Asset Management Plan
Instrument Transformers

Part of the Energy Queensland Group

Executive Summary

This Asset Management Plan (AMP) covers the asset class of instrument transformers, including current transformers (CTs), voltage transformers (VTs), and capacitor voltage transformers (CVTs).

Instrument transformers transform current and voltage levels from large magnitudes to appropriate lower standardised values for protection, system monitoring, and metering purposes. This is done to avoid damaging other integrated assets, as well as allowing the other associated assets such as protective relays to protect the network. Energy Queensland Limited (EQL) manages over 10,800 instrument transformers, 9,410 in Ergon Energy and 1,392 in Energex. Instrument transformers are located across the networks and typically managed based on asset condition and risk.

Continuous improvements for the lifecycle asset management of assets contained in this AMP include reviewing and aligning approaches to condition assessment, investigating causes of defects, and the increasing the volume of substation asset replacement to address the existing Network Access Restrictions and deliver a long-term sustainable program of replacement.

The overall asset population performance is evaluated as part of the general organisation obligations for reliability and annual dangerous electrical events incidents.

Revision History

Revision date	Version number	Description of change/revision
31/01/2019	1	Documents Initial release
04/2/2021	2	Updated for V2 of document.
03/11/2023	3	Updated for V3 of document

Document Approvals

Position title	Date
General Manager Asset Maintenance	Jan 2024
Chief Engineer	Jan 2024

Stakeholders / Endorsements

Title	Role
Manager Asset Strategy	Endorse
Manager Transformer & Reactive Plant	Endorse
Manager Substation Standards	For Information
Engineering Field Support Manager	For Information

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1 Introduction

Energy Queensland Limited (EQL) was formed 1 July 2016. It owns and manages several electrical energy related companies that operate to support energy distribution across Queensland including the Distribution Network Service Providers (DNSPs):

- Energex, covering the area defined by the Distribution Authority for Energex Corporation Limited, and
- Ergon Energy, covering the area defined by the Distribution Authority for Ergon Energy Corporation Limited.

There are variations between EQL's operating networks in terms of asset base and management practice, as a result of geographic influences, market operation influences, and legacy organisation management practices. This Asset Management Plan (AMP) reflects the current practices and strategies for all assets managed by EQL, recognising the differences that have arisen due to legacy organisation management. These variations are expected to diminish over time with the integration of asset management practices.

1.1 Purpose

The purpose of this document is to document the responsible and sustainable management of poles and lattice towers on the EQL network. The objectives of this plan are to:

1. Deliver customer outcomes to the required level of service.
2. Demonstrate alignment of asset management practices with EQL's Strategic Asset Management Plan and business objectives.
3. Demonstrate compliance with regulatory requirements.
4. Manage the risks associated with operating the assets over their lifespan.
5. Optimise the value EQL derives from this asset class.

This Asset Management Plan will be updated periodically to ensure it remains current and relevant to the organisation and its strategic objectives. Full revision of the plan will be completed every five years as a minimum.

This Asset Management Plan is guided by the following legislation, regulations, rules and codes:

- *National Electricity Rules (NER)*
- *Electricity Act 1994 (Qld)*
- *Electrical Safety Act 2002 (Qld)*
- *Electrical Safety Regulation 2013 (Qld)*
- *Queensland Electrical Safety Code of Practice 2020 – Works (ESCOP)*
- *Work Health & Safety Act 2014 (Qld)*
- *Work Health & Safety Regulation 2011 (Qld)*
- Ergon Energy Corporation Limited Distribution Authority No D01/99
- Energex Limited Distribution Authority No. D07/98

This Asset Management Plan forms part of EQL's strategic asset management documentation, as shown in Figure 1. It is part of a suite of Asset Management Plans, which collectively describe EQL's approach to the lifecycle management of the various assets which make up the network used to deliver electricity to its customers. Appendix 1 contains references to other documents relevant to the management of the asset class covered in this plan.

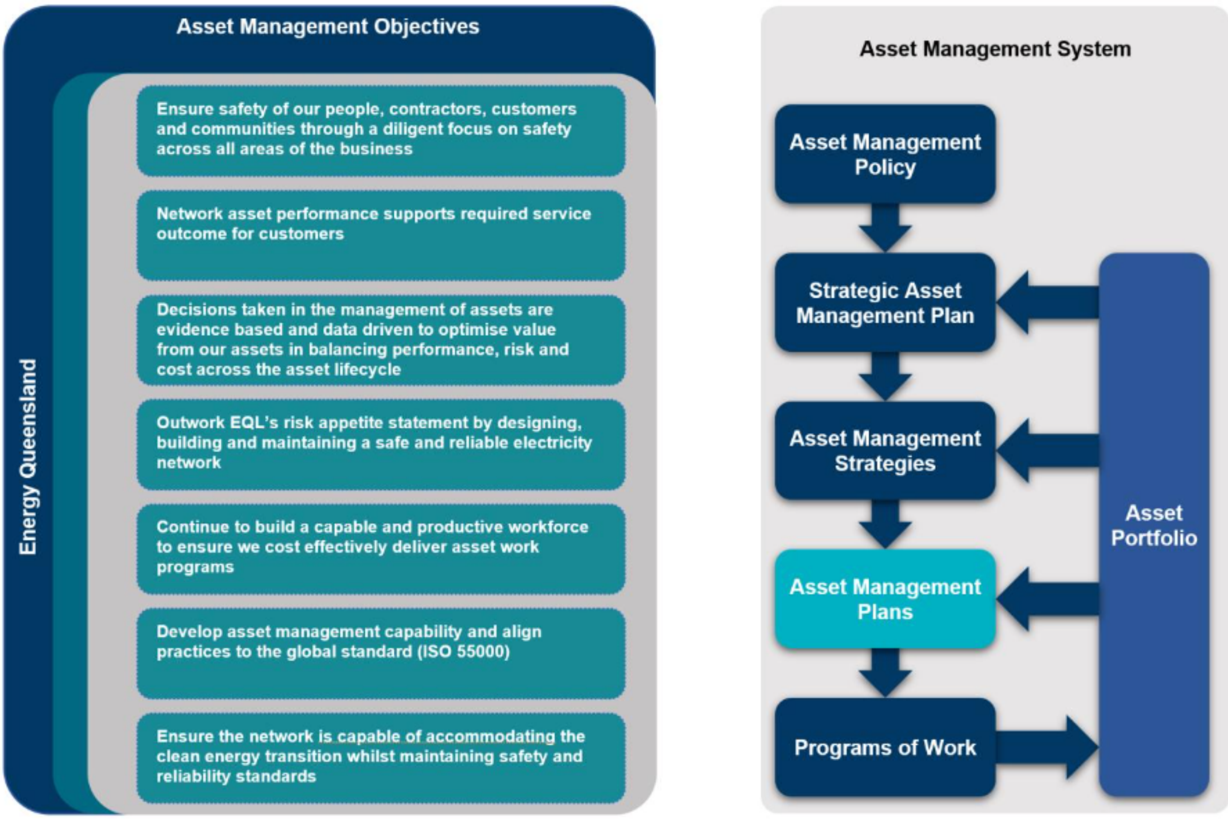


Figure 1: EQL – Asset Management System

1.2 Scope

This plan covers the following assets at voltage level 11kV and above:

- Stand-alone current transformers (CT)
- Stand-alone voltage transformers (VT) and capacitor voltage transformers (CVT).

Instrument transformers that are subcomponents of other assets, as well as those contained in metering units, are excluded from the scope of this document.

Many customers, typically those with high voltage connections, own and manage their own network assets including Instrument Transformers and ancillary equipment. EQL does not provide condition and maintenance services for third party assets, except as an unregulated and independent service. This AMP relates to EQL owned assets only and excludes any consideration of such commercial services.

1.3 Total Current Replacement Cost

Based on asset quantities and replacement costs, EQL stand-alone instrument transformers have a replacement value of approximately $1.69 billion. This valuation is the gross replacement cost of the assets, based on the cost of modern equivalents, without asset optimisation or age assigned depreciation.

Figure 2 provides an indication of the relative financial value of EQL instrument transformers compared to other asset classes.

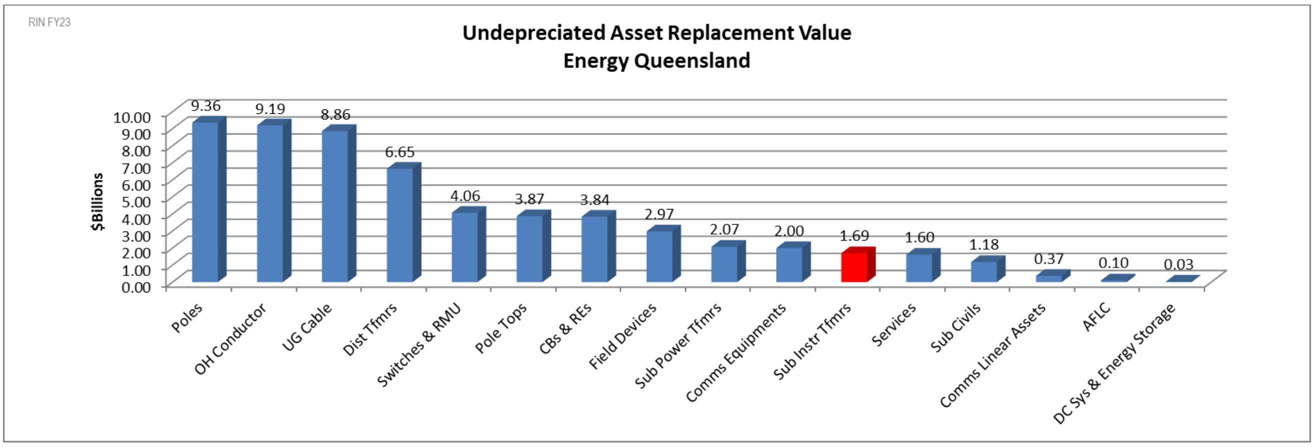


Figure 2: EQL – Total Current Asset Replacement Value

1.4 Asset Function and Strategic Alignment

The functions of current transformers and voltage transformers in the electricity distribution and transmission system are to scale large values of current and voltage to appropriate lower standardised values for protection, system monitoring, and metering purposes. This is done to avoid damaging other integrated assets, as well as allowing the other associated assets such as protective relays to protect the network.

