Asset Management Plan – Protection

Power and Water Corporation

CONTROLLED DOCUMENT

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Executive Summary

Power and Water Corporation (Power and Water) owns and operates the electricity transmission and distribution networks in the Northern Territory (NT) of Australia. Included in the networks are Protection assets which perform (in conjunction with circuit breakers) the critical function of isolating and protecting sections of the network when faults occur.

Assets only contribute to a very small proportion to the total asset base

Protection assets make up 3.4% of the total network value of the asset base and contribute to around 3.7% of the total operating expenditure. Power and Water has a considerable digital relay asset fleet comprising of 65% of their total protection assets and an average age of just six years. Most static and electromechanical relays have exceeded their expected life. Power and Water will replace many of these aging static and electromechanical relays over the coming regulatory period.

The scope does not include other zone substation assets such as SCADA equipment, circuit breakers, or current and potential transformers.

Assets operate across a diverse environment *– temperature, humidity, rainfall, termites, soil types present different challenges to managing the assets.*

The Power and Water power network is subject to unique environmental and operational challenges ranging from the coastal tropical environments prone to cyclones, high temperatures and humidity, and high annual rainfall, to desert environments subject to high ambient temperatures, occasional flooding, droughts, dust storms, and surrounding factors including high termite infestation and aggressive soil conditions. This unique environment results in a more rapid rate of asset deterioration, and lower worker productivity compared to peer distribution businesses.

There are four key challenges that require management *– asset obsolescence, managing personnel skills, managing personnel location, and the integration of different technologies into a cohesive system.*

The key asset challenges include asset obsolescence issues related to end-of-vender support and meeting functionality standards required by Power and Water, NER and the Technical Code. The end of support and production by venders has led to issues around part replacement, servicing needs, and manufacturer expertise.

Diverse environmental conditions also result in many additional asset management challenges for ensuring that a reliable network protection. It is difficult for appropriately skilled field crews to access remote (rural) substations due to distance and/or monsoonal conditions. This can result in increased network risk due to prolonged response times.

The integration of older electromechanical/static relays and newer digital relays into one cohesive protection system is an on-going issue. Electromechanical / static relays have a much more limited functionality compared to digital relays and integrate into Power and Water's SCADA and protection communication system differently. Modern digital relays connect via LAN centres and Ethernet ports at zone substations. Integration into the newer digital system is important to allow for remote engineering access and event recording which is used for data capture, fault analysis and investigations of network issues.

Power and Water also acknowledges that they are in the process of maturing their approach to asset management and need to improve their asset data collection processes. This lack of comprehensive condition data remains is a key asset management challenge. These data sources are required to fully understand the asset fleet and the impact that deterioration of assets has on the operational integrity and functionality of the assets.

***Investment programs are targeted to manage the key challenges** – directed replacement.*

The following asset renewal programs are proposed for the 2019-20 to 2023-24 regulatory period to address key asset challenges:

- Protection relay replacement program [NPR]
- DKTL - Secondary systems upgrade of 132kV substations at Manton, Pine Creek and Katherine [PRD32117]
- Zone substation and key asset replacement programs with secondary relay replacement components:
  - Berrimah ZSS
  - Humpty Doo ZSS
  - Centre Yard ZSS

The renewal programs have been developed with the objective of maintaining risk over time. To achieve this, an asset health and criticality framework was developed that provides for a consistent method of assessing assets and making value based investment decisions. The health and criticality framework was central to establishing the targeted protection investment programs focusing on the highest risk assets as a priority. The protection investment programs are summarised as follows:

Table 0.1: Summary of Protection asset investment programs over the coming regulatory period

Investment category	2019-20 ($ million)	2020-21 ($ million)	2021-22 ($ million)	2022-23 ($ million)	2023-24 ($ million)	Total ($ million)
Renewal	$3.26	$3.26	$1.36	$1.06	$0.76	$9.70
Augmentation	$0.00	$0.00	$0.80	$0.90	$0.80	$2.50
Maintenance Plans	$0.79	$0.79	$0.79	$0.79	$0.79	$3.95
Total	**$4.05**	**$4.05**	**$2.95**	**$2.75**	**$2.35**	**$16.15**

The higher level of expenditure in 2019-21 is due to the DKTL secondary systems replacement program and the Berrimah zone substation replacement.

***Benefits from the investment programs** – maintain reliability.*

The investments are expected to maintain reliability of protection assets at current levels. The investment program targets the highest risk assets with consideration of other works as appropriate to optimise workforce scheduling and address priority defects. The program is expected to materially impact the risk profile of protection assets.

The investment will also meet the longer-term strategy to improve operational monitoring and control that will enable improved operational performance of network assets.

Network risk – *as related to investment & improvement programs.*

Network risk is the combination of the health and criticality of protection assets. It is shown in Table 5.3 using a risk matrix approach. This identifies that there are 151 protection relays with Extreme Risk and 48 with High Risk. The remainder (86% of relays) are of moderate, low or very low risk.

Table 0.2: Protection relay health - criticality matrix

	H1	H2	H3
C1	477	12	249
C2	360	2	46
C3	46	2	151

The Extreme Risk and High Risk relays are driven by:

- 75 Single bus protection for 66kV substations older than ten years
- Three digital and 73 static relays at the highly critical Hudson Creek ZSS
- Relays that have exceeded their expected life

Many of these relays are to be replaced as part of zone substation and key asset replacement programs, the DKTL – secondary systems upgrade program or the protection relay replacement program. The risk profile is expected to evolve as ongoing condition and performance monitoring, methodical inspections, and improved data collection practices provide for better quality data and asset insights over the coming regulatory period.

Performance indicators have been established for Operational Performance, Health & Safety, People & Culture and Financial Performance; these targets are currently being met.

1 Purpose

The purpose of this asset management plan (AMP) is to define Power and Water Corporation's (Power and Water) approach to managing protection equipment. It frames the rationale and direction that underpins the management of these assets into the future:

- Short Term (0-2 years): Detailed maintenance and capital works plans for the upcoming financial year based on current asset condition.
- Medium Term (3-7 years) 2019-24 Regulatory Period: Strategies and plans based on trends in performance and health indicators.
- Long Term (8-12 years) 2024-29 Regulatory Period: Qualitative articulation of the expected long-term outcomes.

The protection assets are managed to comply with the broad external requirements of legislation, codes and standards. This is achieved within an internal framework of policy, strategy and plans that are enabled through interrelated documents, systems and processes that establish the Power Networks asset management practices. The asset management system is summarised in Figure 1.1.

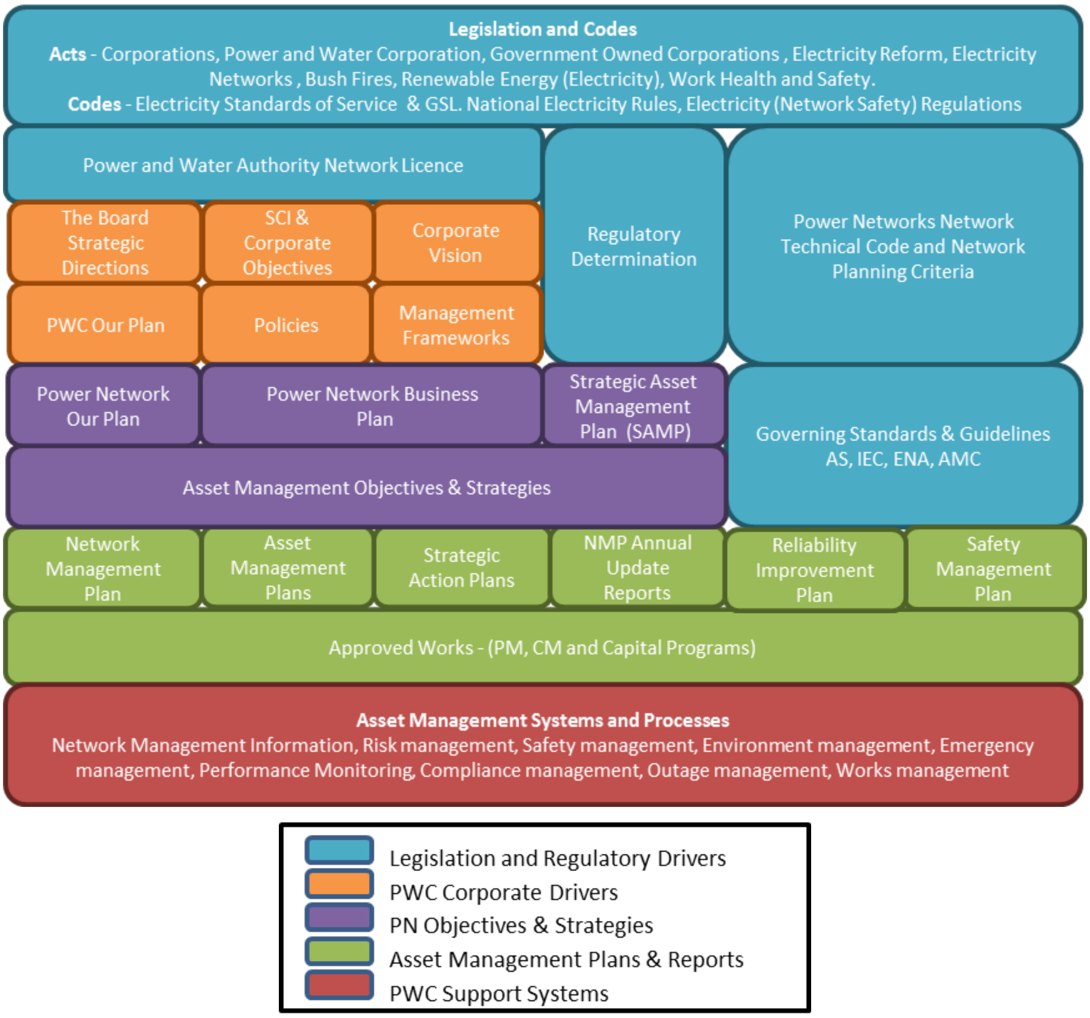


Figure 1.1: Asset Management System

2 Scope

2.1 Asset class overview

This AMP covers all protection relays located in zone substations. Table 2.1 and Table 2.2 provide an overview of the in-scope relay asset fleet separated into their respective technology level; digital, static, and electromechanical. The scope does not include other zone substation assets such as SCADA equipment, circuit breakers, or current and potential transformers.

The scope is separated into regulated and non-regulated assets. Regulated assets comprise of 97% of assets across 33 zone substations with only 3% being non-regulated assets (all of which are located at the Jabiru, Ranger and Yulara zone substations). The analysis throughout this AMP combines regulated and non-regulated protection assets unless otherwise specified.

Table 2.1: Overview of regulated in-scope assets

Asset type	Quantity	Percentage of total	Average Age (years)	Expected life	Percentage exceeding lifespan
Digital	863	66.13%	6.41	20	8.34%
Static	439	33.64%	24.49	20	76.77%
Electromechanical	3	0.23%	31.67	30	100%
Total	**1305**	**100%**	**12.55**		**31.57%**

Table 2.2: Overview of non-regulated in-scope assets

Asset type	Quantity	Percentage of total	Average Age (years)	Expected Life	Percentage exceeding lifespan
Digital	4	10%	22.25	20	75%
Static	28	70%	30.68	20	85.71%
Electromechanical	8	20%	35.25	30	87.5%
Total	**40**	**100%**	**30.75**		**85%**

Power and Water's protection assets are distributed throughout its network footprint, which covers four regions within the Northern Territory (NT), namely Darwin (DRW), Katherine (KTH), Alice Springs (ASP) and Tennant Creek (TC).

Table 2.1 and Table 2.2 show that there are a large percentage of static relays which have exceeded their expected life. With our regular preventive maintenance program we keep track of the performance of static relays and ensure that they are functioning correctly within a specified risk profile.

The asset base, health and criticality, and key challenges are discussed in detail in sections 3.3, 5 and 6 respectively. Asset augmentation, renewals and maintenance are discussed in sections 8, 9 and 10; these sections are used to show how the performance targets, which are outlined in sections 7 and 11, will be met. The remaining appendices provide in depth supplementary information.

2.2 Asset class function

Protection relays are used in conjunction with circuit breakers to isolate sections of the network and protect the network when faults occur. Current and voltage transformers monitor network voltages and currents and are inputs into the protection relays. Relay equipment is designed and configured to detect faults within the system; once a fault is detected the relay will operate to open a circuit breaker to interrupt the fault and protect the system. There is an extensive network of relays which work together to isolate faults while minimising the number of customers that experience an outage.

Depending on the asset and voltage level of the assets being protected, primary protection schemes are set up with redundancy, known as X and Y protection. For example, a single circuit breaker will be protected by two relays of different models/different operating principles, where possible, with duplicate protection and control DC supply, CT inputs coming from different cores, VT inputs coming from different windings and each X and Y protection tripping the separate trip coil of the CB. This set up reduces the risk of common failure modes at each step of the circuit. Different relay models reduce the risk of a relay type fault affecting both X and Y protection devices.

Primary relays, if functioning correctly, will isolate the fault to the immediate area of the network. However, if primary protection fails secondary protection located locally or at the remote end of the feeder will activate. Operation of backup protection will result in an outage that will affect more customers.

Protection relays have following primary functions:

- Public safety and the safety of Power and Water employees
- Protection of assets
- Continued operation of the network
- Reduce the power outage range.

