Transgrid

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Automation Renewal and Maintenance Strategy

AMS Asset Class Strategy

2021/2022

Document Control					
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Table 1 – Change from previous version

Revision no	Approved by	Amendment
8	L. Wee Head of Asset management	Review and update to deliver the 2021/22 Network Asset Strategy. New template.
7	L. Wee Head of Asset Management	Review and update to deliver the 2020/21 Network Asset Strategy.
6	L. Wee Head of Asset Management	Review and update to deliver the 2019/20 AM Strategy and Objectives.
5	L. Wee Head of Asset Management	New document structure. Review and update to deliver the 2018/19 AM Strategy and Objectives.
4	L. Wee Group manager/Asset Management	Review and update to deliver the 2017/18 AM Strategy and Objectives and further enhance the strategy. Inclusion of SCADA systems and GPS clocks.
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	G. Chubb Group Manager/Asset Performance	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 enhanced description of the asset management decision process and the strategic initiatives to be undertaken.

A printed copy of this document may not be the current version. Please refer to the Wire to verify the current version.

Executive Summary

Transgrid's network relies on automation systems to facilitate the unmanned operation of over 100 electricity transmission sites. The technological changes affecting the asset base and increasing renewals required to maintain fitness for purpose are presenting ongoing challenges. Asset condition information is continually refined and improvements in risk methodologies are assisting in investment decisions.

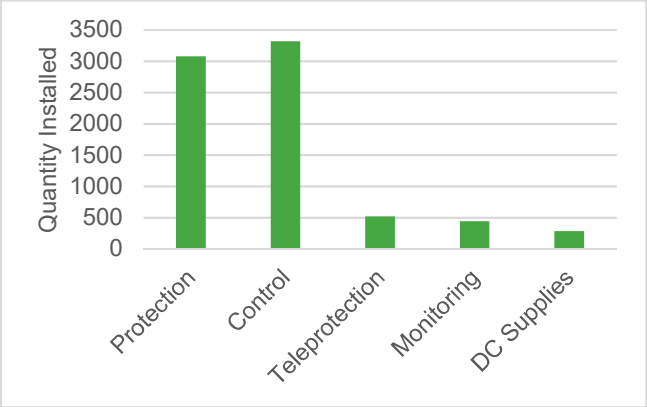
Asset Review

Transgrid's automation systems portfolio covers over 100 sites and all their associated systems facilitating the unmanned operation of a high voltage transmission station. These assets are a combination of many different technologies, approaches and applicable standards.

The automation systems portfolio can be summarised as those assets which directly impact the unmanned control, monitoring and protection of our electricity network assets to provide a secure and reliable energy system.

During FY2020/21 automation systems assets underwent the following developments:

- Improved asset data and continued collection



- Development of efficient system deployments in line with industry best practice as stipulated by our NER requirements.
- One new prescribed site constructed.

Achievements

In FY2020/21 Automation Systems achieved significant goals including:

- Continued efficient delivery of our asset renewal programs
- The initiatives to improve data has exceeded 90% of all assets
- Significant update to the risk methodology framework
- Deployment of IEC61850-7 and IEC61850-8 in standard solutions

Challenges

- IEC61850 gaps in standards for Point on Wave (POW), Data Recorders and Quality of Supply (QoS) monitors remain outstanding
- Achieving cost reductions and efficiencies within a minimalist portfolio of activities
- Optimising capital expenditure to address capital constraints
- Monitoring and improvement of systems to ensure consistent and accurate data capture by Transgrid or outsourced contractors

Initiatives

- Continued review of asset fitness for purpose
- Review of technology capabilities to improve asset monitoring and defect response
- Substitution of NiCd systems with VRLA to mitigate safety risks and maintenance expenditure

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1. Foreword

1.1. Foreword

This document defines the renewal and maintenance strategies for Transgrid's Automation Systems assets. In doing this, it applies the overarching Network Asset Strategy, and relevant Lifecycle Strategies. This strategy document covers all transmission line and easement assets owned and maintained by Transgrid, including non-prescribed assets.