Table 1 details how instrument transformers contribute to EQL corporate strategic asset management objectives.

Relevant Asset Management Objectives	Relationship of Asset to Asset Management Objectives
Ensure network safety for staff, contractors, and the community	Diligent and consistent maintenance and operations support instrument transformer performance and hence safety for all stakeholders
Meet customer and stakeholder expectations	Continued instrument transformer serviceability supports reliable operation of protection devices and promotes delivery of a standard quality electrical energy service.
Manage risks, performance standards, and asset investment to deliver balanced commercial outcomes	Failure of instrument transformer can result in increased EQL personnel safety risk and disruption of the electricity network. Asset longevity assists in minimising capital and operational expenditure.
Develop asset management capability and align practices to the global ISO55000 standard	This AMP is consistent with ISO55000 objectives and drives asset management capability by promoting a continuous improvement environment
Modernise the network and facilitate access to innovative energy technologies	This AMP promotes the replacement of instrument transformer at end of economic life as necessary to suit modern standards and requirements

Table 1: Asset Function and Strategic Alignment

1.5 Owners and stakeholders

The ubiquitous nature of the electrical network means that there are many stakeholders that influence or are affected by EQL's operation and performance. Table 2 lists most of the influential stakeholders that have impacted the strategies defined by this asset management plan.

Responsible Party	Role
Queensland Government	Development of legislative framework and environment for operation of EQL in Queensland. Development of EQL Distribution Authorities.
Queensland Government as sole shareholder of EQL	Owner of company shares, holding equity in EQL and gaining benefits from EQL financial success.
EQL Board of Directors	Corporate direction, operation and performance of EQL and its subsidiaries, in compliance with corporate and Queensland law.
Chief Financial officer	Company Asset Owner – ensuring all EQL investments are consistent with EQL corporate objectives with balanced commercial outcomes
Chief Operating Officer	Overall operational control of EQL networks including maintenance and operation, and execution of project works
Chief Engineer	Overall strategic control of EQL assets, including asset population performance, risk and financial management,
All employees and contractors of Energy Queensland Limited	Performing all duties as required to achieve EQL corporate objectives
All unions that are party to the EQL Union Collective Agreement	Promotion of safe and fair working conditions for all EQL and subsidiary company employees
Queensland Electrical Safety Office	Regulatory overview and control of electrical safety in Queensland
Australian Energy Regulator	Regulatory overview and control of economic performance of EQL under its Distribution Authorities to promote the long term interests of all electrical network customers connected to the National Electricity Market
Powerlink	Queensland Transmission Network Service Provider. Owner and operator of many 110kV to 330kV transmission grid assets and 74 bulk supply substations that connect and deliver energy to EQL networks
All consumers, prosumers and generators connecting to the Energy Queensland network	Operating within the electrical technical boundaries defined by legislation, regulation and connection agreements.
All communities and businesses connected to the Energy Queensland network.	Economic prosperity of Queensland

Table 2: Stakeholders

2 Asset Class Information

Instrument transformers in the electrical system are used to reduce the voltage or current levels, and to provide isolation between high voltage network and secondary system instruments. They provide the necessary inputs to critical protection and control functions. Instrument transformers are classified according to different criteria such as:

- Operating voltage
- Output current and voltage
- Core type and ratios
- Sensing function (electromagnetic sensing type or capacitor sensing type)
- Accuracy based on the installation purpose
- Installed location
- Insulation (external and internal)
- External design characteristics.

The instrument transformers in this document are primarily categorised based on operating voltage.

2.1 Asset Description

Current transformers (CTs) measure current flowing through an electrical circuit element. They are used to proportionally step down the primary current to a suitable level for instrumentation, control, metering, or protection circuitry.

Voltage transformers (VTs) measure voltage at an electrical node. They are used to proportionally step down the primary voltage to a suitable level for instrumentation, metering, control, and protection circuits. Capacitor sensing type VTs are referred to as CVTs.

There is a great diversity of instrument transformer designs and insulation. The internal insulation function is comprised of one of the following:

- Paper – oil insulation
- Paper film – SF_6 insulation
- Solid insulation (e.g. cast resin).

The external insulation function is comprised of one of the following:

- Porcelain insulators and porcelain insulators filled with oil
- Composite insulators
- Cast resin insulators.

2.2 Asset Quantity and Physical Distribution

Table 3 and Table 4 list the current and voltage transformer asset populations by voltage type.

Current Transformer	Ergon Network	Energex Network	Total
<11kV	121	0	121
>11kV & <=33kV	4244	415	4659
>33kV & <=66kV	1945	0	1945
>66kV & <=132kV	431	262	693
Unknown*		*76	76
Total	6750	753	7503

***Due to data quality issues, there are 76 plant items with an "unknown" voltage level in the Energex network**

Table 3: Asset Quantity – Current Transformers

Voltage Transformer	Ergon Network	Energex Network	Total
<11kV	32	0	32
>=11kV & <=33kV	1265	580	1845
>33kV & <=66kV	1019	3	1022
>66kV & <=132kV	344	56	400
> 132kV		0	0
Total	2660	639	3299

Table 4: Asset Quantity – Voltage Transformers

2.3 Asset Age Distribution

Figure 3 and Figure 4 show the age profile of instrument transformers in the Ergon Network as recorded in the 2022-23 Regulatory Information Notice (RIN). The expected life of instrument transformers is 45 years in the EQL network.

