Automation Systems Renewal and Maintenance Strategy

Summary

This strategy guides the management of TransGrid's existing Automation Systems assets.

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Business function:	Strategic Asset Management			**Document type:**	Strategy
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Contents

1. Purpose

This document defines the renewal and maintenance strategies for TransGrid's Automation Systems fleet. In doing this it applies the overarching asset management strategy and objectives, and relevant Lifecycle Strategies.

The document identifies the emerging issues with TransGrid's Automation Systems assets, and details the renewal and maintenance initiatives to be implemented in response to these issues. The output of the strategy is the asset management program of works, which is derived via distinct paths as follows:

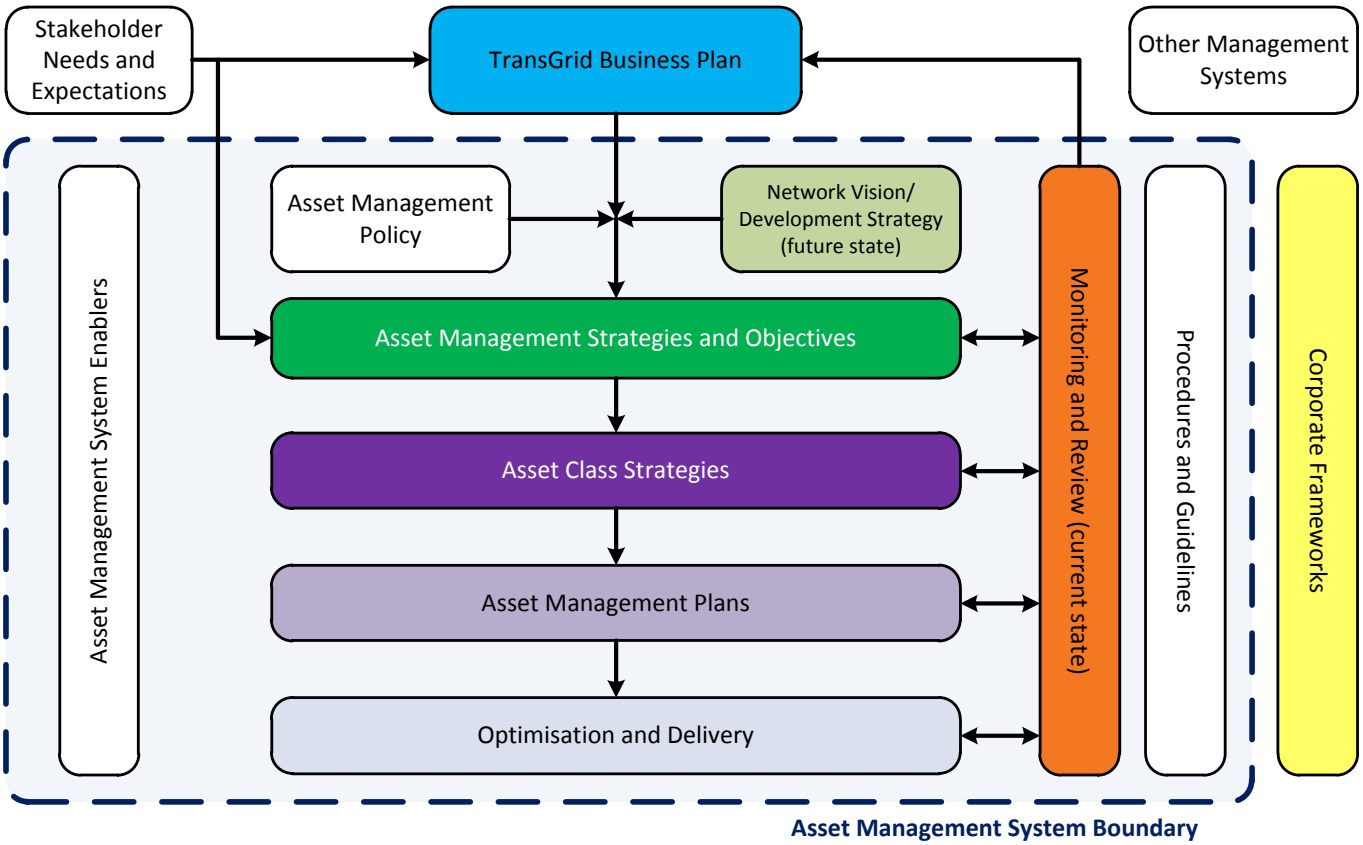
- The renewal and disposal initiatives are considered through the prescribed capital investment process and managed through the Portfolio Management group, which then which then leads to the resource-optimised capital works program.
- The maintenance initiatives directly drive the maintenance regimes which are detailed within the Automation Systems Maintenance Plan. The maintenance plans are then resource-optimised through TransGrid's Enterprise Resource Planning (ERP) system, *Ellipse.*

The strategies contained in this document cover the period to June 2023.

2. Positioning within the Asset Management Framework

The *Automation Systems Renewal and Maintenance Strategy* document is one of several that comprise the Asset Management Strategies within TransGrid's Asset Management System. This document sits below the Asset Management Strategy and Objectives document as shown in Figure 1.

Figure 1: Asset Management System Document Hierarchy



3. Definitions

Table 1: Definitions

Term	Definition
Asset Management Objectives	• Specific and measurable outcomes required of the assets in order to achieve the Corporate Plan and objectives; and/or • Specific and measurable level of performance required of the assets; and/or • Specific and measurable level of the health or condition required of the assets; and/or • Specific and measurable outcomes or achievement required of the asset management system.
Key Hazardous Events	They events of most concern associated with the assets that prevent the achievement of the corporate and asset management objectives.
Emerging Issues	Newly identified issues with an asset that pose a risk to the achievement of the corporate and asset management objectives.
Automation Systems	Systems utilised for the operation of an unmanned transmission network station
Protection	Systems utilised for the detection and rapid interruption of faults in the network to protect primary assets and the stability of the Electricity Market
Control	Systems utilised for the remote monitoring and control of an unmanned transmission network station

4. Asset Management Strategy 'Line of Sight'

The renewal and maintenance strategic initiatives set out in this document support the achievement of the strategies set out in the Asset Management Strategy and Objectives document. The strategic alignment of the initiatives in this document to the Asset Management Strategy and Objectives document is shown in the tables below. <Remove those entries that are not applicable to the asset class>

Table 2: Secondary System Asset Outcomes

Asset Management Objectives	Asset Management Performance Indicators
• Manage network related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Manage network related bushfire risks (people safety) to ALARP/SFAIRP	1. Zero asset related LTIs (contribution of secondary systems to explosive failure) 2. Zero asset related fire starts (contribution of secondary systems to fire starts) 3. Maintain 5 year average level of Key Hazardous Events (catastrophic failure, conductor drop, structure failure, uncontrolled discharge/contact with electricity, and unauthorised entry)
• Maintain network reliability	4. Maintain 5 year average level of loss of supply events due to asset faults 5. Maintain system reliability (achieve 99.9997%) 6. Maintain average age of asset class population to a sustainable level

Table 3: Secondary System Asset Contribution to Financial Outcomes

Asset Management Objectives	Asset Management Performance Indicators
• Improve CAPEX Performance	7. Improve Capital project performance
• Improve OPEX Performance	8. Perform within 1% of Asset Management Program of Works relevant to secondary system assets
• Pursue STPIS revenue where cost effective	9. Secondary System fault and forced outage rates (contributes to STPIS for these measures)

5. Review of Previous Renewal, Disposal and Maintenance Strategies

This section discusses the progress of the previous renewal and maintenance initiatives, and their effectiveness at meeting the asset management objectives.

5.1 Review of Renewal and Maintenance Initiatives

The tables below outline the ongoing renewal and maintenance initiatives from the previous iteration of this strategy.

Table 4 - Renewal Initiatives Historical Expenditure ($m)

Asset Type	Expenditure Type	2013/14[1]	2014/15	2015/16
Protection Relays	Forecast	6.15	4.03	6.07
	Actual	Unavailable	5.94	5.08
VF Intertrips	Forecast	0.214	0.00	0.210
	Actual	Unavailable	0.00	0.09
Analysis Equipment	Forecast	0.380	0.218	0.105
	Actual	Unavailable	0.0	0.0
Control Systems	Forecast	4.26	3.93	2.48
	Actual	Unavailable	1.96	2.43
DC Supplies	Forecast	0.411	0.781	0.370
	Actual	Unavailable	0.750	0.330

Renewal initiatives have had a significant effect on the population of Protection Relays within the network. In all cases excepting Busbar protection schemes, modern designs utilise a single IED capable of performing multiple functions resulting in a reduction in the total number of assets that need to be managed. Traditionally electromechanical and discrete components systems rely on dedicated assets (on average 3-4 per scheme).

Changes to age profiles have been summarised below in respect to the RIN categories as historical age profile data has not traditionally been maintained for individual assets. Average age profiles are summarised in the tables below:

Table 5 Renewal Initiatives Age Profile Effects (Average Age Years)

Asset Type	2013/14	2014/15	2015/16
Protection Relays	20.2	20.5	17.6
VF Intertrips	Unavailable at this time		
Analysis Equipment	Unavailable at this time		
Control Systems	6.25	7.30	7.47
DC Supplies	Unavailable at this time		

[1] Actual expenditure for FY 2013/14 is unavailable due to changes in recording and reporting processes. While the information can be extracted, it is labour intensive.

The historical expenditure in renewal initiatives has resulted in improved maintenance capabilities of assets as new assets are provided with current manufacturer support and the availability of parts for repair and refurbishment. Modern assets have additionally provided the capability for remote monitoring and diagnostics resulting in reductions in maintenance requirements.

Due to the nature of Automation Systems assets, the criticality is generally driven by the primary assets which they serve and as such no changes in the asset base can effectively change the criticality of the assets. However, as age profile, health, and condition of assets improves, the result is a lower risk profile for the network which translates to improvements in the reliability and security of the network.

Table 6: Previous Renewal and Maintenance Initiatives

Asset	Asset Management Objective	Strategic Initiative	Current Issues	Progress (completion and expenditure)	Reference Documents
• Electromechanical, discrete component and microprocessor protection relays identified for replacement	• Maintain Network Reliability • Manage network related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Manage network related bushfire risks (people safety) to ALARP/SFAIRP •	• Replace obsolete assets with limited self-checking capability to reduce the likelihood of consequence for reliability risks. • Replace assets where TransGrid's ability to repair and maintain is either compromised or limited in order to reduce the consequence of failure.	• Historically, replacements have occurred based on factors other than risk, leading to an imbalance in the risk profile of remaining assets. • Replacing assets in isolation limits the benefits that can be extracted from modern designs due to a lack of available infrastructure	Current asset replacement initiatives will be completed by June 2018.	PAD-00000623 PAD-00000620 PAD-00000621 PAD-00000628 PAD-00000637 PAD-00000605 PAD-00000606 PAD-00000638 PAD-00000633 PAD-00000609 PAD-00000604 PAD-00000615 PAD-00000607 PAD-00000608 PAD-00000601 PAD-00000635 PAD-00001091
• VF Intertrips	• Maintain Network Reliability	• Replace assets where TransGrid's ability to repair and maintain is either compromised or limited in order to reduce the consequence of failure.	•	Current asset replacement initiatives will be completed by June 2018.	PAD-00000635

• Control Systems Remote Terminal Units (RTUs)	• Maintain Network Reliability • Manage network related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) •	• Replace assets where TransGrid's ability to repair and maintain is either compromised or limited in order to reduce the consequence of failure.	• Historically, replacements have occurred based on factors other than risk, leading to an imbalance in the risk profile of remaining assets. • Replacing assets in isolation limits the benefits that can be extracted from modern designs due to a lack of available infrastructure	Current asset replacement initiatives will be completed by June 2018.	PAD-00000629
• DC Supplies	• Maintain Network Reliability • Manage network related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP)	• Replace assets that have reached end of life and cannot meet their performance requirements of continual supply of a DC load	• Historically, replacements have occurred based on factors other than risk, primarily on age. •	Current asset replacement initiatives will be completed by June 2018.	PAD-DCN515 PAD-DCN519

5.2 Review of Maintenance Program

The table below highlights the 205/16 financial year's expenditure on maintenance initiatives for automation systems:

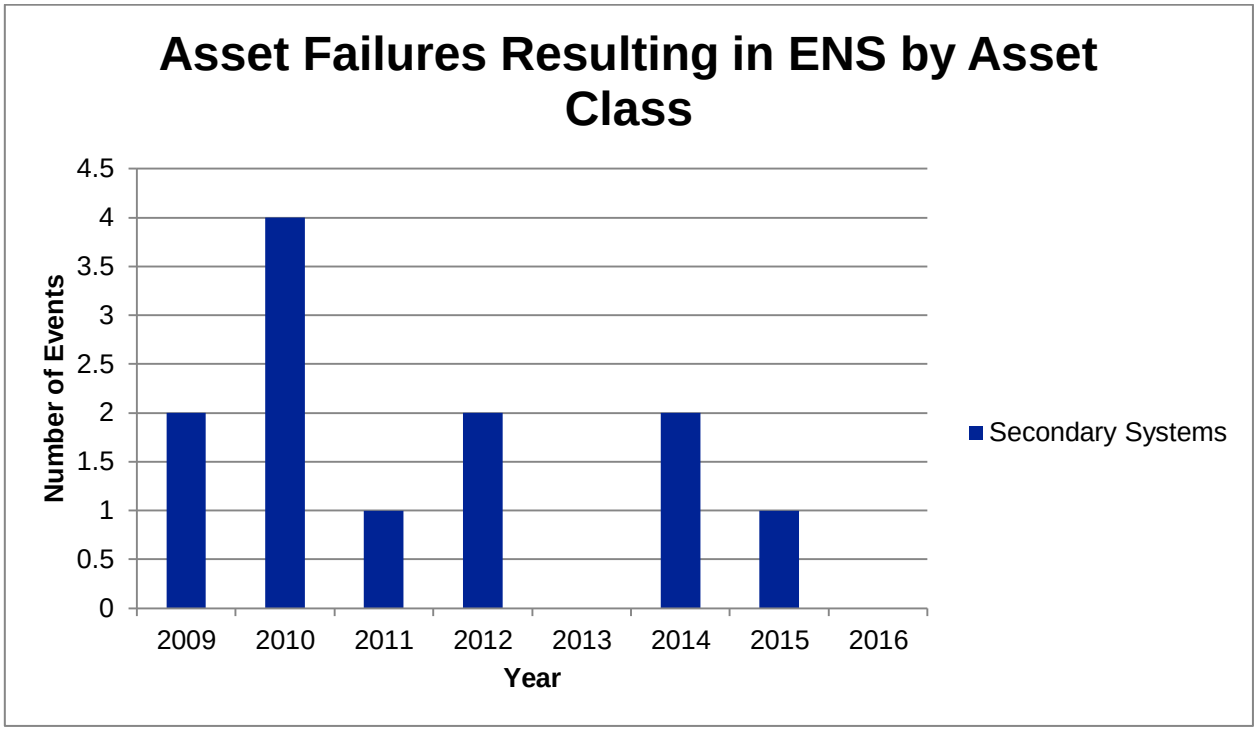
Table 7 2015/16 Maintenance Initiatives ($k)

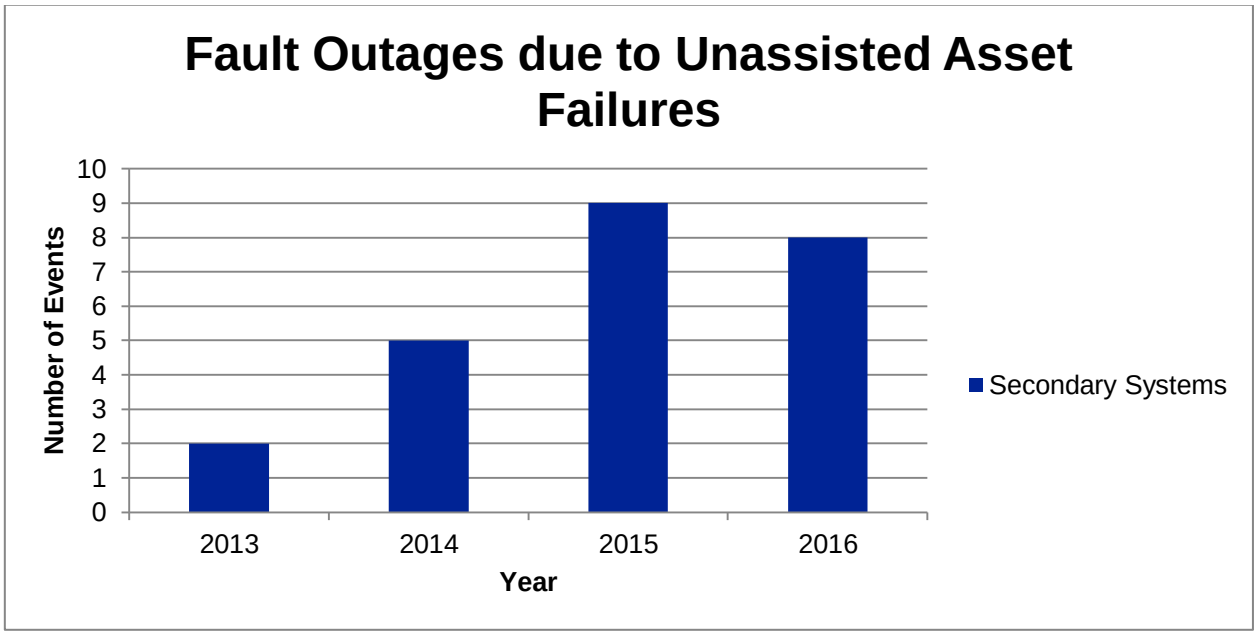
Asset Type	Expenditure Type	Preventative	Corrective	Condition
Protection Relays	Forecast	765	1.42	246
	Actual	611	379	177
VF Intertrips	Forecast	16.8	0.00	0.00
	Actual	11.5	10.4	0.00
Analysis Equipment	Forecast	17.1	16.4	0.00
	Actual	26.7	8.98	0.00
Control Systems	Forecast	8.59	0.00	0.00
	Actual	3.11	119	2.55
DC Supplies	Forecast	248	41.0	0.00
	Actual	245	124	0.00

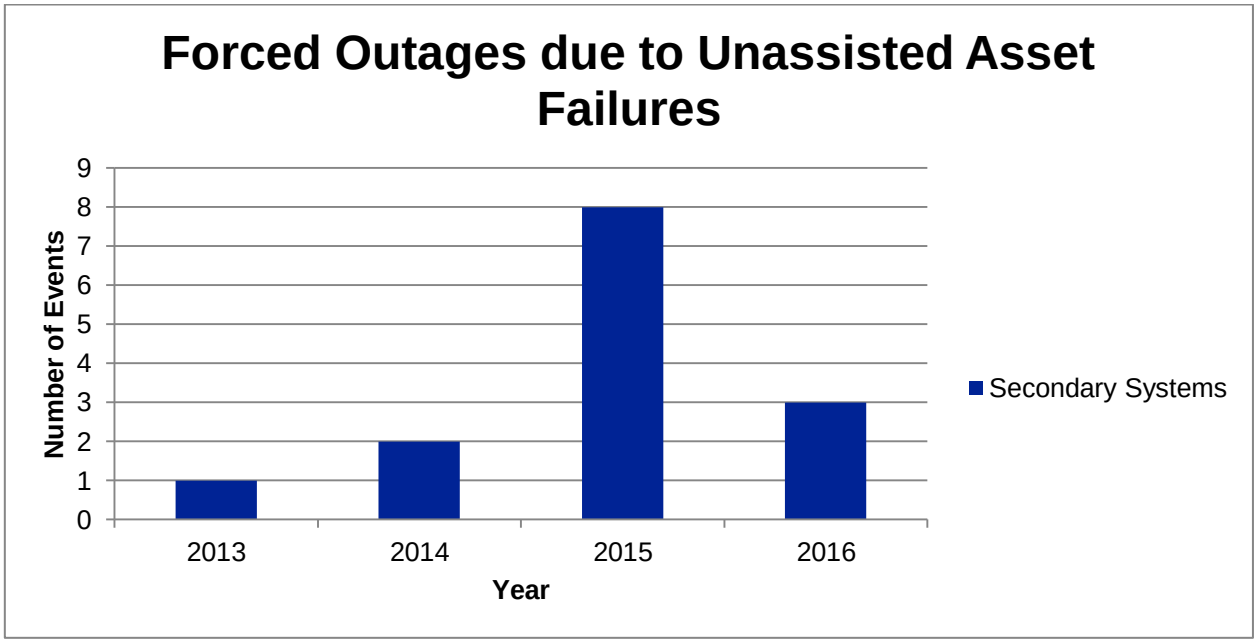
The historical expenditure in maintenance initiatives has resulted in a lower risk profile for the network which translates to improvements in the reliability and security of the network. This has come about mainly due to increasing confidence in the health and condition statistics of the various assets and the identification and replacement of failed asset before any associated consequence is realised.

5.3 Past Performance – Asset Management Performance Indicators

Asset Management Performance Indicator	Past Performance
1. Zero asset related LTIs (contribution of secondary systems to explosive failure) 2. Zero asset related fire starts (contribution of secondary systems to fire starts) 3. Maintain 5 year average level of Key Hazardous Events (catastrophic failure, conductor drop, structure failure, uncontrolled discharge/contact with electricity, and unauthorised entry)	• Zero LTI due to asset failure • Zero substation related fire starts
4. Maintain 5 year average level of loss of supply events due to asset faults 5. Maintain system reliability (achieve 99.9997%) 6. Maintain average age of asset class population to a sustainable level	• ENS events trending as below
7. Better than average performance of the STPIS measures: a. Secondary System fault and forced outage rates (contributes to STPIS for these measures)	• Trending below







It can be seen that in 2016 forced outages and asset failures attributable to Secondary Systems Assets have reduced. This result has come about through the recent renewal expenditure over the last few years. This expenditure has allowed for the delivery of standardised designs that reduced the potential for commissioning and maintenance personnel to erroneously operate an asset.

The recent expenditure has also resulted in the installation of a larger number of singular assets carrying out multiple functions which has reduced the number of potential failure points and thus produced a lower probability of failure across the asset base.

The installation of modern intelligent assets has introduced the capability for remote interrogation and monitoring of new assets and this has resulted in the immediate knowledge of a failed asset which allows Operators to address the failure immediately, limiting the potential for catastrophic failure and a resultant forced outage of the associated primary asset(s).

6. Automation Systems Asset Overview

6.1 Scope of Assets

The following assets are within the scope of this strategy:

- Protection Relays
- VF Intertrips
- Analysis Systems
- Control Systems
- DC Supply Systems - 110V and 250V DC

The following assets are outside the scope of this strategy:

- Telecommunications Assets
- DC Supply Systems - 50V DC
- Market Meters
- SCADA systems associated with the Central Control Room

6.2 Asset Base

6.2.1 Protection Relays

Protection relay assets are those main relays utilised for the protection of primary assets including:

- Transmission Lines
- Transformers
- SVCs
- Reactors
- Capacitors
- Busbars

The assets are comprised of four technology categories with different estimated standard lives for each as outlined below:

- Electromechanical Relays Excluding Busbar Protection - 45 years
- Electromechanical Busbar Protection Relays - 45 years
- Discrete Component Relays - 25 years
- Microprocessor Relays - 15 years

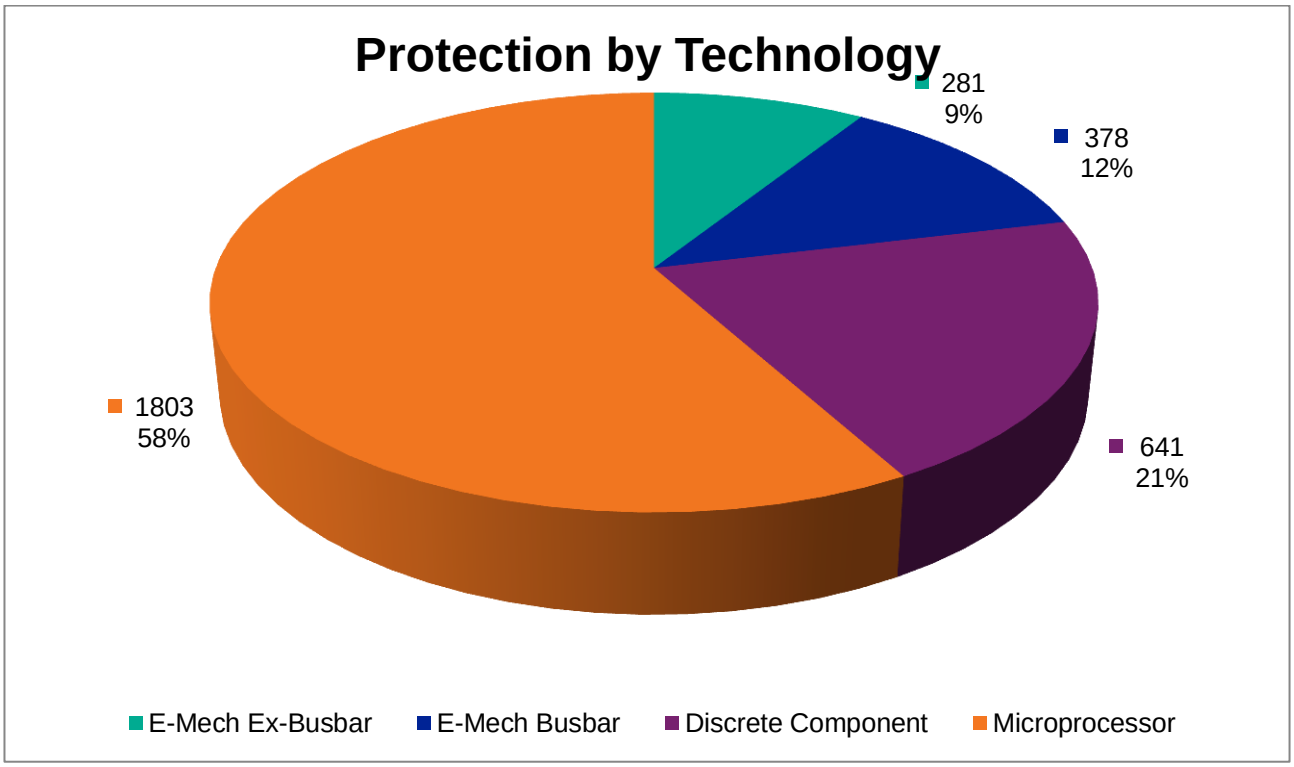


Figure 2 Protection Relay Population by Technology

TransGrid maintains approximately 3000 Primary Protection assets. The majority of assets are within their estimated standard lives with some assets having exceeded this value as summarised below:

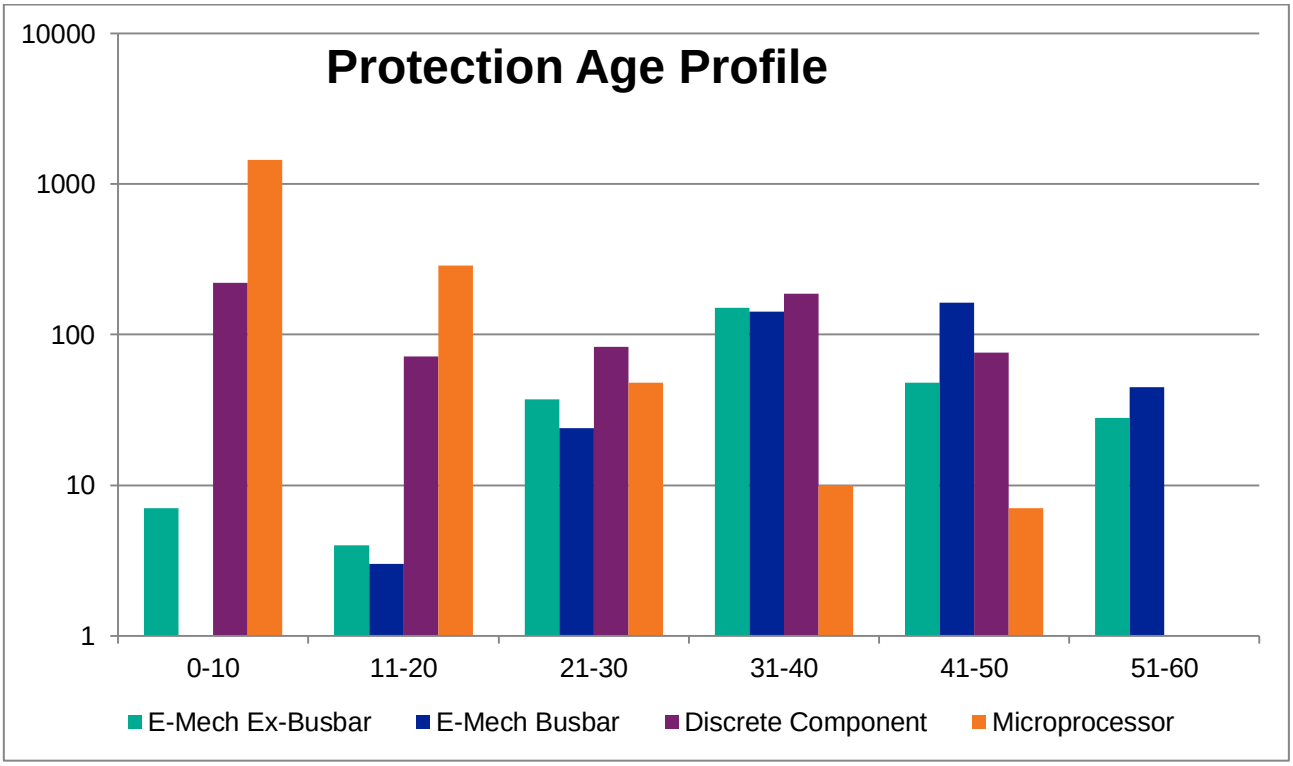


Figure 3 Protection Relay Age Profile by Technology

6.2.2 VF Intertrips

VF Intertrips are utilised to provide accelerated tripping of remote ends of transmission lines during a fault. They rely on an Intertrip signal to and from the primary protection relays and a valid communications path to the partner VF Intertrip unit on the remote end. VF Intertrips are currently utilised with Microwave or Fibre Optic communications bearers.

The assets are comprised of two technology categories with different estimated standard lives for each as outlined below:

- Fujitsu Intertrips - 15 years
- Dewar Intertrips - 15 years

Almost all Discrete Component assets have been withdrawn from service with only two units remaining (both are Fujitsu units).

