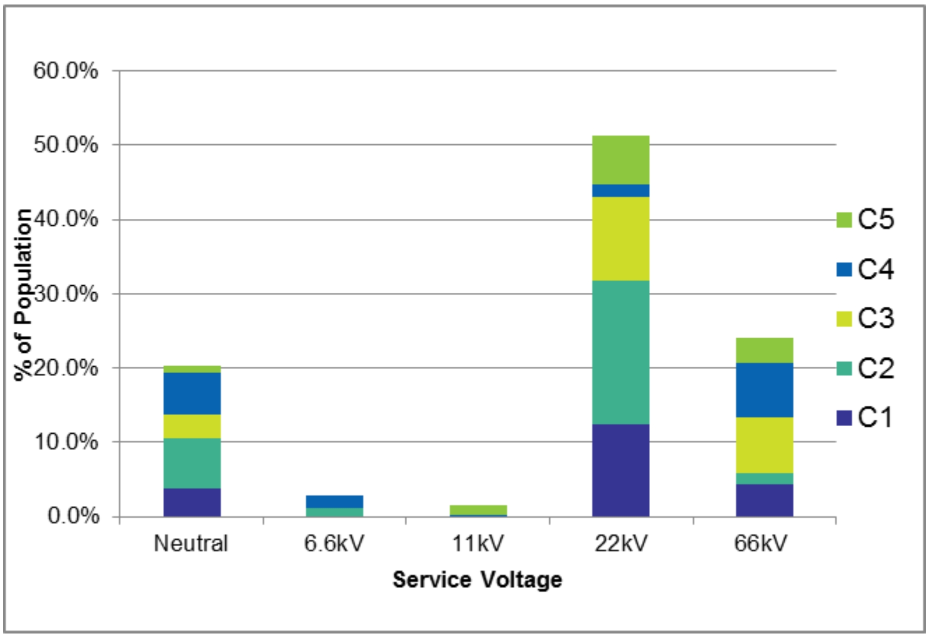

Figure 16 - Condition Profile of Distribution Voltage Transformers by Voltage Class

Distribution voltage transformer asset condition score vs age profile is shown in Figure 17.