The document identifies the emerging issues with Transgrid's Automation 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 by the Head of Asset Management, which then leads to the resource-optimised capital works program.
- The maintenance initiatives directly drive the maintenance regimes which are detailed within the relevant Maintenance Plans. The maintenance plans are then resource-optimised through Transgrid's Enterprise Resource Planning (ERP) system, Ellipse and supporting applications such as TRAC.

The population reviews in this document cover prescribed assets, non-prescribed asset and assets owned by Transgrid services. The strategies contained in this document only cover prescribed assets.

1.2. Overview

We have reviewed the historical technical performance and capital and operating expenditure for Automation assets within the network and we have determined that our current initiatives to date are successfully delivering our stated targets from last year.

The key initiative surrounding modernisation of the infrastructure surrounding our Automation systems has led to greater confidence in the performance of our assets with increases in issue detection due to alarms. This indicates that we are no longer relying as heavily on preventative maintenance to identify failed components of the network.

Overall performance between FY2016/2017 and FY2020/21 has seen:

- An overall reduction in targeted capital expenditure
- An overall reduction in operating expenditure
- A minimised maintenance portfolio to meet operating expenditure constraints.

A review of updated capital cost estimates, asset performance, health and condition has identified several initiatives that will be adjusted to maintain sustainable age profiles and risk levels across the AM portfolio which are anticipated to result in:

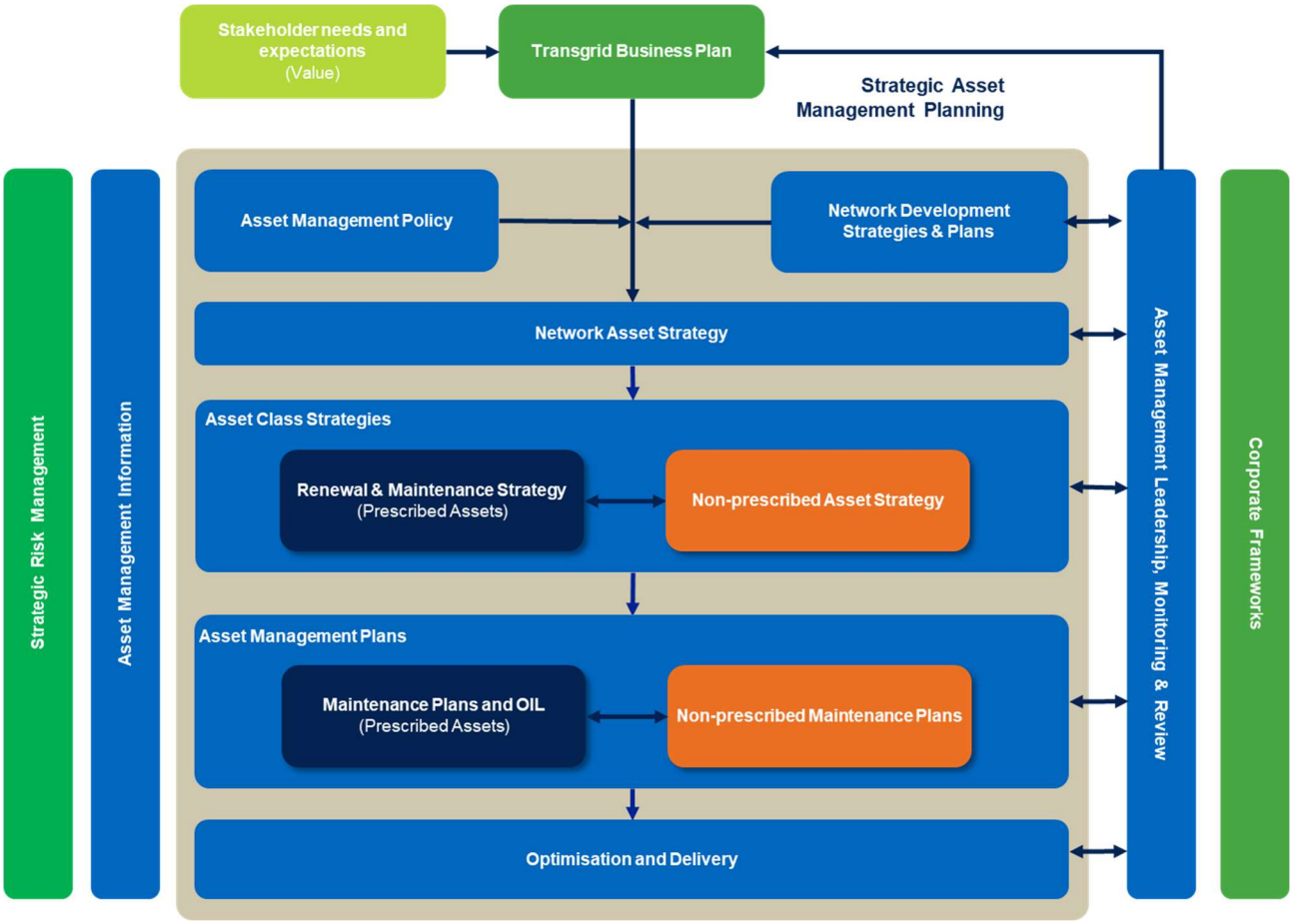
- A base $196 million of capital expenditure over the next five years
- A base $13 million in operating expenditure over the next five years