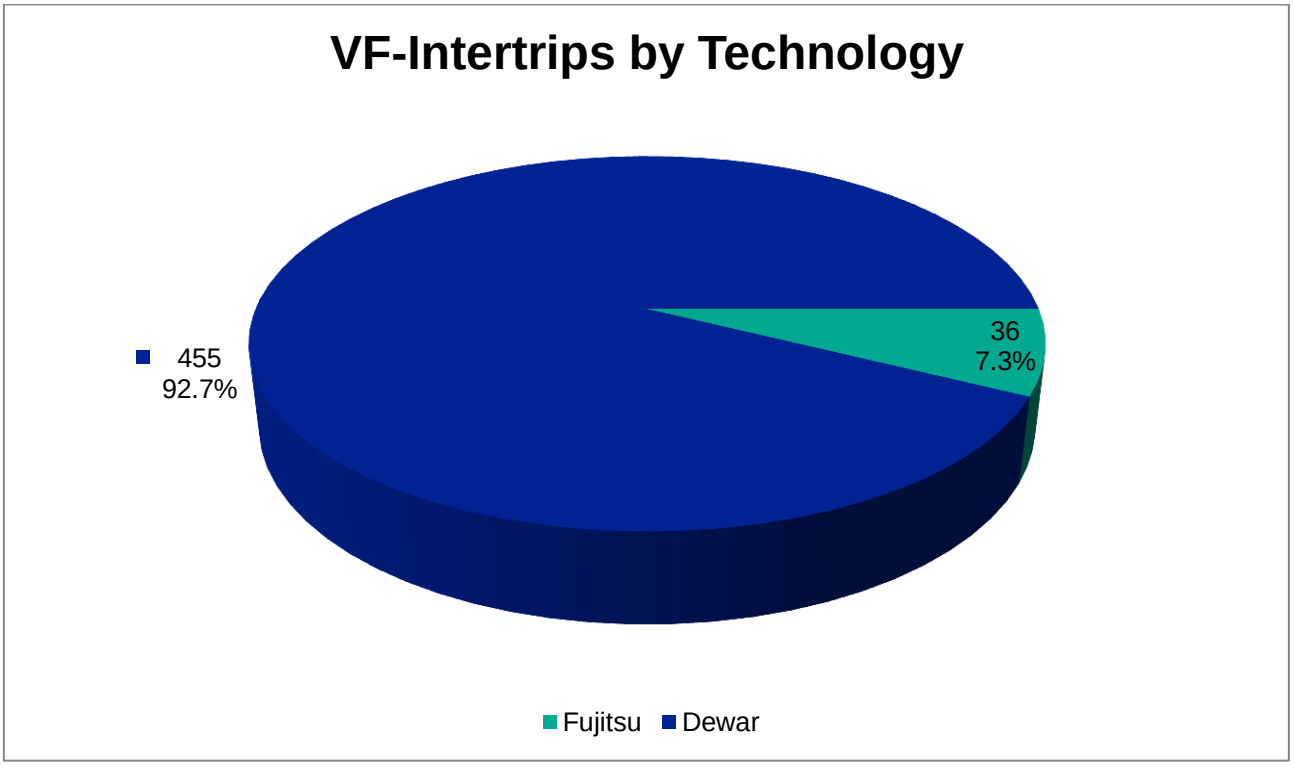


Figure 4 VF Intertrip Population by Technology

TransGrid maintains approximately 490 VF Intertrip assets. The majority of assets are within their estimated standard lives with some assets having exceeded this value as summarised below:

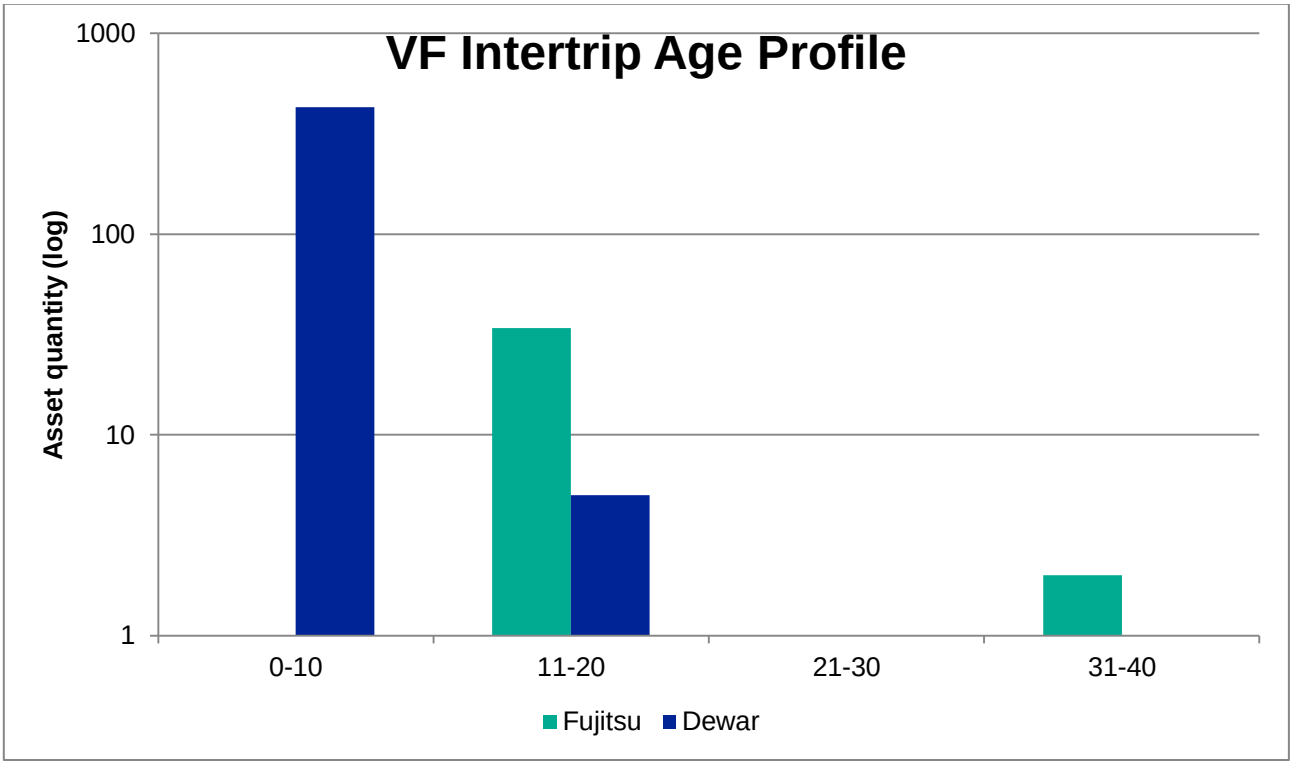


Figure 5 VF Intertrip Age Profile by Technology

6.2.3 Analysis Equipment

Analysis equipment includes those assets that allow operators, engineers, and analysts to determine the operating conditions of the network. These assets ensure that a complete understanding of the network's performance during normal and contingent operating conditions is available.

Analysis equipment includes the following categories of assets with an estimated life of 15 years:

- Disturbance Recorders
- Fault Recorders
- Travelling Wave Locators
- Quality of Supply Monitors
- Statistical Meters

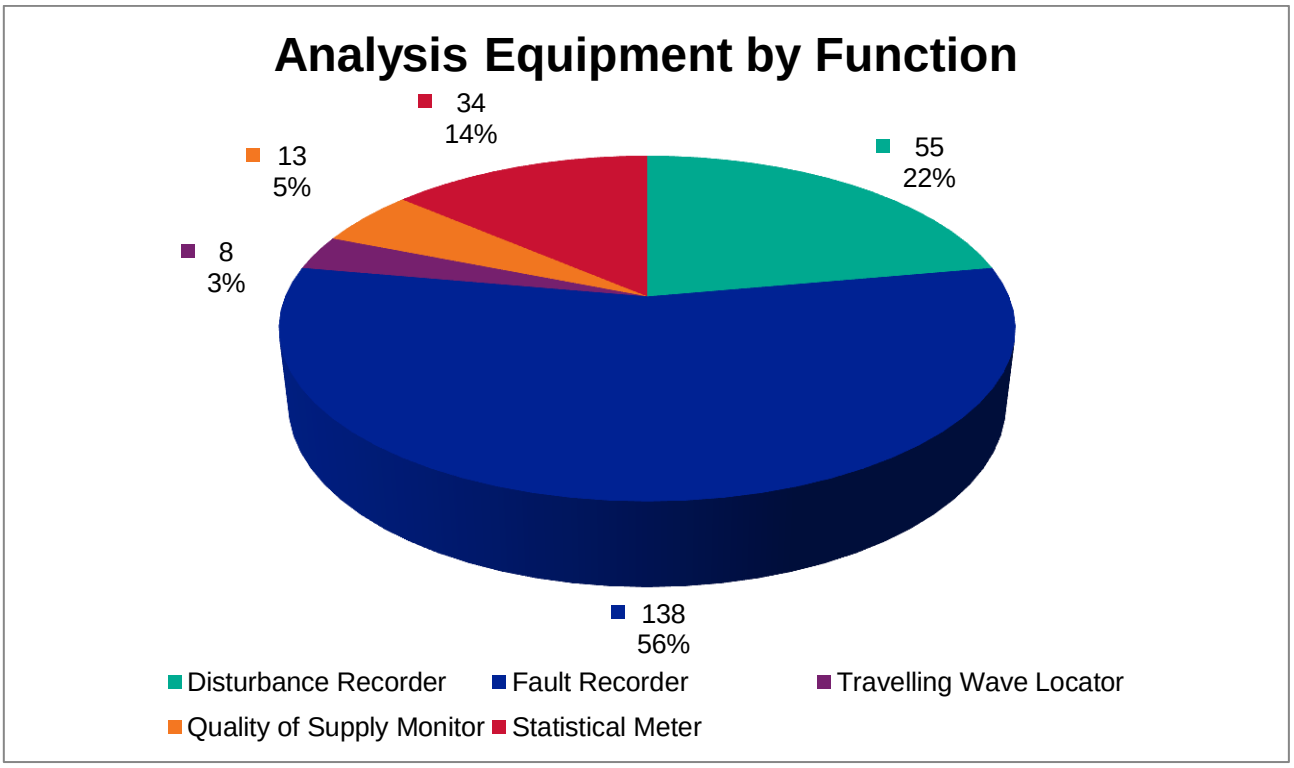


Figure 6 Analysis Equipment Population by Function

TransGrid maintains approximately 250 Analysis assets. The majority of assets are within their estimated standard lives with some assets having exceeded this value as summarised below:

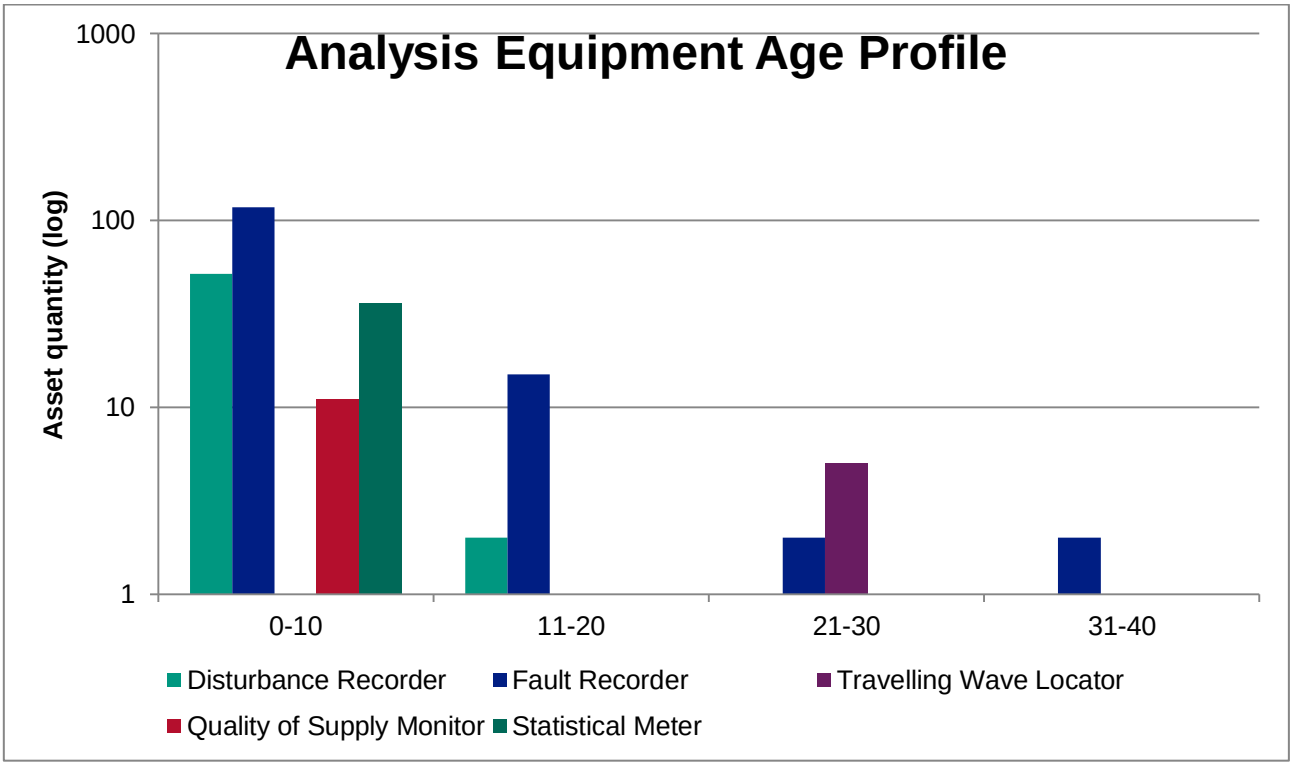


Figure 7 Analysis Equipment Age Profile by Function

6.2.4 Control Systems

Control assets allow for the remote monitoring and control of primary assets. The functionality of these assets allows TransGrid's SCADA Control Room to operate and monitor the status of unmanned substations and switching stations throughout the state. These assets also collect significant amounts of status and condition information to facilitate some level of remote diagnostics during failures and defects.

The assets are grouped into three generations of controller all based on Remote Terminal Unit (RTU) methodology, Human Machine Interfaces (HMI) are used for local interaction with control systems at a site and handle the collection of all data points available to the system. Additionally, there are 4 orphaned technology sites at Molong, Balranald, Gadara and Haymarket.

The control asset can be categorised as follows with an estimated technical life of 15 years for RTUs and 10 years for HMIs:

- MD1000 - earliest iteration of microprocessor based RTUs (single manufacturer/model used)
- MD3311 - second generation of microprocessor based RTUs (single manufacturer/model used)
- Modern - current generation of microprocessor based RTUs (multiple manufacturers and models used)
- HMI - several manufacturers and models (based on generic PC)
- Orphaned Site Control Systems - Gadara, Haymarket and Molong all implement one off Design and Construct control systems (each site has a different system)
- SVC Control Systems - specialised control systems designed and installed by the SVC primary pant manufacturer (each SVC has a dedicated system)

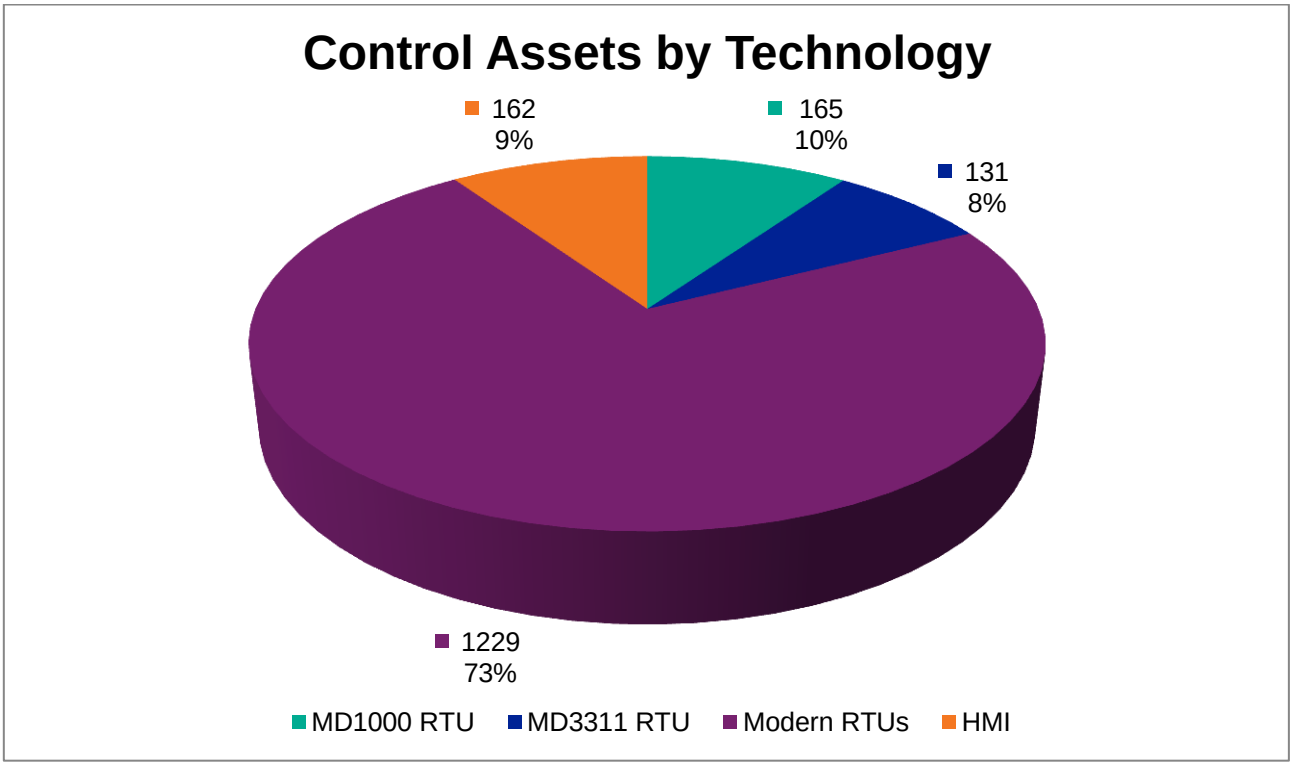


Figure 8 Control Assets by Technology

TransGrid maintains approximately 1690 Control assets. The majority of assets are within their estimated standard lives with some assets (particularly HMIs) having exceeded this value as summarised below:

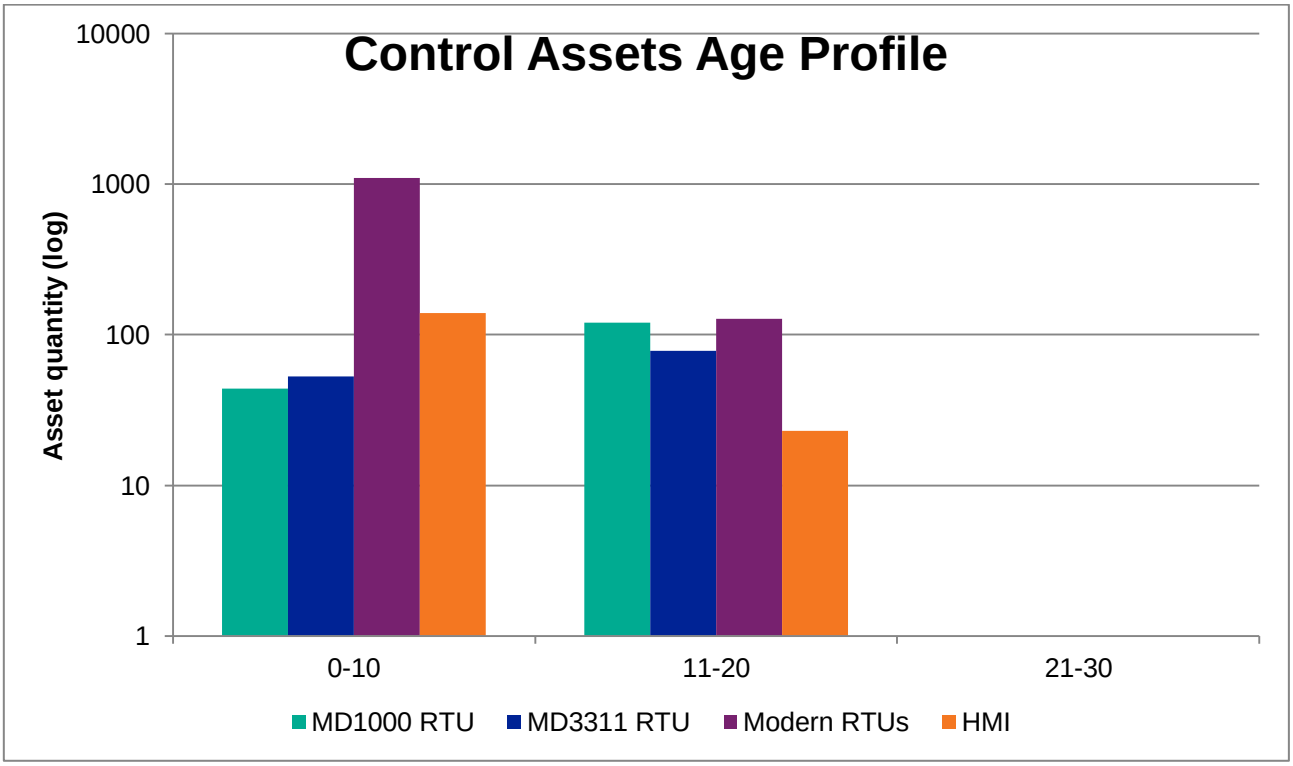


Figure 9 Control Assets Age Profile by Technology

6.2.5 DC Supply Systems

DC batteries and chargers provide the constant DC supply required for the operation of all automation systems within TransGrid sites. The assets additionally charge HV circuit breaker springs and provide backup to continue remote operation of a site during a catastrophic loss of auxiliary supply event within a site or the state.

DC Supply assets include the following categories of assets with an estimated life of 20 years:

- NiCd Batteries - 250V DC and 110V DC
- NiCd Chargers - 250V DC and 110V DC

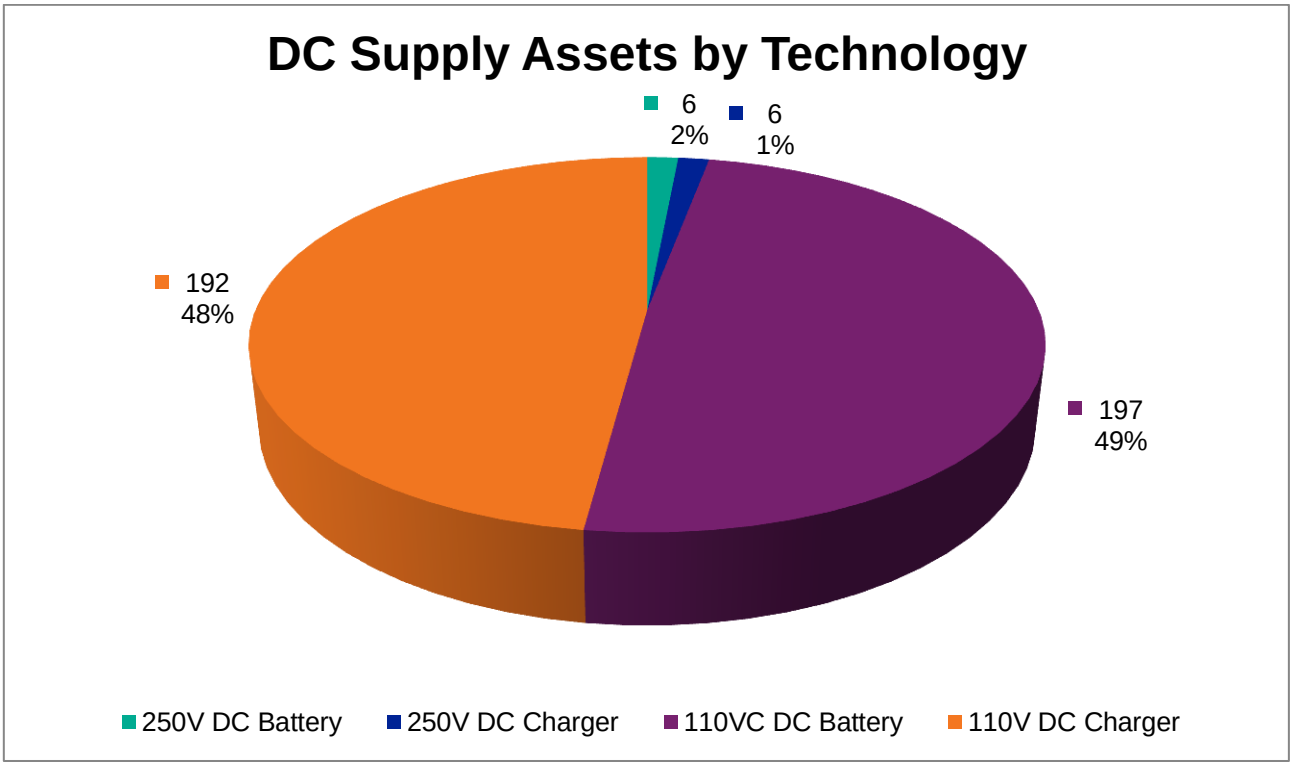


Figure 10 DC Supply Assets by Technology

TransGrid maintains approximately 400 Automation System DC Supply assets. The majority of assets are within their estimated standard lives with some assets (particularly 110V DC Chargers) having exceeded this value as summarised below:

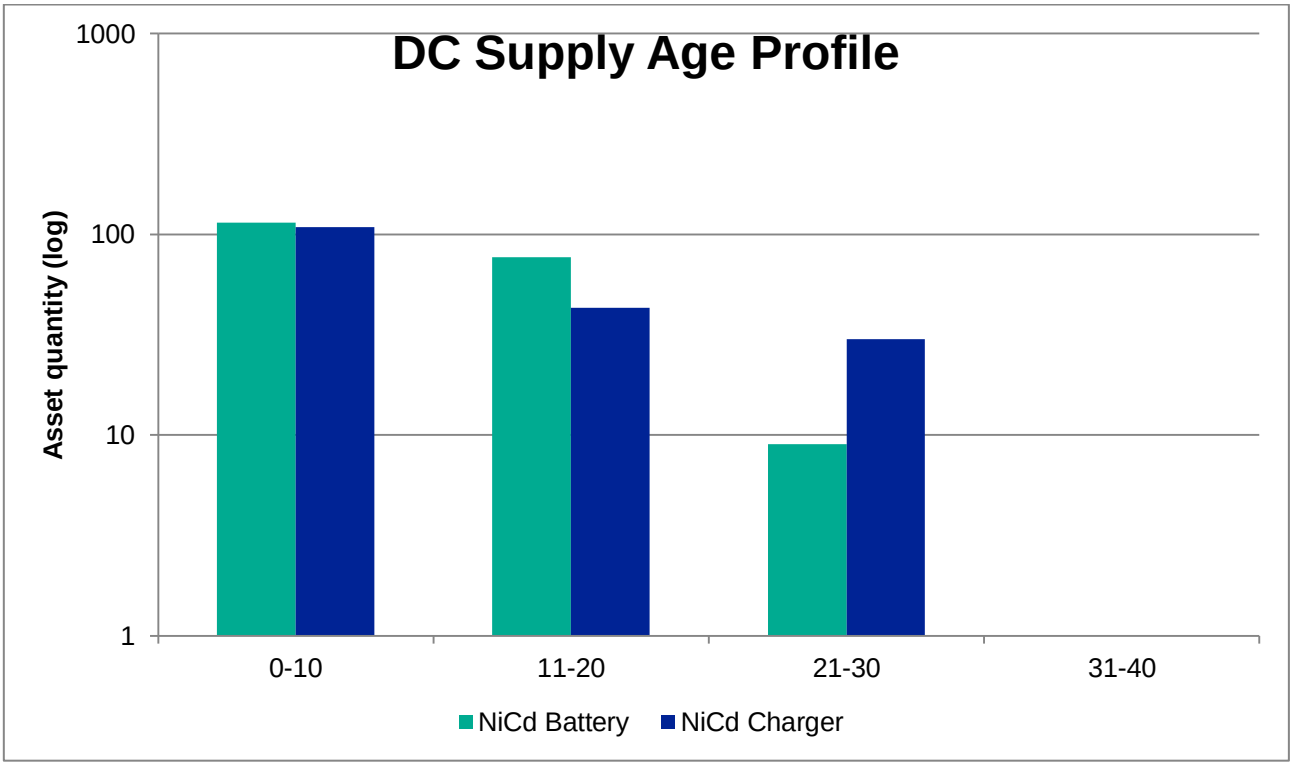


Figure 11 DC Supply Age Profile

7. Protection Relays Asset Review

This section details the emerging issues with the Protection assets, and the renewal and maintenance initiatives to be implemented to address the issues. These are derived through the renewal and maintenance decision process outlined in the *Asset Management Strategy and Objectives* document.

All strategic initiatives with respect to TransGrid's Protection assets are outlined in this section, including the renewal and maintenance initiatives that contribute to the asset management program of works. Further details can be found in the relevant Automation Systems Maintenance Plan, and the referenced governance documents.

7.1 Implementation of the Renewal and Maintenance Decision Process

Asset Health and Asset Criticality have been combined using a scoring methodology to provide a ranking for all assets. Criticality is scored on the basis of the consequence of the failure of the asset this scoring takes into account the probability of a fault occurring in the protected primary asset. Asset Health is calculated as per the Network Asset Health Framework.

Whereas asset criticality is inherently dependent upon the primary assets that are serviced by the secondary systems automation assets, asset health analysis is based upon spares availability, known issues, self-monitoring capabilities as well as age. Asset health has been categorised as three levels;

- OK - assets not requiring any actions at this time as there are no know issues, and a failure of a unit can be addressed immediately.
- Investigate - assets where should an asset fail, it may not be addressed adequately to meet legislative requirements under the current configuration and therefore either replacement or acquisition of spares holdings.
- Replace - assets where immediate replacement is recommended due to the lack of ability for TransGrid to address asset failures within a reasonable timeframe to return an asset to service.

7.2 Electromechanical Relay (Excluding Busbar Protection) Asset Review

The use of electromechanical relays has been phased out of all new installations except for auxiliary functions.

The majority of these relays are no longer supported by their respective manufacturers and as such spare parts are regularly scavenged from failed units. This method of acquiring spares is not reliable as it is difficult to confirm the quality of the parts. The wear associated with mechanical components is leading to failures in pick-up capacity of these relays and poor performance for clearance times.

Operationally, these relays lack remote communication and condition monitoring capabilities making it difficult and costly to monitor the condition of the equipment as it ages further. Additionally technicians who are proficient in the maintenance of electromechanical relays have retired and it is difficult to maintain this equipment.

Historical performance of this type of asset is summarised in the graph below as an average of percentage defects per population and provides forecast defect rate:

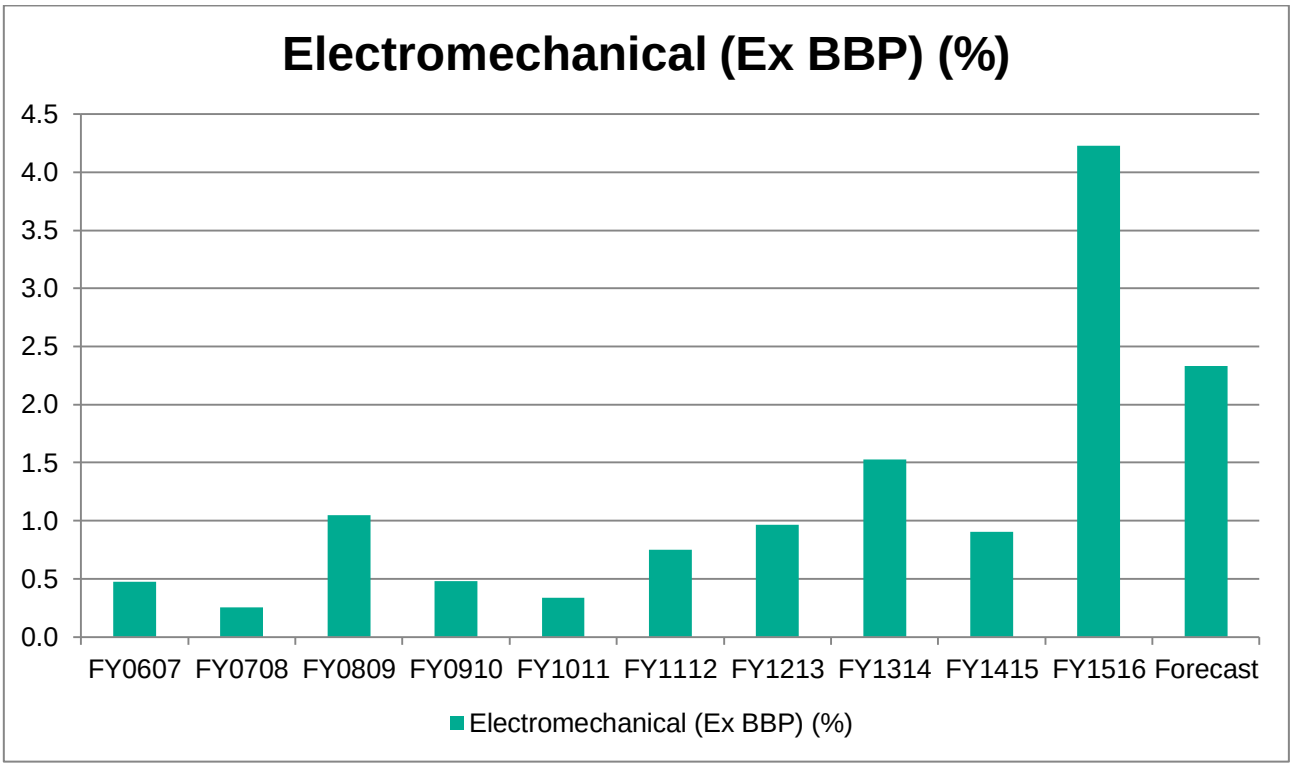


Figure 12 Electromechanical Relays (Ex BBP) Defect Rates

Due to the nature of protection systems, their criticality is scored against the potential for loss of load and the safety and environmental risks associated with the protected primary assets across the network. Scoring is applied in accordance with brackets of failure consequence expressed in monetary terms.

