Asset Management Plan
Circuit Breakers and Reclosers
2020-25

January 2019

Part of the Energy Queensland Group

Executive Summary

This Asset Management Plan (AMP) focuses on the management of circuit breakers and reclosers.

Circuit breakers and reclosers are used in the network to open and close (i.e. switch) an electrical circuit under normal and fault conditions, providing safe operational control. The lifecycle management of circuit breakers and reclosers will assist Energy Queensland Limited (EQL) in the reliable, prudent and efficient operation of the distribution network.

EQL undertakes lifecycle management of circuit breakers and reclosers through performance and condition monitoring that includes periodic routine inspections, maintenance and refurbishment to achieve optimum performance, and where possible to extend asset service life.

EQL manages over 12,700 circuit breakers and reclosers with about 5,400 in the Northern and Southern (Ergon Energy) Regions and 7,300 in the South East (Energex) Region.

There are no specific regulatory performance standards for circuit breakers and reclosers. The failure of these assets can substantially influence the reliability performance of the network. These assets feature prominently in Safety Net contingency plans are required by EQL's Distribution Licences.

Key challenges for the management of the circuit breaker and reclose asset class include:

- Ensuring continuous improvement in asset data quality, recording of accurate failure information, condition assessments, and commissioning / decommissioning data to support asset management objectives;
- Improving maintenance practices to avoid recurring incidents and to achieve optimum asset life; and
- Managing the reduced asset design life of modern circuit breakers and reclosers compared to their older and more conventionally designed models, to ensure minimal impact on the economic viability of future investment of capital and operating expenditure.

EQL continues with the alignment of maintenance and operating practices to drive efficiency, delivery of customer outcomes and to mitigate risks. EQL will also continue to improve safety and the cost-effective management of this asset class through the use of the latest condition monitoring techniques (i.e. online partial discharge monitors).

Document Tracking Details

Network and Non-Network Document Hierarchy Reference Number	Regulatory Proposal Chapter Reference	Document	File Name
NET AMP – 002	7.028	Asset Management Plan - Circuit Breakers and Recloses	EGX ERG 7.028 Asset Management Plan - Circuit Breakers and reclosers JAN19 PUBLIC

Contents

Figures

Tables

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 & 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 Circuit Breakers and reclosers in substations and on feeders on the 11kV and above 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 Energy Queensland derives from this asset class.

This Asset Management Plan (AMP) 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 (Qld) (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 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 used to deliver electricity to its customers. Appendix 1 contains references to other documents relevant to the management of the asset class.

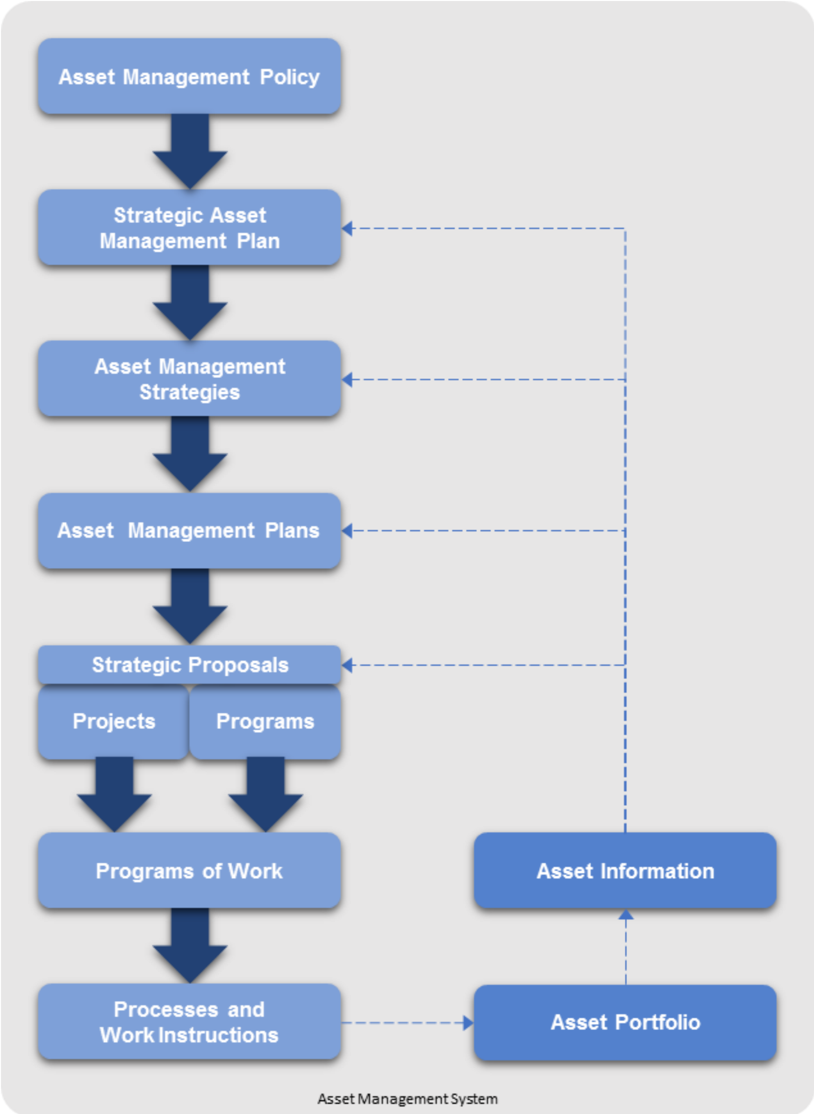


Figure 1: EQL Asset Management System

1.2 Scope

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

- Circuit breakers
- Substation reclosers operated as circuit breakers, and
- Reclosers in distribution feeders.

Many customers, typically those with high voltage connections, own and manage their own network assets including circuit breakers 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 upon asset quantities and replacement costs, EQL circuit breakers and reclosers have a replacement value of the order of $2.63 billion. This valuation is the gross replacement cost of the assets, based on the cost of modern equivalents, without asset optimisation or age assigned depreciation.

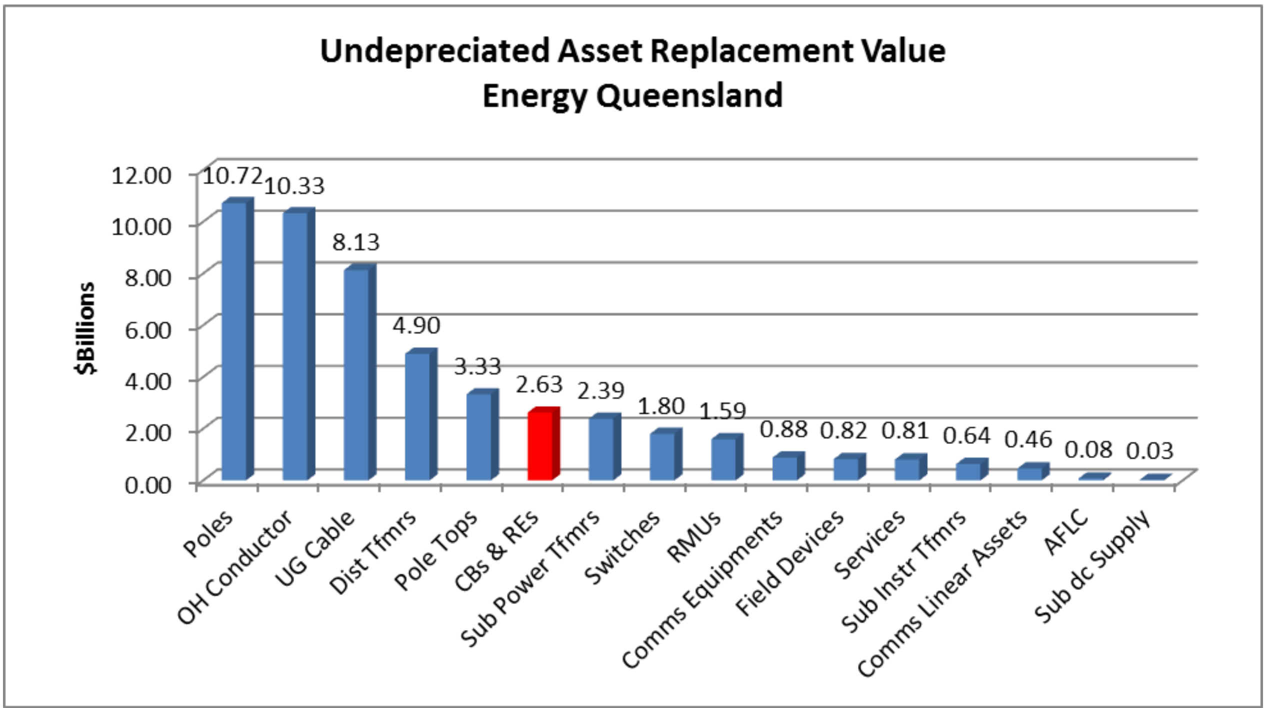


Figure 2: EQL – Total Current Asset Replacement Value

1.4 Asset Function and Strategic Alignment

The function of a circuit breaker/recloser is to open and close (i.e. switch) an electrical circuit under normal and fault conditions, providing safe operational control of EQL's network while preventing or minimising asset damage and reducing the likelihood of public safety issues so far as is reasonably practicable (SFAIRP).

Currently, EQL has an asset population of approximately 12,700 circuit breakers and reclosers.

The table below details how circuit breakers and reclosers 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 maintenance and operations of the circuit breaker and recloser supports performance and hence safety for all stakeholders.
Meet customer and stakeholder expectations.	The reliable performance of the circuit breaker and recloser supports and promotes delivery of a standard quality electrical energy service.
Manage risks, performance standards and asset investment to deliver balanced commercial outcomes.	Failure of circuit breakers and reclosers can result in increased EQL personnel and public safety risks 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 ISO 55000 standard.	This AMP is consistent with ISO 55000 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 modernisation through industry leading condition and health assessment, replacement of circuit breaker and recloser 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
Operational Control	EGM Distribution
Maintenance Control	EGM Strategy, Asset Safety & Performance

Table 2: Stakeholders

2 Asset Class Information

Circuit breakers and reclosers are an essential part of the electrical system. It is a current interrupting mechanism which opens or closes in response to any fault on the network, or to an operator's command. Circuit breaker and recloser types are classified according to many different criteria, such as:

- Operating voltage
- Installed location
- External design characteristics
- Medium used for interruption.

The circuit breakers in this document are primarily categorised based on the operating voltage in EQL.

2.1 Asset Description

Circuit breakers and reclosers switch load and fault currents in electrical networks using a range of electrical and mechanical operating mechanisms. In performing this function, it allows safe and efficient operation of the network, protects plant and equipment from damage, as well as protecting staff and the general public from safety hazards that arise when faults occur in the electricity network.

The difference between a circuit breaker (CB) and a recloser is that a recloser is a self-contained device (containing the circuit interrupter as well as protection/control system) whereas a circuit breaker has a separate relay/control scheme.

2.2 Asset Quantity and Physical Distribution

Table 3 data shows EQL's population of circuit breakers and reclosers.

Circuit Breaker and Recloser	Northern & Southern	South East	Total
=11kV	2,628	5,377	8,005
>11kV & <=22kV	1,761	0	1,761
>22kV & <=33kV	369	1,609	1,978
>33kV & <=66kV	547	1	548
>66kV & <=132kV	116	311	427
Total	5,431	7,298	12,719

Table 3: Asset Quantity

2.3 Asset Age Distribution

Figure 3 and Figure 4 detail the population of circuit breakers and reclosers in the EQL network. The expected life of circuit breakers and reclosers at 11kV is 55 years, and at >11kV is 60 years.

