Asset Management Plan
Protection Relays

Part of the Energy Queensland Group

Executive Summary

This Asset Management Plan (AMP) covers the class of assets known as Protection Relays, which falls in the category of Field Devices.

Protection relays are devices designed to trip circuit breakers during an abnormal network operating events to prevent or minimise damage to plant/equipment also providing a significant role in protecting staff and the general public during these events.

EQL manages approximately 23,000 protection relays comprising approximately 6,000 units in the Northern and Southern Regions (Ergon Energy) and approximately 17,000 units in South East Region (Energex).

Protection relays are relatively low cost assets and are typically asset managed on a site by site basis, using periodic inspection and maintenance for condition and serviceability and through systemic review of age and failure rate.

EQL employs a number of different technology types of protection relays.

- These include:
- Electromechanical
- Analogue/Static
- Hybrid (combination of analogue and electromechanical)
- Digital/Numeric

Each technology type is allocated a generic expected operational life span, with electromechanical being the longest at 45 years and digital relays being the shortest at 20 years. With digital relays being the most procured relays, this significantly impacts the expected upcoming replacement of relays. With less than half the expected operational life to that of electromechanical relays, a large number of replacements is expected in the upcoming AER period. Although electromechanical relays are considered robust, the lack of functionality, limited availability of spares and lack of self-monitoring puts some of these relays at risk. Particular make and model of relays are also prone to spurious operations and failures.

Protection relays play a significant role in keeping the network safe and reliable. Failure of these assets can lead to catastrophic consequences such as major damage to primary assets e.g. transformers.

EQL employs the following measures to ensure protection relays are reliable and operational:

- A planned maintenance cycle.
- Maintain an updated database of all protection relays.
- Analysis to determine high risk relays in the network and promptly declare them for replacement.
- Site audits to validate and improve protection relay data.
- Manage and update strategic spare holdings of relays that can no longer be purchased.

Revision History

Revision date	Version number	Description of change/revision
31/01/2019	1	AER Document Initial release

Document Approvals

Name	Position title	Date
Tim Hart	General Manager Asset Lifecycle Management	31/01/2019
Peter Price	EGM SASP	31/01/2019

Document Tracking Details

Network and Non-Network Document Hierarchy Reference Number	Regulatory Proposal Chapter Reference	Document	File Name
NET AMP – 012	7.038	Asset Management Plan - Protection Relays	EGX ERG 7.038 Asset Management Plan - Protection Relays 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 and Southern Regions (Legacy organisation: Ergon Energy Corporation Limited).

There are variations between the EQL regions 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 integration of asset management practices.

1.1 Purpose

The purpose of this document is to demonstrate the responsible and sustainable management of protection relays 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 to regulatory requirements.
4. Manage the risk associated with operating the assets over their lifespan.
5. Optimise the value EQL derives from the asset class.

This 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 AMP is guided by the following legislation, regulations, rules and codes:

- *Electricity Act 2002 (Qld)*
- *National Electricity Rules (NER)*
- *Electrical Safety Act 2002 (Qld)*
- *Electrical Safety Regulation 2013 (Qld)*
- *Queensland Electrical Safety Code of Practice 2010 – Works (ESCOP).*
- *Work Health & Safety Act 2014 (Qld)*
- *Work Health & Safety Regulation 2011 (Qld)*
- Ergon Energy Corporation Limited Distribution Authority No D01/99.
- Energex Limited Distribution Authority No. D07/98.

This AMP 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.

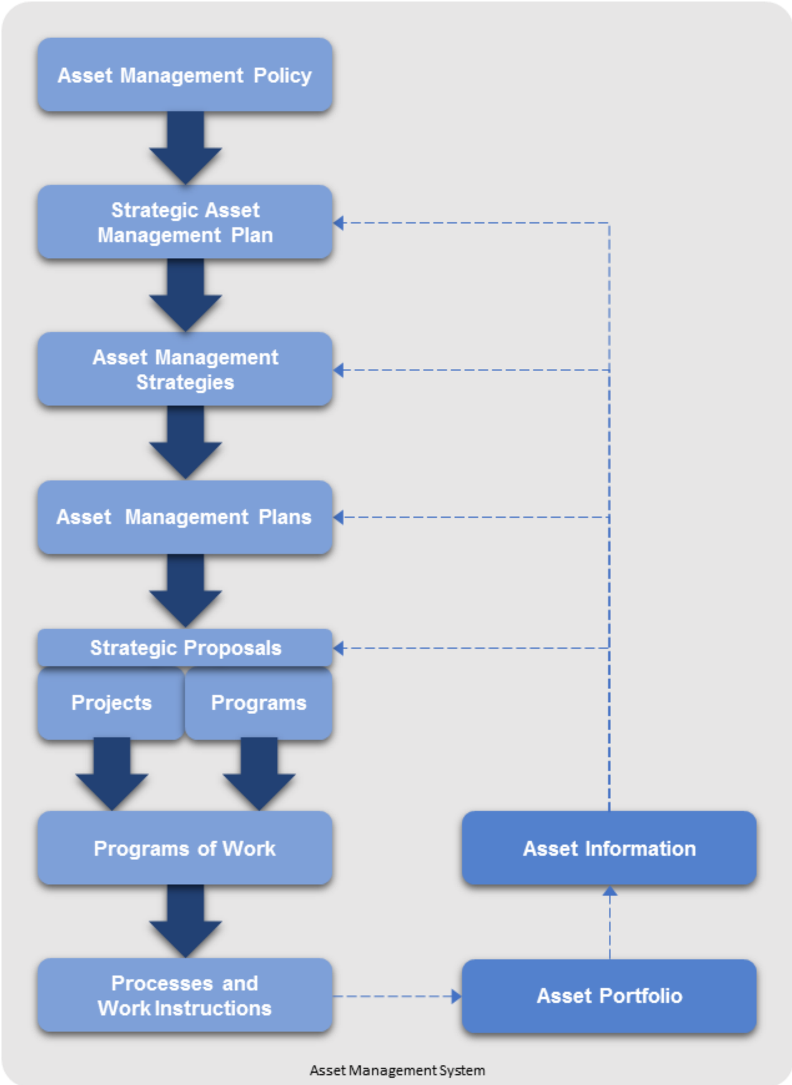


Figure 1: EQL Asset Management System

1.2 Scope

The Asset Management Plan covers the protection relays within the EQL electricity network and their maintenance programs for the 2020-2025 period, as defined by the four categories as listed below:

- Electromechanical
- Analogue/Static
- Hybrid (only applicable to the South East region)
- Digital/Numeric.

This report does not include auxiliary relay items such as inherent component of other plant items (e.g. temperature indicators for transformers), and those that are closely related to telecommunications and Supervisory Control and Data Acquisition (SCADA) plant. Additionally, the electrical wiring and housing apparatus that include protection relays are not covered in this report.

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

1.3 Total Current Replacement Cost

Protection relays fall under the asset class of field devices. Assets of the field device class are generally high volume, low cost assets and are typically asset managed on a population basis using periodic inspection for condition and serviceability as well as systemic review of performance records.

Based upon asset quantities and replacement costs, EQL field devices, of which protection relays contributes towards, has a replacement value in the order of \$820 Million. This valuation is the gross replacement cost of the assets, based on the cost of replacement of modern equivalents, without asset optimisation or age assigned depreciation. Figure 2 provides an indication and comparison of the relative financial value of a variety of EQL Services.

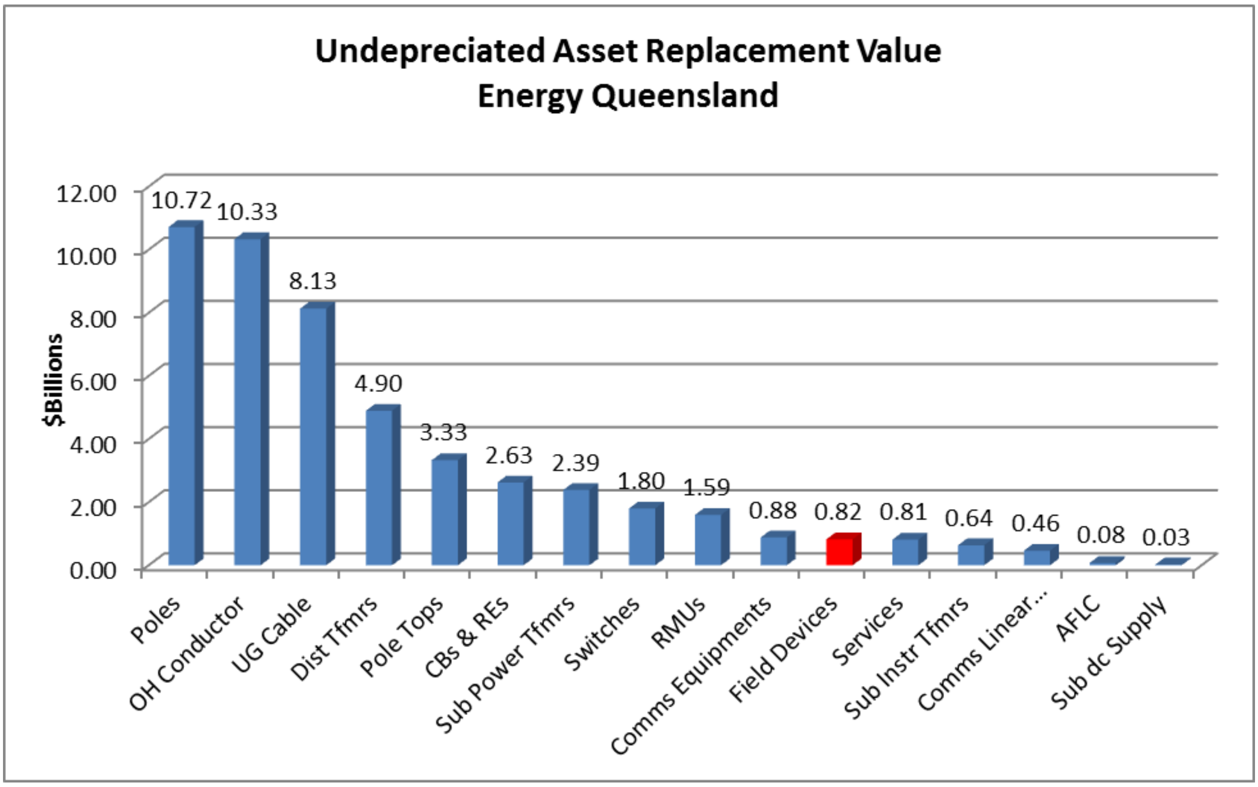


Figure 2: EQL – Total Current Asset Replacement Cost

1.4 Asset Function and Strategic Alignment

The function of a protection relay is to protect plant and equipment by isolating them from, or eliminating, any fault that it is designed to detect. There are many different types of protection relays, each created for certain protection functionalities which target specific abnormal situations or faults that may occur within the network.

The problems that these devices typically detect are deviations of current or voltage that may be damaging to the health or stability of the electric network. When a fault that is beyond the limit set by a user is found, the relay will send a signal to circuit breaking equipment, causing them to operate. This procedure contributes to a significant reduction in harm to personnel and/or equipment.

Table 1 details how the asset lifecycle management of protection relays contributes 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 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.
Manage risk, performance standards and asset investment to deliver balanced commercial outcomes	Failure of this asset can result in increased public safety risk and disruption of the electricity network. Asset longevity assists in minimising capital and operational expenditure.
Develop Asset Management capability and align practices to the global ISO55000 standard	This AMP is consistent with ISO55000 objectives and drives asset management capability by promoting a continuous improvement environment
Modernise the network and facilitate access to innovative energy technologies	This AMP promotes the replacement of 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

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

Table 2: Stakeholders

2 Asset Class Information

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

2.1 Asset Description

Protection relays exist to protect important assets and infrastructure on the electric network by detecting faults or abnormal conditions and sending a triggering response to circuit breaking equipment. These devices vary in their core function, offering schemes such as overcurrent and differential detection, as well as their physical and electrical properties.

Protection relays are categorised into four separate groups based on their construction, as described below. These categories are based on how units are constructed they also give an indication of expected lifespan of the asset, as the unique components within each has differing degradation characteristics and limit the reliability of the device proportionately.

Based on industry best practice and past observations, below are the associated life expectancies of the different relay classifications:

- Electromechanical relays – 45 years
- Analogue / static relays – 25 years
- Hybrid relays – 35 years
- Digital / numeric relays – 20 years.

2.1.1 Electromechanical Relays

Electromechanical relays were first installed in the 1950s and are considered the first generation of protection devices. Electromechanical relays operate via physical phenomena such as magnetic induction or thermal expansion and are often identified by the fact that their functionality is implemented by components that physically move in operation.

These relays typically do not contain printed circuit boards (PCBs), extensive electronic components, or power supplies; rather they generally consist of large solenoids, turning discs, and resistive or heating elements.

Electromechanical relays were the earliest model type to be installed within EQL’s network.

2.1.2 Analogue | Static Relays

Analogue/static relays have been installed since the 1970s. Electronically controlled with no moving parts, this type of relay offered improved accuracy and faster operation times compared with electromechanical relays. These relays utilise circuitry-based measurement in their protection functions and as such have PCBs featuring power supplies, transistors, integrated circuits, or operational amplifiers along with other electronic components that electromechanical relays may not. Often static relays feature analogue dials on their front faceplate to set and display relay settings.

2.1.3 Hybrid Relays

Historically, electromechanical and analogue relay types were considered entirely separate with significantly different expected lifespans. It was recently determined in the South East Region that these classifications were insufficient for a number of relay models that exhibited features of both electromechanical and analogue relays. With this in mind, the “Hybrid” relay classification was formed. Hybrid relays are largely electromechanical and without turning discs, however, they also have electronic components and thus have a shorter expected lifespans than electromechanical relays, at 35 years. This classification is only applicable to the South East Region of EQL.

2.1.4 Digital | Numeric Relays

Digital/numeric relays are the latest generation of relays and have been installed since the early 1990s. They are predominantly identified by their microcontroller component or intelligent auxiliary functionalities. These relays typically operate by interpreting the input signals from instrument transformers via the microcontroller and perform calculations digitally.

These relays require power supplies to operate and have a self-diagnosing health indicator capable of generating alarms as necessary. Additionally, these devices generally have more complex PCBs than their analogue counterparts.

Currently, digital relays are the most popular relay within the EQL network due to their high accuracy, fast response, and additional functions that contribute towards the operation and security of the network.

2.2 Asset Quantity and Physical Distribution

EQL currently has approximately 23,000 protection relays in-service within its network. The breakdown of the different types of technologies in each region is shown in Table 3.

Asset Type	Northern	Southern	South East	Total
Electromechanical	578	786	2,857	4,221
Hybrid	0	0	2,641	2,641
Analogue | Static	872	842	1,646	3,360
Digital | Numeric	1,622	1,511	9,738	12,871
Total	3,072	3,139	16,882	23,093

Table 3: Asset Quantities across EQL Regions

It should be noted that auxiliary relays associated with primary protection systems are not included in the Northern and Southern Regions.

2.3 Asset Age Distribution

Because of the widely varying components and physical constructions that each protection relay classification covers, the expected life of these groups also varies significantly, impacting the associated asset management methods of these groups of devices.

Below is a discussion on each classification and age profiles to detail the distinct age differences between the relay model categories.

2.3.1 Electromechanical Relays

EQL has approximately 4,200 electromechanical relays in service on the network. The age profiles of the installed electromechanical relays by region are shown in **Figure** 3 and Figure 4.

