Asset Management Plan Instrument Transformers 2020-25

January 2019

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 6,500 instrument transformers, 5,472 in the Northern and Southern Regions and 1,075 in the South East Region. Instrument transformers are located across the network and typically managed based on asset condition and risk.

There are no specific regulatory performance standards dedicated to instrument transformers. The overall asset population performance is evaluated as part of the general organisation obligations for reliability and annual dangerous electrical events incidents.

Key actions for the lifecycle asset management of assets contained in this AMP include expanding CVT online monitoring to the South East region to ensure early signs of failure are detected and a review of procurement and data processes to identify and address data quality issues.

EQL will continue the alignment of maintenance and operating practices from its legacy organisations in order to drive efficiency, delivery customer outcomes and mitigate risks.

Document Tracking Details

Network and Non-Network Document Hierarchy Reference Number	Regulatory Proposal Chapter Reference	Document	File Name
NET AMP – 007	7.033	Asset Management Plan - Instrument Transformers	EGX ERG 7.033 Asset Management Plan - Instrument Transformers JAN19 PUBLIC

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1 Introduction

Energy Queensland Limited (EQL) was formed 1 July 2016 and holds Distribution Licences for the following regions:

- South East Region (Legacy organisation: Energex Limited); and
- Northern and Southern Regions (Legacy organisation: Ergon Energy Corporation Limited).

There are variations between EQL's operating regions 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 demonstrate the responsible and sustainable management of Instrument Transformers 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 Energy Queensland Limited'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 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 2010 – 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 1contains references to other documents relevant to the management of the asset class covered in this plan.

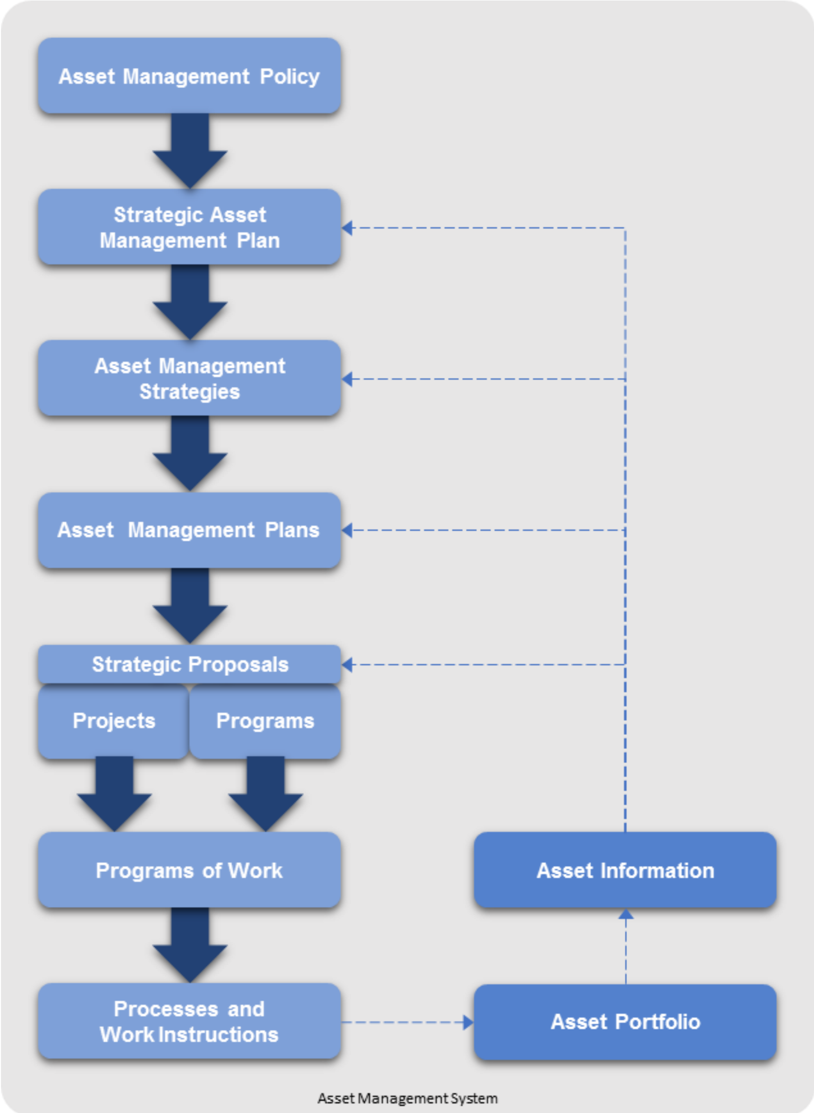


Figure 1: EQL – Asset Management System

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 $640 million. 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.

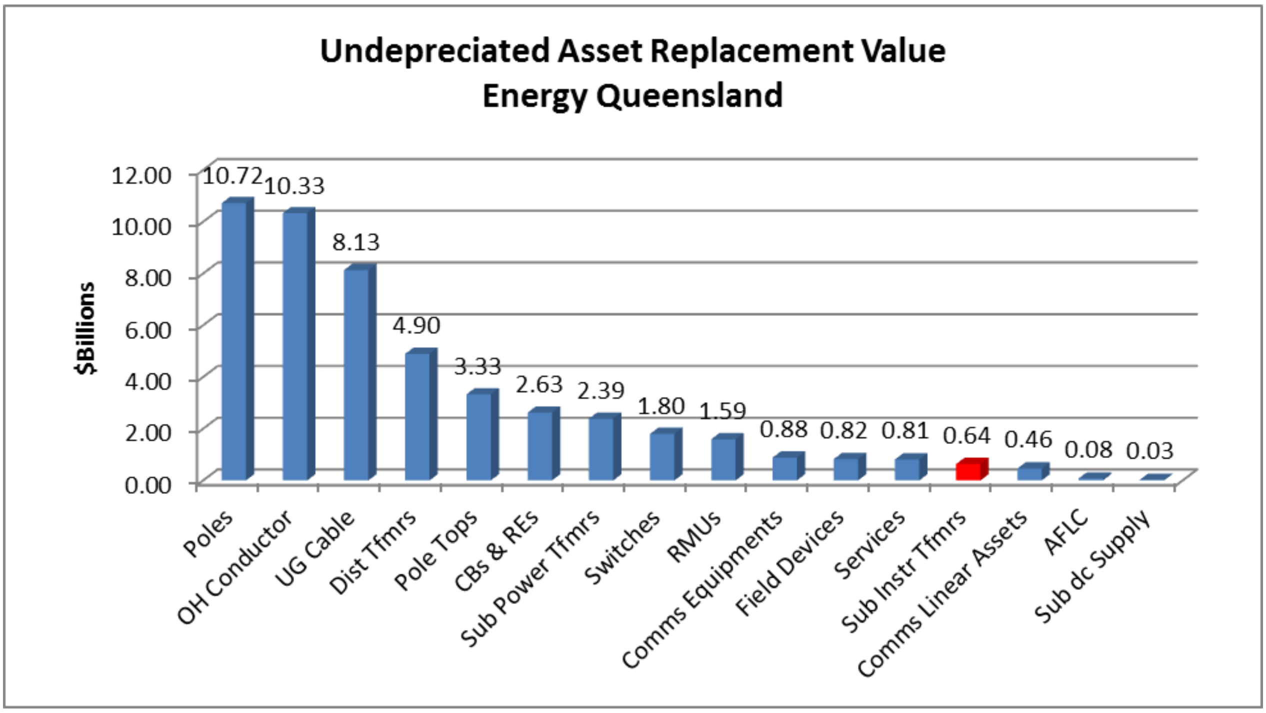


Figure 2: EQL – Total Current Asset Replacement Value

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 key roles and responsibilities for the management of this asset class are outlined in Table 2.

Role	Responsible Party
Asset Owner	Chief Financial Officer
Asset Operations Delivery	EGM Distribution
Asset Manager	EGM Strategy, Asset Safety & Performance

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	Northern and Southern Regions	South East	Total
>11kV & <=22kV	895		895
>22kV & <=33kV	293	420	713
>33kV & <=66kV	1781		1781
>66kV & <=132kV	349	207	556
Unknown*		*15	15
Total	3318	642	3960

*Due to data quality issues, there are 15 plants with an "unknown" voltage level in the South East Region.

Table 3: Asset Quantity – Current Transformers

Voltage Transformer	Northern and Southern Regions	South East Region	Total
=11kV	538	19	557
>11kV & <=22kV	208		208
>22kV & <=33kV	930	224	1154
>33kV & <=66kV	258	3	261
>66kV & <=132kV	220	180	400
Unknown		*7	7
Total	2154	433	2587

*Due to data quality issues, there are 7 items with an "unknown" voltage level in the South East Region.

