Asset Management Plan Distribution Transformers 2020-25

January 2019

Part of the Energy Queensland Group

Executive Summary

This Asset Management Plan (AMP) covers the class of assets relating to distribution transformers, including distribution regulators and reactors, and substation earthing and service transformers.

These assets are low rating devices located across the network and typically managed via a run to near failure asset strategy.

EQL manages over 155,000 distribution transformers regulators and reactors, comprising around 101,000 units in the Northern and Southern regions and 54,000 units in the South East Region.

There are no specific performance targets dedicated to this asset class. Overall asset population performance is evaluated as part of the general organisation obligations for reliability (minimum service standard (MSS)), and annual dangerous electrical event (DEE) incidents.

Distribution transformers, regulators, and reactors represent approximately 10% of the total replacement value of the EQL’s network asset inventory. This AMP details a range of management strategies consistent with the volumes and value of these assets. Factors influencing prudent management of this asset class include public safety, the large, geographically dispersed population, assessed condition, various historical design standards, and diverse environmental and operational conditions.

EQL is also considering line refurbishment strategies to gain works efficiencies across multiple asset classes, including poles and towers, conductors, distribution transformers and other pole top hardware refurbishment.

EQL is actively working to align data collection and record systems relating to distribution transformers, reactors, and regulators across all regions, employing the best and most suitable systems from both legacy organisations. EQL continues to improve safety and the cost effective management of these assets through use of and continuous improvement of the inspection and analysis techniques (such as LiDAR, imagery and predictive analytics), optimal delivery models/techniques and industry best practice management.

Document Tracking Details

Network and Non-Network Document Hierarchy Reference Number	Regulatory Proposal Chapter Reference	Document	File Name
NET AMP - 006	7.032	Asset Management Plan - Distribution Transformers	EGX ERG 7.032 Asset Management Plan - Distribution 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

This plan details a plan for the responsible and sustainable asset management of distribution transformers, regulators and reactors 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 EQLderives 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).*
- *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.

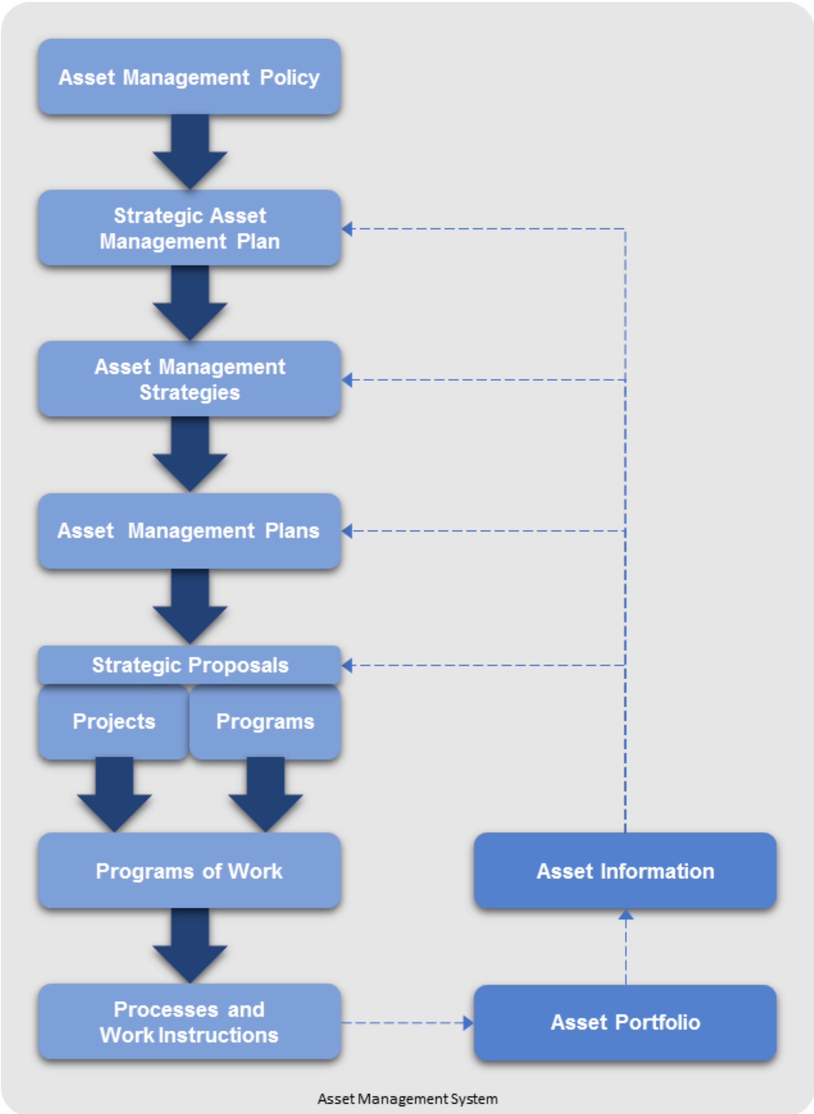

Figure 1: EQL Asset Management System

1.2 Scope

This Asset Management Plan covers the following assets:

- Distribution transformers, including padmount transformers.
- Distribution single wire earth return (SWER) isolation transformers.
- Distribution regulators.
- Distribution reactors.
- Substation earthing transformers.
- Substation service transformers.

Many customers, typically those with high voltage connections, own and manage their own network assets including overhead conductors 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 Value

The assets covered by this AMP are relatively high volume low cost assets and are typically managed on an asset population basis through periodic inspection for condition and serviceability. Based on asset quantities and replacement costs, EQL distribution transformers have an undepreciated replacement value of approximately $4.9 billion. Figure 2 provides an indication of the relative financial value of EQL distribution transformers compared to other asset classes.

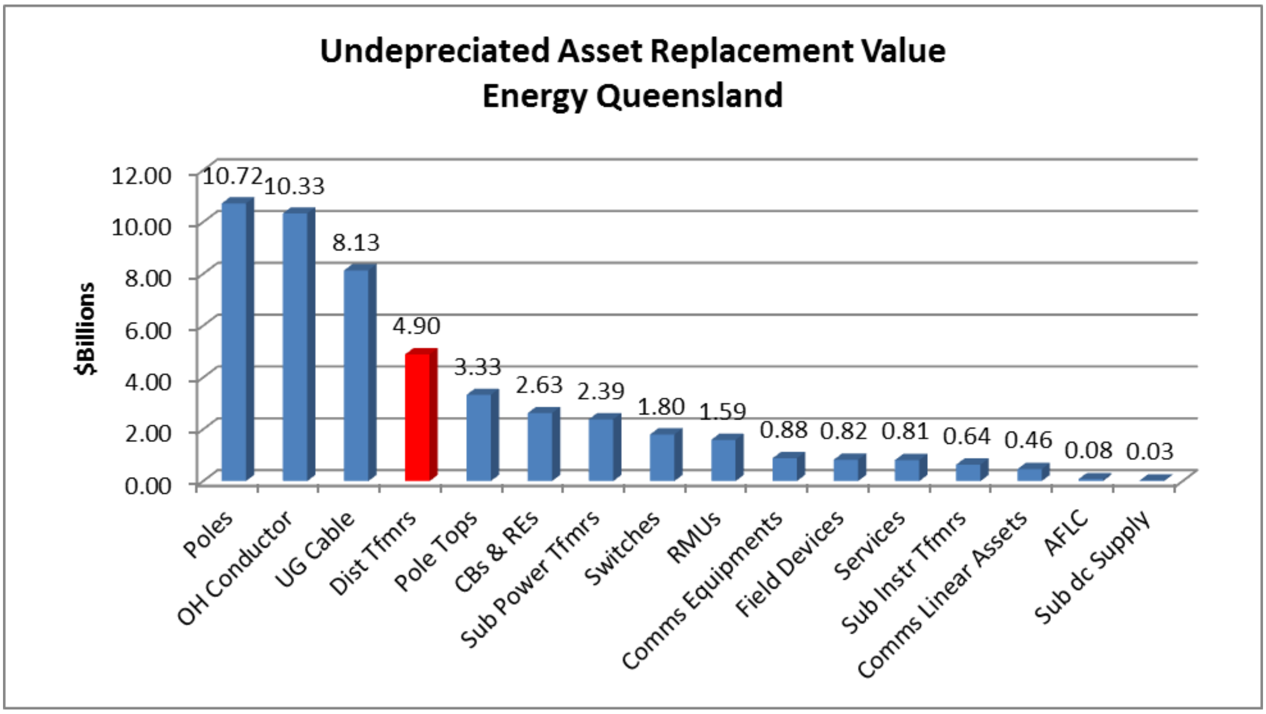

Figure 2: EQL – Total Current Asset Replacement Value

1.4 Asset Function and Strategic Alignment

Transformers, regulators, and reactors are essential components of electrical networks as they allow for the use of cost-effective infrastructure to achieve efficient transportation of electricity across large distances.