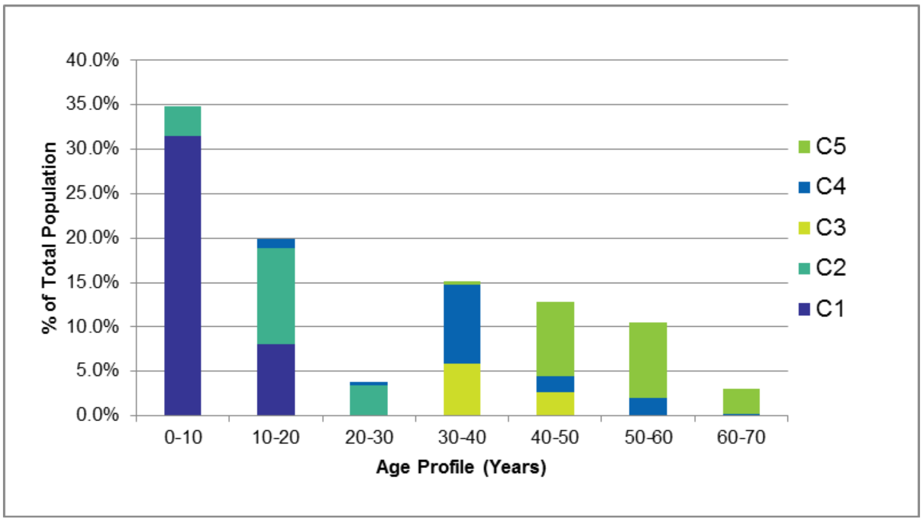

Figure 17 – VT Asset Condition vs Age

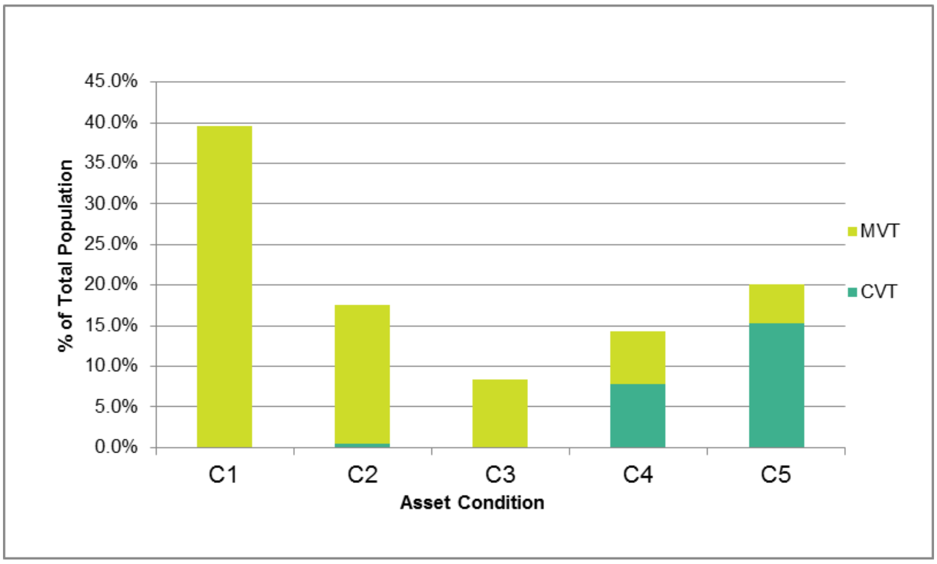

Figure 18 – VT Asset Condition vs VT type

66kV [C.I.C] type CVTs were found to be in “Very Poor” (C5) and “Poor” condition (C4) respectively. 66kV [C.I.C] MVTs were found to be in very poor condition (C5). [C.I.C] were in “Poor” condition (C4). 22kV [C.I.C] MVT types are also found to be in “Very Poor” condition (C5). 22kV [C.I.C] MVTs were found to be in “Poor” condition (C4). “Poor” condition 22kV and below types are being replaced under current station augmentation projects and REFCL projects prior to EDPR 2022-26.

3.5 Asset Criticality

Asset Criticality was determined by considering the following consequences of instrument transformer failure with the failure effects mentioned below.

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

Asset criticality is the severity of consequence in a major failure of an instrument transformer at a certain location due to above failure effects irrespective of the likelihood of the actual failure. This gives an idea of circuit breaker types, located critical locations which represent the total value of risk $.

Safety impact is assessed on catastrophic failure risk and it depends mainly on explosive failure mode of porcelain bushings associated with older oil filled current and voltage transformers.

Modern oil filled current and voltage transformers are provided with polymeric bushings and explosion vents and the safety risk associated with bushing explosion is much lower.

Epoxy cast resin type CTs and MVTs are used at 22kV and below voltages in indoor switchboards and power transformer neutral applications and the safety risks associated with them are negligible.

Community impact due potential value of unserved energy is estimated based on a 2 hour outage for restoration of supply to customers by alternative means when alternative means are available.

3.5.1 Current Transformers

The Figure 19 shows the Relative asset criticality based on Service Voltage.