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 Northern and Southern Regions as recorded in the 2016-17 Regulatory Information Notice (RIN). The expected life of instrument transformers is 45 years in the EQL network.

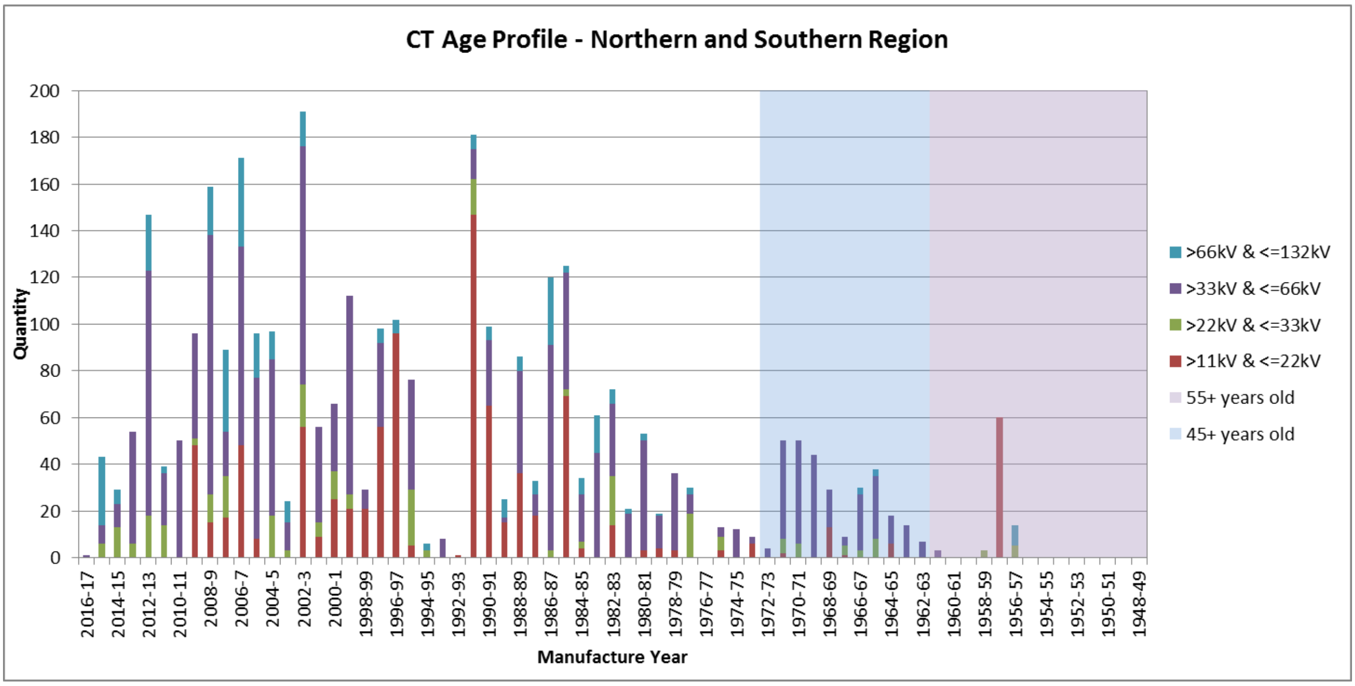


Figure 3: Northern and Southern Regions Current Transformers – Asset Age Profile

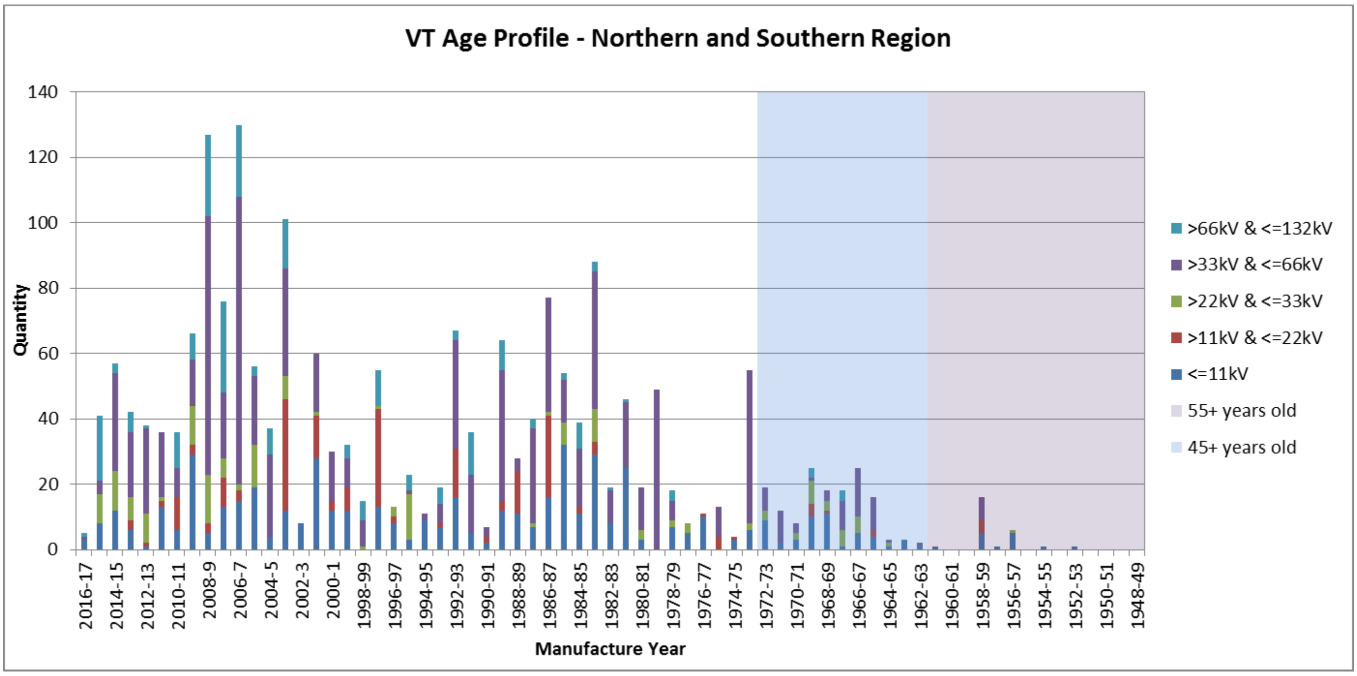


Figure 4: Northern and Southern Regions Voltage Transformers – Asset Age Profile

Figure 5 and Figure 6 show the age profile of instrument transformers in the South East Region network as recorded in the 2016-17 RIN.