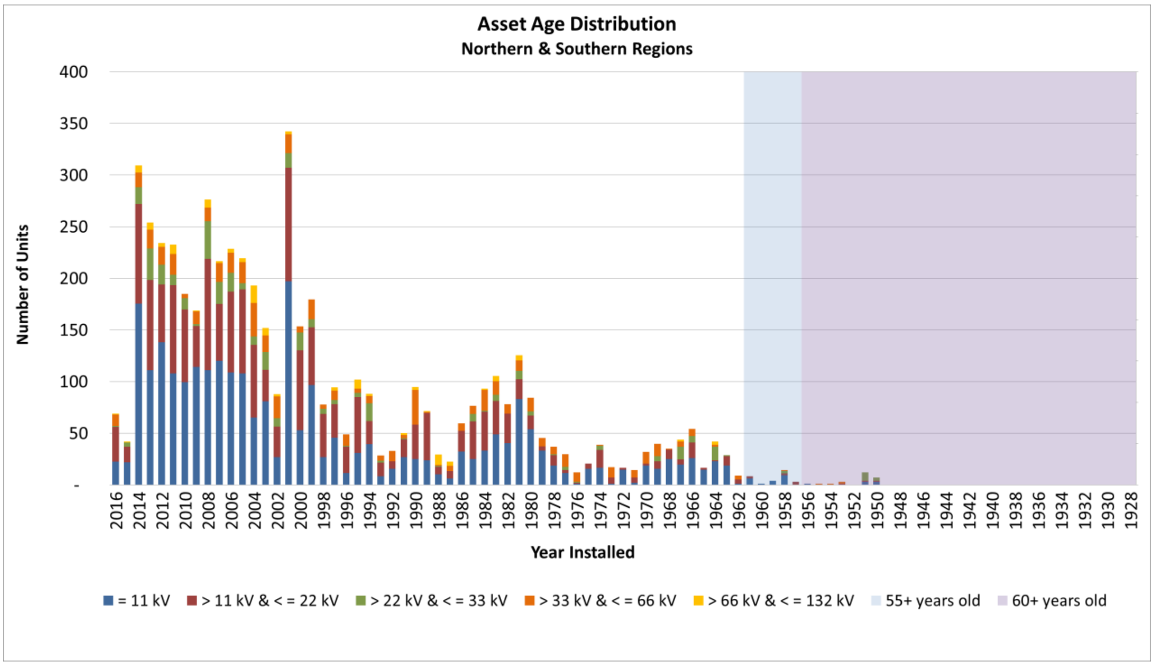


Figure 3: Asset Age Profile – Northern & Southern Regions

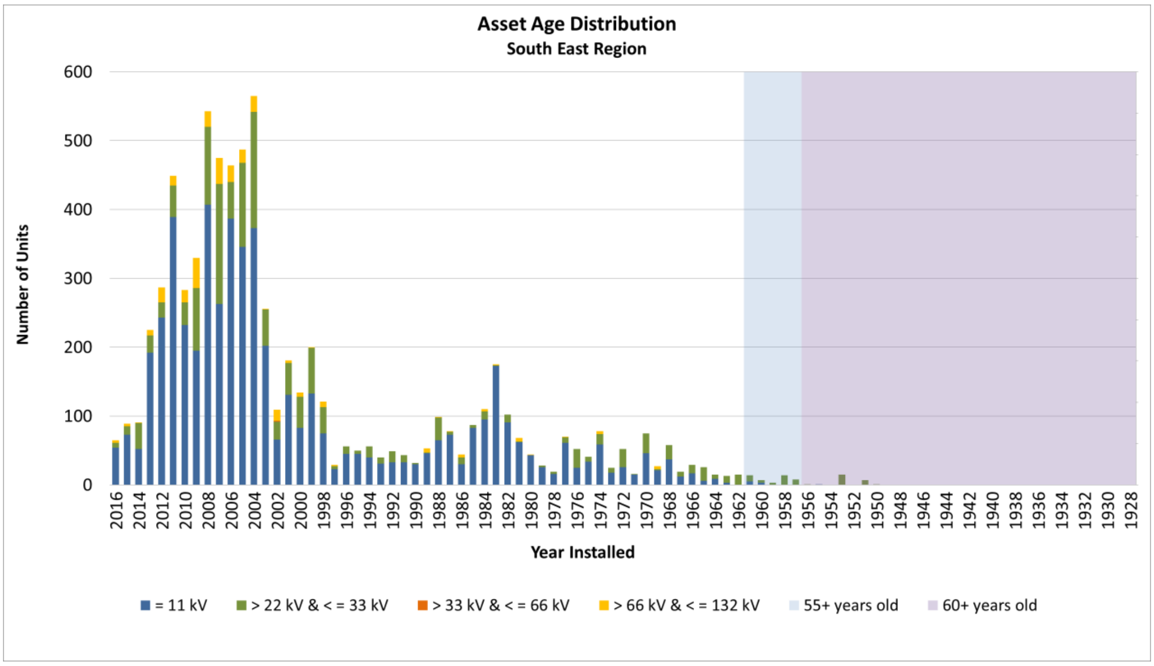


Figure 4: Asset Age Profile – South East Region

2.4 Population Trends

Circuit breakers and reclosers in the EQL network have been installed over a period of decades by various legacy organisations as the network expanded due to demand, and as circuit breaker reliability issues became prominent. In the last few years, many CBs, particularly those installed during the several economic development phases of Queensland after World War II, have started to reach end of life leading to a progressive need for replacement.

Circuit breakers and reclosers in EQL network with an oil interrupting medium have been replaced with modern standard equivalent breakers with vacuum and gas interrupting mediums as they reached life. This resulted in a reduction of oil filled assets and an increase in gas and vacuum assets over the last two decades.

As a result, the population of these assets is diverse. As technology has evolved, so has asset management practice. The EQL asset lifecycle management activities such as inspection, maintenance, monitoring and diagnostic testing of the circuit breakers and reclosers is based on these asset population variations that comprise of interrupting medium (e.g. oil, gas, vacuum), installed location (e.g. indoor, outdoor) and construction type (e.g. dead tank, live tank).

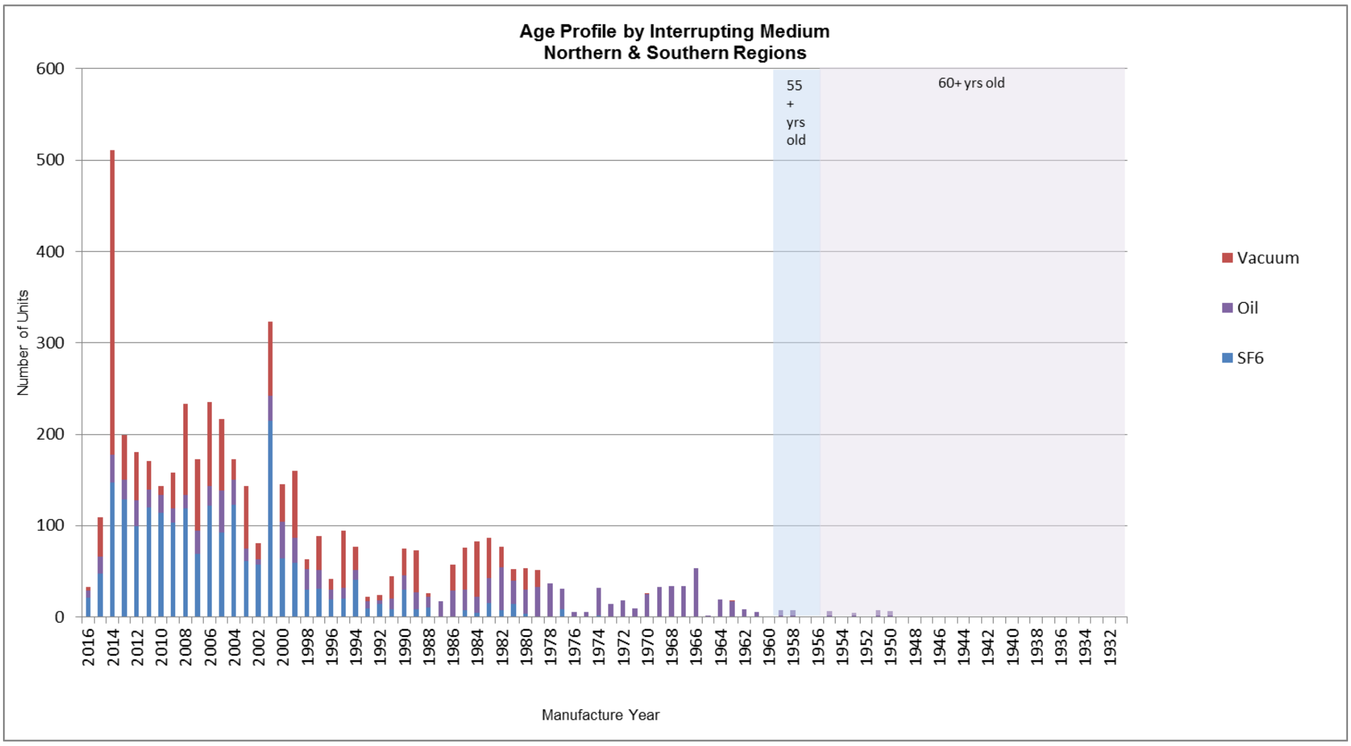


Figure 5: Interrupting Medium Population Trend – Northern and Southern Regions

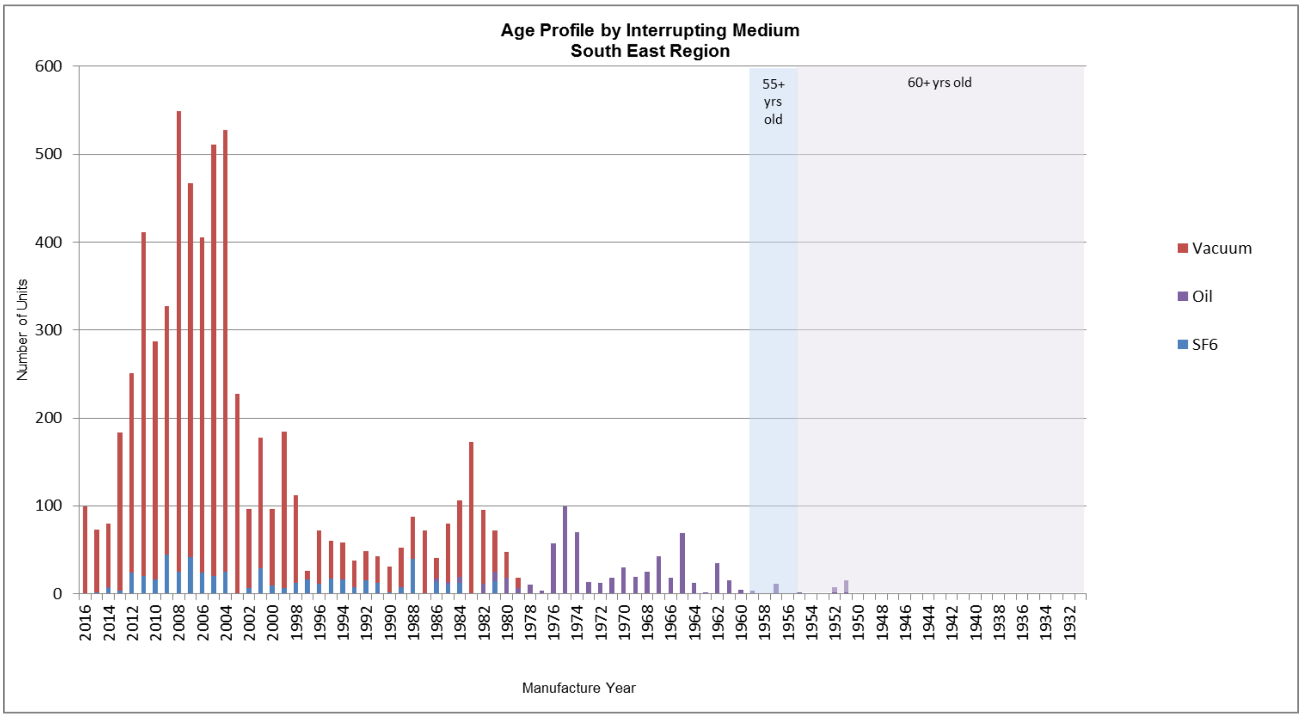


Figure 6: Interrupting Medium Population Trend – South East Region

2.5 Asset Life Limiting Factors

The following table describes the key factors that influence the life of circuit breakers and reclosers, and as a result, have a significant bearing on the programs of work implemented to manage the asset lifecycles of these assets.