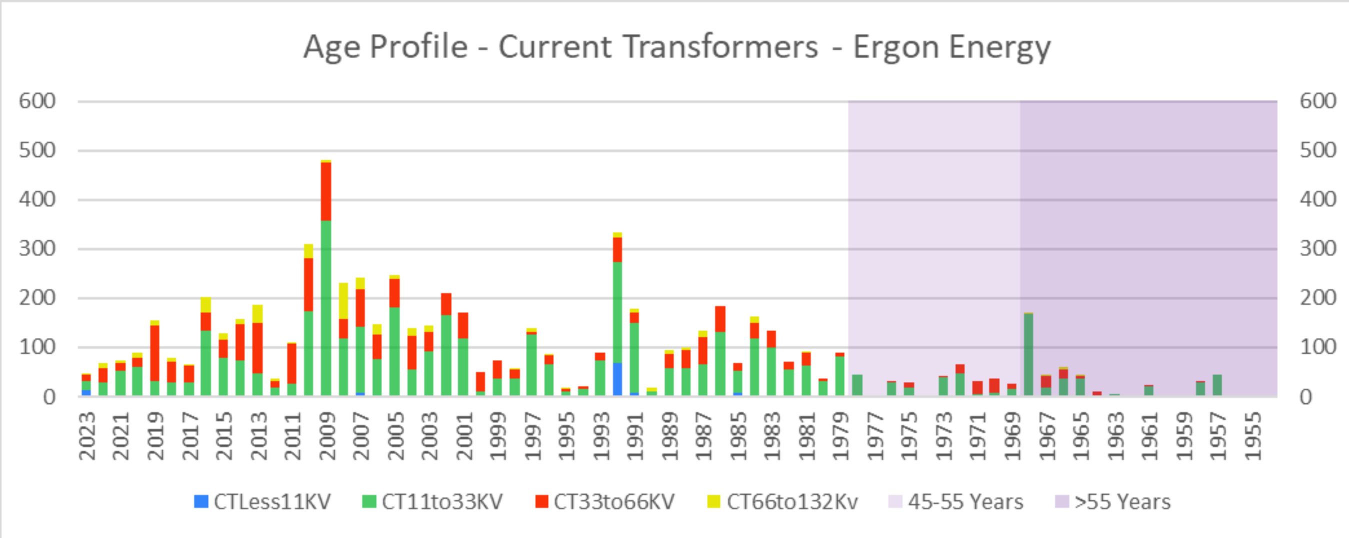


Figure 3: Ergon Network Current Transformers – Asset Age Profile

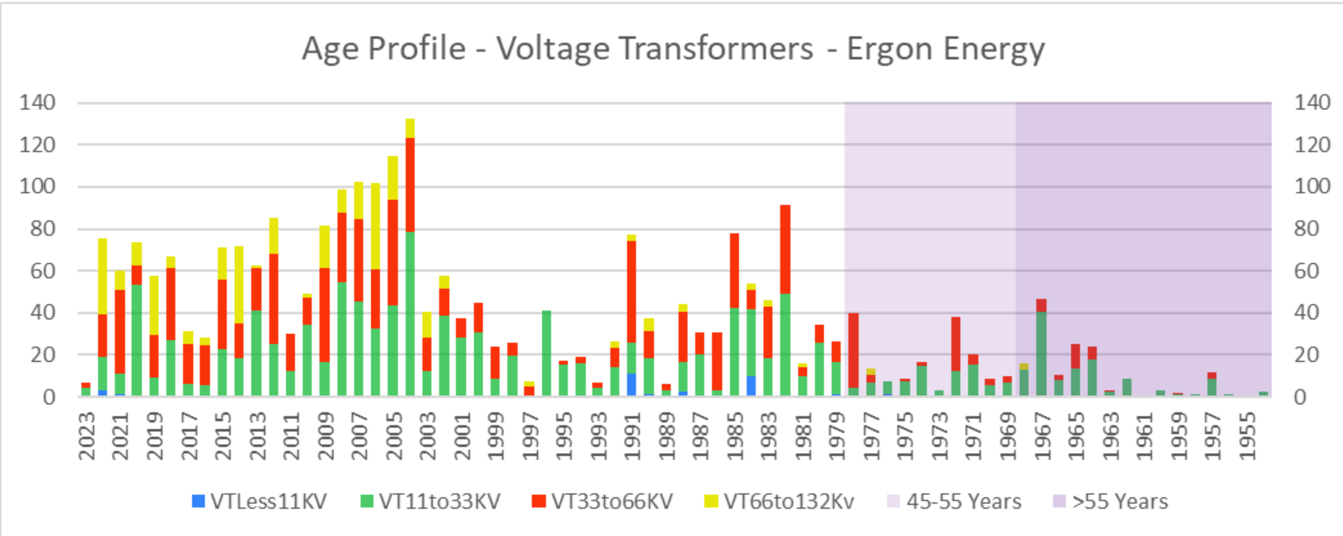


Figure 4: Ergon Network Voltage Transformers – Asset Age Profile

Figure 5 and Figure 6 show the age profile of instrument transformers in the Energex Network as recorded in the 2022-23 RIN.

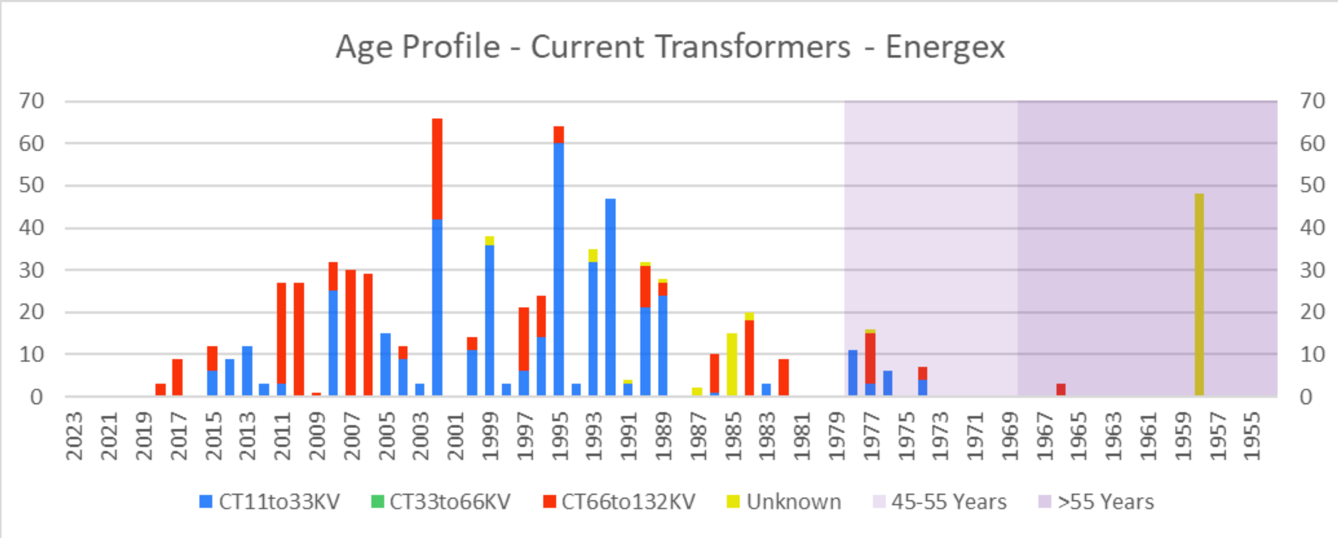


Figure 5: Energex Network Current Transformers – Asset Age Profile

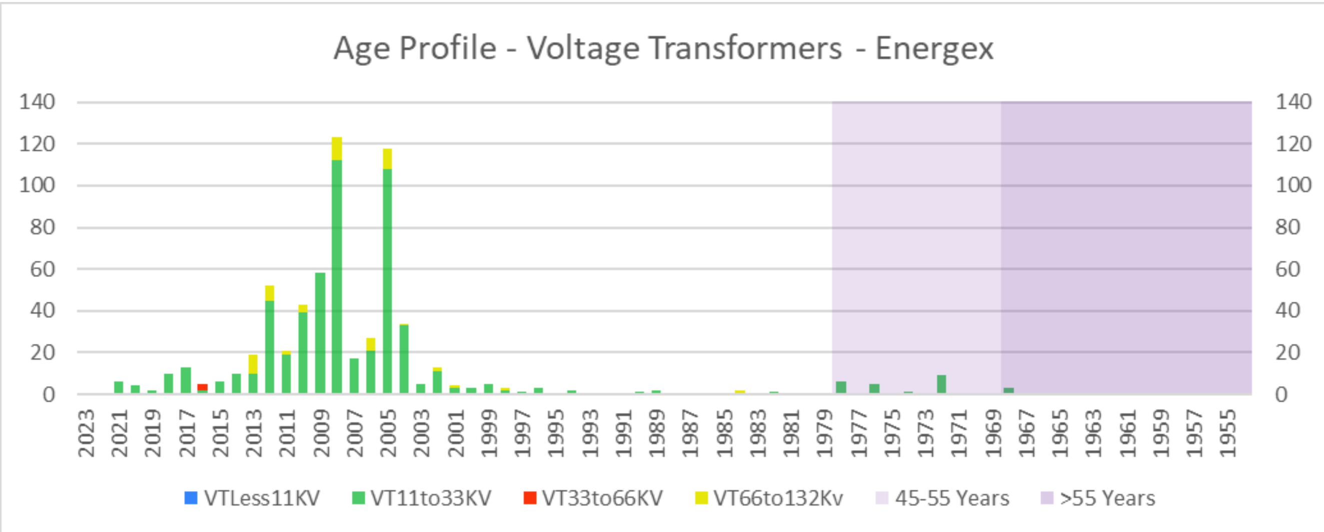


Figure 6: Energex Network Voltage Transformers – Asset Age Profile

2.4 Population Trends

The insulation mediums used in the CT asset population are oil and resin (epoxy). In the Ergon Energy network, 96% of CTs at 33kV and above are oil insulated, and 94% of CTs at 22kV and under are epoxy insulated. In the Energex network, most of the oil insulated CTs are hermetically sealed, and CTs with solid insulation is only used at 11kV and 33kV voltages. The Energex network does not have any gas insulated CTs.

In the Ergon Energy network, VTs at 66kV and above are oil insulated, and 55% of VTs at 33kV and under are epoxy insulated.

2.5 Asset Life Limiting Factors

The following table describes the key factors that influence the life of instrument transformers, and as a result have a significant bearing on the programs of work implemented to manage the asset lifecycle.

Factor	Influence	Impact
Age	Deterioration of materials and components used in construction, such as insulation medium (oil/paper and gaskets).	Failure to operate correctly; loss of insulation due to sealing degradation; mechanical failure.
Environment	Outdoor, corrosive, or coastal environments result in degradation of the physical asset and components; particularly the tank, gaskets, and insulation.	Reduction in useful life and potential asset failure.
Design	Varies based on make and model, and only becomes apparent through operational experience. Typically associated with materials used and design of components (e.g., capacitors in CVTs).	Mal-operation or failure to operate.
Moisture	Degradation of paper insulation and oil. Combined with heat, can result in bubble inception.	Accelerated ageing leading to reduction in useful life. Internal fault leading to failure (potentially catastrophic).

Table 4: Instrument Transformers Life Limiting Factors

3 Current and Desired Levels of Service

The following sections define the level of performance required from the asset class, measures used to determine the effectiveness of delivering corporate objectives, and any known or likely future changes in requirements.

3.1 Desired Levels of Service

This asset class will be managed, consistent with corporate asset management policy, to achieve all legislated obligations and any specifically defined corporate key performance indicators, and to support all associated key result areas as reported in the Statement of Corporate Intent (SCI).

Safety risks associated with this asset class will be eliminated so far as is reasonably practicable (SFAIRP), and if not able to be eliminated, mitigated SFAIRP. All other risks associated with this asset class will be managed as low as reasonably practicable (ALARP).

This asset class consists of a functionally alike population that differs in age, brand, technology, material, construction design, technical performance, purchase price, and maintenance requirements. The population will be managed consistently based on generic performance outcomes, with an implicit aim to achieve the intended and optimised life cycle costs contemplated for the asset class and application.

All inspection and maintenance activities will be performed consistent with manufacturers' advice, good engineering operating practice, and historical performance, with intent to achieve the longest practical asset life overall.