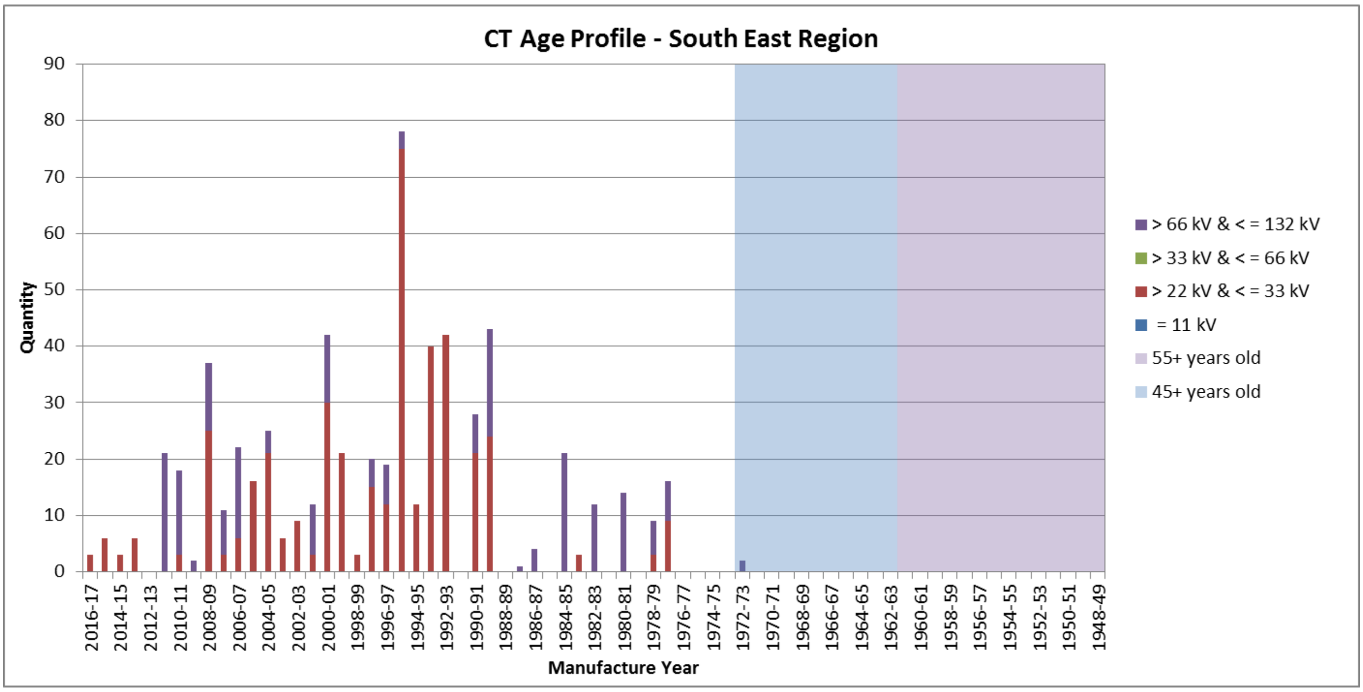


Figure 5: South East Region Current Transformers – Asset Age Profile

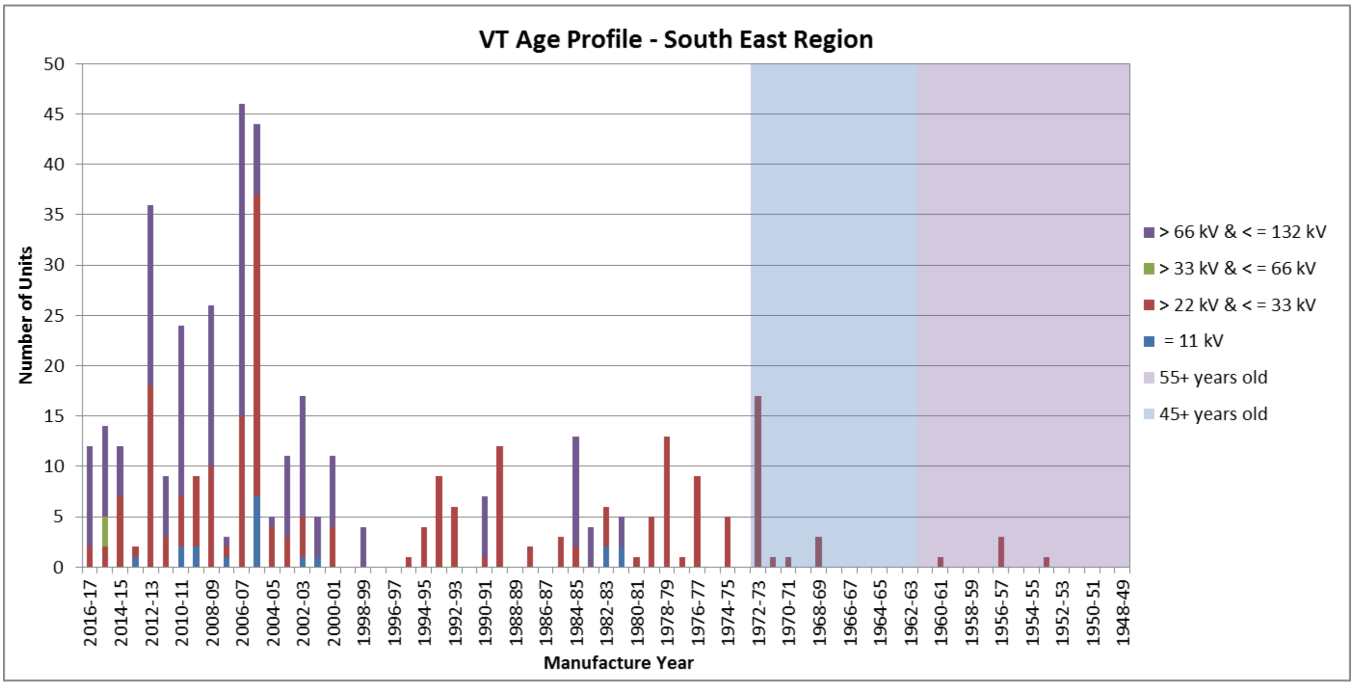


Figure 6: South East Region Voltage Transformers – Asset Age Profile

2.4 Population Trends

The insulation mediums used in the CT asset population are oil and epoxy. In the Northern and Southern Regions, 96% of CTs at 33kV and above are oil insulated, and 94% of CTs at 22kV and under are epoxy insulated. In the South East Region, the majority of oil insulated CTs are hermetically sealed, and CTs with solid insulation is only used at 11kV and 33kV voltages. The South East Region does not have any gas insulated CTs.

In the Northern and Southern Regions, VTs at 66kV and above are oil insulated, and 55% of VTs at 33kV and under are epoxy insulated.

Since 2005, there has been a trend toward using CVTs in the 66kV network in the Northern and Southern Region. In the South East Region CVTs are used at voltages greater than or equal to 110kV only.

In the South East Region, there has been a recent asset population trend in the 33kV networks, with oil insulated VTs being phased out and replaced by modern equivalent solid insulation units. Figure 7 illustrates the age profile of the 33kV VTs with oil and solid insulation.

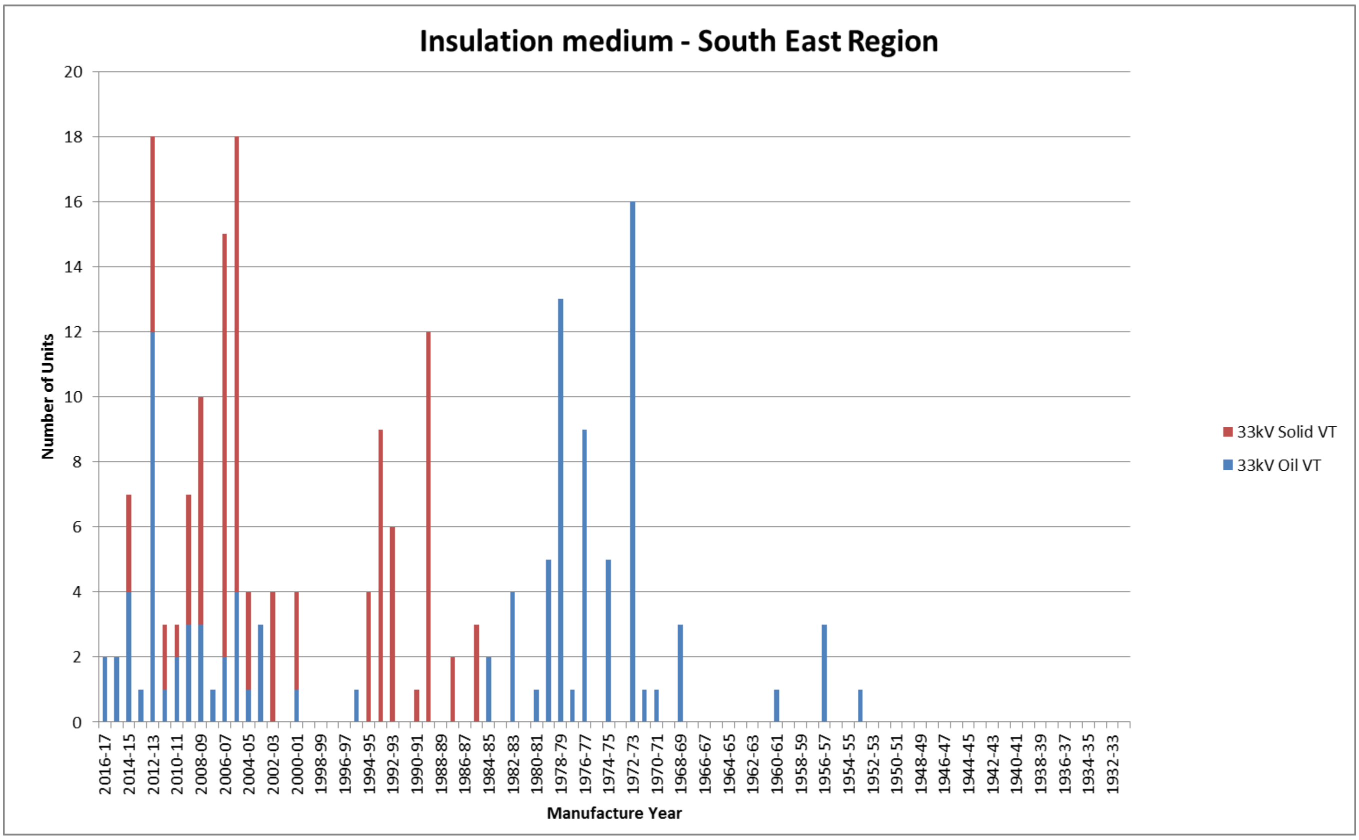


Figure 7: 33kV voltage transformers (oil vs solid) age profile – South East Region

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.

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 to 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 publically 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 regions.