Factor	Influence	Impact
Age	Electrical and mechanical wear.	Decline in the reliability of operation over time.
Environment	Outdoor, corrosive and coastal environment resulting in degradation of the physical structural integrity of an asset such as bushing insulators, tank and gaskets.	Accelerated ageing, non-operation of mechanisms and reduction of useful life.
Operation	Cumulative operations to interrupt short circuit and load current results in mechanical stress, wear and degradation of internal mechanisms.	Accelerated ageing and reduction of useful life.
Design	Design and material specification issues.	Mal-operation or non-operation of assets and reduction of useful life. This tends to affect certain makes and models and only becomes apparent through operational experience.
Fault	Electrical and mechanical stress on the internal components leading to physical damage.	Internal fault leading to failure (potentially catastrophic).
Obsolescence	Inability to source components and skills required to maintain or repair the asset.	Unable to return to service in the event of a failure resulting in early replacement.

Table 4: Circuit Breaker and Recloser 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 the 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.

Assets of this class will be managed by ongoing individual condition assessment and maintenance, and proactively replaced near to and prior to calculated end of life. End of economic asset life will take into account ongoing maintenance and retention costs, replacement costs and benefits, potential future maintenance and retention costs, and risk, and be determined principally by Condition Based Risk Methodology (CBRM) analysis techniques. Replacement will be considered on a project specific basis, and holistic analysis of nearby assets will be performed to support the optimal life cycle cost and customer impact.

Replacement of line reclosers is based on asset condition and risk.

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 Queensland Electrical Safety Act 2002 and the Queensland Electrical Safety Regulation 2013 (ESR).

The Queensland Electrical Safety Act 2002 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 its 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 inspects, 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 circuit breakers or reclosers is usually a significant event and may require Safety Net contingency plans to be exercised. Loss of a distribution recloser will typically only impact the downstream customers on that feeder having a reduced reliability impact.

Both Safety Net and MSS performance information is publically reported annually in the Distribution Annual Planning Reports (DAPR).

3.3 Performance Requirements

There are no specific business targets relating to circuit break and recloser performance. However, these assets are considered critical in nature as they are of high value, require significant lead time to procure, 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 substation circuit breakers and reclosers are conducted regularly, with the performance against defined criteria monitored, and issues addressed to ensure these assets reach the end of their economic life. Distribution reclosers are managed entirely under the routine maintenance programs, with replacement determined based on benchmark defect criteria.

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 across the Northern and Southern Regions and the South East Region.

3.4.1 Regulatory Reported Asset Failure Data

The disparity between the reported failures of the EQL legacy organisations reported failures 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:

- Distribution circuit breakers - the maintenance practice for distribution circuit breakers is to run them to failure and then replace, therefore all replacements are assumed to be failures.
- Distribution reclosers - the stores issues for these assets costed to the OPEX code are considered to be failures.
- Substation circuit breakers and reclosers **-** 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.

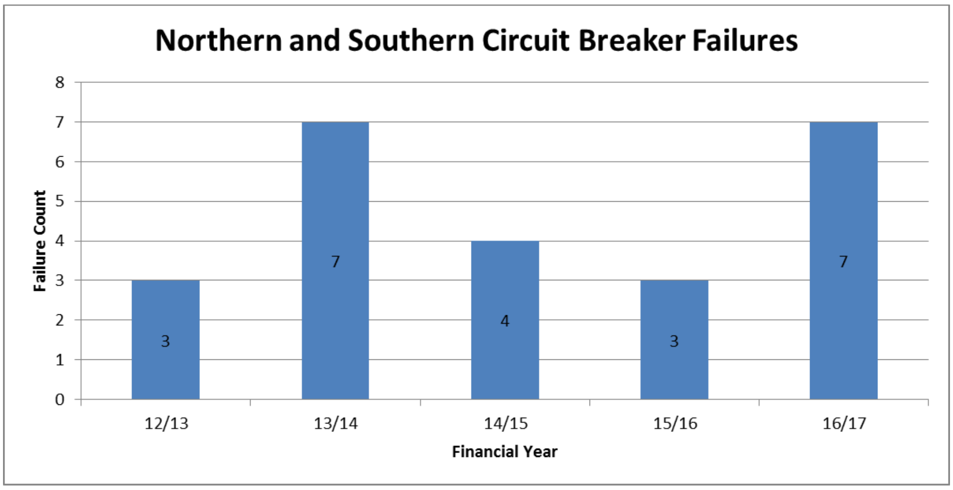


Figure 7: Northern and Southern Regions – Circuit Breaker Failures

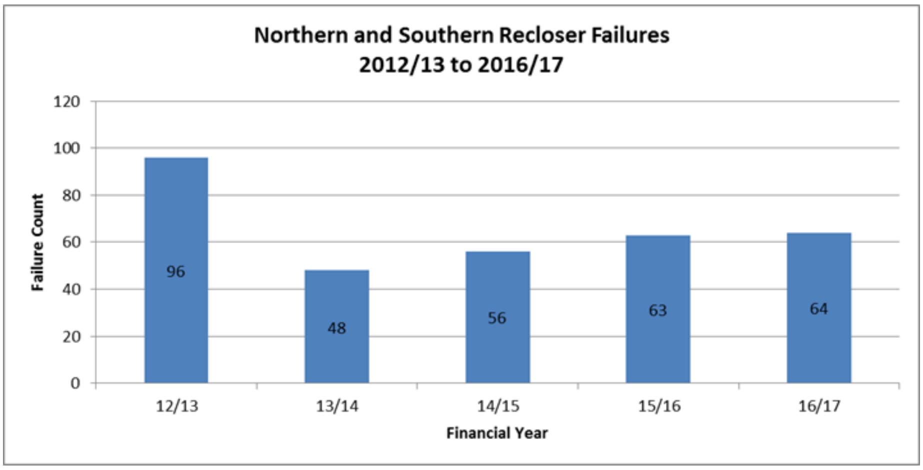


Figure 8: Northern and Southern Regions – Recloser Failures

In the South East Region, in-service failures for distribution reclosers are identified via manually analysing the network outage reports and allocating them to the appropriate asset class. For substation circuit breakers and reclosers, each asset failure event is individually investigated and registered by Investigation and Response department.

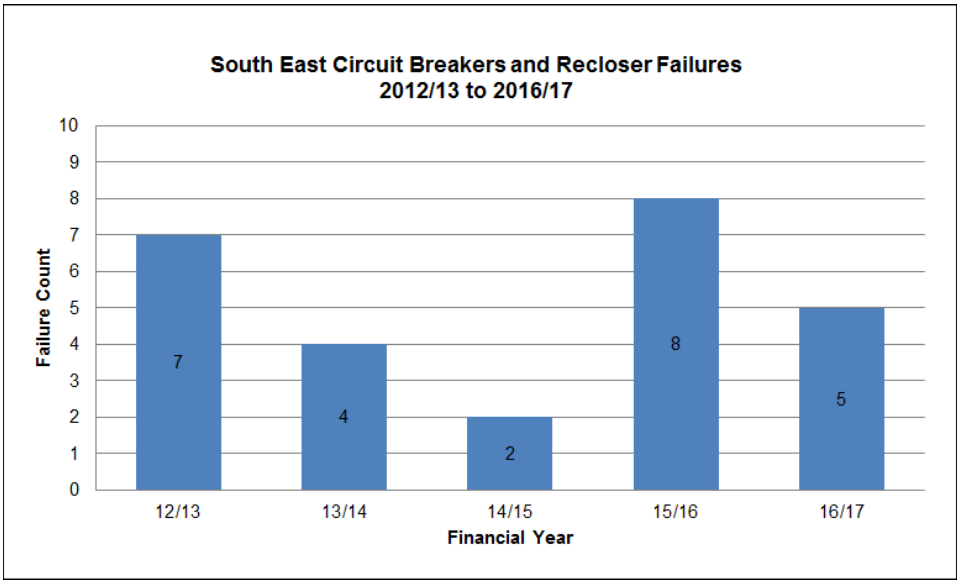
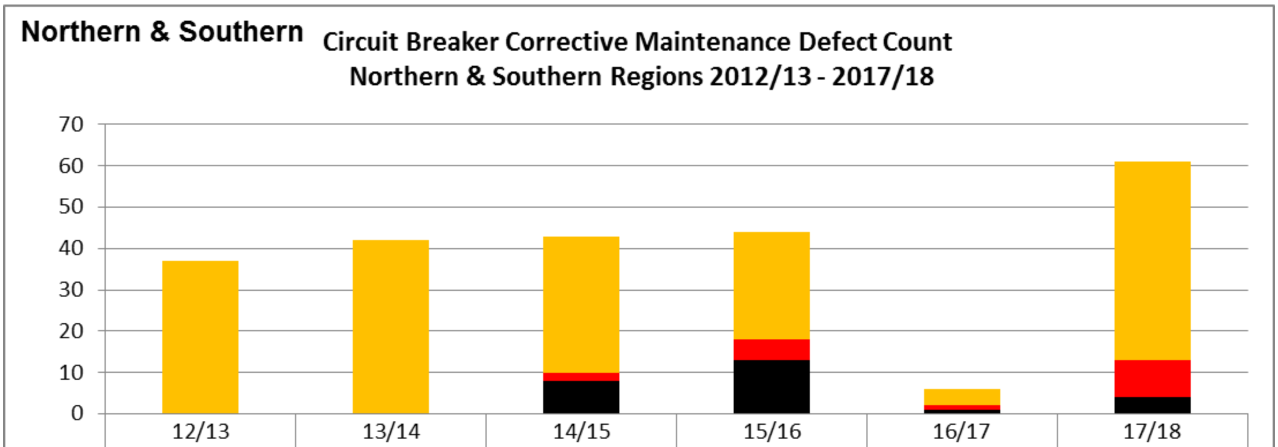


Figure 9: South East Region - RIN Asset Failure

3.4.2 Historical Performance Trends - Northern & Southern Regions

Figure 10 shows the historical trend of defect repair/replacement works that have been conducted on these assets. The P0, P1 and P2 references relate to the priority of work required, which effectively dictates whether normal planning processes are employed (P2), or more urgent repair works are initiated (P1 and P0).



	12/13	13/14	14/15	15/16	16/17	17/18
P2	37	42	33	26	4	48
P1	0	0	2	5	1	9
P0	0	0	8	13	1	4
OS	0	0	0	0	0	0

Figure 10: Northern and Southern Regions Defect Count

A Northern and Southern Regions process change in November 2017 to directly raise defect Work Orders from the electronic field inspection tool has created an anomaly in the defect counts for 2016/17 and 2017/18. However, the long-established Maintenance Strategy Support System (MSSS) coding for defects in Northern and Southern Regions allows analysis of almost 6 years of defects to identify a number of the issues that this plan addresses.

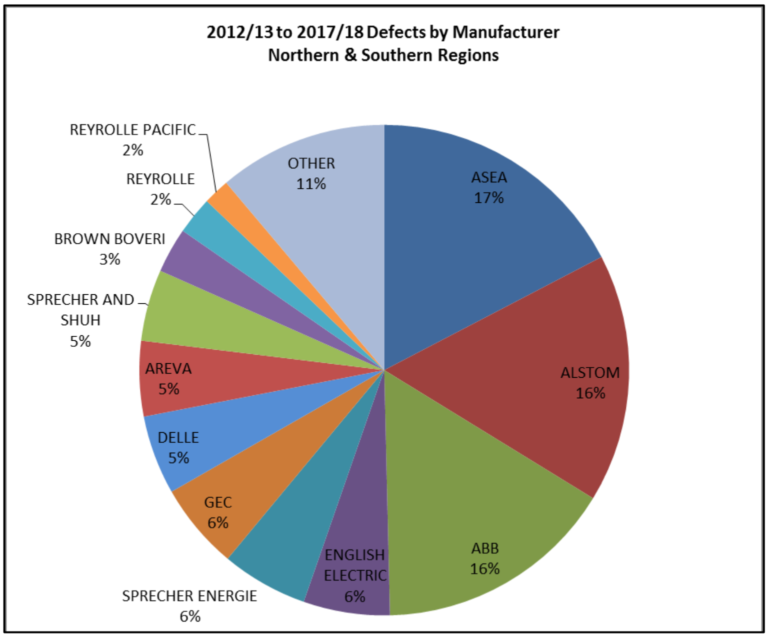


Figure 11: 2012/13 to 2017/18 Defects by Manufacturer – Northern and Southern Regions

Figure 11 above shows the percentage defect by manufacturer for all defects raised in Northern and Southern Regions over an almost 6-year period.