Transformers are a geographically distributed asset class, located in all terrains and environments, in substations, public buildings, and private buildings, and in high traffic areas as well as remote rural areas. Transformers typically provide system earth reference points for sections of the electrical network.

Failure of any transformer, regulator, or reactor to perform its designed function can result in negative impacts to EQL's objectives related to safety, delivery, customer, or legislative compliance.

Table 1 details how distribution transformers, reactors and regulators contribute to the corporate strategic asset management objectives.

Asset Management Objectives	Relationship of Asset to Asset Management Objectives
Ensure network safety for staff, contractors and the community	Diligent and consistent inspection, maintenance and renewal support asset performance and hence safety for all stakeholders.
Meet customer and stakeholder expectations	Continued asset serviceability supports network reliability and promotes delivery of a standard quality electrical energy service at optimal cost.
Manage risks, performance standards and asset investment to deliver balanced commercial outcomes	Failure of this asset can result in a public safety risk, disruption of the electricity network, and disruption of customer amenity. Understanding asset performance allows optimal investment to achieve intended outcomes. 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 AS ISO55000 objectives and drives asset management capability by promoting continuous and targeted improvement.
Modernise the network and facilitate access to innovative energy technologies	This AMP promotes the replacement of assets 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 Finance Officer
Asset Operational Delivery	EGM Distribution
Asset Manager	EGM Strategy Asset Safety & Performance

Table 2: Stakeholders

2 Asset Class Information

The following sections provide a summary of the key functions and attributes of the assets covered in this AMP.

2.1 Asset Description

The assets covered under the scoped of this Asset Management Plan perform a variety of functions including voltage conversion, voltage regulation, reactive load management and earthing. These assets typically contain oil which is used as the insulation medium in conjunction with paper wrapping around the internal windings however dry-type distribution transformers are in use in applications where oil presents a fire risk (e.g. inside basements of commercial and residential buildings). While the functions performed within this class are varied, the overall asset management approach is the same due to the similar construction, criticality, costs and risks presented by the assets which are included. The following sections provide more detail on each of the asset types.

2.1.1 Distribution power transformers

A distribution transformer is a power transformer located outside of a zone substation, often at the top of a pole. Larger units are ground/floor mounted, with some located within buildings.

Distribution transformers reduce high voltage distribution voltages (typically 6.6kV, 11kV, 12.7kV, 19.1kV 22kV and 33kV) to household voltages (typically 240V or 415V).

Distribution transformers are protected by a set of HV fuses, a set of HV surge diverters, and a set of low voltage (LV) surge diverters, all mounted in the immediate vicinity of the transformer. In the last few years, LV fuses have also become part of standard design. Many transformers are now fitted with LV fuses and programs are in place to fit all transformers with them.

Padmount transformers are ground-mounted distribution transformers, usually integrated with a set of three HV switches in a Ring Main Unit (RMU), arranged with a set of transformer HV fuses in the centre switch, and also a small LV switchboard fitted with LV circuit fuses or circuit breakers.

Distribution transformers used in the EQL network do not use on-load tap changers (OLTC) to control the voltage; they are fixed tap units where the transformation ratio is selected from the available range during commissioning based on network requirements. The ratio can be changed by changing the tap position manually while the transformer is not under load.

2.1.2 Distribution regulators

Regulators are a special class of power transformer usually with the primary and tapping winding designed for the same nominal voltage. An on-load tap changer (OLTC) is used to regulate the output voltage to a fixed tolerance output.

Single phase distribution regulators are usually employed to boost (increase) or buck (decrease) voltages on very long distribution SWER lines.

In three-phase systems, two-phase (or two tanks) distribution regulators are typically used to correct interphase voltage imbalance, with the individual phase tap positions controlled separately. Three phase (or three tanks) units control all three-phase voltages, providing overall voltage boost or buck control and also interphase voltage imbalance, with suitable regulator configurations to achieve this control.

Legacy organisation Ergon Energy introduced low voltage regulators (LVRs) around 2006, to improve voltage management on SWER. LVRs are now also commonly used across Northern and Southern Regions to solve common problems such as flickering and excessive voltage, as well as maintain standard-compliant voltage at the point of delivery.

2.1.3 SWER isolation transformers

An isolation transformer is used to isolate earth currents (due to faults or load imbalance) in a secondary electrical network from the primary electrical network.

A SWER system is designed to transmit power over very long distances economically using a single wire. The electrical return path of the circuit is through the ground.

A SWER Isolation Transformer isolates the primary three-phase system from the SWER return path earth currents. This allows for more precise operational protection of the three-phase system as the SWER earth return currents are reflected as normal load current in the three phase network. It also allows sensitive earth fault protection to be appropriately configured in the primary network, promoting a safer network performance overall.

2.1.4 Pole mounted reactors

Reactors are typically of similar construction and design to a transformer and introduce inductive impedance in an electrical circuit. This can be used to substantially lower voltage (shunt reactor), or limit fault current (series reactor), as well as absorb/limit harmonics.

The function of a pole mounted reactor is to stabilize and reduce the system voltage, due to excessively capacitive, lightly loaded powerlines, to allow the system to operate within its design and regulatory envelopes and meet customer expectations for voltage stability.

They are mostly found in SWER systems of long route length.

2.1.5 Substation earthing transformers

An earthing transformer is used to introduce additional impedance into a network earth reference connection point to reduce earth fault and load imbalance currents to a manageable level. It is also used to provide an earth reference point where the source supply does not have one; typically in a delta connected winding.

Generator step-up power transformers typically have the LV winding in star or delta configuration and the HV winding in star configuration. When these transformers are re-used for distribution applications (as step-down transformers), a low voltage delta connected side requires an earthing transformer to provide a start point and earth reference. This situation occurs at various locations in Northern and Southern regions.

2.1.6 Substation service transformers

Substation service transformers are effectively distribution transformers that perform two important functions:

- Supply of all power required for lighting, AC and DC systems, maintenance facilities, and functions within a substation

- Isolation and separation of local substation supply from external sources of supply, to prevent earth potential rise voltage transfer between substation and external facilities.

2.2 Asset Quantity and Physical Distribution

The following sections describe the quantities and physical distribution of distribution transformers and related ancillary assets within the EQL asset base as covered in this AMP.

2.2.1 Distribution Transformers

Table 3 data shows the population of distribution transformers.

Region	Ground mounted	Pad-mounted	Pole mounted 1 Phase	Pole Mounted 3 Phase	Total
Northern and Southern	46	7,929	40,123	53,498	101,596
South East	3,744	11,939	5,780	28,279	49,742
Total	3,790	19,868	45,903	81,777	151,338

Table 3: Distribution transformer population

2.2.2 SWER isolation transformers

Table 4 shows the population of pole mounted SWER isolating transformers.

Region	Quantity
Northern and Southern	728
South East	2
Total	730

Table 4: SWER Isolation transformer population

2.2.3 Pole mounted reactors

Quantity data for pole mounted reactors is unavailable as it has not historically been captured.

2.2.4 Pole mounted regulators

Table 5 shows the population of distribution regulators. There is typically more than one regulator tank at a non-SWER HV site.

In Northern and Southern Regions, there are only 25kVA and 50kVA units installed.

Region	Quantity
Northern and Southern	921
South East	455
Grand Total	1376

Table 5: Pole mounted regulator population

2.2.5 Substation earthing transformers

Table 6 details the number of earthing transformers.

Region	Quantity
Northern and Southern	39
South East	111
Total	150

Table 6: Earthing transformer population

2.2.6 Substation services transformers

Table 7 details the number of earthing transformers.

Region	Quantity
Northern and Southern	444
South East	314
Total	758

Table 7: Station services transformer population

2.3 Asset Age Distribution

The following sections detail the age distribution of the asset populations covered in this AMP, across the Northern and Southern regions, and the South East region.

2.3.1 Distribution Transformers

Figure 3 and Figure 4 show the age profile of distribution transformers in Northern and Southern regions and South East region. The average age at failure of distribution transformers is 45-50 years. details the age profile of distribution transformers in South East region.