While digital relays have increased in number significantly over the last 14 years, there is still a large presence of electromechanical relays throughout EQL's network. Majority of these relays are still found in the 11kV network where the protection scheme does not require complicated digital relays to perform complex monitoring or protection functions. These relays also have the highest expected operational life compared to its counterparts. Hence, the population of electromechanical relays remains second behind digital relays.

Figure 5 and Figure 6 show the instances of electromechanical relay failure events with respect to unit age since 2001, in the South East region and the Northern and Southern Regions respectively. Due to the collection of relay failures only dating back to 2007, the actual failure data of electromechanical relays could be significantly lower than what is reported in Figure 5 and Figure 6.

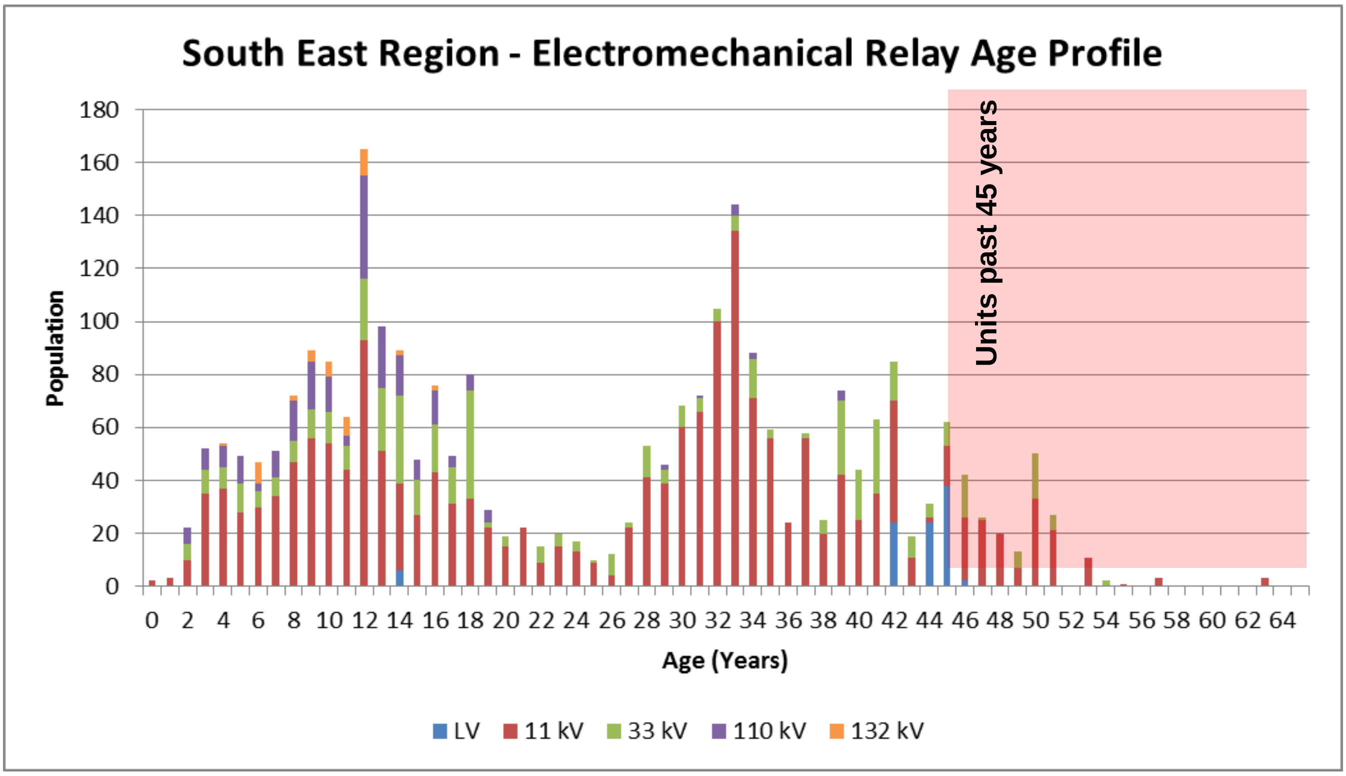


Figure 3: South East Region Electromechanical Relay Age Profile

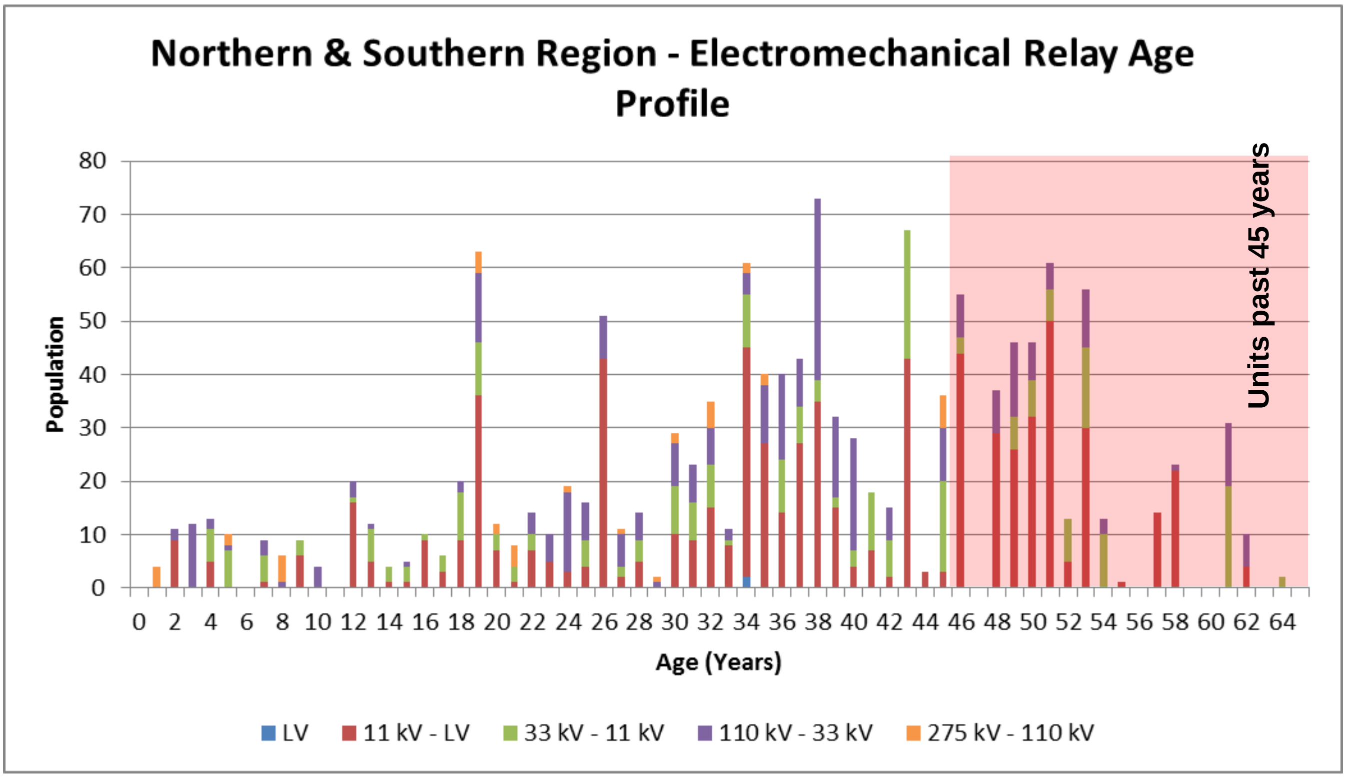


Figure 4: Northern and Southern Regions Electromechanical Relay Age Profile

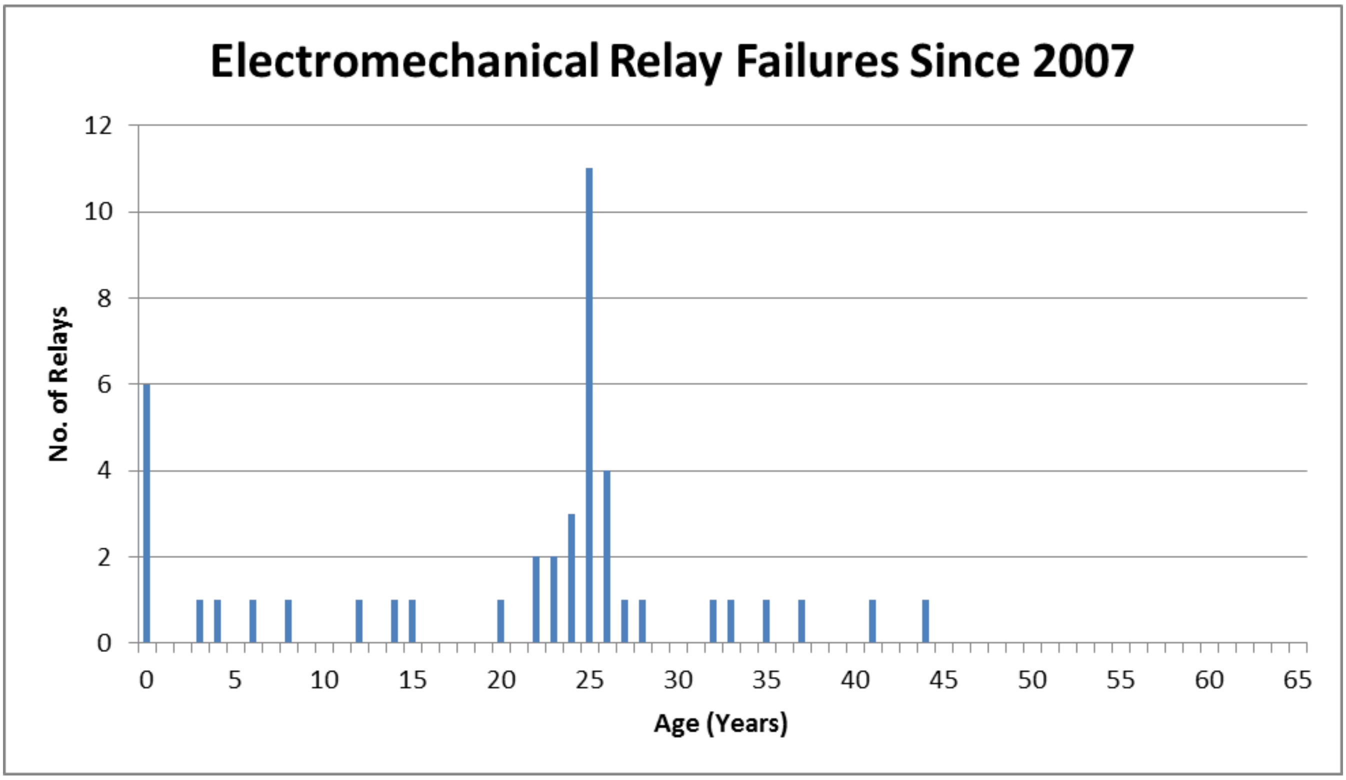


Figure 5: South East Region Electromechanical Relay Failures Since 2007

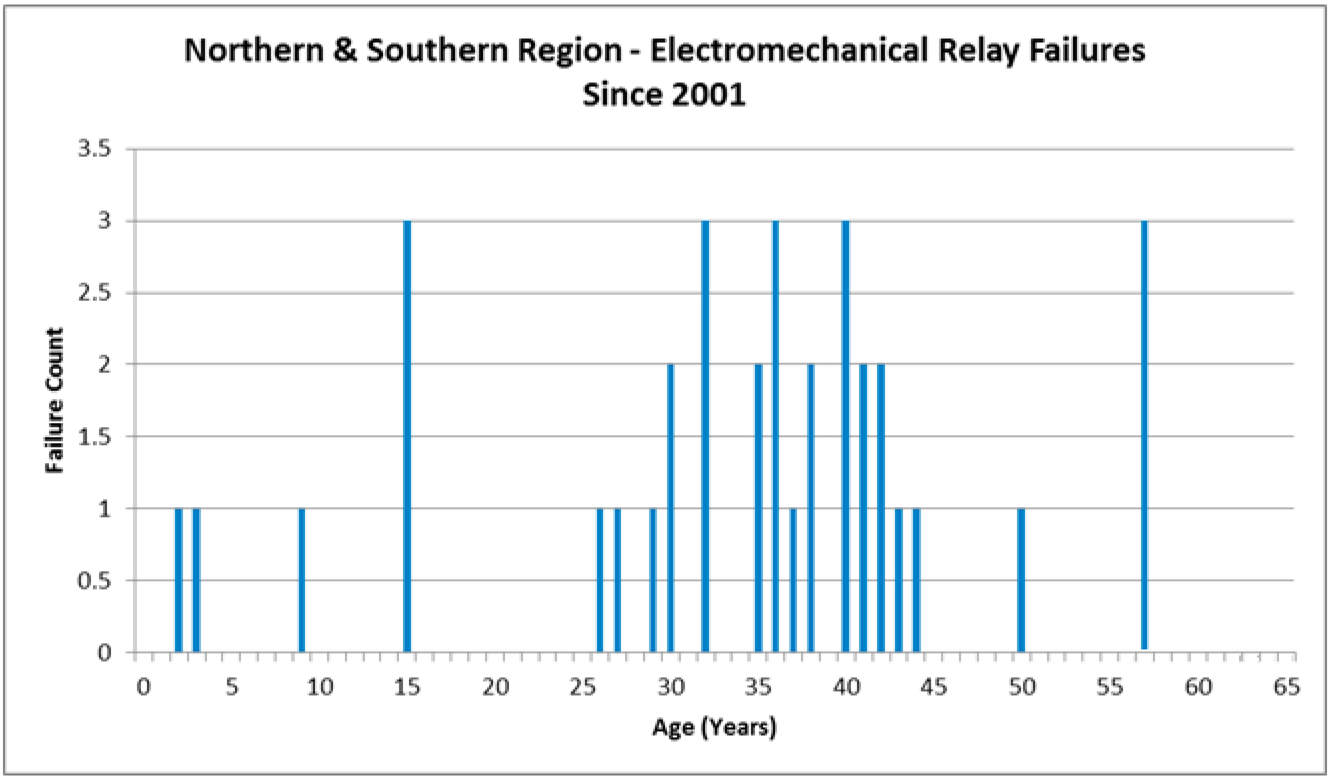


Figure 6: Northern and Southern Regions Electromechanical Relay Failures Since 2001

2.3.2 Analogue | Static Relays

EQL has approximately 3,400 analogue relays in service within its network. The age profile of analogue relays 'in-service' by region is shown in Figure 7 and Figure 8.

Figure 9 and **Figure** 10 display the occurrences of analogue relay failure for the South East Region and Northern and Southern Regions respectively. In the South East Region, failure data is only available since 2007. Analogue relay failures are observed as being predominantly distributed across the first 30 years of its operational life, with the majority experiencing failures at the time of installation of or commissioning. The large number of failures at the age of 0 in Figure 9 is brand new relays that failed test before they are put into service. This number does not provide an accurate representation of the expected operational life of analogue relays but rather the reliability of those particular relays.