3.4.1 Historical Asset Failure Data

The disparity between the reported failures from the EQL legacy organisations is due to differences in source data and calculation methodology. EQL is working towards alignment of methodologies to ensure a common approach moving forward.

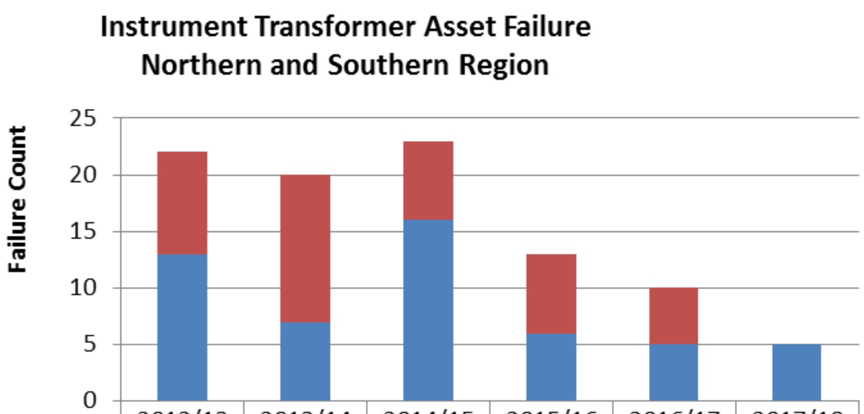
Failures in the Northern and Southern region have been estimated based on the following approach:

The stores issues for these assets costed to the operating expenditure (opex) code are considered to be failures.

Feeder Statistics are used to identify an outage which is then attributed to a particular asset class. In developing this estimate Ergon Energy has assumed that all failures will lead to an outage.

Extreme or atypical weather events were excluded from the data.

The historical failure information based on the above is shown in Figure 8.



	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18
Voltage Transformers	9	13	7	7	5	
Current Transformers	13	7	16	6	5	5

Figure 8: Northern & Southern Regions - Instrument Transformer Asset Failure

In the South East Region, each failure event associated with the assets covered under the scope of this AMP is individually investigated and registered by Investigation and Response department. Figure 9 shows the in-service failures recorded in the South East Region.

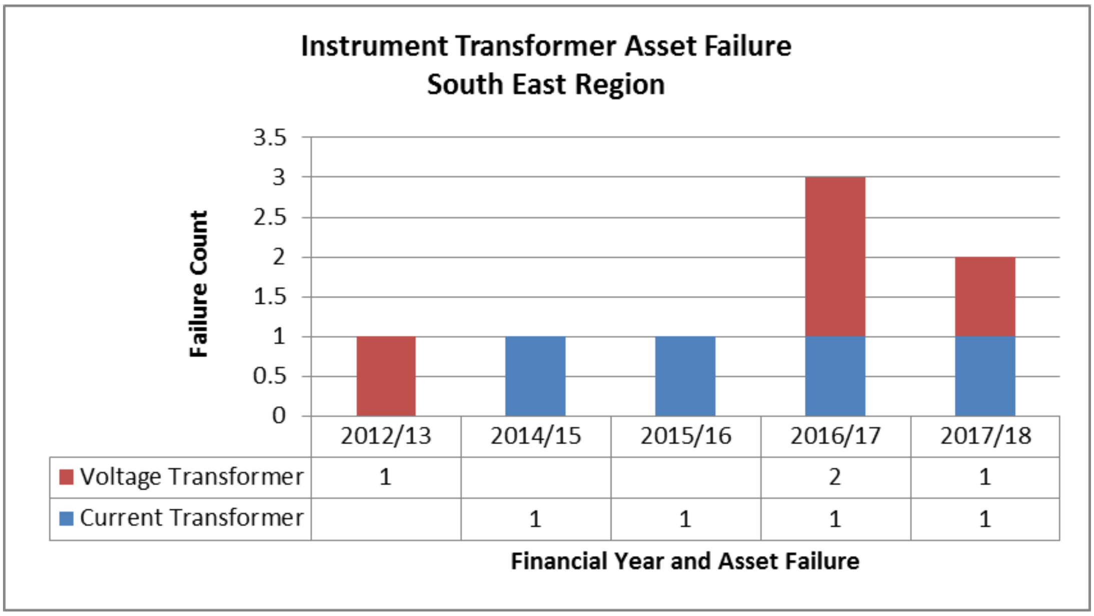


Figure 9: South East Region - Instrument Transformer Asset Failure

3.4.2 Historical Defect Data

Figure 10 and Figure 11 show the historical trends of defect replacement and refurbishment works that have been conducted on these assets. The P0, 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 and P0).

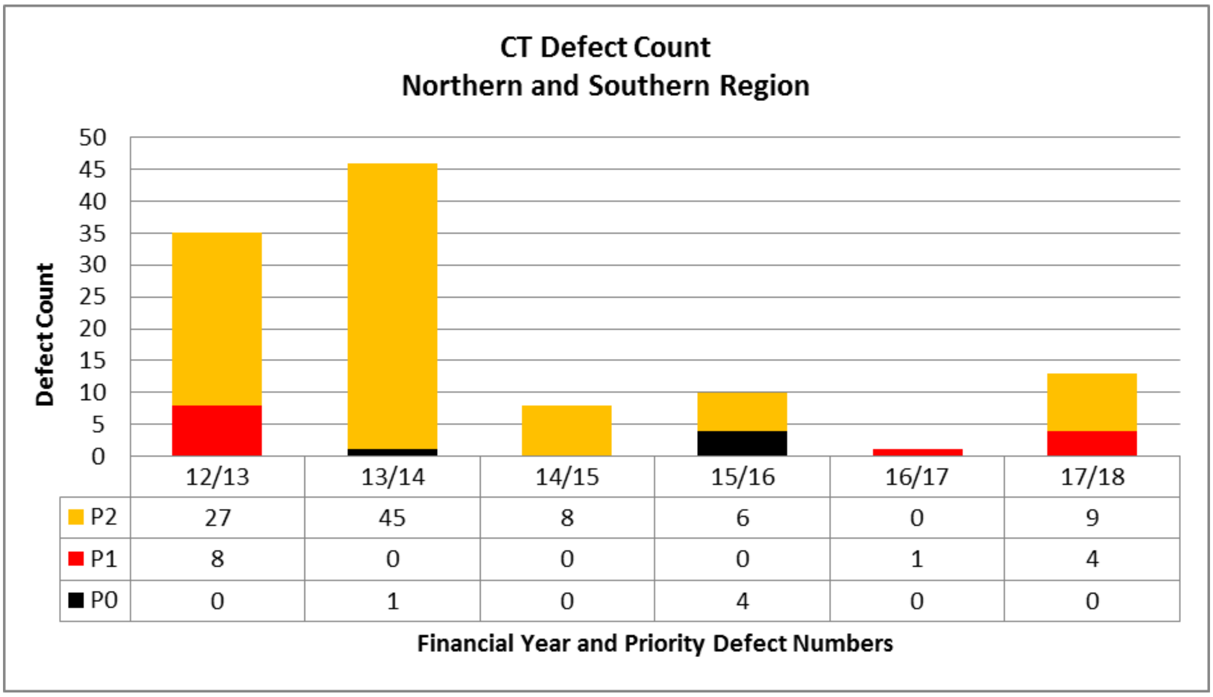
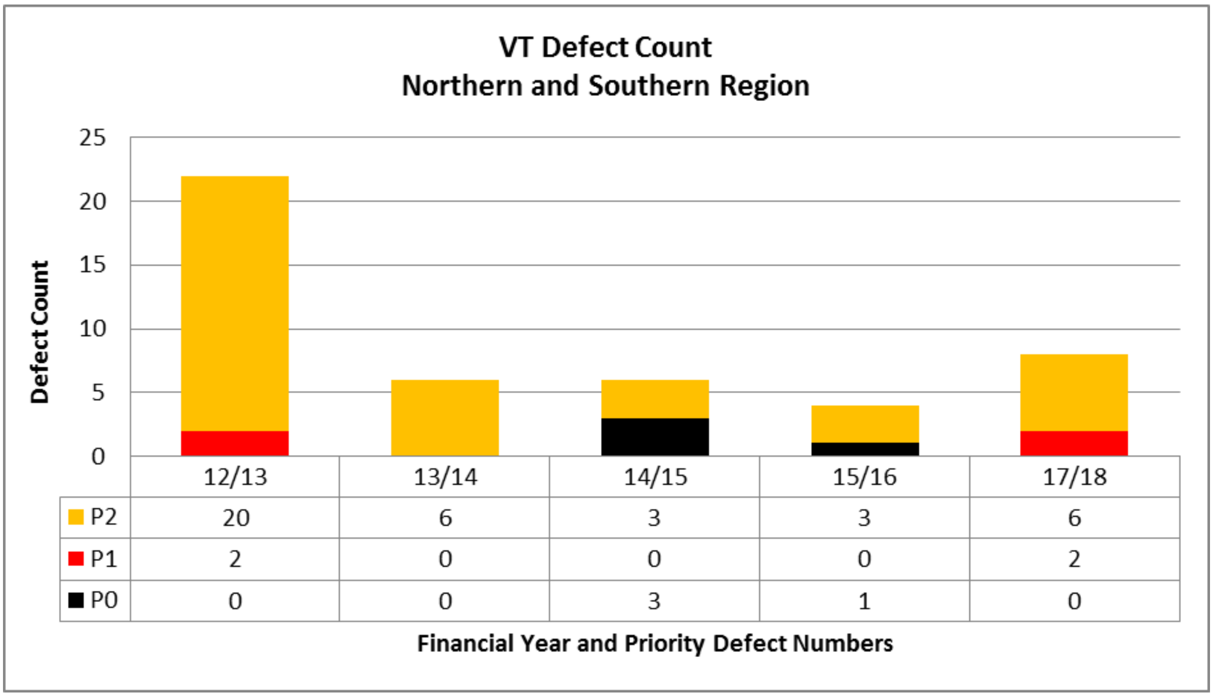