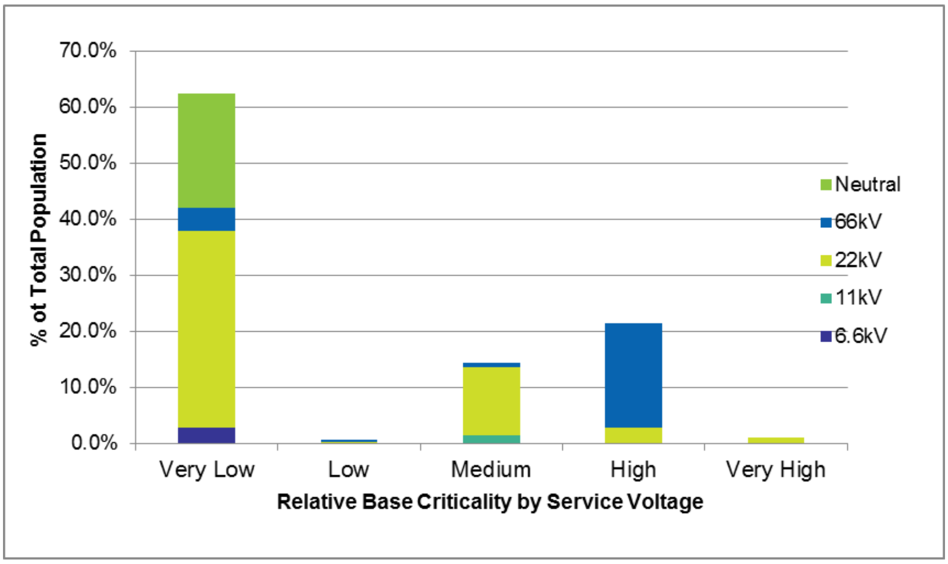

Figure 19 – Relative Base Criticality by Service Voltage

Following observations are made on asset criticality:

Approximately 62.5% of the CT population have a very low criticality risk at all voltages. They are mainly on 22kV and below CTs located in indoor switchboards or Neutral CTs and are epoxy cast resin types. Their asset condition is mainly between C1 to C4.

Approximately 21.5% of the CTs fall into the high criticality category (refer Figure 19) and 18.7% of the population is due to 66kV CTs. Approximately 10.3% are due to C4 and C5 condition CTs. (Notably [C.I.C] fall into this category among other types.)

3.5.2 Voltage Transformers (MVT, CVT)

The Figure 20 shows the Relative asset criticality based on Service Voltage and Asset Condition of VTs.

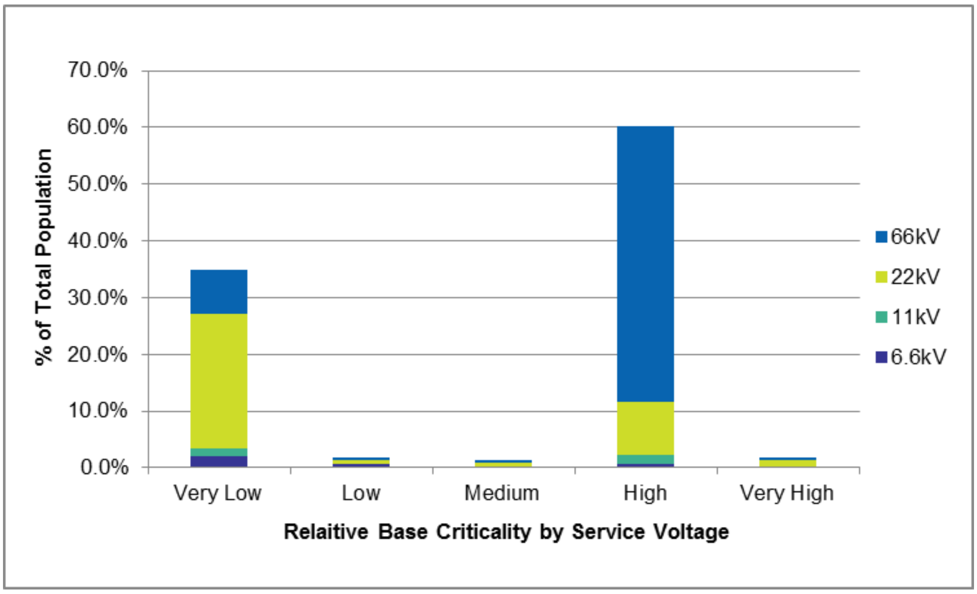

Figure 20 – Relative Base Criticality by Service Voltage

Following observations are made on asset criticality:

Approximately 35.0% of the VT population have a very low criticality risk at all voltages (refer Figure 20). They are mainly on 22kV and below VTs located in indoor switchboards and are mainly epoxy cast resin types. Their asset condition is mainly between C1 to C4.

Approximately 60.2% of the VTs fall into the high criticality category (refer Figure 20) and 48.5% of the population is due to 66kV VTs. Approximately 30.7% are due to C4 and C5 condition VTs. (Notably [C.I.C] fall into this category among other types.)

3.5.3 Relative Base Criticality

The applied interpretation of Relative Base Criticality for CTs and VTs in Section 1.8.1 and 1.8.2 is shown in Table 2.