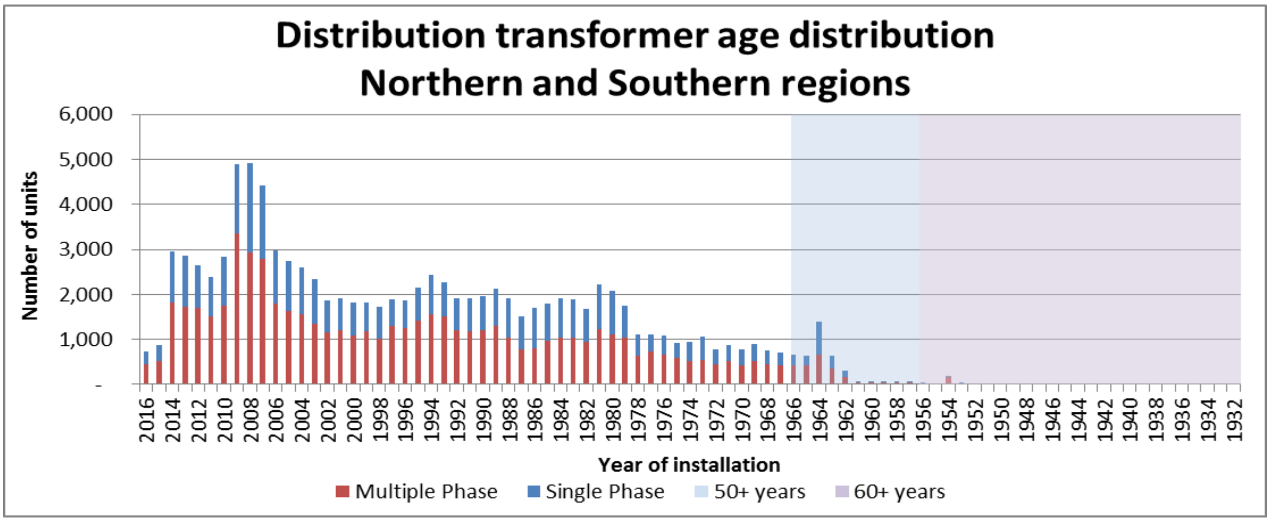

Figure 3: Distribution transformer age profile – Northern and Southern regions

The profile reflects the rural electrification of country Queensland which commenced in the 1950s as a Queensland Government initiative, and two major expenditure periods in 1960-1980 and 1980-mid 1990s during which the SWER networks were developed. Transformer size standardisation practices in the 1990s the past mean that many rural and remote rural transformers are lightly loaded and relatively long lived. More than 4,000 distribution transformers are older than 50 years.

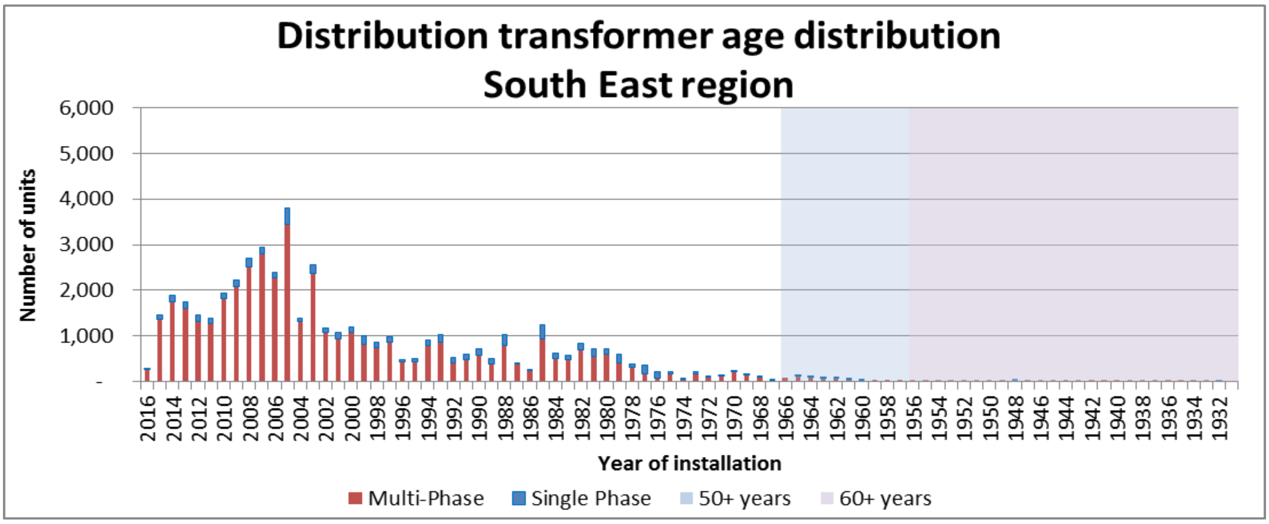

Figure 4: Distribution transformer age profile – South East region

The South East Region age profile reflects a burgeoning network, with network expansion as the greater Brisbane, Gold Coast, and Sunshine Coast regions experienced steady population growth over the last 50 years, and an increasing per capita usage of energy over the same period. Around 700 distribution transformers are older than 50 years.

2.3.2 Distribution regulators

There is no age profile data for distribution regulators in Northern and Southern Regions due to legacy organisation data capture practices. Figure 5 details the age profile of distribution regulators in South East Region.

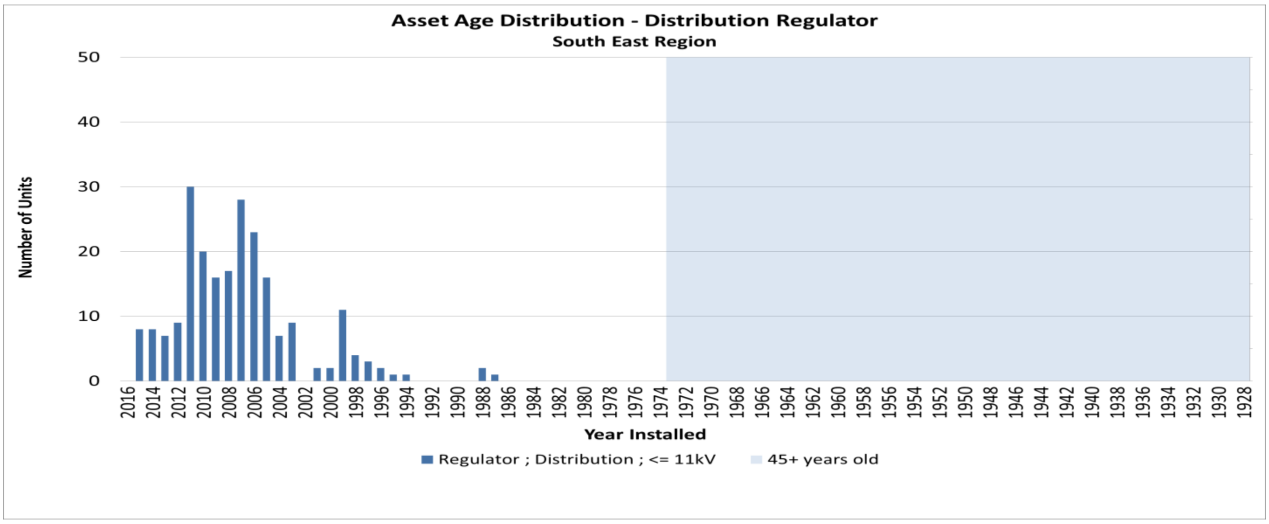

Figure 5: Distribution regulator age profile – South East Region

2.3.3 SWER isolation transformers

There is no age profile data available for this asset type due to legacy organisation data capture practices.

2.3.4 Pole mounted reactors

There is no age profile data available for this asset type due to legacy organisation data capture practices.

2.3.5 Substation earthing transformers

Figure 6 details the age profile of earthing transformers in the Northern and Southern Regions.

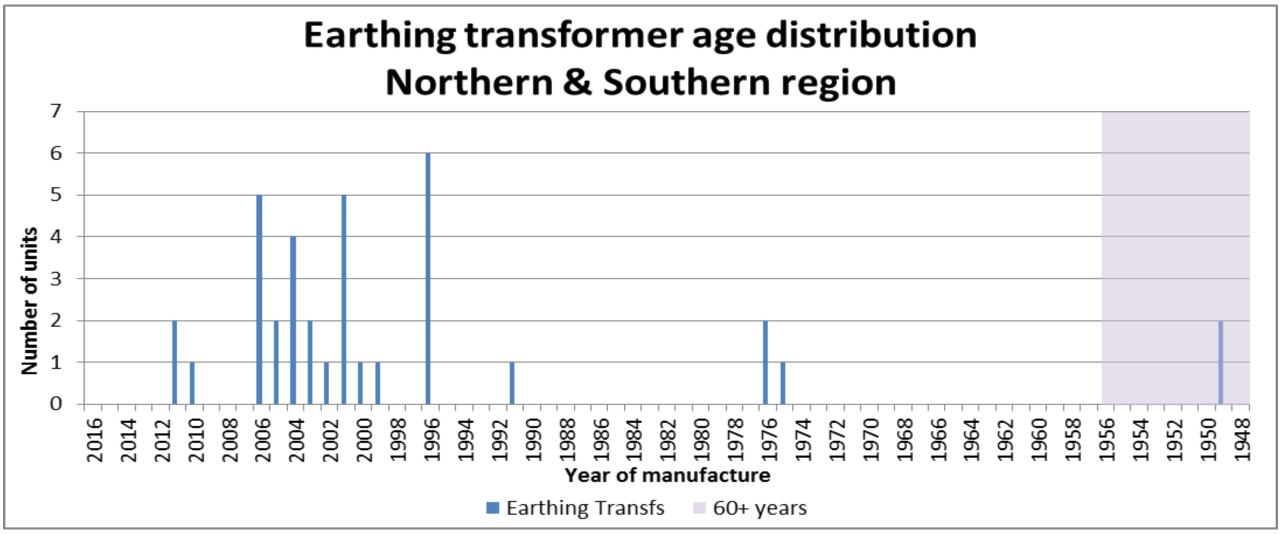

Figure 6: Earthing transformer age profile – Northern and Southern Regions

Figure 7 details the age profile of earthing transformers in the South East Region.