2.3 Asset objectives

The AMP provides a framework which steers the management of the asset class in a manner that supports the achievement of Power and Water's broader organisational goals. The Asset Management strategies are listed in the Strategic Asset Management Plan (SAMP) and are aligned to the Asset Management Objectives and implemented in through Asset Management Plans (specific to asset class) or Strategic Asset Plans as shown in Figure 2-1.

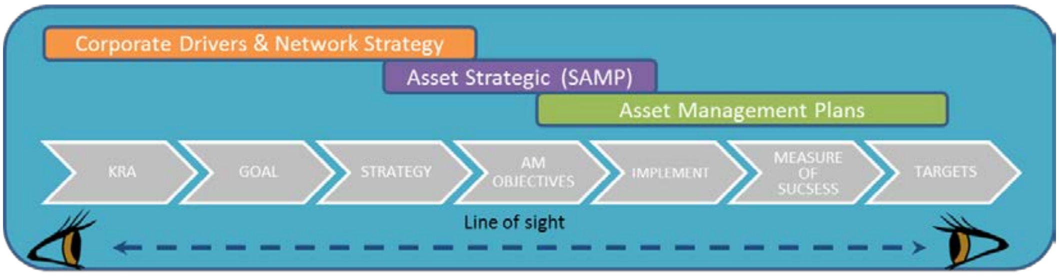


Figure 2-1: Asset Management Line of sight from Corporate and Network strategies through the Asset Management objective to the targets in the asset management plan.

Table 2.3 provides the asset management objectives from the strategies that are relevant to this asset class along with the measures of success and the targets. This provides a 'line of sight' between the discrete asset targets and Power and Water corporate Key Result Areas.

Table 2.3: Asset Management Objectives, Measures of Success and Targets.

Objectives	Measures	Targets
• Network related operation and maintenance tasks are quantified in terms of risk and used to inform investment decisions that affect Health and Safety outcomes for the organisation • Safeguard persons, property and equipment in the event of system faults or abnormal operating conditions.	• Total asset class specific safety incidents • Protection mal-operation extending fault duration	• Total asset class specific safety incidents not exceeding TBA
• Ensure that the systems and processes provide sufficient and appropriate data and information to drive optimal asset and operating solutions. • Minimise disruption to supply availability and quality in the event of system faults or abnormal operating conditions	• Asset class contribution to system SAIDI • Asset class contribution to system SAIFI • GSL contribution per year Guaranteed Service Levels	• SAIDI to be no more than 1.5% for this asset class. • SAIFI to be no more than 3% for this asset class. • GSL contribution per year TBA
• Ensure that the systems and processes provide sufficient and appropriate financial data • Understand the financial risks associated with asset management	• Whole of life cost of assets • Variance to AMP forecast CAPEX • Variance to AMP forecast OPEX	• Variance to AMP forecast CAPEX +/-10% • Variance to AMP forecast OPEX +/-10%
• Develop systems and data that facilitate informed risk based decisions • Ensure that works programs optimise the balance between cost, risk and performance • Ensure the effective delivery of the capital investment program	• Asset health movements (age, condition, remaining life) • Annual in-service asset failures • Assessment of the impact of investments (i.e. capex, opex) on network risk (Bottom-up: Health and Criticality assessment, Top-Down: Risk vs Expenditure tool) • Network risk index quantified (Y/N) • Health and Criticality Parameters defined (Y/N)	• Annual in-service asset failures not exceeding 4 per annum

Objectives	Measures	Targets
• Identify, review and manage operational and strategic risks • Prioritise projects, programs and plans to achieve efficient and consistent risk mitigation. • Achieve an appropriate balance between cost, performance and risk consistent with regulatory and stakeholder expectations. • Define and communicate the level of risk associated with the investment program	• Critical spares analysis completed for asset class • Operator/Maintainer risk assessment completed for asset class and risk register updated	• Achieved
• Ensure that electricity network assets are maintained in a serviceable condition, fit for purpose and contributing positively to Power Networks business objectives.	• All staff are trained and hold appropriate qualifications for the tasks they undertake. • Peer benchmarking, i.e. a reasonableness test of underlying unit costs (capex, opex) • Compliance breaches with the relevant legislation / regulation / standards. • Asset class preventative maintenance completion	• Achieved

3 Context

3.1 Roles and responsibilities

Power and Water operates using an "Asset Owner / Asset Manager / Service Provider" business model. Although there is extensive collaboration and interfacing between the roles, generally:

- The Asset Owner establishes the overall objectives for the assets
- The Asset Manager develops the strategies and plans to achieve the objectives
- The Service Provider performs activities on the ground to deliver the plans.

3.2 RACI

The Responsibility, Accountability, Consulted, Informed (RACI) matrix for protection asset class is provided in Table 3.1. This defines the roles and accountabilities for each task by allocating to specific roles/personnel in Power and Water.

Table 3.1 RACI matrix for protection

Process	Exec GM Power Networks	Group Manager Network Assets	Chief Engineer	Network Planning Manager	Major Project Delivery Manager	Southern Delivery Manager	Group Manager Service Delivery	Manager Test & Protection	Works Management Manager	Strategic Asset Engineering	Asset Quality & Systems	Manager Protection Assets
Establish Condition Limits		A	C	C		I	I	C/I	I	I	I	R
Performance and condition data analysis	I	A	I	I		I	I	I	I	R/C	I	R
Plan capital works (Options, costs, BNIs, BCs etc)	I	R	A	R	C/I	R	R	C/I	C/I	R	I	R
Execute maintenance plans	I	I	I			R	A	R	R	C/I	I	I
Deliver identified major projects and programs of work	I	C	A	C	R	R	R	C/I	C/I	C/I		R
Manage asset data (data entry, verify data)		A	I	I						C/I	R	R
Monitor delivery of capital plans and maintenance	I	A	I	I	I	R	R	R	R	R	R	R

- *Accountable **(A)** means the allocated person has an obligation to ensure that the task is performed appropriately*
- *Responsible **(R)** means the allocated person must ensure the task is completed*
- *Consulted **(C)** means the allocated person must be included in the process for input but do not necessarily have specific tasks to do*
- *Informed **(I)** means this person must be kept up to date with progress as it may impact other parts of their responsibilities or accountabilities.*

3.3 Identification of needs

With respect to asset replacement, the identification of needs is guided by the risk profile for the asset. Table 3.2 below provides the guiding principles for the adoption of the most appropriate asset management strategy.

Table 3.2: Protection asset management strategy overview

Asset Management Strategy	Asset risk profile suitability
Run to failure Reactive (functional failure)	- Protection relays are not intentionally run to failure. At times assets do fail in service, but all reasonable and appropriate measures are undertaken to prevent this from occurring. Implementation of X and Y schemes reduces network risk. Failure also includes unacceptably slow operation time.
Condition based (Conditional failure)	- The failure of protection relays in certain circumstances carries a greater risk due to its respective location and function. Power and Water manages this risk to reduce damage to key components, minimise loss of supply to customers, and to ensure public and environmental safety. - Condition data is gathered and used to forecast optimal timing for the replacement of relay assets. - Asset condition modelling is used to assist prioritisation of asset replacement.
Demand driven	- The forecast demand at a zone substation, and growth/contraction over time, is used to identify when the existing installed capacity is insufficient for the demand and augmentation of the zone substation is planned. - Relay replacement strategy ensures that critical areas of the system have a greater certainty of protection. Demand driven growth can place additional importance on certain assets and zone substations, and by implication the importance of protection in that area increases. - New or revised protection or system requirements (i.e. the under-frequency load shedding (UFLS) scheme) can result in additional relays being installed on the network.
Customer driven	- Large (HV) customers connecting to the network may require dedicated services. These issues are managed through the connections process when they occur.

3.4 Selection of options and solutions

Once a protection asset is identified as being in poor condition or having a risk profile which Power and Water deems too great, a comprehensive set of options are considered to address the risk to ensure the network can continue to be operated safely and reliably. Each unique situation should consider the suite of options and solutions set out in Table 3.3.

Table 3.3: Example options that should be considered

Asset management options	Asset risk profile suitability
Repair/life extension	• Power and Water technicians are unable to repair, or recalibrate older electromechanical relays once their sensitivity is outside of acceptable tolerance. • Static and digital assets can be returned to "as good as old" condition (repair) or "better than old" (life extension) by returning the device to the vendor. Power and Water does not have the capability in-house to repair relays other than firmware upgrades. This only applies to relays still under vendor warranty.
Like-for-like	• Replace an old relay with the same type that may have been salvaged during an upgrade project and retained as a spare. • Replace the relay with a modern equivalent of the same function. • Modern relays have a many-to-one relationship with older versions in terms of functionality.
Alignment with other assets	• Protection relays are often upgraded and modernised when other assets at zone substations such as transformers and circuit breakers are replaced. Economic analysis is undertaken to assess the most efficient option for aligning asset

Asset management options	Asset risk profile suitability
	replacements.
Network solution	• Protection assets are a regulatory requirement and there are no substitutable alternatives.
Demand management/Non-network solutions	• N/A

4 Asset base

4.1 Overview

Power and Water owns and maintains a portfolio of 1345 relays; 1305 of which are located within the regulated network, with 40 relays operating within the non-regulated Jabiru, Yulara and Ranger zone substations.

Protection relays are in 33 regulated zone substations within the Alice Springs, Tennant Creek, and Darwin-Katherine regions of Power and Water's power network. 1107 reside within the Darwin- Katherine region as shown in Table 4.1.

Power and Water's protection assets vary by technology, age and location within the network. This variety results in unique risk profiles; and thus, unique expenditure and management implications for protection assets.

4.2 Asset types

The underlying technology of these devices can be broadly categorised into digital, static and electromechanical devices:

- Digital relays are modern microprocessor based devices which provide multiple types of protection. These devices have a significant advantage in self-diagnostic and communication functionality over other relays. They also have event recording capabilities with data capture which aid in fault analysis and investigations.
- Static relays are non-microprocessor based electronic devices which have few/no moving parts. These devices have a higher level of sensitivity than electromechanical relays but are representative of an older type of technology compared to digital relays. They generally provide only one particular protection function.
- Electromechanical relays are non-microprocessor based mechanical devices which rely on moving parts to function. These devices offer a single type of protection and represent the oldest type of technology.

Table 4.1 shows the number of relays by region; separated by technology and whether they are regulated or unregulated assets.

Table 4.1: Region asset technology breakdown

Relay technology	Digital	Static	Electromechanical	Total
Alice Springs	120	63	1	184
Darwin & Katherine	731	374	2	1107
Tennant Creek	12	2	0	14
Jabiru, Yulara, Ranger (non-regulated)	4	28	8	40
Total	**867**	**467**	**11**	**1345**

4.3 Breakdown of asset population

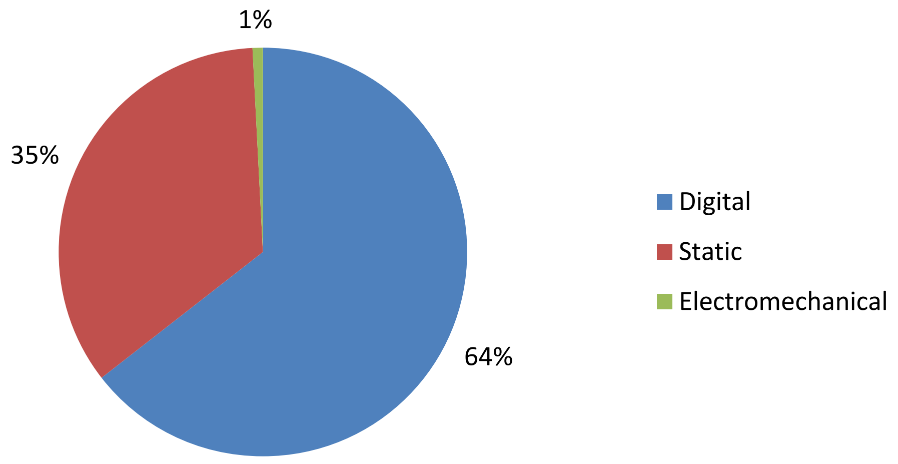
The protection asset fleet varies greatly in make, model and type due to differing functions, circuit voltages, and the asset class being protected. The other key factor is that protection relays have long expected lifespans (up to 30 years for electromechanical relays) which in conjunction with evolving technology results in a diverse asset fleet.

4.3.1 Relay technology

The overall protection asset fleet can be broadly defined into three distinct technology classes as shown in Figure 4.1:

- Digital - 867 relays - 64%
- Static -467 relays - 35%
- Electromechanical - 11 relays - 1%

Figure 4-1: Relay technology - asset population analysis



Each relay technology has a unique risk profile; which leads to unique expenditure and management implications for protection assets.

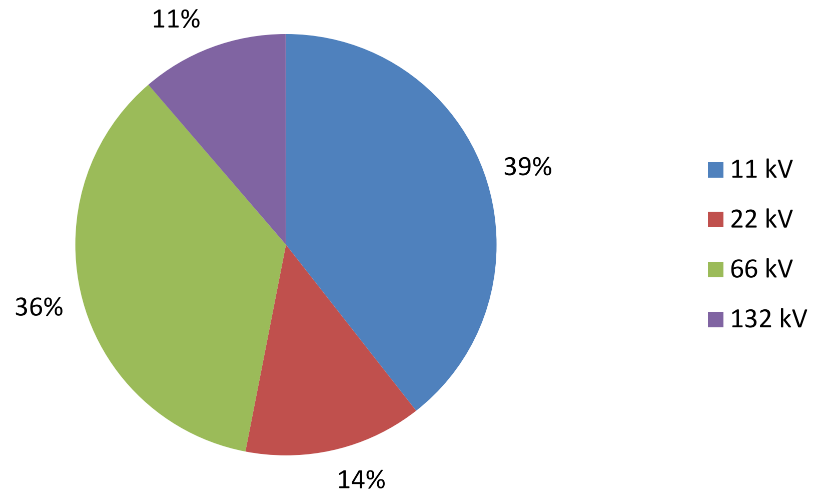
4.3.2 Circuit voltage

This section divides Power and Water's protection assets into 132kV, 66kV, 22kV and 11kV segments. Figure 4.2 displays the proportion of assets with respect to circuit voltages and Figure 4.3 gives an in-depth breakdown of protection assets by technology.