2. Context and Background

2.1. Relationship to Asset Management Systems

This Renewal and Maintenance Strategy (RMS) document is one of several that comprise the Asset Management Strategies within Transgrid's Asset Management System. This document sits below the Network Asset Strategy document as shown in Figure 1.

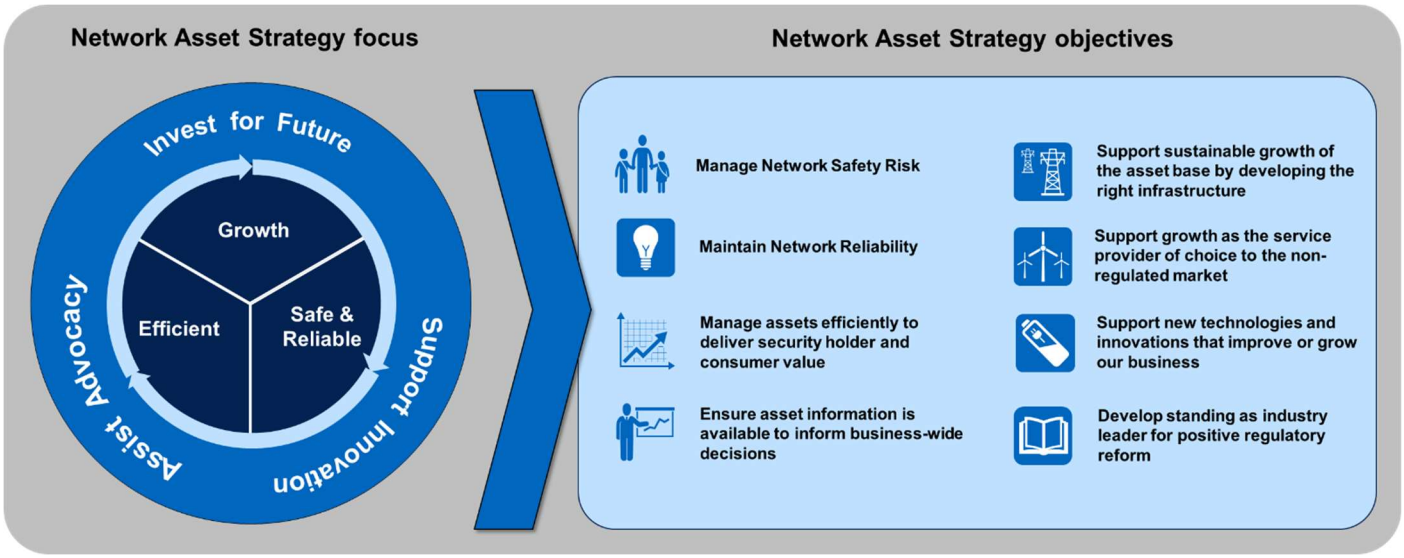
Figure 1 – Asset Management System Hierarchy