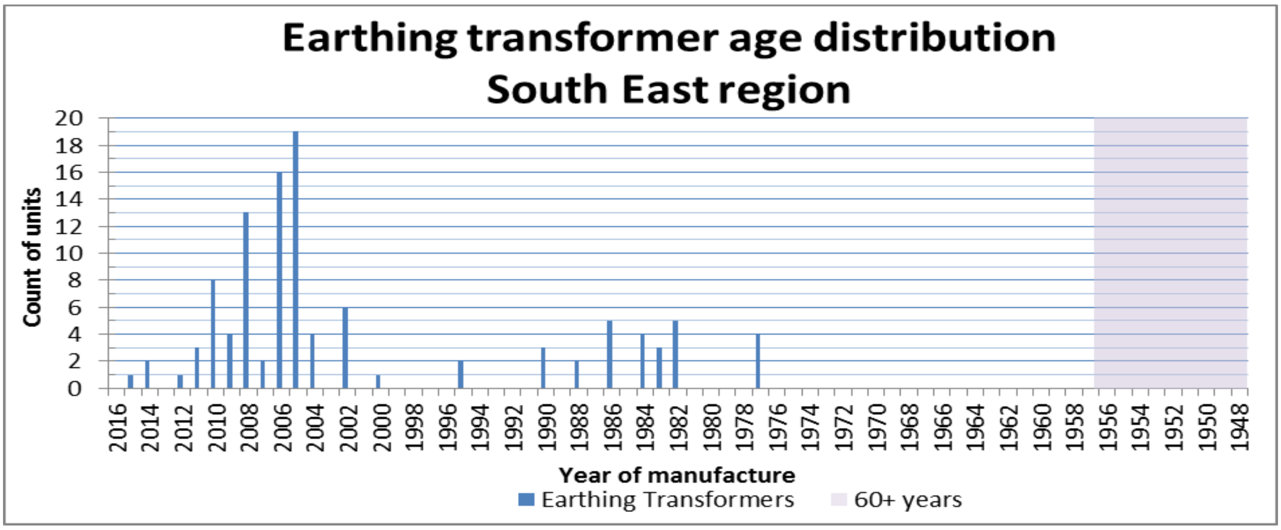

Figure 7: Earthing transformer age profile – South East region

2.3.6 Substation services transformers

Figure 8 details the age profile of substation services transformers in Northern and Southern Regions.

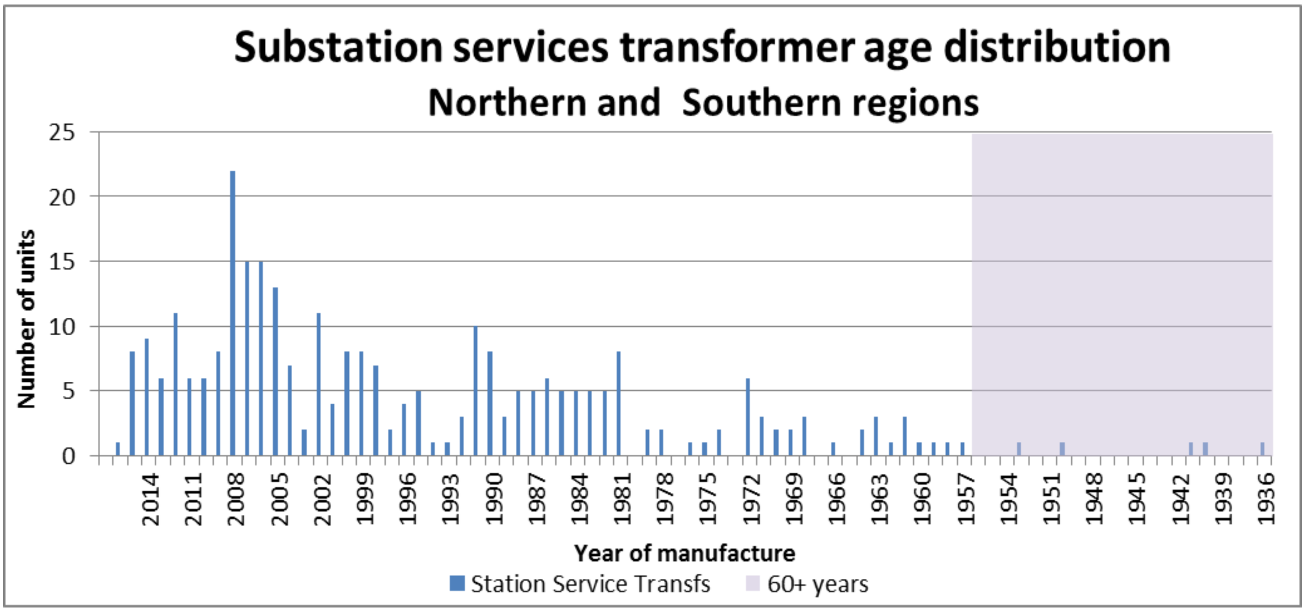

Figure 8: Substation services transformer age profile – Northern & Southern Region

Figure 9 shows the age profile of the substation services transformers in the South East Region.

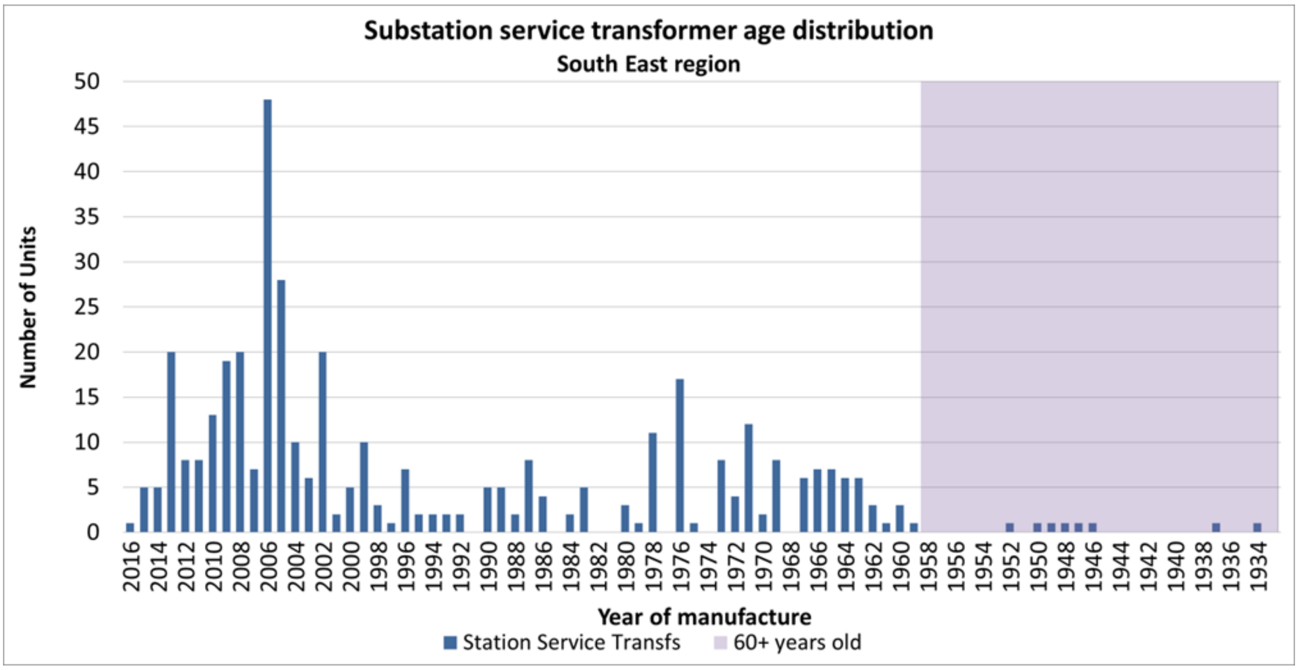

Figure 9: Substation services transformer age profile – South East Region

2.4 Population Trends

System peak load is not substantially increasing across the EQL supply area. The number of distribution transformers is increasing only with new suburb developments, which tend to have underground reticulation, leading to the installation of padmount transformers.

The role of distribution regulators is changing as the penetration of distributed generation systems (e.g. solar systems) occurs. This is creating and an increasingly complex voltage management equation for EQL. Low voltage capacitors and reactors allow fine voltage control close to load and embedded generation sources. It is anticipated that these LV active regulators will become increasing prevalent, although there are currently insufficient installations to form an opinion about forecast future volumes.