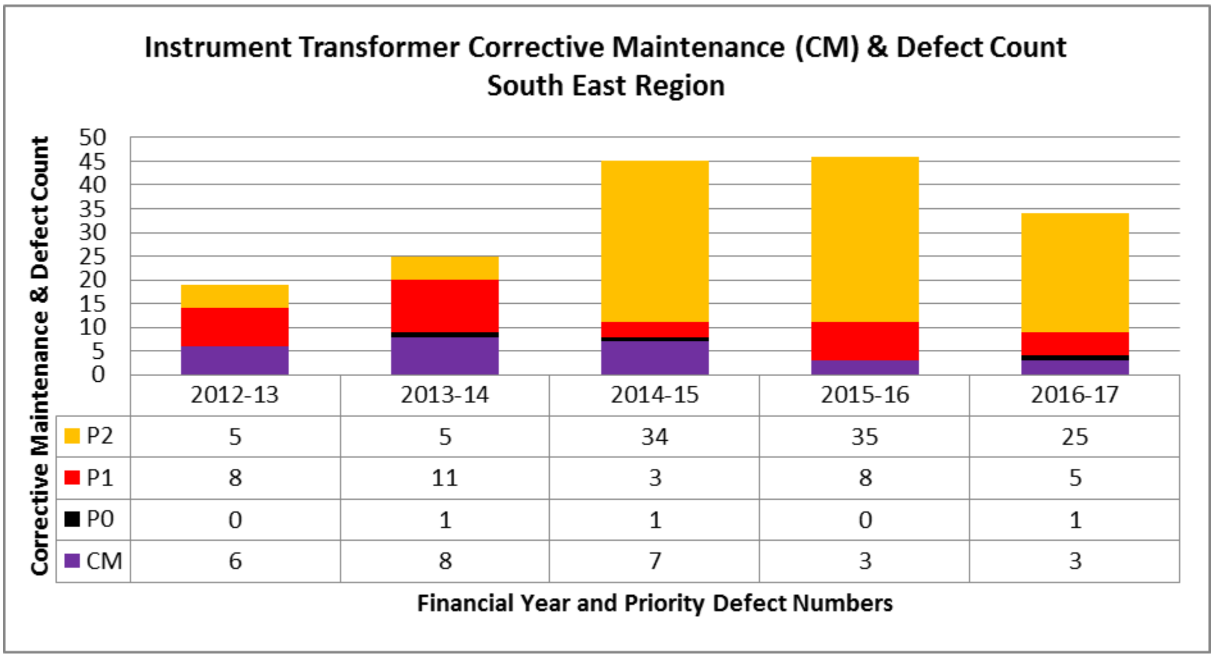
Figure 10: Northern and Southern Regions Current Transformer Defect Count



	12/13	13/14	14/15	15/16	17/18
P2	20	6	3	3	6
P1	2	0	0	0	2
P0	0	0	3	1	0

Figure 11: Northern and Southern Regions Voltage Transformer Defect Count

Figure 12 shows the historical trend of defect replacement/refurbishment works that have been conducted on these assets.



	2012-13	2013-14	2014-15	2015-16	2016-17
P2	5	5	34	35	25
P1	8	11	3	8	5
P0	0	1	1	0	1
CM	6	8	7	3	3

Figure 12: South East Defect Numbers

Ergon Energy developed and implemented a record system for all failures, incorporating a requirement to record the asset component (object) that failed, the damage found, and the cause of the failure. The South East Region also adopted this approach starting from the 2017/18 financial year.

This Maintenance Strategy Support System (MSSS) record set is building over time and starting to provide the systemic information necessary to support improvements in inspection and maintenance practices. There is an expectation that this will also support and influence standard design and procurement decisions. Figure 13 to Figure 18 show instrument transformers corrective maintenance component breakdowns produced through the MSSS system data.

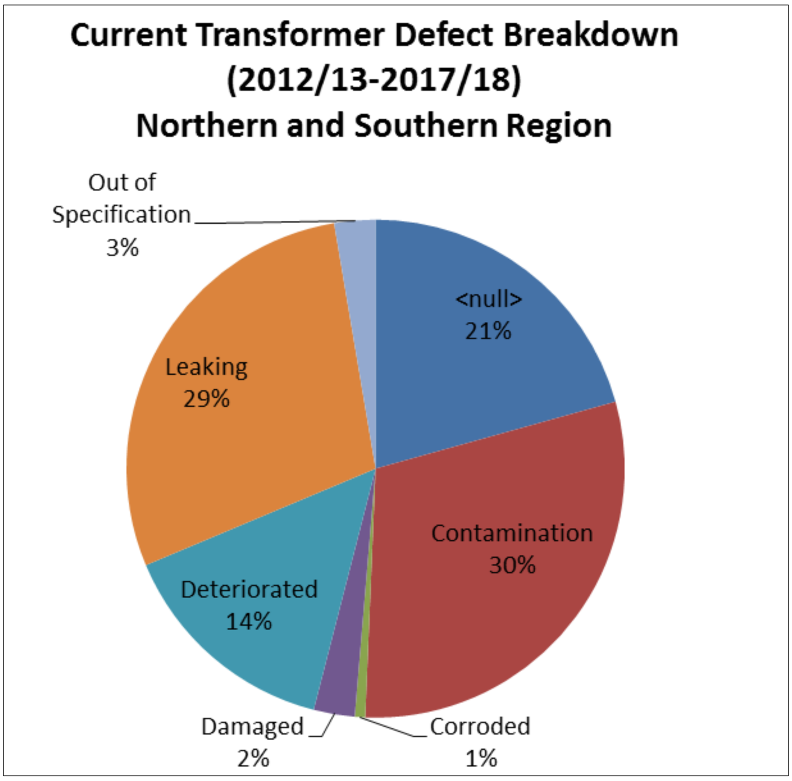


Figure 13: CT Corrective Maintenance (12/13 - 17/18) – Northern and Southern Regions

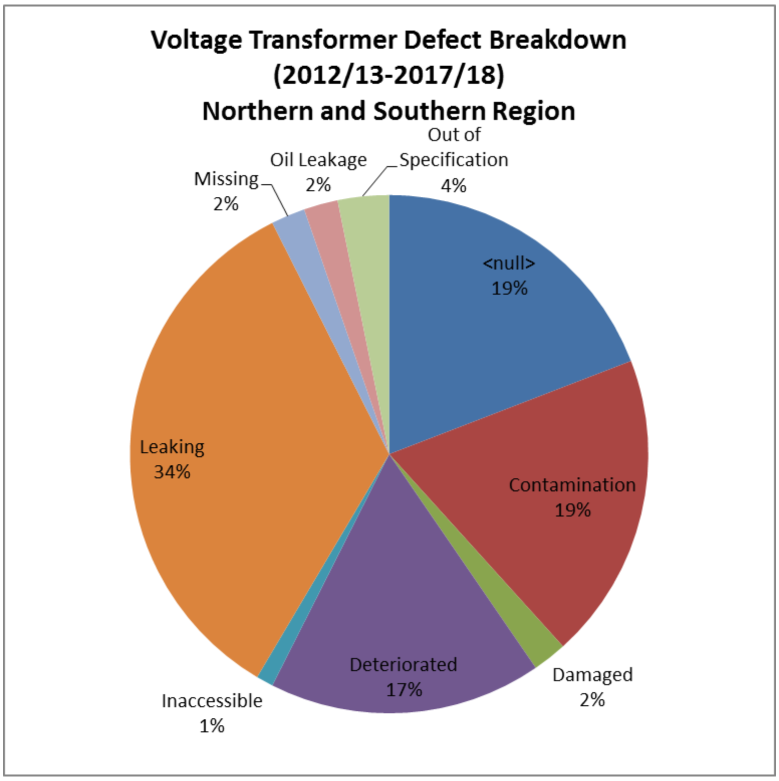


Figure 14: VT Corrective Maintenance (12/13 - 17/18) – Northern and Southern Regions