Figure 4.2 shows percentages as a total of all protection assets;

- 132kV – 152 relays, 11%
- 66kV – 479 relays, 36%
- 22kV – 184 relays, 14%
- 11kV – 530 relays, 39%

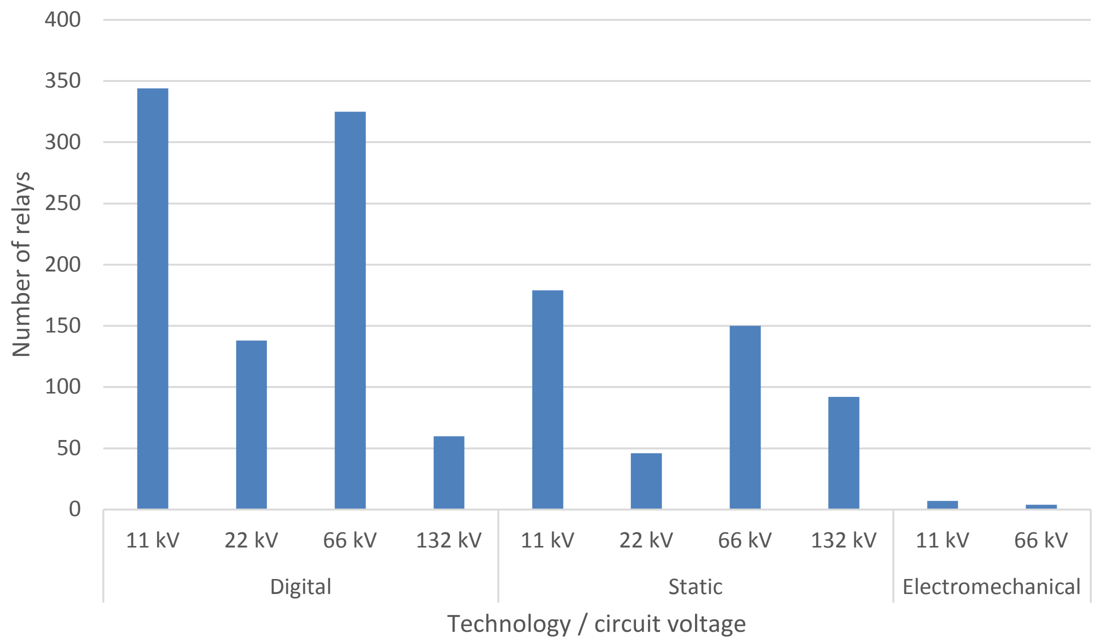
Figure 4.2: Circuit voltage of relay assets population



Total asset proportions from Figure 4.1 can be compared with individual asset class proportions from Figure 4.3.The key points from Figure 4.3 are:

- The 132kV component of Power and Water's network is protected by 152 relays, of which;
  - 39% digital
  - 61% static
- The 66kV component of Power and Water's network is protected by 479 relays, of which;
  - 68% digital
  - 31% static
  - 1% electromechanical
- The 22kV component of Power and Water's network is protected by 184 relays, of which;
  - 75% digital
  - 25% static
- The 11kV component of Power and Water's network is protected by 530 relays, of which;
  - 65% digital
  - 34% static
  - 1% electromechanical

Figure 4.3: Protection asset fleet breakdown by circuit voltage and relay technology



This data shows that 132kV and 66kV components throughout Power and Water's network are protected disproportionally by ageing static relays.

- Digital relays represent 64% of the asset fleet but only 40% of 132kV relays.
- Static relays are 35% of the total asset fleet but represent 61% of 132kV relays.

Static relays need to be inspected, tested and maintained more regularly to ensure that they are operating within the specified margins. This may be reflected in higher operational expenditure due to the higher frequency of maintenance and testing of older relays.

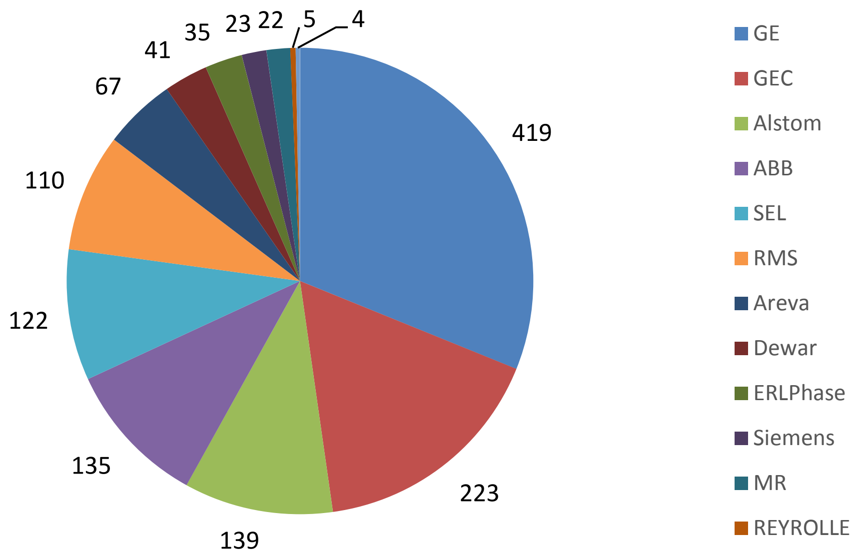
Further details regarding the circuit voltage, technology and age of Power and Water's protection asset fleet is provided in Appendix B – Asset data.

4.3.3 Manufacturer

There are protection relays supplied from 14 separate vendors with a variety of models and functions. This adds complexity to the operation and maintenance of protection assets.

Manufacturers historically used by Power and Water have been GE, GEC, ALSTOM, SEL and ABB. This is shown in Figure 4.4; together these manufacturers account for 77.03% of the current relay fleet. Recent installations of protection assets have been purchased largely from GE and SEL comprising of 66.75% of relays installed relays since 2010.

Figure 4.4: Manufacturer breakdown of protection assets



This shows that although the majority of Power and Water's protection assets come from a few manufacturers, there also remains a diverse range of relays across the network that need to be inspected, tested and maintained. This adds to the complexity of routine maintenance as employees require sufficient knowledge of each relay type. This may be reflected in an increase in operational expenditure due to the need to send specific field crews to locations to ensure the right capability is available.

Further details regarding manufacturers as well as other asset population information is provided in Appendix B – Asset data.

4.4 Asset profiles

4.4.1 Asset installations profile

The number of new protection relays installed each year since 2010 is shown in Table 4.2, including relay installations as part of the development/renewal of zone substations/transformers and renewals due to targeted replacement programs. The number of relays replaced only due to in service failures is shown separately in Table 4.2 and Table 4.3.

Table 4.2: Protection installations total (not including in service failures)

	2010	2011	2012	2013	2014	2015	2016	2017
Number of installations	39	77	216	39	6	226	100	17

Table 4.3: Protection installations from in service failures

	2010	2011	2012	2013	2014	2015	2016	2017
Number of installations	2	4	3	3	4	3	18	4

Historically, Power and Water has aligned replacement programs of protection assets with other major capital works to ensure an efficient delivery of network upgrades, maintenance and asset renewals.

4.4.2 Age profiles

Asset age profiles provide an overview of the protection asset fleet in its current state. Table 4.4 provides a summary of the remaining life of regulated assets for each asset technology class based on asset manufacturer data and assessments from Power and Water Protection Engineers. Table 4.5 provides a summary of the remaining life for unregulated protection assets.

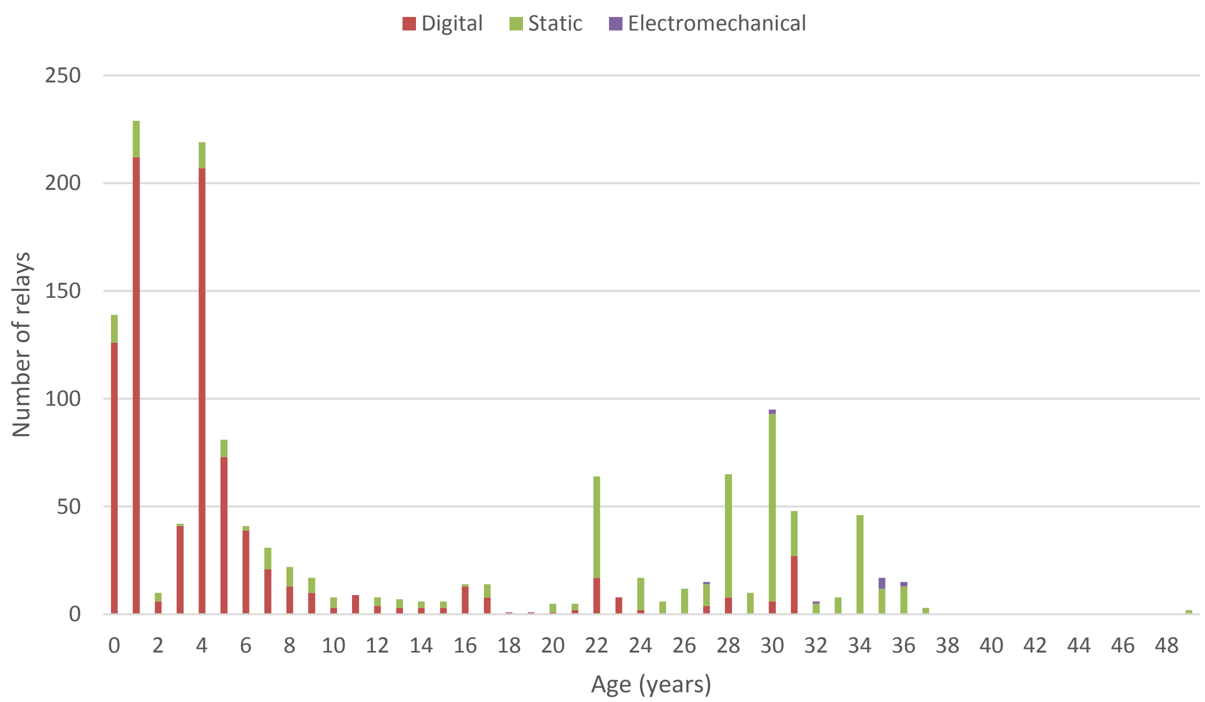
Table 4.4: Average age and remaining life of regulated assets

Asset type	Weighted average age (years)	Weighted average remaining life (years)	Asset type as a percentage of asset population
Digital	6.41	13.59	66%
Static	24.49	-4.49	34%
Electromechanical	31.67	-1.67	0%
Total	12.55	7.47	100%

Table 4.5: Average age and remain life of non-regulated assets (Jabiru, Ranger, Yulara)

Asset type	Weighted average age (years)	Weighted average remaining life (years)	Asset type as a percentage of asset population
Digital	22.25	-2.25	10%
Static	30.68	-10.68	70%
Electromechanical	35.25	-5.25	20%
Total	30.75	-8.75	100%

Figure 4.5: Protection age profile by asset technology



***Note**: Age is based on installation year.*

Figure 4.5 shows the age profile of all protection relays on the network. It highlights that although 62% of the assets fleet has been installed within the past 10 years, there remains some assets that have surpassed their expected lifespan and are likely to be approaching the end of their expected lives, particularly static relays.

5 Health and criticality profiles

This section discusses the health and criticality of the protection relay fleet and resulting network risk. This analysis informs the priorities for Power and Water with respect to where they should focus further condition assessments and future network investments.

The health and criticality framework provides the basis for calculating the risk associated with protection assets. Risk is the product of the probability of an event occurring (determined by asset health) and the consequence should it occur (determined by asset criticality). Network risk can be reduced though improving the condition of assets (opex or repex) and/or by reducing the consequence of failure through changing the network topology/configuration.

Power and Water manages network risk so it can operate the network safely and reliably at the lowest cost to customers.

5.1 Asset health

This section discusses the health of the asset fleet. Power and Water assesses asset health by the relative age of an asset compared to its expected life in conjunction with condition assessments undertaken by field crews during routine maintenance.