The figure below illustrates the breakup of the relay population by criticality levels:

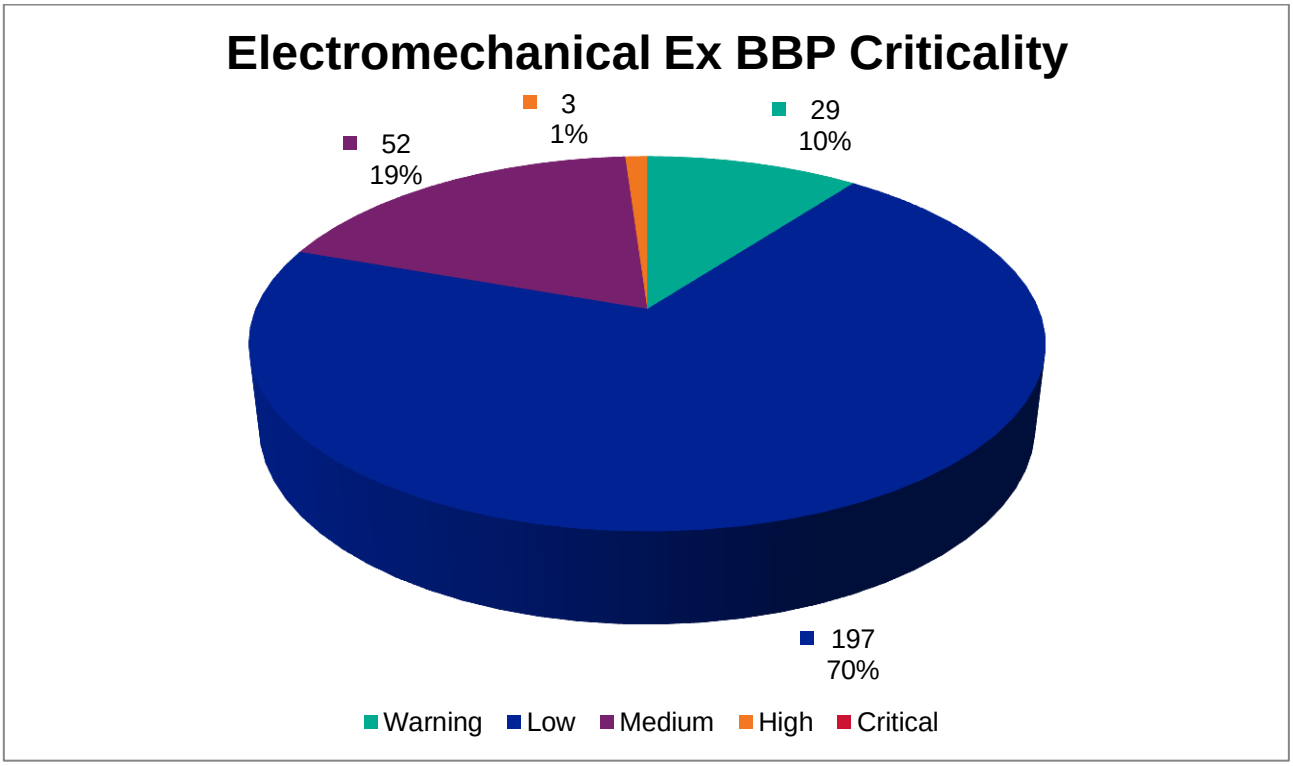


Figure 13 Electromechanical Relay (Ex BBP) Criticality

The health of these assets varies and is primarily dependant on manufacturer support, spares availability, forecast defect rates and the technical life of the assets. The health index has been used to identify the assets that require investigation and those that require replacement. Below is a summary of the current health of the assets:

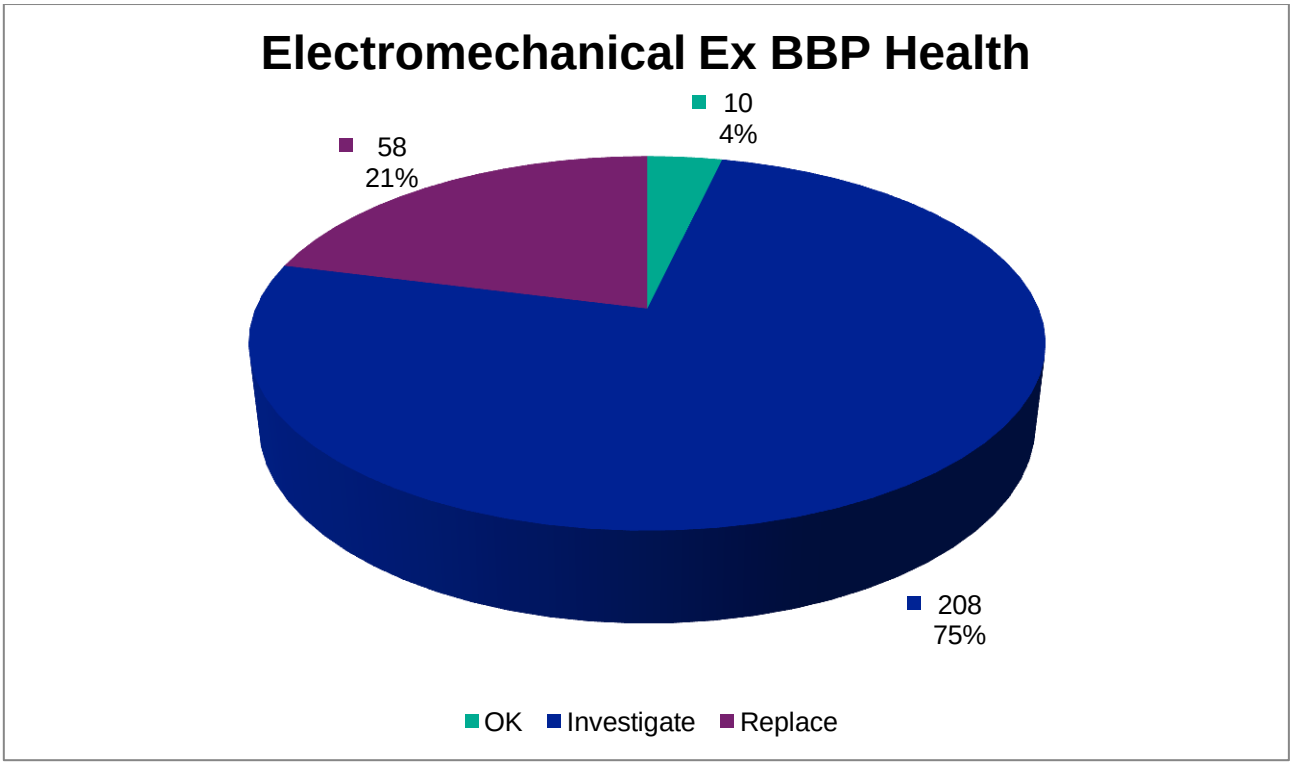


Figure 14 Electromechanical Relay (Ex BBP) Health

7.3 Electromechanical Relay (Busbar Protection) Asset Review

Electromechanical busbar protection installations date back to 1960 and have limited issues associated with them. This is generally due to no current flowing through the units except during faults and testing.

The majority of these relays are no longer supported by their respective manufacturers; as such spare parts are regularly scavenged from failed units. This method of acquiring spares is not reliable as it is difficult to confirm the quality of the parts. The wear associated with mechanical components is leading to failures in pick-up capacity of these relays and poor performance for clearance times.

Operationally, these relays lack remote communication and condition monitoring capabilities making it difficult and costly to monitor the condition of the equipment as it ages further. Additionally technicians who are proficient in the maintenance of electromechanical relays have retired and it is difficult to maintain this equipment.

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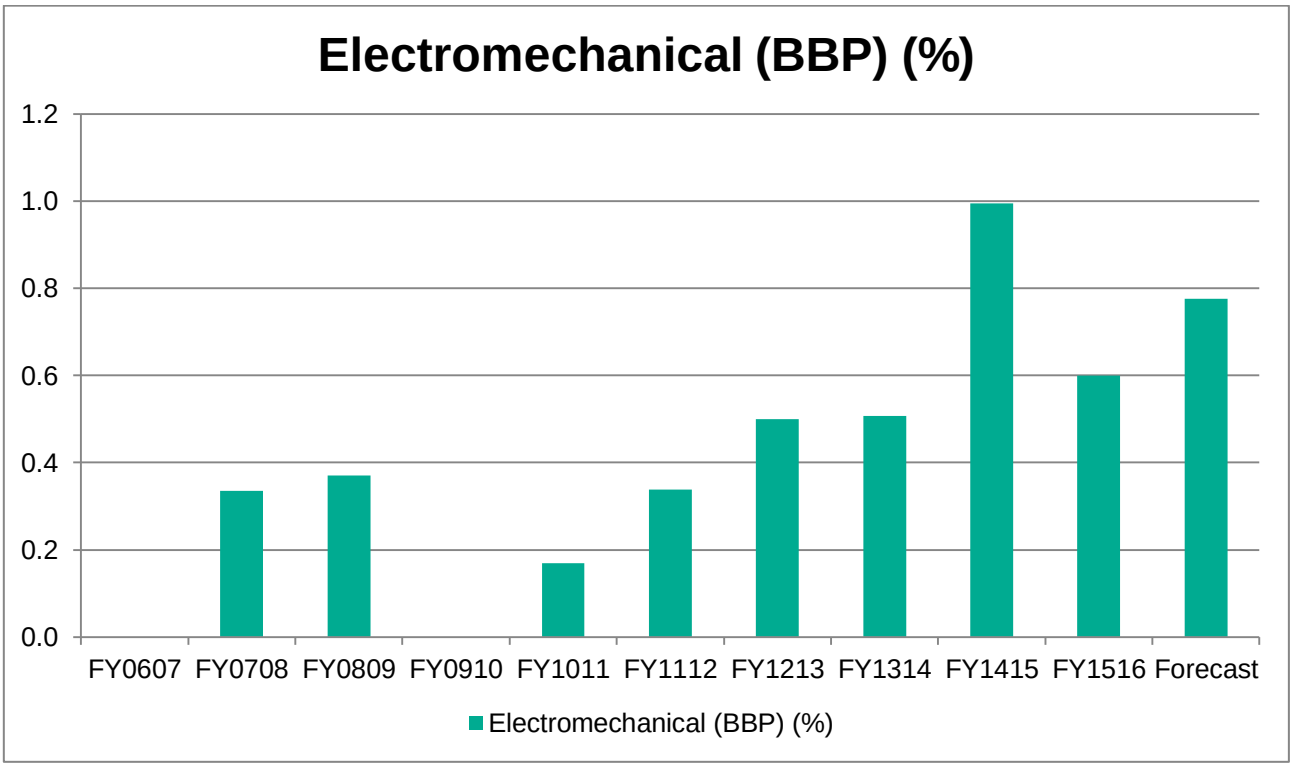

Figure 15 Electromechanical Relay (BBP) Defect Rates

Due to the nature of protection systems, their criticality is scored against the potential for loss of load and the safety and environmental risks associated with the protected primary assets across the network. Scoring is applied in accordance with brackets of failure consequence expressed in monetary terms.

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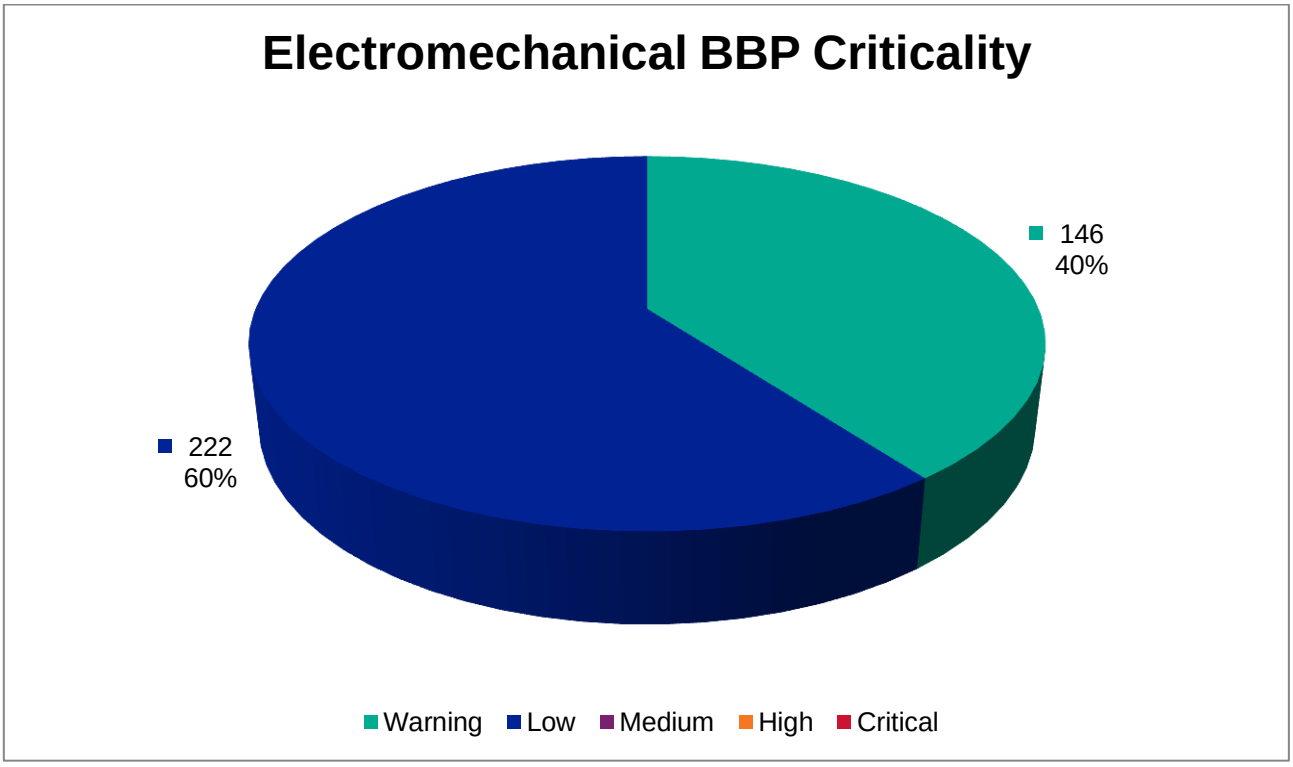

Figure 16 Electromechanical Relay (BBP) Criticality

The health of these assets varies and is primarily dependant on manufacturer support, spares availability, forecast defect rates and the technical life of the assets. The health index has been used to identify the assets that require investigation and those that require replacement. Below is a summary of the current health of the assets:

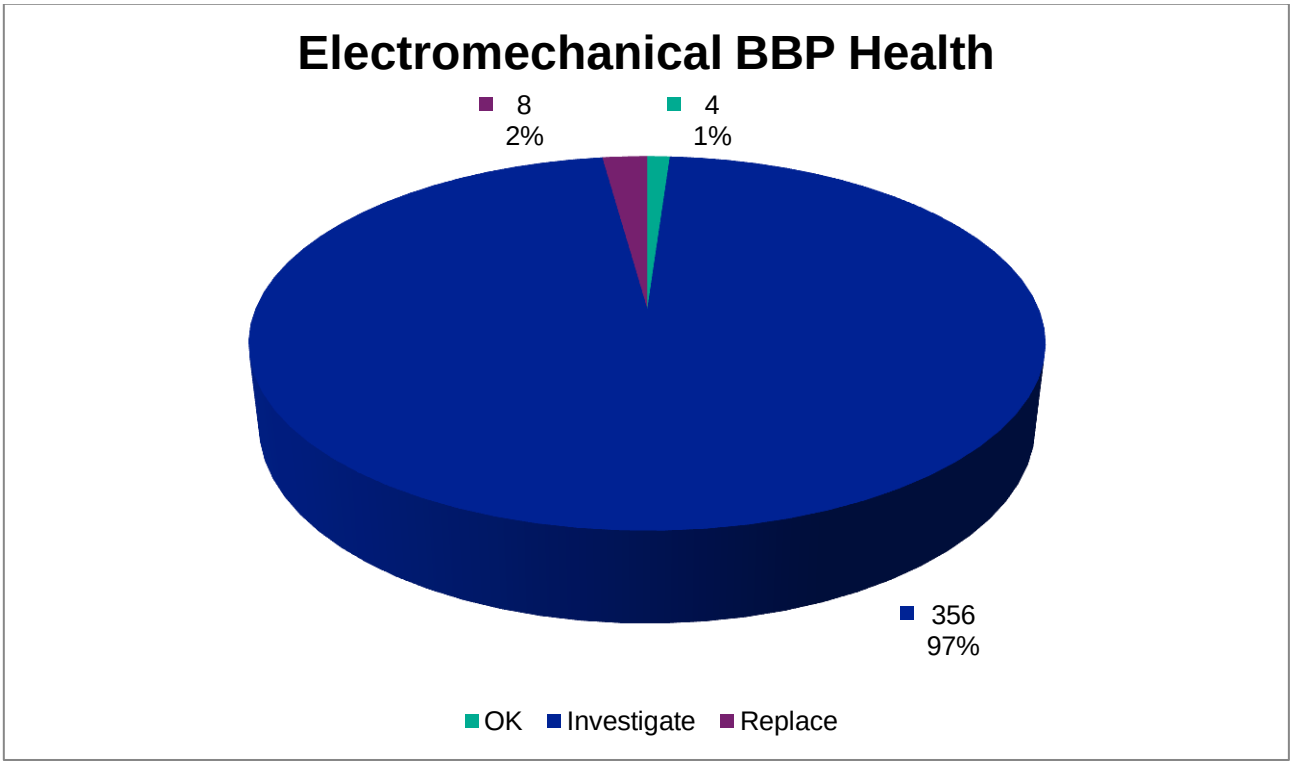

Figure 17 Electromechanical Relay (BBP) Health

7.4 Discrete Component Relay Asset Review

Early electronic Protection systems based on discrete electronic components installed on printed circuit boards. The majority of these systems were installed between 1970 and 1995. The installations are displaying signs of degradation due in particular to capacitor dielectric issues resulting in calibration issues affect the accuracy and reliability of the equipment.

TransGrid does not have the capability to repair this equipment and it is no longer supported by the original manufacturer.

Discrete Component Protection Systems are still actively pursued only for the purpose of high impedance differential protection systems.

Historical performance of this type of asset is summarised in the graph below as an average of percentage defects per population and provides forecast defect rate:

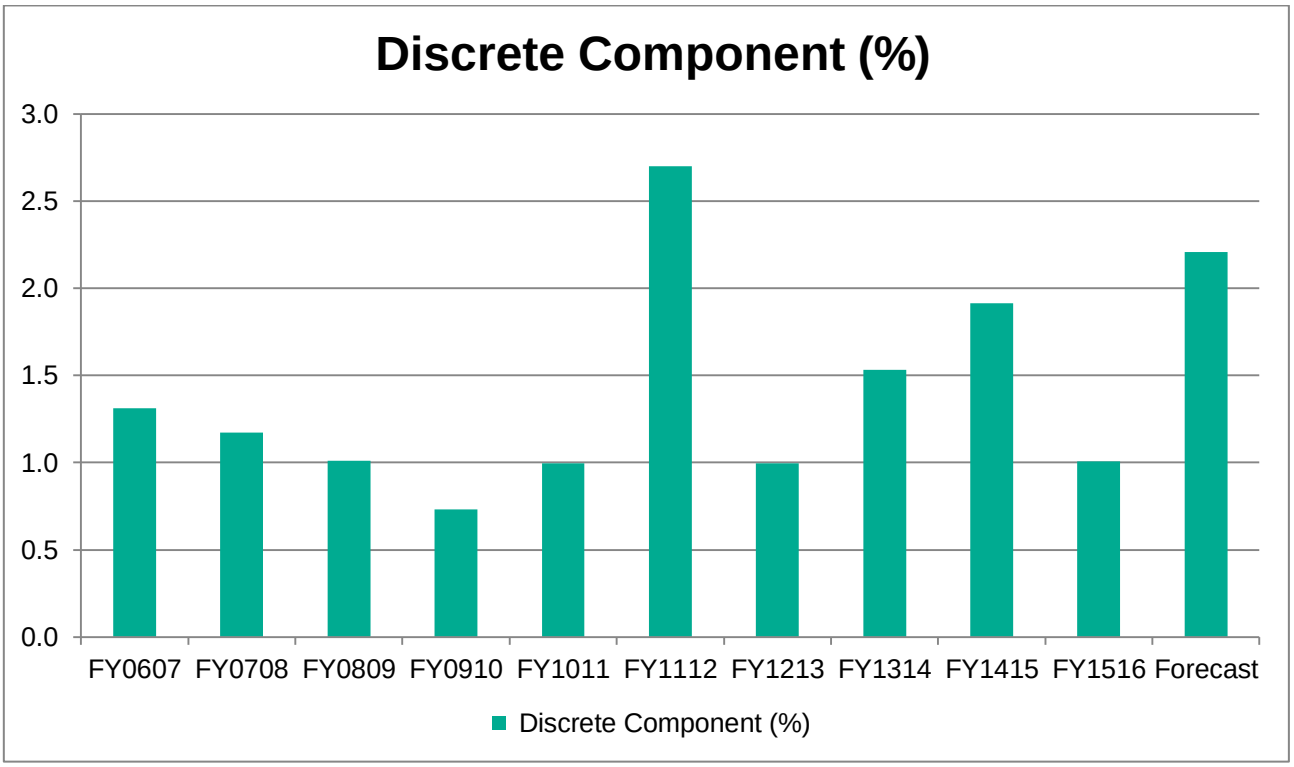

Figure 18 Discrete Component Relay Defect Rates

Due to the nature of protection systems, their criticality is scored against the potential for loss of load and the safety and environmental risks associated with the protected primary assets across the network. Scoring is applied in accordance with brackets of failure consequence expressed in monetary terms.

The figure below illustrates the breakup of the relay population by criticality levels:

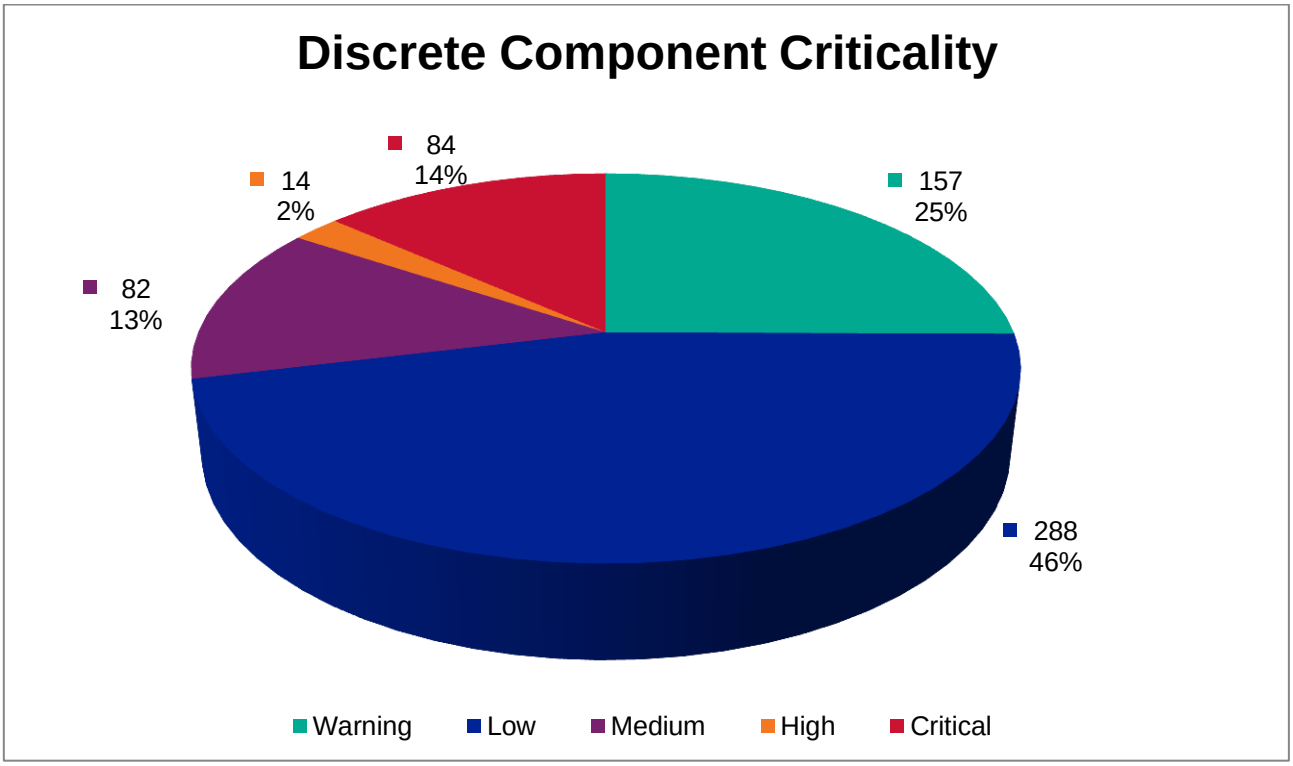

Figure 19 Discrete Component Relay Criticality

The health of these assets varies and is primarily dependant on manufacturer support, spares availability, forecast defect rates and the technical life of the assets. The health index has been used to identify the assets that require investigation and those that require replacement. Below is a summary of the current health of the assets:

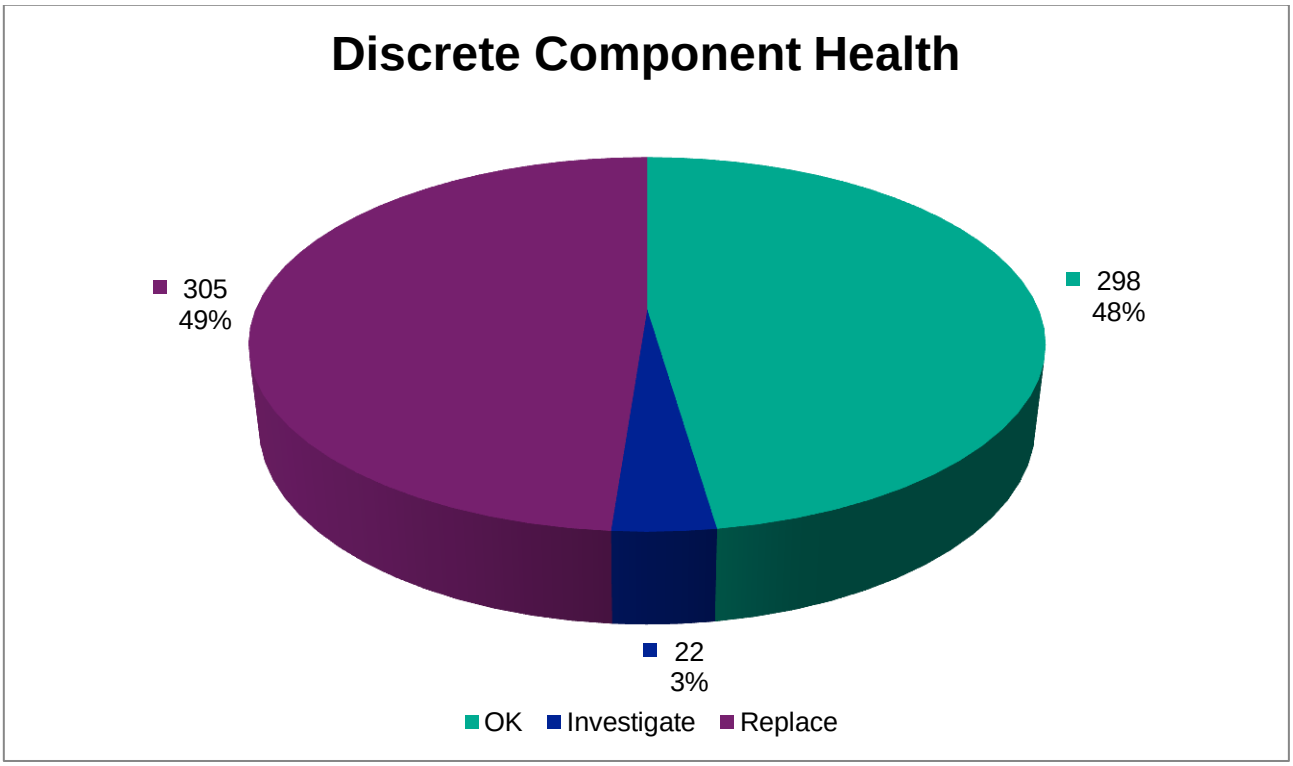

Figure 20 Discrete Component Relay Health

7.5 Microprocessor Relay Asset Review

This equipment utilises microprocessors to carry out protection operations and calculations within one unit, thus eliminating many auxiliary relay requirements.

This type of relay does not degrade in functionality over time to provide an indication of pending failure, they tend to fail completely and require replacement.

TransGrid does not have the capability to repair this equipment and earlier versions are no longer supported by the original manufacturer.

Microprocessor relays are broken down into two subcategories; early microprocessor and modern microprocessor to differentiate between the first generation types.