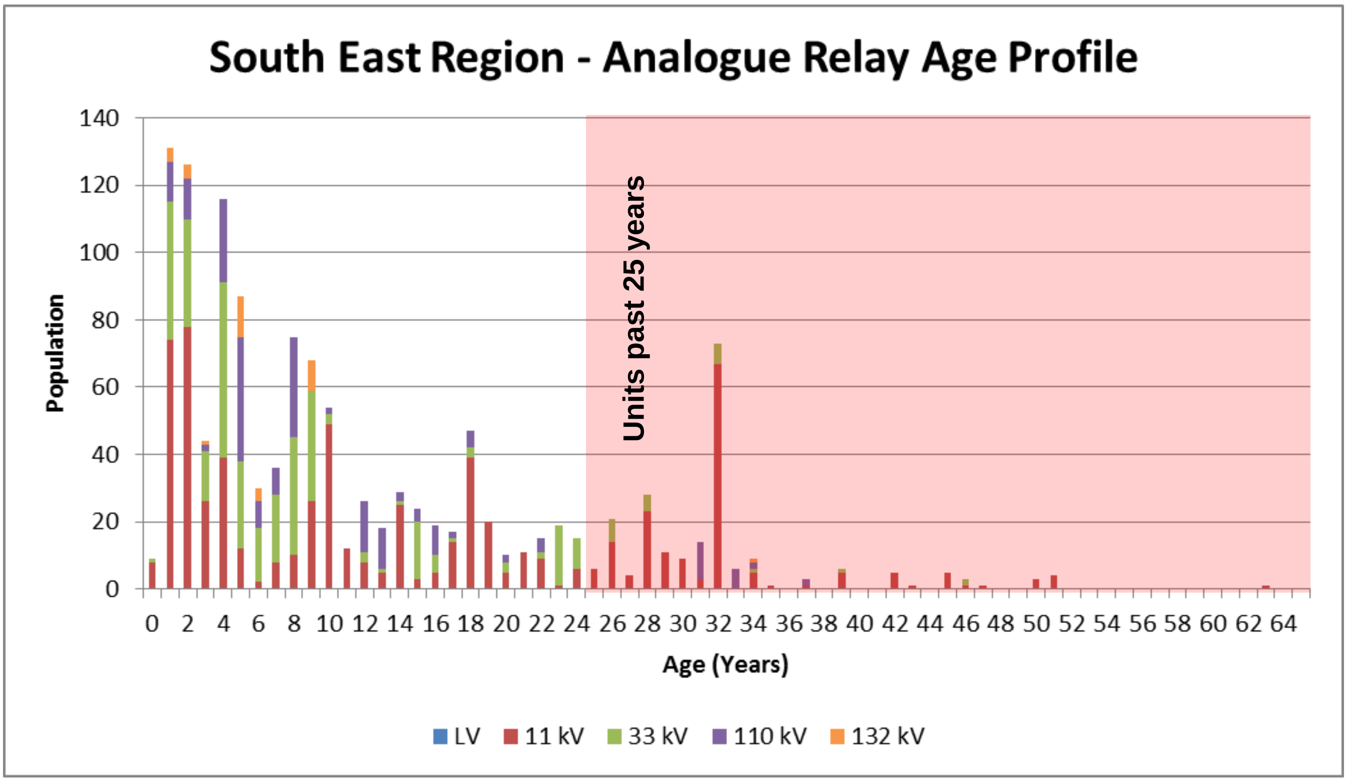


Figure 7: South East Region Analogue Relay Age Profile

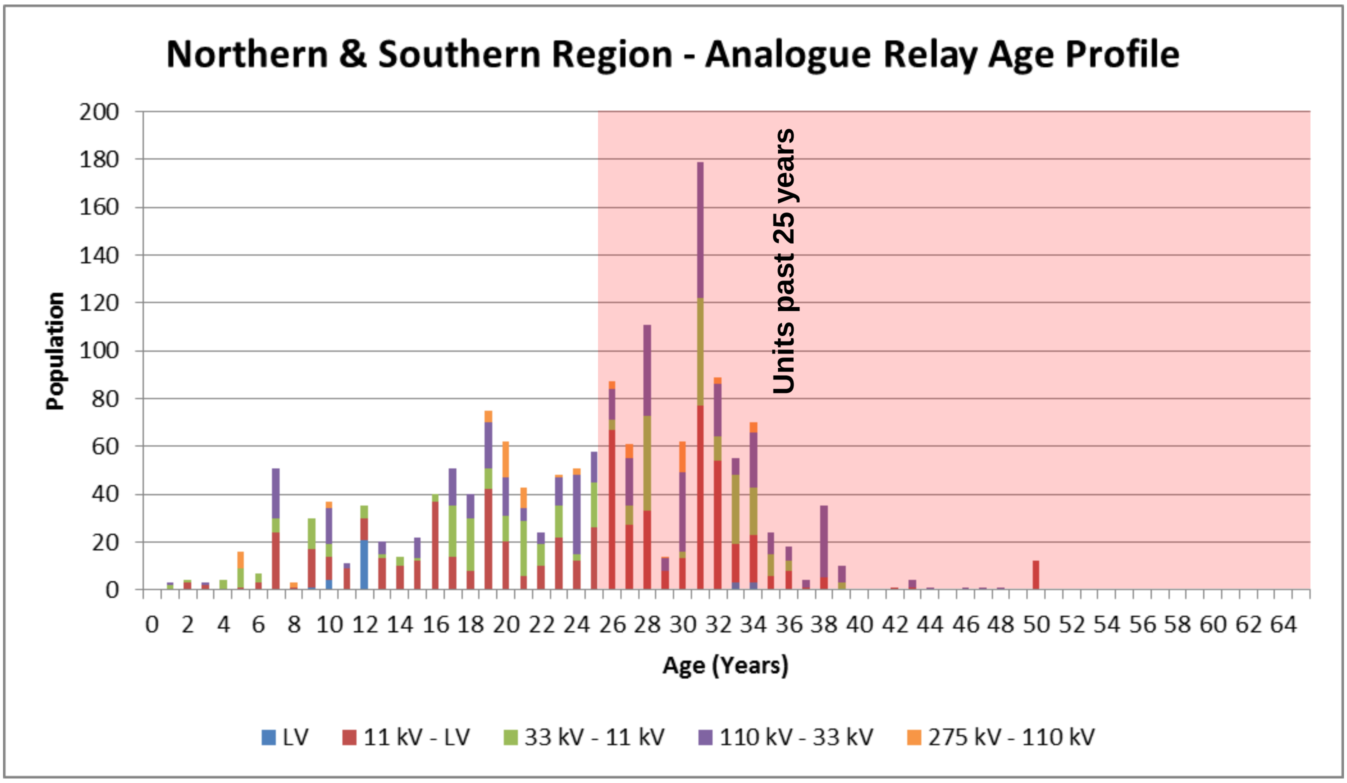


Figure 8: Northern and Southern Regions Analogue Relay Age Profile

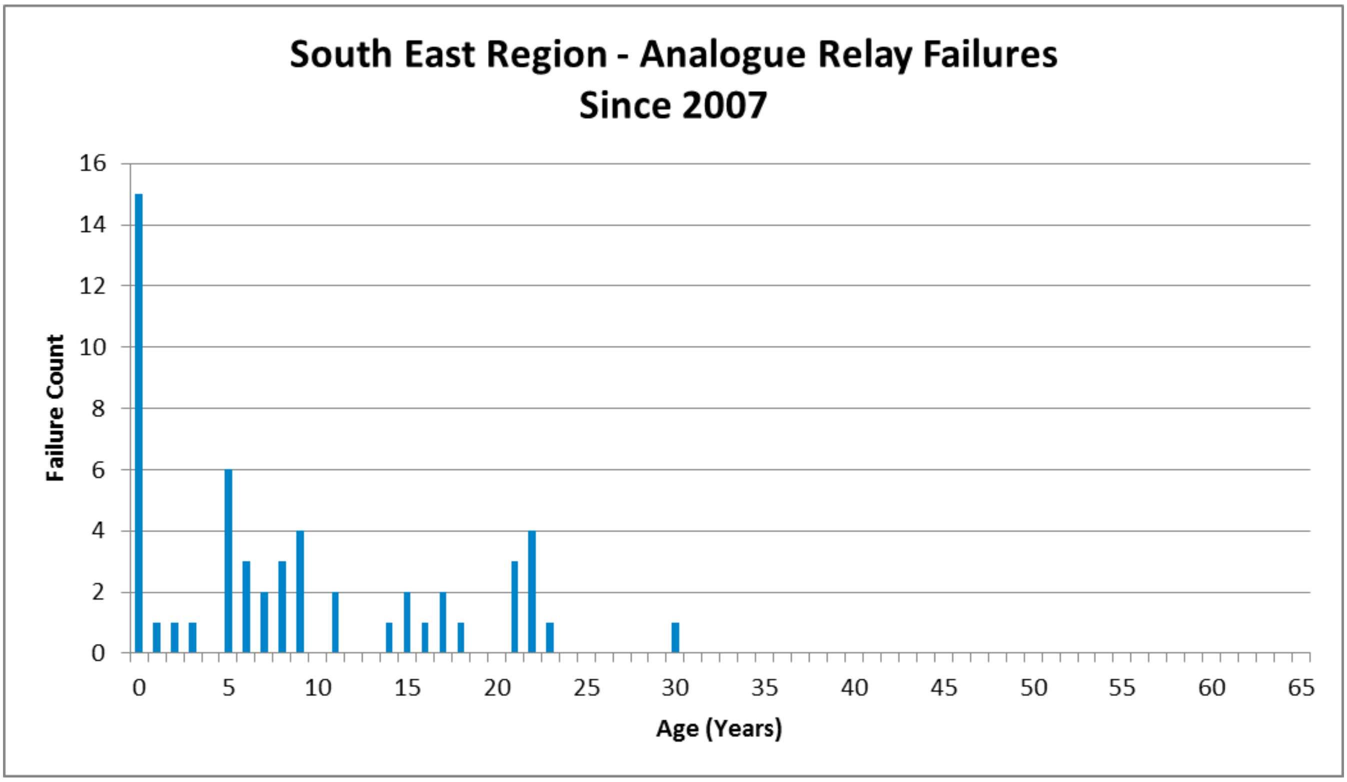


Figure 9: South East Region Analogue Relay Failures Since 2007

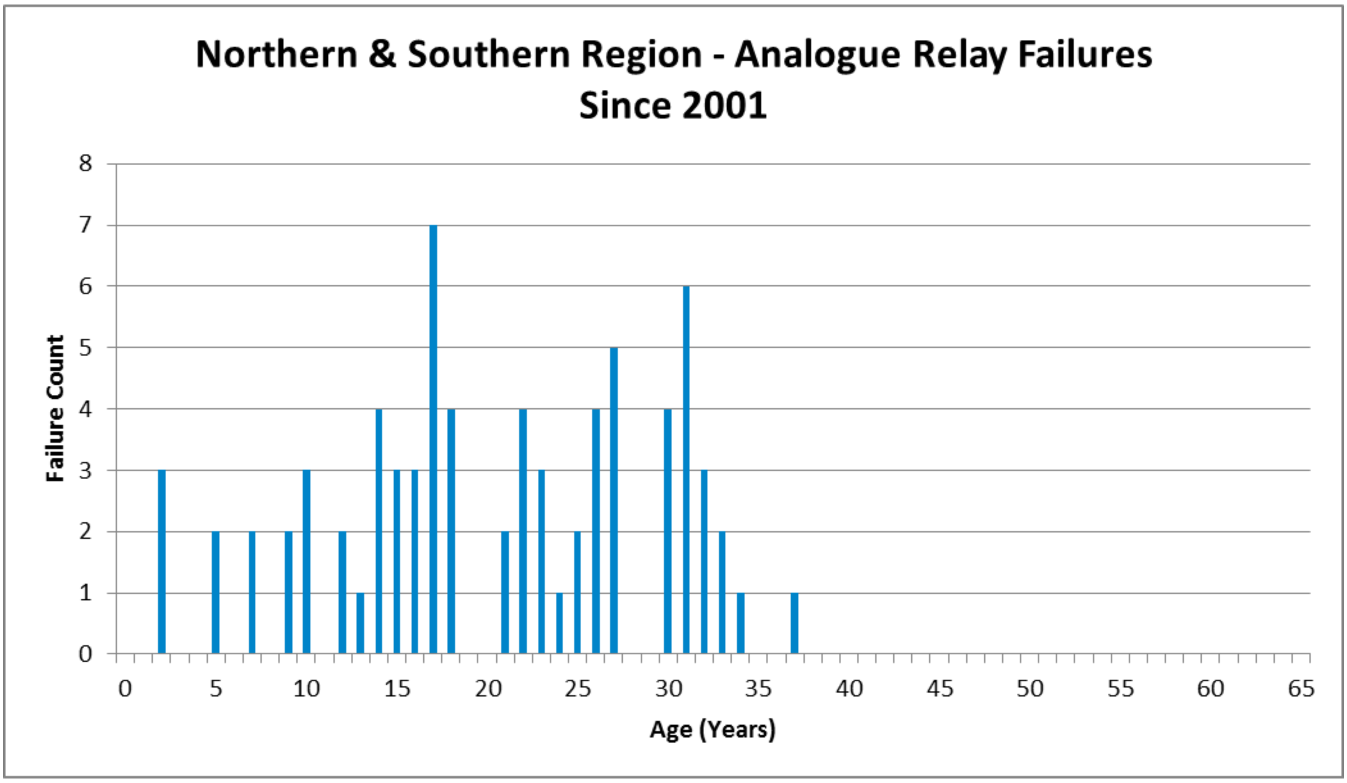


Figure 10: Northern and Southern Regions Analogue Relay Failures Since 2001

2.3.3 Hybrid Relays

EQL’s South East Region has approximately 2,600 hybrid relays in service on its network. The age profile of the installed hybrid relays is shown in Figure 11.

Although the age failure profile of the hybrid relay shown in Figure 12 appears similar to that of analogue relays, there are currently more than 200 relays operating beyond the 35 years of age.