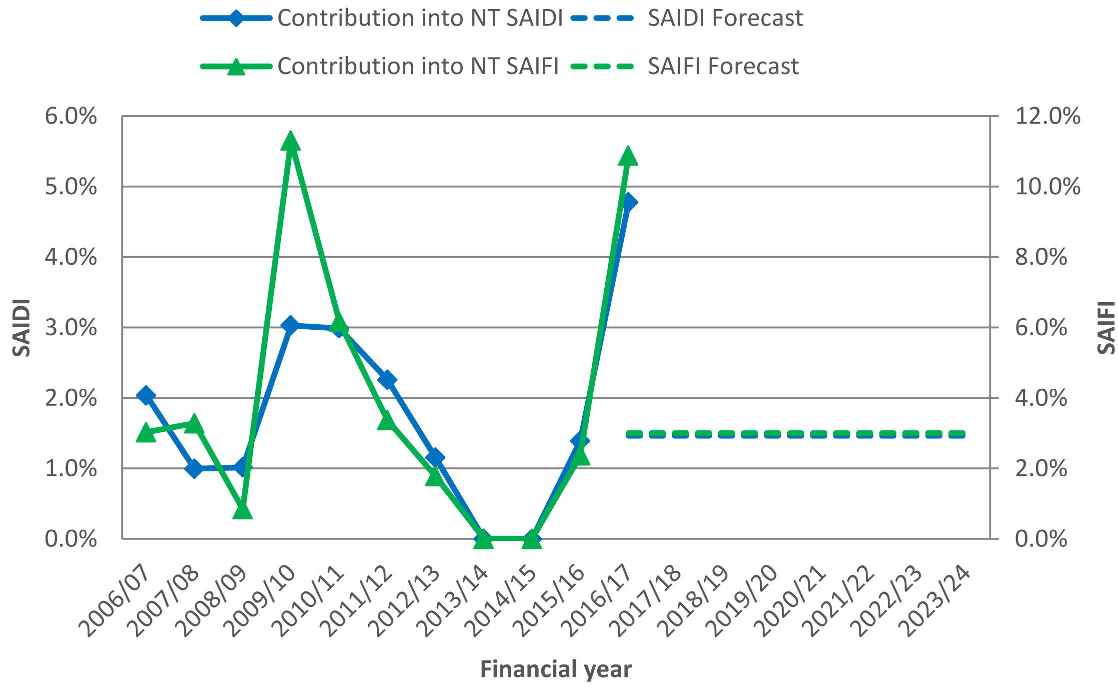
Overall, the fleet is performing reliably with only a few relays replaced each year due to loss of calibration or failure.

5.1.1 Asset performance (reliability)

Protection asset performance and network reliability is measured by tracking the number of asset failures, as well as analysing protection's SAIDI and SAIFI contribution to network performance. These measures are discussed below.

Unless otherwise stated, SAIDI and SAIFI are shown as the total for Power and Water with all regions combined.

Figure 5.1: Protection's contribution to SAIDI / SAIFI



The data shows that the contributions to SAIDI/SAIFI are volatile without a clear trend between periods/across time, hence it is prudent to look at a simple average of the data when considering historical performance. These charts show that protection assets make a significant contribution to SAIDI and SAIFI.

The dashed lines in Figure 5.1 are the projected contribution of protection assets into SAIDI and SAIFI based on historical trends:

- Contribution into SAIDI averages 1.46% per year since 2006-07
- Contribution into SAIFI averages 3.01% per year since 2006-07.

Figure 5.2: Protection– number of failures & contribution to SAIFI

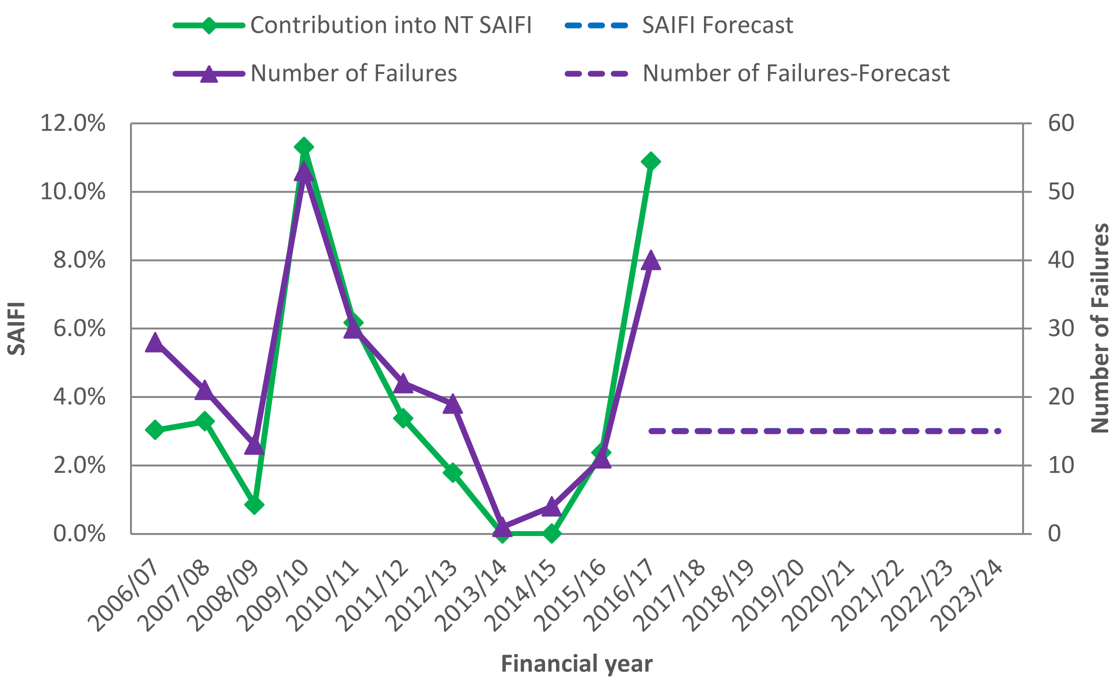


Figure 5.3: Protection – number of failures & and contribution to SAIDI

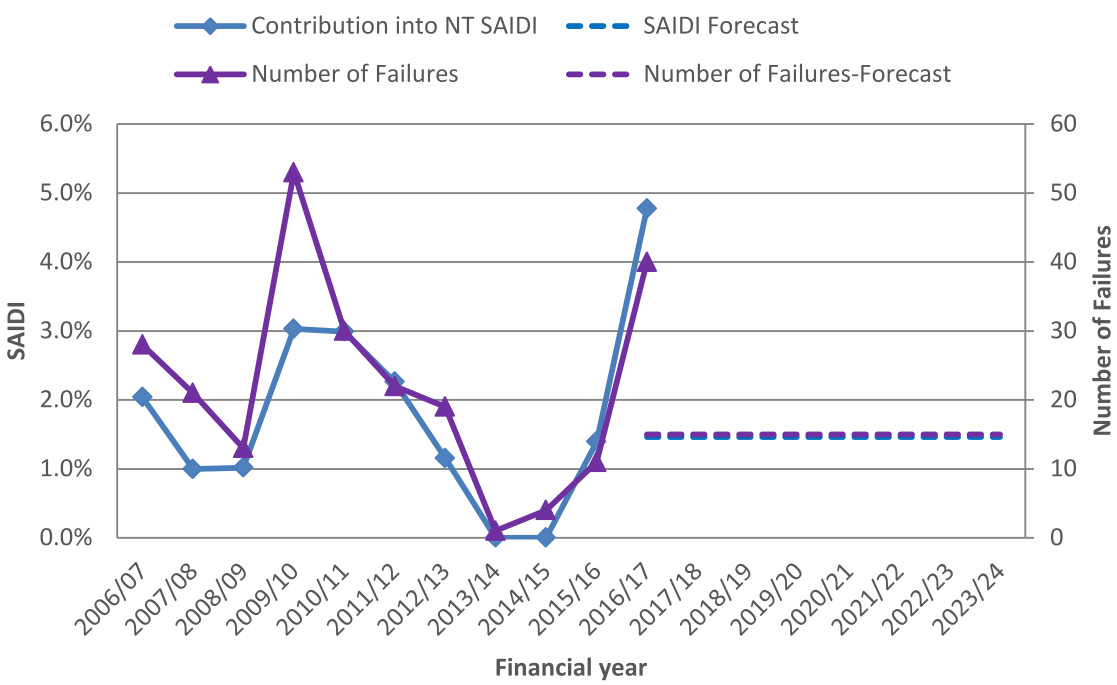


Figure 5.2and Figure 5.3 display the relationship between asset failures and protection's contribution to SAIFI and SAIDI. The majority of relays run with N-1 redundancy schemes which mean that most asset failures do not impact supply, however at times these failures result in outages to customers.

Power and Water experienced 242 relay asset failures that were identified to have been caused by incorrect operation or a failure of protection assets since 2007, an average of 22 per year which is a failure rate of approximately 1.52% per annum for the fleet. The relative magnitude of asset failure is also important; to reduce this, Power and Water assesses protection relay criticality and implements asset management strategies to reduce the risk of asset failure of highly critical assets. This methodology is discussed in Section 5.

The clear link between asset failures, outages and the contribution to SAIFI is displayed in Figure 5.2. Power and Water through the augmentation and renewal projects (outlined in sections 8 and 9) will improve the future performance and reliability of the protection relays.

5.1.2 Remaining life

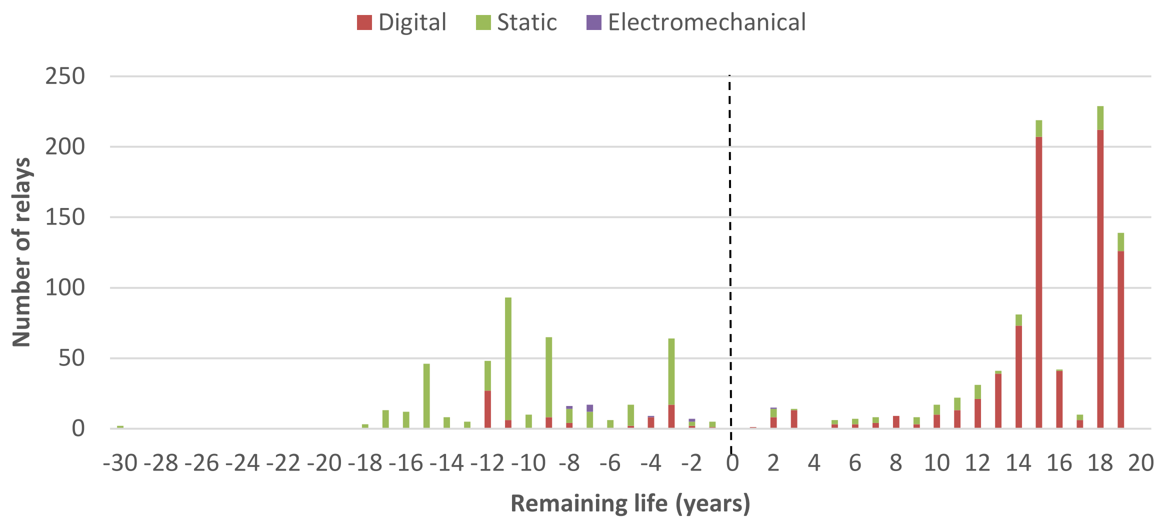
The effective remaining life of the relay protection fleet is calculated based on the current life of the asset compared to the estimated expected life of the asset determined by the type of relay technology:

- Digital relays - 20 years expected life
- Static relays - 20 years expected life
- Electromechanical relays - 30 years expected life

Figure 5.4 shows the expected remaining life of protection assets, some key characteristics of Power and Water's protection relay fleet are:

- Digital relays - are still relatively young due to a large volume of zone substation replacement works over the past five years.
  - 8.65% of digital relays have exceeded expected lifespan
  - 90% of digital relays have more than 10% of their expected life remaining
- Static relays – 77% have surpassed their expected life of 20 years
- Electromechanical relays – all have exceeded their expected life.

Figure 5.4: Protection relays – remaining life and technology class



5.1.3 Condition assessments

Inspection and testing had identified a number of relays that were deteriorating or operating slowly. The specific makes or models have been replaced systematically over the past few years. In general, most deterioration appears to be caused by normal operational use in the harsh environment of Northern Territory.

5.1.4 Health assessment matrix

Power and Water considers the results of the age and condition assessments identified above to develop an Asset Health Score. The Health Score identifies the assets that are considered to have the highest risk of failure. There are three categories: Acceptable, Caution/ Monitor, Urgent.

The health score assessment is calculated by the remaining life of the asset.

- Acceptable - greater than 10% of the expected asset life remaining.
- Caution/Monitor – within the last 10% of the expected asset life remaining.
- Urgent – the asset has exceeded its life expectancy.

Table 5.1 shows the output of the health assessment - this assessment is made directly from the age of the asset as it is Power and Water's best indicator of health for protection assets.

Table 5.1: Health score results

Condition Rank	Condition	Number of protection relays
H1	Acceptable	883
H2	Caution – monitor	16
H3	Urgent	446

5.2 Criticality

The criticality of protection relays is taken to be the same as the network element with which it is associated. In other words, the criticality of a protection relay for a transformer circuit breaker is taken to be the same as the transformer. The criticality of protection relays at 66kV substations older than 10 years has been increased to the highest level as the 66kV Bus protection is not duplicated.

The criticality of a relay reflects its importance to the continued operation, reliability, stability and security of the power network. Criticality is dependent on the following key attributes which are assessed at the level of a zone substation:

- The type of customer they serve, typically broken down into:
  - CBD, Urban and Rural for reliability metrics; and
  - Residential, Industrial and Commercial for the value of lost load (VoLL) or Value of Customer Reliability (VCR).
- The redundancy of the zone substation, that is, a zone substation's capacity in maintaining power supply in case of system fault or disturbance.
- The amount of time required to replace protection assets.

- Older electromechanical/static relays utilise older SCADA and wiring systems, this may lead to longer maintenance and asset renewals of these legacy systems to newer digital relay systems.
- The ability to undertake the installation and commissioning works may be limited to the dry season.

These characteristics have been assessed to provide a ranking of the criticality of protection assets, by substation, as shown in Table 5.2. The analysis shows that Hudson Creek is the most critical substation, and out of the other 33 substations, there are five that rank highly, five that rank moderately and the remainder are of low/very low criticality.