The number of SWER isolation transformers is virtually constant as the cost of alternative energy sources has fallen substantially. There are no new SWER systems being developed.

The number of substation earthing transformers remains relatively constant. There are very few new zone substations forecast to be built across EQL over the next few years, due to low load growth.

2.5 Asset Life Limiting Factors

Manufacturers typically design transformers and regulators in line with Australian and international standards. Design life of insulation is typically of the order of 30 years based upon continuous and very high load application. EQL transformers and regulators are usually operated according to daily and seasonal cyclic loading patterns, and therefore most EQL transformers and regulators would operate at very high design load conditions less than 10% of the time. This has the effect of extending asset lives well beyond the design life expectations. This pattern of cyclic loading is changing as more distributed energy resources are employed across the network.

Table 8 describes the key factors that influence the life of the assets covered by this AMP, and as a result, have a significant bearing on the programs of work implemented to manage the lifecycle.

Factor	Influence	Impact
Age	Gradual deterioration of materials and components used in construction; particularly the oil, paper insulation, gaskets, and bushings.	Reduction in useful life.
Environment	Outdoor, corrosive or coastal environments result in degradation of the physical asset and components; particularly the tank, bushings, gaskets, and instrumentation.	Reduction in useful life and component failure.
Loading	Heating of the winding resulting in degradation of the paper insulation. Loading above rating can lead to very rapid deterioration.	Accelerated ageing leading to a reduction in useful life. Internal fault leading to failure (potentially catastrophic).
Fault (inc Lightning)	Electrical and mechanical stress on internal windings leading to physical damage.	Internal fault leading to failure (potentially catastrophic)
Moisture	Degradation of paper insulation and oil. Combined with heat, even at low loadings, can result in bubble inception.	Accelerated ageing leading to a reduction in useful life. Internal fault leading to failure (potentially catastrophic).

Table 8: 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, and if not able to be eliminated, mitigated so far as is reasonably practicable. 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 differing 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 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.

Assets of this class are managed by population trends, inspected regularly and allowed to operate as close as practical to end of life before replacement. End of asset life will be determined by reference to the benchmark standards defined in the Defect Classification Manuals and or Maintenance Acceptability Criteria. Replacement work practices will be optimised to achieve bulk replacement to minimise overall replacement cost and customer impact.

3.2 Legislative Requirements

These assets are not specifically referenced in legislation, and therefore are expected to achieve the 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.

It is clear from the legislated requirements above that there is an intention to ensure inspection is undertaken at some reasonable periodic intervals. EQL adopts an approach that the nature of the inspection and the interval are defined by engineering judgement, taking into account overall safety and performance obligations.

Dangerous electrical events (DEEs) are defined in legislation[1]. DEEs are typically circumstances involving a high voltage asset, where a person's electrical safety would have been compromised had they been exposed to the event. EQL assigns DEES into two categories as follows:

- Unassisted DEEs – incidents where the root cause may have been preventable via a maintenance program (e.g. corrosion)
- Assisted DEEs – incidents where the root cause of failure occurs outside the control of any maintenance program (e.g. lightning strike).

3.3 Performance Requirements

There are no specific business targets specifically relating to distribution transformers, regulator, or reactor failures, nor maximum business levels for safety incidents arising from these failures.

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 increased 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)
- System Average Interruption Frequency Index (SAIFI).

[1] Queensland Electrical Safety Act 2002, s12

Distribution transformer, regulator, and reactor failures typically have low impact upon SAIDI and SAIFI. Earthing transformers form part of substation transformer operation, and overall performance is generally overshadowed by the typically lower reliability performance of the substation power transformers.

Safety Net measures are intended to mitigate against the risk of low probability high consequence network outages. 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.

Both Safety Net and MSS performance information is publicly reported annually in the Distribution Annual Planning Reports (DAPR). MSS Performance is monitored and reported within EQL daily.

DEEs are generally reviewed for severity on an individual basis, with response and investigation driven by severity of incident. DEE volumes are reported monthly. There are no specific targets for DEEs other than a general intent to minimise the quantities.

3.4 Current Level of Service

The distribution transformer/regulator/reactor and substation services/earthing transformer are expected to safely achieve its function all day every day for many years (typically 40-60 years).

In 2016-17, EQL exceeded its Safety Net and MSS performance standards[2].

With a geographically distributed network, the prescribed (legislated) performance standards can be adversely impacted by poor performance of individual assets in individual subsections of the network. EQL's realised level of service is therefore directly related to asset population condition and performance.

Distribution transformers, regulators, and reactors and substation and services transformers are typically too small for failures to impact Safety Net performance standards. Cumulative impact of failures impacts MSS performance. Substation earthing transformer failures impact the overall substation power transformer reliability, but due to their overall quantity, and the fact they are completely static devices, have little practical influence upon MSS performance.

EQL manages over 150,000 distribution transformers, regulators and reactors across Queensland. Because of this high volume, these assets are managed on a population basis rather than on an individual basis.

All distribution transformers, regulators, and reactors are periodically inspected, consistent with the ESCOP-Works. Due to differing legacy organisation interpretations of the ESCOP–Works documents, there are differences in inspection expectations and repair timing expectations between the Northern and Southern Regions, and the South East Region.

EQL does not routinely monitor and record detailed condition information for each distribution transformer, regulator, or reactor. Records are kept of basic nameplate information (brand, capacity, year of manufacture), time and date of each inspection, any defects identified, and any defects repaired.

Figure 10 details the number of actual failures of distribution transformers, excluding failures caused by external influences such as storms or third parties. This represents an actual failure rate of 0.67% per annum in the Northern and Southern Regions and 0.14% per annum in the South East Region.

[5] Ergon Energy Distribution Annual Planning Report 2017-18 to 2021-22 and Energex Distribution Annual Planning Report 2017-18 to 2021-22

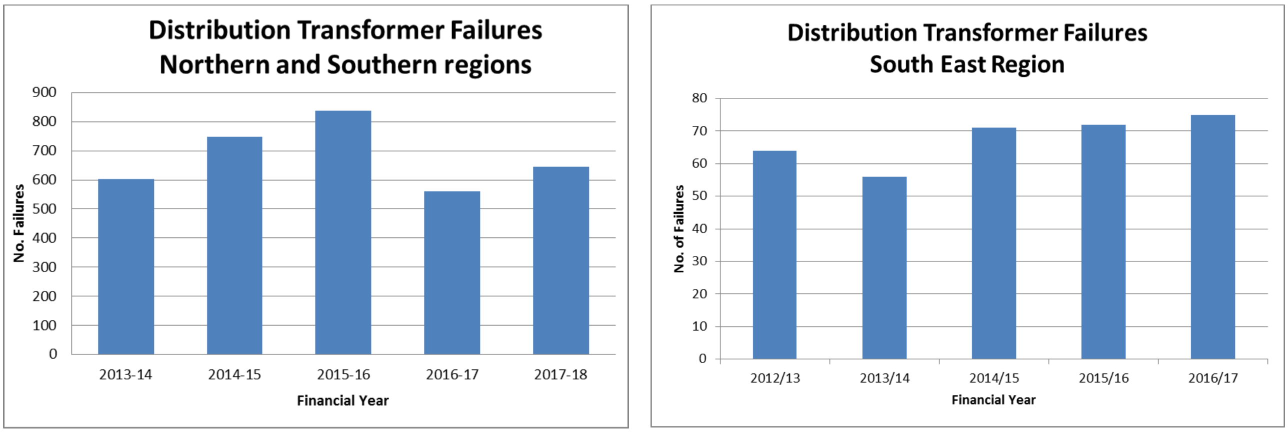

Figure 10: Distribution transformer failures

The contribution of distribution transformers and regulators to the overall volumes of DEEs recorded in either region is very small. In the period between 1 July 2013 and 31 December 2017 approximately 0.4% of the total DEEs in the Northern and Southern region, and approximately 1.1% of the DEEs in the South East region were associated with this asset class. The causes of the recorded DEEs are outlined below.

Northern and Southern Region:

- Four were related to padmount transformers – one due to explosive failure, and three due to vandalism
- Ten were related to theft of copper earth leads from distribution transformers
- Six were related to earthing issues of distribution transformers – two due to earths being dug up and four due to high resistance issues

South East Region:

- Seven were related to padmount transformers – two due to explosive failure of a dry-type transformer, five due to padmount doors being unsecured.
- Two were related to theft of copper earth leads from distribution transformers.
- Nine were related to related to earthing issues of distribution transformers.

The condition of substation earthing transformers is tested due to their impact upon substation performance, but they are still typically operated to near-failure before replacing. There are no recorded DEE events associated with earthing transformers or substation service transformers.

Figure 11 and Figure 12 detail the historical trend of defect replacement and refurbishment works that have been conducted on these assets. The trend is normalised against the asset population in each region to provide a relative performance indication. The P0, P1, and P2 classifications relate to priority of work required, which effectively dictates whether normal planning processes are employed (P2), or more urgent repair works are initiated (P1 and P0). Due to the run-to-failure strategy employed, the defects recorded result in transformer replacement.