Historical performance of this type of asset is summarised in the graphs below as an average of percentage defects per population and provides forecast defect rate. The assets are broken up into two subcategories; early microprocessor and modern microprocessor to differentiate between first generation assets:

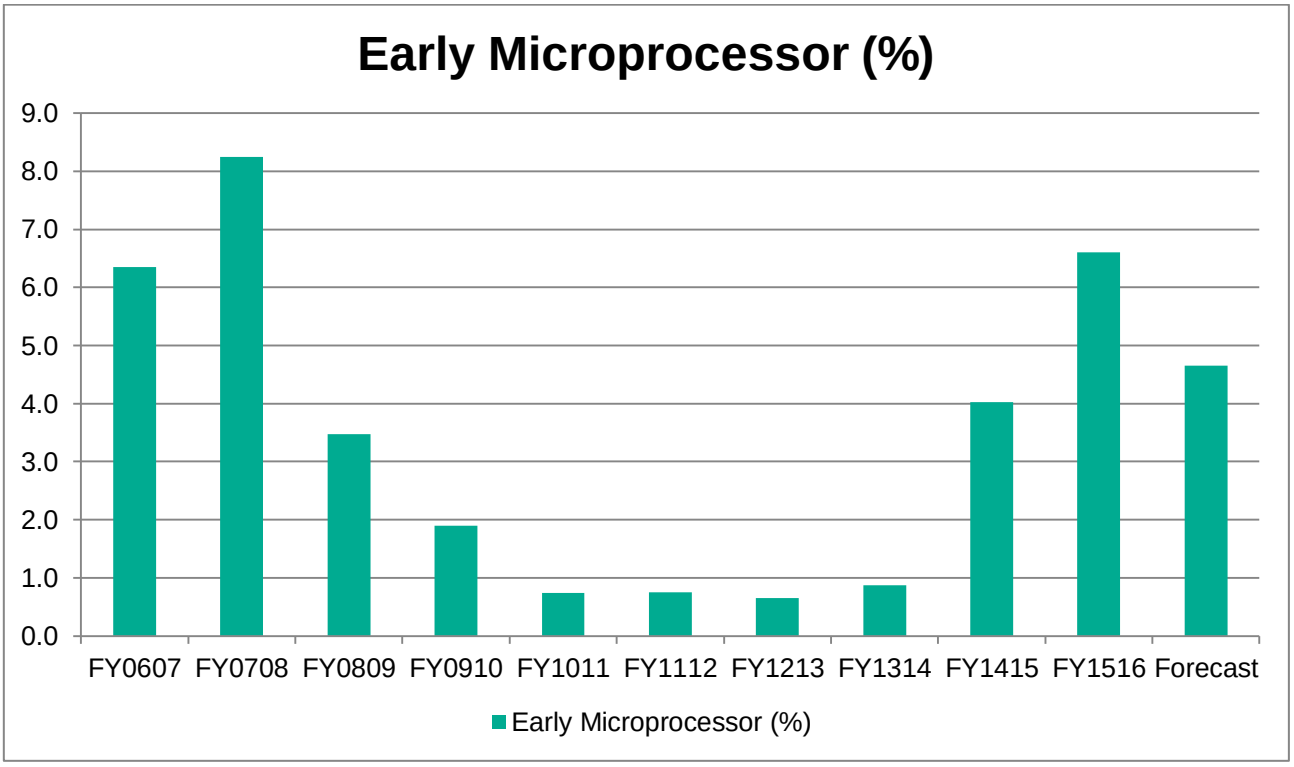

Figure 21 Early Microprocessor Relay Defect Rates

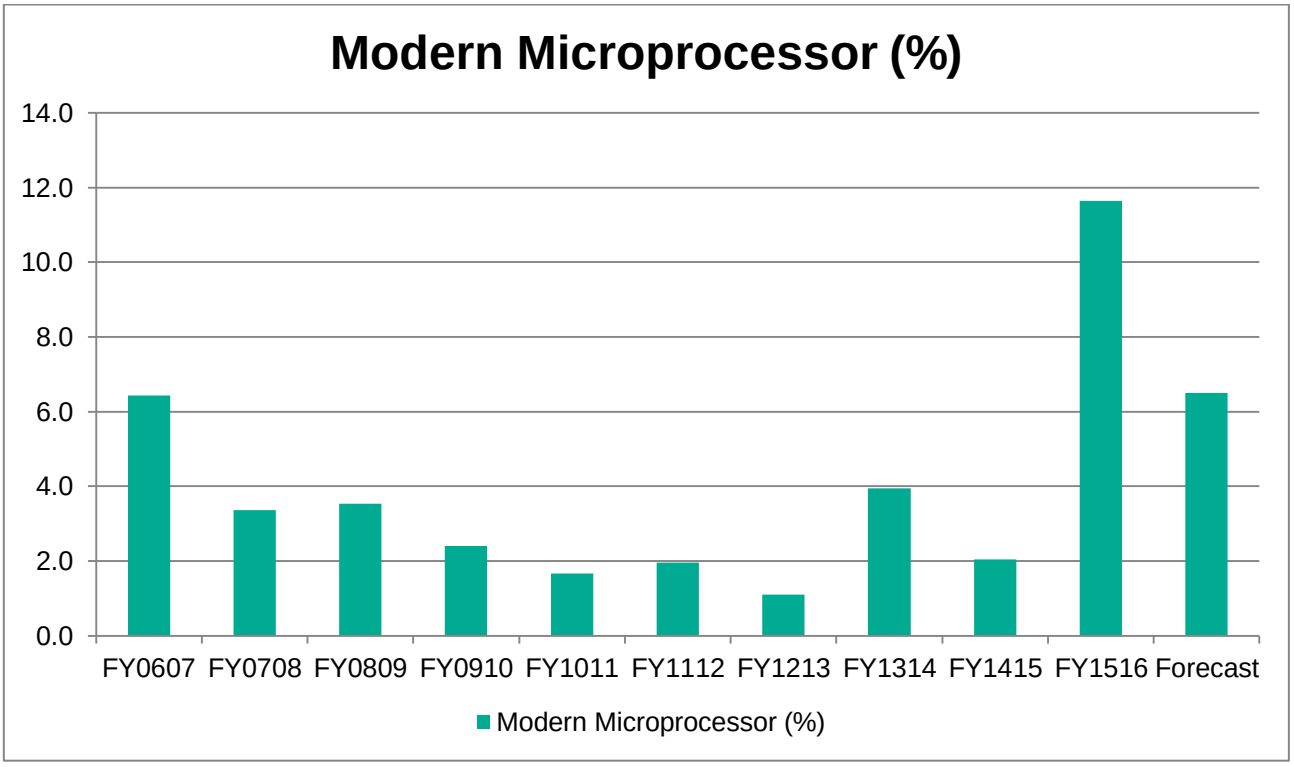

Figure 22 Modern Microprocessor Relay Defect Rates

Due to the nature of protection systems, their criticality is scored against the potential for loss of load and the safety and environmental risks associated with the protected primary assets across the network. Scoring is applied in accordance with brackets of failure consequence expressed in monetary terms.

The figure below illustrates the breakup of the relay population by criticality levels:

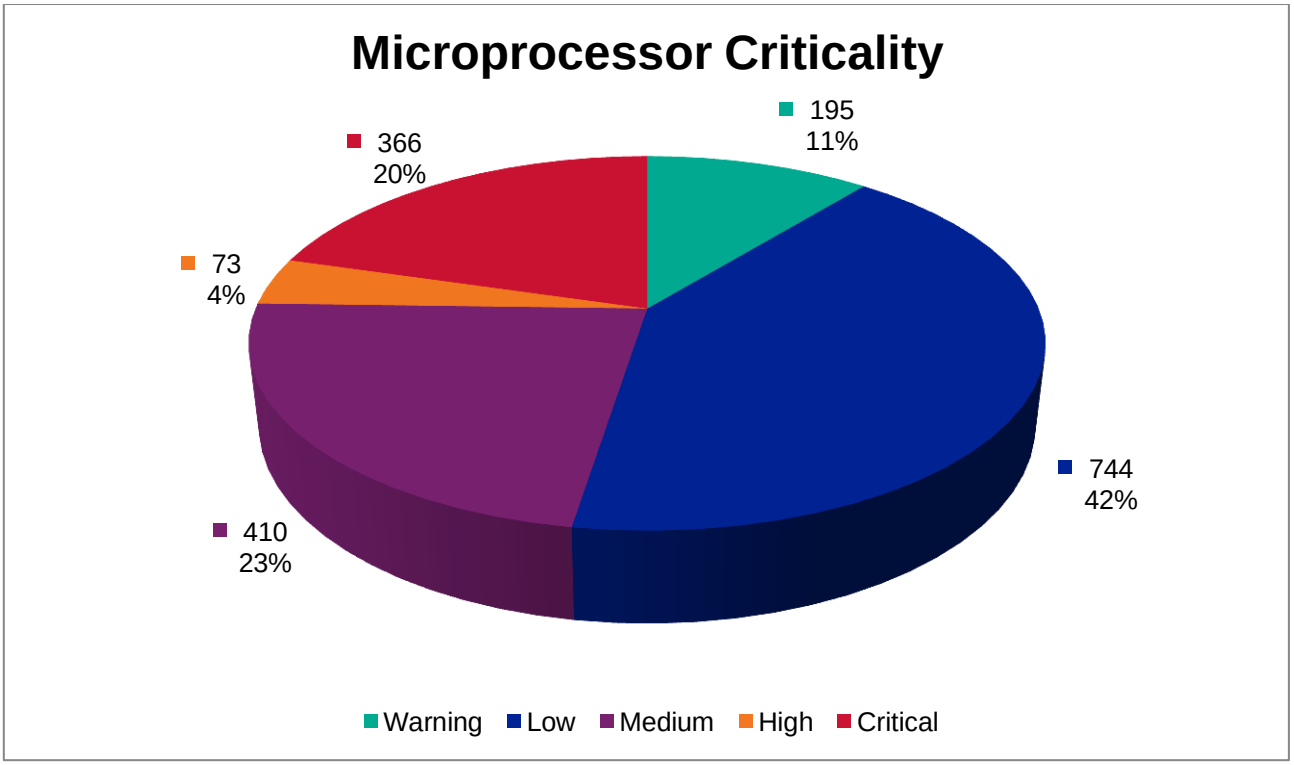

Figure 23 Microprocessor Relay Criticality

The health of these assets varies and is primarily dependant on manufacturer support, spares availability, forecast defect rates and the technical life of the assets. The health index has been used to identify the assets that require investigation and those that require replacement. Below is a summary of the current health of the assets:

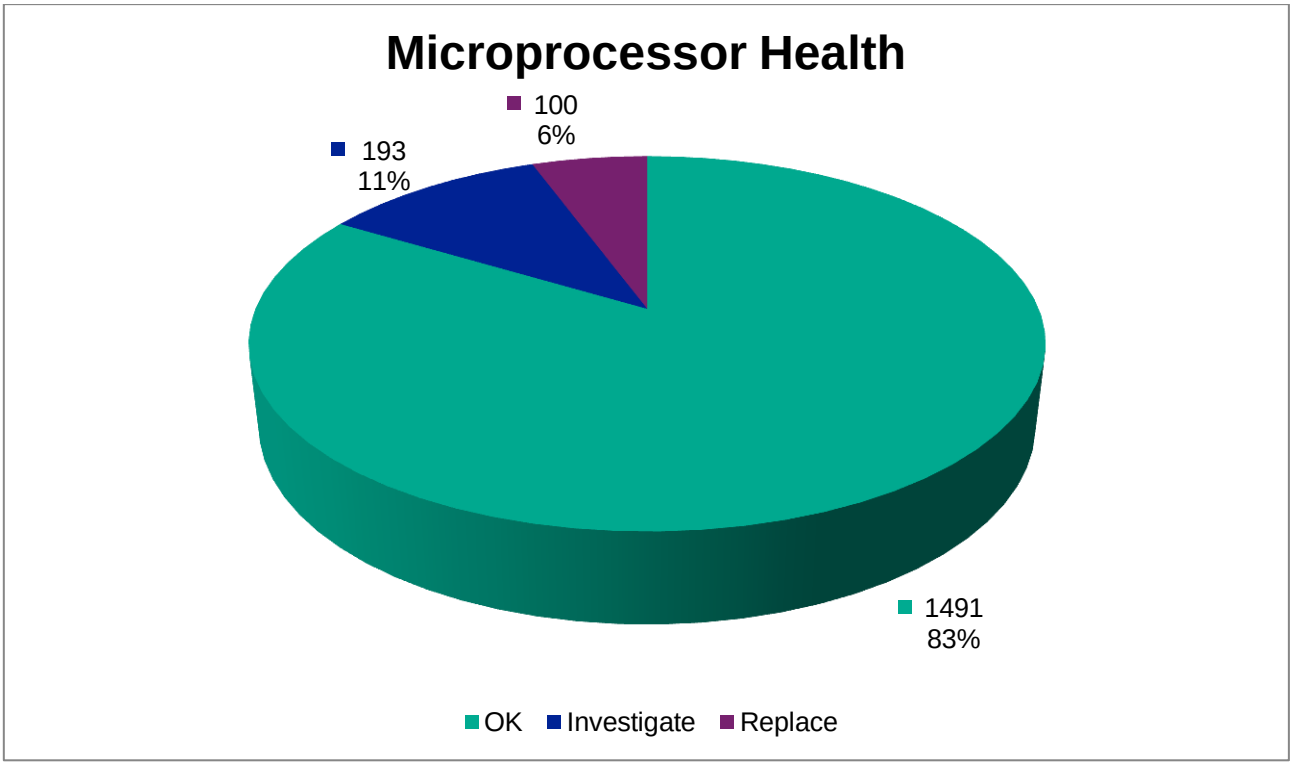

Figure 24 Microprocessor Relay Health

7.6 Emerging Issues, and Renewal and Maintenance Initiatives

A major issue currently emerging is the withdrawal of manufacturer support from various models of microprocessor relays within the network. The withdrawal of support introduces issues particularly surrounding the replacement of failed assets. Once spares are depleted, the MTTR of a failed asset increases beyond permissible outage times of a single protection unit and results in the removal from service of primary plant. This is mainly due to the need to develop new designs and build new protection panels, along with several days required for installation and commissioning.

Age profiles for these assets are progressing and as the ages increase annually relays will need to be renewed in a timely manner to maintain the reliability and security of the network.

Additionally a new issue has arisen over the past year associated with certain microprocessor models and a shortcoming associated with the manufacturer's Digital Signal Processing implementation leading to random trips including circuit breaker fail which results in the loss of busbar sections.

Assets continually reach end of life and require addressing, the withdrawal of manufacturer support is also an ongoing issue to be addressed as this leads to a lack of spares, an inability to repair, and an inability to connect to assets to carry out maintenance tasks as modern operating systems are not supported (e.g. Windows 7).

The current emerging issues and the renewal and maintenance initiatives to be implemented in response to these issues are summarised in the table below.

Table 8: Emerging Issues, and Renewal and Maintenance Initiatives

Asset	Asset Management Objective	Strategic Initiative	Emerging Issues	Forecast Expenditure ($m)	Reference Documents
GE Multilin: • Transformer • Transmission Line	• Manage network related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Maintain network reliability •	• In the short term pursue a refurbishment program including card replacement and firmware upgrades to stabilise and reduce the defect rate. • In the medium term, pursue a replacement strategy as capital becomes available, based on the success of the refurbishment program.	• DSP issues resulting in mal-operation of protected asset and busbars • Firmware updates are required to correct programming issues	35.5	NS-000001379 TIWR-00001466 TIWR-00001711
Protection: • Transmission Line • Transformer • Busbar • Reactor • Capacitor • UFLS	• Manage network related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Maintain network reliability • Improve OPEX Performance	• Pursue a replacement strategy to bring protection assets to modern standards which include self-monitoring capabilities and remote diagnostics	• Manufacturer support withdrawn • Obsolete connection software • Asset health and age		NS-00001377 NS-00001376 NS-00001389 NS-00001387 NS-00001368 NS-00001382 NS-00001383 NS-00001385 NS-00001356 NS-00001380 NS-00001381 NS-00001386 NS-00001370

7.7 Maintenance Program

Routine maintenance is based on periodic testing and inspection of protection installations to determine their adequacy for maintaining the reliability, security and stability of the network during contingent fault events. Routine maintenance is scheduled at regular intervals which are balanced against previous performance particularly in the detection of defects.

Different frequencies for routine maintenance activities are set dependant on the technology utilised in the protection scheme and its capacity for self-checking and reporting of internal faults.

Some corrective maintenance activities have been scheduled and planned to address firmware changes issued by manufacturers where the potential for undermined performance is identified.

Failures that are identified during the normal operation of the relays are addressed in emergency replacement of the failed unit. This is to meet NER requirements and ensure that duplicated protection schemes are maintained throughout the network.

The maintenance program is reviewed annually and no changes have been identified or applied for this financial year (2016/17).

8. VF Intertrip Asset Review

This section details the emerging issues with the VF Intertrip assets, and the renewal and maintenance initiatives to be implemented to address the issues. These are derived through the renewal and maintenance decision process outlined in the *Asset Management Strategy and Objectives* document.

All strategic initiatives with respect to TransGrid's VF Intertrip assets are outlined in this section, including the renewal and maintenance initiatives that contribute to the asset management program of works. Further details can be found in the relevant Automation Systems Maintenance Plan, and the referenced governance documents.

8.1 Implementation of the Renewal and Maintenance Decision Process

Asset Health and Asset Criticality have been combined using a scoring methodology to provide a ranking for all assets. Criticality is scored on the basis of the consequence of the failure of the asset. Asset Health is calculated as per the Network Asset Health Framework.

Whereas asset criticality is inherently dependent upon the primary assets that are serviced by the secondary systems automation assets, asset health analysis is based upon spares availability, known issues, self-monitoring capabilities as well as age. Asset health has been categorised as three levels;

- OK - assets not requiring any actions at this time as there are no know issues, and a failure of a unit can be addressed immediately.
- Investigate - assets where should an asset fail, it may not be addressed adequately to meet legislative requirements under the current configuration and therefore either replacement or acquisition of spares holdings.
- Replace - assets where immediate replacement is recommended due to the lack of ability for TransGrid to address asset failures within a reasonable timeframe to return an asset to service.

8.2 Fujitsu Series VF Intertrip Asset Review

Fujitsu VF protection signalling equipment was in common use before the adoption of the current fleet of VF signalling systems.

This equipment was installed over a 20 year period culminating in the late 1990's/early 2000's. It has been very reliable but is no longer supported and is beginning to show signs of ageing. All remaining assets bar 2 are microprocessor based.

Historical performance of this type of asset is summarised in the graph below as an average of percentage defects per population and provides forecast defect rate:

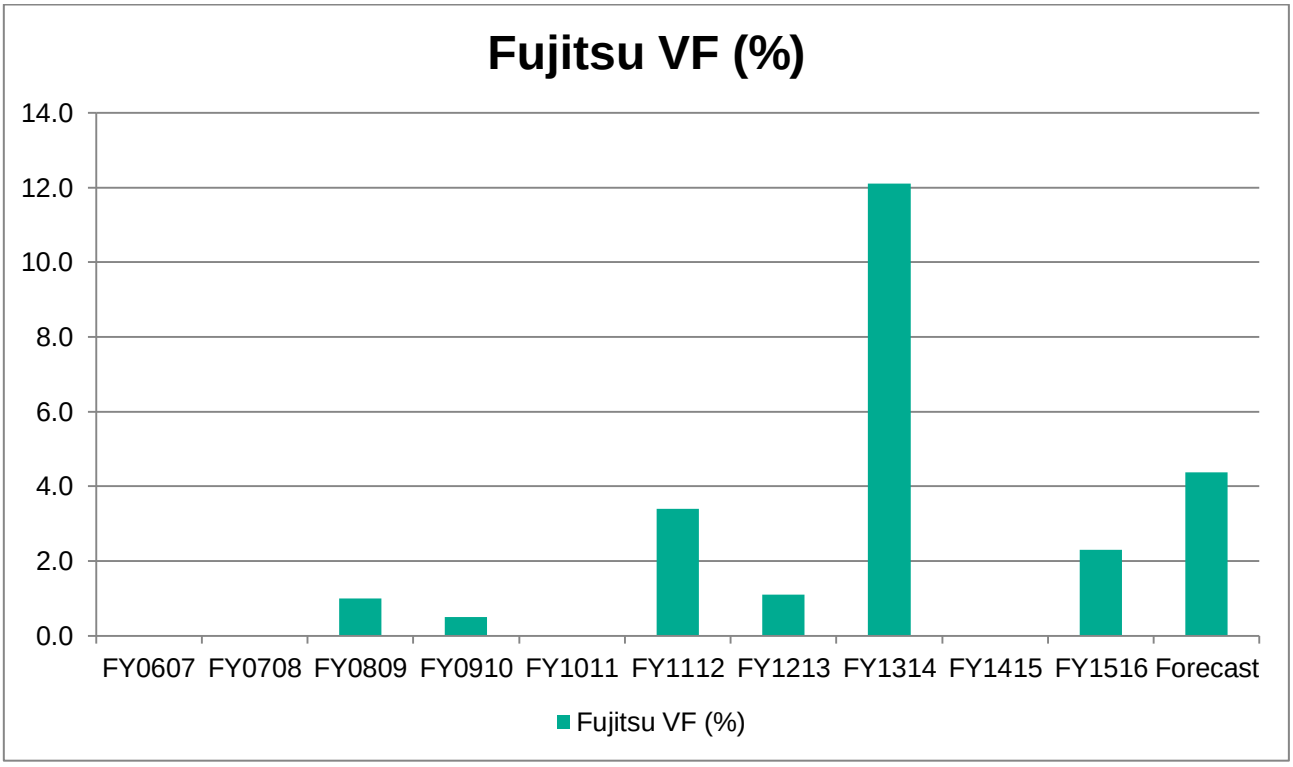

Figure 25 Fujitsu VF Intertrip Defect Rates

Due to the need for VF Intertrips to provide high speed remote end clearance of transmission line faults. Scoring is applied in accordance with brackets of voltage level protected. This is due to the potential network stability impacts and clearance time requirements at different voltage levels.

The figure below illustrates the breakup of the relay population by criticality levels:

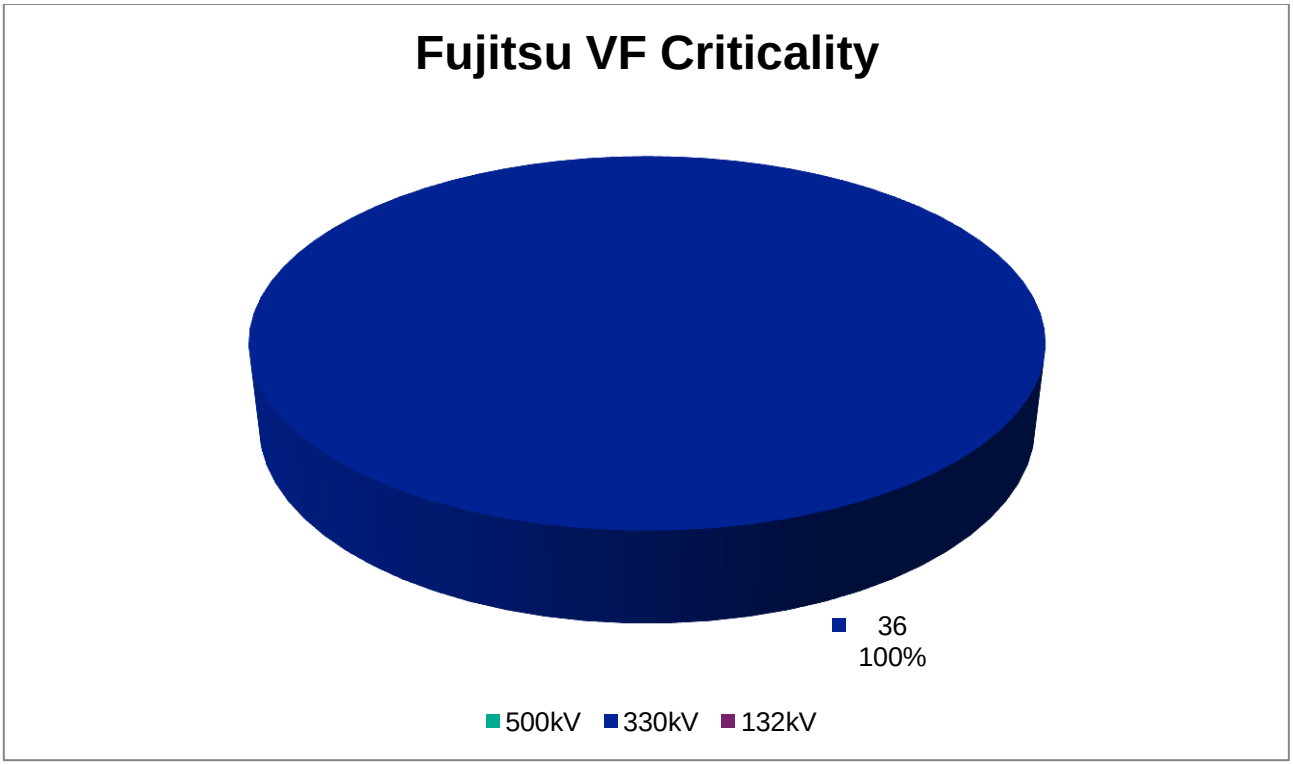

Figure 26 Fujitsu VF Intertrip Criticality

The health of these assets varies and is primarily dependant on manufacturer support, spares availability, forecast defect rates and the technical life of the assets. The health index has been used to identify the assets that require investigation and those that require replacement. Below is a summary of the current health of the assets:

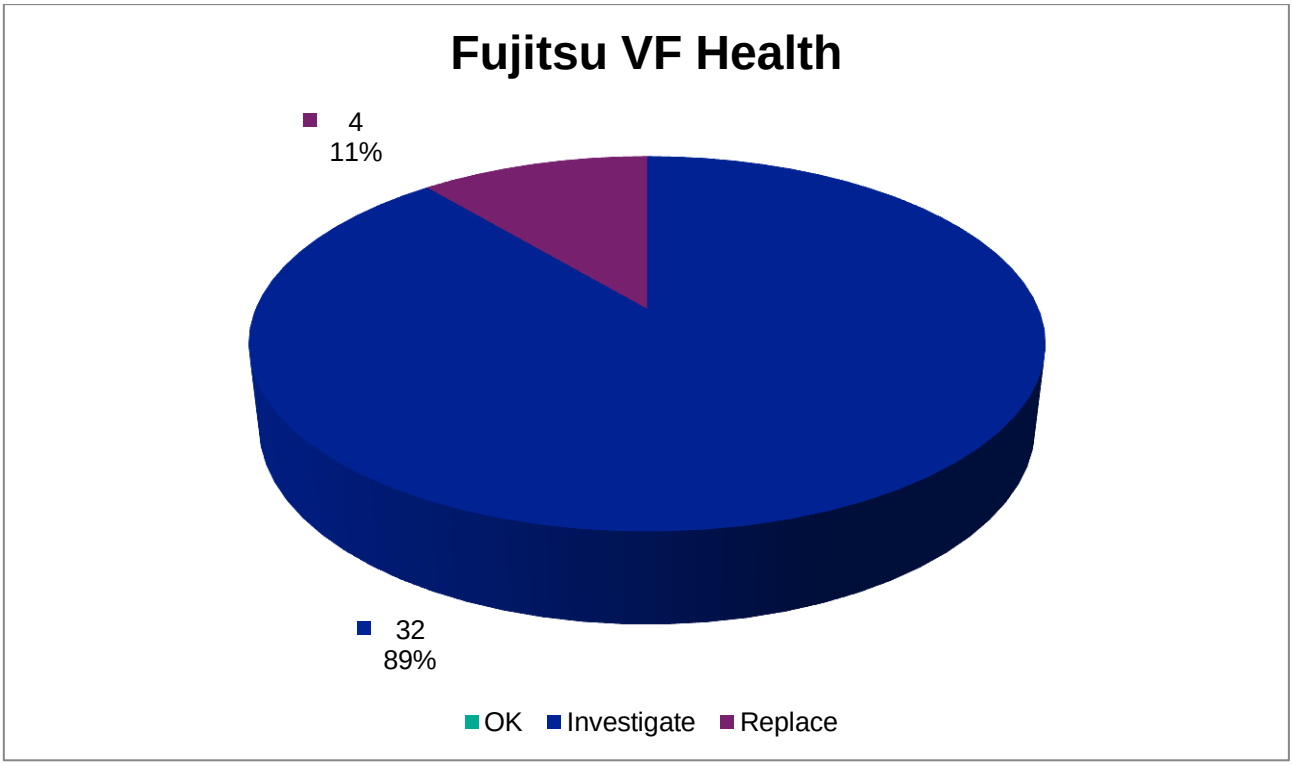

Figure 27 Fujitsu VF Intertrip Health

8.3 Dewar Series VF Intertrip Asset Review

This equipment is based on the use of microprocessors and multi-layer circuit boards. This equipment is the current preferred system for general use within the TransGrid network.

It continues to be maintained by the manufacturer.

Historical performance of this type of asset is summarised in the graph below as an average of percentage defects per population and provides forecast defect rate:

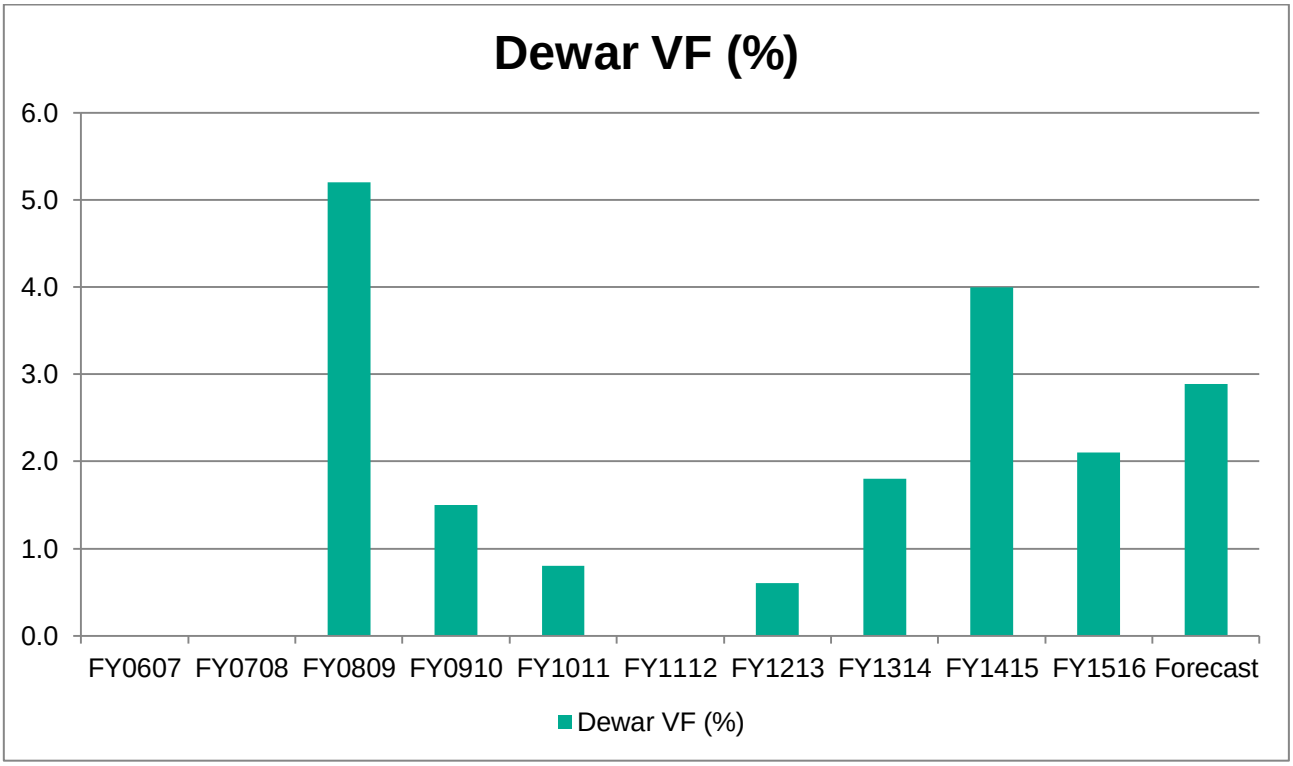

Figure 28 Dewar VF Intertrip Defect Rates

Due to the need for VF Intertrips to provide high speed remote end clearance of transmission line faults. Scoring is applied in accordance with brackets of voltage level protected. This is due to the potential network stability impacts and clearance time requirements at different voltage levels.