Relative Base Criticality	Criticality Banding	Definition
Very low	1	Total failure effect cost < 0.3 times Replacement Cost
Low	2	Total Effect Cost is between 0.3 – 1.0 times of replacement cost
Medium	3	Total Effect Cost is between 1 - 3 times of replacement cost
High	4	Total Effect Cost is between 3 -10 times of replacement cost
Very high	5	Total Effect Cost exceeds 10 times of replacement cost

Table 2- Interpretation of Relative Base Criticality

3.6 Asset Performance

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

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

3.6.1 Major Asset Failures

A number of major defects and failures associated with instrument transformers during the period from 2008 - 2017 which require complete replacement or replacement of a major component is shown in Appendix 1. Major failures or defects can result in extended duration outages and deplete critical spares holding especially the older instrument transformers which are technically obsolete. Alternatively newer instrument transformer types have to be used with modified adapter mounting and also match secondary specification for old legacy types.

3.6.2 Catastrophic Failures

Catastrophic failures of instrument transformers can have serious health and safety risk to personal and result in damage to adjacent plant and equipment in the station due to dangerous fragments of porcelain projectiles associated with oil fires.

There were no reports of catastrophic failures of current transformers or voltage transformers reported during the last 10 years. AusNet Services had been able to avert possible catastrophic failures due to detective and predictive methods adopted using life cycle management techniques adopted as mentioned in section 3.6 to detect evident failures. There were number of instances as indicated in Appendix 1 where poor oil DGA results indicating signs of partial discharge activity taking place inside the instrument transformer and they were replaced within a short period of time. However oil sampling is not possible in all types and not possible to predict hidden failures. (ex: [C.I.C])

Catastrophic failures had been experienced in the industry for following types.

3.6.2.1. [C.I.C]:

[C.I.C] are showing strong ageing degradation evidence in DGA results. Informal reports from Queensland indicate there have been a number of catastrophic failures of this type of these 66kV CTs need to be replaced. A unit failed at Powercor in 2004.

3.6.2.2. [C.I.C]:

[C.I.C] of various voltage ratings have a generic construction weakness related to the paper insulation system. This has been confirmed by strip-down tests in NSW and Victoria. AusNet Transmission Network had 500 kV, 330 and 220 kV [C.I.C] have been replaced on condition.

An Australian Cigre CT study reported replacement of several [C.I.C] in NSW based on DGA results. AusNet Services [C.I.C] DGA results show signs of degradation of insulation.

3.6.2.3. [C.I.C]

[C.I.C]

4 Other Issues

4.1 PCB in Oil-paper insulated instrument transformers

Older oil filled instrument transformers such as [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 with environment.

4.2 Asbestos in Instrument Transformers

Black Asbestos containing material is found only in some older instrument transformer electrical backing boards in older stations. However no asbestos containing material was found in secondary terminal boards.

Asbestos material has the potential to cause harm to the safety and health of people, equipment, or the environment. Certain control measures have to be adopted when it is required to modify or removing asbestos as per HSP-05-05-1 guideline.

4.3 Technical Obsolescence /Spares Management

Manufacturers generally cease to formally support identical spare instrument transformers for older types beyond 30 years. Although serviceability can be improved midway through asset operational life, by increasing the level of spares held in stores just before the OEM ceases manufacture stores holding will deplete to the point that salvaging older instrument transformers in good condition become the only means of supporting a fleet of CTs or VTs.

[C.I.C] types are now technically obsolete. They have inherent design issues and safety concerns when the condition becomes poor. They are replaced with fail safe modern CTs or VTs with polymeric housings during station augmentation and asset replacement programs.

5 Risk and Option Analysis

Risk Assessment for distribution current transformers and voltage transformers was performed using combined AWB / spreadsheet based quantitative risk method. AWB modelling was used to quantify the risk benefit of asset replacement against business as usual (BAU) on a five point condition scale (C1, C2, C3, C4 and C5) obtained for each circuit breaker from CB condition model (refer section 3.4).

NPV benefit during a 45 year asset life for each instrument transformer was calculated using the combined AWB / spreadsheet model using quantified effects of a major failure for different technology type of circuit breakers.

Following failure effects were taken into consideration for the risk model.

1. Safety impact,
2. Community impact due to outages (unserved energy),
3. Environment and Collateral damage,
4. Corrective replacement costs.