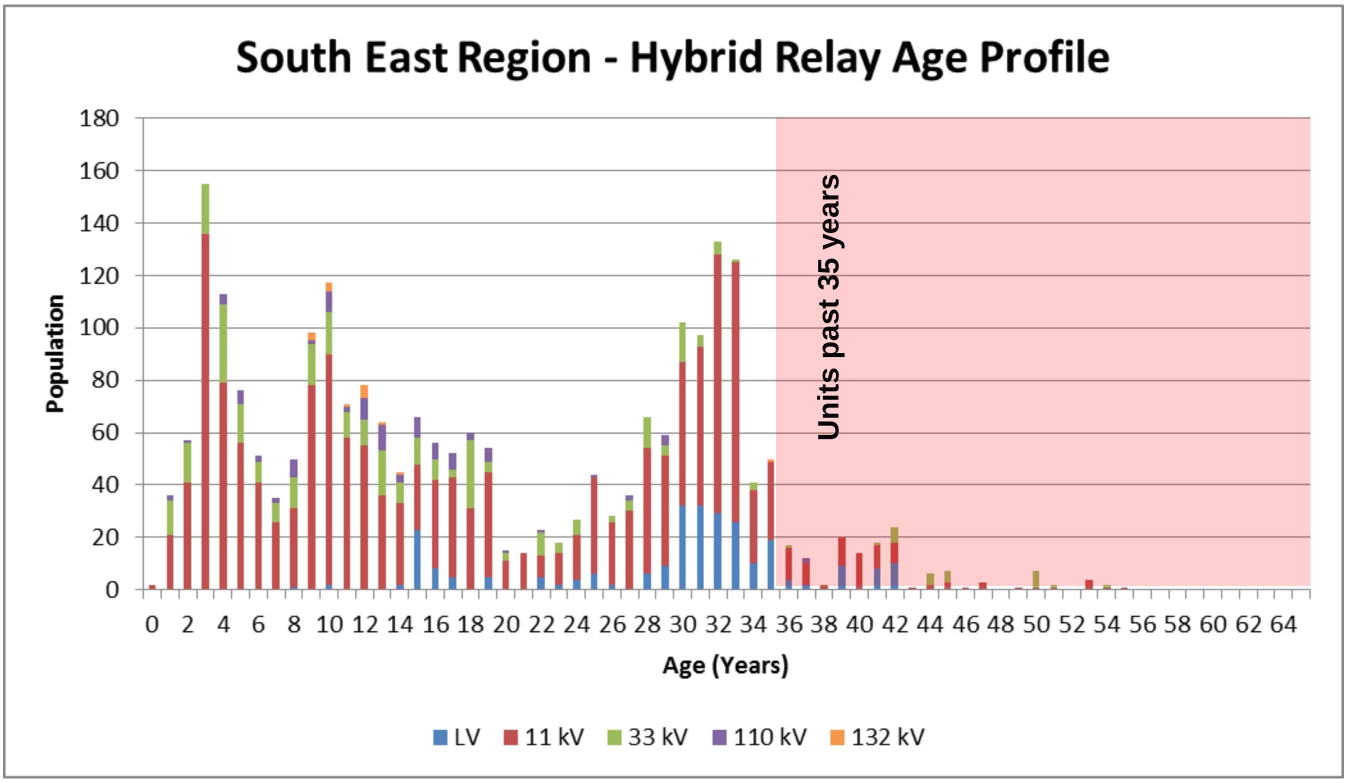


Figure 11: South East Region Hybrid Relay Age Profile

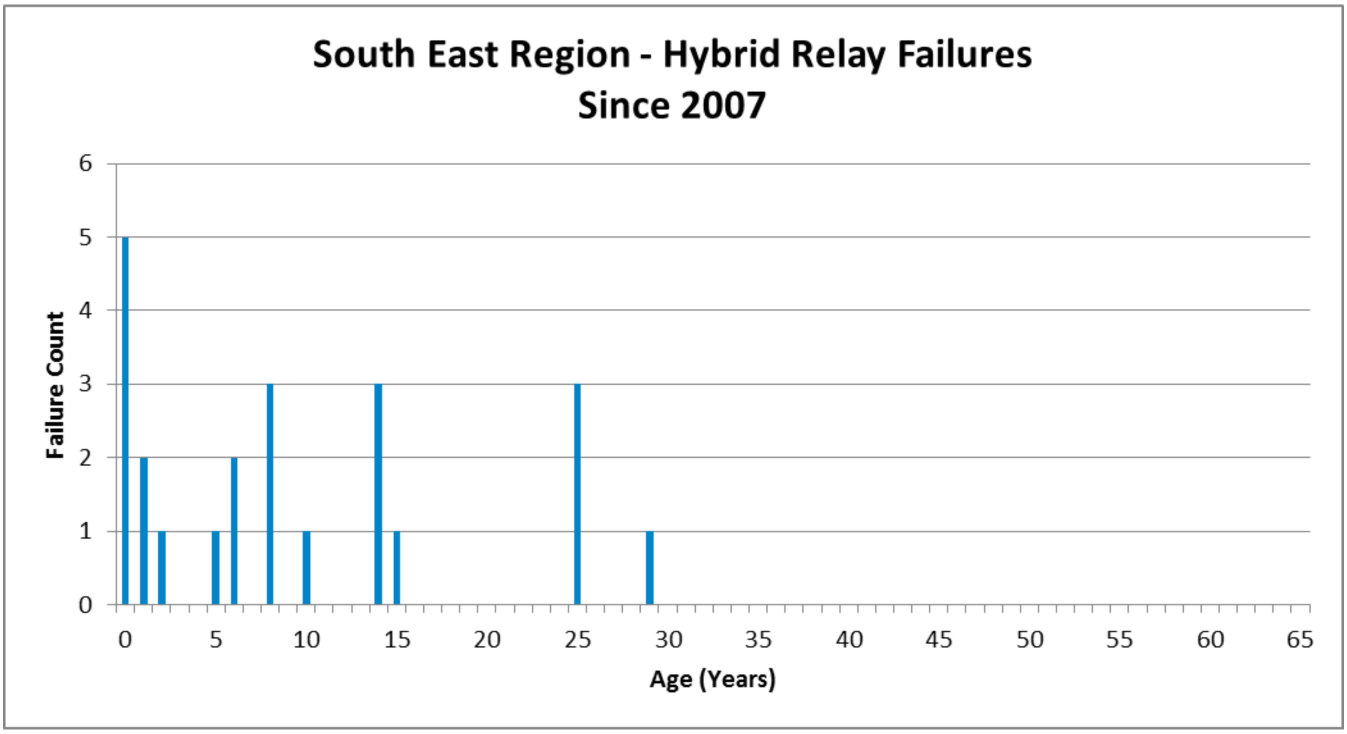


Figure 12: South East Region Hybrid Relay Failures Since 2007

2.3.4 Digital | Numeric Relays

EQL has approximately 13,000 digital relays in service throughout its network. The age profiles of digital relays 'in-service' by region are shown in Figure 13 and **Figure** 14. As is clearly evident, the majority of the digital/numeric relays were installed within the past 15 years. As they have an expected lifespan of 20 years, this poses an emerging issue with an anticipated greatly increased need for replacement funding in the near future.

With much more complex componentry than the other relay technologies, Digital relays are more prone to failures as evident in Figure 15 and Figure 16. The majority of the recorded relay failures occur within the first 13 years of operational life, with a large number occurring at the time of installation as indicated by test failures. It should be noted that many of the observed failures were not due to mal-operation, but rather the failure of specific components like LCD screens, power supplies, or software related issues.