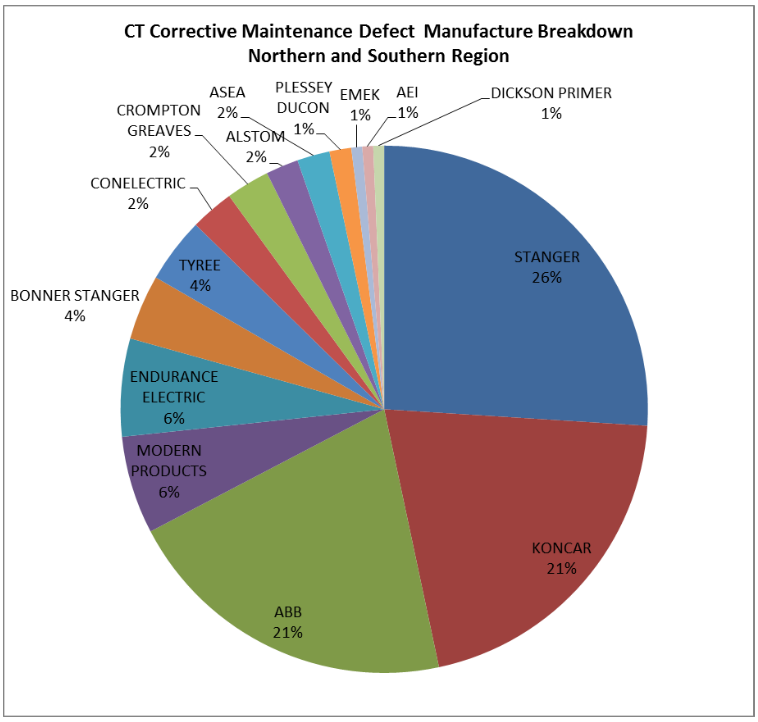


Figure 15: CT Corrective Maintenance by Manufacturer – Northern and Southern Regions

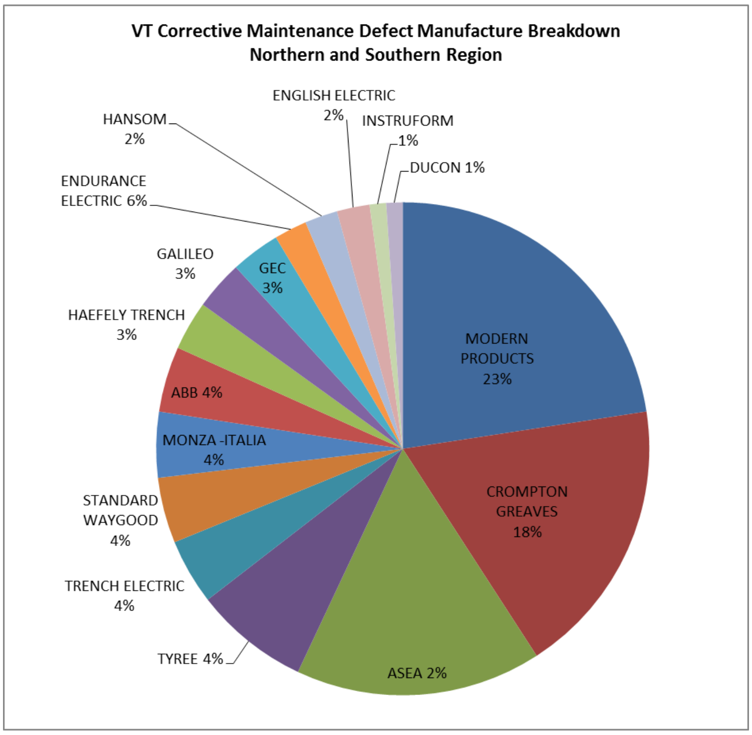


Figure 16: VT Corrective Maintenance by Manufacturer – Northern and Southern Regions

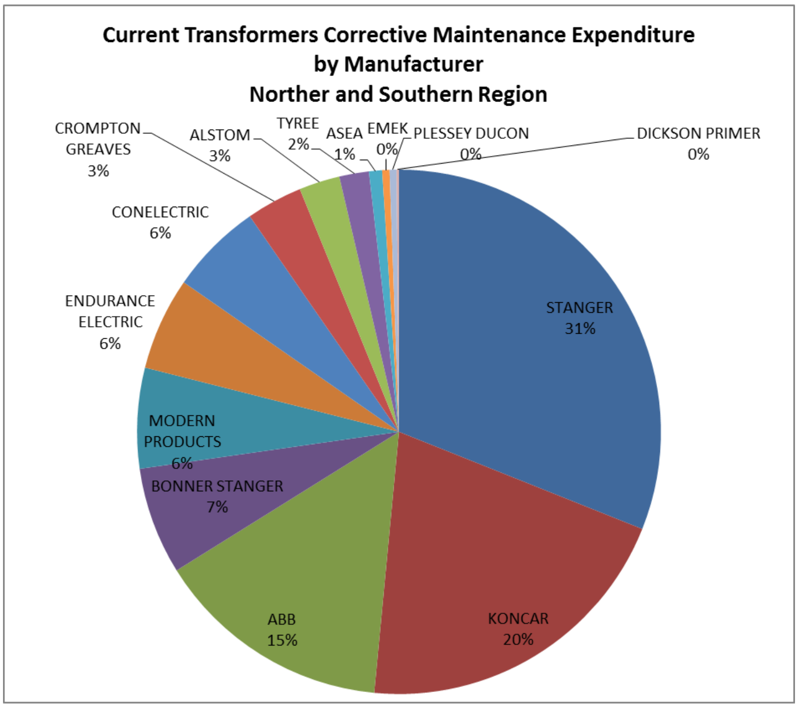


Figure 17: VT Corrective Maintenance Expenditure – Northern and Southern Regions

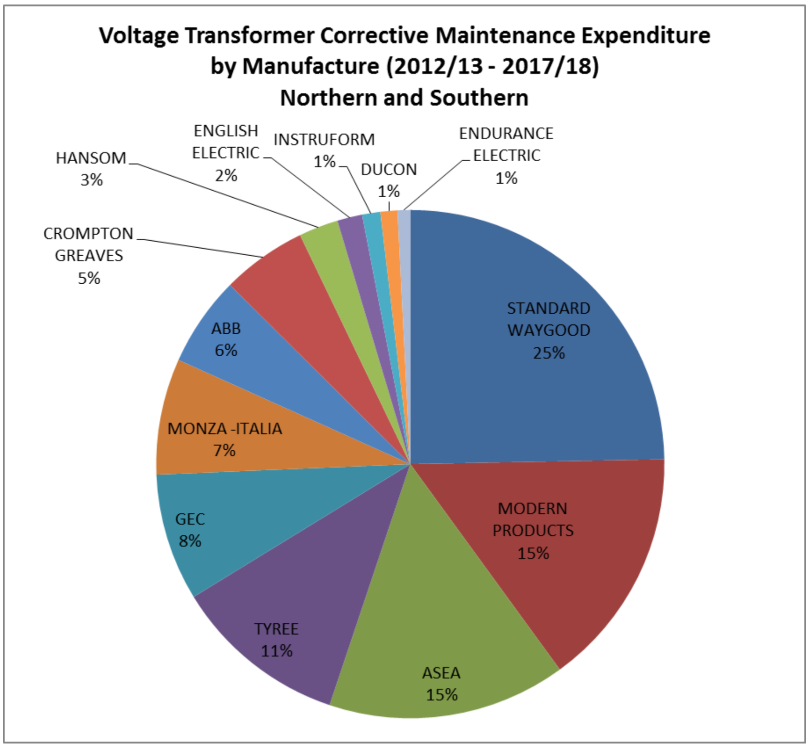


Figure 18: CT Corrective Maintenance Expenditure – Northern and Southern Regions

The figures above show that the most common defects identified in the instrument transformer population are associated with leaking and contamination (including moisture). These issues are discussed along with detail on specific problematic units in Section 6.

Figure 19 shows the results of the South East Region MSSS approach to corrective maintenance, which started in 2017/18 financial year. Due to the relatively low population of assets in this class and the MSSS system only having been in effect for a short period there is minimal information at this stage however this will continue to build over time.