Table 5.2: Criticality ranking of substations

Condition Rank	Criticality	Number of substations	Number of relays
C1	Very low	9	268
	Low	12	470
C2	High	5	300
	Moderate	5	108
C3	Critical	1	199

The full criticality analysis is shown in Appendix B – Asset data.

5.3 Network risk

Network risk is the combination of the health and criticality of protection assets. It is shown in Table 5.3 using a risk matrix approach. This identifies that there are 151 protection relays with extreme risk and 48 with high risk. The remainder are of moderate, low or very low risk.

Table 5.3: Protection relay health - criticality matrix

	H1	H2	H3
C1	477	12	249
C2	360	2	46
C3	46	2	151

Risk legend				
Extreme	High	Moderate	Low	Very low

Table 5.3 shows that the majority of protection relays (86%) are at an acceptable level of risk. However, there are 151 Extreme Risk and 48 High risk relays. This is driven by:

- 75 Single Bus protection for 66kV substations older than 10 years:
  - Berrimah - 24
  - Cosmo Howley - 5
  - Humpty Doo - 6
  - Palmerston - 20
  - Pine Creek - 20
- Three digital and 73 static relays at highly critical Hudson Creek ZSS;

- 33 aged static relays that have exceeded their expected life at the following zone substations;
  - Austin Knuckey - 4
  - Casuarina - 8
  - Katherine - 8
  - Manton - 9
  - Yulara (non-regulated) - 4
- 13 aged digital relays that have exceeded their expected life at the following zone substations:
  - Austin Knuckey - 4
  - Katherine - 2
  - Manton - 4
  - Yulara (non-regulated) - 3

Many of these relays are to be replaced as part of zone substation and key asset replacement programs, the DKTL – secondary systems upgrade program or the protection relay replacement program. Refer to section 9 for more information.

6 Key challenges

6.1 Environmental challenges

The network covers a range of environments and geographies which present different challenges for the protection asset fleet.

Table 6.1 provides an overview of environmental challenges in relation to managing Power and Water's protection assets across its operating regions.

Table 6.1: Environmental challenges in relation to protection asset management

Region	Environment	Challenges	Expenditure / risk implications
Alice Springs	Desert	• *High temperatures contributing to the overheating of digital assets.* o *This issue has been significantly mitigated through ensuring digital assets are in AC environments*	• *Infant mortality/early life replacement due to technical failure.* • *An increased dependence on temperature control / air-conditioning at zone substation control centres.*
Darwin	Coastal/Tropical	• *High humidity possibly resulting in damage to internal components of relays.* • *High levels of rainfall during wet season can damage digital relays if there are leaks in substation control rooms.* • *High temperatures contributing to overheating of digital assets if air conditioners within substation control rooms are damaged/fail.* • *Access to substations and ability to work on assets during the wet season – heat and rain/flooding (safety issue and detrimental to assets).*	• *Increase in the frequency of functional and digital relay I/O trip testing maintenance.* • *Increased importance of maintenance to address leaks.* • *An increased dependence on temperature control / air-conditioning at zone substation control centres.* • *Upgrading/maintaining integrity of zone substation control building.* • *Public and Power and Water employee safety is reduced if*

Region	Environment	Challenges	Expenditure / risk implications
		• *Seasonal constraints; loading during build up and wet season restricts access to circuits for maintenance*	*relays fail to operate as intended.*
Katherine	Inland/Tropical	• *as above*	• *as above*
Tennant Creek	Desert	• *High temperatures contributing to overheating of digital assets.* o *This issue has been significantly mitigated through ensuring digital assets are in AC environments*	• *Infant mortality/early life replacement due to technical failure.* • *An increased dependence on temperature control / air-conditioning at zone substation control centres.*

6.2 Technical challenges

Downed/ broken conductor

An Earth Fault relay with neutral current and time delay input is used to detect high impedance ground faults on distribution feeders. However, there have been a few cases of downed conductors in the network where relays didn't detect the fault as the fault current was less than the pickup threshold or was pulsating above and below the pickup threshold and didn't time out. We are currently researching various options which can be implemented to prevent this situation.

Sympathetic inrush

The Alice Spring network has predominant sympathetic interaction between transformers during switching giving rise to neutral current flowing between stations. Sensitive Earth Fault (SEF) on the distribution feeder needs to be turned off during switching lest we comprise on the system stability as the feeder trips on SEF. We are investigating this issue in-depth and want to propose a solution which will prevent feeder trips without turning off SEF.

Network Structure

Channel island Power Station (CIPS) is the major generation source for the Darwin-Katherine system. CIPS is connected to Hudson Creek (HC) zone substation via two 132kV transmission lines. At HC the voltage is stepped down to 66kV and then distributed to various step down substations which form a meshed network. As CIPS and HC are analogous to a strong and weak source, with mutual coupling, there is a challenge on protection setting design for this transmission line.

Similarly, it is very difficult to get an outage for maintenance, setting modification or testing on these lines/substations as it might compromise system stability. Likewise, 132kV parallel transmission lines cause current reversal for a fault on a single line. This phenomenon is true for the 66kV meshed network as well. Settings need to be robust in order to prevent false tripping during this condition.

Lightning strikes

With the Northern Territory being one of the most lightning prone areas on earth, we experience a lot of faults resulting from lightning flashover and back flashover. We continually investigate the relay tripping to assess the performance of the protection system.

Remote Engineering Access

As most of the substations don't have remote engineering access to the relays, it is quite time consuming for staff to travel to these sites to download the events/oscillography following a major fault for investigation and reporting. This increases the opex for the network.

6.3 Operational challenges

When planning routine maintenance, testing, and inspections for the network, the following operational issues are taken into consideration for protection assets:

1. Personnel have inadequate skills to recalibrate electromechanical equipment.
   - Static/Electromechanical relays exhibit slower operating times as they age. As soon as calibration is outside of the tolerated operating margin they are replaced.
2. Personnel with appropriate skills are located in Darwin.
   - It is difficult for appropriately skilled field crews to access remote (rural) substations due to distance and/or monsoonal conditions. This can result in increased network risk due to prolonged response times.
3. Accessing circuits in Territory Generation (TGen) sites due to the service level agreement has been difficult.

These challenges can result in the deterioration of asset performance as measured through condition testing. There can be a reduction in network reliability and safety in the case that an operational failure of protection assets results in either an inability to efficiently isolate faults or spurious tripping of parts of the network.

In addition, the need for appropriately qualified staff (who are predominantly Darwin based) to travel to remote sites and the other networks (Alice Springs and Tennant Creek) increases the operational cost of maintaining the asset fleet.

6.4 Asset challenges

There are four primary current and emerging challenges in relation to Power and Water's protection assets.

Operational failure

Power and Water sets response timing thresholds that protection assets must meet to remain in operation. Inspection and testing is undertaken in accordance with maintenance policy (see section 13); if a relay is found to fail testing a defect report is raised to Power and Water Protection Engineers who then determine the most appropriate action to be taken on a case by case basis.

- Electromechanical and static relays demonstrate slower operating times as they age.

- Power and Water does not have the required skills to recalibrate electromechanical relays. These relays need to be replaced once they exceed their tolerances.

The operating time of digital relays can deteriorate with age. This is due to loss of electrolytic fluid from capacitors. Digital relays have other failure modes including; screen faults, faulty contact, A/D converter fault, faulty module, and communications failures. When any of these failures occur, if the relays are still within warranty, they are returned to the manufacturer for replacement/repair and otherwise they are replaced.

The assessment of the required operating speed is undertaken on a case by case basis to ensure the maximum expected life of the relay is achieved within a tolerated level of risk. The acceptable operating speed will depend on the fault levels on the feeder and type of customers being served.

Obsolescence (targeted replacement program)

Relay obsolescence occurs through either the loss of ability to service specific relay types, or the end of production and support of models by vendors. The inability to provide adequate service to older relays is an industry wide problem; there are several reasons as to why:

- Electromechanical relay assets have a 30-year asset expected lifespan.
- The skillset required to monitor, maintain and repair electromechanical relays differs greatly from digital relays.
- Older digital and static relays have a poor interface which makes repair and maintenance difficult.
- Power and Water does not retain the skills to repair relays in-house. If digital or static relays are under warranty, they are returned to the vendor otherwise they must be replaced. Due to the low volume of electromechanical relays on the network, Power and Water does not retain the skills to maintain them in house.

The end of support and production by venders has led to issues around part replacement, servicing needs, and manufacturer expertise. Specific type issues are outlined below:

- MCGG51 and MCGG22 static relays are no longer in production with no spares in store.
- RADSB static relays are no longer in production with no spares in store.
- DDR2000 disturbance recorders showing signs of random failure.
- GOULD PLC's in service on DKTL – responsible for OLTC and ARC no longer supported.
- ABB RAZOA relays- 66kV Distance Protection no longer in production with no spares in store.
- Dimat Signalling units.
- Quadramho distance relays no longer in production with no spares in store.
- GE LFCB current differential no longer in production with no spares in store.
- 2SY110 synch. check relays no longer in production with no spares in store.

Type issues (targeted replacement program)

Power and Water Protection Engineers have identified the following relay type issues;

- Electromechanical relays lose calibration over time with accelerating rates of loss as assets approach end of life.

- GE SR750 and SR760 are second generation digital relays and are starting to show signs of failures - three to four per year.
- Pilot Wire – Some 66kV differential current protection relies on Pilot Wires. Due to deteriorating condition of the pilot wires, these schemes are at risk.

Insufficient functionality (targeted replacement program)

- The existing bus tie scheme at various zone substations doesn't have OCEF protection. The bus tie protection scheme will be replaced by digital relays with OCEF functionality to align with Power and Water policy.
- Distribution management relays will be installed to implement the Under Frequency Load Shedding scheme (UFLS)

Information regarding the current protection asset fleet with respect to these asset challenges is outlined in Appendix B – Asset data.

6.5 Asset management challenges

This section discusses the key challenges associated with managing protection assets in terms of technological changes, informational requirements and business processes.

Data deficiencies

A key asset management challenge is a lack of comprehensive asset condition data. This data is required to fully understand the impact that deterioration of calibration has on the operational integrity and functionality of the assets.

Integration of relay technology into a cohesive system

The integration of older electromechanical/static relays and newer digital relays into one cohesive protection system is an on-going issue. Electromechanical/static relays have a much more limited functionality compared to digital relays and integrate into Power and Water's SCADA and protection communication system differently. Modern digital relays connect via LAN centres and Ethernet ports at zone substations. Integration into the newer digital system is important to allow for remote engineering access and event recording which is used for data capture, fault analysis and investigations of network issues.

7 Performance indicators

The performance of protection assets against the specific objectives and measures identified in section 2.3 are provided here. The performance indicators represent the historical performance of the asset class to date. It is expected that benefits from investments proposed in the next regulatory period will manifest as benefits in these key objectives. The projected investment outcomes in relation to past performance trends are provided in section 11.

7.1 Operational Performance

Table 7.1: Operational performance objectives

Description	Targets	Actual
Protection contribution to SAIDI (five-year average)	Under development	2.23
Protection contribution to SAIFI (five-year average)		0.22
Annual number of protection relay failures (five-year average)		4

7.2 Health and Safety

Table 7.2: Health and Safety performance objectives

Description	Targets	Actual	Gap
Number of safety incidents (near misses, injuries, fatalities).	0	0	0
Compliance breaches with the relevant legislation / regulation / standards.	0	0	0

8 Growth requirements

Increases to the protection relay fleet are driven by expansion of the network due to customer demand or compliance requirements. This can include new substations, additional transformers installed at existing substations or other network security requirements. The key drivers are listed below.

Protection relay growth associated with new/augmented zone substation developments

Growth in protection assets is predicated on capital expenditure associated with new/augmented zone substations. The growth in protection relays until the end of FY24, listed by ZSS augmentation or ZSS establishment is shown in Table 8.1.

Table 8.1: Relay growth associated with new/augmented zone substations

Item	FY18	FY19	FY20	FY21	FY22	FY23	FY24
Wishart new ZSS							55

Long-term (8-12 years) 2024-29 regulatory period: Qualitative articulation of the expected long-term outcomes

There is significant industry research and development occurring in protection assets which has resulted in their improvement/development. This process will continue which will likely contribute positively to system stability and reliability. We will continue to monitor developments and look at implementing them into in our system when suitable.

9 Renewal and maintenance requirements

The following sections provide an evaluation of renewal and maintenance requirements in relation to existing assets.

9.1 Protection relay replacement program

Refer to the Business Needs Identification – Protection relay replacement, NPR, for details of this program.

9.1.1 Overview

The protection relay replacement program covers the need to address normal in service failures of protection assets, end of vendor support, loss of calibration and emerging issues and failure modes in the protection relay asset fleet.

In addition to the planned replacement, Power and Water forecasts a need to replace relays that fail while in operation. This is in line with the protection asset management policy of replace at failure of non-critical relays within Power and Water's network.

9.1.2 Issues and options

Five options were considered including;

1. Do nothing – replace at failure
2. Replace at failure/loss of calibration or timing. This will reactively replace failed or poor performing relays.
3. Targeted replacement program (for type issues, obsolescence or insufficient functionality) this could be run in conjunction with an end of life replacement program
4. End of life replacement program (replace at end of expected life) - likely to result in early replacement.
5. Proactive replacement (prior to failure) - hard to predict the failure of relays. This option is likely to result in early replacement.