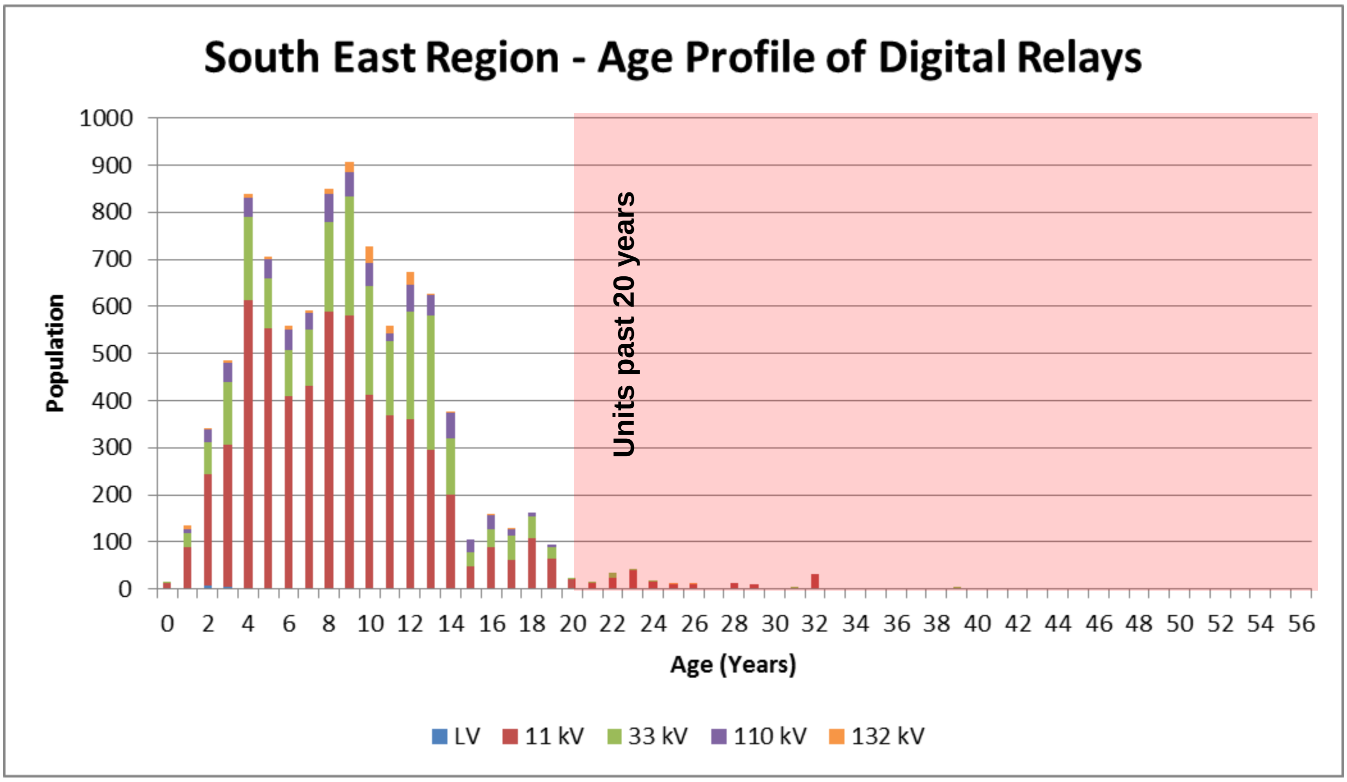


Figure 13: South East Region Digital Relay Age Profile

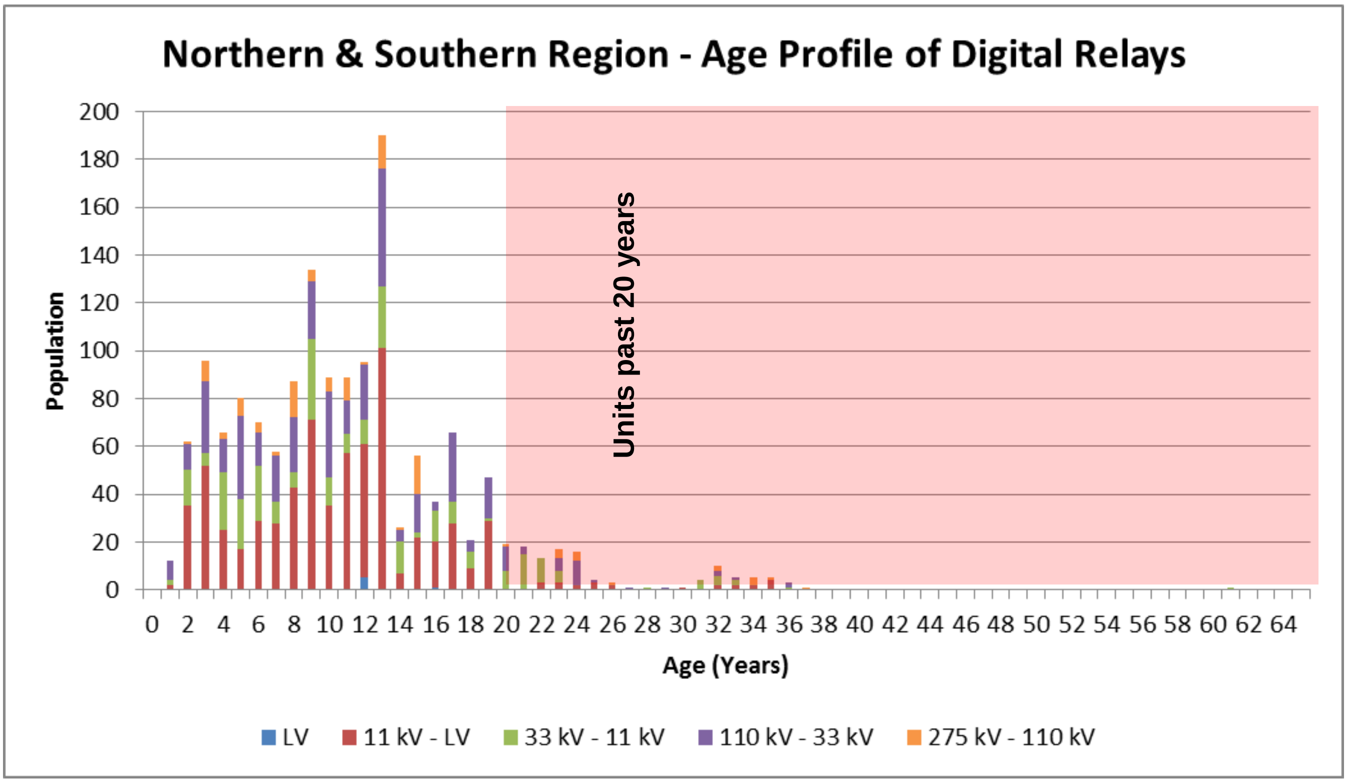


Figure 14: Northern and Southern Regions Digital Relay Age Profile

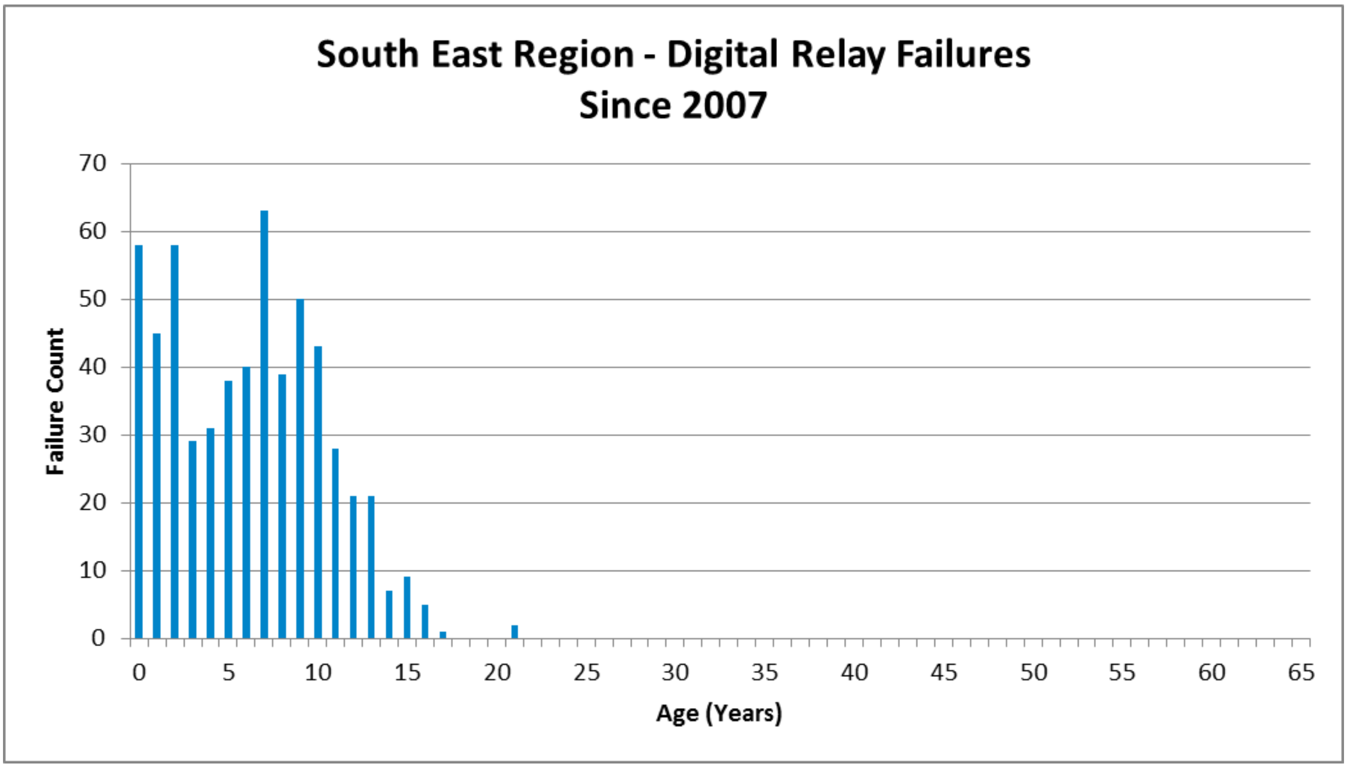


Figure 15: South East Region Digital Relay Failures Since 2007

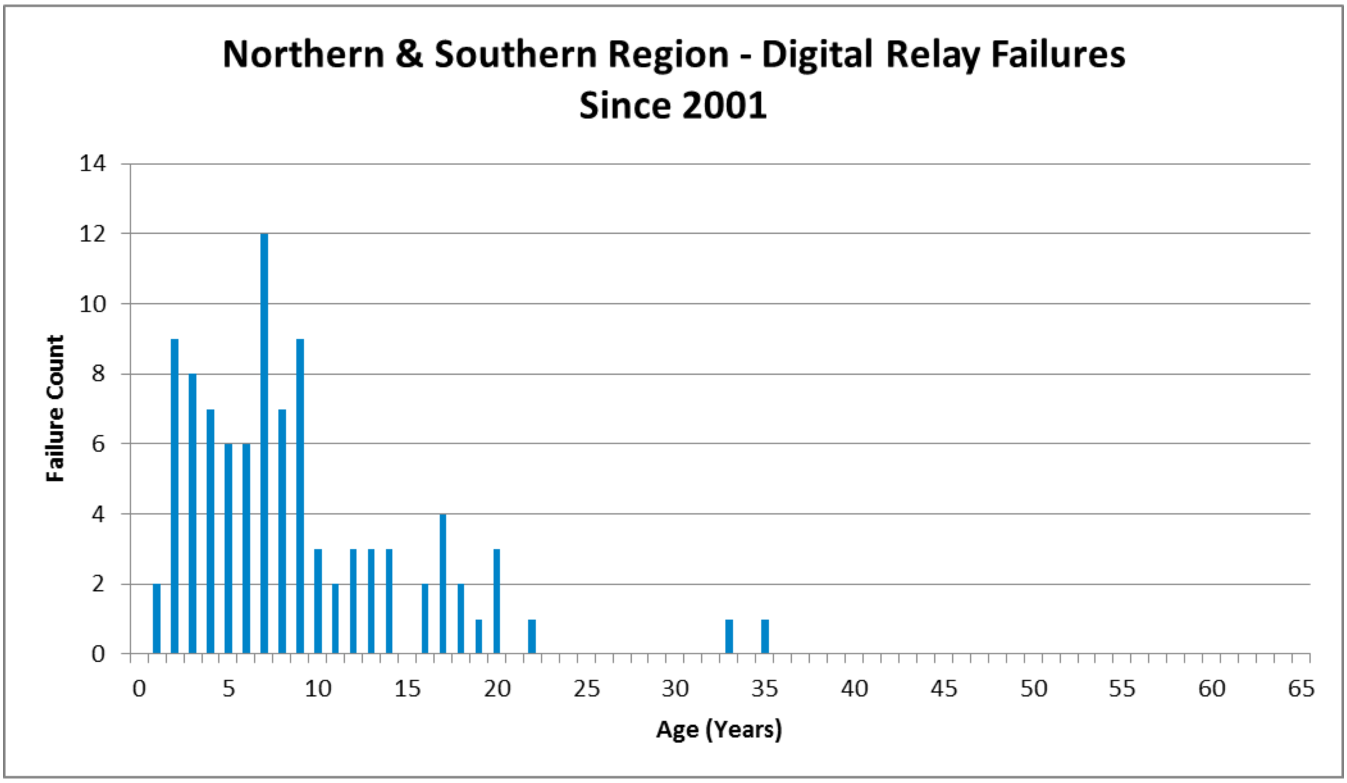


Figure 16: Northern and Southern Regions Digital Relay Failures Since 2001

2.4 Population Trends

With the advent of more advanced digital relays, the overall number of protection relays on the EQL network has been decreasing over time. This trend is not at the expense of protection coverage, as the fact that a single digital relay is able to cater for multiple protection schemes reduces the number of relays required to protect particular circuits or plant. This, in turn, has led to a trend in favouring digital relays when considering the replacement of analogue and electromechanical relays at end of life.

This downward trend in the overall population of relays is expected to continue into the future as digital relays continue to be the preferred replacement model type when removing older analogue and electromechanical relays.

Figure 17 and Figure 18 show the population trends of protection relay assets across the South East Region and the Northern and Southern Regions respectively.

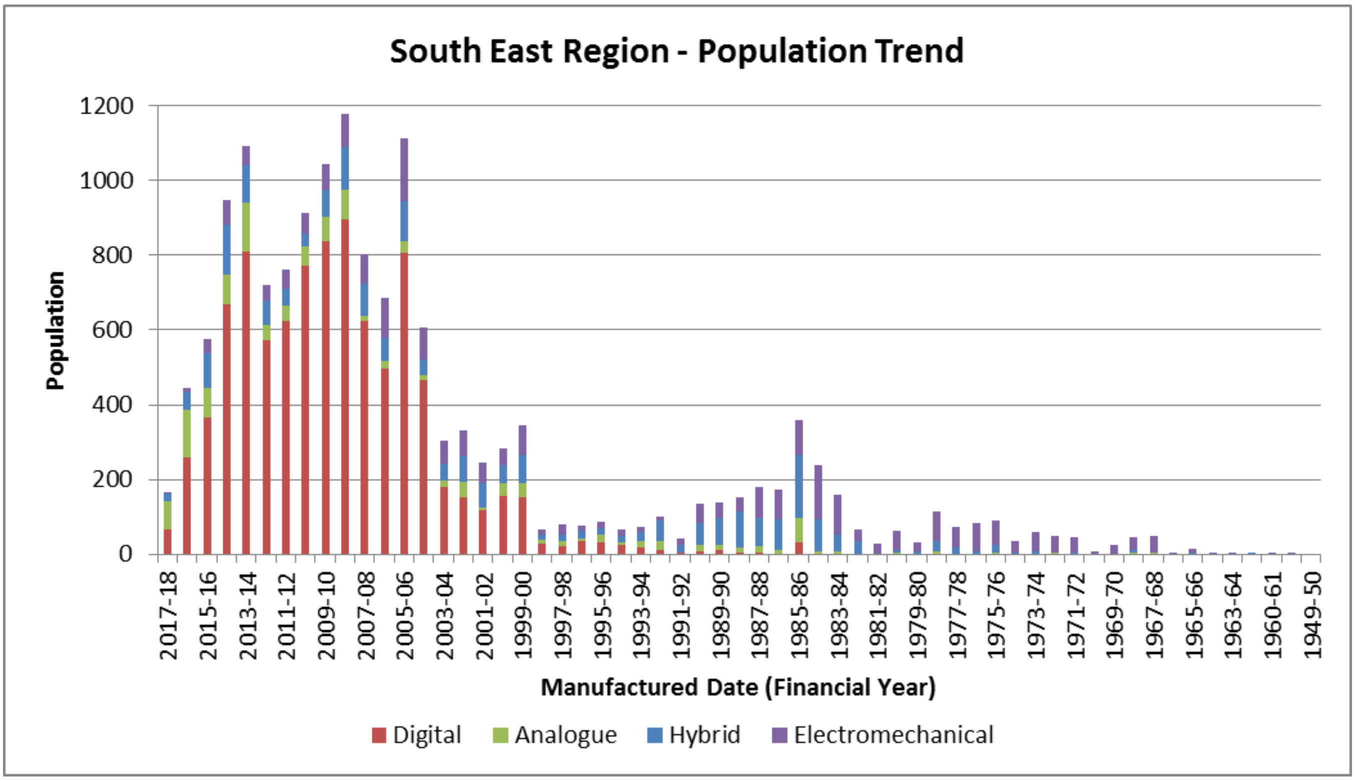


Figure 17: Population trend of technology type in the South East Region

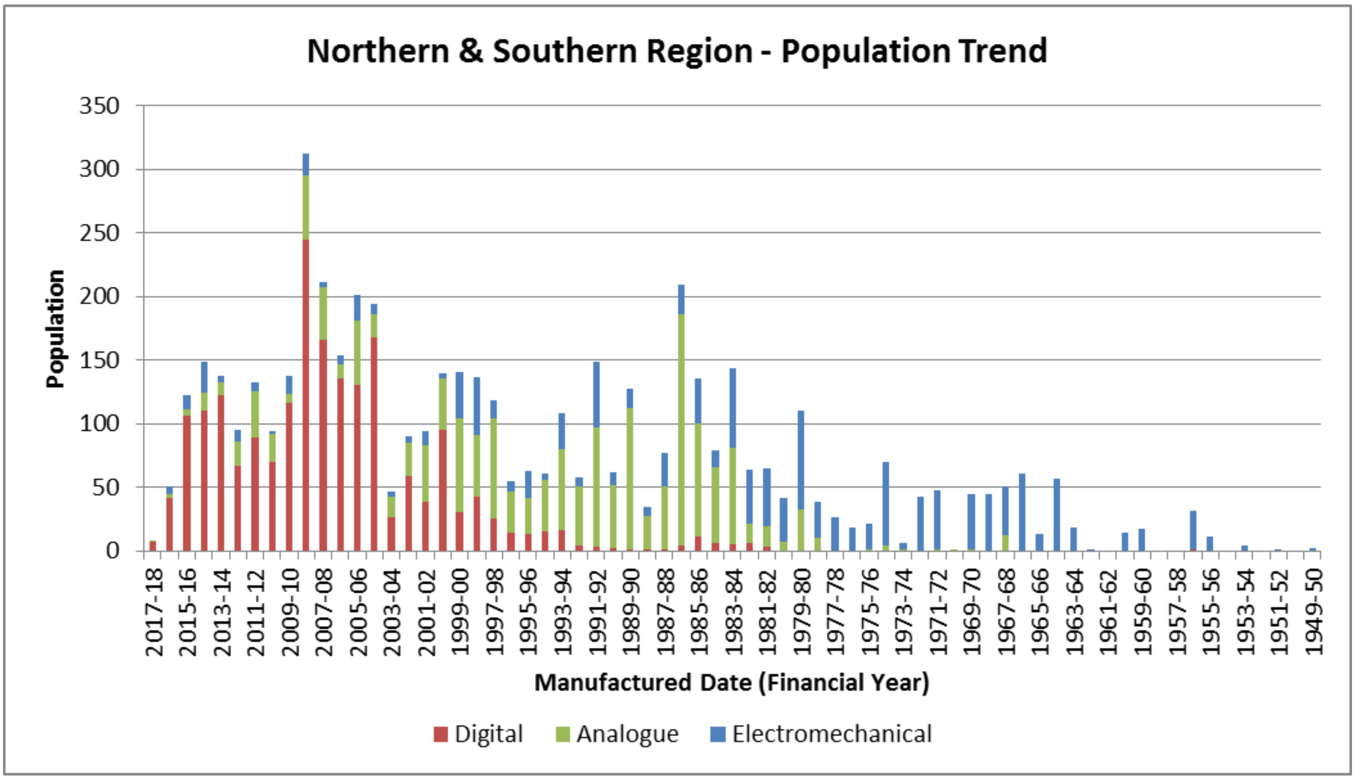


Figure 18: Population trend of technology type in the Northern and Southern Regions

2.5 Asset Life Limiting Factors

Table 4 describes the key factors that influence the operational life of protection relays and drivers for replacement/renewal which contributes towards the lifecycle management of protection relays.

Factor	Influence	Impact
Age	Deterioration of asset components over time due to natural processes; mechanical wear, capacitors drying, etc.	Gradual decrease in asset performance and reliability, ultimately resulting in device malfunction and failure; potential loss of network protection.
Operations	Deterioration of asset components over time due to natural processes; mechanical wear, capacitors drying, etc.	Gradual decrease in asset performance and reliability, ultimately resulting in device malfunction and failure; potential loss of network protection.
Abnormal Weathering or Other External Damage	Deterioration or destruction of asset components due to abnormal atmospheric conditions or third-party, unexpected events.	Increased deterioration or sudden failure of asset performance and reliability.

Factor	Influence	Impact
Obsolescence	From time to time, particular relay models may have firmware upgrades or model upgrades. The predecessor may no longer be produced and available for purchase.	Due to the inability to purchase obsolescent relays, spares and replacement strategies needs to be revised. Relay models may require proactive replacement and existing in-service population may need to be pulled from service to enter strategic spares inventory.
Problematic/Obsolete	These relays are known for their inherent problems or failures in-service. They are high risk and unreliable which requires immediate replacement.	Use of relays in this category may result in mal-operation such as a through fault event. Furthermore, these relays may not operate during a fault scenario within its setting.
Manufacturer Defects	Unexpected component defects due to errors within the manufacturing process or the use of poor components.	Relays may fail earlier than the expected end of life asset defects may be detected within the service life via manufacturer notices or asset failure, resulting in the need to replace the relay or consider if the defect warrants action.
Obsolete Firmware/End of Firmware Support	The risk of security and operability of the relay may be increased due to outdated firmware. Some functionalities may not be available with existing firmware.	The relay may be exposed to security breaches or mal-operations. Required protection functionality is unavailable?
Augmentation Requirements	Changing network requirements.	Existing relays may be incompatible with changes in the network and require replacement.
Primary Systems Upgrade	Replacement of primary plant such as circuit breakers or transformers.	Existing relays may need to be upgraded to the current protection standard. Additional or replacement functionality may be required as part of this standard.
Secondary Systems Upgrade	Replacement of secondary plant such as batteries or communication systems.	Existing relays may be incompatible with the new technology and require replacement.
Protection Standard	Protection standards evolve and recommend the implementation of different protection schemes.	Existing relays may no longer meet the latest standard and require replacement.
Risk Assessments	Risk assessments performed may identify particular relays to be of high risk of failure.	Particular refurbishment projects may target relays for replacement if they have been identified as at risk.
Replacement Prioritisation Analysis	Particular relays will be identified as being high priority for replacement as a result of the prioritisation analysis system.	As a result of a number of characteristics for a particular relay, it may be flagged as being of a high priority for replacement and removed from service.

Factor	Influence	Impact
Project Bundling	In order to improve project macro-efficiency, specific projects at the same substation location may be bundled in order to reduce time and cost expenditures.	Particular in-service relays may be chosen to have their replacement brought forward (up to 3 years) to align with the earlier project required by date.
Strategic Spares	Relays in the strategic spares holding are obsolescent. Once strategic spares holding drops below a certain level, stock can no longer be replenished.	In a scenario where a relay fails in-service and there are no spare relays, it is possible the substation may experience loss of customers while design is done on a replacement relay.
Population (and Strategic Spares)	Low population (20 units or less in the network) on its own does not influence the reliability of a relay. However, when taken account with strategic spares holding, it can become critical should there be no spares.	In a scenario where a relay fails in-service and there are no spares, it is possible the substation may experience loss of customers while design is done on a replacement relay.

Table 4: Protection Relay Life Limiting Factors

3 Current and Desired Levels of Service

The in-service failure of protection relays can create temporary shortfalls in the required performance of the electric network, with the potential to impact on service levels. EQL actively manages and maintains the protection relay fleet to ensure that the following are met:

- Safety of personnel, the general public, plant and equipment, public areas, and the environment
- High network reliability through supply quality and security of the network
- Minimised costs through efficient programs and prudent spending.

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

3.1 Desired Levels of Service

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

Safety risks associated with this asset class will be eliminated “so far as is reasonably practicable” (SFAIRP), and if not able to be eliminated, mitigated SFAIRP. All other risks associated with this asset class will be managed “as low as reasonable 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 will be managed by age, failure rate, population trends, defects, and regular maintenance, and will be allowed to operate as close to and prior to calculated end of life. Once the asset is obsolete or deemed problematic, assets will be managed or replaced as appropriate to achieve appropriate risk management and optimum asset class longevity and performance.

3.2 Legislative Requirements

Regulatory performance outcomes for this asset include compliance with all legislative and regulatory standards, including the *Electrical Safety Act 2002 (Qld)*, the *Electrical Safety Regulation 2013 (Qld)*, and the *Queensland Electrical Safety Codes of Practice*.

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 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 inspect, test and maintain the works.