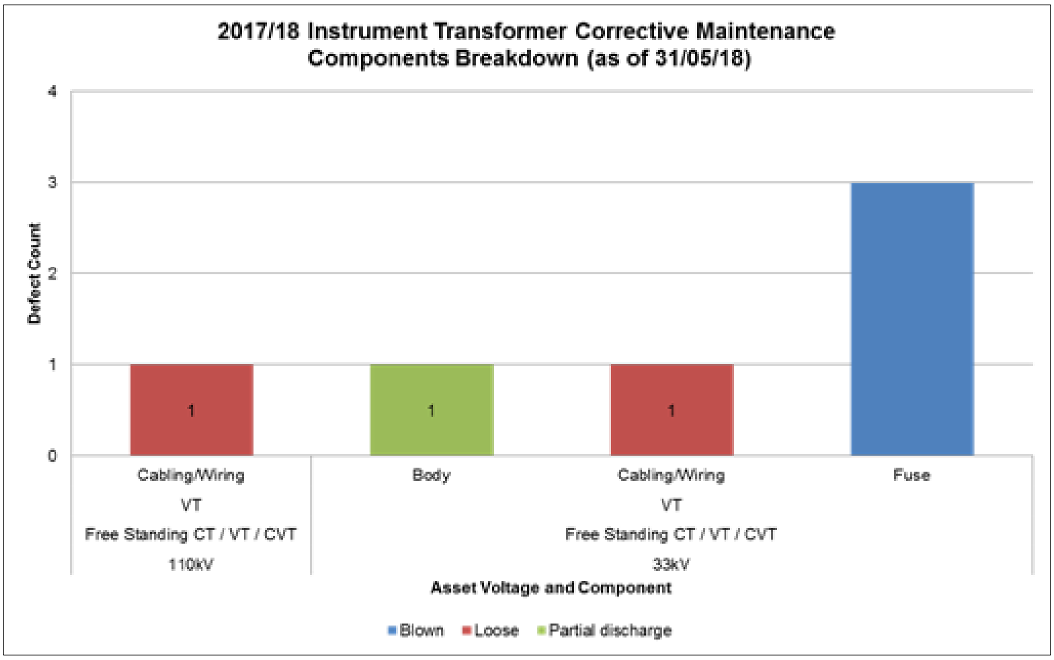


Figure 19: Instrument Transformers Corrective Maintenance (2017/18) – South East Region.

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 20 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.

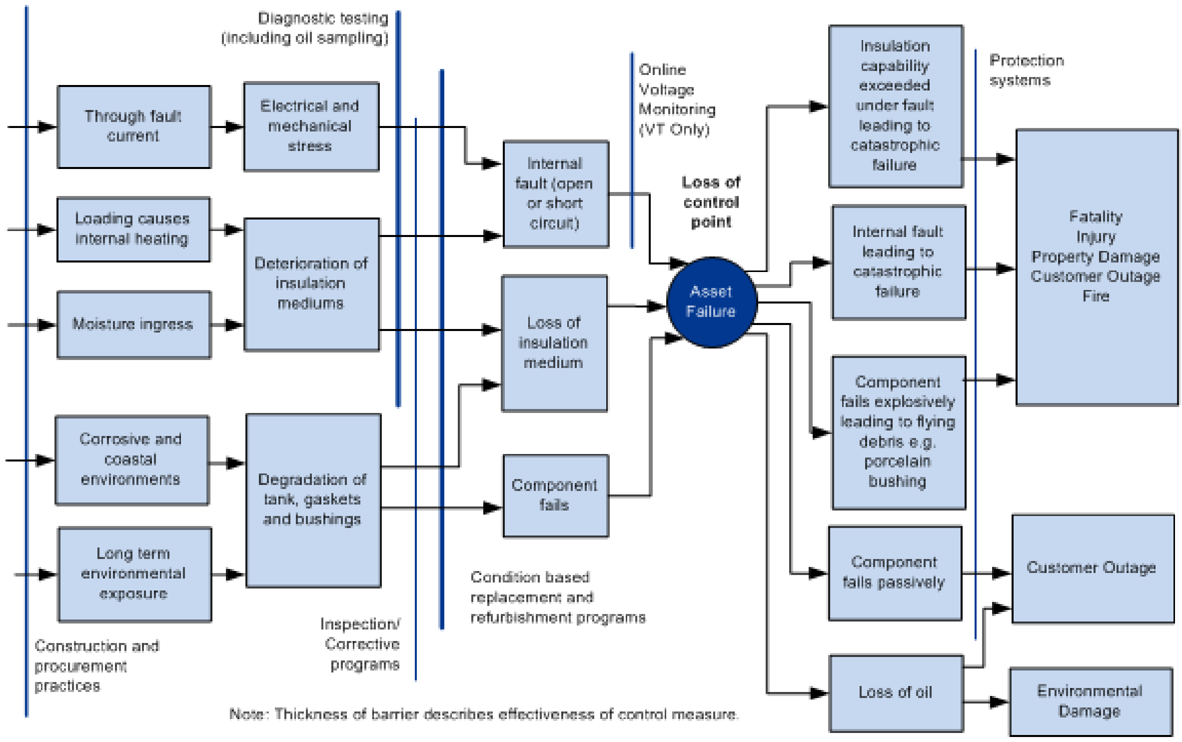


Figure 20: Threat-Barrier Diagram for Instrument Transformer

The following sections detail the ongoing asset management journey necessary to continue to achieve high performance standards into the future. Action items have been raised in the following sections where relevant, detailing the specific actions that EQL will undertake as part of program delivery of this Asset Management Plan.

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.

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 Northern and Southern Regions 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. Only in preparation for major maintenance, oil change, or disposal of all transformers, reactors, and regulators, 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 Northern and Southern Regions have experienced issues with CVTs failing in service due to their capacitors drying and/or leaking. There were 37 failed units replaced in the last five years with the year of manufactured dating between 1983 and 2007.

The South East Region 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.

There are currently 414 CVTs in service across EQL. In the Northern and Southern regions, the replacement of 23 CVT units is planned over the next four years. The South East Region has planned replacements for all 27 CVT units which are greater than 20 years old over the determination period 2015/16-2019/20. Four sites totalling 23 CVT units have been replaced so far, and the remaining four units are scheduled for replacement in 2019.

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 Northern and Southern Regions, therefore purchase cost is not a large barrier for CVT replacement in the 66kV network.

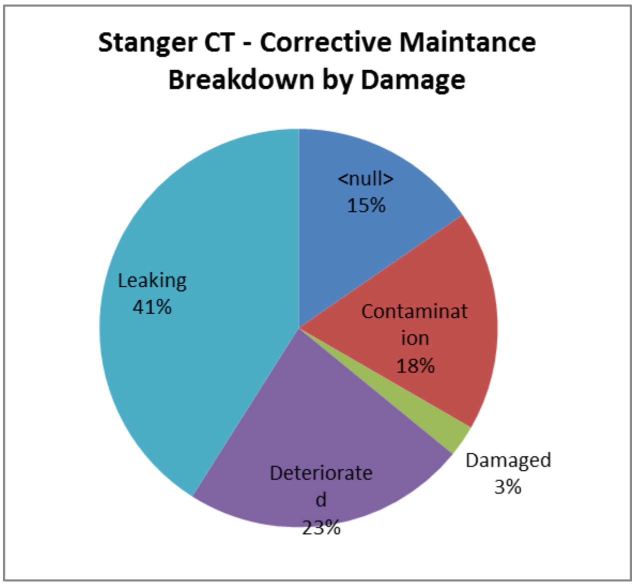
Substation maintenance engineers proactively provide voltage testing for CVTs every 18 months and install monitor alarms to detect voltage imbalance, either in the form of individual alarms or major substation alarms. Improvements being undertaken for CVT monitoring are discussed in Section 8.1.

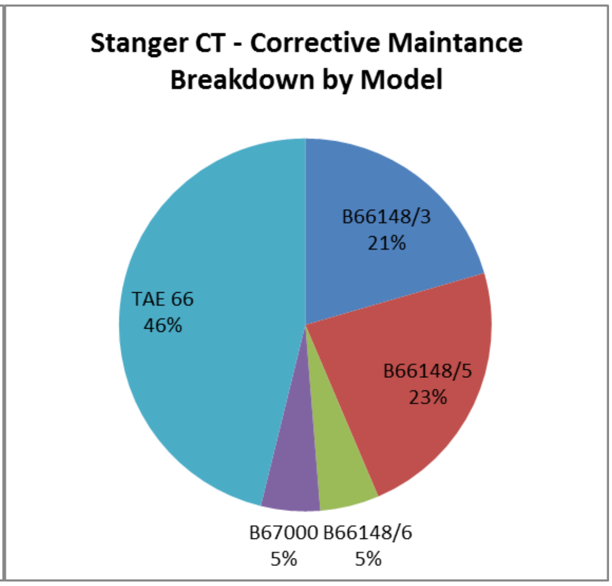
6.2 Stanger TAE66 CT Leaking Issue

Stanger TAE66 model CTs experience several common issues identified by field crews, with the primary issue being oil leakage from the secondary terminal box. Figure 15 shows that 26% of the CT corrective maintenance is associated with Stanger CTs. Figure 21 shows that leaking and deterioration were the causes of 41% and 23% of defects respectively in Stanger CT models and that 46% of recorded defects were associated with the Stanger TA series TAE66 model.