2.2. Asset Management Line of Sight

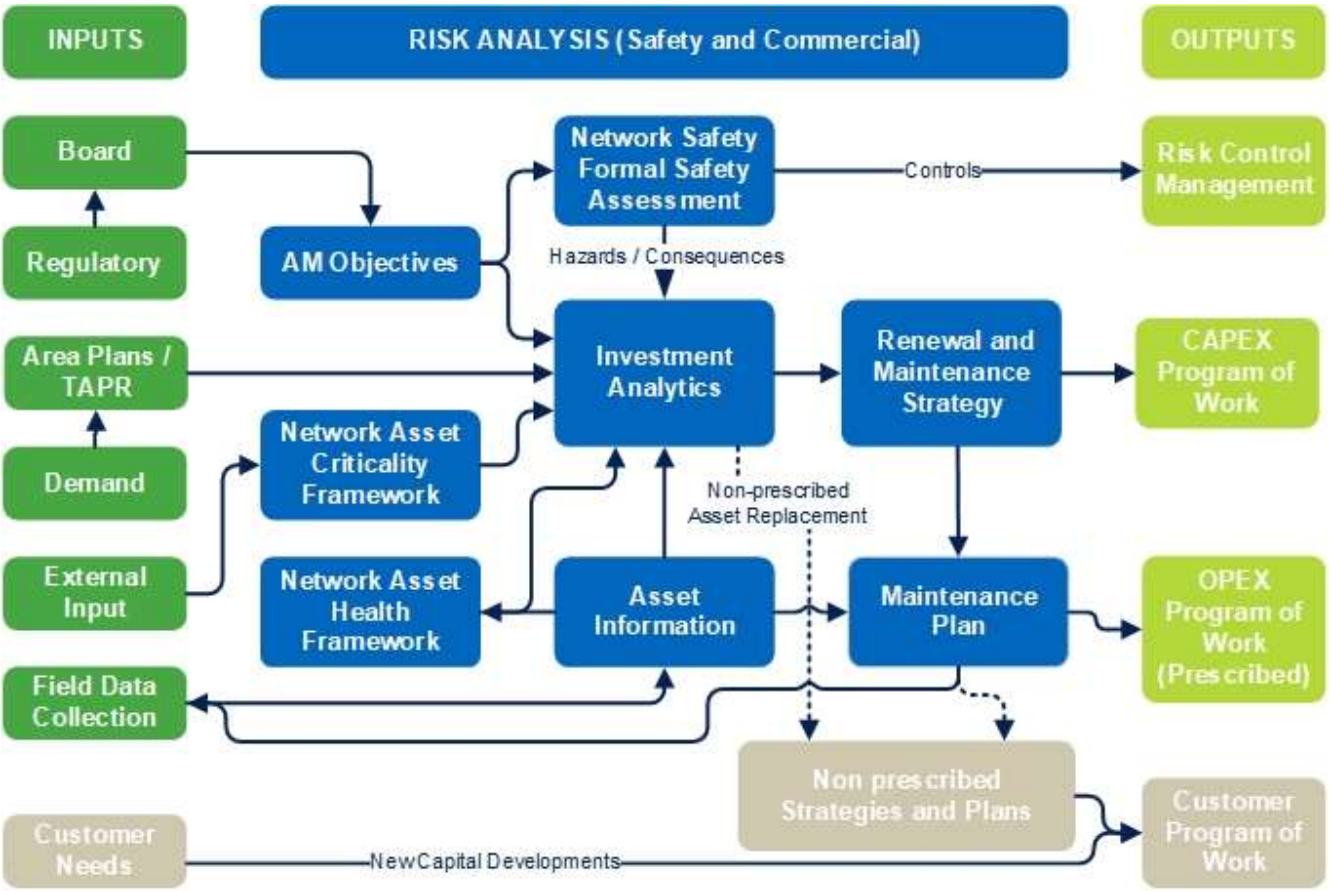
The renewal and maintenance strategic initiatives set out in this document support the achievement of the strategies set out in the Network Asset Strategy. The strategic alignment of the initiatives in this document to the Network Asset Strategy is based on meeting its strategic themes.