The figure below illustrates the breakup of the relay population by criticality levels:

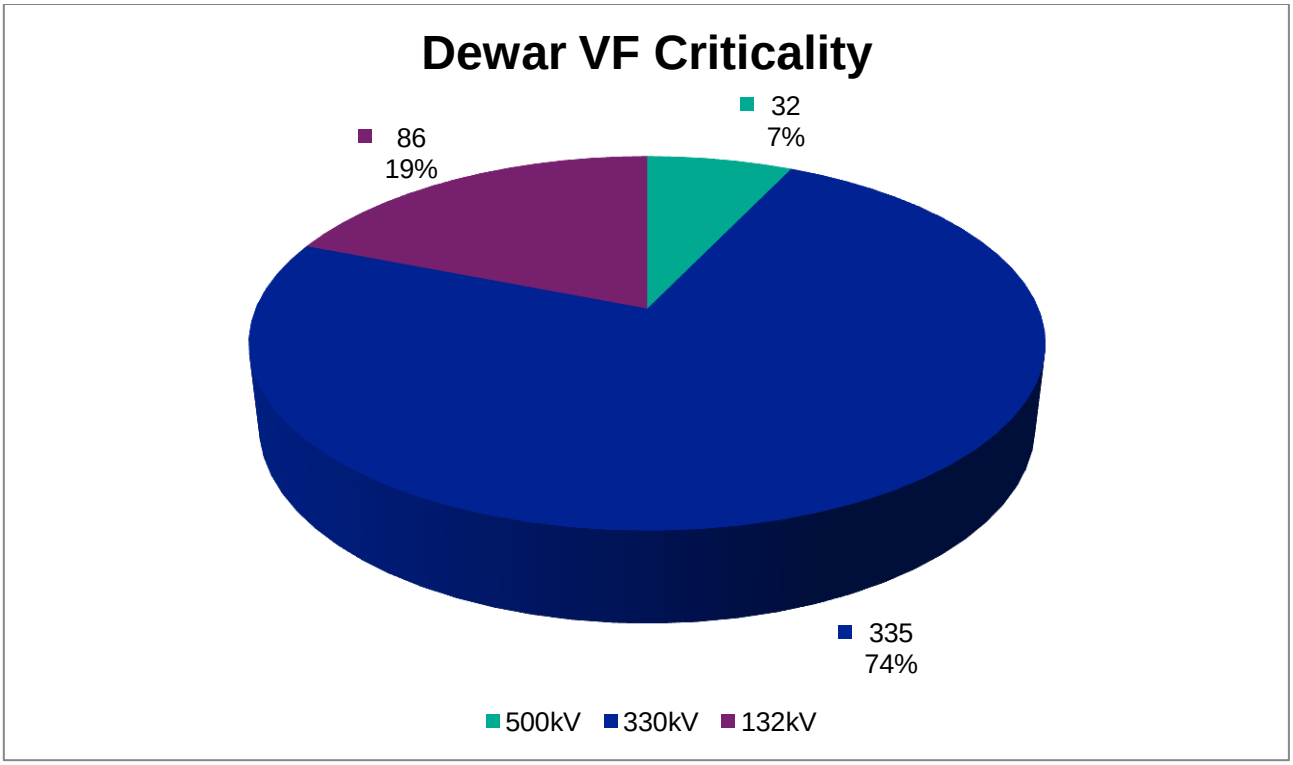

Figure 29 Dewar VF Intertrip Criticality

The health of these assets varies and is primarily dependant on manufacturer support, spares availability, forecast defect rates and the technical life of the assets. The health index has been used to identify the assets that require investigation and those that require replacement. Below is a summary of the current health of the assets:

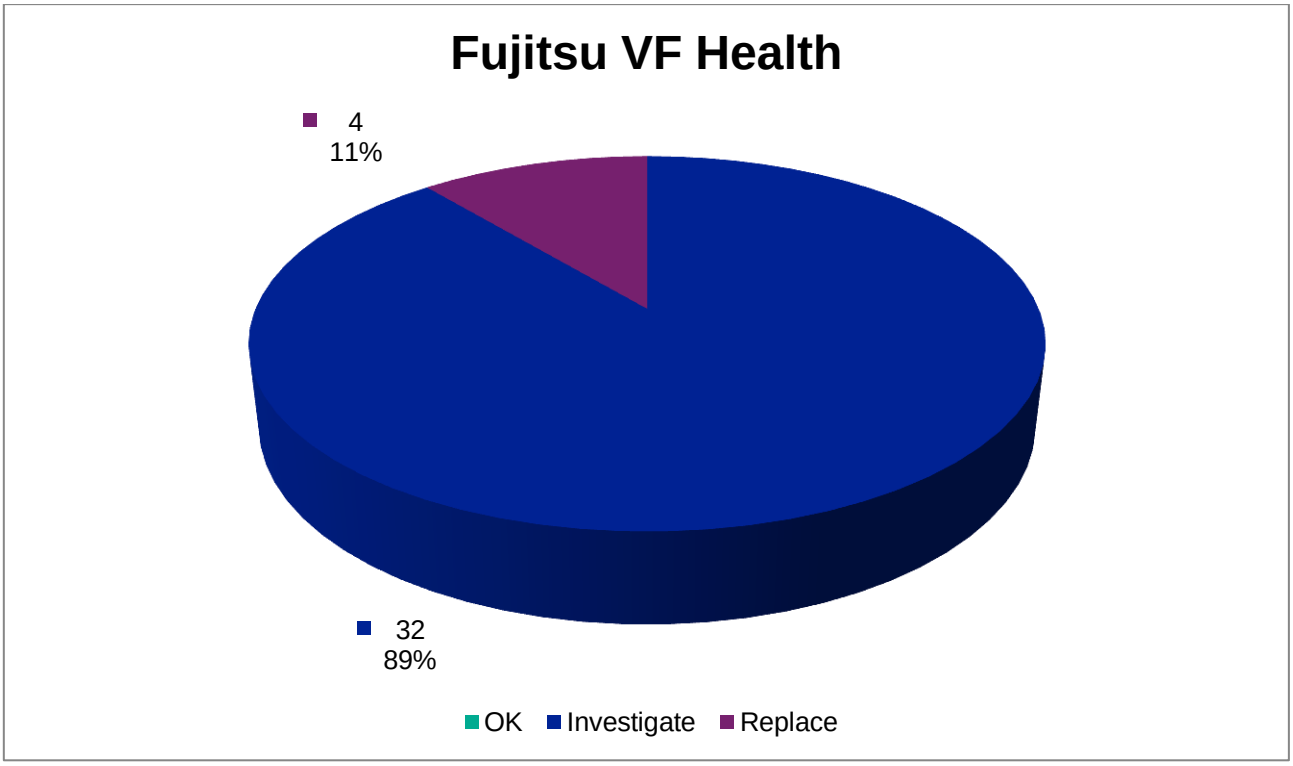

Figure 30 Dewar VF Intertrip Health

8.4 Emerging Issues, and Renewal and Maintenance Initiatives

A major issue currently emerging is the withdrawal of manufacturer support from various models of VF Intertrip within the network. The withdrawal of support introduces issues particularly surrounding the replacement of failed assets. Once spares are depleted, the MTTR of a failed asset increases beyond permissible outage times of a single failed unit and results in the potential for removal from service of primary plant. This is mainly due to the need to develop new designs and build new Intertrip panels, along with several days required for installation and commissioning.

Age profiles for these assets are progressing and as the ages increase annually, Intertrips will need to be renewed in a timely manner to maintain the reliability and security of the network.

The current emerging issues and the renewal and maintenance initiatives to be implemented in response to these issues are summarised in the table below.

Table 9: Emerging Issues, and Renewal and Maintenance Initiatives

Asset	Asset Management Objective	Strategic Initiative	Emerging Issues	Forecast Expenditure ($m)	Reference Documents
• VF Intertrips	• Manage network related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • • Maintain network reliability	• Pursue a replacement strategy to bring protection assets to modern standards.	• Asset health and age	2.13	NS-000001371
• VF Intertrips	• Improve OPEX Performance	• Combine maintenance activities at a site for VF Intertrips due to capability for in service testing.	• N/A	N/A	Maintenance Plan

8.5 Maintenance Program

Routine maintenance is based on periodic testing and inspection of VF Intertrip installations to determine their adequacy for maintaining the remote end clearance time requirements during contingent fault events. Routine maintenance is scheduled at regular intervals which are balanced against previous performance particularly in the detection of defects. Additionally, VF Intertrips are tested as part of the routine maintenance activities of the associated primary protection relays.

Failures that are identified during the normal operation of the assets are addressed in emergency replacement of the failed unit. This is to meet NER requirements and ensure that duplicated protection schemes are maintained throughout the network.

The maintenance program is reviewed annually and for this financial year (2016/17), only a change in the bundling of testing at sites has been implemented due to the ability for modern VF Intertrips to be tested while the corresponding Transmission Line is in service. This change facilitates the testing of all VF Intertrips at a site during a single visit as opposed to multiple visits at varying times to test individual Transmission Lines.

9. Analysis Equipment Asset Review

This section details the emerging issues with the Analysis assets, and the renewal and maintenance initiatives to be implemented to address the issues. These are derived through the renewal and maintenance decision process outlined in the *Asset Management Strategy and Objectives* document.

All strategic initiatives with respect to TransGrid's Analysis assets are outlined in this section, including the renewal and maintenance initiatives that contribute to the asset management program of works. Further details can be found in the relevant Automation Systems Maintenance Plan, and the referenced governance documents.

Whereas asset criticality is inherently dependent upon the primary assets that are serviced by the secondary systems automation assets, asset health analysis is based upon spares availability, known issues, self-monitoring capabilities as well as age. Asset health has been categorised as three levels;

- OK - assets not requiring any actions at this time as there are no know issues, and a failure of a unit can be addressed immediately.
- Investigate - assets where should an asset fail, it may not be addressed adequately to meet legislative requirements under the current configuration and therefore either replacement or acquisition of spares holdings.
- Replace - assets where immediate replacement is recommended due to the lack of ability for TransGrid to address asset failures within a reasonable timeframe to return an asset to service.

9.1 All Assets Review

Analysis equipment assets are utilised to review and analyse performance of the network. The vast majority of these assets are microprocessor based and are utilised to support the operation of the network.

The assets can be sub categorised into the following:

- Disturbance Recorders - High speed microprocessor based monitoring and recording equipment that allow the review of various network parameters prior to, during and post a disturbance event. Due to the nature of data requirements for disturbance analysis, a dedicated device is required for this function and Disturbance monitors allow this function to be met.
- Fault Recorders - Dedicated microprocessor based monitoring and recording equipment similar to disturbance recorders with the high specifications. Traditionally these devices monitor multiple analogue and digital values and allow for the analysis of system performance during a fault event in the network. These assets are generally used at the 330kV and 500kV voltage levels.
- Travelling Wave Locators - Dedicated microprocessor based devices that provide very accurate location of faults (within +/- 200 meters) as opposed to utilising protection relays "distance to fault" which can have an error margin of +/- 1km due to the reliance on impedance characteristics.
- Quality of Supply Monitors - Dedicated microprocessor based specialist metering devices capable of monitoring sufficient values to meet the requirements for network voltages as set In Schedule S5.1 of the NER.

- Statistical Meters - Microprocessor based class 0.2 and class 0.5 meters throughout the network that were traditionally used to monitor network energy flows in various locations where earlier control and monitoring systems were insufficient. Some installations are a result of a customer changing their preferred metering point to outside TransGrid's network resulting in stranded assets.

The criticality of these assets are broken down into those that are required by AEMO which is pursuant to Clause 4.11.1(d) of the NER, those assets that provide operational benefits to asset managers, planners, operators and designers, and those assets which are to be considered as obsolete and no longer required for the operation of the network. A summary of these criticalities is provided below:

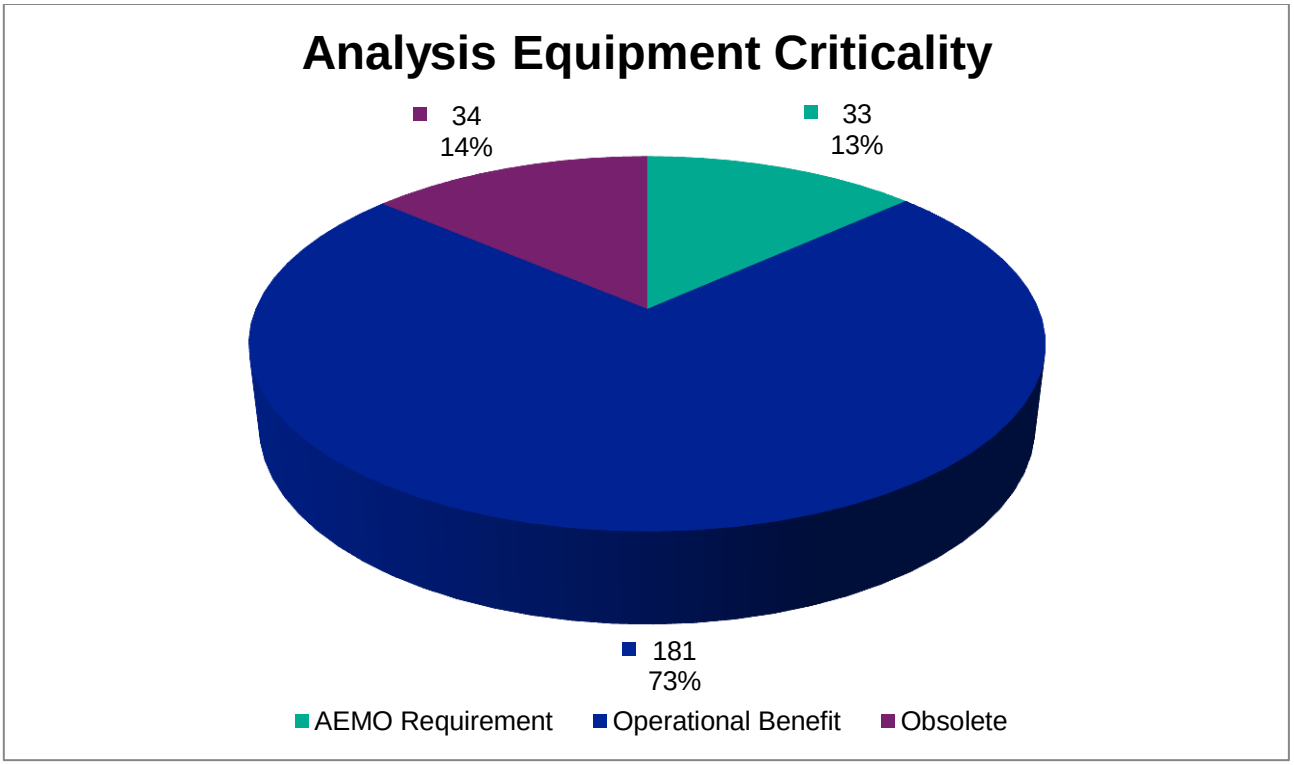

Figure 31 Analysis Equipment Criticality

Due to the essentially non-critical nature of these assets, an analysis of asset health has not been carried out at this time.

9.2 Emerging Issues, and Renewal and Maintenance Initiatives

No specific renewal initiatives have been initiated for these assets. Under the latest investment framework, an analysis of cost benefits has found that the optimal solution for TransGrid is to run to failure. The current approach is to replace on failure as required for those assets that are part of the AEMO requirements for High Speed Monitor (HSM). This approach may increase our risk for non-compliance with AEMO's requirements. It is noted that these HSM systems fall under "remote monitoring equipment" and have been assigned an availability requirement as outlined in AEMO's "HSM Specification" that;

"*Remote monitoring equipment* and *data communications facilities used* for HSM shall be designed to reasonably ensure that in any 12 month assessment period:

i) the total period of *critical outages* of any *remote monitoring equipment* including associated *data communications facilities* is not greater than 5 business days per site; "

Due to the emerging capability on modern protection relays for accurate fault recording, where non-HSM fault recorders fail, their continued requirement is analysed and a determination is made as to whether they are replaced or the associated protection relays are capable of performing fault recording tasks. This is determined on a case by case basis.

Age profiles for these assets are progressing and as the ages increase annually, defect rates are expected to rise.

The current emerging issues and the renewal and maintenance initiatives to be implemented in response to these issues are summarised in the table below.

Table 10: Emerging Issues, and Renewal and Maintenance Initiatives

Asset	Asset Management Objective	Strategic Initiative	Emerging Issues	Forecast Expenditure ($m)	Reference Documents
• Disturbance Recorders	• National Electricity Rules Compliant •	• Replace AEMO required HSM systems upon failure.	• Asset health and age	NA	NA
• Fault Recorders •	• Maintain Network Capability •	• Review requirements on failure and replace as necessary	• Asset health and age	NA	NA
• Travelling Wave Locators	• Pursue STPIS revenue where cost effective	• Replace on failure	• Asset health and age	NA	NA

9.3 Maintenance Program

No specific preventative maintenance is carried out on Analysis Equipment. The policy is to address issues upon failure. Where the asset is a statistical meter, it is to be removed from service upon failure.

10. Control Systems Asset Review

This section details the emerging issues with the Control assets, and the renewal and maintenance initiatives to be implemented to address the issues. These are derived through the renewal and maintenance decision process outlined in the *Asset Management Strategy and Objectives* document.

All strategic initiatives with respect to TransGrid's Control assets are outlined in this section, including the renewal and maintenance initiatives that contribute to the asset management program of works. Further details can be found in the relevant Automation Maintenance Plan, and the referenced governance documents.

10.1 Implementation of the Renewal and Maintenance Decision Process

Asset Health and Asset Criticality have been combined using a scoring methodology to provide a ranking for all assets. Criticality is scored on the basis of the consequence of the failure of the asset. Asset Health is calculated as per the Network Asset Health Framework.

Whereas asset criticality is inherently dependent upon the primary assets that are serviced by the secondary systems automation assets, asset health analysis is based upon spares availability, known issues, self-monitoring capabilities as well as age. Asset health has been categorised as three levels;

- OK - assets not requiring any actions at this time as there are no know issues, and a failure of a unit can be addressed immediately.
- Investigate - assets where should an asset fail, it may not be addressed adequately to meet legislative requirements under the current configuration and therefore either replacement or acquisition of spares holdings.
- Replace - assets where immediate replacement is recommended due to the lack of ability for TransGrid to address asset failures within a reasonable timeframe to return an asset to service.

10.2 MD1000 RTU Asset Review

The MD1000 family of RTUs are of the earliest generation of controllers utilised in the TransGrid network. These assets were used in a centralised controller philosophy where there is a single brain and multiple IO points for the various primary assets controlled. These assets are microprocessor and Linux based and require specific and complex programming in a variation of C Language.

These assets are no longer supported by the manufacturer and have been progressively upgraded to modern systems.

Historical performance of this type of asset is summarised in the graph below as an average of percentage defects per population and provides forecast defect rate:

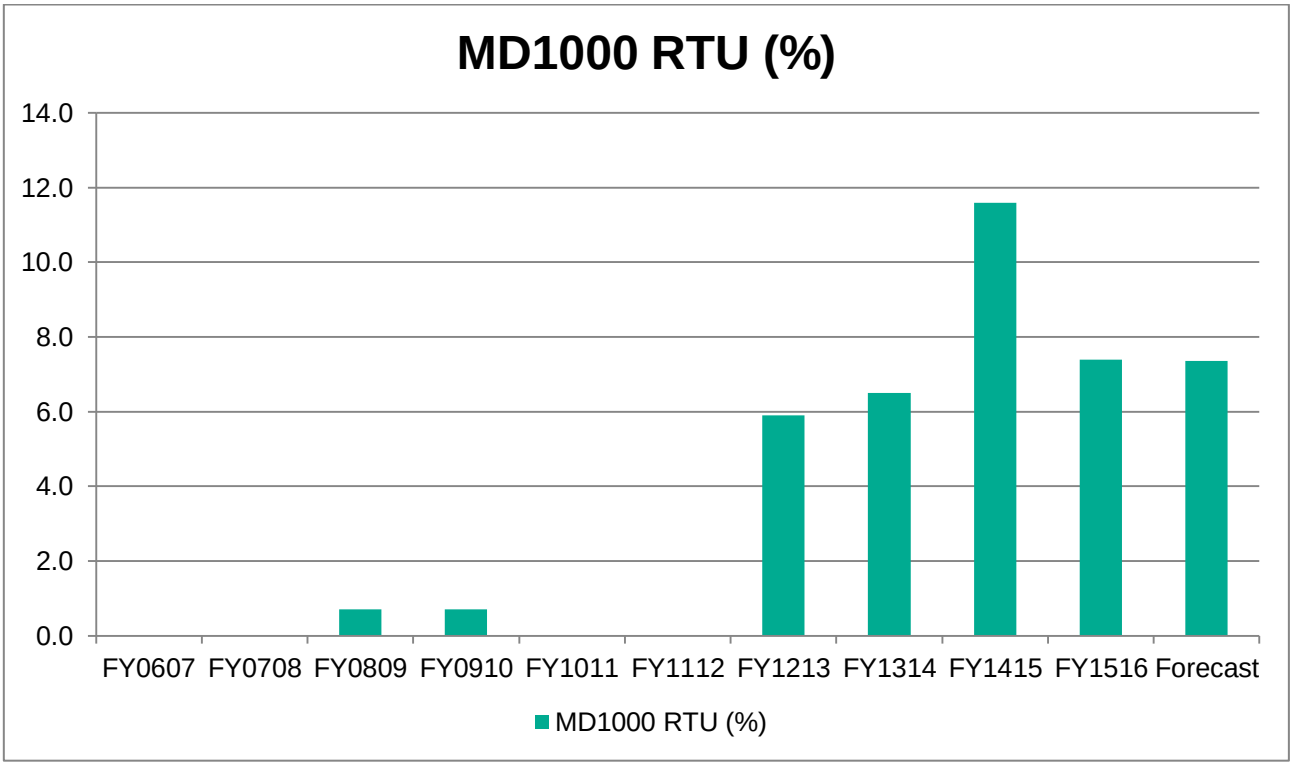

Figure 32 MD1000 RTU Defect Rate

Due to the need for control systems to monitor and operate all aspects of an unmanned high voltage electricity transmission station, criticality has been categorised on the purpose for the station which is being controlled based on generation connector, transmission network backbone or Distributor connection point.

The figure below illustrates the breakup of the asset population by criticality levels:

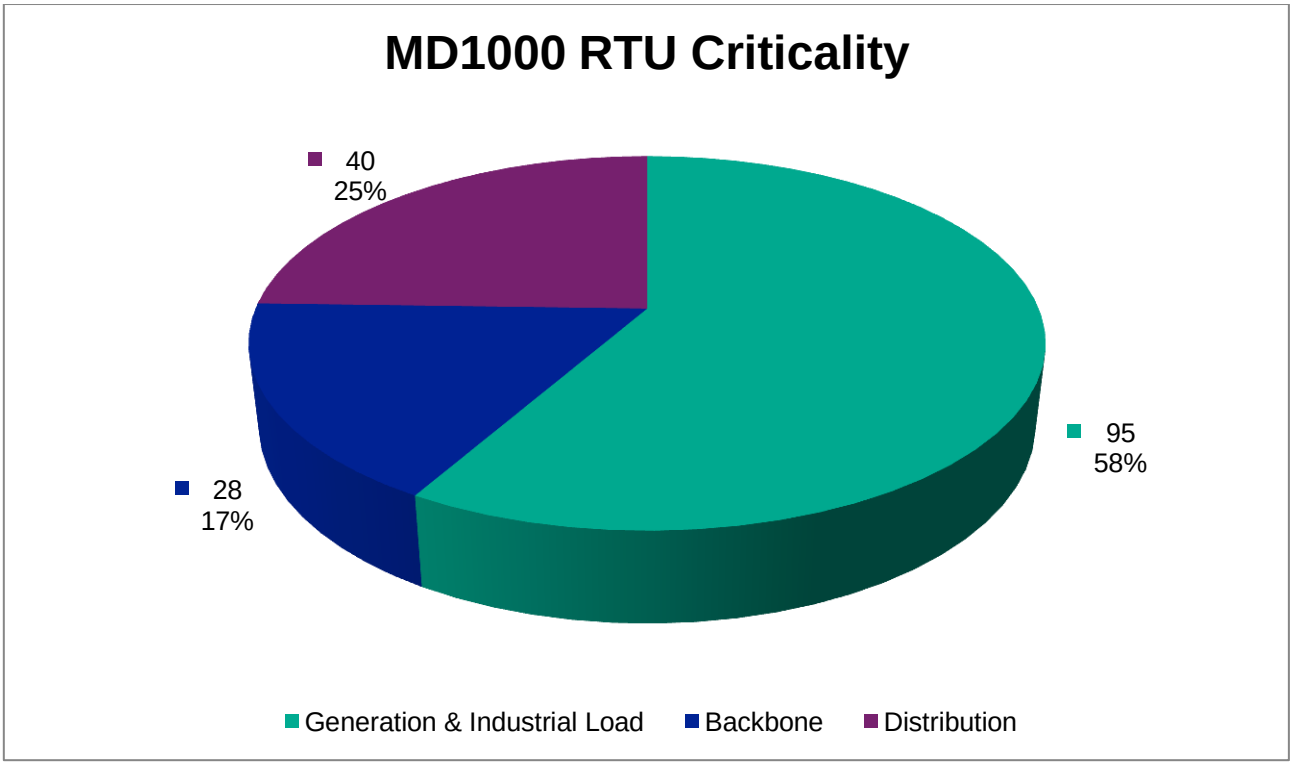

Figure 33 MD1000 RTU Criticality

The health of these assets varies and is primarily dependant on manufacturer support, spares availability, forecast defect rates and the technical life of the assets. The health index has been used to identify the assets that require investigation and those that require replacement. Below is a summary of the current health of the assets:

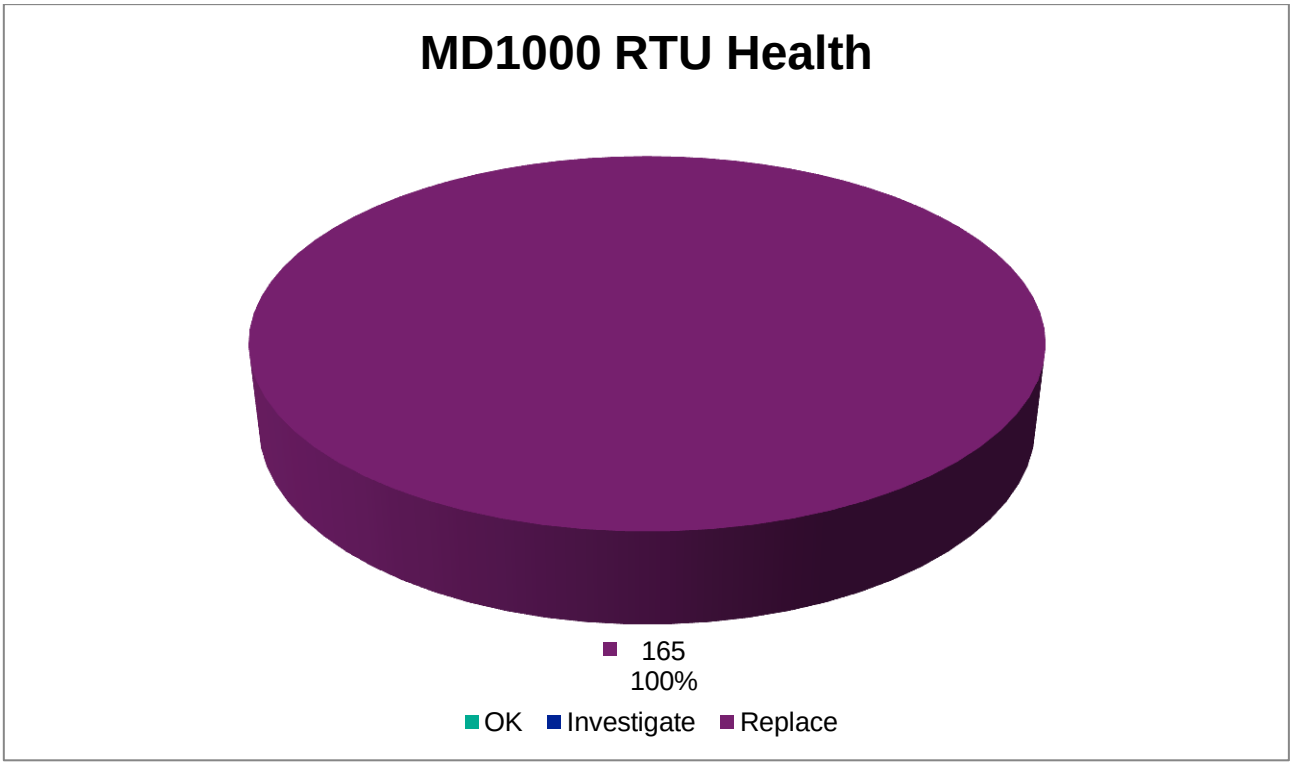

Figure 34 MD1000 RTU Health

10.3 MD3311 RTU Asset Review

The MD3311 series of RTUs were the second generation of microprocessor RTUs utilised in TransGrid's network. These assets were used for both centralised and distributed controller design philosophies. These assets are microprocessor and Linux based and require specific and complex programming in a variation of C Language.

These assets are no longer supported by the manufacturer and have been progressively upgraded to modern systems.

Historical performance of this type of asset is summarised in the graph below as an average of percentage defects per population and provides forecast defect rate:

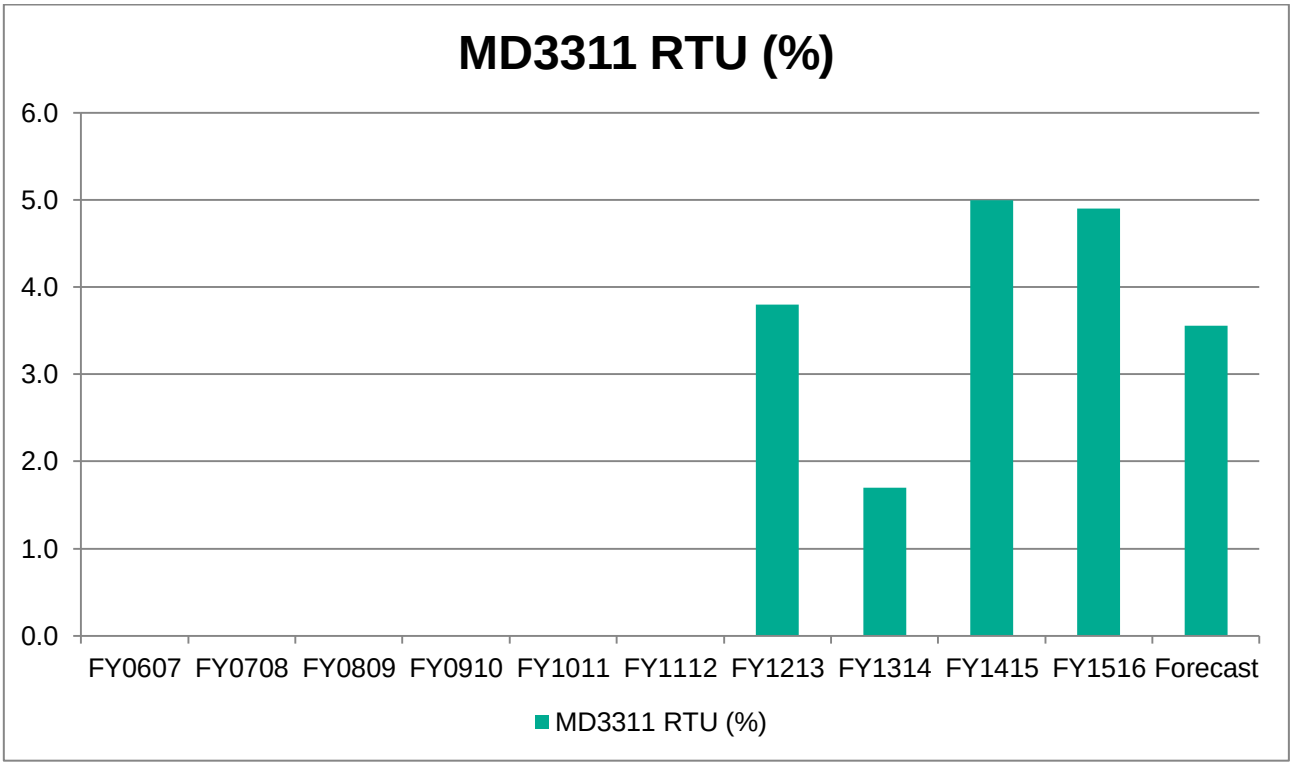

Figure 35 MD3311 RTU Defect Rates

Due to the need for control systems to monitor and operate all aspects of an unmanned high voltage electricity transmission station, criticality has been categorised on the purpose for the station which is being controlled based on generation connector, transmission network backbone or Distributor connection point.