Life extension techniques will be applied where practical, consistent with overall legislative, risk, reliability, and financial expectations. Problematic assets such as very high maintenance or high safety risk assets in the population will be considered for early retirement.

Instrument transformers will be managed by ongoing individual condition assessment such as partial discharge testing and maintenance and replaced based on asset condition, risk, and age. End of economic asset life will take into account ongoing maintenance and retention costs, replacement costs and benefits, potential future maintenance, retention costs, and risk. Replacement will normally be achieved on a project basis, and holistic analysis of nearby assets will be performed to support optimal life cycle cost and customer impact.

3.2 Legislative Requirements

The assets described in this AMP are not specifically referenced in legislation, and therefore are expected to achieve general obligations surrounding asset safety and performance and service delivery. These obligations include compliance with all legislative and regulatory standards, including the *Electrical Safety Act 2002 (Qld)* and the *Electrical Safety Regulation 2013 (Qld)*.

The *Electrical Safety Act 2002 (Qld)* s29 imposes a specific duty of care for EQL, which is a prescribed Electrical Entity under that Act:

1) An electricity entity has a duty to ensure that it works—
    a. are electrically safe; and
    b. are operated in a way that is electrically safe.
2) Without limiting subsection (1), the duty includes the requirement that the electricity entity inspect, test and maintain the works.

Under its distribution licences, EQL is expected to operate with an 'economic' customer value-based approach to reliability, with "Safety Net measures" aimed at managing low probability high consequence outage risks. EQL is expected to employ all reasonable measures to ensure it does not exceed minimum service standards (MSS), assessed by feeder type, as:

- System average interruption duration index (SAIDI), and
- System average interruption frequency index (SAIFI).

Safety net targets are described in terms of the number of times a benchmark volume of energy is undelivered for more than a specific time period.

Loss of substation instrument transformers is usually a significant event and may require safety net contingency plans to be exercised.

Both safety net and MSS performance information are publicly reported annually in the Distribution Annual Planning Reports (DAPR).

3.3 Performance Requirements

There are no specific business targets relating to instrument transformer performance. However, these assets are considered critical in nature as they support network protection functionality and failure events have the potential to result in safety consequences, as well as substantial and extended customer load interruption. As a result, these assets are proactively managed on an individual basis with the intent of replacement prior to failure.

Maintenance and testing of stand-alone instrument transformers are conducted regularly, with the performance against defined criteria monitored, and issues addressed to ensure these assets reach the end of their economic life.

Defects identified via inspection programs are classified and prioritised according to the EQL Substation Defect Classification Manual. Identified defects are scheduled for repair according to a risk-based priority scheme (P1/P2/C3/no defect). The P1 and P2 defect categories relate to the priority of repair, which effectively dictates whether normal planning processes are employed (P2), or more urgent repair works are initiated (P1). Additionally, classification of C3 aims to gather information to inform or create a "watching brief" on possible problematic asset conditions.

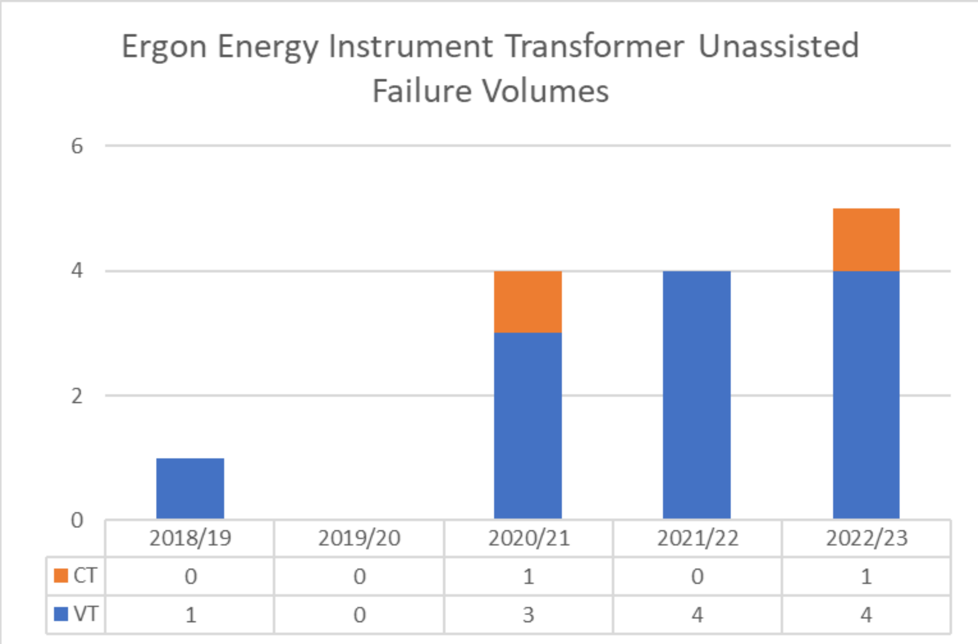
The following sections provide a summary of performance against these measures as a defect rate.

3.4 Current Levels of Service

The following sections detail the current levels of service of this asset class, with respect to defect and failure data, historical performance trends, and defect causes across the EQL network.

3.4.1 Historical Asset Failure Data

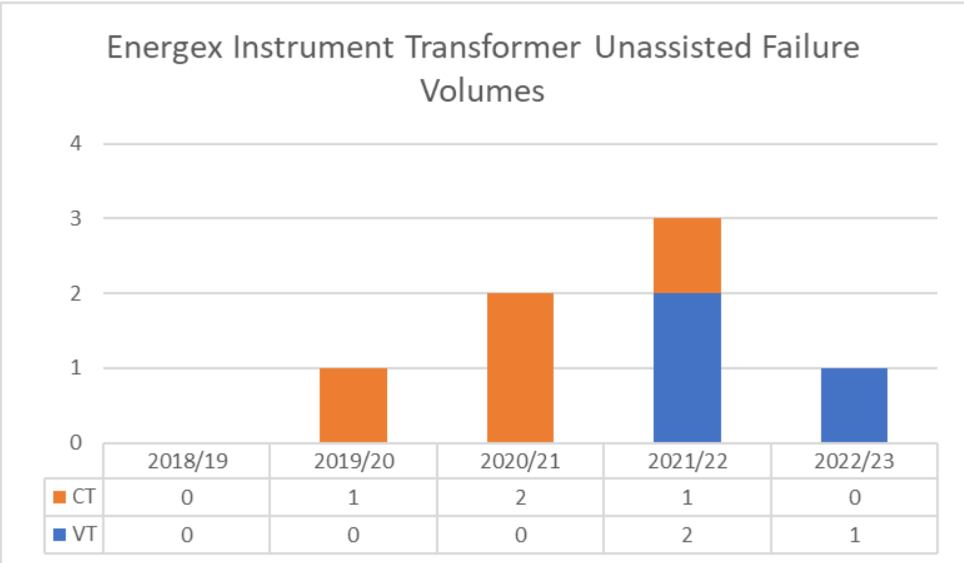
The historical failure information for Ergon Energy is shown in Figure 7 from 2018/19*.



	2018/19	2019/20	2020/21	2021/22	2022/23
CT	0	0	1	0	1
VT	1	0	3	4	4

Figure 7: Ergon Network - Instrument Transformer Asset Failure

The Figure 8 shows the Energex network failure information for instrument transformers over time from 2018/19*.



	2018/19	2019/20	2020/21	2021/22	2022/23
CT	0	1	2	1	0
VT	0	0	0	2	1

Figure 8: Energex network - Instrument Transformer Asset Failure

*some historical data may be updated in due course due to improved asset reporting

3.4.2 Historical Defect Data

Figure 9 and Figure 10 show the historical trends of defect replacement and refurbishment works that have been conducted on these assets. The P1, and P2 references relate to the priority of work required, which dictates whether normal planning process is employed (P2), or more urgent repair works are initiated P1.