9.1.3 Asset management plan

The preferred option is **option 3 in conjunction with option 2** - replace at failure or as identified by testing and inspection with a targeted replacement program.

Option 2 ensures the maximum life of the asset used. A risk assessment is undertaken on a case-by-case basis to determine what constitutes unacceptable timing of operation based on the feeder and its respective load and fault levels.

Option 3 (targeted replacement program) will be established as required. This occurs when type issues are identified, relays become obsolete or no longer have vendor support without any spares in store, or if they have insufficient functionality to meet the network requirements.

It is forecasted that four relays will fail in operation per year and require replacement. Power and Water proposes to replace 42 relays during the next regulatory control period due to obsolescence.

Table 9.1: Forecast relay replacement volumes

Item	FY18	FY19	FY20	FY21	FY22	FY23	FY24	Total
Planned	0	0	9	9	9	9	8	44
Unplanned	0	0	4	4	4	4	4	20
Total	0	0	13	13	13	13	13	64

These exclude any replacements in the works included in section 9.3.

9.2 DKTL - Secondary systems upgrade of 132kV substations at Manton, Pine Creek and Katherine [PRD32117].

Refer to the Business Needs Identification – Secondary systems upgrade of 132kV substations at Manton, Pine Creek and Katherine, PRD32117, for details of this project.

9.2.1 Overview

The Darwin to Katherine 132kV Transmission Line (DKTL) runs from Channel Island Power Station to Manton, Pine Creek and Katherine zone substations. It was constructed in 1986 and predominantly contains original equipment.

While piecemeal replacement has been undertaken to date, where required, the interconnected nature of these systems means that this is becoming increasingly difficult. Modern relays interface directly with SCADA and communications systems, rather than via hard wiring. As such, the communications system must be upgraded to accommodate the new relay requirements whilst maintaining an obsolete technology for the older relays which adds complexity, risk and cost.

This situation of aging, unsupported assets on a critical line is an increasing risk to the power network.

9.2.2 Issues and options

A holistic review of the entire DKTL secondary systems is necessary to determine the most prudent and efficient method for update/replacement. There are a number of related individual issues that need to be resolved on the DKTL. The following dot points set out the preferred solutions as they relate to protection assets:

- Replace the line protection system at Manton, Pine Creek and Katherine 132kV substations
- Replace the transformer protection at Pine Creek 132kV substation

9.2.3 Asset management plan

The Darwin secondary systems upgrade program will replace outdated and failing assets with new vender supported and easy to maintain assets. This in turn will reduce the asset failure rate of the protection asset fleet and improve protection’s reliability and functionality.

Table 9.2: Forecast replacement assets and volumes

Item	FY18	FY19	FY20	FY21	FY22	FY23	FY24	Total
DKTL secondary systems upgrade			15	15				

9.3 Zone substation and key asset replacement programs with secondary relay replacement components.

Refer to the Business Needs Identification for each of the individual zone substation replacement or augmentation projects for further details.

9.3.1 Overview

Relay renewal is a key component of zone substation replacement and upgrade programs. When Power and Water replaces key assets or entire zone substations the adjoining protection relay asset fleet associated with the replacement is upgraded to ensure congruency in technology. This process also minimises system downtime.

There are several projects which will have a significant impact on the protection asset fleet;

- Berrimah ZSS replacement
- Humpty Doo ZSS
- Centre Yard ZSS

9.3.2 Issues and options

The renewal of zone substations and transformers without an upgrade to the protection systems could result in conflicting technology between assets. When a substation requires augmentation or replacement (in full or in part) the options analysis includes an assessment of the most prudent and efficient manner in which to manage the protection assets.

The most efficient approach to manage the protection assets will depend on the extent of the zone substation project, the age and type of the existing assets and the long-term strategy for the substation.

Considerable challenges faced with interfacing existing protection and control circuits with new primary plant, result in:

- Prolonged outages
- Significant risk of spurious tripping
- Cabling to be replaced due to age
- Incompatible protection with modern switchgear.

9.3.3 Asset management plan

These programs set out in Table 9.3 are to be completed in over the next regulatory control period. Approximately 62 (Berrimah, Centre Yard, Humpty Doo) relays are to be replaced.

Table 9.3: Relay replacement program are part of ZSS and key asset upgrades– Regulated networks

Item	FY18	FY19	FY20	FY21	FY22	FY23	FY24
Berrimah ZSS replacement				55			
Humpty Doo ZSS					6		
Centre Yard ZSS				1			
Cosmo Howley transformer replacement				0			

*note for Cosmo Howley transformer replacement, no relays are added in the recommissioning of the secondary systems but $0.1 million is allocated for this process in FY20.

9.4 Long-term (8-12 years) 2024-29 regulatory period: Qualitative articulation of the expected long-term outcomes.

Current projections predict the progressive replacement of all remaining electromechanical relays and the phasing out of older static relays. Power and Water will continue to monitor the protection asset fleet and will react to any type issues that emerge as we have done in the past.

At the beginning of the 2024-29 regulatory period most of the static/first generation digital relays on our transmission network will cross their expected lifespan. The performance of the relays will be tracked through regular maintenance and if signs of random failure emerge then a replacement plan for these relays will be worked out. This is also the case for first generation digital relays on our distribution network.

Power and Water will also aim to align relay replacements with other major capital works such as switchboard and transformer replacements. This will ensure technological continuity as well as minimise network downtime and minimise overall cost.

10 Investment program

The investment program is developed based on the:

- Continuation of the established lifecycle asset management approaches – discussed in Section 13
- Specific requirements related to growth in the asset class – outlined in Section 4.4
- Specific requirements related to renewal and maintenance of the asset class – outlined in Section 9.

10.1 Capital expenditure (capex)

10.1.1 Augmentation expenditure (augex)

Augmentation (growth) related investment in the protection asset class has been identified for the short and medium term as shown in Table 10.1.

Table 10.1: Augmentation expenditure forecast ($real FY18)

Program	FY18	FY19	FY20	FY21	FY22	FY23	FY24	Total
Wishart new ZSS					0.8	0.9	0.8	2.6

10.1.2 Renewal expenditure (repex)

Replacement related investment in the protection asset class has been identified for the short and medium terms as shown in Table 10.2.

Table 10.2: Replacement expenditure forecast – regulated networks ($real FY18)

Program	FY18	FY19	FY20	FY21	FY22	FY23	FY24	Total FY20-24
Protection Relay Replacement Program			0.76	0.76	0.76	0.76	0.76	3.80
DKTL secondary systems upgrade (protection)			1.20	1.40				2.60
Berrimah ZSS replacement			1.20	1.10				2.30
Humpty Doo ZSS					0.40	0.30		0.70
Centre Yard ZSS					0.20			0.20
Cosmo Howley transformer replacement			0.1					0.10
Total			**3.26**	**3.26**	**1.36**	**1.06**	**0.76**	**9.7**

10.2 Operational expenditure (opex)

The operating expenditure forecast for cables for the next regulatory period is provided in Table 10.3.

Table 10.3: Operating expenditure forecast

Asset type	Expenditure category	FY14 (H)	FY15 (H)	FY16 (H)	FY17 (H)	FY18 (H)	FY19 (F)	FY20 (F)	FY21 (F)	FY22 (F)	FY23 (F)	FY24 (F)
Protection	Routine	$0.57	$0.76	$0.94	$0.68	$0.61	$0.56	$0.52	$0.52	$0.52	$0.52	$0.52
	Non-routine	$0.10	$0.49	$0.27	$0.26	$0.28	$0.25	$0.22	$0.22	$0.22	$0.22	$0.22
	Fault and emergency	$0.03	$0.06	$0.03	$0.10	$0.05	$0.05	$0.05	$0.05	$0.05	$0.05	$0.05
Total		**$0.71**	**$1.31**	**$1.25**	**$1.04**	**$0.94**	**$0.86**	**$0.79**	**$0.79**	**$0.79**	**$0.79**	**$0.79**

11 Asset class outcomes

The performance of protection assets against the specific objectives and measures identified in section 2.3 are provided here. The performance indicators represent the forecasted performance of the asset class based on the program of works planned from FY18 through to FY24. It is expected that benefits from investments proposed in the next regulatory period will manifest as benefits in these key objectives.

11.1 Operational Performance

Table 11.1 Operational performance objectives

Description	Targets	Actual
Protection contribution to SAIDI (five-year average)	Under development	2.23
Protection contribution to SAIFI (five-year average)		0.22
Annual number of protection relay failures (five-year average)		4

11.2 Health and Safety

Table 11.2 Health and Safety performance objectives

Description	Targets	Actual	Gap
Number of safety incidents (near misses, injuries, fatalities).	0	0	0
Compliance breaches with the relevant legislation / regulation / standards.	0	0	0

12 Performance monitoring and improvement

Ongoing condition and performance monitoring is a key part of Power and Water's performance evaluation and improvement strategy. Study of the condition and performance data captured over time assists in developing valuable insights on protection defect modes and trends. These insights provide for informed decision making on whether to repair or replace assets. It assists in the continuous development of the asset management strategy for protection.

12.1 Monitoring and improvement

This Asset Management Plan will be reviewed at least every two years or when there is a significant driver from the network or other events that requires revision.

Improving data resources, undertaking data analysis and deriving insights will be undertaken as business as usual activities. Any improvements in analysis of the protection relay fleet will be included in this AMP when it is updated.

13 Appendix A – Lifecycle asset management

Power and Water make great efforts to be a customer oriented organisation that provides a safe, reliable and efficient electricity supply in the Northern Territory. This is demonstrated in the approach Power and Water take in managing its assets. The life cycle asset management approach applied by Power and Water is aimed at making prudent asset management decisions such that its assets do not cause harm to any person, have minimal environmental impact, and meet agreed service performance outcomes, consistent with current and future needs.

The approach includes:

- Maximising the utilisation of its assets throughout its life cycle
- Optimising life cycle asset management costs
- Reducing asset risks as low as reasonably practical
- Continually improving its knowledge in respect of its assets.

The following asset management activities details Power and Water's life-cycle management of its protection assets.

13.1 Planning (augmentation)

The asset planning stage defines the need for an asset to exist. It also establishes the functional requirements of the assets and ultimately the number of assets, design, function, criticality, configuration, level of redundancy, capability and capacity.

Key criteria to ensure optimal line route selection, establishing prudent, cost efficient, intrinsically safe, and sustainable corridors for the life cycle management of the protection assets include consideration of:

- Optimised utilisation of existing protection relays
- Schedule and cost impacts from existing adjacent infrastructure
- Transport and logistics
- Project cost implications
- Safety and reliability risks
- Environmental and approvals risk
- Stakeholder and community requirements
- Design and execution requirements
- Operation and maintenance requirements.

13.2 Design

The design phase is where decisions around the physical characteristics and functioning of the asset are made. This life cycle stage defines the quality and reliability of the asset, and the whole of life cycle costs that can be realised. It influences the total cost and the level of service that the assets can deliver to customers and shareholders.

The standardisation of protection asset designs considers whole of life cycle management in a prudent and efficient manner. Standardisation is defined as the process of developing and agreeing on uniform technical design criteria, specifications and processes and is a key aspect of Power and Water's asset management process.

Along with continuity, leverage and scalability, standardisation enables consistent application of best industry practise and continuous performance improvement. It establishes technical commonality that allows for an off-the-shelf, best practice, and fit-for-purpose approach to engineering solutions. It also allows for interchangeability that provides operations and asset management benefits. Power and Water's protection asset design standardisation includes the following processes:

- Standardisation of construction equipment and processes
- Periodic review of existing settings/schemes when system topography/fault level changes
- Extensive peer review verifying that the relay settings meet the specifications of the relay and control application
- Extensive fault studies by using robust calculation/system analysis tools and templates to reduce errors
- Use of standard templates for setting standard schemes using complex relays
- Review of relay commissioning/maintenance test sheets/plan and results
- Cater for future maintenance; increased efficiency and reduced risk of spurious tripping
- Data capture for fault analysis and investigation
- Greater isolation of pilot cabling and protection schemes
- Functional isolation points for future maintenance
- Design to reduce requirement for circuit disturbance
- Increased circuit supervision
- Greater segregation of duplicated protection schemes; cabling allocation, cable routing, appropriate relay setting based on relay operation.

Power and Water's protection asset design standardisation offers the following benefits to the business:

- Helps with the ranking and prioritisation of investment projects
- Gives confidence in the safe and reliable functioning of the assets
- Provides assurance that the assets will do the job they were intended for
- Boosts production and productivity
- Encourages higher quality of engineering leveraging specialist knowledge and optimum solutions
- Allows for the uniform execution of projects
- Greater safety for personnel undertaking future maintenance
- Provides functionality for other maintenance activities e.g. CB Testing/maintenance

13.3 Operation

Primary relays, if functioning correctly, will isolate the fault to the immediate area of the network. However, if primary protection fails secondary protection located locally or at the remote end will activate. Operation of backup protection will result in a wider spread outage with more customers off supply.

Protection relays have following primary functions:

- Public safety and the safety of Power and Water employees
- Protection of assets
- Continued operation of the network
- Reduce the power outage range.

Maintenance (opex)

Inspection and testing is undertaken in accordance with the maintenance policy which sets out the type and frequency of inspection and testing to be undertaken. The testing schedule is modified to align with major asset inspections or works.

If a relay is found to fail testing a report is raised to the Protection Engineers to determine the most appropriate action to be taken on a case-by-case basis.

If a relay is found to have failed, it is replaced immediately by the field crew. Most failures have been found to occur on distribution feeder relays, as the technical code requires other assets to incorporate back-up (N-1) protection schemes.