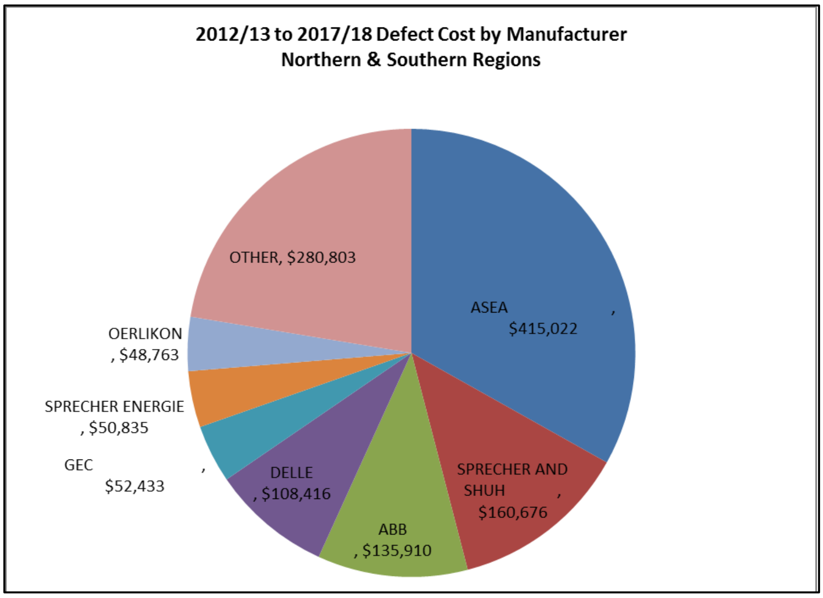


Figure 12: 2012/13 to 2017/18 Defects by Manufacturer – Northern and Southern Regions

When examined from the point of view of the cost associated with the defects in Figure 12 above, a slightly different picture emerges that shows many of the issues that this plan has identified for attention. The figures below explore further into the models of manufacturers identified with higher defect costs in Figure 12 above.

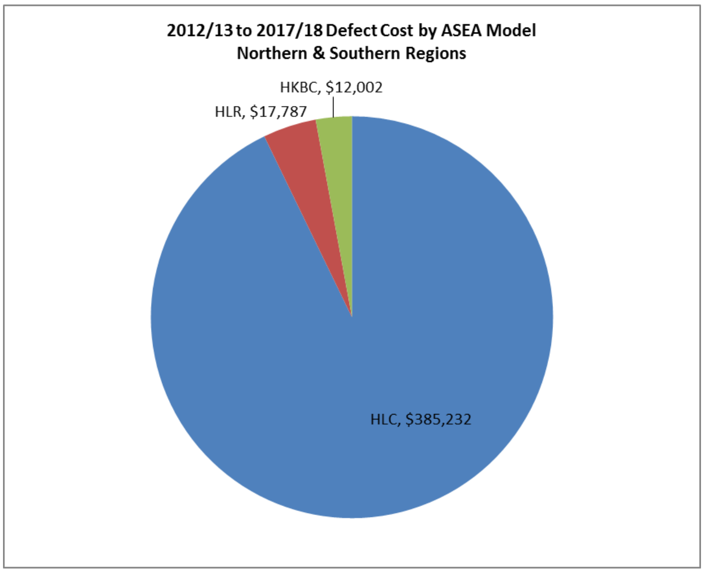


Figure 13: 2012/13 to 2017/18 Defect Cost by ASEA Model – Northern and Southern Regions

Exploring further into the ASEA models clearly demonstrates significant expenditure on the HLC models which have been well known due to explosive failures experienced the Ergon Energy business and other utilities. Further details of the issue and resultant action are given in 6.4.1.

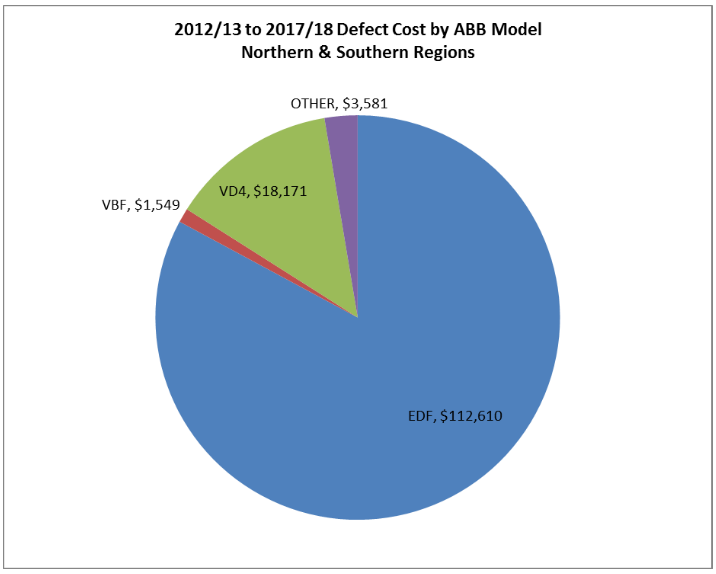


Figure 14: 2012/13 to 2017/18 Defect Cost by ABB Model – Northern and Southern Regions

Exploring further into the ABB models shows significant expenditure on the EDF models which have a well-known issue with leaking SF6. Further details of the issue and resultant action are given in 7.3.

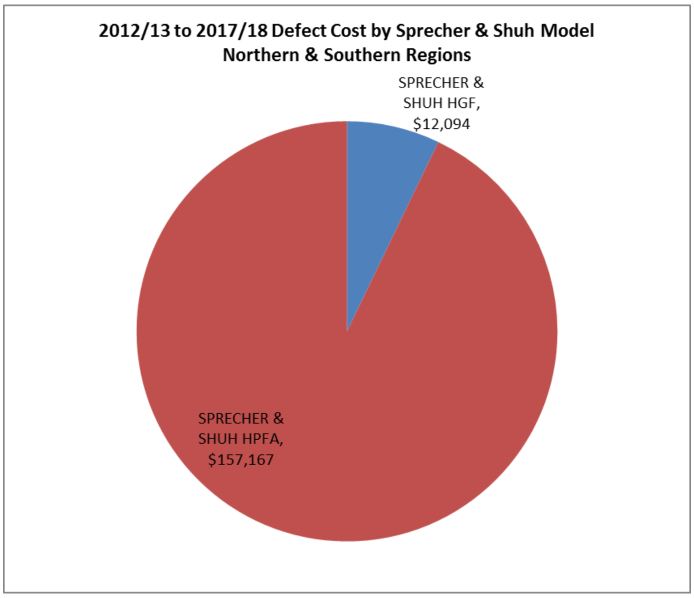


Figure 15: 2012/13 to 2017/18 Defect Cost by Sprecher & Shuh Model – Northern and Southern Regions

Similarly, known issues with HPFA models made by Sprecher and Shuh also show significant defect expenditure. Further details of the issue and resultant action are given in 6.4.5.

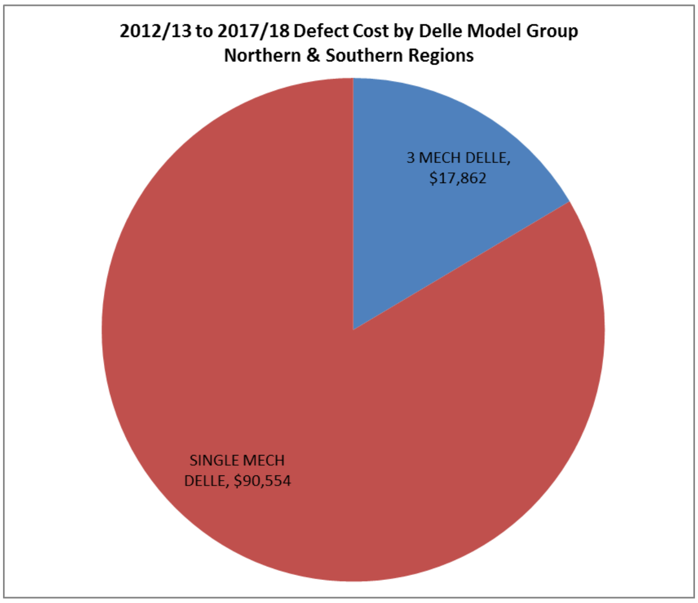
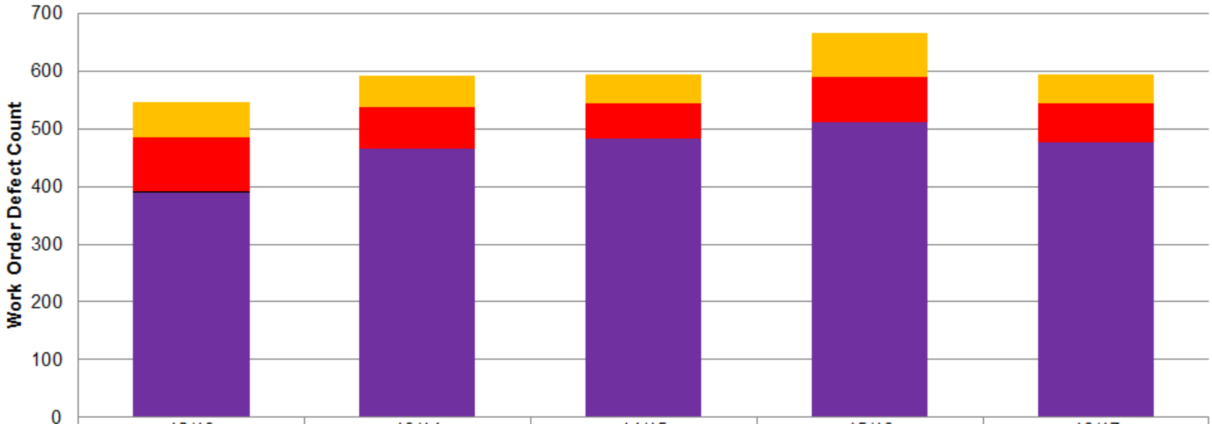


Figure 16: 2012/13 to 2017/18 Defect Cost by Delle Model Group – Northern and Southern Regions

In the case of Delle Circuit Breakers there are really only two versions of the same circuit breaker but both are known for slow operations which manifests itself slightly differently depending on whether it is the ‘Single Mech’ or ‘3 Mech’ version. Nevertheless, both are problematic and further details of the issue and resultant action are given in 6.4.2.

3.4.3 Historical Performance Trends – South East Region

Figure 17 shows the historical trend of defect repair/replacement works that have been conducted on these assets. The P0, P1 and P2 references relate to the priority of work required, which effectively dictates whether normal planning processes are employed (P2), or more urgent repair works are initiated (P1 and P0).



	12/13	13/14	14/15	15/16	16/17
P2	61	54	50	77	52
P1	93	72	62	77	67
P0	2			1	
CM	390	465	482	511	476

Figure 17: South East Region Defect Count

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 from 2017/18 financial year.

This MSSS record set for South East Region 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. The following figures show the extent of valuable data EQL has started to gather due to the implementation of the MSSS system, such as:

- Corrective Maintenance Numbers by Major Component
- Corrective Maintenance Numbers by Manufacturer
- Corrective Maintenance Numbers Normalised by Manufacturer
- Corrective Maintenance Spend
- Corrective Maintenance Jobs Normalised by the Volume of Jobs Issued
- Asset Specific Maintenance Details.