The figure below illustrates the breakup of the asset population by criticality levels:

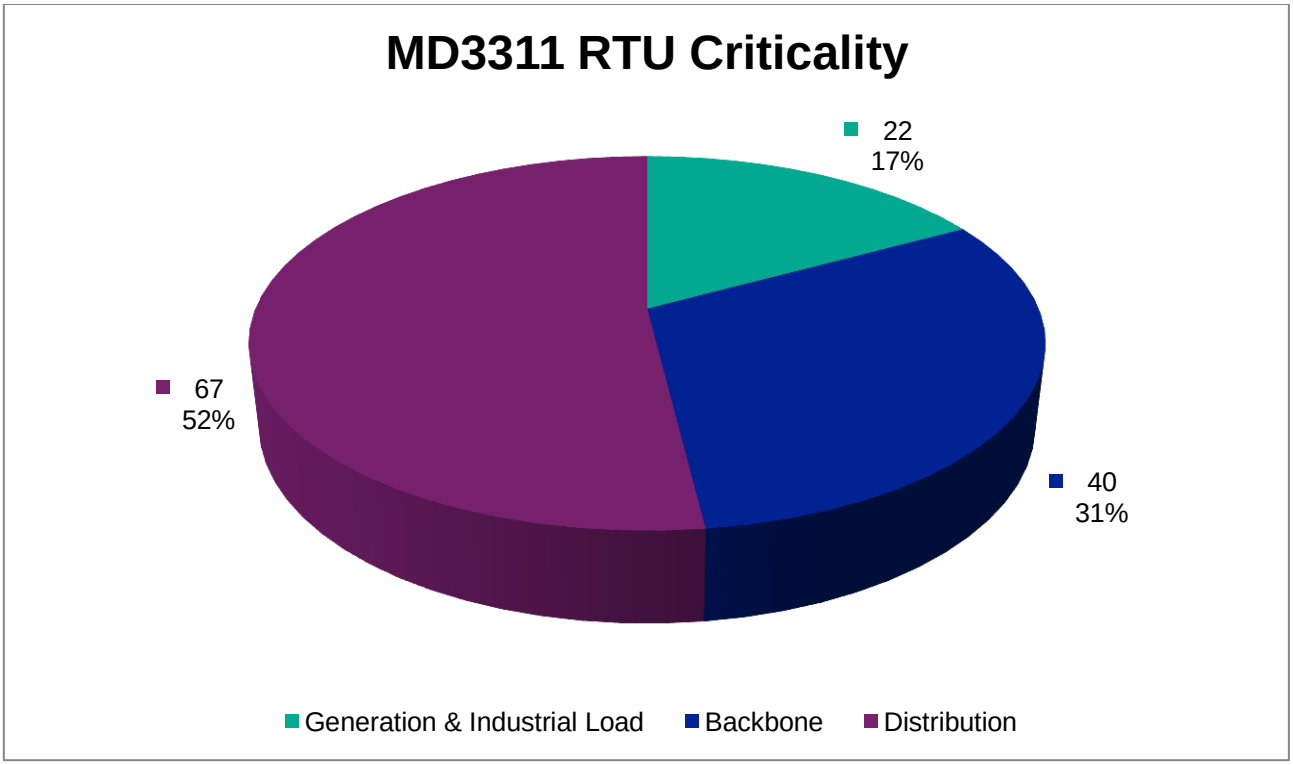

Figure 36 MD3311 RTU Criticality

The health of these assets varies and is primarily dependant on manufacturer support, spares availability, forecast defect rates and the technical life of the assets. The health index has been used to identify the assets that require investigation and those that require replacement. Below is a summary of the current health of the assets:

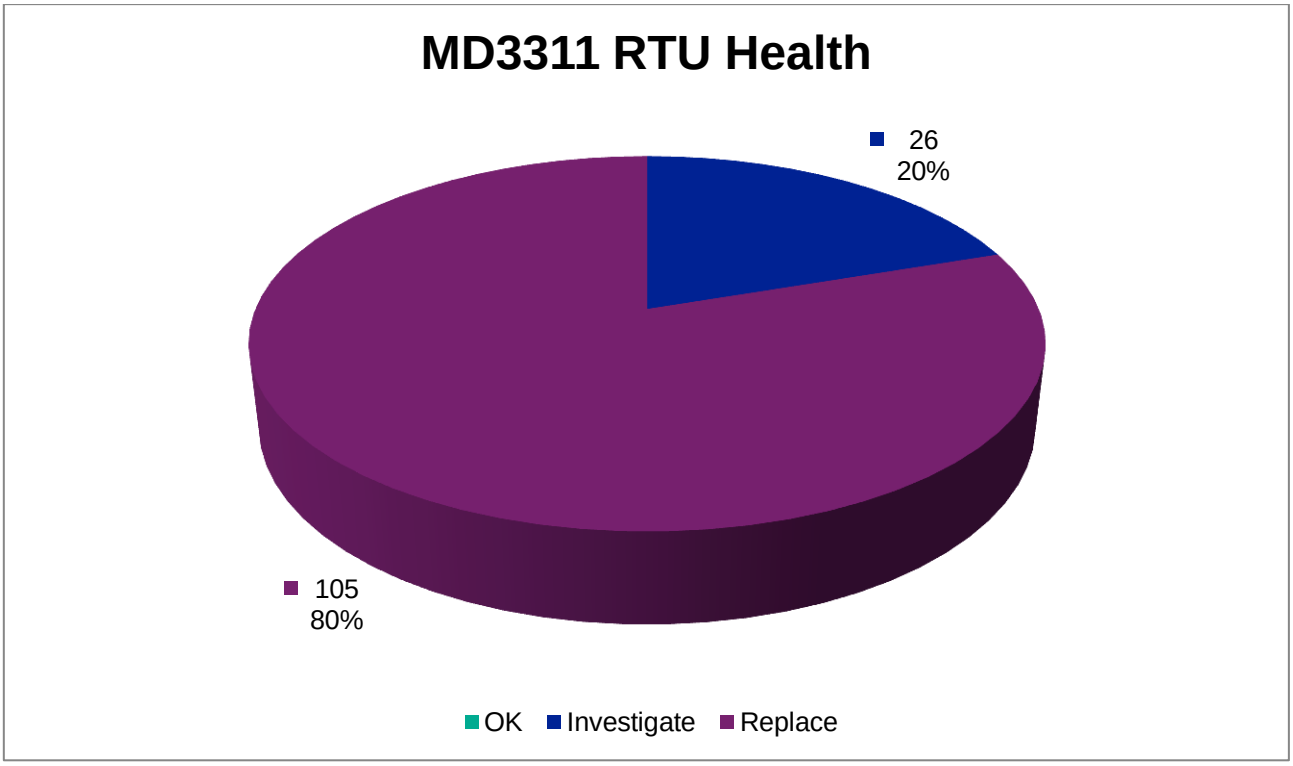

Figure 37 MD3311 RTU Health

10.4 Modern RTU Asset Review

Modern RTUs are the latest generation of control equipment utilised within TransGrid's network. The assets span multiple manufacturers and differing models. Manufacturer support has ceased for several models under this category. These assets are used primarily with the distributed control philosophy. These assets are microprocessor and Linux based and require specific and complex programming in a variation of C Language.

Historical performance of this type of asset is summarised in the graph below as an average of percentage defects per population and provides forecast defect rate:

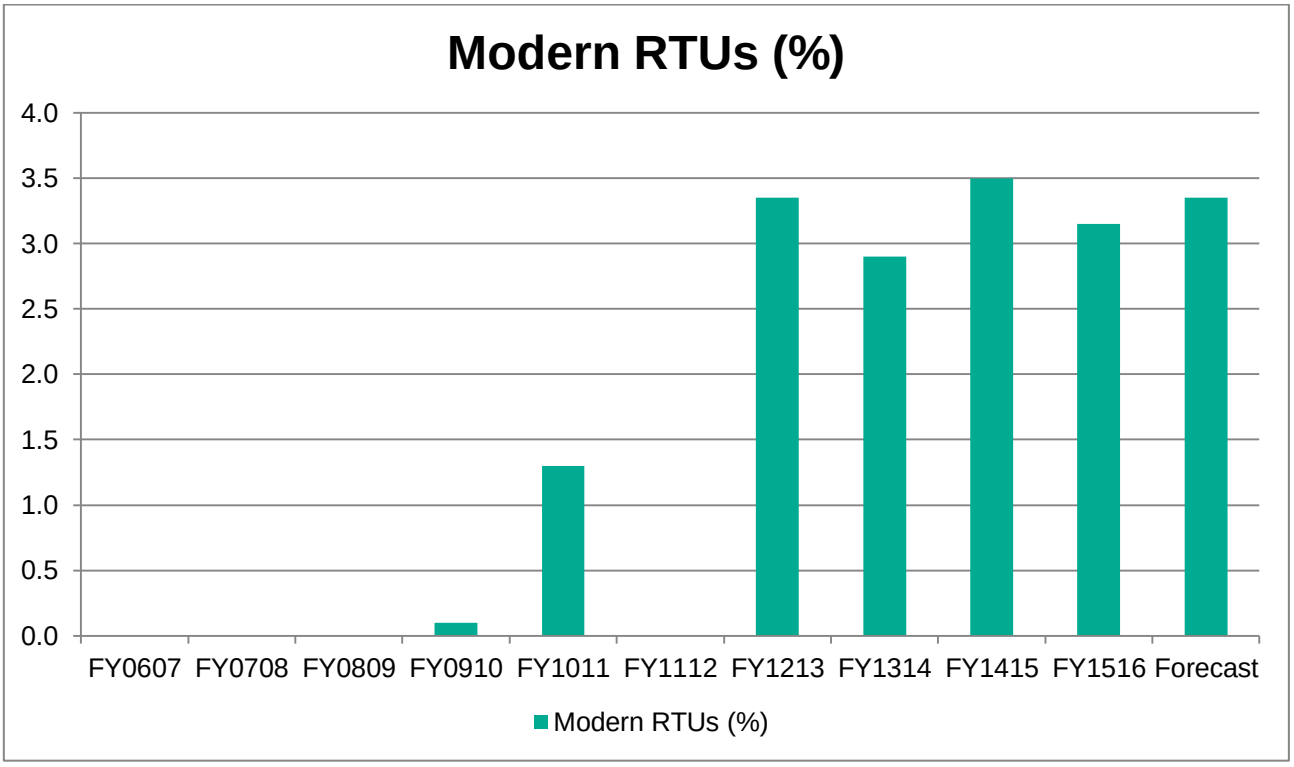

Figure 38 Modern RTU Defect Rates

Due to the need for control systems to monitor and operate all aspects of an unmanned high voltage electricity transmission station, criticality has been categorised on the purpose for the station which is being controlled based on generation connector, transmission network backbone or Distributor connection point.

The figure below illustrates the breakup of the asset population by criticality levels:

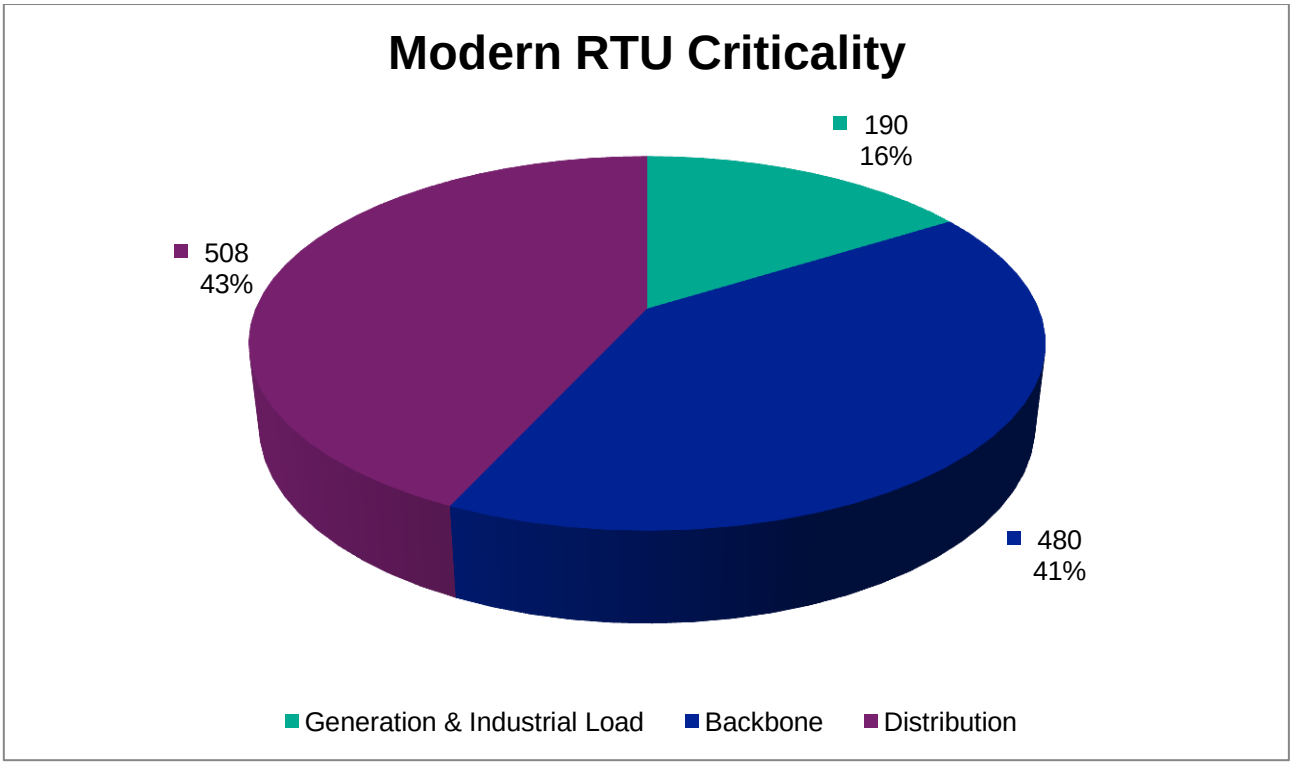

Figure 39 Modern RTU Criticality

The health of these assets varies and is primarily dependant on manufacturer support, spares availability, forecast defect rates and the technical life of the assets. The health index has been used to identify the assets that require investigation and those that require replacement. Below is a summary of the current health of the assets:

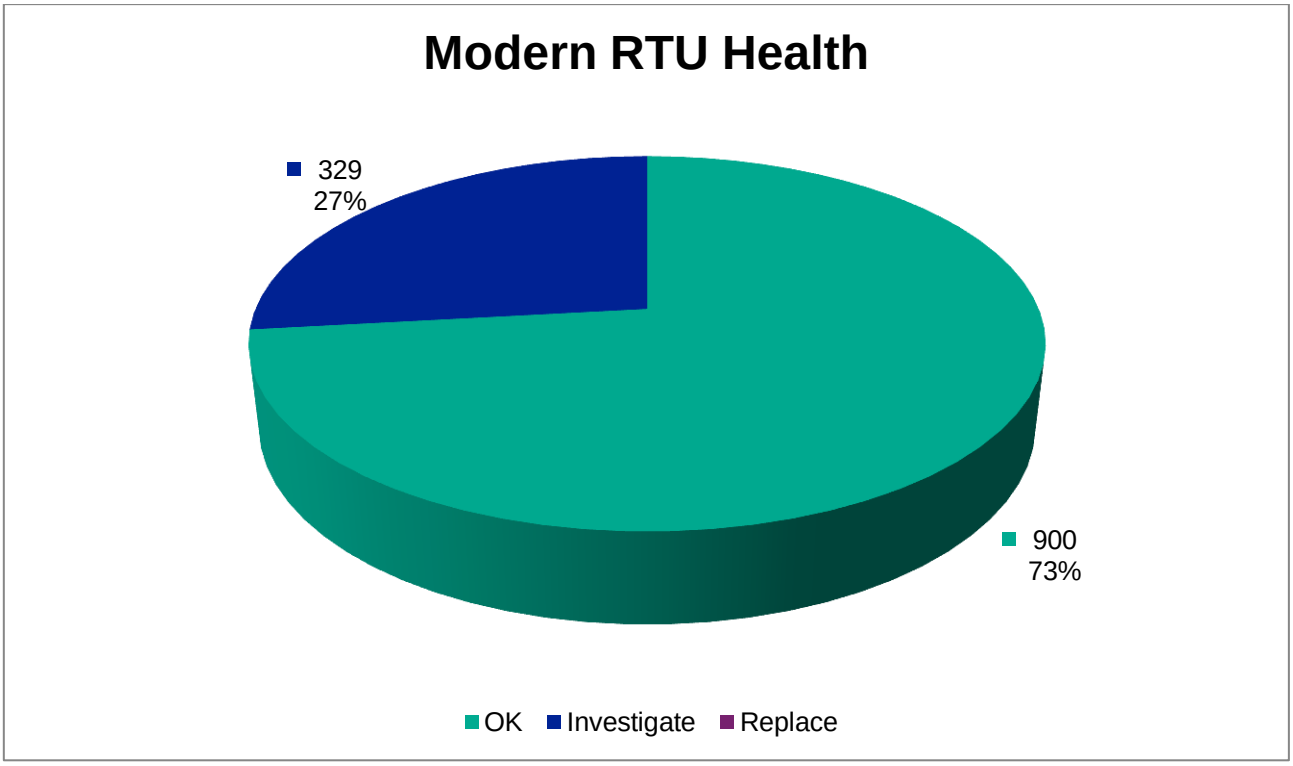

Figure 40 Modern RTU Health

10.5 HMI Asset Review

HMIs are based on an industrial PC package utilising Serck SCX6 as the software interface platform. The systems operate on the Windows XP operating system.

HMIs are used for local control of plant (from within the site) during maintenance activities and for the collection of operational information as a historian system.

Historical performance of this type of asset is summarised in the graph below as an average of percentage defects per population and provides forecast defect rate:

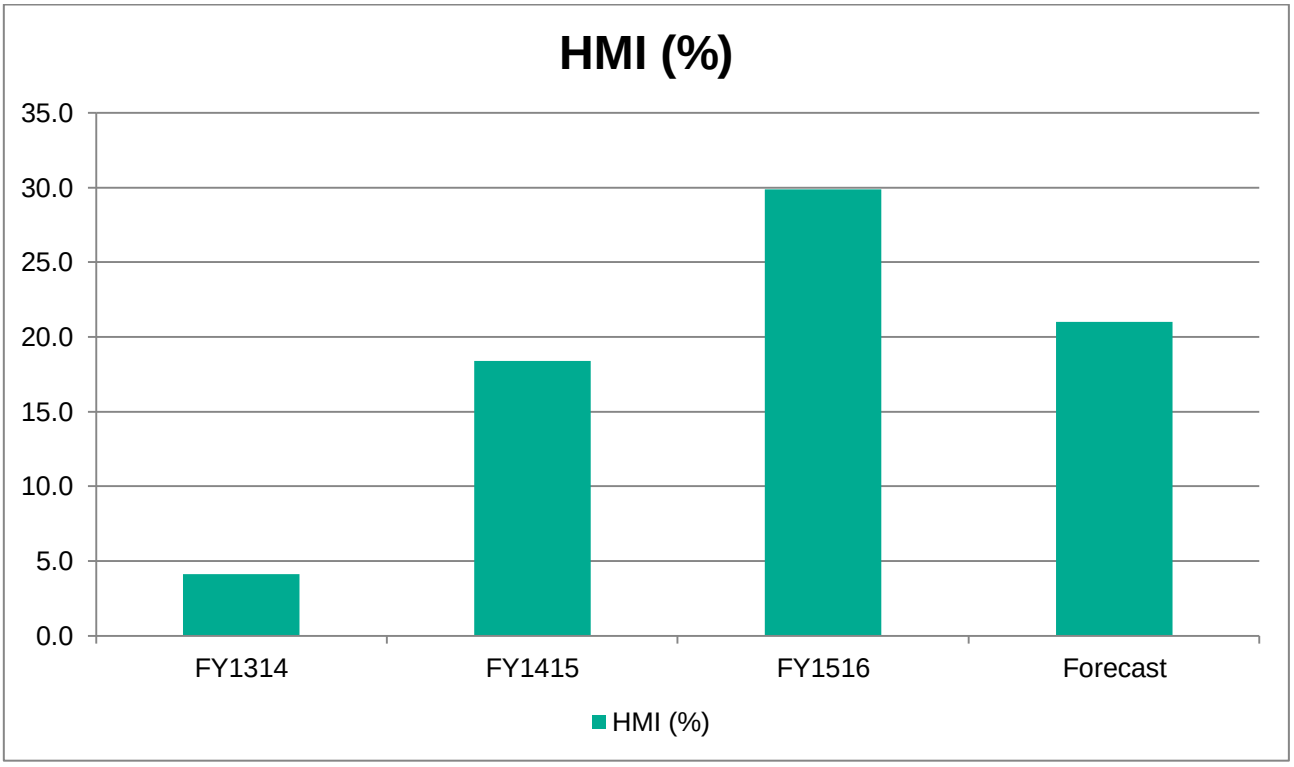

Figure 41 HMI Defect Rates[2]

Due to the need for control systems to monitor and operate all aspects of an unmanned high voltage electricity transmission station, criticality has been categorised on the purpose for the station which is being controlled based on generation connector, transmission network backbone or distributor connection point.

The figure below illustrates the breakup of the asset population by criticality levels:

[2] Recording of HMI defect rates only commenced in Financial Year 2013/14

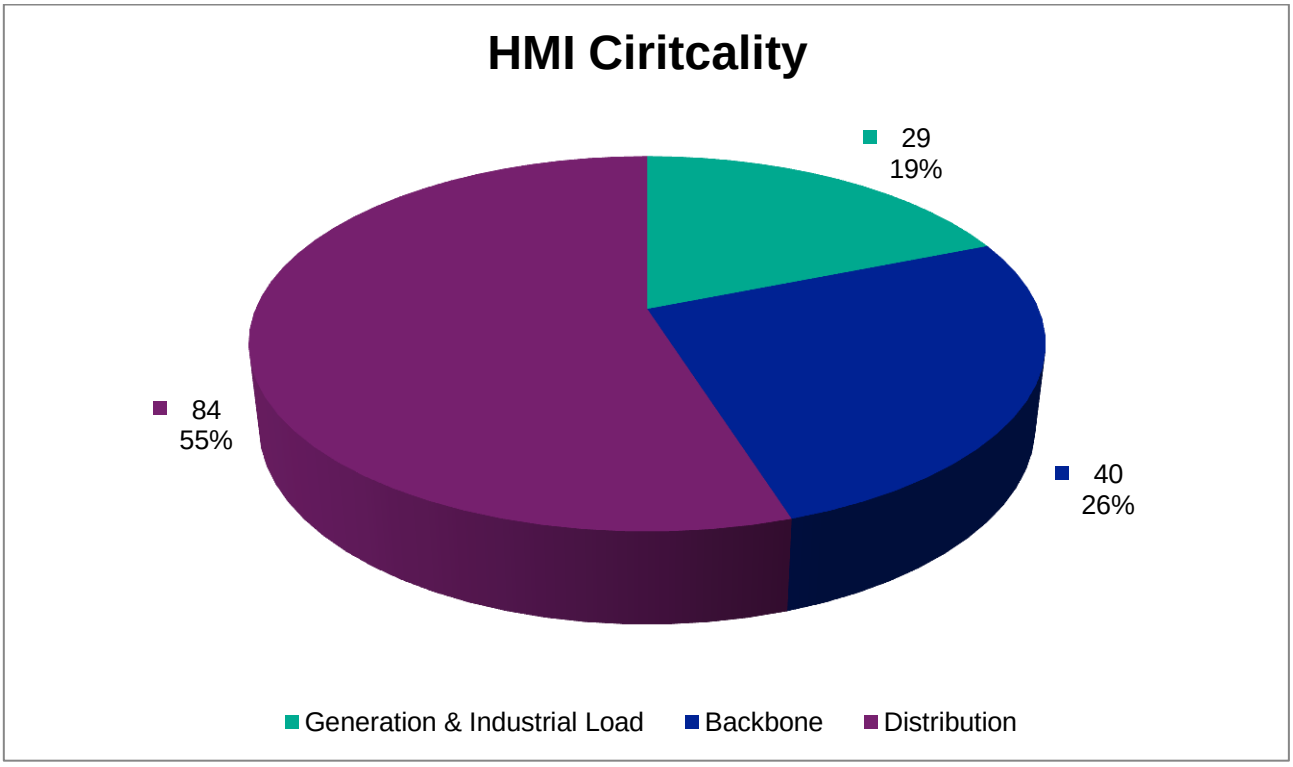

Figure 42 HMI Criticality

The health of these assets varies and is primarily dependant on manufacturer support, spares availability, forecast defect rates and the technical life of the assets. The health index has been used to identify the assets that require investigation and those that require replacement. Below is a summary of the current health of the assets:

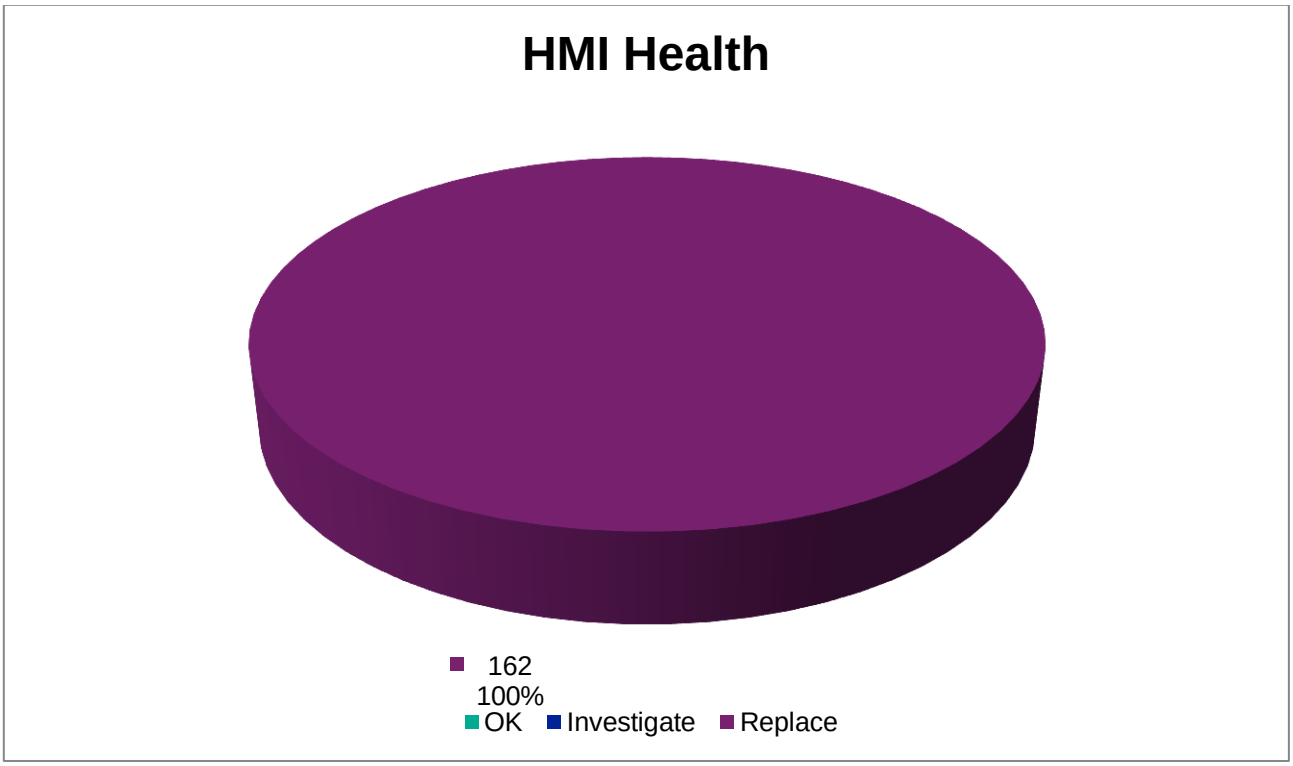

Figure 43 HMI Health

10.6 Orphaned Control System Sites

Orphaned systems are standalone non-standard control systems deployed with Design and Construct projects where the contractor was not limited to implementing TransGrid approved equipment. There are currently 3 sites operating with these types of systems.

- Gadara - ABB system - In Service 16 years
- Haymarket - Siemens system - In Service 12 years
- Molong - Alstom system - In Service 15 years

These systems are all microprocessor based assets with an expected life of 15 years.

10.7 SVC Control Systems

SVC control systems are manufacturer specific systems for the internal control of SVCs. These systems are specifically designed and commissioned for the unique SVC configuration at each site.

There are currently 4 sites operating with SVC systems.

Armidale - In Service 2 years

Broken Hill - (2x SVCs) In Service 1 year

Lismore - In Service 16 years

Sydney West - In Service 12 years

10.8 Emerging Issues, and Renewal and Maintenance Initiatives

A major issue currently emerging is the withdrawal of manufacturer support from various models of microprocessor assets within the network. The withdrawal of support introduces issues particularly surrounding the replacement of failed assets. Once spares are depleted, the MTTR of a failed asset increases beyond permissible outage times of a single failed unit and results in the extensive expenditure for development of replacements. This is mainly due to the need to develop new designs and build new panels, along with several days required for installation and commissioning.

RTU systems require several additional assets to successfully perform their tasks including transducers, synch check relays and power meters. This results in additional maintenance requirements and spares management requirements for all ancillary components.

Additionally, the older types of RTU assets that utilised a centralised control philosophy face additional issues once units fail in that a heavily specialised design of a new unit is required to match the overall design installed at the affected site. This often leads to severe increases in replacement costs, particularly where communications protocols available in remaining devices are not TCP/IP compliant.

Renewal of these assets has been targeted as part of complete secondary systems renewal initiatives as outlined in the Secondary Systems Site Installations Renewal and Maintenance Strategy.

HMIs are facing obsolescence in the form of hardware, software and the withdrawal of support of Microsoft Windows XP. This has resulted in difficulties to replace even failed units mainly due to the advent of new BIOS technologies (UEFI) that do not allow Microsoft Windows XP to be installed. Additionally as existing licensed copies of XP are depleted, there is no way to procure more licences for further installations.

Table 11: Emerging Issues, and Renewal and Maintenance Initiatives

Asset	Asset Management Objective	Strategic Initiative	Emerging Issues	Forecast Expenditure ($m)	Reference Documents
• RTU	• Manage network related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Maintain network reliability • Improve OPEX Performance	• Replace on failure and through Secondary Systems Renewal projects as identified in the Site Installations Renewal and Maintenance Strategy	• As aged and unsupported assets fail, they result in loss of asset visibility and operability for extended periods	NA	NS-000001359
• HMI	• Maintain network reliability • Improve OPEX Performance	• Replace assets with modern design utilising modern software and operating systems	• Obsolescence of operating system and software means failed units can no longer be replaced	$3.00	NS-00001111
• SVC Control	• Maintain network reliability • Improve OPEX Performance	• Replace identified systems	• Age and obsolescence result in faults. TransGrid cannot repair the obsolete technologies internally or externally	$16.4	NS-00001286 NS-00001287

10.9 Maintenance Program

The current maintenance program for control assets is essentially defect based corrective maintenance. The only periodical maintenance applies to Transducer testing and Auto-Reclose checks carried out at intervals to determine the correct operation of these assets.

Due to the "operate or fail" nature of RTUs and HMIs, there is no need for the establishment of maintenance routines for these assets.

The maintenance program is reviewed annually and no changes have been identified or applied for this financial year (2016/17).

11. DC Supplies Asset Review

This section details the emerging issues with the DC Supply assets, and the renewal and maintenance initiatives to be implemented to address the issues. These are derived through the renewal and maintenance decision process outlined in the *Asset Management Strategy and Objectives* document.

All strategic initiatives with respect to TransGrid's DC Supply assets are outlined in this section, including the renewal and maintenance initiatives that contribute to the asset management program of works. Further details can be found in the relevant Automation Maintenance Plan, and the referenced governance documents.

Whereas asset criticality is inherently dependent upon the primary assets that are serviced by the secondary systems automation assets, asset health analysis is based upon spares availability, known issues, self-monitoring capabilities as well as age. Asset health has been categorised as three levels;

- OK - assets categorised as "OK" do not require any actions at this time as there are no know issues, and a failure of a unit can be addressed immediately.
- Investigate - assets requiring investigation are those assets where should an asset fail, it may not be addressed adequately to meet legislative requirements under the current configuration and therefore either replacement or acquisition of spares holdings.
- Replace - assets where immediate replacement is recommended due to the lack of ability for TransGrid to address asset failures within a reasonable timeframe to return an asset to service.

11.1 Implementation of the Renewal and Maintenance Decision Process

Asset Health and Asset Criticality have been combined using a scoring methodology to provide a ranking for all assets. Criticality is scored on the basis of the consequence of the failure of the asset. Asset Health is calculated as per the Network Asset Health Framework.

Whereas asset criticality is inherently dependent upon the primary assets that are serviced by the secondary systems automation assets, asset health analysis is based upon spares availability, known issues, self-monitoring capabilities as well as age. Asset health has been categorised as three levels;

- OK - assets not requiring any actions at this time as there are no know issues, and a failure of a unit can be addressed immediately.
- Investigate - assets where should an asset fail, it may not be addressed adequately to meet legislative requirements under the current configuration and therefore either replacement or acquisition of spares holdings.
- Replace - assets where immediate replacement is recommended due to the lack of ability for TransGrid to address asset failures within a reasonable timeframe to return an asset to service.

11.2 NiCd Battery Asset Review

NiCd batteries are utilised in arrays to meet load and capacity demands and differ for each site. Banks are installed in a duplicated fashion with each bank providing supply for each of the redundant protection schemes installed.