Figure 2 – Asset Management Strategy Key Themes


Network Asset Strategy focus
Invest for Future
Growth
Efficient
Safe & Reliable
Support Innovation
Assist Advocacy
Network Asset Strategy objectives
Manage Network Safety Risk
Maintain Network Reliability
Manage assets efficiently to deliver security holder and consumer value
Ensure asset information is available to inform business-wide decisions
Support sustainable growth of the asset base by developing the right infrastructure
Support growth as the service provider of choice to the non-regulated market
Support new technologies and innovations that improve or grow our business
Develop standing as industry leader for positive regulatory reform

2.3. Renewal and Maintenance Process Overview

Figure 3 – Investment Development Framework



2.4. Asset Overview

2.4.1. Scope of Assets

The following Digital Infrastructure assets are within the scope of this strategy this totals over 6000 major assets in this category:

- Protection Relays
- Teleprotection Intertrips
- Analysis and Monitoring Systems
- Control Systems
- Point on Wave Systems
- DC Supplies - 110V and 250V DC
- Backup Diesel Generators
- SCADA systems associated with the Network Control Rooms

The following assets are outside the scope of this strategy:

- Telecommunications Assets – Covered in the Telecommunications Renewal and Maintenance Strategy
- DC Supply Systems - 50V DC – Covered in the Telecommunications Renewal and Maintenance Strategy
- Market and TUOS Meters – Covered in the Metering Renewal and Maintenance Strategy
- Network Property – Covered in the Network Property Renewal and Maintenance Strategy
- AC supply schemes – Covered in the Infrastructure Systems Renewal and Maintenance Strategy

2.4.2. Protection Services

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

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

Protection assets serve Transgrid's assets as well as a variety of connected customers including Distributors, Generators and large commercial customers.

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

Table 2 Protection Asset Base

Protection Equipment Type	Quantity	Description
Electromechanical Relays (Excluding Busbar Protection)	213	The use of electromechanical relays has been phased out of all new installations except for some auxiliary functions. This is mainly due to the low value they provide us compared to the capabilities of modern microprocessor based assets. These have an estimated technical life of 40 years.
Electromechanical Busbar Protection	303	The use of electromechanical relays has been phased out of all new installations except for some auxiliary functions. This is mainly due to the low value they provide us compared to the capabilities of modern microprocessor based assets. These have an estimated technical life of 50 years.
Discrete Component Relays	569	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. Discrete Component Protection Systems are still actively pursued only for the purpose of high impedance differential protection systems. These have an estimated technical life of 25 years.

Protection Equipment Type	Quantity	Description
Microprocessor Relays	2247	Microprocessor based protection assets are the current standard for the protection of all network elements with limited Busbars. These have an estimated technical life of 15 years.

The spread of assets still contains a significant number of elements protected without self-checking features. This translates to a lack of visibility of the protection assets' condition and status (exclusive of trips activated) as a result of the expected magnetic fade or sub-component degradation of such assets.

2.4.3. Intertrip Services

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

Table 3 Intertrip Asset Base

Intertrip Type	Quantity	Description
Digital Intertrip	518	These are the current standard for intertrips and provide zone accelerated intertripping to clear faults on transmission line within defined Critical Clearance Times. These have an estimated technical life of 15 years.

2.4.4. Analysis Services

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 technical lives as listed below:

Table 4 Analysis Asset Base

Intertrip Type	Quantity	Description
Fault and Disturbance Recorders	160	These are very high speed recording devices generally stipulated in the NER for generator connection points or requested by AEMO for system planning/monitoring purposes. These have an estimated technical life of 15 years.
Travelling Wave Locators	32	These systems facilitate the accurate location of a fault and are a significant cost saver in transmission line review post-fault. These have an estimated technical life of 15 years.
Quality of Supply Monitors (QoS)	36	These monitor the system harmonics and ensure we meet our NER QoS obligations. These have an estimated technical life of 15 years.