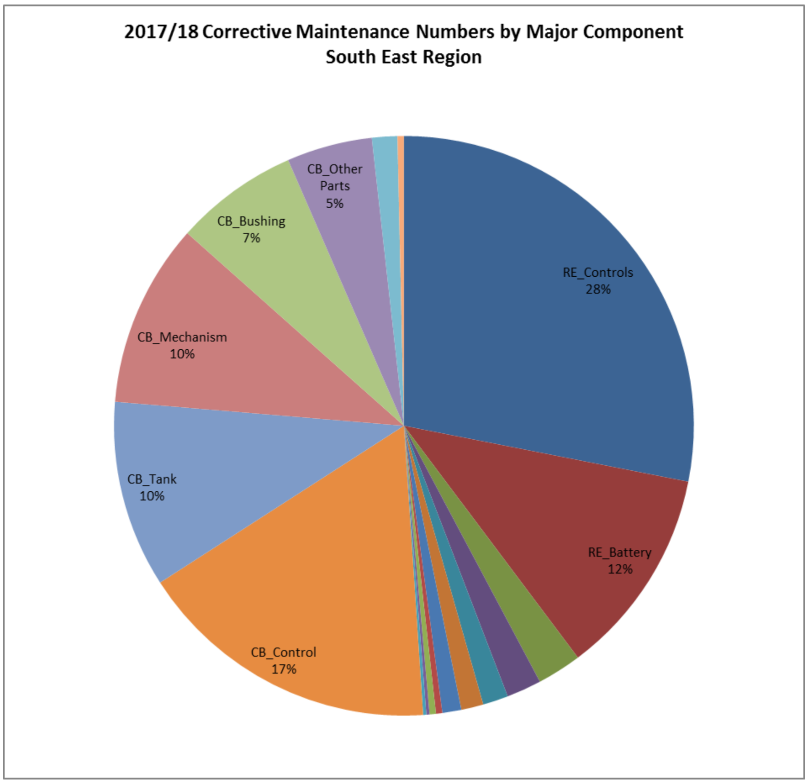


Figure 18: 2017/18 Corrective Maintenance by Major Component – South East Region

Figure 18 represents the major component breakdown for financial year 2017/18. The majority of recorded issues were related to the recloser battery and control system. The other major defects are circuit breaker tank leaks and gasket issues, mechanisms and control systems.

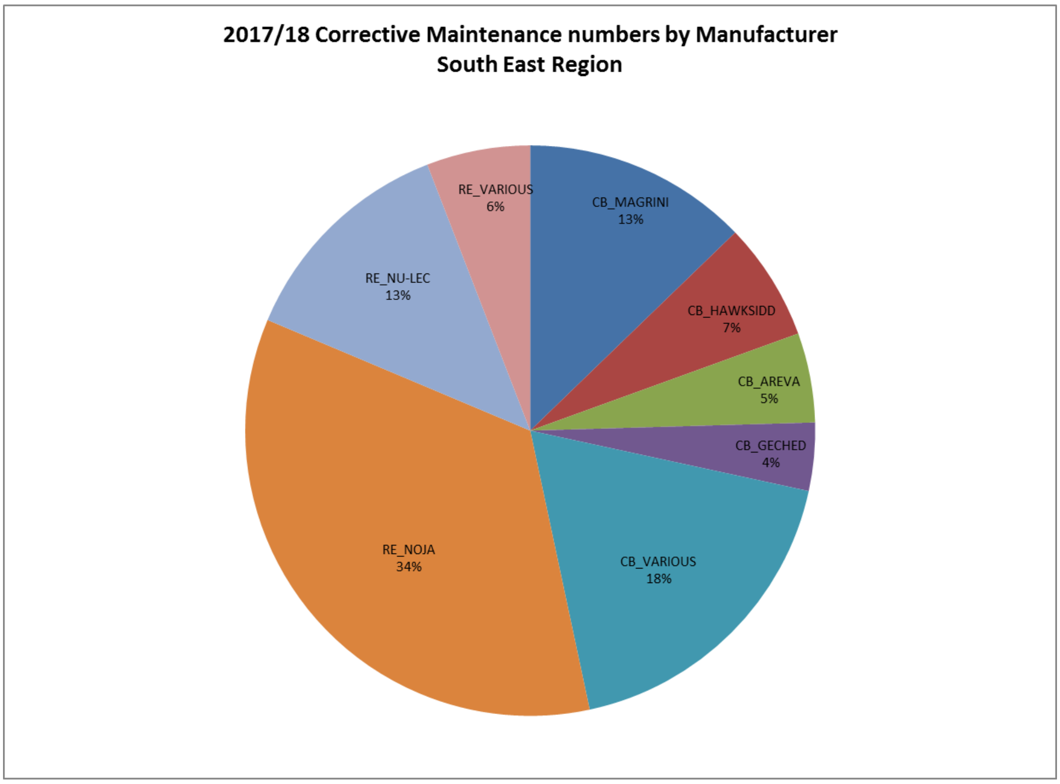


Figure 19: 2017/18 Corrective Maintenance by Manufacturer – South East Region

Figure 19 above shows the percentage defect by manufacturer for all defects raised in South East Region for 2017/18. Recloser manufacturers Noja and Nulec have been flagged due to a number of control system issues experienced by these units. Circuit breaker manufacturer Magrini is a major contributor to corrective maintenance due to consistent SF6 gas leaks (further detail on these issues is described in section 7.2).

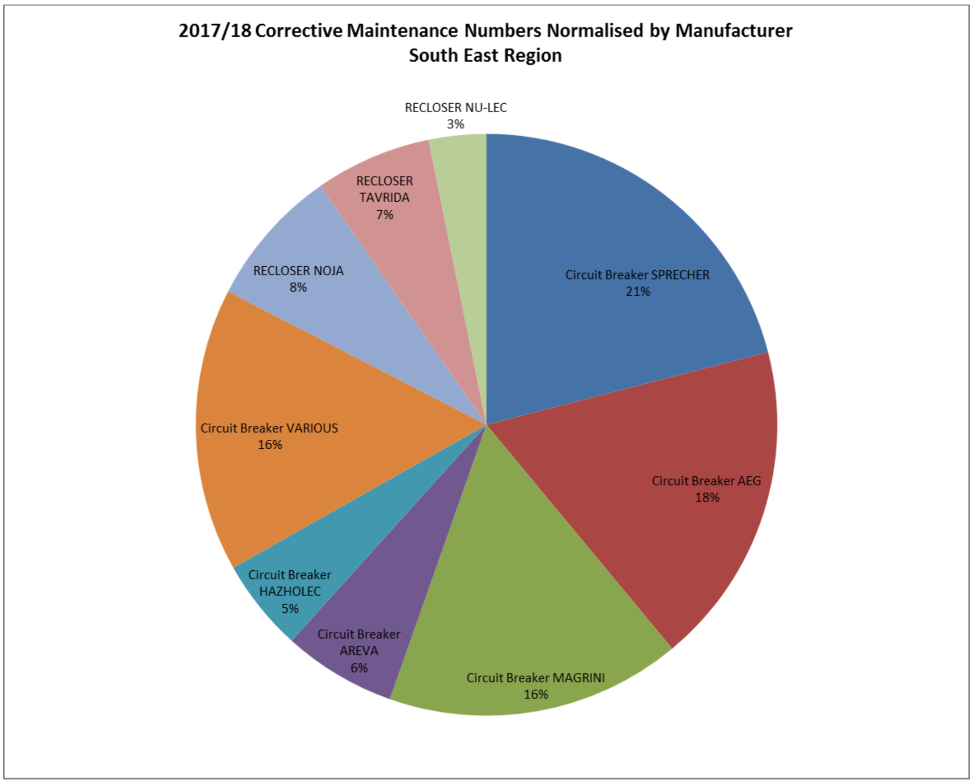


Figure 20: 2017/18 Corrective Maintenance by Manufacturer (normalised) – South East Region

Figure 20 represents a summary of corrective maintenance by manufacturer normalised for asset population. Having adjusted for asset population, Magrini and Noja remain major contributors to corrective maintenance on these assets.

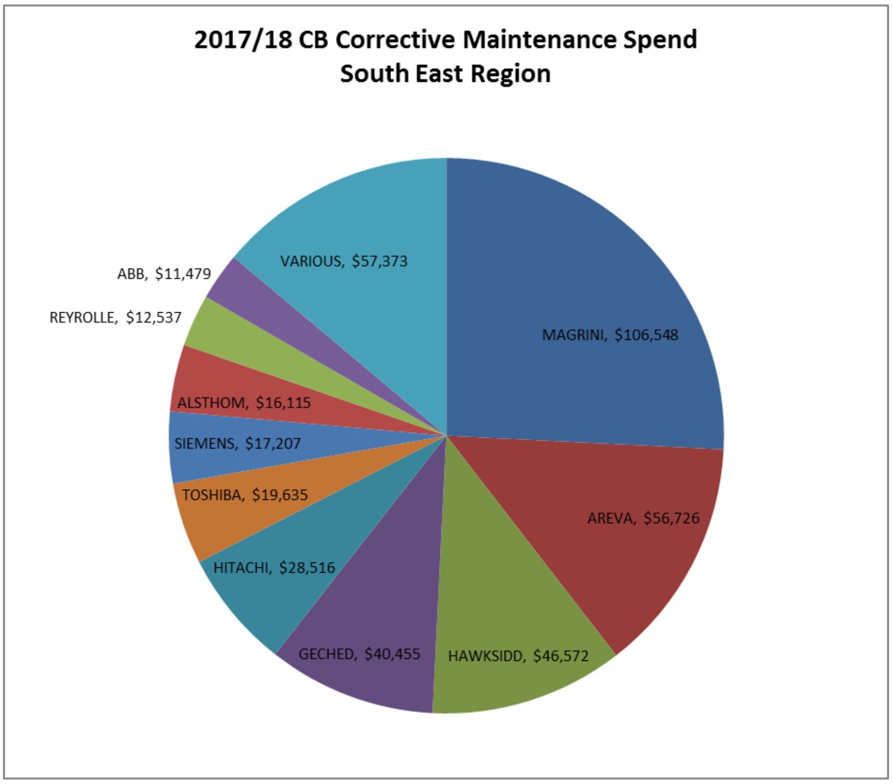


Figure 21: Corrective Maintenance Spend by Manufacturer – South East Region

Figure 21 summarises corrective maintenance spend by manufacturer. Magrini and Areva have the highest spend, primarily due to known recurring SF6 gas leaks in components provided by these manufacturers.

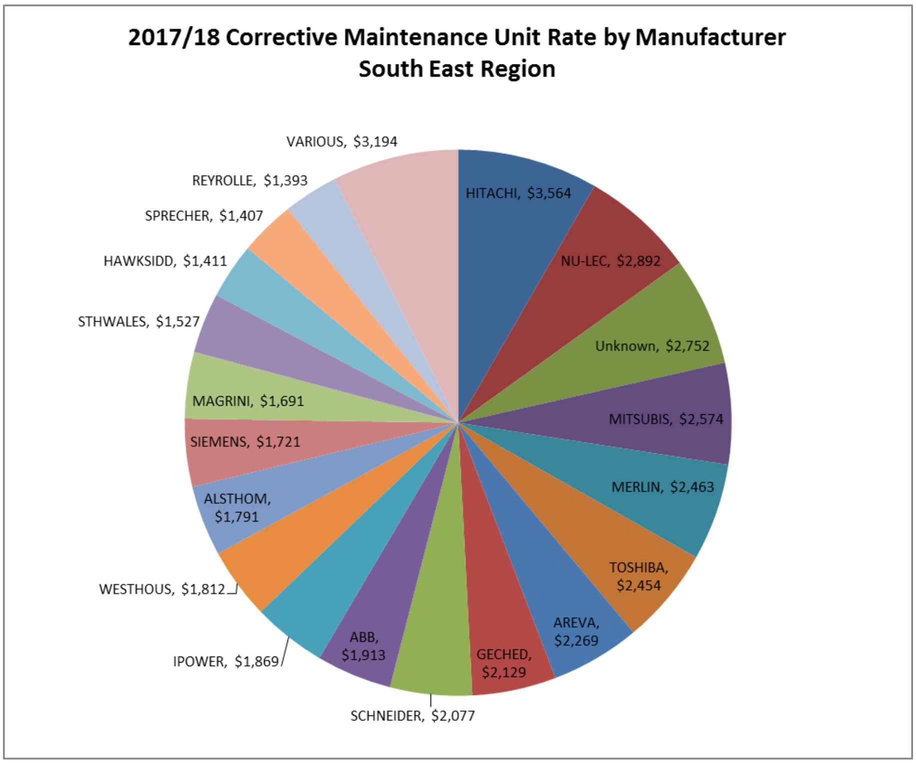


Figure 22: Corrective Maintenance Unit Rate by Manufacturer – South East Region

Figure 22 shows the corrective maintenance unit rate by manufacturer for 2017/18. This graph is used for analysing whether the organisation corrective maintenance cost is well within the acceptable unit rate.