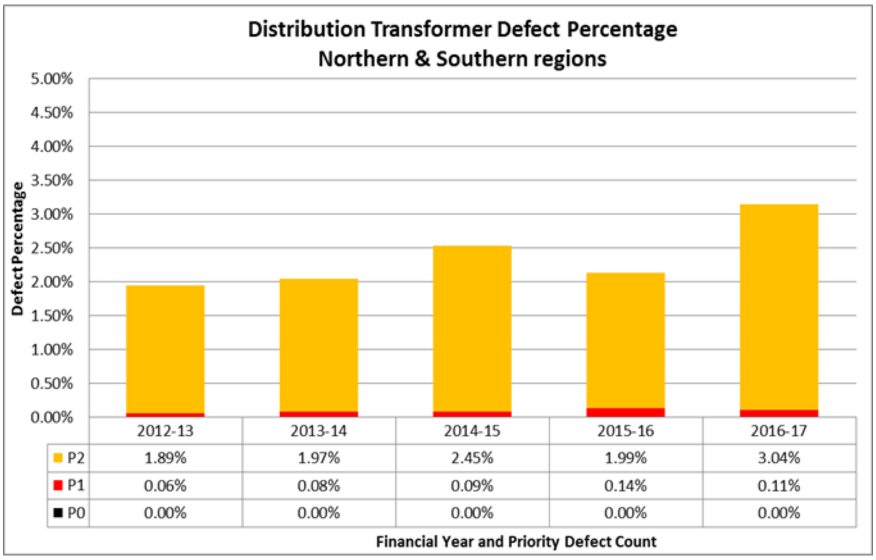

Figure 11: Distribution transformer defect performance – Northern and Southern Region

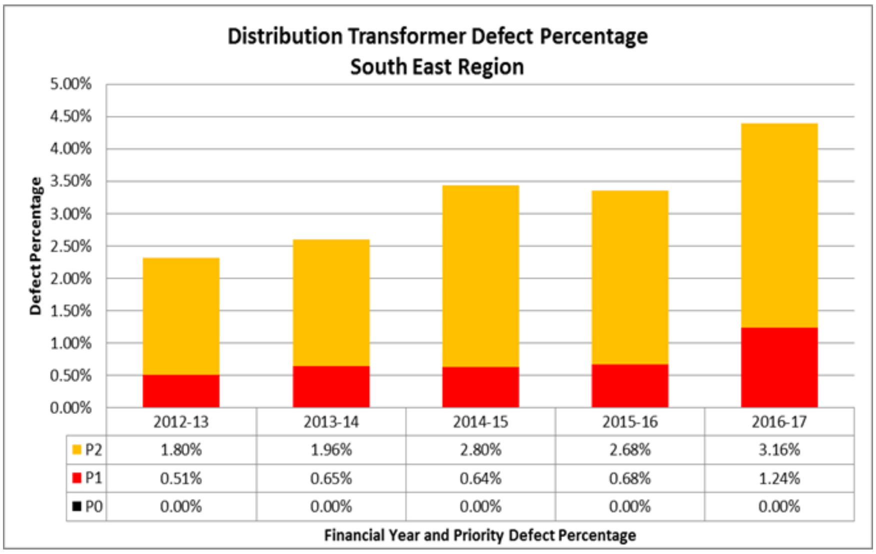

Figure 12: Distribution Transformer defect performance – South East Region

The historical data currently available in the Northern and Southern regions has been improved by several years implementation of Maintenance Strategy Support System (MSSS) history records. This allows for further breakdown of the defect damage, as detailed in Figure 13.

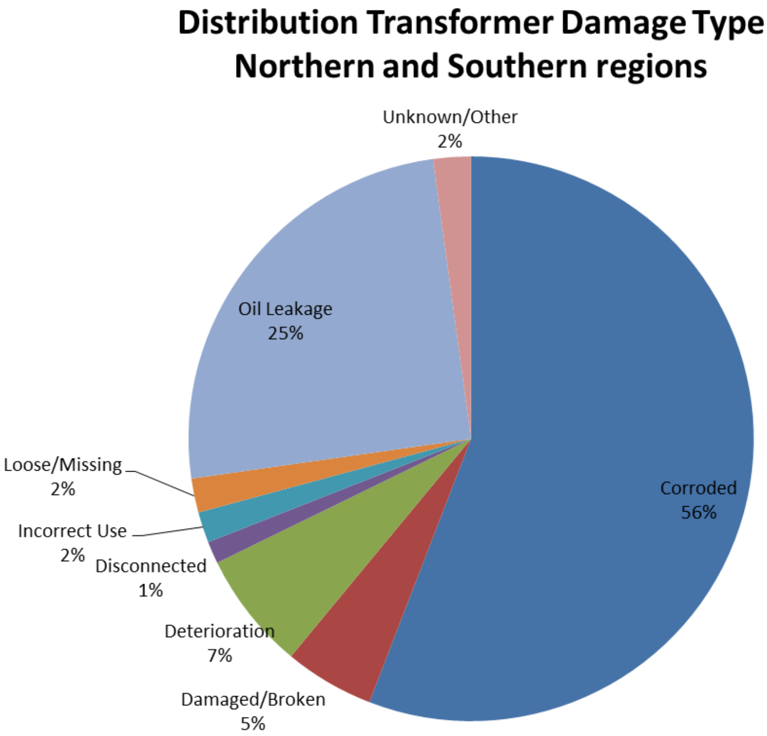

Figure 13: Distribution Transformer damage type – Northern and Southern Regions

Figure 13 reflects that corrosion and loss of oil are the main reasons for replacement of distribution transformers, supporting the asset management strategy approach.

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 to eliminate safety related risks, and where it is not possible to eliminate these risks, to mitigate them as far as is reasonably practicable. Risks in all other categories are managed to levels as low as reasonably practicable.

Figure 14 presents a threat-barrier diagram for EQL distribution transformer assets. Many threats cannot be controlled (e.g. third-party damage), although EQL undertakes a number of actions to mitigate them so far as is reasonably practicable / as far as is reasonably practicable.

EQL's construction and design practices, which prevent public access, tend to eliminate most public safety risks associated with these assets. Use of HV and LV fusing as standard significantly limits potential for catastrophic failure.

Failure of a distribution transformer, regulator or reactor typically results in loss of supply or out-of-tolerance voltage supply to a customer.

Environmental risks are managed by periodic visual inspections.

The asset performance outcomes described in Section 3.4 detail EQL's achievements to date in respect of this safety duty. The following sections detail the ongoing asset management journey necessary to continue to achieve to high performance standards into the future. Action items are raised where relevant, detailing the specific actions that EQL will undertake as part of program delivery of this Asset Management Plan.

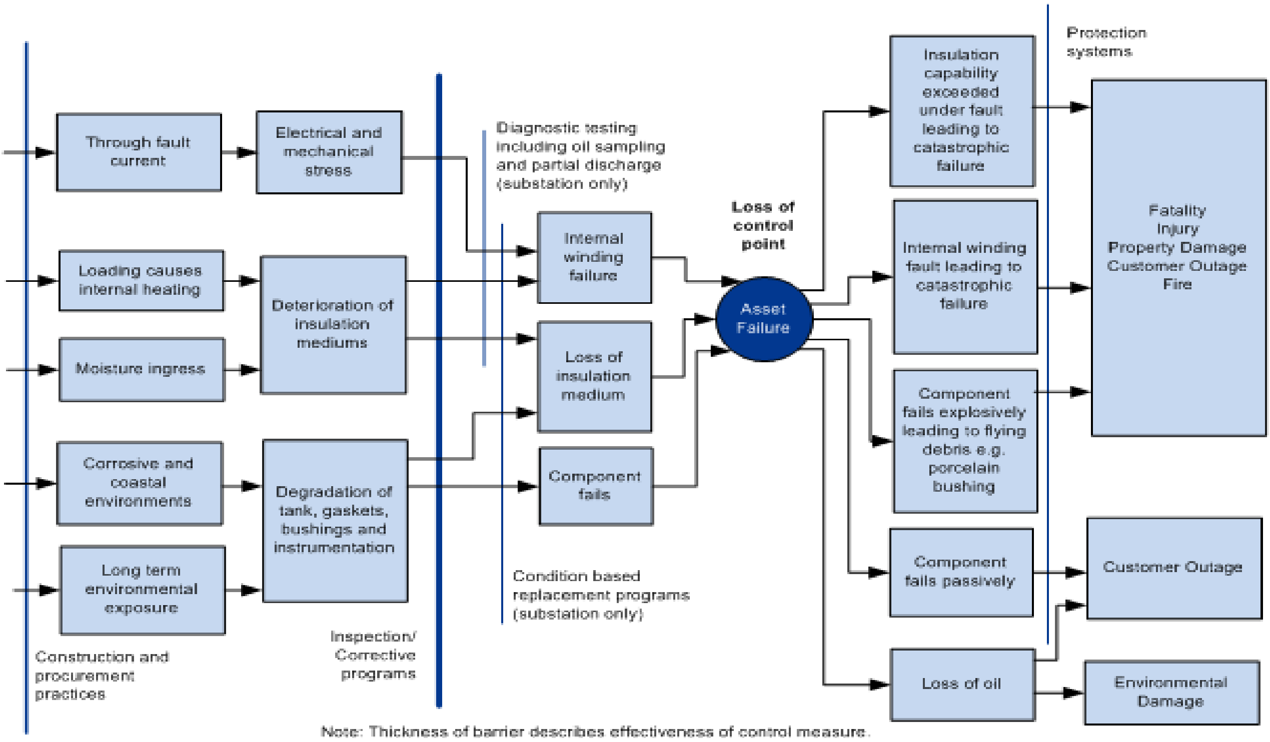

Figure 14: Threat-barrier diagram for distribution transformers, regulators and reactors

5 Health, Safety & Environment

Polychlorinated biphenyl chemicals (PCBs) were commonly used in transformer oils 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 bioaccumulate, 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.