NPV benefit was derived for three replacement timing options, mainly replace now, replace in 5yrs and replace in 10 yrs. Instrument Transformers that recommend replacement now and in 5 years (excluding the instrument transformers s already identified under current EDPR period) were identified for replacement in the EDPR 2022-26 period.

5.1.1 Current Transformers

Figure 21 below provides the graph showing the cumulative current transformer replacement cost vs cumulative benefit cost. The straight lines in red colour show the optimum expenditure on CT replacements.

C.I.C

Model forecasts replacement of 156 current transformers between now and 2025 based on risk associated with individual current transformer compared to the cost of replacement over 45 year asset life.

The Table 3 below shows the proposed CT replacement strategy EDPR 2022-26 under the program.

CT Replacements (single phase units)	22kV	66kV	Total
Current projects 2018-2021 (REFCL, station rebuild and asset replacement programs)	18	57	75
Proposed Station Rebuilds - EDPR 2022-26	23	24	47
CT Replacement program - EDPR 2022-26	10*	21*	31*

Table 3 – Proposed Current Transformer Replacement program 2018 -2025

*Note: Replacement of three 66kV current transformers in C4 condition was differed to EDPR 2025-30 period due to the current good condition (C3) of the associated live tank circuit breaker along with the live tank CB. 66kV CTs to be replaced reduced to 21. Ten off poor condition 22kV feeder metering current transformers require removal only with the introduction of new static feeder relays which could do the metering function.

Table 4 shows the key 22kV and 66kV CT types identified for replacement in the EDPR period 2022-26. These current transformers have reached end of life and found to be in “Very Poor” condition and had major technical issues as described in the preceding sections.

The outdoor CT types pose a significant safety risk to operators since housings of these CTs have porcelain housings and their failures could result in catastrophic failures. The electricity act requires AusNet services to design, construct, operate, maintain and decommission its supply network to minimize hazards and risks ‘as far as practicable’, to the safety of any person arising from the supply network. Hence proactive replacement of this “Very Poor” condition high safety risk CBs would be practical approach to manage safety risks.

66kV	**22kV +**
C.I.C	

Table 4 – Current Transformer Replacements- EDPR 2022-26

+ Note: These are 22kV metering transformers at one station which involves removal only as they are no longer required with the introduction of modern static feeder relays.

5.1.2 Voltage Transformers (MVT, CVT)

Figure 21 below provides the graph showing the cumulative voltage transformer replacement cost vs cumulative benefit cost. The straight lines in red colour show the optimum expenditure on VT replacements.

C.I.C

Model forecasts replacement of 205 VTs between now and 2025 based on risk associated with individual voltage transformers compared to the cost of replacement over 45 year asset life.

The Table 5 below shows the proposed 22kV & 66kV VT replacement strategy EDPR 2022-26 under the program.

VT Replacements (single phase units)	22kV	66kV	Total
Current projects 2018-2021 (REFCL, station rebuild and asset replacement programs)	22	64	86
Proposed Station Rebuilds - EDPR 2022-26	8	36	44
CVT/ VT Replacement program - EDPR 2022-26	1	31	32
CVT CAMs Installation program - EDPR 2022-26	0	43	43

Table 5 – Proposed Voltage Transformer replacement program 2018 -2025

Table 6 shows the key 66kV VT types identified for replacement and installation of CVT asset monitoring system (CAMs) in the EDPR period 2022-26. CVTs and VTs identified for replacements have reached end of life and are in “Very Poor” condition (C5) and had major technical issues as described in the preceding sections.

A cost effective solution has been adopted for [C.I.C] CVTs which are in “Poor” condition (C4) to provide dedicated Online Condition Monitoring equipment (CAMs) is installed to monitor and collect condition and performance data where replacement will be carried out on early detection alarms. CAMs installation is very effective and widely adopted in CVTs installed wide transmission network and it is a cost effective solution for CVTs with moderate failure risk.

The outdoor VT types pose a significant safety risk to operators since housings of these VTs have porcelain housings and their failures could result in catastrophic failures. The electricity act requires AusNet services to design, construct, operate, maintain and decommission its supply network to minimize hazards and risks ‘as far as practicable’, to the safety of any person arising from the supply network. Hence proactive replacement of this “Very Poor” condition high safety risk CBs would be practical approach to manage safety risks.