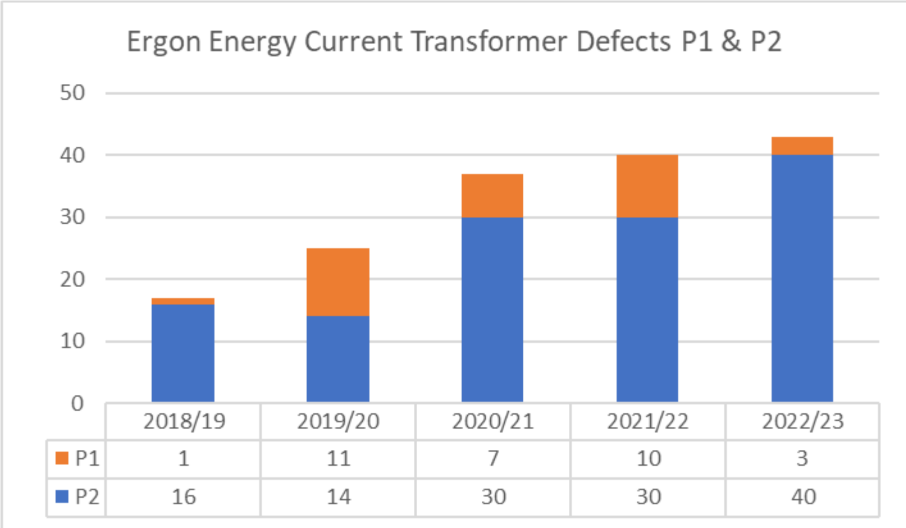


Figure 9: Current Transformer (CT) Defect Count - Ergon Network

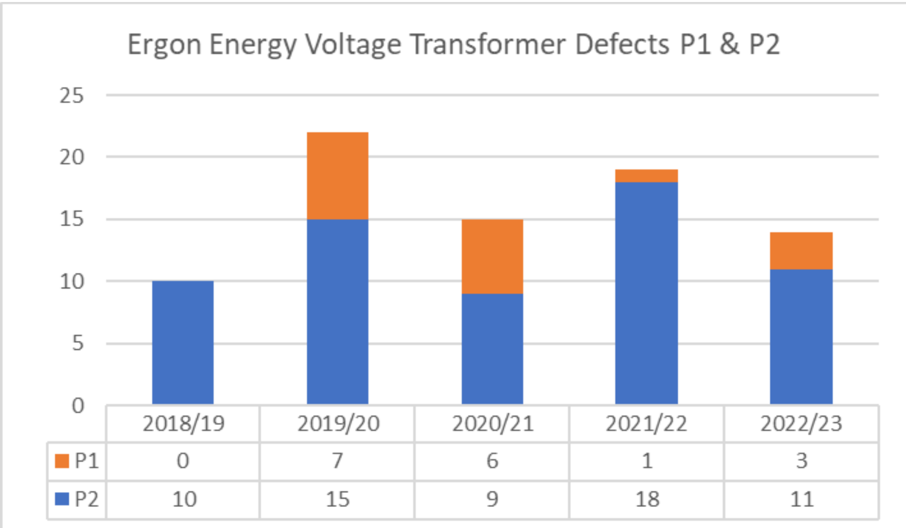


Figure 10: Voltage Transformer (VT) Defect Count- Ergon Network

Figure 11 shows the historical trend of defect replacement/refurbishment works that have been conducted on these assets.

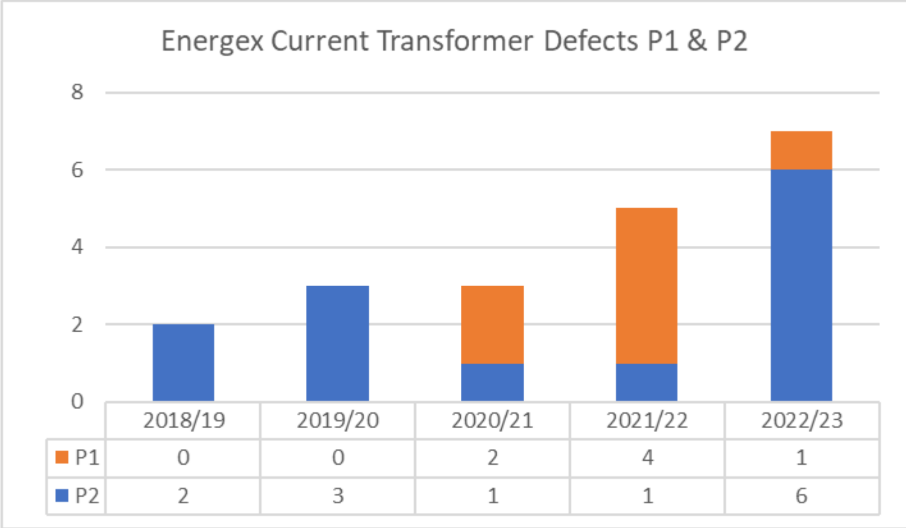


Figure 11: Defect Numbers for current transformers - Energex Network

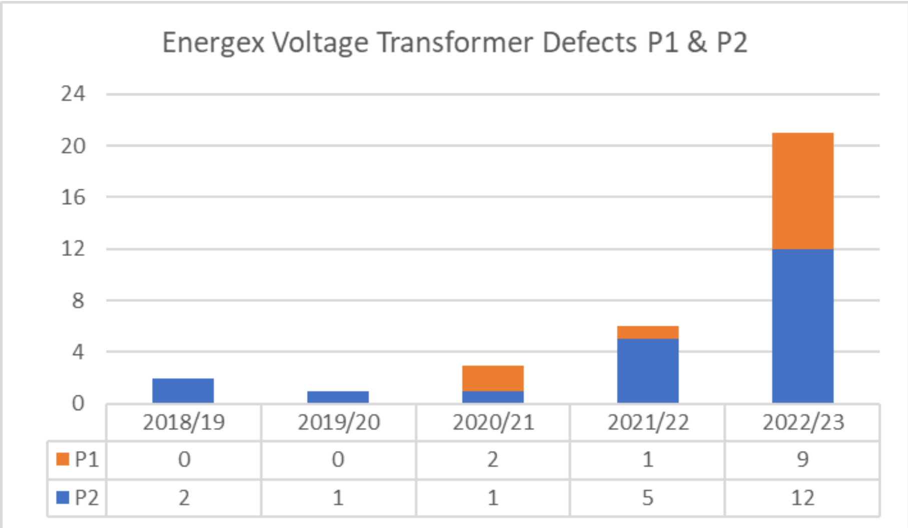


Figure 12: Defect Numbers for voltage transformers - Energex Network

Figure 13 to Figure 16 show instrument transformers corrective maintenance component breakdowns produced through the MSSS system data.