3.3 Performance Requirements

EQL does not have any specific business targets relating to protection relay asset failures. Instead, relays are prioritised for replacement predominately based on age and failure rate, in order to remain consistent with asset management objectives. Relays that are obsolete or obsolescent with low population or inadequate strategic spares are also considered for replacement. Routine inspection and testing of relays may result in relays being classified with defects of differing severities and may result in their retirement and replacement.

EQL monitors the performance of protection relays through monthly reporting systems and the Asset Safety Performance report is published.

3.4 Current Levels of Service

Asset failures occur where the programs in place to manage the assets do not identify and rectify an issue prior to it failing in-service. Failures typically result in or expose the organisation to risk, and represent the point at which asset related risk changes from being proactively managed to retrospectively mitigated. The following table shows the asset failures for protection relays by region for the last five years.

Technology Type	FY2013/14		FY2014/15		FY2015/16		FY2016/17		FY2017/18	
	SE	NS	SE	NS	SE	NS	SE	NS	SE	NS
Electromechanical	1	4	1	19	2	2	0	3	0	11
Hybrid	2		3		4		3		0	
Analogue	10	2	5	4	10	15	5	6	3	0
Digital	61	10	79	14	74	13	59	7	35	4
Total	74	16	88	39	90	30	67	17	38	15

Table 5: Failure History

Some of the age-related failure characteristics of different asset types were discussed under their respective subheadings in Section 2.3.

4 Asset Related Corporate Risk

As detailed in Section 3.2, Queensland legislation details that EQL has a duty to ensure its works are electrically safe. This safety duty requires that EQL take action SFAIRP to eliminate safety related risks, and where it is not possible to eliminate these risks, to mitigate them SFAIRP.

Figure 19 provides a threat-barrier diagram for EQL protection relay assets. Many threats cannot be controlled (e.g. third-party damage), although EQL undertakes a number of actions to mitigate them SFAIRP. Failure of a Service risks public and staff safety in several ways, most notably:

- Damage to equipment and/or plant resulting in dangerous exposure to fire hazards or shrapnel
- Circuit failure leading to potential shock and electrocution within the substation, public vicinity and/or customer premises
- Loss of supply to customer premises.

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

The asset performance standards described in Section 3 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 have been raised in the following sections where relevant, detailing the specific actions that EQL will undertake as part of program delivery of this Asset Management Plan.

Threat/barrier diagram: Protection Relay Failure

Note: Thickness of barrier describes effectiveness of control measure.

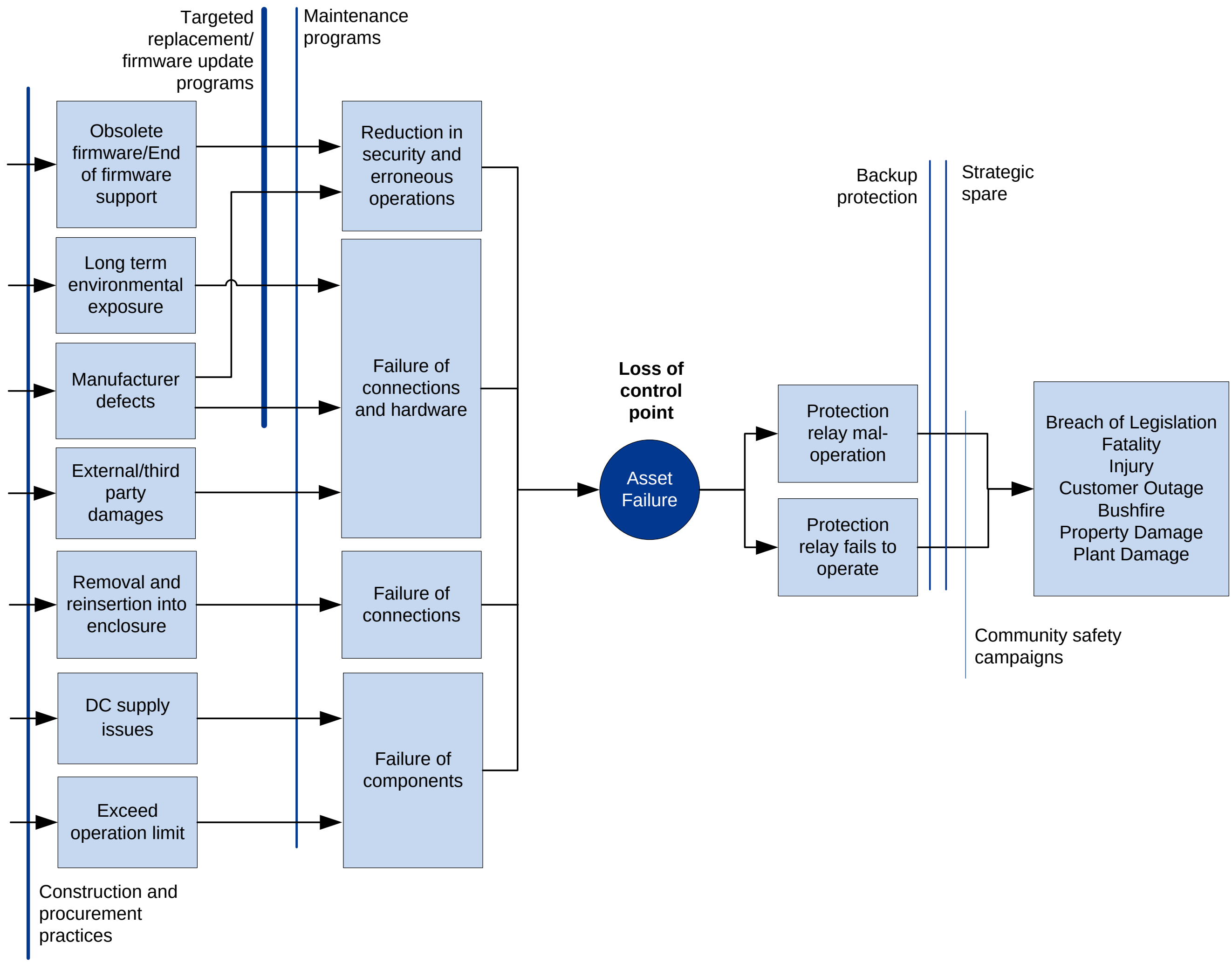


Figure 19: Threat/barrier diagram for protection relay failure

5 Health, Safety & Environment

Health, safety, and the environment are a focus for EQL as a business and in its network operations across all regions. Therefore, maintaining the serviceability of the protection relay asset class is vital for the safety of the community, staff, environment, and the network, due to the important functions performed by the protection relay asset class in addressing the detrimental effects of faults on the network.

6 Current Issues

The following sections outline the pertinent issues currently facing the asset management EQLs protection relay population.

6.1 Data Quality

The quality of relay records in EQL databases requires updating and review. As shown in Figure 20, more than half of the data records within protection relay setting database (IPS) are either missing or require updating for the SE region alone. Under the "Incorrect/Missing Data Entry", critical information such as serial numbers and dates of manufacture are incorrectly detailed or absent. This information helps determine the reliability and replacement priority of each relay.

Currently, assumptions are made in order to assign a date of manufacture, either by inferring from known characteristics of neighbouring relays installed in the same panel or by referring to the project's commissioning date. While this methodology might be sufficient, the relays could be targeted for replacement before their end of operational life. This assumption might also result in protection relay failures if the relay was not correctly identified and assigned for an appropriate future replacement date. Section 8.1 discusses possible improvements and solutions that could be implemented toward correcting and managing data quality.

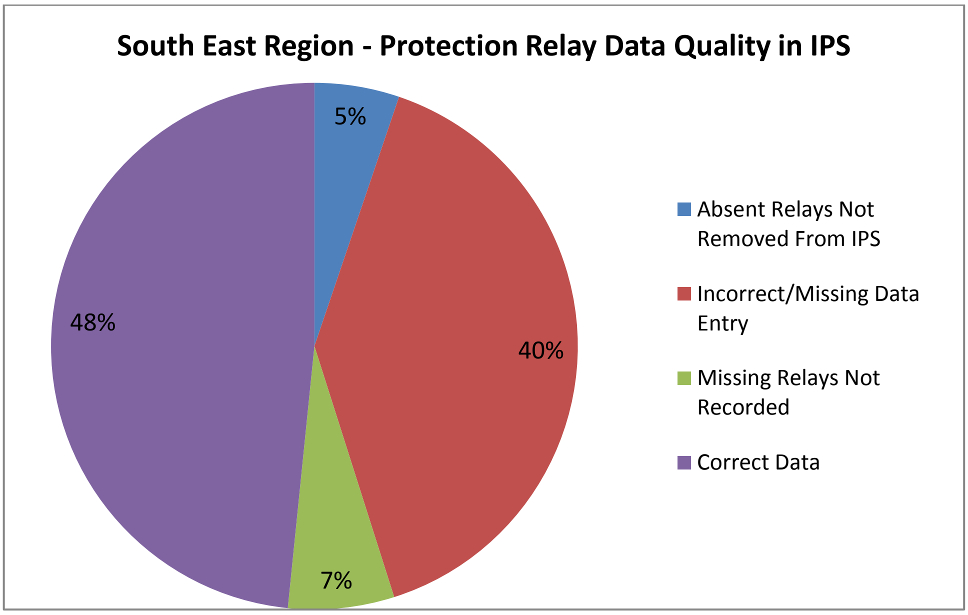


Figure 20: South East Region – Relay data quality based on audits from 13 substations with 1,459 total protection relays

Similarly, for EQL's Northern and Southern Regions, information on the asset location, population, status, and other characteristics is often vastly inaccurate or missing. To improve and manage corporate asset records, several programs have been introduced, including the Maintenance Strategy Support System (MSSS), Joint Asset Management Inspection Tool (JAMIT), IPS, and Network Asset Information Quality (NAIQ). As most of these software and reporting tools have only been used since 2014, current records are insufficient to produce any credible analysis.

Action 6-1: Northern and Southern Regions - Formal update, procurement and management of relay asset records within all suitable corporate management systems whether by JAMIT, IPS, NAIQ or other means enforcing general corporate business processes or introducing other means of effective record keeping.

Action 6-2: Northern and Southern Regions - Encourage and employ auditing of substation inventory including protection relays, ensuring appropriate updates to corporate asset records to reflect accurate network plant and infrastructure and updating of corporate system records (e.g. during site visitations and plant inspections).

6.2 Spares Holdings

Obsolescent relays are categorised as no longer on current contracts and can no longer be procured. If an obsolescent relay fails in-service and an available in project/general spares have been depleted, engineering redesign and rewiring are required as the replacement relay will be a different make or model. This process is especially difficult if the existing panel does not have sufficient space to house the new relay.

In response, a specific inventory of strategic spares holdings was created for the storage of obsolescent relays, allowing for in-service relay failures to be replaced like for like.

Use of these strategic spares relays in the South Eastern Region requires the approval of the Asset Management Engineer associated with their custody. The strategic spare records in the South Eastern Region are readily available; however, many of these relays are depleted or critically low in stock. The temporary solution at present is removal of these relays via incorporated replacement into upcoming projects. Relays with low populations are also considered for replacement even if they are in a healthy state. However, a more permanent approach is required.

The record-keeping issues and decentralisation across the regions with no formal management or governance has affected the inventory holding of strategic spares in the Northern and Southern Regions. Management of inventory spares throughout all regional depots is also questionable. Asset details, kept within independent database systems, are not aligned with the more centralised asset management systems such as Ellipse and are missing significant and crucial details. Asset records held in warehouse inventory systems are missing key characteristics such as the model description or part number creating significant problems in identifying and sourcing immediate 'like for like' model replacements.

A similar issue across both the South East Region and the Northern and Southern Regions is the age of relays in strategic spares holding, as records do not trace the logistical or operational history relating to strategic or inventory spares.

Action 6-3: South East and Northern and Southern Regions – Produce generic marked up protection line diagrams and circuitry drawings to allow in-service relays to be replaced with a completely different relay immediately upon failure without having to request protection engineering and design.

Action 6-4: South East and Northern and Southern Regions – Audit and update corporate inventory systems to develop accurate asset records.

Action 6-5: Northern and Southern Regions – Develop and approve asset spares inventory management systems for general, strategic, and emergency spares.

Action 6-6: South East and Northern and Southern Regions – Formalise relay spare management with policy.

6.3 Manufacturer Defects

Specific protection relays have shown to have an abnormal weakness amongst their components leading to shorter lifespans than anticipated. Relays classified to be problematic or their functionality deemed obsolete are actively replaced. Below are a few examples:

- Relays with no definite time functionality need to be replaced when used on earthing transformers for NEF protection in the South Eastern Region. When there is a fault and current circulates through the earthing transformer, it may burn out the transformer as it does not operate until the set pickup. Pickups are generally set higher than what the winding of the transformer can withstand. Relays are to be replaced on all 132/110kV transformers performing NEF protection.
- A particular model of relay used for SEFCK and SEFCKT functionality in South East Region substations are now classified as obsolete. These relay types have known defects that degrade their performance under fault conditions. Issues with their harmonic filtering ability cause erratic operation of the relay.

Action 6-7: South East Region – Amalgamate the South East Region problematic relay list to the Northern and Southern Regions 'problematic relay flipchart'.

6.4 Maintenance of Protection Relays

Analysis confirms that protection relays have a defined lifecycle with a noted increase of operational failures as the asset approaches the end of its operational life (EOL). There is a significant population of relays approaching their EOL within the next five to ten years. Although the relay replacement program attempts to address these high-risk items, consideration should be taken in identifying and assigning relays approaching or operating beyond their EOL to a more frequent maintenance check regime, more frequent than the recommended standard six year cycle (as per Maintenance Activity Frequency (MAF)).

Applying a special maintenance inspection regime could also potentially capture relays that have failed without notice and prevent potential consequences of network failures when unaddressed.

In addition, assigned maintenance tasks could increase in scope to include management of firmware as well as confirmation of asset records.

Action 6-8: South East and Northern and Southern Regions – Review the performance of devices operating beyond end of life to confirm the need for changed maintenance policies.

6.5 Protection Relay Test Records

The Northern and Southern regions' protection relay test record history is poor, with no single source of information used to produce the database. To assist in assessing the asset lifecycle of protection relays, a comprehensive history of a relay's performance and behaviour is beneficial.

The South East Region maintains test records through software called Doble. It is current and up to date.

Action 6-9: South East and Northern and Southern Regions – Develop and maintain a corporate management system that records and enables the analysis of test-bench and maintenance history for all operational relays.

7 Emerging Issues

The following sections outline some of the emerging issues associated with managing EQL's protection relay assets.

7.1 Technology Requirements and Advancement

Existing substations with aged assets will eventually be required to be replaced. Due to vastly changing technological environment, 'like for like' model replacement may not be possible due to availability or inability to conform to current standards. Therefore, these assets will need to be replaced with current contract items which may not be compatible with other equipment on site. This leads to unnecessary replacement of relays that may not be EOL.

7.1.1 DNP3

Recently there has been a requirement for all new substations to utilise the latest set of communications protocol, allowing relays to communicate directly with one another, bypassing the in-house designed IEDs. This requirement results in relays utilising the older protocol becoming obsolete due to inherent incompatibility issues. This reduces flexibility in the choice of relay models and forces an eventual complete upgrade of the substation.

7.1.2 Communications

As communications systems within substations are refurbished and upgraded to utilise fibre optic cabling over the existing copper-based pilot cable technology, existing relays may be incompatible and require replacement. This imposes design constraints and causes particular relay models to become unsuitable for use.

7.1.3 Firmware

Programmable digital relays are highly sophisticated devices, a portion of which are integrated with firmware. The Northern and Southern Regions have limited records regarding the management and history of relay firmware.