Table 6 – VT/CVT Replacements & CAMs installation- EDPR 2022-26

66kV CVT / MVT Replacement	**66kV CAMs installation**
C.I.C	

6 Asset Strategies

6.1 Current Transformers

6.1.1 New Assets

- Install dead tank circuit breakers with integral CT's where possible
- Where associated 66kV CB is not being replaced, install polymer housed oil –paper insulated outdoor current transformers to latest specification
- Install high quality epoxy cast resin current transformers for operating voltages at and below 22kV.

6.1.2 Inspection

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

6.1.3 Maintenance

- Continue condition monitoring through regular oil sampling and DGA analysis, as per PGI 02-01-04.

6.1.4 Replacement

- Replace 78 "Very Poor" condition 22kV and 66kV current transformer types: [C.I.C] [C.I.C] under station rebuild and asset replacement program during the EDPR period 2022-26.

6.2 Voltage Transformers

6.2.1 New Assets

- At 66kV install polymer housed oil –paper insulated outdoor voltage transformers to latest specification
- At 22kV and below install high quality epoxy cast resin voltage transformers
- Install CVT asset monitoring system (CAMs) on all 66kV CVTs installed in the distribution system

6.2.2 Inspection

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

6.2.3 Maintenance

- Continue condition monitoring through regular oil sampling and DGA analysis of MVT

6.2.4 Condition Monitoring

- Install CVT asset monitoring system (CAMs) on 43 of poor condition [C.I.C] installed in the distribution system

6.2.5 Replacement

- Replace 76 "Very Poor" condition 22kV and 66kV voltage transformers types: [C.I.C] [C.I.C], under station rebuilds and asset replacement program during the EDPR period 2022-26.

7 Appendix 1 – Major Instrument Transformer Failures / Defects 2008 - 2018

No	Object Type	Manufacturer	Model	Voltage (kV)	Insulation type	Year of Failure	Age at Failure	Station	Location Description	Location	Major failure / Defect
	Current Transformers:										
1	CT	C.I.C		22	Epoxy Cast Resin	2008	26	WO	WO 11	feeder	Catastrophic solid insulation failure
2	CT			66	Oil-paper insulation	2009	32	BRA	CB A	Bus	Poor DGA oil result (high internal PD predicted)
3	CT			66	Oil-paper insulation	2010	28	BGE	CB A	Bus	Poor DGA oil result (high internal PD predicted)
4	CT			66	Oil-paper insulation	2010	33	EPG	CB A	Bus	Poor DGA oil result (high internal PD predicted)
5	CT			66	Oil-paper insulation	2010	33	LDL	CB A	Bus	Poor DGA oil result (high internal PD predicted)
6	CT			66	Oil-paper insulation	2010	33	LDL	CB C	Bus	Poor DGA oil result (high internal PD predicted)
7	CT			66	Oil-paper insulation	2011	25	NLA	CB C	Bus	Poor DGA oil result (high internal PD predicted)
8	CT			66	Oil-paper insulation	2018	14	WGI	CB A & B	Bus	Extensive secondary control box corrosion and arcing damage.
	Voltage Transformers:										
1	CVT	C.I.C		66	Oil-paper insulation	2009	41	LDL	Bus 7	Bus	High temperature detected. Internal fault.
2	MVT			66	Epoxy Cast Resin	2010	8	MSD	Bus	Bus	Hole in Epoxy cast resin insulator – manufacture defect
3	MVT			22	Oil-paper insulation	2011	1	CYN	Bus 2	Bus	Internal winding failure – design issue
4	MVT			22	Oil-paper insulation	2011	1	BWR	Bus 2	Bus	Internal winding failure – design issue
5	MVT			22	Oil-paper insulation	2011	1	TGN	Bus 1	Bus	Internal winding failure – design issue
6	MVT			66	Epoxy Cast Resin	2014	12	LGA	Bus	Bus	Epoxy cast resin insulator crack and flashover to earth
7	CVT			66	Oil-paper insulation	2017	46	BDL	No 6 bus	bus	Major oil leak –catastrophic failure risk due to insulation failure
8	CVT			66	Oil-paper insulation	2018	47	MOE	YPS -WGL	Line	Major oil leak –catastrophic failure risk due to insulation failure