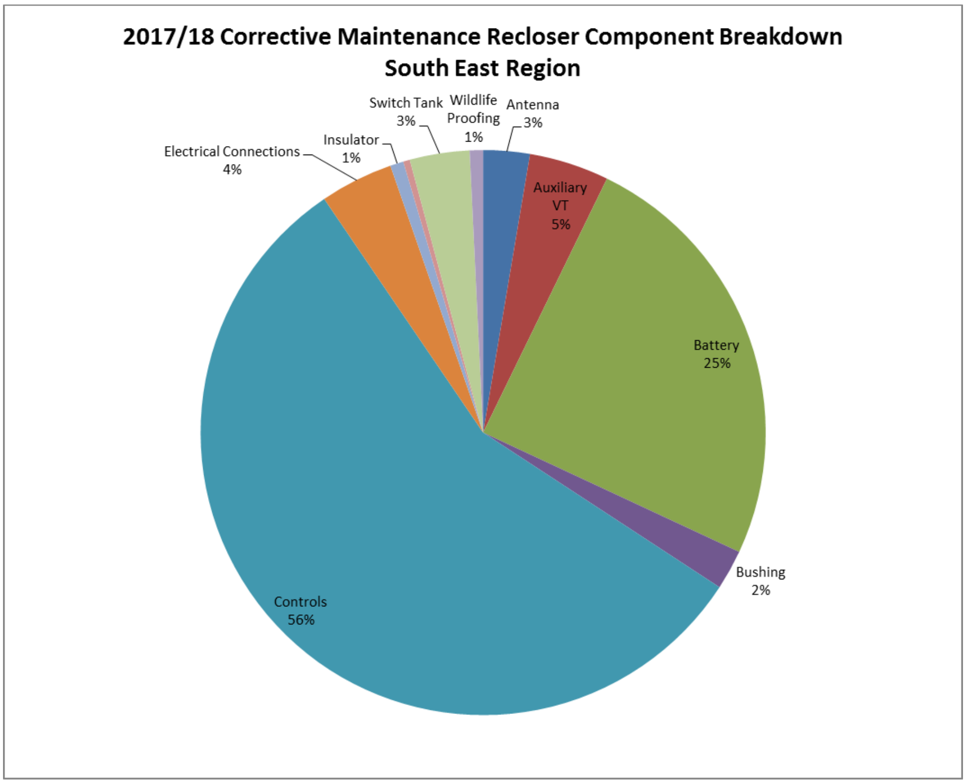


Figure 23: Corrective Maintenance Recloser Component Breakdown – South East Region

Figure 23 shows the recloser component breakdowns for the financial year 2017/18. The major issue with reclosers is in the controls and battery system. For further analysis in these systems and their maintenance issues, refer to their respective AMPs.

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 24 provides a threat-barrier diagram for circuit breakers and reclosers. The “threats” (or hazards) presented in the diagram are applicable to all asset types covered in this document. Many threats are unable to be controlled (e.g. lightning), although EQL undertakes a number of actions to mitigate them SFAIRP/ALARP.

EQL’s safety duty results in most inspection, maintenance, refurbishment and replacement works, and expenditure related to circuit breakers and reclosers, being entirely focused upon preventing and mitigating failure.

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 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.

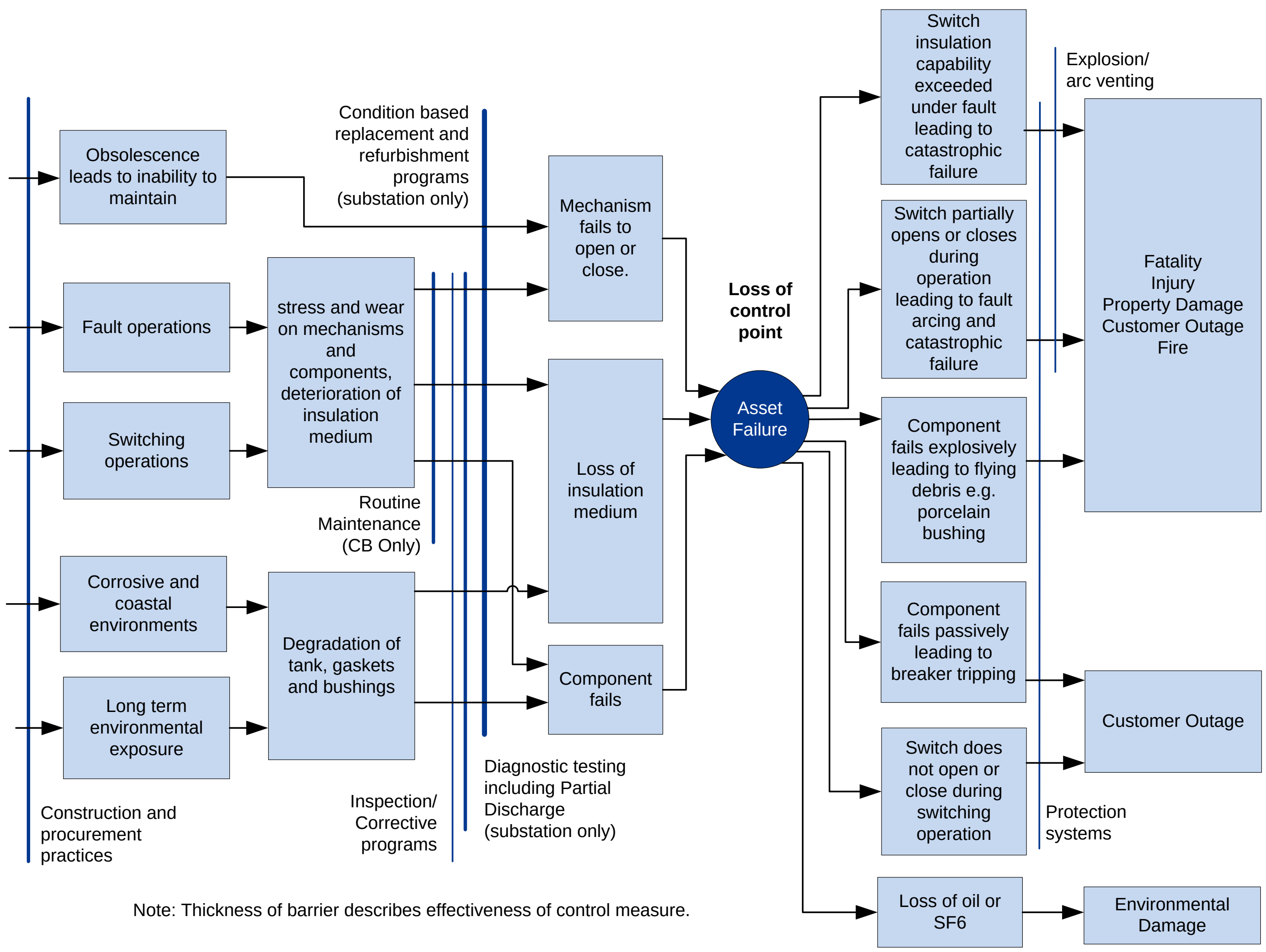


Figure 24: Threat Barrier Diagram for Circuit Breakers and Reclosers

5 Health, Safety & Environment

The following sections outline key health, safety and environment issues related to the asset management of circuit breakers and reclosers.

5.1 Asbestos

The hazards associated with asbestos are reasonably well known in the general community and Australian industry. Asbestos Containing Materials (ACM) and products had been used extensively throughout the EQL network and in the substation building, circuit breakers, cable terminations, basements and switchboards built prior to 2004.

In circuit breakers, ACM was found in gaskets, washers, seals, and insulators. Most of the circuit breakers manufactured pre-1970 have been programmed to be replaced by the end of the 2020-25 Regulatory Control Period however there will still be some units that remain in service until the subsequent period.

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 Sulphur Hexafluoride:

Sulphur hexafluoride (SF6) is a global warming gas, and although the amount in the atmosphere is small in comparison to carbon dioxide, its global warming potential is approximately 23,900 times greater. As a result, it is important that release of SF6 into the atmosphere is minimised to the extent that is practicable so as to demonstrate responsible use and assure the continuing availability of SF6 to the electricity supply industry.

SF6 has been used in electrical equipment for more than 40 years such as circuit breakers and reclosers. Extensive use continues to be made by the manufacturers of high voltage switchgear because of its high dielectric strength (2.5 times that of air under the same conditions), excellent arc quenching capabilities, high thermal conductivity, and chemical stability. This resulted in an increase of the SF6 switchgear population in EQL for the last two to three decades.

EQL monitors and controls the release of SF6 gas to the atmosphere by implementing alarm systems throughout switchgear control systems. Corrective works will be raised to rectify release issues on a case by case basis.

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 Network Access Restrictions on Circuit Breakers

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 6.1-1: 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 condition.

6.2 Indoor Oil Filled Circuit Breakers Without Remote Control

Manually operated oil filled circuit breakers installed in an indoor environment inside a substation building pose a serious safety hazard compared to remote controlled oil-filled circuit breakers as the operator is standing next to the circuit breaker during switching. These assets are not designed to enclose or direct the blast associated with a fault away from the operator which can result in serious safety consequences (examples of these incidents have already occurred globally). This type of circuit breaker has been identified and included in the Asset Management Risk Register as a high-risk plant item.

In the South East Region, between 1960 and 1980, around 96 commercial and industrial (C&I) substations had been installed with approximately 430 non-remote-controlled oil filled circuit breakers. Approximately 330 circuit breakers have been replaced between years 2012 to 2016 and a remaining 100 circuit breakers have been programmed to be replaced by 2020.

Northern & Southern Regions have 6 non-remote-controlled oil filled circuit breakers across 2 substations and are programmed to be replaced within the determination period 2020-2025.

6.3 Indoor breakers in outdoor cubicles

Following the three catastrophic in-service failures of Email manufactured S15 circuit breakers in one year in the South East Region, it was identified that the circuit breakers were actually indoor circuit breakers that had been installed in outdoor cubicles. Exposure to the environment as a result of the design led to the deterioration of the insulation and ultimately failure. Failure of the HV insulation can present a safety risk to any personnel in the substation due to the porcelain bushings, and regular partial discharge (PD) scanning is used to monitor the immediate risk.

In the South East Region, between 1960 and 1975 approximately 72 Email S15 11kV circuit breakers were installed in an outdoor environment around 12 zone substations. Sixty (60) circuit breakers have already been replaced and a remaining 12 circuit breakers across 2 substations are programmed to be replaced by 2019.

In Northern and Southern Regions, seven S15 11kV circuit breakers were installed in one substation in the year 1970. These circuit breakers are planned to be replaced by 2022.

6.4 Discovered deficiency

In the Northern and Southern Regions, a number of circuit breaker models that have deficiencies have been discovered during their in-service life and have been the subject of detailed investigation.

The following identified circuit breakers have been programmed to be replaced over coming years (determination periods 2015-2020 and 2020-2025).

6.4.1 ASEA - HLC

Northern and Southern Regions have had specific issues with the ASEA HLC Circuit Breakers which are currently being addressed in a replacement program. These circuit breakers have a history of explosive failure due to moisture ingress. In addition, several similar (much older) ASEA HKEY Circuit Breakers are included for replacement due to similar issues.

6.4.2 DELLE HPGE

Northern and Southern Regions have had specific issues with the Delle HPGE Circuit Breakers that is currently being addressed in a replacement program. These breakers have a history of slow operation which has led to the operation of backup protection systems and extensive outages. The ‘3 mechanism’ model (which experiences the slow operating issue as well as timing discrepancies between the three separate poles) is prioritised slightly higher than the single mechanism model.

6.4.3 GEC - FL1

Northern and Southern Regions have had specific issues with the GEC FL1 Circuit Breakers that is currently being addressed in a replacement program. These breakers have a history leaking SF6, slow operation, failing to latch and moisture ingress. Only one of these circuit breakers remains in the network.

6.4.4 ABB - VBF

Northern and Southern Regions have had specific issues with the ABB VBF Circuit Breakers that is currently being addressed in a replacement program. These breakers have a history of moisture ingress from loss of gas pressure. This has caused catastrophic failures when the circuit breaker operates.

6.4.5 EIB and Sprecher & Shuh – HPFA

Northern and Southern Regions have identified specific issues with the EIB and Sprecher & Shuh HPFA and HPF Circuit Breakers that is currently being addressed in a replacement program. These breakers have an issue where the arc interrupting turbulator falls off inside the circuit breaker, and there is a potential risk that this could lead to catastrophic failures when the circuit breaker operates.