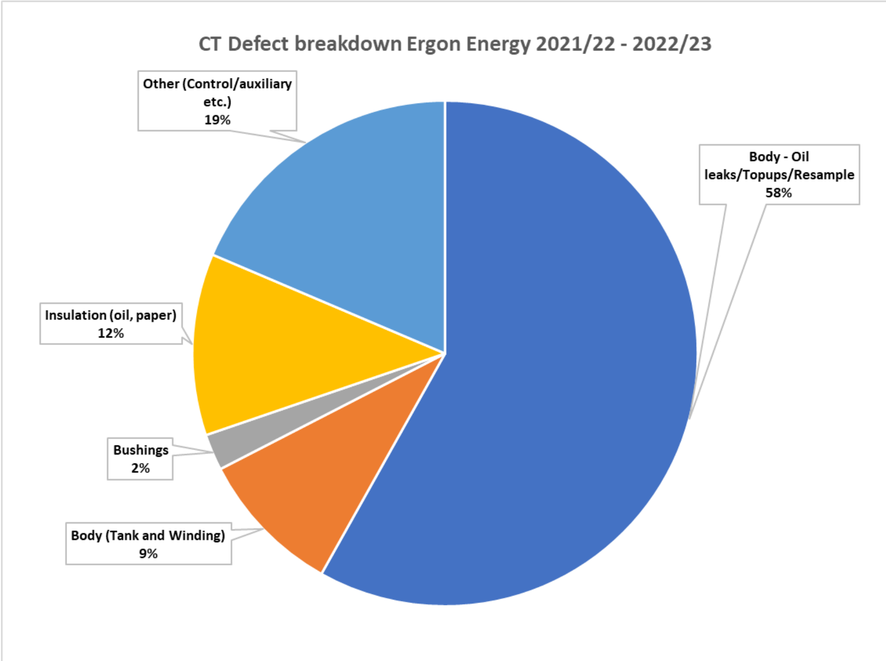


Figure 13: CT Corrective Maintenance by defect types – Ergon network

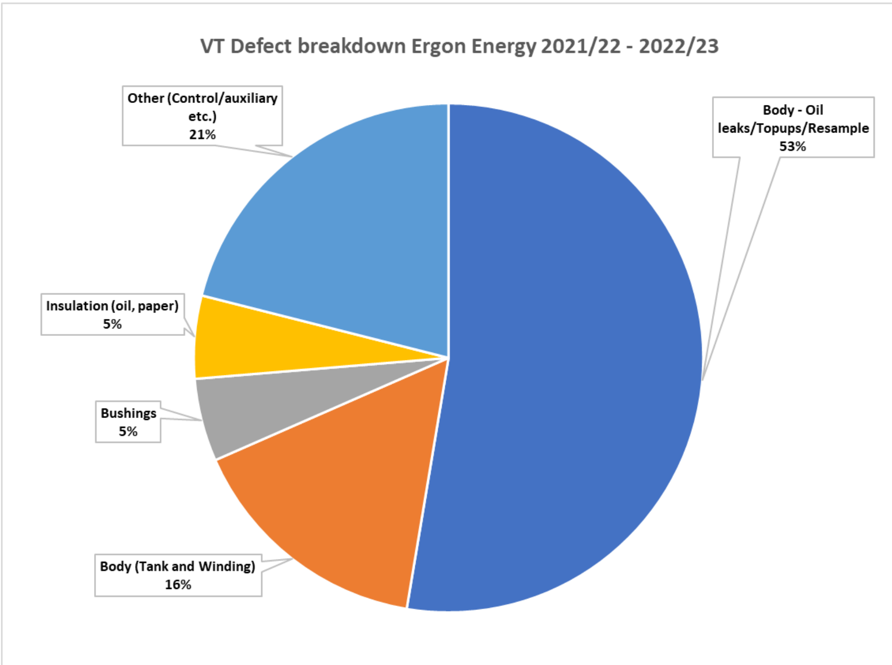


Figure 14: VT Corrective Maintenance by defect types – Ergon network

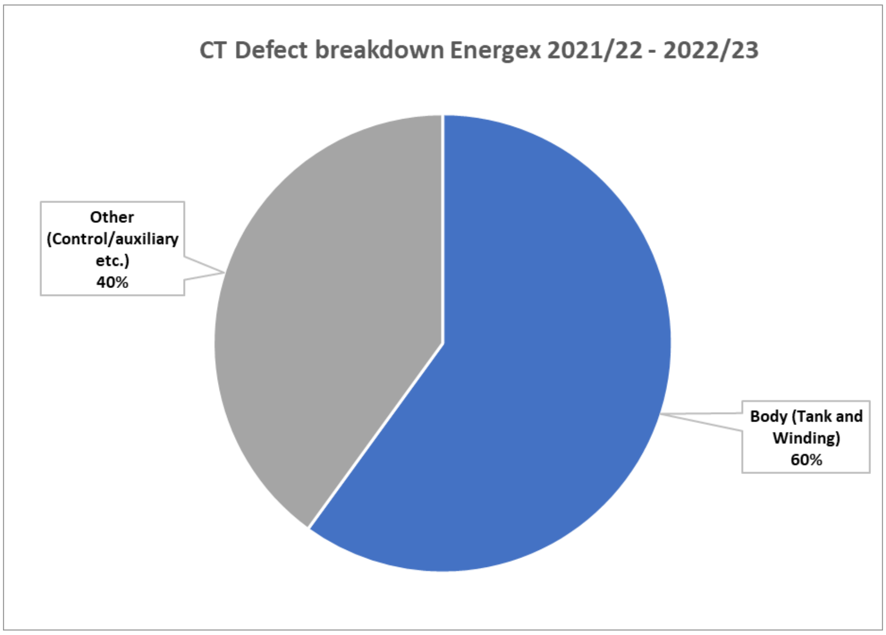


Figure 15: CT Corrective Maintenance by Defect Type –Energex Network

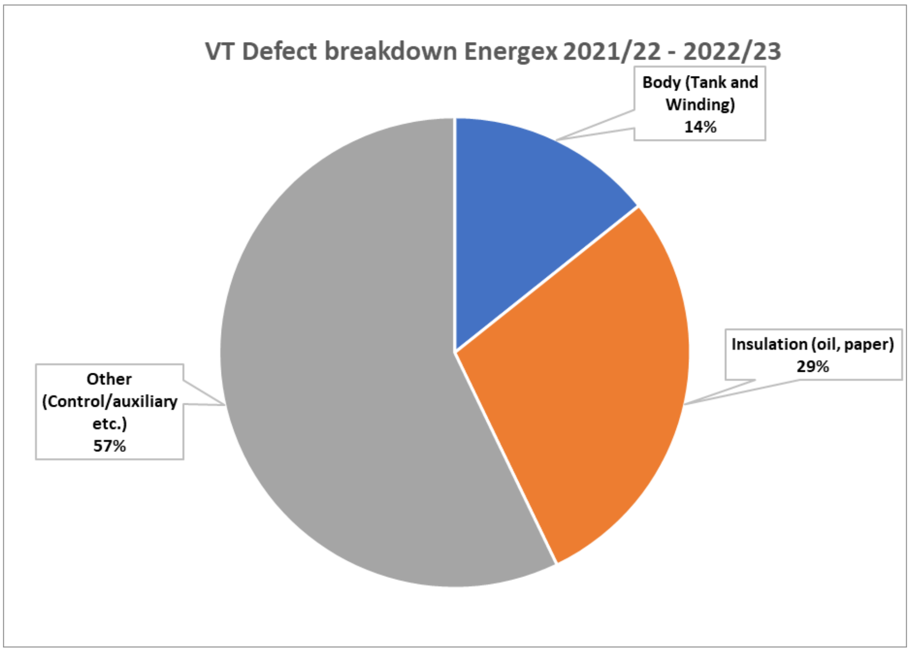


Figure 16: VT Corrective Maintenance by Defect Type – Energex Network

The figures above show that the most common defects identified in the instrument transformer population for Ergon are associated with leaking/top-ups of oil. The most common defects for Energex instrument transformers are to do with Control/auxiliary and body tank/winding issues.

4 Asset Related Corporate Risk

As detailed in Section 3.2, EQL has a duty to ensure its assets are electrically safe. This safety duty requires EQL to take action so far as is reasonably practicable (SFAIRP) to eliminate safety related risks, and where it is not possible to eliminate these risks, to mitigate them SFAIRP. Risks in all other categories are managed to levels as low as reasonably practicable (ALARP).

Figure 17 illustrates a threat-barrier diagram for instrument transformers in the EQL network. EQL undertakes a number of actions such as inspections and maintenance to eliminate or mitigate the risks to SFAIRP/ ALARP.

EQL's safety duty results in most inspection, maintenance and replacement works and expenditure related to instrument transformers being entirely focused upon preventing and mitigating failure.

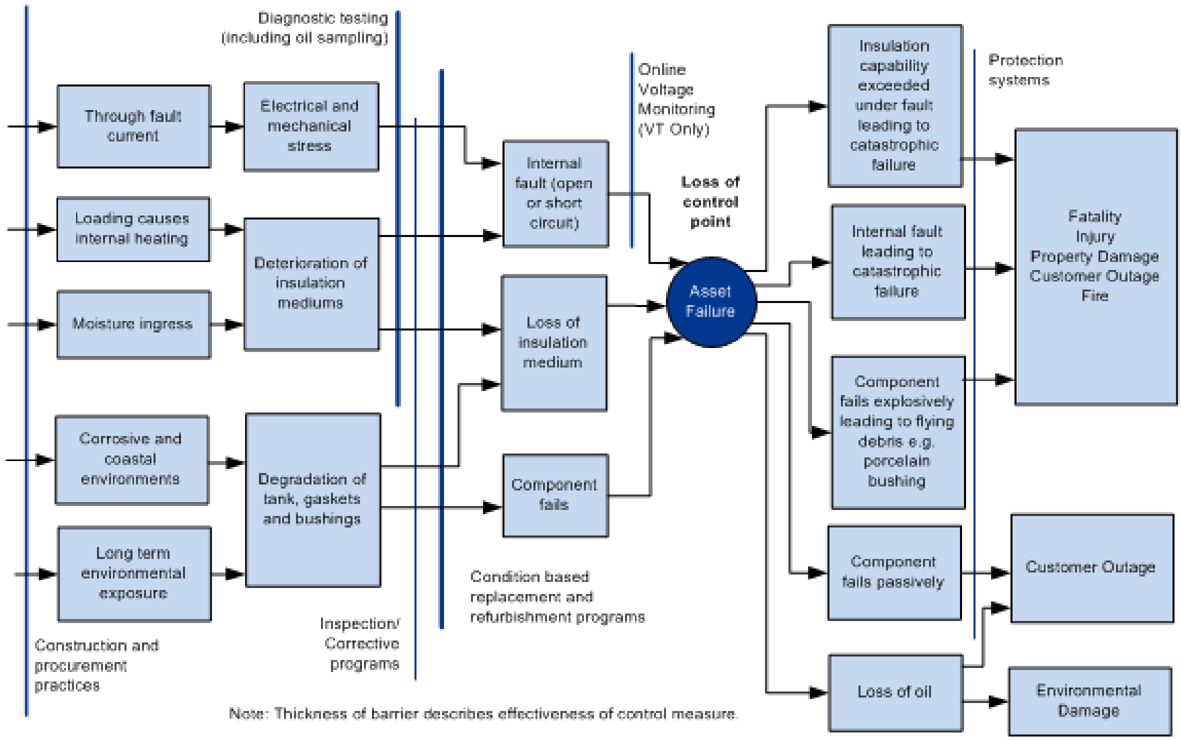


Figure 17: Threat-Barrier Diagram for Instrument Transformer

The following sections detail the ongoing asset management journey necessary to continue to achieve high performance standards into the future.

5 Health, Safety & Environment

The following sections detail some of the health, safety, and environmental risks which may be associated with the management of this EQL asset base.

The risk of bushfires within a substation is minimal, primarily owing to the presence of crushed rock within the substation, which makes it not applicable for this asset class.

5.1 Asbestos

Asbestos is a naturally occurring mineral used historically as an insulation material that can cause serious illnesses if inhaled into the lungs. Asbestos-related diseases take many years to develop and can be chronic.

Powerlink conducted asbestos sampling and testing at their H006 Gin Gin substation and found asbestos contained within in-service CTs manufactured by ABB prior to 1977. The results confirmed the presence of bonded (non-friable) asbestos in the padding material located between the porcelain insulator and CT tank.

The Ergon Network have 11 ABB CTs manufactured prior to 1977, meaning that there is a high potential for EQL assets to also have this issue.

The overarching drivers, principles and objectives regarding EQL's corporate approach to asbestos management are documented in EQL's Asbestos Management Plan. EQL employs a Permit to Work System to control all risks when removing asbestos.

5.2 PCB Contamination

Polychlorinated biphenyl chemicals (PCBs) were commonly used in transformer oils including instrument transformers until the 1970s. They accumulate in transformer windings so that replacing the transformer oil does not guarantee complete removal of the chemical. When released in the environment, PCBs linger and bio-accumulate, becoming absorbed in the fatty tissues of animals and slowly transmitted through the food chain to humans. PCBs can cause liver damage, nervous system damage, and are considered to be carcinogenic.

Oil is considered to be PCB free if the concentration is less than 2 ppm. Oil with PCB concentration greater than 50ppm is considered scheduled waste and must be disposed of only via authorised companies.

Testing for presence of PCBs is not a routine oil test for instrument transformers. Only in preparation for major maintenance, oil change, or disposal, the oil is tested for presence of PCBs.