Additionally, while performing maintenance tasks on these units, the float of the oil indicators sunk, leading to overfilling during maintenance. There are 32 Stanger TA CTs in the Northern and Southern regions with the year of manufacture (YOM) between 1971 and 1980. Consideration should be given to the balance of the 20 CTs as potential candidates for future replacement.

This issue does not apply to South East Region.





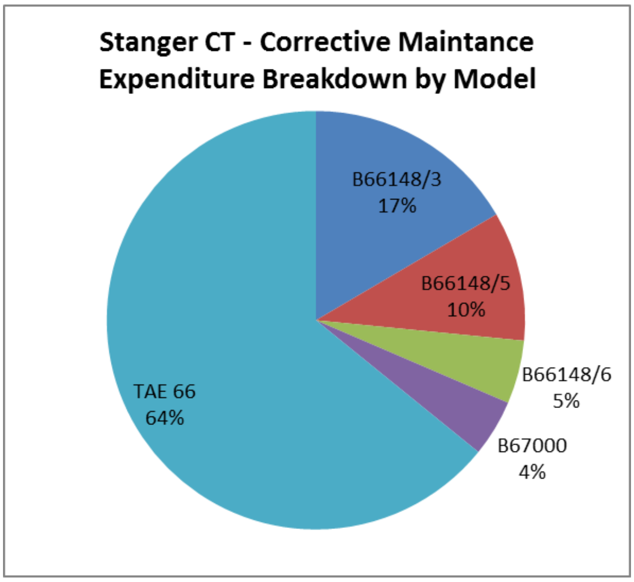


Figure 21: Stanger CT Corrective Maintenance Quantity and Expenditure

Action 6.2-1: Investigate the requirement for a proactive replacement program for Stanger TAE 66kV CTs due to systemic defects associated with the asset population.

6.3 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 particular procedures to be undertaken in addition to the usual safety mitigations associated with a task being performed.

The network investment undertaken in the Northern and Southern Regions in recent history has been directed towards managing the safety risks in the overhead distribution network due to the greater exposure to customers and the broader community. These programs have included defect management, small copper conductor replacement, and remediation of clearance to ground and clearance to structure issues. During this period of focus on the distribution network, risks in substations were managed through the NAR processes resulting in an increasing number of restrictions across sites.

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.

Action 6.3-1: Increase the volume of substation asset replacement in the Northern and Southern Region to address the existing Network Access Restrictions, and to deliver a long term sustainable program of replacement where assets are removed from the network prior to requiring a network access restriction to be imposed due to the condition.

7 Emerging Issues

No emerging issues have been identified for this asset class. EQL will continue to monitor the performance of this class to ensure any future issues are identified.

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 Northern and Southern region 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 South East region 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.

Action 8.1-1: Review the design standards for CVTs to include the establishment of online voltage monitoring as an individual asset alarm as standard functionality.

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 Historical Failure Data

There is a disparity between asset records being kept in the Northern and Southern regions and the South East region. Historical data capture practices restrict the ability to analyse the data associated with this asset class without substantial manual effort and offers significant potential for improved asset management.

Legacy organisation Ergon Energy developed and implemented a recording system for all failures, incorporating a requirement to record the asset component (object) that failed, the damage found, and the cause of the failure using the Maintenance Strategy Support System (MSSS) in Ellipse; the current Enterprise Asset Management (EAM) System. Energex maintained records of transformer failures and causes in a separate database outside of corporate systems. EQL has adopted the MSSS approach and is building this system of record over time, providing the information necessary to support improvements in inspection and maintenance practices. There is an expectation that this will also support and influence standard design and procurement decisions. Alignment of failure and defect data capture across regions is required to take full advantage of the larger data set available across the state.

Action 9.2-1: Align and improve defect, failure, and dangerous electrical event data capture processes and reporting methodologies to ensure consistency across EQL.

9.2.2 Asset Condition Data

In order 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. In order 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.

Action 9.2-2: Incorporate asset condition data requirements in the new Enterprise Asset Management system being proposed for EQL, to ensure the accurate and efficient capture of data from the field including provision for online condition sensor information.

9.2.3 Asset Identifier

In the South East Region, instrument transformer attribute data is managed in Network Facility Management (NFM) which functions as the current asset register. An interface exists between NFM and the Enterprise Resource Planning system (Ellipse) that requires an asset to have a unique asset identifier in order for the interface to recognise a new asset and subsequently enable planned maintenance and testing programs to be scheduled in Ellipse. Issues identified with the existing data have been highlighted and are currently being proactively managed to ensure appropriate maintenance is undertaken and that the root cause of the data issues are addressed. The data issues are scheduled to be corrected by mid-2019.

9.3 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.

9.4 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 1for 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.

9.4.1 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 for specified asset types, problematic units, or based on previous condition results.

9.4.2 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.

9.4.3 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.

Action 9.4-1: Continue the development of the strategic spares approach for instrument transformers to ensure that network requirement and risk are balanced against the cost of holding spares.

9.5 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.

9.5.1 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.

9.5.2 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.

9.6 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.

11 Summary of Actions

The following provides a summary of the specific actions noted throughout this AMP for ease of reference.

Action 6.2-1: Investigate the requirement for a proactive replacement program for Stanger TAE 66kV CTs due to systemic defects associated with the asset population.

Action 6.3-1: Increase the volume of substation asset replacement in the Northern and Southern Region to address the existing Network Access Restrictions, and to deliver a long term sustainable program of replacement where assets are removed from the network prior to requiring a network access restriction to be imposed due to the condition.

Action 8.1-1: Review the design standards for CVTs to include the establishment of online voltage monitoring as an individual asset alarm as standard functionality.

Action 9.2-1: Align and improve defect, failure, and dangerous electrical event data capture processes and reporting methodologies to ensure consistency across EQL.

Action 9.2-2: Incorporate asset condition data requirements in the new Enterprise Asset Management system being proposed for EQL, to ensure the accurate and efficient capture of data from the field including provision for online condition sensor information.

Action 9.4-1: Continue the development of the strategic spares approach for instrument transformers to ensure that network requirement and risk are balanced against the cost of holding spares.

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.

Legacy organisation	Document Number	Title	Type
Ergon	STNW1127	Maintenance Standard for Free Standing Instrument Transformers	Standard Document
Energex	STD01115	Maintenance Standard for Free Standing Instrument Transformers	Standard Document
Energex		Substation Defect Classification Manual	Manual
Ergon		Substation Defect Classification Manual	Manual
Ergon	PRNG003	Protocol for Strategic Spares Management	Protocol Document
Energex	00652	Asbestos Management Plan Standard	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
AIDM	Asset Inspection & Defect Management system
AMP	Asset Management Plan
Augex	Augmentation Expenditure
CBRM	Condition Based Risk Management
CB	Circuit Breaker
CT	Current Transformer
CVT	Capacitor Voltage Transformer
DEE	Dangerous Electrical Event
DGA	Dissolved Gas Analysis
DLA	Dielectric Loss Angle
EQL	EQL Limited
ESCOP	Electricity Safety Code of Practice
ESR	Queensland Electrical Safety Regulation (2013)
IoT	Internet of Things
ISCA	In-Service Condition Assessment
LDCM	Lines Defect Classification Manual
LV	Low Voltage
MU	Metering Unit
MVAr	Mega-VAr, unit of reactive power
NER	Neutral Earthing Resistor
NEX	Neutral Earthing Reactor
OLTC	On-load tap -changers
OTI	Oil Temperature Indicators
PCB	Polychlorinated Biphenyls
POC	Point of Connection (between EQL assets and customer assets)
POEL	Privately owned Electric Line
PRD	Pressure Relief Device
QLD	Queensland
REPEX	Renewal Expenditure
RIN	Regulatory Information Notice
RMU	Ring Main Unit
SCAMS	Substation Contingency Asset Management System

Abbreviation or acronym	Definition
SDCM	Substation Defect Classification Manual
SHI	Security and Hazard Inspection
SM	Small
SVC	Static VAR Compensator
VT	Voltage Transformer
WCP	Water Content of Paper
WTI	Winding Temperature Indicators
WTP	Wet Transformer Profile