Intertrip Type	Quantity	Description
Statistical Meters	57	These are metering systems that are no longer in use for any market settlement. Typically these are located at points where NEM metering has moved due to reclassification of network components, or at TNSP/DNSP metering boundaries for Regulatory reporting These have an estimated technical life of 15 years.
GPS Clocks	92	These systems are utilised to provide accurate timestamping of events across our sites. This ensures that during investigations, we can efficiently determine events leading to any action. These have an estimated technical life of 15 years.

2.4.5. 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 assets can be categorised as follows:

Table 5 Control Asset Base

Control Type	Quantity	Description
MD1000	93	These are the earliest iteration of microprocessor based RTUs (single manufacturer/model used). Installation counts include IO modules These have an estimated technical life of 15 years.
MD3311	129	These are the second generation of microprocessor based RTUs (single manufacturer/model used). These have an estimated technical life of 15 years.
Modern RTU	855	These are the last generation of microprocessor based RTUs (multiple manufacturers and models used). These have an estimated technical life of 15 years.
Modern IED	24	These are modern generation of IED based devices. These have an estimated technical life of 15 years.
Human Machine Interface (HMI)	215	These provide local interface to the control system. These systems are provided by several manufacturers and models (based on a generic PC) These have an estimated technical life of 10 years.

Control Type	Quantity	Description
Orphaned Site Control Systems	3	Gadara, Haymarket and Molong all implement one off Design and Construct control systems (each site has a different system). These have an estimated technical life of 15 years.
SVC Control Systems	5	These are specialised control systems designed and installed by the SVC primary pant manufacturer (each SVC has a dedicated system). These are similar in principle to orphaned control systems. These have an estimated technical life of 15 years.

2.4.6. Point on Wave Systems

Point on Wave (POW) systems are deployed throughout the network predominantly connected to our HV Reactive Plant, with some instances of installations on Transformers where deemed essential by Network Planning. These systems are very expensive solutions that require specialist commissioning teams provided by the circuit breaker manufacturer.

These assets provide switching at appropriate points on a voltage or current waveform to minimise the effects of "$L\frac{di}{dt}$" and "$C\frac{dv}{dt}$ ". This functionality is provided by intelligent relays that are tuned to the parameters of the associated circuit breaker and trigger opening and closing as required on a phase by phase level. Traditionally these systems are deployed as part of the circuit breaker with the relay and parameters set by the supplier of the breaker.

The current position from Network Planning indicates the deployment of POW systems is likely to increase within the HV network into the future.

Table 6 POW Systems Asset Base

HV Asset	Quantity	Description
Capacitor	76	POW on these HV assets is becoming the standard approach and hence the largest population base. These have an estimated technical life of 15 years.
Reactor	8	POW on these HV assets is being reviewed on a case by case basis but preliminary discussions appear to be seeing an increase. These have an estimated technical life of 15 years.
Transformer	3	POW on these HV assets has been set on a very limited case approach and is not currently foreseen to be a normal function at this time. These have an estimated technical life of 15 years.

2.4.7. DC Supply Services

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 at a site.

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

Table 7 DC Supply Systems Asset Base

DC Supply Asset	Quantity	Description
250V DC NiCd Battery	4	These systems were transitioned to our asset profile when a subset of Snowy Hydro assets were reclassified as Transgrid's. The 250V DC level is no longer utilised throughout the network. These have an estimated technical life of 20 years.
250V DC NiCd Charger	4	These systems were transitioned to our asset profile when a subset of Snowy Hydro assets were reclassified as Transgrid's. The 250V DC level is no longer utilised throughout the network. These have an estimated technical life of 20 years.
110V DC NiCd Battery	201	These systems have bene the standard deployment for DC supplies to power automation systems. These have an estimated technical life of 20 years.
110V DC NiCd Charger	198	These systems have been the standard deployment for DC supplies to power automation systems. These have an estimated technical life of 20 years.
110V DC SLA Systems	4	These systems are becoming the new standard in DC deployments. These have an estimated technical life of 20 years.

2.4.8. Backup Diesel Generators

Multiple sites are fitted with backup 415V diesel generators. An internal audit is underway to determine quantities and condition of these assets.

2.4.9. Control Room SCADA Systems

There are two Operational Control Rooms in operation within our network, these are located at the Sydney West (primary control room) and Newcastle regional centres.