EQL has more than 6,500 distribution transformers of an age where PCBs are likely to have been used.

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 PCB Contamination

Across the EQL distribution transformer asset population, there are over 6,500 distribution transformers of an age where PCBs are likely to have been used. Older transformers that contain PCBs may remain in-service and require additional maintenance and replacement precautions.

At the time of the disposal of a transformer, EQL confirms the level of PCB contamination to determine the appropriate disposal methodology in accordance with the Part 6 (Management of PCBs) of the Queensland Environmental Protection (Waste Management) Regulation 2000. Environmental Management of Fuel and Oil (ES000904R122) provides further detail.

Recovered transformer oil that is not PCB contaminated is stored, filtered, and reused for circuit breaker maintenance.

Procedures are in place to manage the HS&E risks and are considered effective.

6.2 SWER Earthing

SWER transformer poles carry "active earths". Active earths are conductors that run down the pole and connect the SWER transformer HV winding to the general mass of earth to complete the HV electrical circuit.

Failure of the active earth conductor can lead to situations where a high voltage energised asset is directly accessible by the public (above ground failure), or step and touch potential rise in the immediate vicinity of the pole (below ground failure), which can lead to shock or electrocution. While these situations are extremely rare, the most common root causes leading to the situation are trenching or grading/scrapping in the immediate vicinity of the pole (within 5m).

A strategy has been developed to apply a suitable hazard sign to the ~20,000 poles with active earths. Development and procurement of the sign is in progress. Subsequently, asset inspectors will be tasked with applying the signs as they inspect each site.

6.3 Noise

Some SWER pole mounted reactors are noisy, a feature attributed to their design and construction. Identified units are replaced, returned to stores, and subsequently returned to the manufacturer.

6.4 Pole Mounted Regulators

There have been issues with early life failures of a large number of relatively new assets due to corrosion in coastal environments. The technical specification has been revised to install stainless steel tank versions for coastal areas, and to use existing cast iron tank model units only in non-coastal (less corrosive) areas.

7 Emerging Issues

The following sections outline emerging issues which have been identified as having the potential to impact on EQL's ability to meet corporate objectives in the future.

7.1 Pole Mounted LV Regulator End of Life

Pole mounted LV regulators use electronic circuitry to regulate voltage. Manufacturer advice indicates that the electronics will only have a life of about 10 years, hence the LV regulators that started to be installed in 2007 are approaching the point where these electronics will begin to fail. At this time there is no methodology available to replace the electronics componentry alone in order to get the full service life out of the regulator. Should an alternative to replace the electronics not be feasible or cost effective, replacement of the LV regulator would be required.

It is recommended that the replacement of the electronic componentry in LV regulators be investigated to develop a prudent approach to extend the life of the assets.

Action 7.1-1: Develop a replacement strategy for the electronics componentry of the LV regulators to extend the life of the assets in service.

7.2 Changing Load Profiles

The useful life of a transformer is directly related to the loading which causes heating of the internal windings and degradation of the paper insulation. Historically, power flow has been in a single direction from generation to customer and load cycles have varied over the course of a 24 hour period as demand for electricity changed throughout the day. The cyclic loading allowed for transformers to run at higher load during shorter periods during which the useful life is used at a greater rate as this was compensated for during the lightly loaded periods.

While the prevalence of distributed energy resources such as solar PV, generation and batteries, the traditional power flow is changing and it is possible for load to flow in either direction. The result is that transformers are beginning to see a more continuous load cycle as they provide load to customers during periods of peak usage and then experience reverse power flow as the customer generation feeds back to the grid. This has a direct impact on the way transformers are rated and their potential useful life.

EQL is continuing to monitor the effects of distributed energy resources on load cycles and the impacts on the life of transformers to ensure the lifecycle of the assets is managed.

Action 7.2-1: Monitor the effects of distributed energy resources on load cycles and the resultant impacts on the useful life of transformers.

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 Biodegradable Oils

Biodegradable oils offer significant benefits over the currently used mineral oils. They offer the potential for reduced environmental harm after spillage and promote winding longevity by absorbing moisture from the paper insulation. Biodegradable transformer oil can be retrofitted to transformers previously filled with mineral oils, with the potential to substantially extend transformer life. This type of oil is used extensively in other countries, especially where very strict environmental laws apply.

Many of the same DGA diagnostic tests, currently used for mineral oil, are applicable to biodegradable oil.

Use of this oil could be beneficial for the environment, especially in locations where oil release into sensitive environments is possible (e.g. water courses, oceans etc.)

A trial use of biodegradable oil is currently underway to confirm the efficacy of biodegradable oils for Queensland tropical conditions.

Action 8.1-1: Monitor the biodegradable oil transformer trial, with a view to introducing biodegradable oils in distribution transformers.

8.2 Inspection Task Alignment Across Regions

While both legacy organisations employed a common set of standard processes and inspection defect benchmarks, the practical implementation of the inspection work across the organisations differed. This has developed as a result of variations in approach to use of contractors for tasks, contractual obligations, asset environments (e.g. CBD vs long rural), routine travel distances, and diversity of environments promoting a range of work practices and policy.

With the establishment of EQL, there is intent to merge these practices, policies and procedures were prudent, such as when contracts fall due and are renewed, and to actively pursue opportunities for common approach and service delivery where performance improvement opportunities arise.

Action 8.2-1: Review and align the inspection strategies and methodologies to ensure a common EQL approach and to maintain industry best practice management of distribution transformer assets.

8.3 Distribution Transformers Located in Buildings

Distribution transformers are typically run to near failure based on observed condition determined through inspection. Some distribution transformers, however, are located inside buildings and substations which present in increased level of risk in comparison to a typical unit. These units receive additional oil testing and dissolved gas analysis to monitor the condition. While access is restricted, catastrophic asset failure could lead to fire and potentially damage to the building and other assets. All units are protected by fuses or circuit breakers, and fire alarm and deluge systems are typically installed.

While programs are in place to manage this risk and no observations of increasing failure rates or issues have been observed, this risk has been identified as an area of focus to ensure it remains so far as is reasonably practicable. It is recommended that the performance and condition of distribution transformers located inside buildings and substations be reviewed to determine whether it is prudent to establish a proactive replacement program.

Action 8.3-1: Review the performance and condition of distribution transformers located inside buildings and substations to determine whether it is prudent to establish a proactive replacement program.

8.4 Future Network Implications

With the increase of distributed energy resources (DERs) within EQL distribution networks (e.g. solar PV generation and batteries), the role of distribution transformers is expected to change.

Virtually all distribution transformers operate on a fixed tap and have a much less expensive off-line tap changer. Voltage control downstream of the distribution transformer has traditionally been via the main substation transformers. As there is no automatic voltage regulation on distribution transformers, “reverse” power flow is easily accommodated. “Reverse flow”, is power flow from low voltage to high voltage, and occurs when the DER on the LV side generates more power than the load on the LV side.

Issues arising from this situation include:

- LV phase voltage imbalance, leading to a neutral displacement and potential increase in the number of reported shocks. There is some evidence of this situation already.
- Reverse power flow supported by battery sources increases the risk that a feeder fault, traditionally managed by de-energising with upstream devices, will continue to remain energised after traditional protection operation has occurred, increasing public safety risk.
- As most distribution transformers are delta connected on the HV side, reverse power flow supported by batteries has potential to create electrical sub-systems without earth reference, which may increase public safety risks and is contrary to legislation.

- The increasing amount of DERs will increase the amount of system harmonics absorbed by the distribution transformer and manifest as increased transformer temperature. This will effectively de-rate the distribution transformer for power flow in either direction.

The challenges associated with the growth of DER on the distribution network and the subsequent impact on the distribution assets are being monitored to develop understanding and ensure appropriate asset management strategies are put in place.

Action 8.4-1: Monitor the impacts of distributed energy resources on the distribution network assets to develop understanding and ensure appropriate asset management strategies are in place.