Risk assessment of protection assets is undertaken on a case by case basis to determine what constitutes an acceptable level of calibration and operational timing. Older assets deteriorate at an accelerated pace which poses increased levels of risk on the network.

Evidence based condition testing by maintenance in the form of:

- Relay secondary injection testing and digital relay I/O testing
- Digital relay self-diagnostics
- Monitoring of digital relays through the central control centre.

This process enables Power and Water to rank the criticality of asset renewal and maintenance plans to ensure that resources are allocated efficiently.

13.3.1 Condition assessment

The deterioration will be evidenced through condition assessments carried out by maintenance engineers/ technical specialists; such as operating time analysis conducted through functional and I/O trip tests.

On-site relay testing

There are several external/observable metrics that are considered when assessing the overall condition of protection relays. This data is primarily collected as part of the following tests:

Secondary injection testing:

- Confirms accuracy of analogue digital converter
- Correct operation of CPU in terms of configured logic
- Operating time of output contacts

I/O trip testing for digital relays:

- Conformance of non-supervised components

- Conformance of functionality of entire circuit

The planned operational maintenance measures are outlined in section 13.3.2.

However, when considering options to mitigate network risk, the overall condition, and therefore maintenance requirements, are an important input to assessing the most prudent and efficient solution.

The combined condition assessment is considered when prioritising and assessing risk mitigation on the network.

13.3.2 Inspection and maintenance

Table 13.1 outlines the frequency of Power and Water's inspection and maintenance for various relay asset types.

Table 13.1: Maintenance frequency by relay type and protection asset

Circuit	Relay type	Maintenance frequency (years) Functional checks	I/O Trip Checks
132kV Line/Bus/Transformer	Digital	6	2
	Static	2	
	Electromechanical	2	
66kV Line /Bus/Transformer	Digital	6	2
	Static	2	
	Electromechanical	2	
66kV Distance VF teleprotection	Teleprotection	6	2
22kV/11kV Line/Bus/Transformer	Digital	6	3
	Static	3	
	Electromechanical	3	
22kV and 11kV Express Feeders with pilot wire differential	Static	3	
Under-frequency	Digital or static	6	2

13.4 Renewal (repex)

Asset renewal is the establishment of a new asset in response to an existing asset's condition. The need for the renewal of existing assets is identified in the asset maintenance stage and verified in the asset planning stage. Asset renewal aims to optimise the utilisation of an asset whilst managing the safety and reliability risk associated with the failure of the asset.

If a protection relay is replaced as part of a zone substation renewal and has not reached the end of its expected life, and if the asset is still operating efficiently, then the asset should be kept as a spare. Spares should be used for modular replacements, quick like-for-like replacement (when required), or when vender support for the asset has ceased; this is assuming Power and Water has the personnel with the required skills to repair to as-good-as new replacement level.

Power and Water has asset replacement programmes in place to renew assets of poor condition prior to the asset failing, whilst keeping within a tolerated level of assessed risk.

13.5 Disposal

The decision to reuse or dispose of an asset is made with consideration of the potential to:

- Reuse the asset
- Utilise the asset as an emergency spare
- Salvage asset components as strategic spare parts.

The remaining asset is disposed of in an environmentally responsible manner.

14 Appendix B – Asset data

14.1 Protection assets age by circuit voltage

Table 14.1 Digital protection assets by circuit voltages (years)

Circuit voltage	0-5	5-10	10-15	15-20	20-25	25-30	30-35	Total
11	233	43	5	19	15	3	26	**344**
22	99	25	3		4	3	4	**138**
66	231	77	7	3	5	1	1	**325**
132	29	11	7		6	5	2	**60**
Total	**592**	**156**	**22**	**22**	**30**	**12**	**33**	**867**

Table 14.2: Static protection assets by circuit voltages (years)

Circuit voltage	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-50	Total
11	44	23	8	6	17	19	51	9	2	**179**
22	3	1			26	12	4			**46**
66		1	7	1	16	8	98	19		**150**
132		11	1		10	56	14			**92**
Total	**47**	**36**	**16**	**7**	**69**	**95**	**167**	**28**	**2**	**467**

Table 14.3: Electromechanical protection assets by circuit voltages (years)

Circuit voltage	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-50	Total
11						1	1	5		**7**
22										
66							2	2		**4**
132										
Total						**1**	**3**	**7**		**11**

Table 14.4: All protection assets by circuit voltages (years)

Circuit voltage	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-50	Total
11	277	66	13	25	32	23	78	14	2	**530**
22	102	26	3		30	15	8			**184**
66	231	78	14	4	21	9	101	21		**479**
132	29	22	8		16	61	16			**152**
Total	**639**	**192**	**38**	**29**	**99**	**108**	**203**	**35**	**2**	**1345**

14.2 Region and asset class protection

The following tables display the protection asset fleet by region with respect to asset class protection and asset technology.

Table 14.5: All regions asset technology and asset class protection

Alice Springs	Digital	Static	Electromechanical	Total
DDR	35			**35**
Distribution	414	150	7	**571**
HV Bus Differential	61	19		**80**
HV Bus Tie	32	22		**54**
LV Bus Differential		32		**32**
MV Bus		19		**19**
Transformer	128	127	4	**259**
Transmission	197	98		**295**
Total	**867**	**467**	**11**	**1345**

Table 14.6: Darwin and Katherine asset technology and asset class protection

Darwin & Katherine	Digital	Static	Electromechanical	Total
DDR	26			**26**
Distribution	345	96	5	**446**
HV Bus Differential	49	19		**68**
HV Bus Tie	28	22		**50**
LV Bus Differential		27		**27**
MV Bus		16		**16**
Transformer	103	121	4	**228**
Transmission	181	97		**278**
Total	**732**	**398**	**9**	**1139**

Table 14.7: Alice Springs asset technology and asset class protection

Darwin & Katherine	Digital	Static	Electromechanical	Total
DDR	8			**8**
Distribution	60	54	2	**116**
HV Bus Differential	12			**12**
HV Bus Tie	4			**4**
LV Bus Differential		3		**3**
MV Bus		3		**3**
Transformer	23	6		**29**
Transmission	16	1		**17**
Total	**123**	**67**	**2**	**192**

Table 14.8: Tennant Creek asset technology and asset class protection

Tennant Creek	Digital	Static	Electromechanical	Total
DDR	1			**1**
Distribution	9			**9**
LV Bus Differential		2		**2**
Transformer	2			**2**
Totals	**12**	**2**		**14**

14.3 Manufacturer

Table 14.9: Manufacturer breakdown of relay asset fleet

Manufacturer	Number of relays
GE	419
GEC	223
Alstom	139
ABB	135
SEL	122
RMS	110
Areva	67
Dewar	41

Manufacturer	Number of relays
ERLPhase	35
Siemens	23
MR	22
REYROLLE	5
AML	4
Total	**1345**

Figure 14.1: Manufacturer of relays - entire protection asset fleet (number of relay installations)

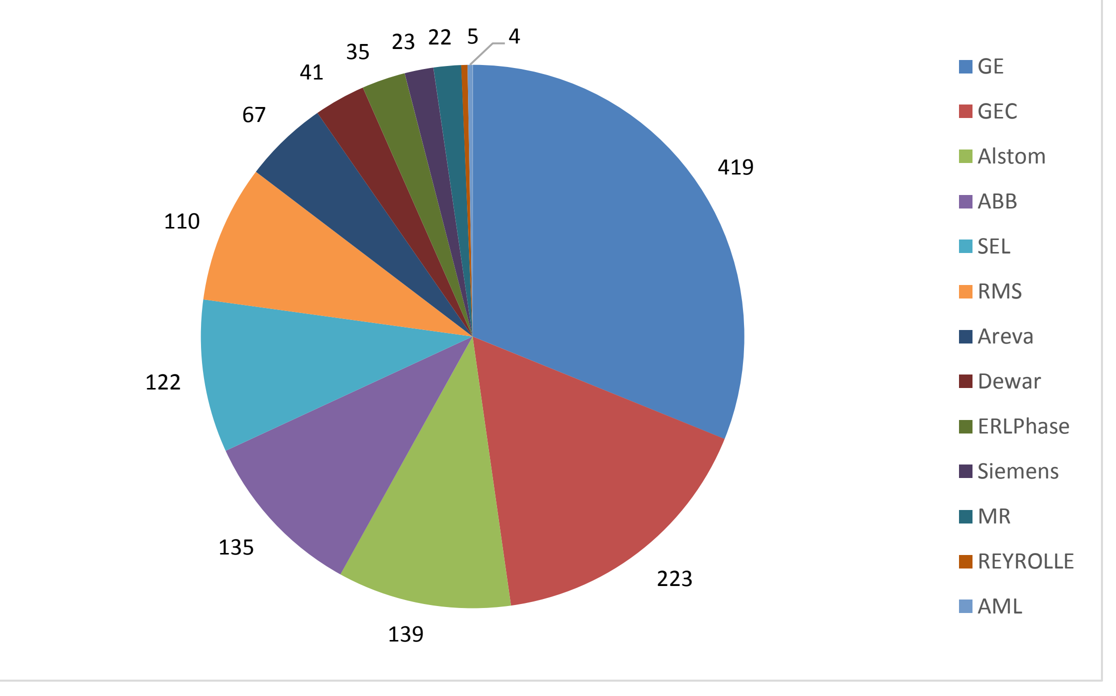


Figure 14.2: Manufacturer of relays 2010-2017 (number of relay installations)

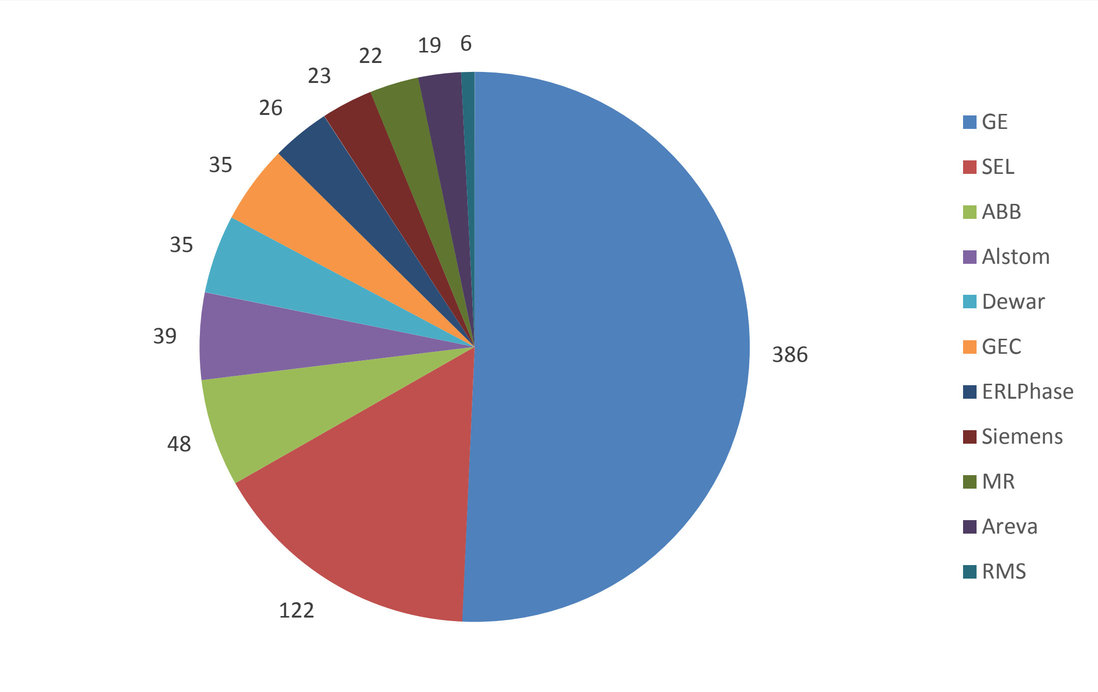
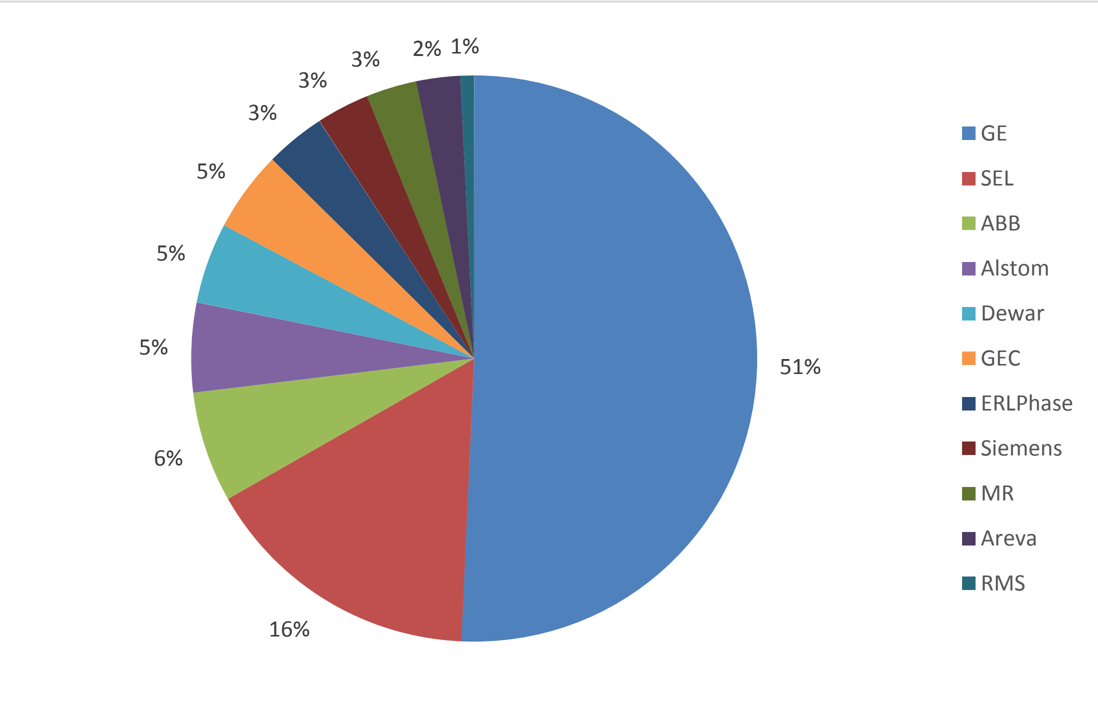


Figure 14.3: Manufacturer of relays 2010-2017 (percentage)



14.4 Zone substation, relay technology and age.

The following tables display the respective age and technology of relay assets per zone substation.