6 Current Issues

The following sections outline current issues that have been identified as having the potential to impact EQL's ability to meet corporate objectives.

6.1 Common CVT Failure Modes

EQL faces the issue of common failures of CVT type assets, with poor performance and catastrophic failures occurring across the CVT asset base. CVTs are susceptible to several common failure modes, namely capacitor and sealing failure, which can result in the failure of the CVT before the plant reaches its expected engineering life.

The Ergon Network have experienced issues with CVTs failing in service due to their capacitors drying and/or leaking. There were 7 failed units replaced in the last five years with the year of manufactured dating between 2005 and 2007.

6.1.1 Trench CVT

The Energex Network has experienced two catastrophic failures of the Trench (Trench Electric and Haefely Trench) model CVT. Investigations carried out on failed units identified that there is an inherent defect with this CVT model, where the hermetic seal on the unit fails, allowing for moisture ingress. Water inside the transformer tank causes short circuits in the windings, generating heat and combustible gas and ultimately leading to catastrophic failure. Failure of these assets poses a safety risk to personnel, due to injury from porcelain bushing fragments as a result of asset explosion. Additionally, network reliability is affected if adjacent plant equipment is damaged by an exploding instrument transformer inside the switchyard.

While recorded numbers of catastrophic failures may seem low, Powerlink has also experienced an unacceptable number of catastrophic failures of this model, encouraging removal and replacement of these assets over time. This failure mode has been identified to occur in units greater than 20 years of age. Ergon Energy experienced a catastrophic failure of one Haefely Trench CVT in 2022 which was 34 years old and fit the failure mode outlined above.

6.1.2 Crompton Greaves CVT

Crompton Greaves CVTs perform poorly and are experiencing early life failures. These failures include 66kV, 110kV and 132kV. Up until November 2021, Ergon network decommissioned and/or scrapped 21 x 66kV Crompton Greaves CVTs and 35 x 110kV and above Crompton Greaves CVTs. The YOM of these CVTs are between 2005 and 2014. In 2021, these CVTs were identified as a problematic model.

There are currently 432 Crompton Greaves CVTs in service across EQL. In the Ergon Network, all Crompton Greaves CVTs are registered in the limitation model as problematic model with estimated retirement year of 2022 (YOM between 2005 and 2009) and 2024 (YOM after 2009). These CVTs are also registered in Copperleaf for inclusion in replacement projects. As the replacement number is large, and in the current economic climate and limited resource, Ergon network has not been able to replace all problematic CVTs within this timeframe. CVT voltage monitors are recommended as an immediate solution to prevent catastrophic failure. There are 45 bays of CVTs without CVT voltage monitoring registered in Copperleaf as a limitation. 30 bays of the above CVTs only involve SCADA software upgrade / update to activate the voltage monitor function. The remaining 15 bays involve projects to install voltage monitor function.

Energex Network has replaced all 27 CVT units which are greater than 20 years old. CVTs are more cost-effective compared to a magnetic (inductive) VTs for transmission equipment at 110kV and above. The purchase costs of CVTs and magnetic VTs are almost identical at 66kV in the Ergon Network, therefore purchase cost is not a large barrier for CVT replacement in the 66kV network.

Substation maintenance engineers proactively provide voltage testing for CVTs every 18 months and install monitor alarms to detect voltage imbalance, either in the form of individual alarms or major substation alarms. Improvements being undertaken for CVT monitoring are discussed in Section 8.1.

6.2 Stanger TAE66 CT Leaking Issue

Stanger TAE66 model CTs experience several common issues identified by field crews, with the primary issue being oil leakage from the secondary terminal box. While performing maintenance tasks on these units, the float of the oil indicators sunk, leading to overfilling during maintenance. There are currently 13 Stanger TA CTs in the Ergon Network with the year of manufacture (YOM) between 1971 and 1980. Two of these have active oil leaks that are being managed under a defect management plan (DMP) Consideration should be given to proactively replace this model of CT.

This issue does not apply to the Energex Network.

6.3 Asea and ABB IMBD and IMBE CT

ASEA/ABB type IMBD/IMBE 132kV CTs have a known history of failure. There have been instances in both Powerlink and Ergon network where they have failed at times catastrophically. These included explosive failure, top tanks of CT split open and oil leak.

Currently there are 30 110kV and 132kV IMBD/IMBE CTs in service in the Ergon network. All these CTs are marked as problematic model and registered in limitation model and Copperleaf with estimated retirement year 2021. The condition of these are being monitored more frequently with 12 monthly oil samples.

There has been one recent failure of this type of CT in Ergon in 2023 that matched the failure mode described above.

7 Emerging Issues

7.1 ABB IMBO CT

CTs procured under Ergon Energy period Contract 2001/T/62 with serial numbers beginning with 072Y have been found to have a number of issues. These are being investigated further and will possibly cause problems leading into the future. This is currently under investigation as a population.

Moisture ingress has been found, managed as per general instructions for any other instrument transformer with high moisture. The CT's will need to be monitored and patched with the ultimate plan to replace them once moisture ingress occurs.

Some have high moisture and elevated hydrogen. May be related to "stray gassing" where steel and galvanised steel react with water and oxygen can create hydrogen. This contract is known to have high moisture, possibly from manufacture.

The current population of these CTs is 146 over 26 sites. Out of these 146, 35 are currently within defect levels for moisture and another 10 are nearing defect levels. All these CTs are marked as problematic model and registered in limitation model and Copperleaf. The moisture issues are currently under investigation will be monitored under defect management plans (DMPs) once hitting defect levels until they are replaced.

8 Improvements and Innovation

The following sections outline any improvements or innovations to asset management strategies relevant to this asset class, being investigated by EQL.

8.1 CVT Voltage Monitoring

Voltage monitoring is a reliable method of detecting the onset of short circuit winding faults in CVTs. The Ergon Network has established online voltage monitoring on CVTs along with alarms in the SCADA system to detect issues in real time, enabling network operators to take action to prevent catastrophic failure. This provides significant safety benefits as it reduces the risk of staff or contractors working on site being directly exposed to an explosive failure. Similarly, it reduces the likelihood of damage to other equipment at the substation as a result of explosion or flying debris. Currently, these alarms are set up as either an individual asset alarm or paralleled with a substation general alarm. Individual alarms are preferred due to the additional benefits associated with identifying the issue in a timely manner.

The Energex Network is in the process of establishing voltage monitoring and alarming across the population of 110kV and 132kV CVTs. The functionality has been delivered within the SCADA system and the alarm thresholds are currently being established in consideration of regional alignment.

Voltage monitoring on CVTs has historically been undertaken by adding the functionality to existing units or during asset replacement where possible. It is recommended that this functionality be included in design standards to ensure that it is established for all new CVTs installed on the network.

8.2 Health Index and Risk Monetisation

To support / justify the increased replacement volumes and resolve the economic limitation of Ergon Energy, EQL has:

- Developed a condition-based risk quantification modelling tool to establish optimum replacement volumes.
- Committed to adopt an economic, customer value-based approach when it comes to ensuring the safety and reliability of the network. To substantiate the advantages of this approach for the community and businesses over the modelling period, we have employed Net Present Value (NPV) modelling. This commitment is in line with their efforts to minimize the impact on customer prices.
  - A cost benefit analysis has been conducted to confirm that the Instrument transformer replacements are prudent capital investments.

9 Lifecycle Strategies

The following sections outline the planned approach of EQL to the lifecycle asset management of this asset class.

9.1 Philosophy of Approach

EQL manages instrument transformers based on asset condition and risk informed by a combination of inspection-based assessments and preventive maintenance. Due to potential safety consequences associated with the catastrophic failure of these assets, they are monitored and replaced as they approach end of life and prior to failure. Targeted replacement of specific asset populations may occur where systemic issues and risks are identified. Wherever possible, these assets are replaced in conjunction with other works occurring at the site to ensure efficiency of delivery.

9.2 Supporting Data Requirements

The following sections detail some of the data quality issues that can impact efficient asset lifecycle assessment and management.

9.2.1 Maintenance Strategy Support System

This Maintenance Strategy Support System (MSSS) dataset is building over time and starting to provide the systemic information necessary to support improvements in inspection and maintenance practices. This is a data record system for all failures, incorporating a requirement to record the asset component that failed, the damage found, and the cause of the failure. There is an expectation that this will also support and influence standard design and procurement decisions.

9.2.2 Asset Condition Data

To assess instrument transformer condition, an ongoing regime of inspection and testing is required, with a need for data records to support asset population issue identification as well as individual asset performance.

The data required for asset assessment includes routine inspection and maintenance records as well as test result records relating to the internal condition. To collect this information accurately and efficiently, the in-field asset management devices and systems of record must be configured accordingly and provide the necessary functionality.

EQL is currently replacing the legacy Enterprise Asset Management systems under a renewal project. This presents an opportunity to ensure that the new systems are configured to meet the data requirements necessary to support the asset management objectives including provision for online condition monitoring sensor information such as the voltage monitoring on CVTs.

9.3 Network Access Restrictions

Network access restrictions (NARs) are a process control used to limit access to assets and sites where safety risks have been identified, and where the assets must remain in service to continue to provide supply to customers. Typically, an NAR will involve either an exclusion zone being set around the asset while in-service, or requirements to switch the asset out prior to accessing the site. Other circumstances may require procedures to be undertaken in addition to the usual safety mitigations associated with a task being performed.