TransGrid policy has been to use NiCd batteries for station batteries due to their reliability, tolerance of temperature variation and suitability for the load requirements.

Historical performance of this type of asset is summarised in the graph below as an average of percentage defects per population and provides forecast defect rate:

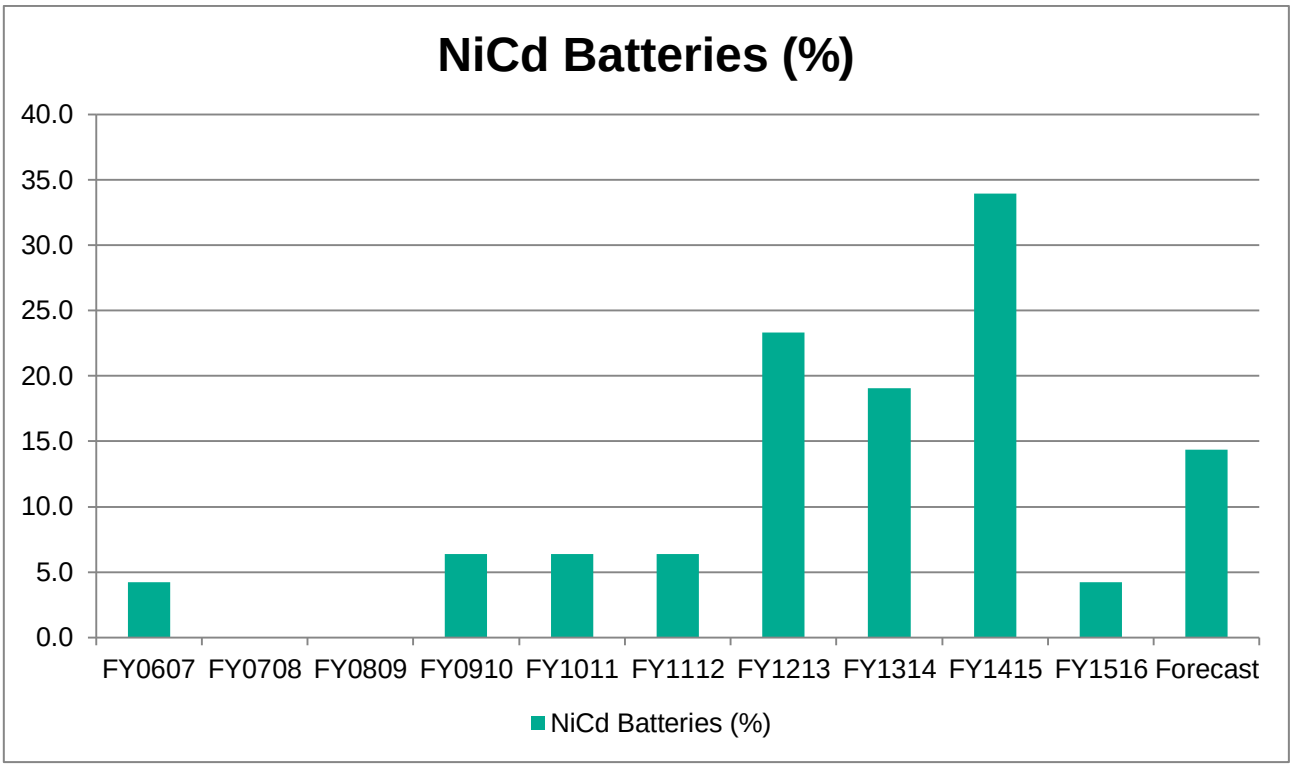

Figure 44 NiCd Batteries Defect Rates

Due to the need for DC Supply Systems to power all protection and control aspects of an unmanned high voltage electricity transmission station, criticality has been categorised on the purpose for the station which is being operated based on generation connector, transmission network backbone or Distributor connection point.

The figure below illustrates the breakup of the asset population by criticality levels:

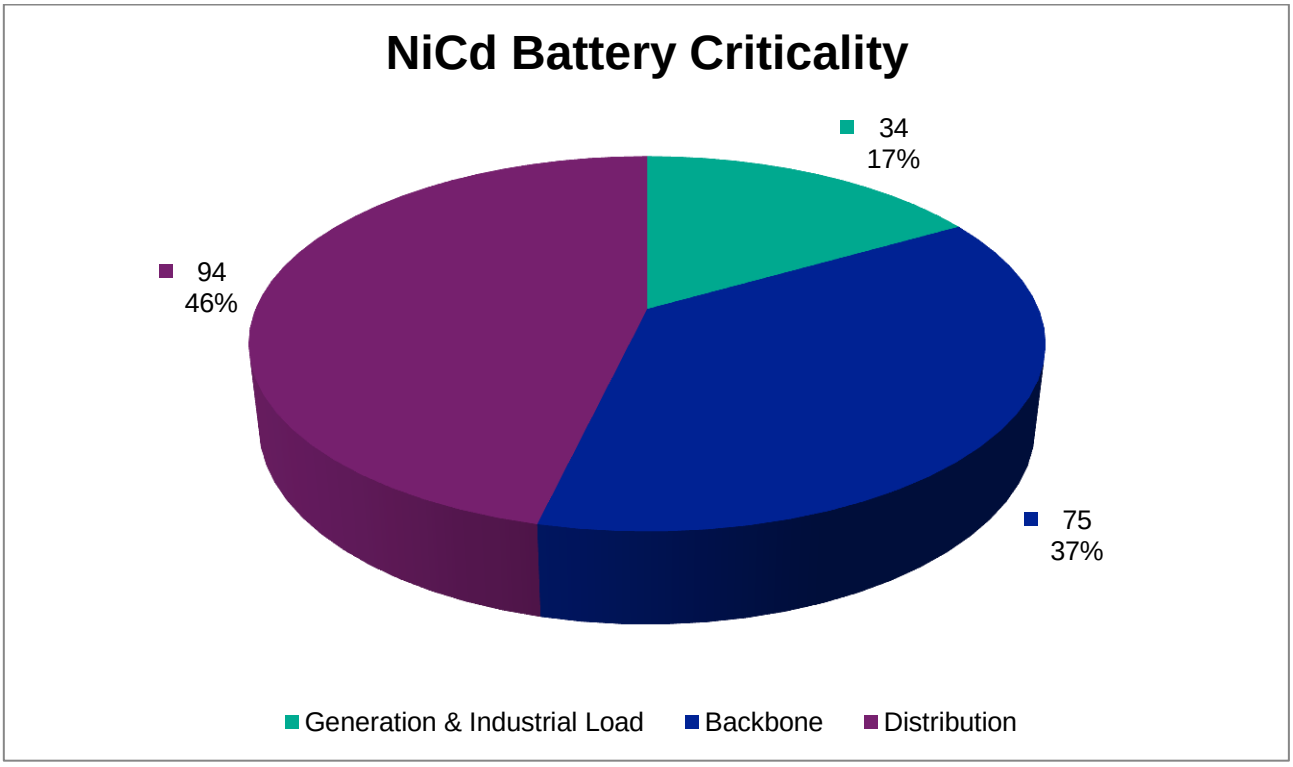

Figure 45 NiCd Batteries Criticality

The health of these assets varies and is primarily dependant on manufacturer support, spares availability, forecast defect rates and the technical life of the assets. The health index has been used to identify the assets that require investigation and those that require replacement. Below is a summary of the current health of the assets:

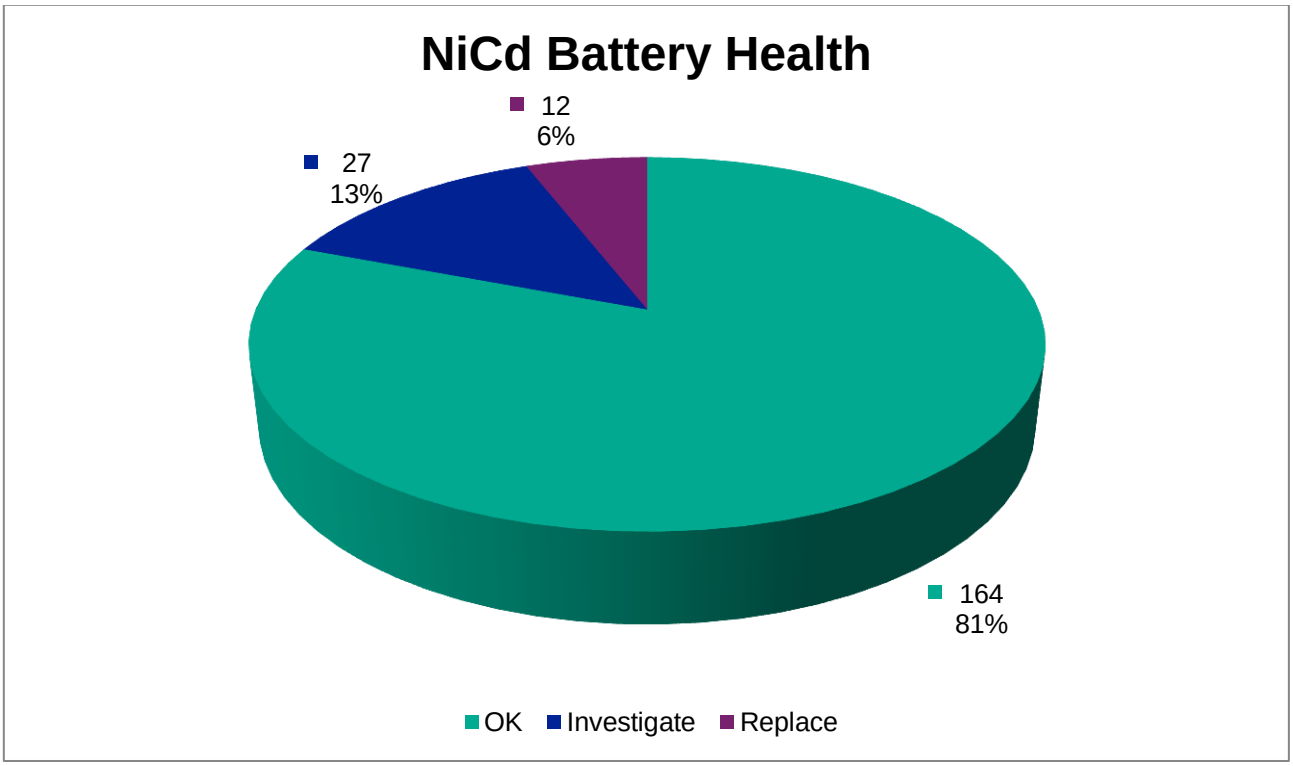

Figure 46 NiCd Batteries Health

11.3 NiCd Charger Asset Review

NiCd Chargers are utilised wherever NiCd Batteries are installed, generally these are applied as one charger dedicated to each battery bank. There are some instances where a single charger may service duplicated battery banks, this is very rare and is an interim step to full duplication of entire systems where it occurs within the network.

Historical performance of this type of asset is summarised in the graph below as an average of percentage defects per population and provides forecast defect rate:

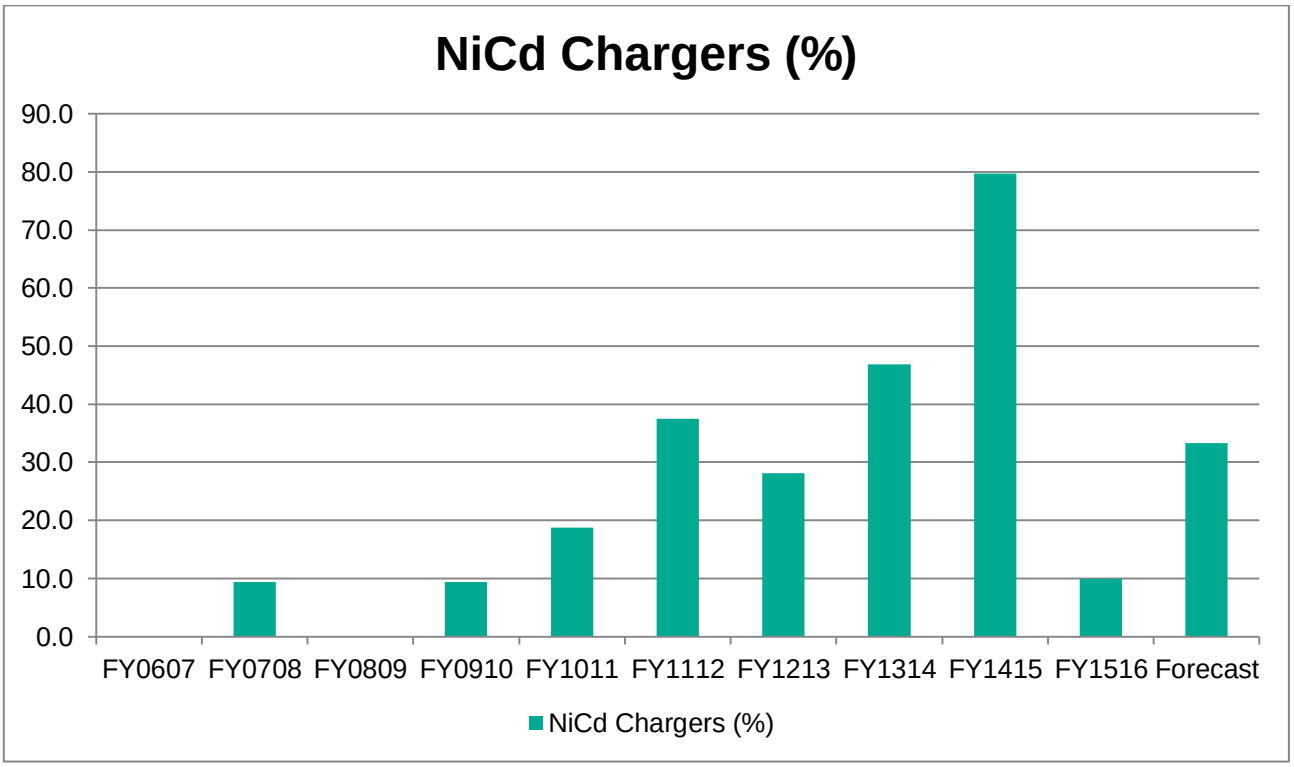

Figure 47 NiCd Charger Defect Rates

Due to the need for DC Supply Systems to power all protection and control aspects of an unmanned high voltage electricity transmission station, criticality has been categorised on the purpose for the station which is being operated based on generation connector, transmission network backbone or Distributor connection point.

The figure below illustrates the breakup of the asset population by criticality levels:

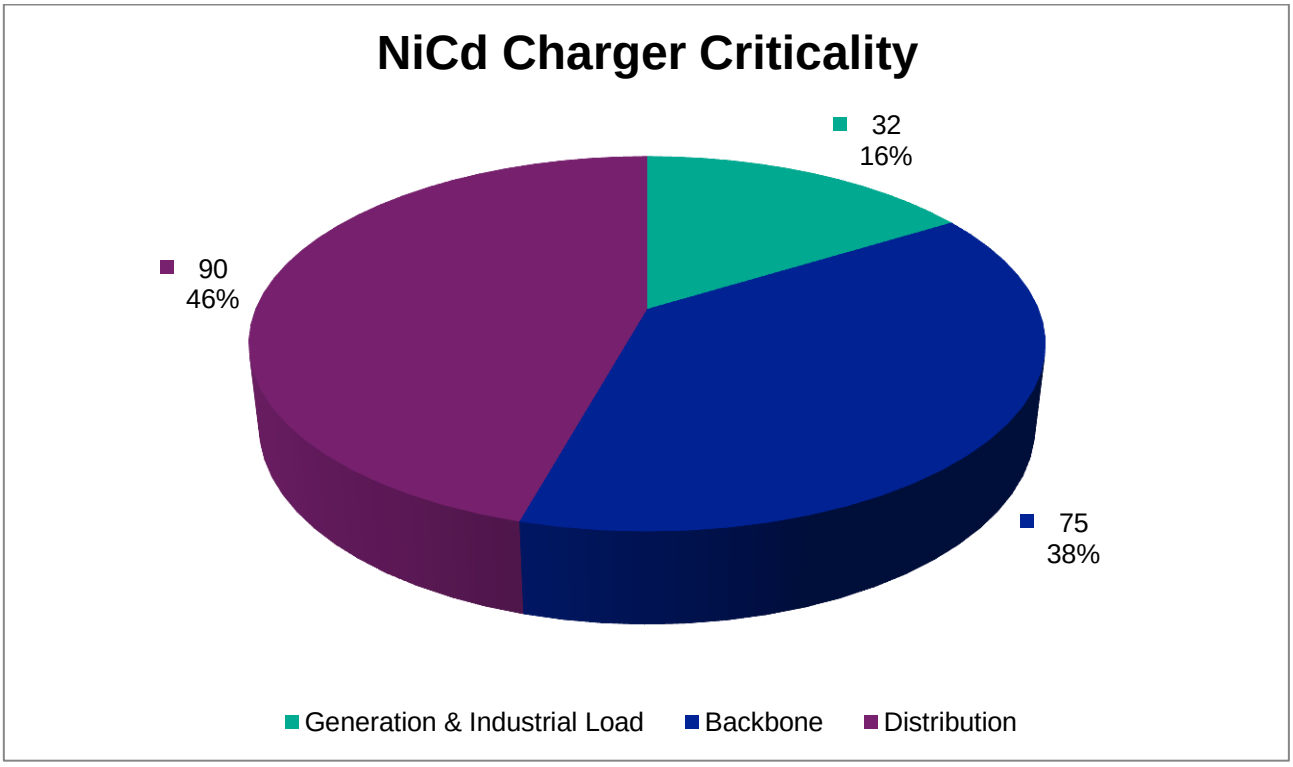

Figure 48 NiCd Charger Criticality

The health of these assets varies and is primarily dependant on manufacturer support, spares availability, forecast defect rates and the technical life of the assets. The health index has been used to identify the assets that require investigation and those that require replacement. Below is a summary of the current health of the assets:

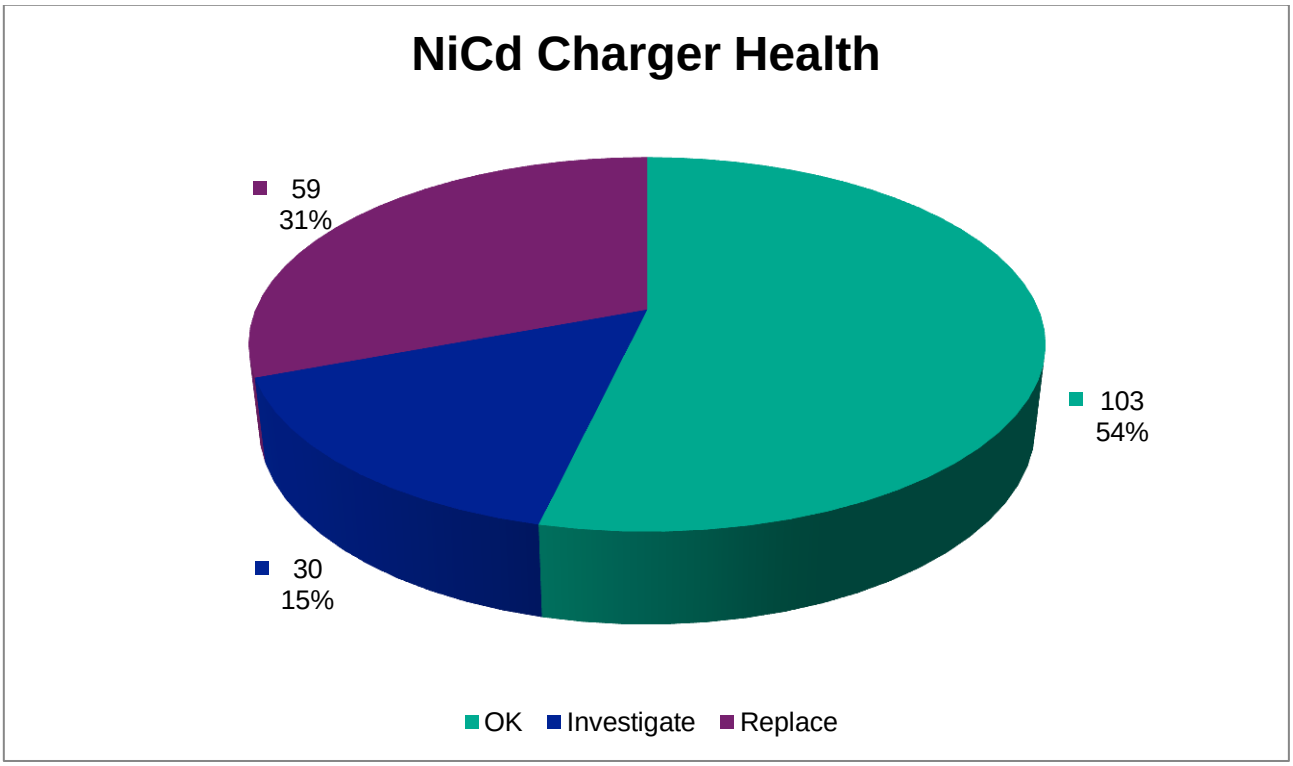

Figure 49 NiCd Charger Health

11.4 Emerging Issues, and Renewal and Maintenance Initiatives

There are currently 6x 250V DC systems remaining on the network that were inherited from Snowy Hydro Limited and are targeted for complete replacement with 110V DC systems, this is mainly due to safety risks with 250V DC systems and their classification as “Low Voltage” by the Australian Standard AS3000. Due to the complexity of DC systems are their use throughout all secondary systems in a substation as well as Circuit Breaker charging motors; these are being targeted for upgrade as part of Secondary Systems Site Installations Renewal and Maintenance Strategy.

The continual issue faced by these types of assets is age and the need for replacement to reduce defect rates for the assets to ensure the continuous operation of all automation systems within an unmanned transmission network substation or switching station.

Table 12: Emerging Issues, and Renewal and Maintenance Initiatives

Asset	Asset Management Objective	Strategic Initiative	Emerging Issues	Forecast Expenditure ($m)	Reference Documents
• DC Supplies	• Maintain Network Reliability • Manage network related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP)	• Replace assets that have reached end of life and cannot meet their performance requirements of continual supply of a DC load	• Assets are ageing and are reducing in capacity to maintain supply to connected assets	$4.50	NS-00001360 NS-00001362

11.5 Maintenance Program

Preventative maintenance is carried out on all NiCd batteries installed within the network. Two different maintenance intervals exist and are based on the age of the assets. This allows for minimal maintenance on newer assets where it is reasonable to accept a lower risk of defects occurring.

A program of inspections and random checks is also in place to identify any potentially harmful issues in between regular maintenance tasks.

The maintenance program is reviewed annually and no changes have been identified or applied for this financial year (2016/17).

12. Future Outlook

12.1 Forecast Expenditure

The following highlights the forecast renewal initiatives expenditure to 2022/23:

Table 13 Forecast Renewal Initiatives Expenditure to FY 2022/23 ($k)

Asset	FY 2016/17	FY 2017/18	FY 2018/19	FY 2019/20	FY 2020/21	FY 2021/22	FY 2022/23
Protection Relays	7500	8920	11100	11500	11900	12300	12700
VF Intertrips	186	159	456	474	488	504	521
Analysis Equipment	80.9	243	0.00	0.00	0.00	0.00	0.00
Control Systems	676	860	106	111	114	118	122
DC Supplies	202	202	955	988	1010	1040	1070

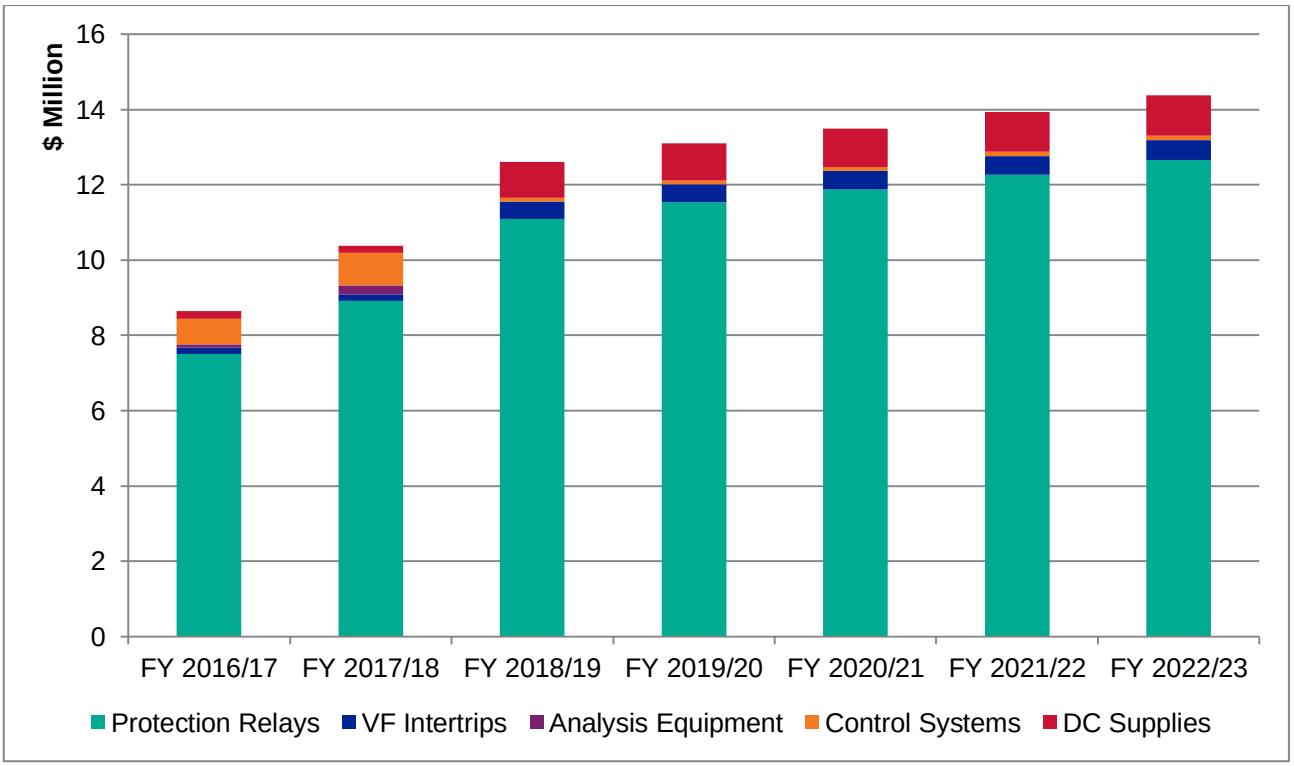

Figure 50 Forecast Renewal Initiatives Expenditure to 2022/23

The current AER REPEX model highlights expenditure based on age profile and can be seen summarised below. The model currently bundles all secondary systems and Communications Assets as one grouping and as such has been compared to the overall forecast costs for all four Renewal and Maintenance Strategies including this document (Automation Systems), Telecommunications Systems, Metering Systems and Site Installations.

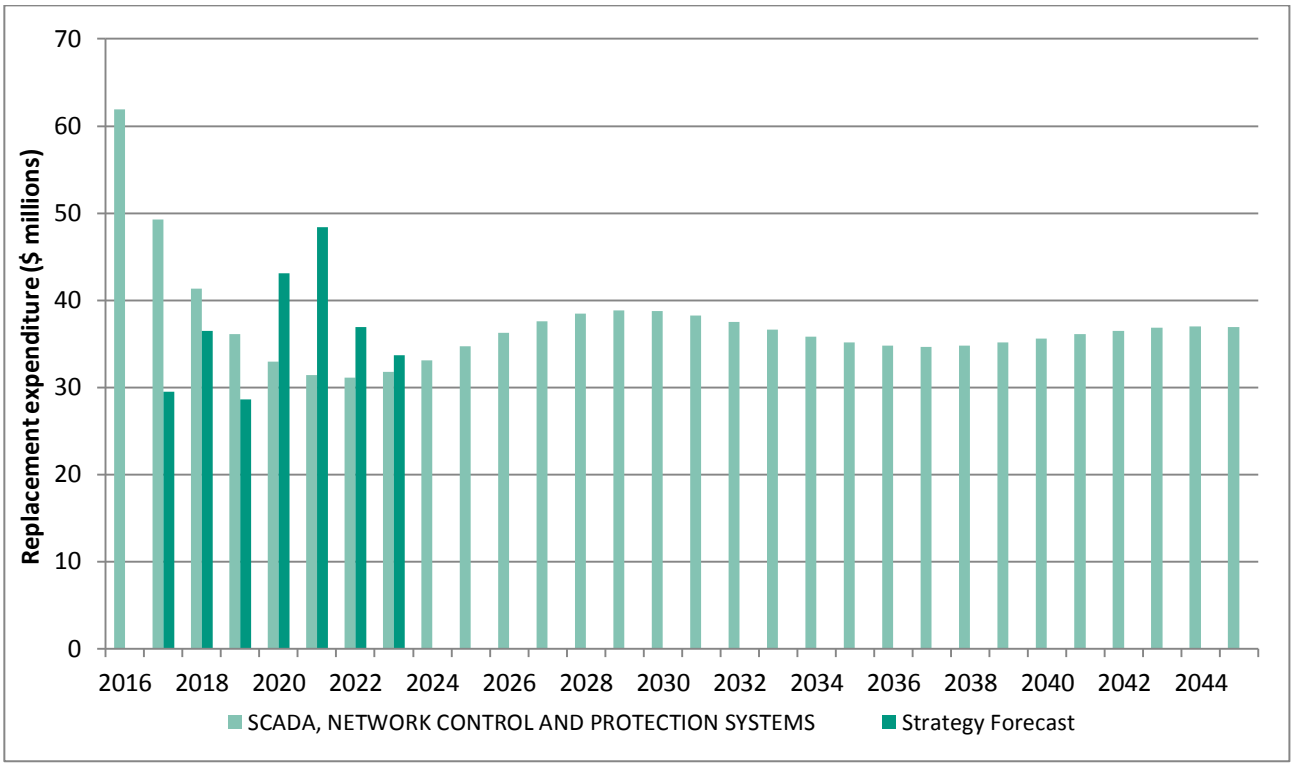

Figure 51 AER REPEX Model Forecast Expenditure

12.2 Anticipated Changes to the Asset Base

The figure below highlights the REPEX model's forecast age profile. The model shows a gradually increasing age profile of the assets over time. However it is foreseen that the average age of assets will likely reduce at first and stabilise over time. This performance is anticipated due to the eventual consolidation of several assets into single units, which the current model does not adequately capture.

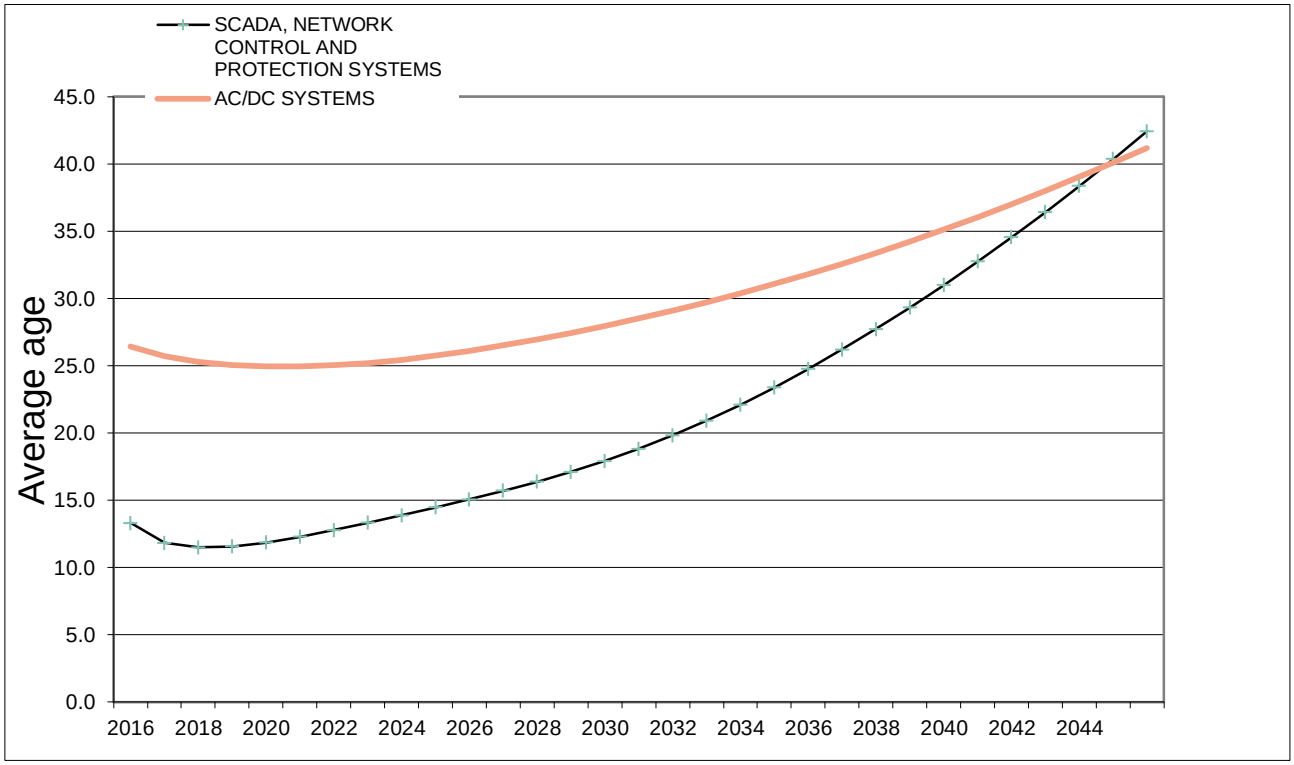

Figure 52 AER REPEX Model Forecast Age Profile

It is foreseen that the forecast expenditure as highlighted in the previous section will result in improvements in the overall asset health throughout the majority of asset classes. These are summarised in the sections below along with the forecast statistics should the expenditure not be applied.