9 Lifecycle Strategies

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

9.1 Philosophy of Approach

EQL actively manages distribution transformers using a combination of condition based visual assessment and preventative maintenance tasks, which include:

- Periodic visual inspection of physical condition and immediate environment.
- Routine maintenance activities to ensure correct functionality.
- Earthing system integrity testing.
- Identified defects are resolved through the Corrective Maintenance Program.
- Failed assets are replaced under the Failed in Service Program.

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 and condition 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 large volumes of data associated with this asset class without substantial manual effort and offer 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 has historically relied on the manual assessment of distribution network outages to determine asset failure records. 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 Attribute Data

Historically, it was not considered cost-effective to record installation age for distribution transformers, reactors, or regulators. The advancement in technology, asset management discipline, and corporate external reporting imperatives have together acted to change this approach. The South East Region commenced recording the age of distribution transformers, reactors, and regulators in early 2016, and the Northern and Southern Regions have been recording service installation date for some time. The age and type of assets installed is expected to provide valuable asset management information once sufficient portions of the population are recorded.

Action 9.2-2: Incorporate asset data capture processes in the new Enterprise Asset Management system and mobile inspection platforms being proposed for EQL, to ensure adequate asset data is captured to inform asset management decisions and processes.

9.3 Acquisition and procurement

EQL's procurement policy and practices are detailed in Policy P011 – Sustainable Procurement Policy. These assets are procured on period contracts awarded through technical and commercial evaluation in line with Queensland Government's QTenders process.

The asset growth rate for pole mounted distribution transformers is driven mainly by augmentation and improvement and is forecast to be 1%.

There is little population growth currently forecast for ground-based distribution transformers.

The asset growth rate for padmount distribution transformers is driven mainly by augmentation and improvement and is forecast to be 1%.

The forecast asset growth rate for pole mounted HV regulators is 1%.

The forecast asset growth rate for pole mounted LV regulators is 5%. This is substantially driven by the spread and development of customer solar generation.

No population growth rate is forecast for pole mounted reactors.

Asset growth rate for SWER Isolation transformers is driven mainly by augmentation and improvement and is forecast to be 1%.

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 1 for reference.

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

9.4.1 Preventive maintenance

Preventive maintenance consists of inspection, testing, and routine maintenance activities as follows:

- In-Service Condition Assessment – periodic inspection of external condition and operational checks of ancillary equipment to identify defects. A partial discharge survey is included for ground mounted plant.
- Out of Service Condition Assessment – oil sampling for the purpose of dissolved gas analysis to assess internal condition. Applies to ground mounted units in buildings with a rated power of greater than 1MVA and substation auxiliary transformers >25 years old.
- Intrusive Maintenance (ground-mounted dry-type only) – a combination of detailed inspection, functional checks, electrical testing, and routine restoration activities intended to restore serviceable items to an acceptable condition. Intrusive maintenance requires the asset to be out of service.

Where defects are found during routine inspections, they are risk assessed, classified, and prioritised in accordance with the Defect Classification Manuals.

9.4.2 Corrective maintenance

Corrective maintenance is generated from preventative maintenance programs, ad-hoc inspections, and public reports. Non-urgent actions to address asset issues identified through customer notification or ad-hoc inspections may be rectified at the time of inspection or scheduled for a later time through corrective maintenance.

For corrective maintenance, assets covered under the scope of this AMP are repaired if cost effective, or replaced with like-for-like to the current standard.

9.4.3 Strategic spares

In some instances, certain sizes of ground mounted transformers may be retained as strategic spares for similar in-service units. Generally, there is no need to hold strategic spares for distribution transformers, regulators or reactors, as they are standard stock items. Volumes held are based upon historical performance, with small stocks in most depots.

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

In the event that in-situ correction or repair is not deemed appropriate by risk assessment and classification, defective assets are replaced by suitable spares units from EQL stores.

Initial in-field condition assessment is performed on the defective transformers to determine whether they can be refurbished or need to be disposed of before they are moved to EQL workshops. The workshop will perform a detailed condition assessment and testing. The results, combined with existing knowledge of the type of transformer, its age, and other relevant factors such as the cost of refurbishment, are assessed to determine whether the transformer can be cost-effectively refurbished, or whether it should be considered to be at the end of its service life and scrapped.

Workshop refurbishments are performed under corrective maintenance, and refurbished transformers are redistributed through EQL's stores system. Transformers that cannot be cost-effectively refurbished are disposed of appropriately.

A routine replacement program for electronic controllers and associated electronic components is necessary due to the disparity between electronic component life and primary plant component life.

9.5.2 Replacement

EQL has no proactive replacement program for these asset classes. The units are operated until they exhibit end of life indicators. As outlined in7.2 and Section 7.1 replacement strategies for large oil filled distribution (>= 1MVA) transformers located in third party buildings and LV regulators that are approaching end of life are being considered.

9.6 Disposal

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

An initial on-site review of all substation power transformers, regulators, and reactors physically removed from service determines the cause of the deteriorated condition. The transformer is either disposed of or sent to a workshop for assessment and possible refurbishment.

Distribution transformers, regulators, and reactors are typically not able to be cost-effectively refurbished, and following replacement, the old assets are scrapped via scrap merchants in a manner reflective of prudent and responsible recycling outcomes.

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 and 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 7.1-1: Develop a replacement strategy for the electronics componentry of the LV regulators to extend the life of the assets in service.

Action 7.2-1: Monitor the effects of distributed energy resources on load cycles and the resultant impacts on the useful life of transformers.

Action 8.1-1: Monitor the biodegradable oil transformer trial, with a view to introducing biodegradable oils in distribution transformers.

Action 8.2-1: Review and align the inspection strategies and methodologies to ensure a common EQL approach and to maintain industry best practice management of distribution transformer assets.

Action 8.3-1: Review the performance and condition of distribution transformers located inside buildings and substations to determine whether it is prudent to establish a proactive replacement program.

Action 8.4-1: Monitor the impacts of distributed energy resources on the distribution network assets to develop understanding and ensure appropriate asset management strategies are in place.

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 data capture processes in the new Enterprise Asset Management system and mobile inspection platforms being proposed for EQL, to ensure adequate asset data is captured to inform asset management decisions and processes.

Appendix 1. References

It takes several years to integrate all documents after a merger between two large corporations. This table details all documents currently authorised/approved for use in either organisation that supports this Management Plan.

Organisation	Document Number	Title	Type
Ergon Energy Energex	EPONW01 EX 03595	Network Asset Management Policy	Policy
Ergon Energy Energex	PRNF001 EX 03596	Protocol for Network Maintenance	Protocol
Ergon Energy Energex	PRNF003 EX 04080	Protocol for Refurbishment and Replacement	Protocol
Ergon Energy Energex	STNW0330 EX 03918	Standard for Network Assets Defect/Condition Prioritisation	Standard
Ergon Energy Energex	STNW1160 EX STD00299	Maintenance Acceptance Criteria	Manual
Ergon Energy Energex		Lines Defect Classification Manual	Manual
Ergon Energy Energex	NA000403R328 EX 00294	QLD Electricity and Metering Manual	Manual
Ergon Energy Energex	STNW1125 EX 01105	Standard for Power Transformers	Standard
Ergon Energy Energex	STNW1126 EX 04131	Standard for On-Load Tap Changers	Standard
Ergon Energy Energex	STNW1128 EX04133	Standard for Neutral Earthing Resistors and Reactors	Standard
Ergon Energy	EP26	Risk Management Policy	Policy
Ergon Energy	EP51	Defect Management Policy	Policy
Ergon Energy	SGNW0004	Network Optimisation Asset Strategy	Strategy
Ergon Energy	STNW0717	Standard for Preventive Maintenance Programs for 2017-18	Standard
Energex	00569	Network Risk Assessment	Procedure
Energex		Work Category Specification 5.6.	
Energex		Work Category Specification 12.3	

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 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 the condition and routine parts replacement designed to keep the asset in an ongoing continued serviceable condition, capable of delivering its intended service.
Subtransmission	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 appear in this Asset Management Plan.

Abbreviation or acronym	Definition
AIDM	Asset Inspection & Defect Management system
ALARP	As low as reasonably practicable
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	Energy Queensland Limited
ESCOP	Electricity Safety Code of Practice
ESR	Queensland Electrical Safety Regulation (2013)
HV	High voltage
IoT	Internet of Things
ISCA	In-Service Condition Assessment
LDCM	Lines Defect Classification Manual
LV	Low Voltage
LVR	Low voltage regulator
MSS	Minimum Service Standard
MSSS	Maintenance Strategy Support System
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
SFAIRP	So far as is reasonably practicable
SHI	Security and Hazard Inspection
SVC	Static VAR Compensator
THD	Total Harmonic Distortion
VT	Voltage Transformer
WCP	Water Content of Paper
WTI	Winding Temperature Indicators
WTP	Wet Transformer Profile