Action 7-1: Northern and Southern Regions – Enable recording within corporate asset systems to include the management of firmware and the inclusion of asset management tasks such as the maintenance of firmware.

7.2 South East Region and Northern and Southern Regions Amalgamation

As the merging of the South East Region and the Northern and Southern Regions into EQL occurs, there are a number of differences in engineering processes, data capture, and management strategies emerging, and discussion is underway regarding how best to handle their alignment. Currently, differences in data capture processes and records are too great for unified data analysis to occur, and thus limit the application of unified asset management strategies.

With the amalgamation of the South East Region and the Northern and Southern Regions into EQL, strategic policies within asset lifecycle management's domain shall eventually align. The South East Region and the Northern and Southern Regions currently have slightly different approaches in the identification and selection of relay replacements, however, both approaches based upon asset age.

As the quality of relay records improve, risk and priority replacement strategies and methodologies will change.

Action 7-2: Develop clearly defined asset lifecycle management philosophies, strategies, and business processes.

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 Data Quality & Database Improvements

Historical data capture has proven to be less than ideal for current data analysis strategies. Due to an increasing amount of data categories being recorded over time, there are a significant number of errors and inconsistencies in data collection which need to be accounted for in analysis. Furthermore, data has historically been collected in a number of databases and from different information sources, leading to issues in naming conventions and detail capture differences. All of these issues create challenges when attempting to combine data from multiple sources.

In an effort to improve ease of access to asset data, work has begun in producing a unified protection relay database, eliminating inconsistencies across historical databases. This system is also undergoing continual improvement with efforts being made to clean the data, fill detail gaps, and optimise the performance of the database, allowing for faster and more efficient use.

In addition to the database, site audits are conducted in the South East Region during project planning phases to accurately capture site asset details and update corporate system records accordingly.

9 Lifecycle Strategies

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

9.1 Philosophy of Approach

Protection relays in the EQL electricity network are managed with the goal of conducting relay replacements as quickly and efficiently as possible to minimise network downtime. Considering that in-service repairs or maintenance on protection relays are difficult or impossible to carry out, the best method of asset management is to have an ample supply of spares on hand and to accurately identify the at-risk relays before they fail.

In order to identify at-risk relays, there are a number of systems utilised. The first is a predictive analysis based system, used to predict the relays that are close to the end of their service life by incorporating information on specific failure rates, age, and availability of spares. In addition, some relay models are monitored for faults and logged for observation. All systems result in the ability to send maintenance crews to the targeted relays to verify their condition with physical diagnostic testing.

If a relay fails diagnostic testing and is removed from service, an assessment process is carried out to determine whether to scrap the relay or send it away for repair and/or storage. A detailed flowchart for determining a relay's retention can be found in Appendix 6 as applied to the South Eastern Region.

The overall approach to the management of protection relays is to prioritise the proactive replacement of these assets before they fail in-service. This strategy improves the efficiency of the electric network, through both improved protection, decreased downtime, and lowered operational costs to the organisation.

9.2 Supporting Data Requirements

EQL requires high quality and detailed relay registry to provide accurate asset reporting. As mention in Section 6.1, both the South East Region and the Northern and Southern Regions are currently embarking on various data quality initiatives that, when realised, will improve lifecycle management strategies and continue to support current strategies.

Improvements to job completion processes would also increase the ability of EQL to identify lifecycle trends, leading to better engineering outcomes for the business. More details captured in job completion comments from field crews when investigating and determining asset failures would be highly beneficial.

9.3 Acquisition and Procurement

EQL has a regular review process in the selection of protection relays for its network.

Periodic contracts are renewed with a focus on the needs and architecture of the distribution network. Numbers of contract relay models are determined for procurement and purchased as general spares.

Numbers of spares carried are based on their failure rate performance of the particular model and type.

Previously, relay warranties were not clearly defined in the South Eastern Region. Under the current contract 10259, all relays purchased carry a specific warranty period across all manufacturers. An inventory listing for the Northern and Southern Regions of the periodic contract can be found within 'Protection IED 00000823 Contract Items' document.

9.4 Maintenance

EQL employs both preventive and corrective maintenance for protection relays depending on the serviceability. An important distinction to note is that out of warranty relay repair is rarely feasible and as such, the maintenance programs discussed in this section of the report relate to the replacement of the asset unless specified otherwise.

For the vast majority of relays within the network, preventive maintenance is the typical method of replacement used as the asset approaches the end of its operational life and is flagged for replacement, rather than a reactive response to 'failed in-service' events requiring immediate action.

Action 9-1: Review of all standards between the South East Region and Northern and Southern Regions, and amalgamation of the business processes.

9.4.1 Preventive Maintenance

The policies for preventative maintenance for EQL are outlined below:

- Relays are visually checked every 36 months (3 years). This is purely a condition assessment and does not require taking the relay out of service.
- Relays are tested and maintained every 72 months (6 years). This maintenance is non-intrusive.

Additional South East Region specific maintenance policy is outlined below:

- Maintenance is not required if protection system has been tested (as part of reactive/corrective maintenance or commissioning) within the past 18 months.
- If the protection system is to be decommissioned within 12 months, testing and maintenance should be confirmed with Lifecycle Engineering Intelligent Asset Team

9.4.2 Corrective Maintenance

EQL reacts to corrective and forced maintenance issues as they arise and are identified. These are usually addressed by an immediate replacement with the same make and model relay, sourced from the strategic spares inventory or general inventory depending on obsolescence status. If the relevant spares inventory is depleted, then the current standard contract relay will be installed instead.

9.4.3 Spares

Spares are managed in two different sets – general and strategic. The general spares are accessible by any part of the EQL business as required. These relays are typically current standard contract relays that can still be procured through normal channels.

Strategic spares, on the other hand, are held for the purpose of minimising network downtime and as such are controlled through restricted access. Approval is required from the Lifecycle Engineering Intelligent Asset Team before the relay is released. Relays in these categories are transferred from the general inventory to the strategic spares inventory.

The number of strategic spares in the South East Region to be held at any given time is determined by statistical analysis which makes use of specific failure rates, asset population size, and acquisition lead times, utilising a Poisson distribution.

There are situations where a necessary number of spares are not at hand and EQL is unable to source any additional spares through the vendor. In such instances, some in-service relays of that particular model can be proactively removed and held as spares, being replaced by a different current contract relay model. It is quicker and more convenient for EQL to replace a relay like-for-like in the event of an unexpected failure than it is to source a new current contract model, which typically has a far longer lead time to procure.

9.5 Refurbishment and Replacement

Any relays deemed faulty during routine maintenance and testing will be removed and replaced with a like-for-like replacement relay. In the South East Region, any faulty relay removed will either be sent for repairs or disposed of as per the 'Policy for Treatment of Decommissioned Protection Relays' document. The Northern and Southern Regions do not currently have a formal policy document for decommissioned protection relays. Any failed relays will be immediately disposed of.

Action 9-2: Northern and Southern Regions – Create a policy document for decommissioned protection relays.

9.5.1 Refurbishment

EQL does not generally refurbish protection relays. Refurbishment generally only occurs if relays are still under warranty, or if the relays are sent back to the manufacturer. Sometimes the repair issues are very simple (e.g. replacing an LCD display on a digital relay), and in these instances, an in-service repair is performed, with the manufacturer providing the replacement parts, rather than taking a relay out of service.

9.5.2 Replacement

In general, relays in EQL are replaced as per the following conditions.

- Any relays that fail in-service or during maintenance are managed following the corrective maintenance process outlined under Section 9.4.2.

- Aging relays flagged for replacement by targeted selection methods are replaced either with a like-for-like model or by an equivalent current contract relay. This method makes use of relay age information supported by failure data with consideration given to their market availability and procurement lead times. Please refer to Appendix 6 for the relay replacement selection and prioritisation methodology utilised by the South East Region and Appendix 8for the Northern and Southern Regions. An additional consideration is to determine whether there is an existing project at the target substation site to bundle the relays with. This method is considered effective and would reduce additional labour costs from creating a new project. Any relays predicted to fail within plus or minus 3 years of the project required by date is also recommended for replacement in the same project to avoid potential rework and revisitation of the site.

9.6 Disposal

Assets will be disposed of in accordance with standard EQL corporate process. When a protection relay is marked for disposal, there are no specific concerns considered in the scrapping process as the equipment does not contain any material that might present a hazard or require special handling. Any hazardous materials are to be disposed of in accordance with other corporate materials handling and disposal policies.

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 list provides a summary of the specific actions noted throughout this AMP document for ease of reference:

Action 6-1: Northern and Southern Regions - Formal update, procurement and management of relay asset records within all suitable corporate management systems whether by JAMIT, IPS, NAIQ or other means enforcing general corporate business processes or introducing other means of effective record keeping.

Action 6-2: Northern and Southern Regions - Encourage and employ auditing of substation inventory including protection relays, ensuring appropriate updates to corporate asset records to reflect accurate network plant and infrastructure and updating of corporate system records (e.g. during site visitations and plant inspections).

Action 6-3: South East and Northern and Southern Regions – Produce generic marked up protection line diagrams and circuitry drawings to allow in-service relays to be replaced with a completely different relay immediately upon failure without having to request protection engineering and design.

Action 6-4: South East and Northern and Southern Regions – Audit and update corporate inventory systems to develop accurate asset records.

Action 6-5: Northern and Southern Regions – Develop and approve asset spares inventory management systems for general, strategic, and emergency spares.

Action 6-6: South East and Northern and Southern Regions – Formalise relay spare management with policy.

Action 6-7: South East Region – Amalgamate the South East Region problematic relay list to the Northern and Southern Regions 'problematic relay flipchart'.

Action 6-8: South East and Northern and Southern Regions – Review the performance of devices operating beyond end of life to confirm the need for changed maintenance policies.

Action 6-9: South East and Northern and Southern Regions – Develop and maintain a corporate management system that records and enables the analysis of test-bench and maintenance history for all operational relays.

Action 7-1: Northern and Southern Regions – Enable recording within corporate asset systems to include the management of firmware and the inclusion of asset management tasks such as the maintenance of firmware.

Action 7-2: Develop clearly defined asset lifecycle management philosophies, strategies, and business processes.

Action 9-1: Review of all standards between the South East Region and Northern and Southern Regions, and amalgamation of the business processes.

Action 9-2: Northern and Southern Regions – Create a policy document for decommissioned protection relays.

Appendix 1. References

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

Legacy organisation	Document Number	Title	Type
Energex	TSD0086D	Technical Instruction Protection Relays	Standard
Energex		Strategic Protection Relay Replacement List	Standard
Energex		Policy for Treatment of Decommissioned Protection Relays	Memorandum
Energex	WP1093	Work Practice Protection Maintenance	Work Practice
Energex & Ergon Energy	00299	Maintenance Standard – Standard for Maintenance Acceptance Criteria	Standard
Energex & Ergon Energy		Maintenance Activity Frequency (MAF)	Standard
Energex & Ergon Energy	BMS 4187	Energy Queensland Protection Philosophy	Standard
Energex & Ergon Energy		Statement of Corporate Intent	Document
Energex	TSD0086D	Technical Instruction Protection Relays	Standard

Appendix 2. Definitions

Term	Definition
Auxiliary Relay	Secondary relay that operates in response to the opening or closing of its operating circuit to assist another primary relay or device in performing a function.
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 Contract	The latest agreed contractual specifications of specific equipment, e.g. protection relays, between Energex and the manufacturer that has not expired
Current transformer	Current transformers are used to provide/transform currents suitable for metering and protection circuits where current measurement is required.
Distribution	LV and up to 22kV (and some 33kV) networks, all SWER networks
Forced maintenance	This type of maintenance involves urgent, unplanned repair, replacement, or restoration work that is carried out as quickly as possible after the occurrence of an unexpected event or failure; in order to bring the network to at least its minimum acceptable and safe operating condition. Although unplanned, an annual estimate is provided for the PoW against the appropriate category and resource type.
In-service	The state of plant or equipment that is considered operating within the network.
Instrument transformers	Refers to Current Transformers (CTs), Voltage Transformers (VTs) and Metering Units (MUs)
Like for Like	Refers to the exact same make and model relay
Metering Units	A unit that includes a combination of both Current Transformers and Voltage Transformers for the purpose of statistical or revenue metering
Obsolescent	Can no longer be purchased from the manufacturer but can still be requisition or checked back into stores
Obsolete	Can no longer be purchased from the manufacturer and can no longer be requisition nor checked back into stores
Preventative maintenance	This type of maintenance involves routine planned/scheduled work, including systematic inspections, detection and correction of incipient failures, testing of condition and routine parts replacement designed to keep the asset in an ongoing continued serviceable condition, capable of delivering its intended service
Sub transmission	33kV and 66kV networks
Transmission	Above 66kV networks
Voltage Transformers	Voltage or potential transformers are used to provide/transform voltages suitable for metering and protection circuits where voltage measurement is required.

Appendix 3. Acronyms and Abbreviations

The following abbreviations and acronyms may appear in this asset management plan.

Abbreviation or acronym	Definition
AC	Alternating current
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
dc	Direct Current
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
IED	Intelligent Electronic Device
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
NEF	Neutral Earth Fault
NER	Neutral Earthing Resistor
NEX	Neutral Earthing Reactor

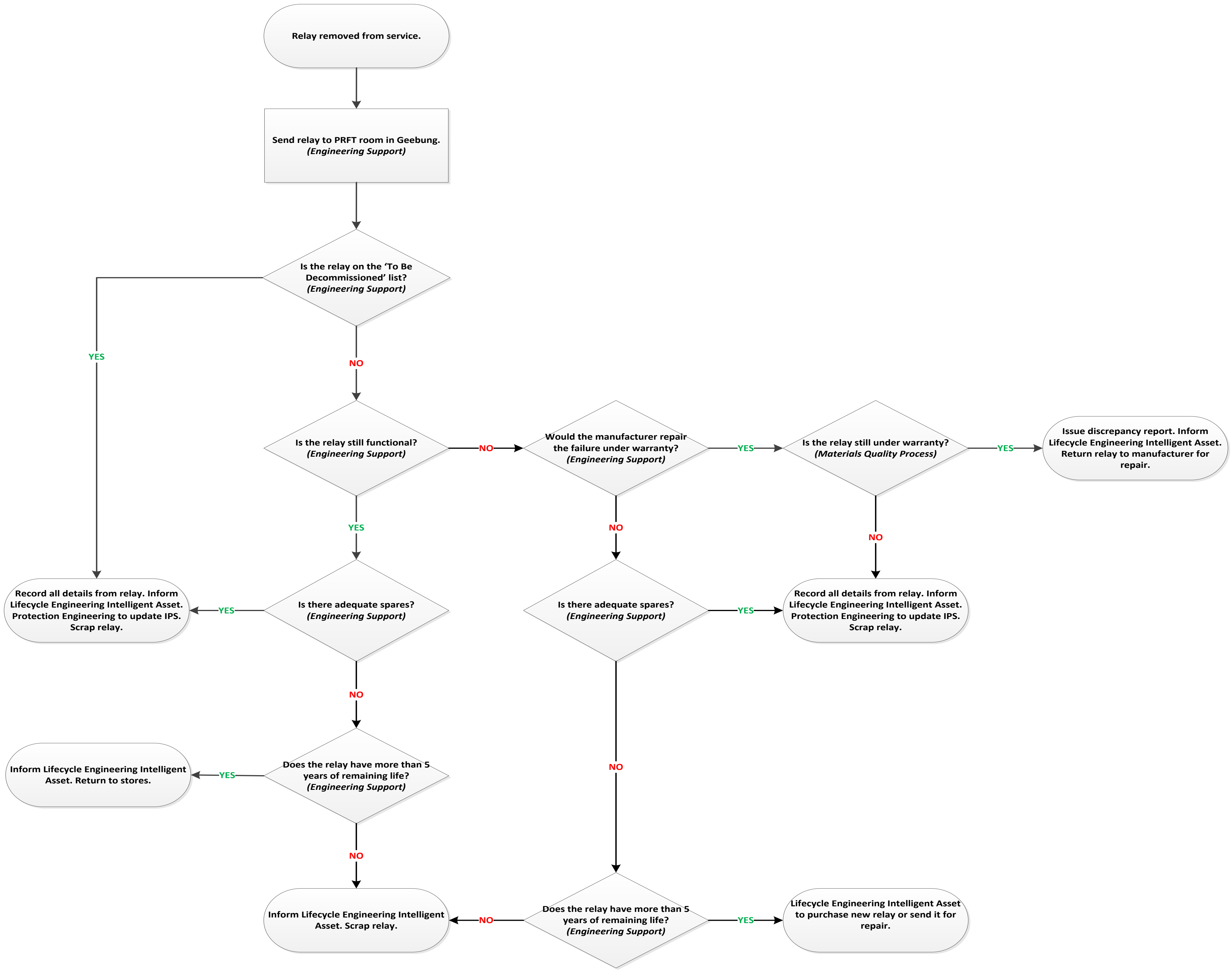
Abbreviation or acronym	Definition
NS	Northern and Southern Regions
+OLTC	On-load tap –changers
OTI	Oil Temperature Indicators
PCB	Polychlorinated Biphenyls
PD	Partial Discharge
POC	Point of Connection (between EQL assets and customer assets)
POEL	Privately owned Electric Line
PRD	Pressure Relief Device
QLD	Queensland
REPEX	Renewal Expenditure
RIN	Regulatory Information Notice
RMU	Ring Main Unit
SCADA	Supervisory Control and Data Acquisition
SCAMS	Substation Contingency Asset Management System
SCI	Statement of Corporate Intent
SDCM	Substation Defect Classification Manual
SE	South East Region
SEFCK	Sensitive Earth Fault Check
SEFCT	Sensitive Earth Fault Check Trip
SFAIRP	So Far As Is Reasonably Practicable
SHI	Security and Hazard Inspection
SICM	Serial Interface Control Module
SVC	Static VAR Compensator
THD	Total Harmonic Distortion
VT	Voltage Transformer
WCP	Water Content of Paper
WTI	Winding Temperature Indicators
WTP	Wet Transformer Profile