6.5 Distribution Reclosers

The major issues in relation to distribution recloser defects are in the auxiliary components such as control system modules and battery systems. The analysis on these components is covered under their respective AMPs. There are no known issues in relation to the main body and component of the distribution reclosers.

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 Hawker Siddeley Horizon Circuit Breaker type

The Horizon type circuit breaker population in the South East Region is around 10% of the >22kV & <=33kV voltage population with an average age of 8 years. These circuit breakers have an inherent material defect in the stress control screen which causes accelerated insulation degradation. This problem is not limited to South East Region, as other distribution utilities nationally and internationally have faced similar issues with Horizon circuit breakers. As a retrofit solution did not deliver the desired outcome, investigation is still in progress to find a permanent solution. In the interim, Horizon circuit breakers are monitored through periodic inspection.

7.2 Gas filled Circuit Breakers - SF6 Leak

Across EQL, the Magrini Galileo GI E series and GEC Areva OX36 gas filled circuit breakers have been experiencing SF6 leaks more frequently than normal in the span of a single year. The numbers of instances experienced indicate potential issues with maintenance practices. A review of maintenance activities will be undertaken to identify and address any opportunities to reduce and remove the number of units experiencing SF6 leaks.

Currently, the issue is addressed by re-filling gas to an acceptable level. If the issue is not addressed through maintenance, it will lead to the reduction in useful life for the units affected and result in an increase in the maintenance expenditure and asset replacement forecast.

Action 7.2-1: Review maintenance activities to identify and address any opportunities to reduce and remove the number of circuit breakers experiencing SF6 gas leaks.

7.3 ABB EDF – SF6 Low Dew Point

In the Northern and Southern Regions, the issue with ABB EDF circuit breakers is the 100% dew point failure rate. The issue affects the whole fleet of ABB EDF circuit breakers of which there are 165 units installed in the Northern and Southern Regions.

SF6 gas is used as insulation in EDF type circuit breakers. Material moisture can affect the insulation properties of SF6 gas. Due to oxygen and moisture vapour contaminants in SF6 and being continuously replenished via ingress from the external environment through seals, corrosive SF6 decomposition products can form which in excess quantities adversely affects critical parts of the circuit breaker.

To manage these emerging issues, new retrofit canisters have been developed by ABB. Retrofit constitutes replacement or modification of vital parts that have similar or advanced features, for life extension and eliminates intrusive replacement processes for desiccant in EDF for bottom and top desiccant locations.

It is envisaged that installing this device will allow increased moisture absorption resulting in improved dew point inside the circuit breaker. Retrofit options are currently being explored to understand if this will be a solution to the EDF circuit breaker low dew point issue.

Action 7.3-1: Continue to explore the potential for the retrofit of canisters developed by the manufacturer to overcome the issue of dew point in EDF circuit breakers.

7.4 Proportion of Population Approaching End of Life

EQL has a large population of circuit breakers that are approaching end of life, particularly in the Northern and Southern Regions. In order to manage network risk, maintain current levels of customer service, and ensure sustainable programs in the longer term, the rate of replacement of circuit breakers will need to increase.

The increase in the number of replacements will require substantial capital investment and will present operational challenges, particularly in the areas of procurement and resources to undertake the works. The program of circuit breaker replacement will be managed on a risk basis within the portfolio of capital expenditure required for EQL. The program of circuit breaker replacement will be optimised within broader constraints to ensure it is deliverable and sustainable, with replacements aligned with other major site works for efficiency wherever possible.

Forecast programs of replacement to manage this issue have been developed in accordance with the CBRM methodology. Refer to Section 9.5.2 for further information. Assets that cannot be replaced due to constraints in this program will require additional operational expenditure to manage the network risk.

8 Improvement 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 Online Condition Monitoring

Online condition monitoring allows a finer granularity of data capture and trending, which aids in the assessment of asset end-of-life and asset utilisation. This aims to prevent incidences of costly failures and premature replacement and provides opportunities to optimise capital and operating expenditure.

EQL's strategy is to prudently invest in online/remote monitoring on a range of network assets where the assets are supply critical or have suspected condition limitations and operational/access issues.

The installation of fixed/mobile acoustic and electromagnetic probes on switchgear used to detect and locate defects in switchgear insulation is being further explored. In the South East region, a mobile PD monitor unit is being used on a condition-based approach where the plant was required to be monitored continuously. The program has been successful in providing the information required to make timely and accurate engineering risk decisions.

Action 8.1-1: Review and, where viable, extend the use online partial discharge monitoring solutions currently employed in the South East Region to the Northern and Southern Regions to ensure a common EQL approach to the condition assessment of switchgear insulation.

8.2 Switchboard Condition Assessment

Northern and Southern Regions have been implementing a switchboard condition assessment program, using offline electrical testing of switchboards which have been identified to present a potentially high risk of failure from modelling. These assessments are then used for indoor switchboards to determine whether the asset is suitable for refurbishment or requires replacement.

The South East Region undertakes routine diagnostic testing to monitor the condition of switchboards after they have reached 20 years of age. This information is used in both maintenance and replacement forecasting to manage the condition of the assets.

The programs for diagnostic testing and condition assessment for switchboards in both regions are targeted at achieving the same outcomes however the implementation is different. There is an opportunity to align these processes to ensure a consistent approach to switchboard condition monitoring and ensure the most efficient process is implemented.

Action 8.2-1: Review the programs of switchboard condition assessment undertaken in each region with a view to an alignment where it is prudent.

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

Substation circuit breakers and reclosers are considered critical in nature as they are of moderate value, require significant lead time to procure, and failure events have the potential to result in safety consequences, as well as substantial and extended customer load interruption. The critical nature of these assets combined with the relatively low population makes it prudent and cost effective to manage them on an individual basis and to replace them when they are approaching end of life and prior to failure.

The condition of substation circuit breakers and reclosers is proactively monitored through a combination of inspection and testing. The results of these programs are analysed over the life of the asset to provide insight into the condition and remaining life. Periodic non-intrusive and intrusive maintenance is also undertaken to ensure that assets continue to function as required to the end of their economic life. Additional maintenance activities may be undertaken based on the results of the aforementioned inspection and testing programs.

Distribution reclosers are managed through inspection only and replaced based on observed condition related defects as they do not pose the same level of risk or criticality as reclosers used in a substation environment. Failure of a distribution recloser will typically only result in the loss of supply to customers connected to the associated feeder as opposed to causing a wider spread outage.

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 Condition Assessment Data

In order to assess circuit breaker 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.

EQL's use of CBRM provides a platform for defining economic end of life for substation circuit breakers as well offering significant potential for condition-based and reliability-centred maintenance and inspection practices.

The data required for asset assessment includes routine inspection and maintenance records as well as test result records relating to 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.

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, substation circuit breakers and recloser 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

Circuit breakers and reclosers are procured on an as-needed basis, driven by condition-based replacement, network augmentation and replacement of assets that have failed in service. Contracts for these assets typically span at least several years for logistical and pricing reasons and are based on technical specifications guided by the needs of the network. The contract periods determine the opportunity available to change technical specification to improve asset performance by engineering out identified defects, standardising products or implementing newer technologies.

As outlined in Section 7.4 the volume of substation circuit breaker replacement required in the Northern and Southern Regions in order to deliver customer outcomes and manage network risk is forecast to increase, presenting a challenge for procurement.

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 circuit breakers and reclosers as they relate to the management of the asset lifecycle.

EQL has a commenced the ongoing process of alignment of maintenance practices between regions where it is prudent and efficient. This alignment will occur over a number of years to maintain compliance with maintenance tolerances during any transition.

9.4.1 Preventive maintenance

The preventive maintenance strategy is to be proactive in nature, to prevent failures occurring in between routine maintenance activities. Preventive maintenance consists of inspection, testing and routine maintenance activities as follows:

- Non-intrusive Maintenance
    - Circuit Breaker - combination of detailed inspection, functional checks, electrical testing and routine restoration activities intended to restore serviceable items to an acceptable condition. Non-intrusive maintenance does not require access to internals of circuit breaker. Periodic interval for non-intrusive maintenance is between 6 years and 12 years based on asset specification.
- Intrusive Maintenance
    - Circuit Breaker - combination of detailed inspection, functional checks, electrical testing and routine restoration activities intended to restore serviceable items to an acceptable condition. Intrusive maintenance requires access to internal components of the circuit breaker. Periodic interval for intrusive maintenance is between 6 years and 12 years based on asset specification.
    - Recloser – for oil filled reclosers installed inside bulk, zone and major distribution substations, intrusive maintenance activities such as inspection of external condition, connection, steelwork, surge arrestors, insulation will be conducted once every 12 years. Replacement and maintenance activities will be carried out based on requirement. Mechanism functional checks will be conducted once every 6 years.
- Out of Service Condition Assessment
    - Circuit Breaker - electrical testing was undertaken to determine the condition of components that cannot be accessed while the asset is in service. This includes dielectric loss angle test for the circuit breaker. Periodic interval for out of service condition assessment is between 6 years and 12 years based on asset specification.
    - Recloser – out of service condition assessment will be conducted on specified types and problematic units if required.
- In-service Condition Assessment
    - Circuit Breaker - periodic inspection of external condition and operational checks of ancillary equipment to identify defects. Inspections are also used to collect condition data for performance and risk analysis and replacement programs. An online partial

discharge survey and a thermographic survey of all assets within the substation site complement the routine visual inspection. Periodic interval for in-service condition assessment of substation assets is 1.5 years.

  - Recloser – assets installed inside substation, in service condition assessment for all type of reclosers occur every 1.5 years. For remotely monitored reclosers installed on the feeder, the periodic interval is between 2.5 and 3 years, for unmonitored reclosers, the interval is between 12 and 15 months.

- Post Fault maintenance
  - Circuit breakers and reclosers installed inside substations – post fault maintenance activities such as renewing the insulation medium, dressing / replacing worn or pitted contacts, cleaning internal components maintaining the mechanism and carrying out post-maintenance electrical tests and functional checks are undertaken based on asset specification (typically 6 fault operations).
- Switchboard Condition Assessment
  - Circuit breaker – the Northern and Southern Regions have a program to assess actual conditions through offline electrical testing of switchboards which have been identified to present a potentially high risk of failure from modelling. These assessments are used to inform decisions on the future actions required to maintain an indoor switchboard in service at their respective sites.

For detailed information on inspection and maintenance process and activities, refer policy standard documents in Appendix 1.

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 low gas or oil
- Equipment failure
- Fault indication on protection and monitoring equipment.

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. It is recommended that EQL increase the focus on the monitoring of corrective activities as an opportunity to improve the asset management of this asset class.

Action 9.4-1: Monitor corrective maintenance activities to identify and address any opportunities to reduce and remove the number of units experiencing repetitive defects.

9.4.3 Strategic Spares

Spares management is one of the main components of a lifecycle strategy to ensure that a suitable replacement asset is available at right place and at the right time. This results in minimizing any unplanned disruption period promote efficiency and reduce cost in long term. Spares may be either purchased as a new asset or recovered from service if they are assessed as still having a useful life.

Strategic spares holdings for these asset classes are determined through assessment of the populations, failure rates and provisioning period 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 when required across the state.

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

Spares for reclosers are held as general stock and are catered for within the distribution stock requirements. The same stock items are used for both distribution and substations.

Action 9.4-2: Investigate opportunities to manage the risk associated with in-service failure across the diverse populations of circuit breakers without holding every variation as a spare. Areas of focus should include the use of site specific contingency planning and standard designs for brownfield applications.

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.

Drivers for refurbishment or replacement can be determined on either a population (e.g. all assets of that type) or individual plant item basis. Drivers and means to determine priority include:

- Risk to safety e.g. deterioration of insulation properties, deterioration of mechanical properties (structural failure, failure to operate)
- Operational safety, equipment not meeting modern standards and requirements
- CBRM results (unacceptable Health Index)
- Technical obsolescence (lack of spare parts, trade skills, equipment)
- Deterioration of electrical performance (UG cable joint failures, failure to clear fault).

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. Refurbishment activities are determined via assessment of the condition and can vary in complexity, from component replacement (e.g. bushings) through to circuit breaker truck replacement and indoor bus renewal.