Table 14.10: Archer protection asset technology and age (years)

Archer	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-50	Total
Digital	56	0	0	0	0	0	0	0	0	**56**
Static	2	0	0	0	0	0	0	0	0	**2**
Total	**58**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**58**

Table 14.11: Austin Knuckey protection asset technology and age (years)

Austin Knuckey	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-50	Total
Digital	1	0	1	0	3	0	1	0	0	6
Static	2	0	2	0	0	0	4	0	0	8
Total	3	0	3	0	3	0	5	0	0	14

Table 14.12: Batchelor protection asset technology and age (years)

Batchelor	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-50	Total
Digital	0	11	0	0	0	0	0	0	0	11
Static	0	8	0	0	0	0	0	0	0	8
Total	**0**	**19**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**19**

Table 14.13: Berrimah protection asset technology and age (years)

Berrimah	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-50	Total
Digital	11	1	5	15	1	0	0	0	0	33
Static	0	1	8	1	0	8	30	0	0	48
Total	**11**	**2**	**13**	**16**	**1**	**8**	**30**	**0**	**0**	**81**

Table 14.14: Casuarina protection asset technology and age (years)

Casuarina	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-50	Total
Digital	17	24	0	0	0	0	0	0	0	41
Static	1	4	0	0	0	0	0	8	0	13
Total	**18**	**28**	**0**	**0**	**0**	**0**	**0**	**8**	**0**	**54**

Table 14.15: Centre Yard protection asset technology and age (years)

Centre Yard	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-50	Total
Digital				**1**						**1**
Total				**1**						**1**

Table 14.16: Channel Island protection asset technology and age (years)

Channel Island	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-50	Total
Digital	10	9	0	0	0	0	0	0	0	19
Static	0	4	0	0	0	38	0	0	0	42
Total	**10**	**13**	**0**	**0**	**0**	**38**	**0**	**0**	**0**	**61**

Table 14.17: Cosmo Howley protection asset technology and age (years)

Cosmo Howley	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-50	Total
Digital	0	0	0	0	0	1	0	0	0	1
Static	0	0	0	0	0	4	0	0	0	4
Total	**0**	**0**	**0**	**0**	**0**	**5**	**0**	**0**	**0**	**5**

Table 14.18: Darwin protection asset technology and age (years)

Darwin	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-50	Total
Digital	78	0	0	0	0	0	0	0	0	78
Static	3	0	0	0	0	0	0	0	0	3
Total	**81**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**81**

Table 14.19: Frances Bay protection asset technology and age (years)

Frances Bay	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-50	Total
Digital	41	13	0	0	0	0	0	0	0	54
Static	7	10	0	0	0	0	0	0	0	17
Total	**48**	**23**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**71**

Table 14.20: Hudson Creek protection asset technology and age (years)

Hudson Creek	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-50	Total
Digital	28	3	2	0	0	0	3	0	0	36
Static	0	0	0	0	0	8	65	0	0	73
Total	**28**	**3**	**2**	**0**	**0**	**8**	**68**	**0**	**0**	**109**

Table 14.21: Humpty Doo protection asset technology and age (years)

Humpty Doo	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-50	Total
Digital	0	0	0	0	0	0	2	0	0	2
Static	0	0	0	0	0	0	8	0	0	8
Electromechanical	0	0	0	0	0	0	2	0	0	2
Total	**0**	**0**	**0**	**0**	**0**	**0**	**12**	**0**	**0**	**12**

Table 14.22: Jabiru protection asset technology and age (years) – non-regulated

Jabiru	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-50	Total
Digital	1	0	0	0	0	0	0	0	0	1
Electromechanical	0	0	0	0	0	0	0	5	0	5
Static	2	2	0	0	0	0	0	12	0	16
Total	3	2	0	0	0	0	0	17	0	22

Table 14.23: Katherine protection asset technology and age (years)

Katherine	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-50	Total
Digital	36	0	1	0	0	1	1	0	0	39
Static	36	0	2	0	0	9	1	0	0	48
Electromechanical	0	0	1	0	0	8	0	0	0	9
Total	36	0	1	0	0	1	1	0	0	39

Table 14.24: Leanyer protection asset technology and age (years)

Leanyer	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-50	Total
Digital	46	0	0	0	0	0	0	0	0	46
Static	2	0	0	0	0	0	0	0	0	2
Total	**48**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**48**

Table 14.25: Lovegrove protection asset technology and age (years)

Lovegrove	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-50	Total
Digital	13	36	0	0	1	1	14	0	0	65
Static	0	7	3	0	12	3	5	0	0	30
Total	**13**	**43**	**3**	**0**	**13**	**4**	**19**	**0**	**0**	**95**

Table 14.26: Manton protection asset technology and age (years)

Manton	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-50	Total
Digital	13	0	4	0	0	4	0	0	0	21
Static	1	0	0	0	0	9	0	0	0	10
Total	**14**	**0**	**4**	**0**	**0**	**13**	**0**	**0**	**0**	**31**

Table 14.27: Marrakai protection asset technology and age (years)

Marrakai	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-50	Total
Digital	3	0	0	0	0	0	0	0	0	3
Total	**3**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**3**

Table 14.28: Mary River protection asset technology and age (years)

Mary River	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-50	Total
Digital	3									3
Total	**3**									**3**

Table 14.29: Mitchell Street SS protection asset technology and age (years)

Mitchell Street SS	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-50	Total
Digital	1	0	0	0	0	0	6	0	0	7
Static	4	0	0	0	0	0	14	0	0	18
Total	**5**	**0**	**0**	**0**	**0**	**0**	**20**	**0**	**0**	**25**

Table 14.30: Mott Street protection asset technology and age (years)

Mott Street	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-50	Total
Digital	12	0	0	0	0	0	0	0	0	12
Static	6	0	0	0	0	0	0	0	0	6
Total	**18**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**18**

Table 14.31: Owen Springs protection asset technology and age (years)

Owen Springs	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-50	Total
Digital	0	26	0	0	0	0	0	0	0	26
Total	**0**	**26**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**26**

Table 14.32: Palmerston protection asset technology and age (years)

Palmerston	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-50	Total
Digital	27	3	3	0	4	0	1	0	0	38
Static	1	0	0	0	0	0	36	0	0	37
Total	**28**	**3**	**3**	**0**	**4**	**0**	**37**	**0**	**0**	**75**

Table 14.33: Pine Creek protection asset technology and age (years)

Pine Creek	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-50	Total
Digital	0	0	2	0	12	0	1	0	0	15
Static	0	0	0	0	35	0	0	0	0	35
Total	**0**	**0**	**2**	**0**	**47**	**0**	**1**	**0**	**0**	**50**

Table 14.34: Ranger protection asset technology and age (years) – non-regulated

Ranger	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-50	Total
Static	0	0	0	0	0	0	0	8	0	8
Electromechanical	0	0	0	0	0	0	0	2	0	2
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**10**	**0**	**10**

Table 14.35: Ron Goodin protection asset technology and age (years)

Ron Goodin	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-50	Total
Digital	12	4	0	6	4	0	2	0	0	28
Static	0	0	0	6	20	6	1	0	0	33
Electromechanical	0	0	0	0	0	0	1	0	0	1
Total	**12**	**4**	**0**	**12**	**24**	**6**	**4**	**0**	**0**	**62**

Table 14.36: Sadadeen protection asset technology and age (years)

Sadadeen	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-50	Total
Digital							1			1
Total							**1**			**1**

Table 14.37: Strangways protection asset technology and age (years)

Strangways	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-50	Total
Digital	53	0	0	0	0	0	0	0	0	53
Static	2	0	0	0	0	0	0	0	0	2
Total	**55**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**55**

Table 14.38: Tennant Creek protection asset technology and age (years)

Tennant Creek	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-50	Total
Digital	12	0	0	0	0	0	0	0	0	12
Static	2	0	0	0	0	0	0	0	0	2
Total	**14**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**14**

Table 14.39: Tindal protection asset technology and age (years)

Tindal	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-50	Total
Digital	1	1	4	0	1	3	0	0	0	10
Static	0	0	0	0	2	7	2	0	0	11
Total	**1**	**1**	**4**	**0**	**3**	**10**	**2**	**0**	**0**	**21**

Table 14.40: Weddell protection asset technology and age (years)

Weddell	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-50	Total
Digital	8	25	0	0	0	0	0	0	0	33
Total	**8**	**25**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**33**

Table 14.41: West Bennett SS protection asset technology and age (years)

West Bennett SS	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-50	Total
Digital	2	0	0	0	4	0	0	0	0	6
Static	2	0	2	0	0	0	2	0	2	8
Total	**4**	**0**	**2**	**0**	**4**	**0**	**2**	**0**	**2**	**14**

Table 14.42: Wishart protection asset technology and age (years)

Wishart	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-50	Total
Digital	3	0	0	0	0	0	0	0	0	3
Static	1	0	0	0	0	0	0	0	0	1
Total	**4**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**4**

Table 14.43: Woods Street protection asset technology and age (years)

Woods Street	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-50	Total
Digital	14	0	0	0	0	0	0	0	0	14
Static	6	0	0	0	0	0	0	0	0	6
Total	**20**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**20**

Table 14.44: Woolner protection asset technology and age (years)

Woolner	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-50	Total
Digital	90	0	0	0	0	0	0	0	0	90
Static	3	0	0	0	0	0	0	0	0	3
Total	**93**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**93**

Table 14.45: Yulara protection asset technology and age (years) – non-regulated

Yulara	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-50	Total
Digital	0	0	0	0	0	2	1	0	0	3
Static	0	0	0	0	0	4	0	0	0	4
Electromechanical	0	0	0	0	0	1	0	0	0	1
Total	**0**	**0**	**0**	**0**	**0**	**7**	**1**	**0**	**0**	**8**

14.5 Protection asset type failure & replacement

Figure 14.4: Protection replacement due to asset failure (including asset type failure - SPAJ, DDR2000, DDR3000)

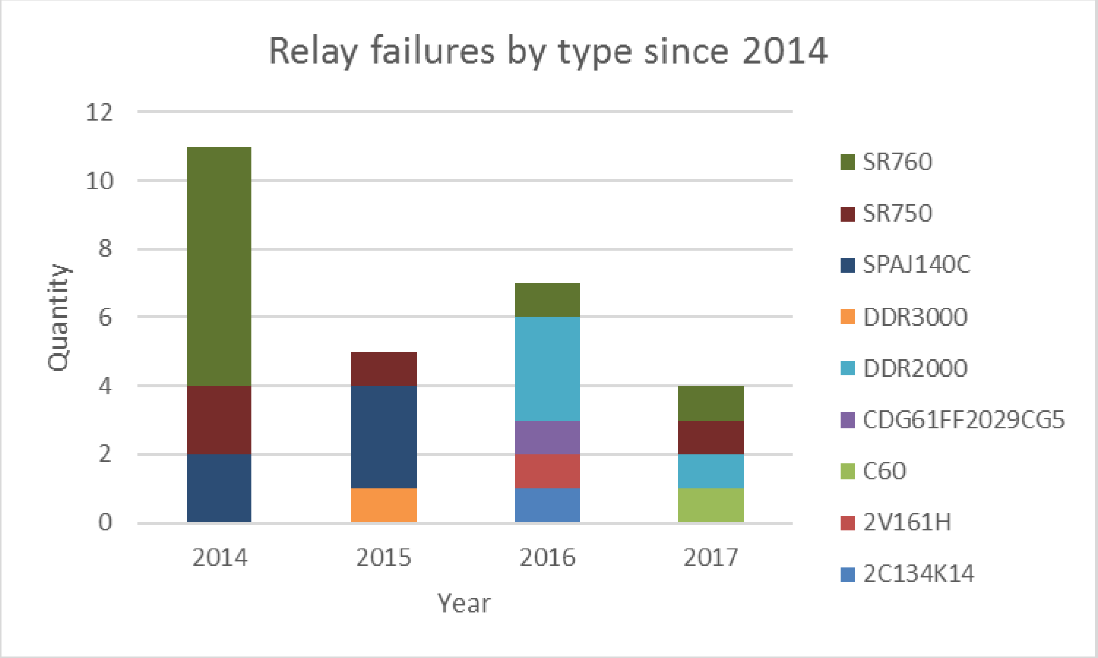


Figure 14.5: Protection replacement due to asset failure (excluding asset type failure)