Appendix 4. Regional References

The following outlines the regional distinctions between Ergon Energy and Energex as well as their amalgamation into EQL.

Company						
	Energy Queensland (EQL)		**Ergon Energy (Legacy)**		**Energex (Legacy)**	
	Acronym & Description		**Acronym & Description**		**Acronym & Description**	
Regions	N	North Queensland	FN	Far North including the district of Far North incorporating - Thursday Is, Bamaga, Cooktown, Mossman, Mareeba, Atherton, Ravenshoe, Normanton, Georgetown		
			NQ	North Queensland including districts of Tropical Coast and Herbert		
			MK	Mackay including districts of Flinders and Pioneer		
	S	Southern Queensland	CA	Capricornia including districts of Capricornia and Central West		
			SW	South West including districts of South West and Darling Downs		
			WB	Wide Bay including districts of Bundaberg Burnett, Fraser Burnett		
	SE	South East Queensland			SE	South East Queensland including districts of Sunshine Coast, Brisbane, Ipswich Lockyer, Gold Coast

Appendix 5. South East Region - Treatment of Decommissioned Relays



Appendix 6. South East Region - Relay Replacement Methodology

South East Region's proposed risk-based protection relay replacement program for the next five year period is based on the reliability matrix below.

Reliability Matrix						
Age as % of Expected Life		Failure Rate				
		<0.0025	0.0025-0.005	0.005-0.01	0.01-0.05	>0.05
		1	2	4	8	16
<70%	1	1	2	4	8	16
70-80%	2	2	4	8	16	32
80-90%	4	4	8	16	32	64
90-110%	8	8	16	32	64	128
110-120%	16	16	32	64	128	256
>=120%	32	32	64	128	256	256

The matrix takes into account the failure rate of the relay and age of the relay. Relays with a failure rate of 0.0025 failures per service year or lower are allowed to remain in service beyond the expected life of each technology type. Any relays classified as problematic should be replaced promptly and bundled with other work as efficient delivery allows. There are various programs previously to remove all the problematic relays from the network and only 6 relays remain but are disconnected from operation.

Reliability Matrix						
Age as % of Expected Life		Failure Rate				
		<0.0025	0.0025-0.005	0.005-0.01	0.01-0.05	>0.05
		1	2	4	8	16
<70%	1	1	2	4	8	16
70-80%	2	2	4	8	16	32
80-90%	4	4	8	16	32	64
90-110%	8	8	16	32	64	128
110-120%	16	16	32	64	128	256
>=120%	32	32	64	128	256	256

Below is the explanation of the reliability score from the reliability matrix. Any relay in the "Replace" or "Problematic" category is to be prioritised and replaced first. "Consider Replacement" relays are the next priority after "Replace". These relays are not critical but are either coming of age or have a higher failure rate which can be considered for replacement. Relays categorized as "Discretionary" carries the lowest replacement priority.

Reliability Score	Replacement Priority
1	
4	Discretionary
8	Discretionary
16	Consider Replacement
32	Replace
64	Replace
128	Replace
256	Replace
PROB	Problematic

Appendix 7. South East Region – Protection Relay Contract Agreement

The following clause applies to all current manufacturers:

4.15 Supply Condition

a. The Supplier will supply at the time of shipment in Excel spread sheet form the following information in a format outlined by the Purchaser.

MANUFACTURER
MODEL
SERIAL NO.
MODEL/PART NO.
RELAY TYPE
MONTH AND YEAR OF MANUFACTURER
COUNTRY OF MANUFACTURER
RATED SECONDARY VOLTAGE NOM.
RATED SECONDARY CURRENT NOM.
AUX SUPPLY VOLTAGE TYPE
AUX SUPPLY VOLTAGE LOWER
AUX SUPPLY VOLTAGE UPPER
FIRMWARE VERSION
FIRMWARE VER. RELEASE DATE
BATTERY TYPE
HARDWARE VERSION
HARDWARE VER. RELEASE DATE
BATTERY VOLTS
BATTERY INSTALL DATE
STANDARDS TESTED TO

-

Appendix 8. Northern and Southern Regions – Relay Replacement Methodology

The following section outlines Northern and Southern Regions' Priority Weighted Index (PWI) methodology and ranking relay replacements.

The PWI model attempts to compare asset and/or substation characteristics with its neighbours within Ergon's network based upon models, model series or model families. Each asset characteristic is measurable and can be 'weighted' against other unique asset characteristics enabling the flexibility of considering its contribution towards an overall PWI score.

The following steps outline the process and methodology of an applied PWI model applied to the above options.

Step 1 – Define the relay population

From an established inventory of quality relay records, first, define the population in which you want to prioritise and identify as high risk. This could include:

- ***Relay Characteristics*** – including Technology Type, Problematic Models, Auxiliary Relays, Model Sample,
- ***Age*** - Age Limitation,
- ***Locality*** – Region, Substation,
- ***Hierarchy*** – Status, Ownership, Site Type, Transmission Level, Protected Plant, Voltage Rating, Available Backup Scheme
- ***Existing Replacement Projects*** – Defined and considered period where an assigned replacement project already exists.

For example, a suitable relay population shall consider excluding all auxiliary relays, ownership outside Ergon Energy.

Step 2 – Identify attributes or limitations for PWI filtering

The next step is to target relay or substation characteristics/attributes that are deemed undesirable; contribute towards a high risk of failure; and/or negatively impacts customers or reliability of service. In addition, consideration is also taken in comparison of assets either by specific model, model series or model family. A list of these limitations for regard towards the PWI model is as follows:

- **Age –** actual age, age difference (between actual age and average age), age difference (between actual age and predicted average model age), age difference (between actual age and ideal model age), technological age limitation,
- **Substation Demand Characteristics** – substation/plant load, substation/plant customers,
- **Response –** distance to depot, predictive restoration time
- **Failure Rates** – ideal model replacement prediction (CDF), inverse mean time between replacements and failures,
- **Other Factors –** value to customer reliability, problematic relay models, obsolescence

Step 3 – Weigh and compare the importance of characteristics/limitations

Similarly, to the previous step once the key characteristics to judge priorities are identified; there is a need to weigh or compare the importance of these against each other. For example, a relay's advanced age could be considered a greater contributor towards justifying a relay's replacement as opposed to whether it is deemed to be a problematic model and is consequently scored or weighed higher in priority. This flexibility in assigning or distributing priorities allows companies to change strategies if required. For instance, should the company find itself experiencing poor network reliability issues, it may want to change its strategies away from targeting perceived problematic relay models and focus upon reliability characteristics.

For example, the following limitation criteria chosen for a PWI calculation:

Selection of characteristics and weighted considerations (or limitations) for PWI (Prioritisation Weighted Index) replacement modelling

Age characteristics					
Age:	1	*Model Family Selection:*	***Specific Model***		
Age Diff (Age & Avg Age):	-	*Model Family Selection:*	-		
Age Diff (Age & Avg Predicted Model Age):	-	*Model Family Selection:*	-		
Technological Age Limitation:	5	*Replaced within ? years of limit:*	8		
Age Diff (Age & Ideal Model Age):	3	*Model Family Selection:*	***Specific Model***		
Demand characteristics					
Sub Load kVA:	-				
Sub Customers:	-				
Plant Load kVA (MAX):	-				
Plant Load kVA (AVG):	-				
Plant Customers:	-				
Response					
Distance to Depot:	-				
Predicted Restoration Time:	-	*Predicted average travel speed between depot and substation (km/h):*	-	*Predicted average time to restore/replace relay (hours):*	-
Failure Rates					
Ideal Model Replacement Prediction (CDF):	-	*Year of consideration (for CDF analysis):*	-		
Inverse Mean Time Between Replacements (1/MTBR):	-	*Model Family Selection:*	-		
Inverse Mean Time Between Failures (1/MTBF):	-	*Model Family Selection:*	-		
Other					
Value to Customer Reliability (VCR):	-				
Problematic Relay:	2				
No available Backup Scheme:	-				
Obsolescence:	1	*Model Family Selection:*	***Specific Model***		

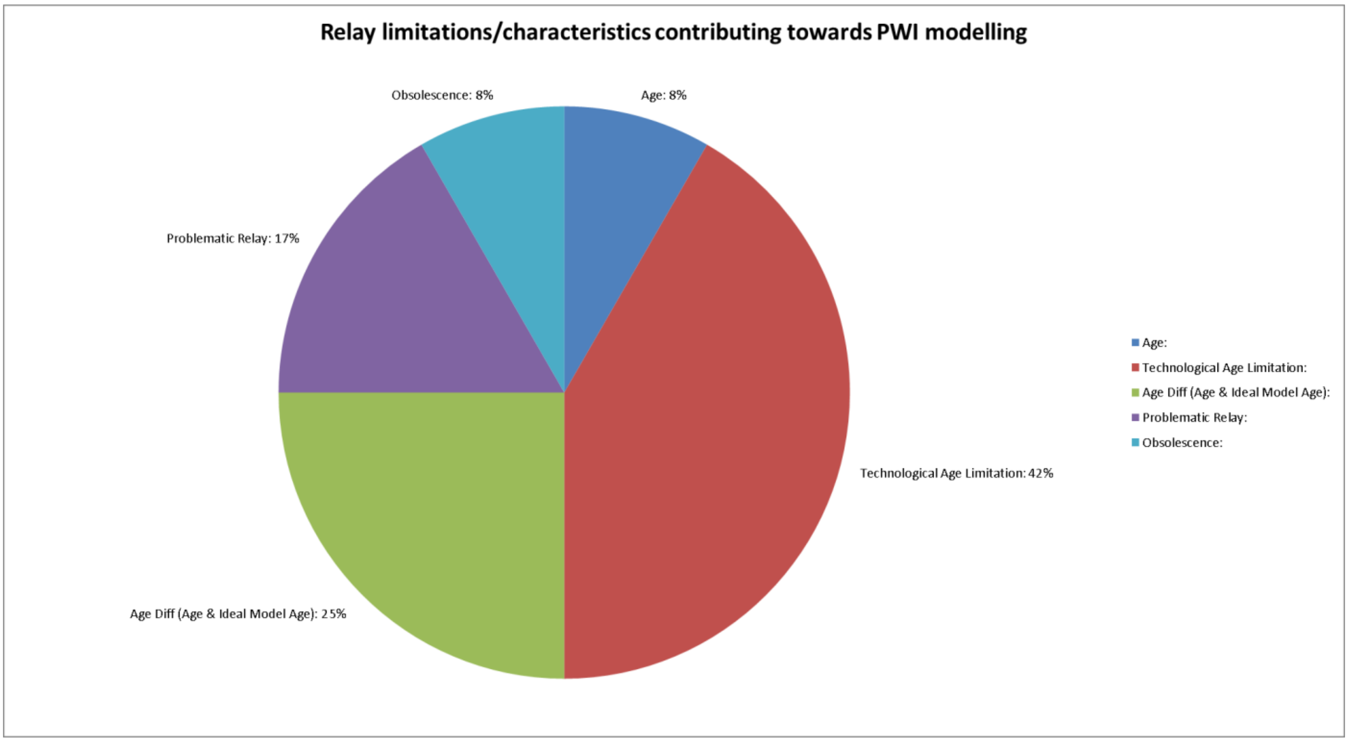
Update Page | Calculate Model

Summary of Limitations selected for the prioritisation of asset replacement:

1 *Age: When compared by similar Specific Model types*
2 *Technological Age Limitation: Identifying whether the asset in question is eligable to be replaced within 8 years of its technological limit (i.e. electromechanical 37-45+yrs; static 17-25+yrs and numeric 12-20+yrs)*
3 *Age Diff (Age & Ideal Model Age): When compared by similar Specific Model types*
4 *Identifying if the asset in question is considered to be 'problematic'*
5 *Obsolescence: When compared by similar Specific Model types*

This includes attributes such as actual age (weighting of 1); technological age limitation reached within 8 years (weighted score of 5); age difference between actual age and ideal model age limit (weighted score of 3); identification of problematic relay model (weighted score of 2); and obsolescence when compared to other like models (weighted score of 1).

The following pie graph depicts the distribution of these chosen characteristics with a value of their importance:



This graph can also be defined as a representation of the worst possible characteristics a targeted relay could possess when evaluated by the PWI model.

For an individual relay, the weighted measure is calculated by comparing the specific attribute(s) of the targeted relay with the rest of the desired relay population (either by specific model, model group, model series or model family) as per the equation below:

$$\boldsymbol{Weighted.Relay}(\boldsymbol{Attribute}) = \frac{\boldsymbol{Relay}(\boldsymbol{Attribute})}{Max(All\ Network\ \boldsymbol{Relay}(\boldsymbol{Attribute}))} \times \frac{\boldsymbol{Relay.WEIGHT}(\boldsymbol{Attribute})}{\boldsymbol{\Sigma}(\boldsymbol{Weight})}$$

Step 4 – Prioritisation Calculate

The final step is to evaluate and compare all the chosen characteristics for each individual asset against the defined population producing a prioritised listing.

The Weighted Priority Index (PWI) calculation results as a sum total of the weighted attributes considered and measured as a percentage. The PWI formula is as follows:

$$\boldsymbol{PWI}(\boldsymbol{Total}) = \Sigma \text{ of all Weighted (Substation OR Plant)Attributes}$$

These results, calculated for each individual relay, are in-turn ranked according to score to identify priority of replacements.