Whilst an NAR is an effective short-term risk mitigation method, the restrictions imposed on operations are significant. Additional costs are incurred to undertake routine work at substations where NARs are in place, in order to maintain the exclusion zones and undertake work safely. Similarly, the cost of asset replacement projects increases substantially to accommodate the staging requirements necessary to work at the site for an extended period. Outage durations and therefore customer impacts associated with undertaking work at sites with NARs are also extended significantly as a result of the additional requirements. NARs are not considered appropriate risk mitigation for long term management of safety issues, and so ultimately asset replacement or maintenance is required to return the site to a fully operational state.

In order to deliver a sustainable program of works and balance network risk, customer outcomes, and cost, it is necessary at this stage to increase the volume of substation asset replacement to address the sites with existing restrictions, and to ensure that the assets are removed from the network prior to requiring NARs to be implemented. This will have a flow on effect to the investment and resourcing required to deliver the programs. Programs of replacement will be forecast in accordance with the methodologies outlined in Section 9.

9.4 Acquisition and Procurement

EQL's procurement policy and practices align with 2017 Queensland Government procurement policies. Instrument transformers are procured on an as needs basis, driven by network augmentation, and replacement of assets. Contracts for these assets typically span at least several years for various logistical and pricing reasons and are based on technical specifications guided by the needs of the network. The contract periods provide the opportunity to change technical specifications to improve asset performance by engineering out identified defects, standardising products, or implementing new technologies.

9.5 Operation and Maintenance

Operation and maintenance include planned and corrective maintenance. Operation and maintenance procedures are supported by a suite of documentation which describes in detail the levels of maintenance applicable, the activities to be undertaken, the frequency of each activity, and the defect and assessment criteria to which the condition and testing are compared to determine required actions. The relevant documents are included in Appendix 1 for reference.

The following sections provide a summary of the key aspects of the operation and maintenance of instrument transformers as they relate to the management of the asset lifecycle.

9.5.1 Preventive Maintenance

The preventive maintenance plan for instrument transformers includes planned inspection, maintenance, and condition monitoring activities including:

- In Service Condition Assessment (ISCA) – a periodic check on the condition of the asset to ensure it remains fit for purpose including detailed visual inspection of all external components and non-intrusive diagnostic tests to detect partial discharge activity and thermographic hot spots.
- Out of Service Condition Assessment (OSCA) – electrical activities and testing undertaken to determine the condition of components that cannot be accessed while the asset is in service, including oil sampling. Oil re-sampling is often recommended after a defined period and scheduled when the results of dissolved gas analysis (DGA) indicate an emerging abnormal plant condition.
- Specialist Survey (SS) – consists of out-of-service insulation condition assessment (OSICA) for specified asset types, problematic units, or based on previous condition results.

9.5.2 Corrective Maintenance

Corrective maintenance is generated from preventive maintenance programs, ad-hoc inspections, system alarms, protection operations, public reports, and in-service failures. Minor corrective actions usually occur during routine inspection and maintenance activities to avoid scheduling another visit to the site. Subsequent scheduling of required corrective actions that did not occur at the time of inspection is performed as specific corrective maintenance activities.

The main triggers for corrective and forced maintenance include:

- Defects found during inspection and maintenance activities
- System alarms such as voltage monitoring
- Equipment failure.

Repeated corrective maintenance activities on the same asset are an indication of an underlying problem and can potentially result in significant operating costs if not identified early. Similarly, early identification of issues can typically be addressed by minor maintenance.

9.5.3 Spares

Replacement of instrument transformers that fail in-service occurs from strategic spares holdings purchased for this purpose. Instrument transformer specifications vary due to the range of sizes rated continuous thermal currents, core numbers, and types of voltage and current units in service. Spares may be purchased as new assets or recovered from service if they are assessed as still having useful life.

EQL is continuing to develop the spares management approach for instrument transformers. Strategic spare holdings for CTs and VTs will be determined through assessment of the asset populations, failure rates, and provisioning period in order to provide a 90% probability of a spare being available when required. This requirement is balanced against the cost of holding spares and the risk associated with not having a spare available. Consideration is also given to the storage location of spares in this category due to the logistics associated with transporting them across the state when required.

EQL maintains a register of the strategic spare assets, which includes their storage location and asset attributes. The strategic spares are recorded in a separate stores holding from operational stock in corporate systems to ensure they are available for use when required. Similarly, strategic spares will be regularly maintained to ensure they remain serviceable.

9.6 Refurbishment and Replacement

The following sections outline the practices used to either extend the life of the asset through refurbishment or to replace the asset at the end of its serviceable life.

9.6.1 Refurbishment

Refurbishment activities aim to extend the life of assets and postpone the need for complete replacement. An economic assessment of the cost and potential useful life is used to determine whether refurbishment is viable. The refurbishment of instrument transformers is quite rare and typically limited to minor refurbishment activities such as replacing degraded gaskets and repairing oil leaks.

9.6.2 Replacement

EQL has proactive replacement programs for instrument transformers. Identification for proactive replacement is determined by asset condition and risk, as well as the age of the asset. Asset condition is monitored through a combination of inspection and testing including oil sampling and dissolved gas analysis (DGA). Where practical, timing of replacement is coordinated with other necessary works occurring in the substation to promote works efficiencies. Replacement is also coordinated with network augmentation requirements to deliver the lowest present value cost to customers and avoid duplication of works.

9.7 Disposal

At the time of the disposal of any asset containing oil, EQL test for the presence of PCBs to determine the appropriate disposal methodology in accordance with the Part 6 (Management of PCBs) of the Queensland Environmental Protection (Waste Management) Regulation 2000.

Assets that have reached end of life are salvaged for useable components to provide maintenance spares before being sold for scrap or disposed of accordingly. Assets that are recovered prior to end of life due to augmentation or other network requirements that cannot be reused in the network may be sold to other organisations (such as mining companies) before disposal is considered.

10 Program Requirements and Delivery

The programs of maintenance, refurbishment, and replacement required to outwork the strategies of this AMP are documented in Network Program Documents and reflected in corporate management systems. Programs are typically coordinated to address the requirements of multiple asset classes at a higher level, such as a substation site or feeder, to provide delivery efficiency, as well as reduce travel costs and overheads. The Network Program Documents provide a description of works included in the respective programs, as well as the forecast units.

Program budgets are approved in accordance with Corporate Financial Policy. The physical and financial performance of programs is monitored and reported on a monthly basis to manage variations in delivery and resulting network risk.

Appendix 1. References

It takes several years to integrate all standards and documents after a merger between two large corporations. This table details all documents authorised/approved for use in either legacy organisation, and therefore authorised/approved for use by EQL, that supports this Asset Management Plan.

Document Number	Title	Type
3054137	Standard for Free Standing Instrument Transformers	Standard Document
SDCM	Substation Defect Classification Manual	Manual
PRNG003	Protocol for Strategic Spares Management	Protocol Document
690840	Asbestos Management Plan R077	Standard Document

Appendix 2. Definitions

For the purposes of this Asset Management Plan, the following definitions apply:

Term	Definition
Condition Based Risk Management	A formal methodology used to define current condition of assets in terms of health indices and to model future condition of assets, network performance, and risk based on different maintenance, asset refurbishment, or asset replacement strategies.
Corrective maintenance	This type of maintenance involves planned repair, replacement, or restoration work that is carried out to repair an identified asset defect or failure occurrence, in order to bring the network to at least its minimum acceptable and safe operating condition. An annual estimate is provided for the PoW against the appropriate category and resource type.
Current transformer	Current transformers are used to provide/transform currents suitable for metering and protection circuits where current measurement is required.
Distribution	LV and up to 22kV (and some 33kV) networks, all SWER networks
Forced maintenance	This type of maintenance involves urgent, unplanned repair, replacement, or restoration work that is carried out as quickly as possible after the occurrence of an unexpected event or failure; in order to bring the network to at least its minimum acceptable and safe operating condition. Although unplanned, an annual estimate is provided for the PoW against the appropriate category and resource type.
Instrument transformers	Refers to current transformers (CTs), voltage transformers (VTs) and metering units (MUs)
Metering Units	A unit that includes a combination of both current transformers and voltage transformers for the purpose of statistical or revenue metering
PCB	Polychlorinated Biphenyls are synthetic chemicals manufactured from 1929 to 1977 and was banned for use in 1979 in transformers, voltage regulators and switches
Preventative maintenance	This type of maintenance involves routine planned/scheduled work, including systematic inspections, detection and correction of incipient failures, testing of condition and routine parts replacement designed to keep the asset in an ongoing continued serviceable condition, capable of delivering its intended service
Sub transmission	33kV and 66kV networks
Transmission	Above 66kV networks
Voltage Transformers	Voltage or potential transformers are used to provide/transform voltages suitable for metering and protection circuits where voltage measurement is required.

Appendix 3. Acronyms and Abbreviations

The following abbreviations and acronyms may appear in this Asset Management Plan.

Abbreviation or acronym	Definition
AMP	Asset Management Plan
CB	Circuit Breaker
CT	Current Transformer
CVT	Capacitor Voltage Transformer
DGA	Dissolved Gas Analysis
DLA	Dielectric Loss Angle
EQL	EQL Limited
ISCA	In-Service Condition Assessment
LV	Low Voltage
MU	Metering Unit
PCB	Polychlorinated Biphenyls
QLD	Queensland
RIN	Regulatory Information Notice
VT	Voltage Transformer
WCP	Water Content of Paper