As outlined in previous sections, EQL has observed condition issues in its population of substation circuit breakers, particularly in the Northern and Southern Regions. Refurbishment provides an alternative to complete replacement of the asset and assists in reducing the impacts of the increasing program of replacement. It also provides an opportunity to introduce components with higher reliability and lower maintenance cost, to reduce operational costs.

EQL is currently undertaking a program of refurbishment to replace oil filled circuit breaker trucks with compatible vacuum circuit breaker trucks for Reyrolle LMT circuit breakers. There is potential for this sort of refurbishment program to extend to other circuit breaker types if a compatible circuit breaker truck can be sourced. Potential applications include the South Wales – C&D series and GEC – OLX and SBV series.

Action 9.5-1: Develop, where viable, the specification and purchasing arrangements required to retrofit switchboard panels containing oil filled circuit breaker trucks with vacuum units to extend the useful life of the asset.

9.5.2 Replacement

EQL has proactive replacement programs for substation circuit breakers and reclosers. The 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 net present value cost to customers and avoid duplication of works.

EQL uses Condition Based Risk Management (CBRM) to forecast the end of useful life of substation circuit breakers and reclosers. This process combines asset data, engineering knowledge and practical experience to define the current and future condition, performance and risk for modelled assets. This information is summarised and presented as a Health Index (HI). The following figures show the relationship between the HI, remaining life and the probability of failure.

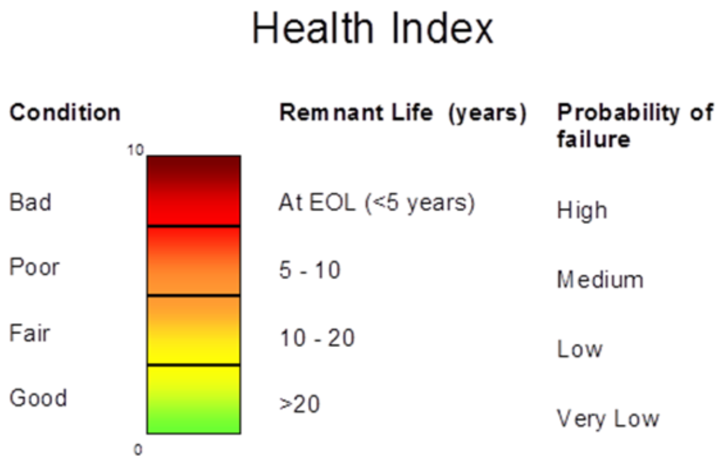


Figure 25: CBRM Health Index

EQL has set a HI threshold of 7.5 as the point to initiate consideration of planned replacement of the assets covered in this AMP. This recognises that projects of this nature typically take several years to design and commission and that assets continue to degrade beyond the threshold value while they remain in service. Refer to the Condition Based Risk Management Application Document for further detail on the CBRM process. In-service failure rate provides a measure of the performance of the proactive replacement programs initiated from CBRM, and is used as an ongoing calibration input for the models.

The program of replacement is managed on a risk basis within the portfolio of capital expenditure required for EQL. The following table provides a summary of replacement programs for circuit breakers and reclosers.

Driver	Asset	Program Timing	
		Northern and Southern Regions	South East Region
Indoor oil filled Circuit Breakers without remote control	South Wales - C&D series Reyrolle - LMT GEC - OLXs& SBVs	2020-2025	2015-2025
Indoor Circuit Breakers in outdoor cubicle	Email – S15 ASEA – HKBC Reyrolle – LMT EE – OLX	2015-2025	2015-2020
Targeted condition based	ASEA – HLC & HKEY: Historical explosive failure due to moisture ingress ABB – VBF: Historical catastrophic failure due to loss of gas and moisture ingress. EIB and Sprecher & Shuh – HPFA: Arc interrupting turbulator falls off inside the Circuit Breaker DELLE – HPGE: Slow to operate.	2015-2025	-
Condition based	LG 1C 345GC JB 424 Reyrolle – LMT	2015-2025	2015-2025
Asset condition and risk	Distribution Reclosers	Ongoing	Ongoing

Table 5: Current Replacement Programs in EQL

9.6 Disposal

Replacement and refurbishment activities of circuit breakers and reclosers comply with all requirements for the safe disposal of hazardous materials such as sulphur hexafluoride (SF6) and asbestos. EQL will adopt all reasonable and practicable measures to:

- Store, transport and dispose of all waste streams in accordance with state and local authority requirements.
- Segregate waste streams to prevent the generation of wastes requiring disposal as hazardous (regulated) wastes due to contamination.
- Minimise, reuse or recycle waste as the preferred option over disposal to landfill.

9.6.1 Sulphur Hexafluoride (SF6)

The National Greenhouse Energy and Reporting (NGER) Act 2007 places a statutory obligation on EQL to report emissions of SF6 gas associated with its network operations including disposal of SF6 circuit breakers and reclosers. Processes and procedures are in place to ensure SF6 emission is quantified and recorded during the asset decommissioning process, in compliance with this statutory requirement.

9.6.2 Asbestos

The critical drive of EQL's approach for ACM is to remove and replace ACM at highest risk and volume locations and to ensure suitable precautions are introduced until ACM replacement has happened.

EQL employs a Permit to Work System to control all risks when removing asbestos from properties and assets including circuit breaker and reclosers. EQL has a panel of preferred licensed asbestos removalists available. Safe work practices are developed for each specific asset type containing ACM.

10 Program requirement 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 6.1-1: 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 condition.

Action 7.2-1: Review maintenance activities to identify and address any opportunities to reduce and remove the number of circuit breakers experiencing SF6 gas leaks.

Action 7.3-1: Continue to explore the potential for the retrofit of canisters developed by the manufacturer to overcome the issue of dew point in EDF circuit breakers.

Action 8.1-1: Review and, where viable, extend the use online partial discharge monitoring solutions currently employed in the South East Region to the Northern and Southern Regions to ensure a common EQL approach to the condition assessment of switchgear insulation.

Action 8.2-1: Review the programs of switchboard condition assessment undertaken in each region with a view to an alignment where it is prudent.

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: Monitor corrective maintenance activities to identify and address any opportunities to reduce and remove the number of units experiencing repetitive defects.

Action 9.4-2: Investigate opportunities to manage the risk associated with in-service failure across the diverse populations of circuit breakers without holding every variation as a spare. Areas of focus should include the use of site specific contingency planning and standard designs for brownfield applications.

Action 9.5-1: Develop, where viable, the specification and purchasing arrangements required to retrofit switchboard panels containing oil filled circuit breaker trucks with vacuum units to extend the useful life of the asset.

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 Management Plan.

Organisation	Document Number	Title	Type
Energex	STD 01114q STD 01110q STD 01111q STD 01200 STD 01113q STD01136q STD 01137q	Maintenance Standards for Circuit Breakers and Reclosers	Standard
Ergon Energy	STWN1124 STNW1120 STNW1121 STNW1123 STNW1147 STNW1148	Maintenance Standards for Circuit Breakers and Reclosers	Standard
Ergon Energy Energex		Substation Defect Classification Manual	Manual
Ergon Energy Energex		Lines Defect Classification Manual	Manual
Energex	CD002	Maintenance standards for handling SF6	Standard
Energex	00652	Asbestos Management Plan	Policy

Appendix 2 – Definitions

Term	Definition
Distribution	LV and up to 22kVnetwork, all SWER networks
Sub transmission	33kV and 66kV networks
Transmission	Above 66kV 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.

Appendix 3 – Acronyms and Abbreviations

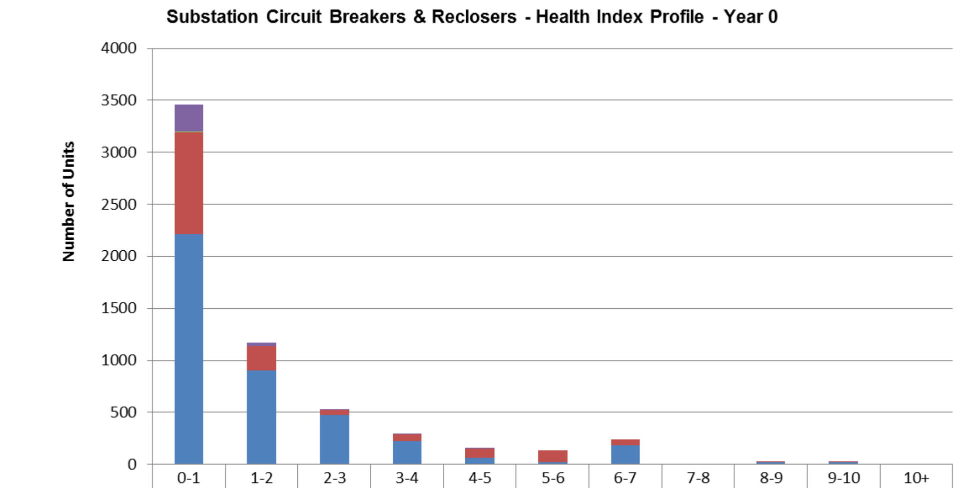
The following abbreviations and acronyms may appear in this Asset Management Plan.

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	Energy Queensland 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
MSSS	Maintenance Strategy Support System
MU	Metering Unit
MVAr	Mega-VAr, unit of reactive power
NER	Neutral Earthing Resistor
NFM	Network Facility Management
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

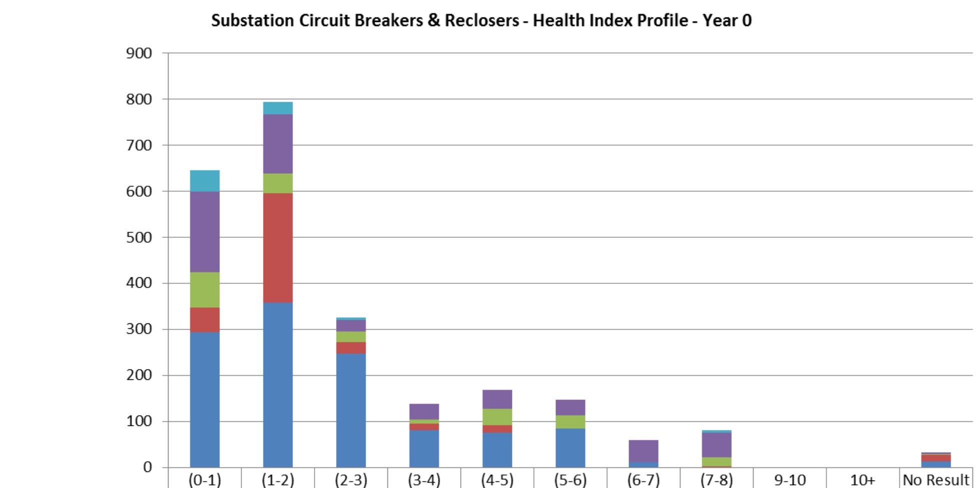
Appendix 4 - CBRM Health Index (HI) Profile

The health of the substation circuit breakers and reclosers are measured by the CBRM Health Index (HI). The figures below show the Health Index profile of in service substation circuit breakers and reclosers at the current time (Year 0).



	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10+
>66kV & <=132kV	262	29	14	6	5	0	0	0	0	0	0
>33kV & <=66kV	1	0	0	0	0	0	0	0	0	0	0
>22kV & <=33kV	980	238	47	63	94	107	57	0	1	2	0
<=11kV	2215	900	474	226	59	25	180	0	24	22	0

Figure 26: South East Region – Substation CBs and REs HI Profile



	(0-1)	(1-2)	(2-3)	(3-4)	(4-5)	(5-6)	(6-7)	(7-8)	9-10	10+	No Result
> 66 kV & < = 132 kV	47	26	6	0	0	0	0	5	0	0	0
> 33 kV & < = 66 kV	174	130	25	33	41	34	48	54	0	0	4
> 22 kV & < = 33 kV	78	42	22	10	36	30	0	19	0	0	1
> 11 kV & < = 22 kV	53	238	25	14	16	0	0	3	0	0	14
< = 11 kV	294	358	248	81	76	84	11	0	0	0	14

Figure 27: Northern and Southern Regions CBs HI profile

The performance of the reclosers installed on the feeder network is measured by the number of defects as these assets are not measured by CBRM Health Index (HI) due to insufficient information available for calculation of HI.