12.2.1 Protection Relays

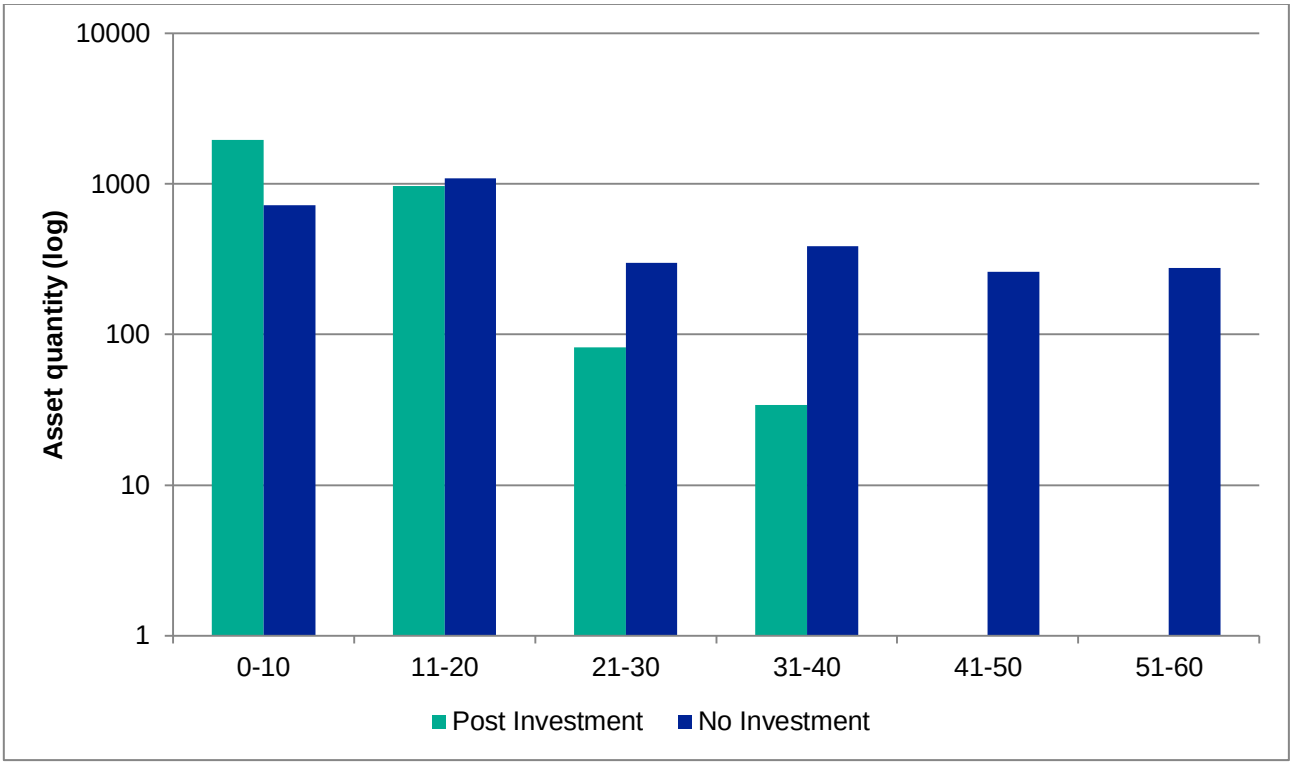

Figure 53 Forecast Protection Age Profile (end 2022/23)

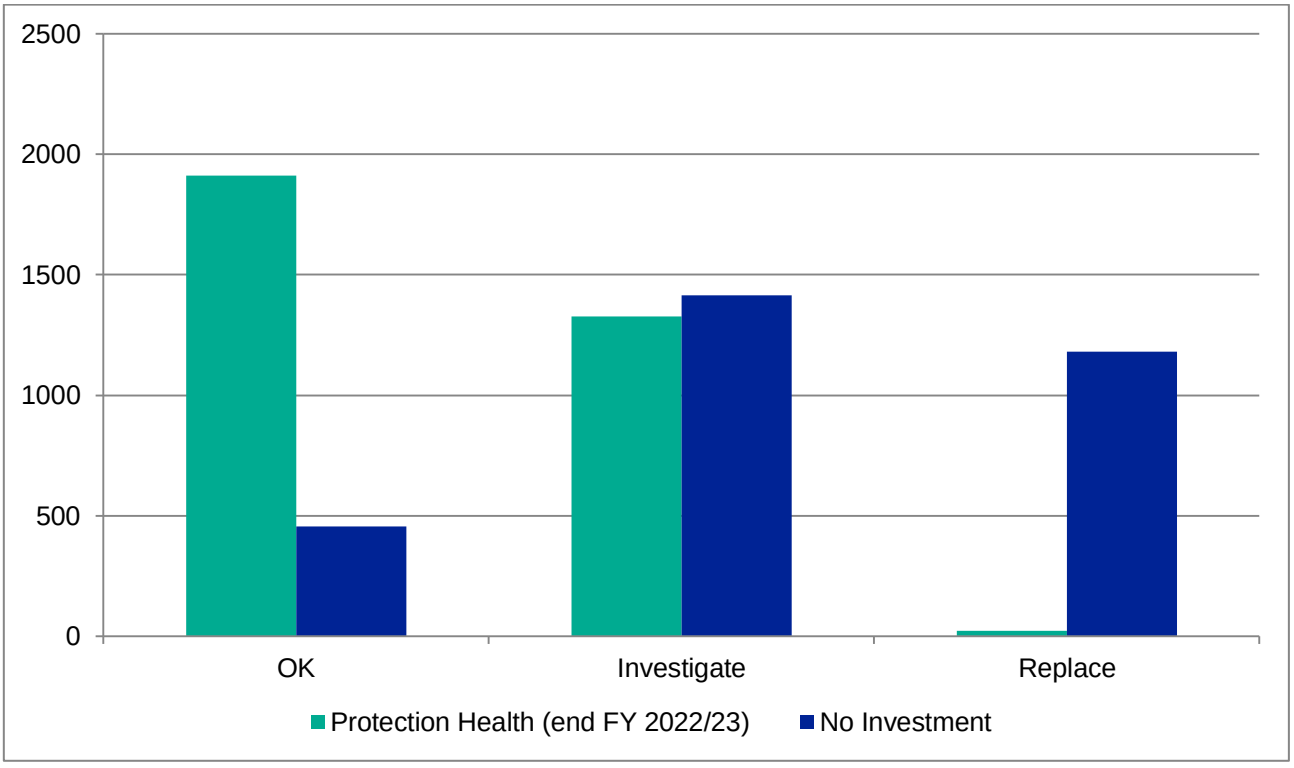

Figure 54 Forecast Protection Asset Health (end 2022/23)

12.2.2 VF Intertrips

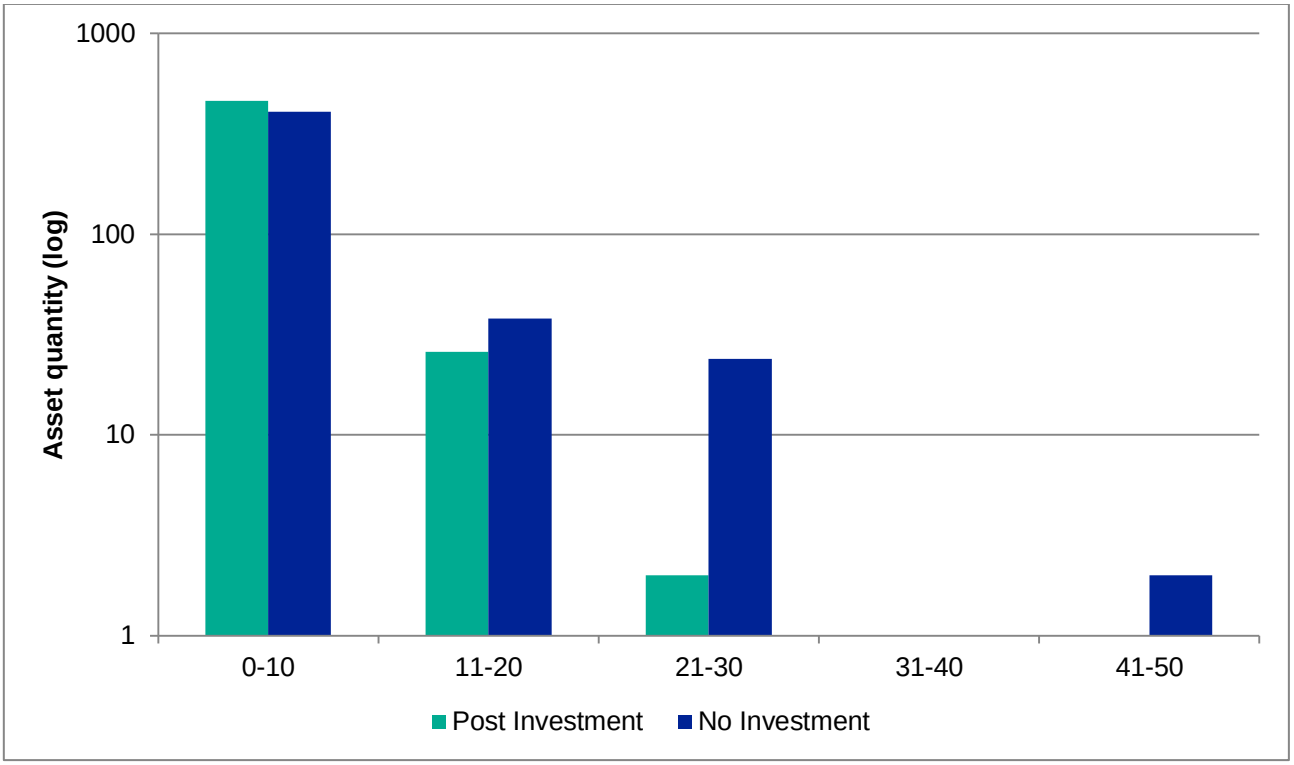

Figure 55 Forecast VF Intertrip Age Profile (end 2022/23)

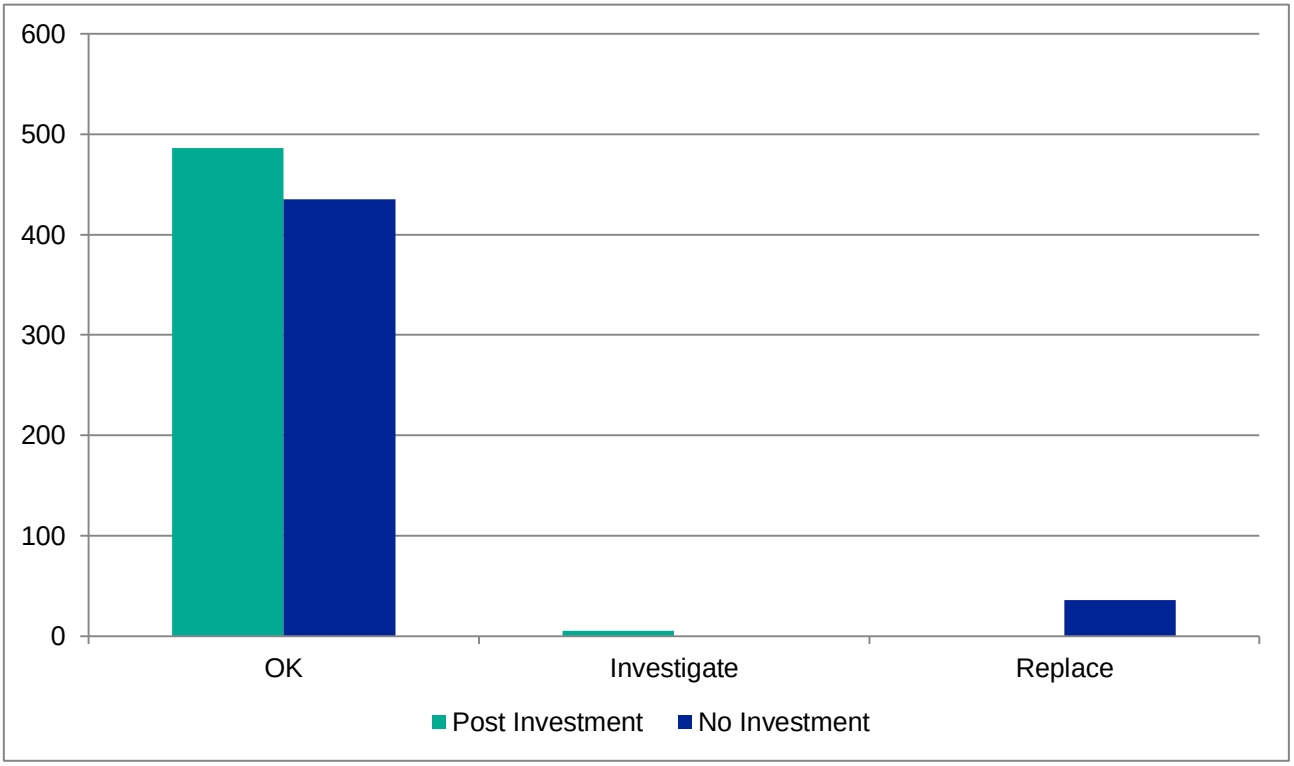

Figure 56 Forecast VF Intertrip Health (end 2022/23)

12.2.3 Control Systems

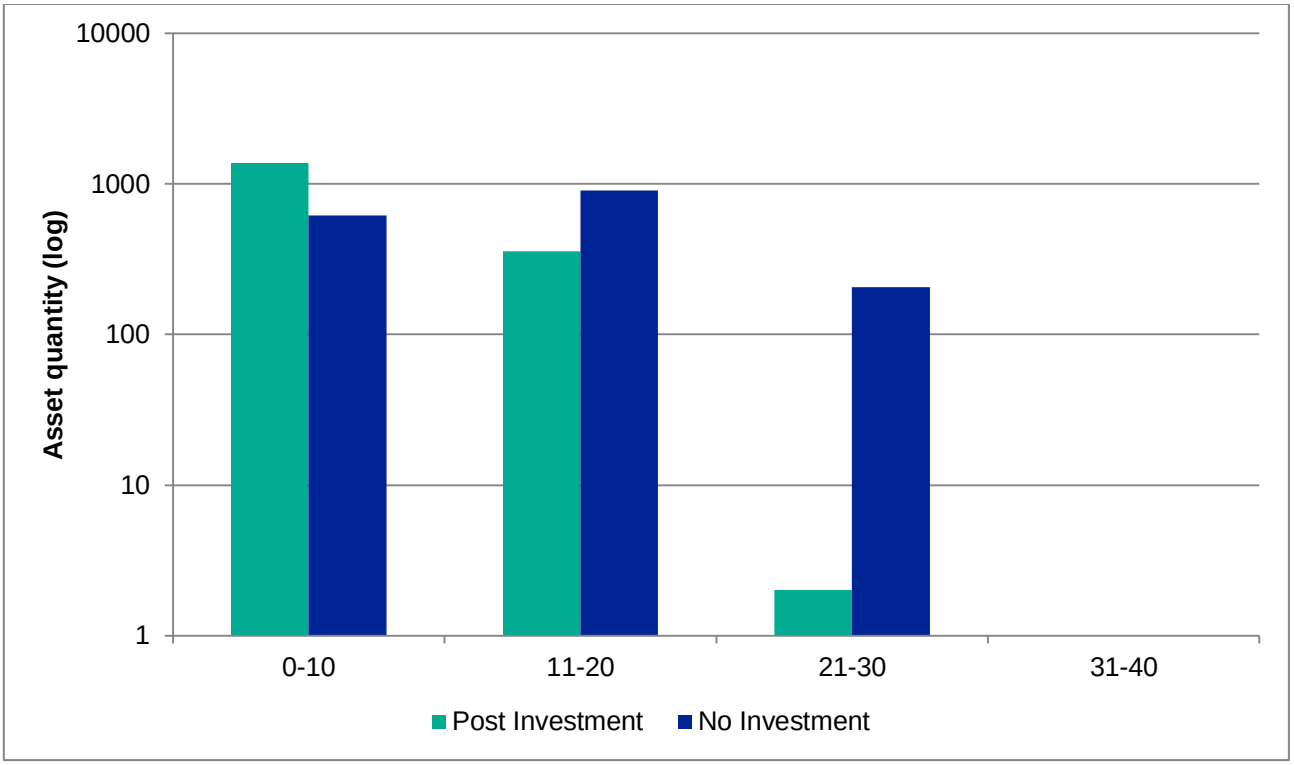

Figure 57 Forecast Control Age Profile (end 2022/23)

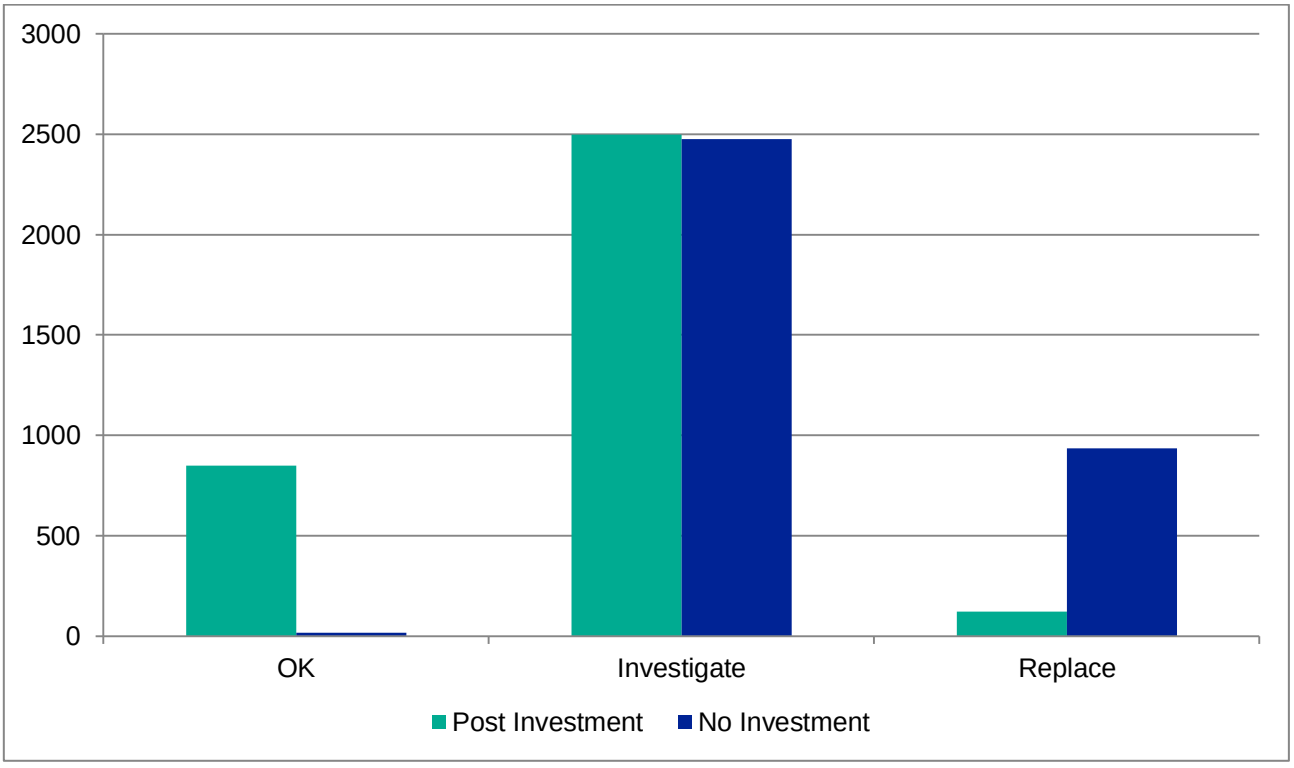

Figure 58 Forecast Control Health (end 2022/23)

12.2.4 DC Supplies

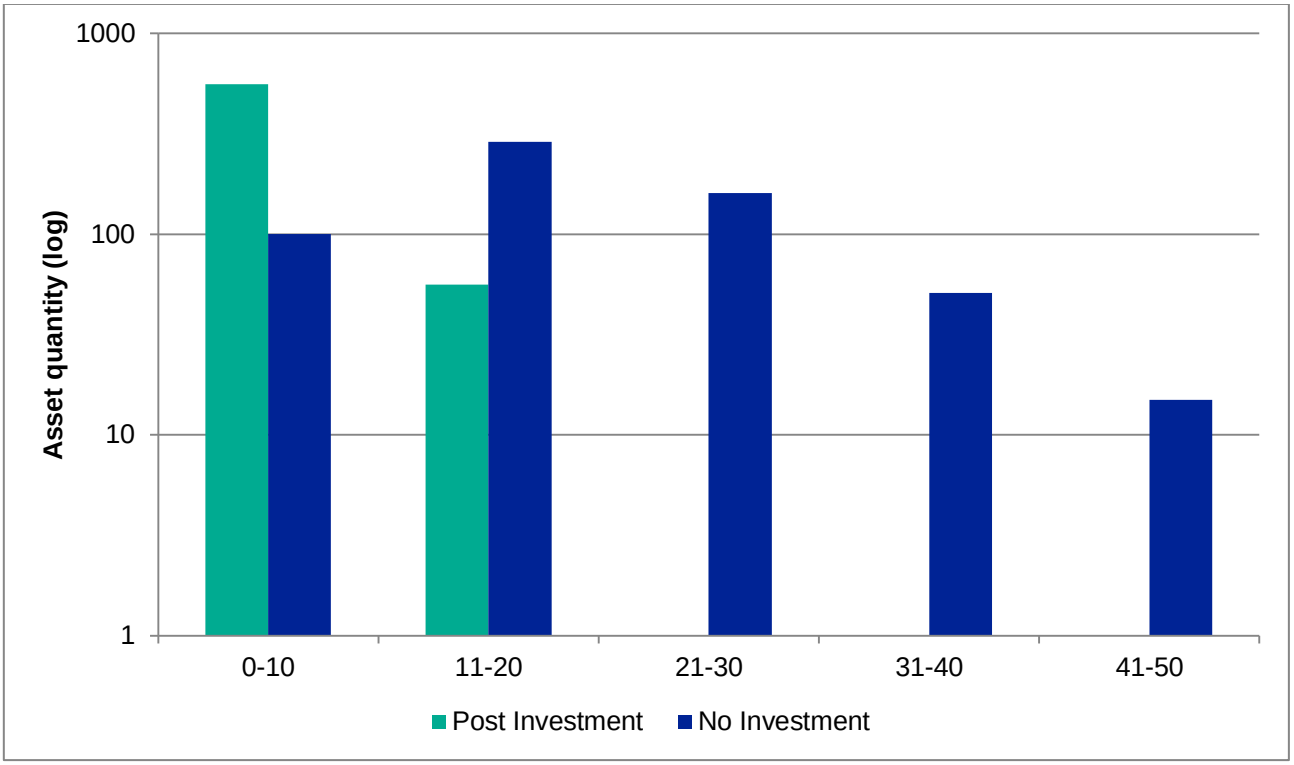

Figure 59 Forecast DC Supply Age Profile (end 2022/23)

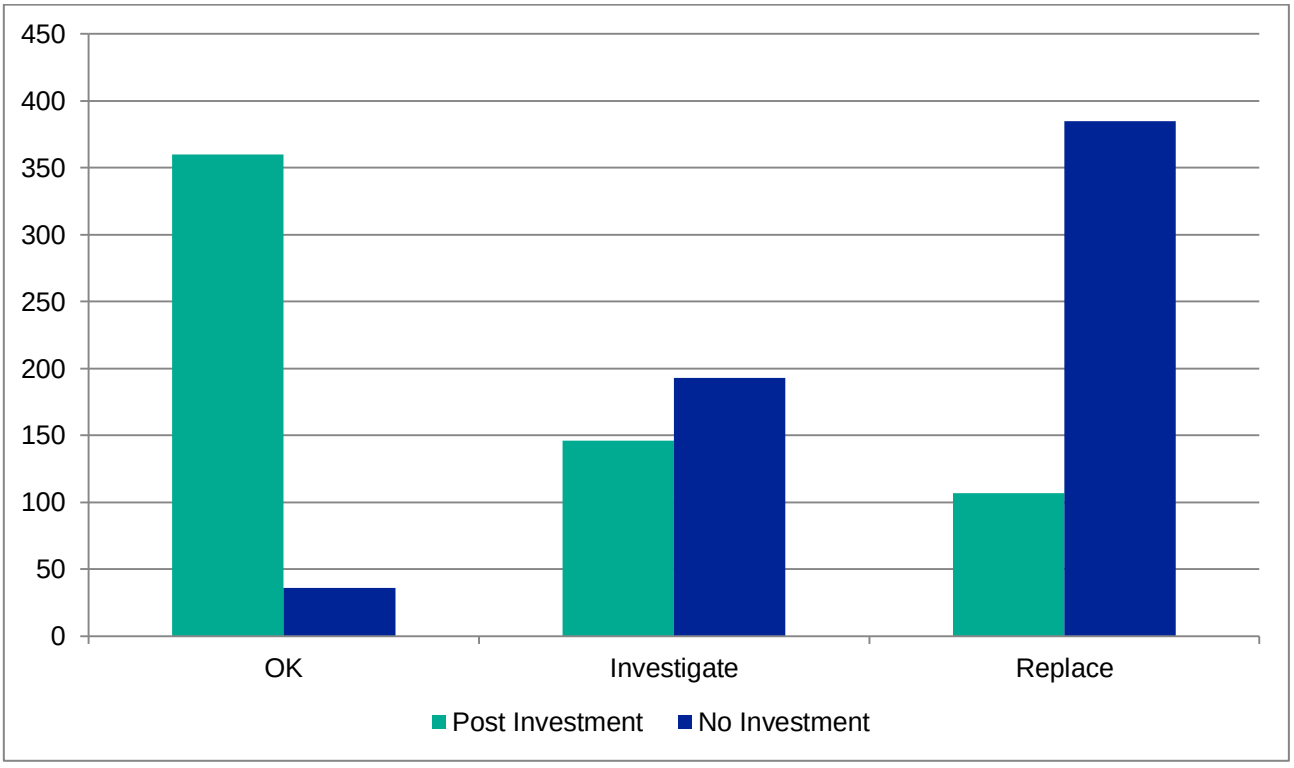

Figure 60 Forecast DC Supply Health (end 2022/23)

13. Spares

Spares are items of serviceable equipment that are booked into and stored in TransGrid's storage facilities for maintenance and project purposes. This document does not cover the spares required for project purposes.

TransGrid has purchased a range of strategic spare equipment to improve the organisations ability to restore supply and system security in a timely manner, following the major failure of an in-service unit.

The current spares strategy is to hold a sufficient percentage of spares in respect to the installed asset base, as well as the predicate defect rates of the different asset types with a minimum of 1 spare required for each critical asset within the network. Due to the large numbers of different asset models utilised throughout the network and incomplete reporting systems in place, a forecast spares expenditure has not been provided at this time, this will become available in the next iteration of this strategy.

14. Asset management capability and continual improvement

Asset Management Objectives	Asset Management Actions	Status
• Deliver a successful revenue determination •	1. Documentation required for RP2 submitted	• All documentation complete
• ISO 55001 Compliant • Continually improve the Asset Management System	2. Asset information improvements (governance, data, reporting and systems) implemented 3. Asset replacement life optimised 4. Asset maintenance scope and frequency optimised 5. Asset management competency enhanced 6. Plant and design standards optimised	• Utilisation of the risk tool to provide a more granular view of the pre and post-investment risks associated with renewing assets. • ALARP analysis completed for proposed RP2 renewals. • Asset data improved through incremental recording of assets in Ellipse. • Overhaul of the Ellipse Data rules for Automation Systems is underway.
• AS 5577 compliant • Continually improve the Electricity Network Management System	7. Formal Safety Assessments complete and externally audited	• IPART brushfire preparedness completed on an annual basis. • Public Electricity Safety Awareness (PESA) Plan reviewed on an annual basis.
• Improve CAPEX performance	8. REPEX and risk scenarios understood 9. Investment governance/prioritisation/optimisation process enhanced	• Utilisation of the risk tool to provide a more granular view of the pre and post-investment risks associated with building new or replacing assets. • ALARP analysis completed for proposed RP2 renewals. • NPV analysis completed on all solutions to ensure value for money.

Table 14: Continual Improvement Initiatives

Asset management capabilities are those elements that facilitate best practice asset management decision making. These include:

- Risk management practices.
- Asset information.
- Staff skills and competency.
- Continual improvement initiatives for the system.

15. Implementing the Strategies

To implement the strategic renewal and maintenance initiatives stemming from this document, actions are to be established via the:

- Automation Systems Maintenance Plan: The maintenance plan outlines the routine maintenance tasks and frequencies for each asset type.
- Capital Works Program: The capital works program outlines the approved asset renewal and disposal projects.
- Other enabler plans detailing how the asset management capability improvements are being implemented

The Secondary Systems and Communications Asset Manager is responsible for preparation of the maintenance plans and referring the renewal and disposal initiative to the network investment process. Field Services is responsible for delivering the maintenance plans as per the Service Level Agreements, and Portfolio Management group/Project Services are responsible for delivering the renewal and disposal initiatives detailed in the approved capital works program.

16. Monitoring and review

Implementation of the Automation Systems Renewal and Maintenance Strategy is monitored and reviewed by the Secondary Systems and Communications Asset Manager, Manager/Asset Strategy and Executive Asset Strategy Committee annually.

17. Roles and Responsibilities to Develop this Asset Strategy

The roles and responsibilities of those responsible for the development of this asset strategy are as follows:

- The Manager/Asset Strategy is responsible for the approval of this strategy.
- The Secondary Systems and Communications Asset Manager is responsible for the development and regular review of this strategy. The document will be reviewed biannually and as significant changes to investment needs become apparent.

18. Change history

Revision no	Approved by	Amendment
3	L. Wee Group Manager/Asset Strategy	Review and update to deliver the 2016/17 Business Plan and further enhance the strategy.
2	L. Wee Group Manager/Asset Strategy	Review and update to deliver the 2015/16 Corporate Plan and further enhance the strategy.
1	Garrie Chubb Group Manager/Asset	Updated to reflect the continual improvement in the “top down” approach for the line of sight to the Asset Management Strategy and the Corporate Plan and an

	Performance	enhanced description of the asset management decision process and the strategic initiatives to be undertaken.

19. References

- Asset Management Strategy and Objectives
- Asset Management System Description
- Secondary Systems Site Installations Renewal and Maintenance Strategy
- Automation Systems Maintenance Plan

20. Attachments

NIL