2.4.9.1. SCADA Terminal Equipment

The currently aged and soon to be unsupported ABB Control room SCADA system is under renewal, this renewal will additionally incorporate CIS20 enhancements to increase our OT cybersecurity posture.

Monitoring of these assets has been placed on hold until the new system is brought online. This decision has been made as the entire system and all subcomponents are under renewal and as such any continued monitoring and review of these assets provides little value for strategic asset management at this point in time.

2.4.9.2. SCADA AC Supplies

Each Control Room is supplied directly from the adjacent substation's 415V auxiliary transformers. This provides a level of security of supply that cannot be met through the connection to council supplies.

The two control rooms are also connected to 2x 415V Diesel Generators each to provide backup supply should the auxiliary transformers simultaneously fail.

2.4.9.3. SCADA DC Supplies

Each Control Room is connected to duplicated battery and charger systems to provide ride through capacity during an outage of AC supplies and during the changeover time required to initiate a diesel generator from loss of auxiliary supply.

2.5. Spares

Our current strategy for spares is to maintain holdings which are proportional to the installed quantities in the network as per practices specified in the Spares Policy. Additionally, we monitor the support availability for the different assets and a scale is applied as support is diminished.

When notification is received for the withdrawal of support for a particular asset, a review of that asset's historical performance, age profile and population size is carried out. Based on this review we may decide to renew the assets with a modern replacement or purchase sufficient spares to support the assets towards the end of their technical lives.

3. Current Performance

3.1. Review of Previous Renewal, Disposal and Maintenance Strategies

This section discusses the performance of the current prescribed asset base.

3.1.1. Historical Expenditure

Historical expenditure has been analysed from Transgrid's RIN submissions between FY2016/17 and FY2020/21. Due to the structure of RIN reporting, the following analysis has been carried out against protection and control assets only.

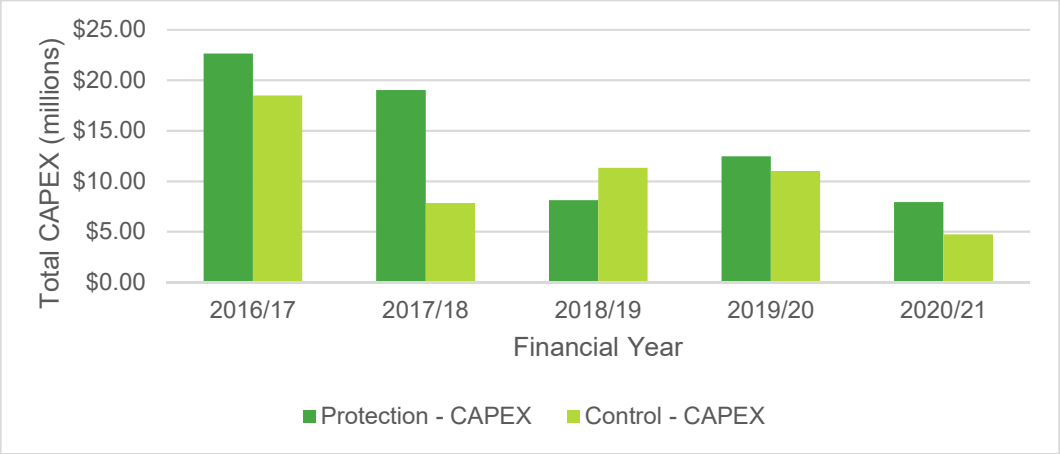
3.1.1.1. Capital Expenditure

Previous initiatives had identified a general move for Control Systems to a defect based approach. This was applied to most modern control systems utilising modern principles and standards. A few sites that required significant effort to be upgraded to current standards, were invested in through capital expenditure.

Initiatives had also identified the need to upgrade underlying infrastructure as outlined in the Renewal and Maintenance Strategy – Infrastructure Systems. The costs for these site based initiatives form part of the capital expenditure captured at a unitised per asset level. These infrastructure style initiatives commenced in RP1 with capitalisation realised since FY2016/17.

Overall, capital expenditure has been relatively steady for protection assets until FY2018/19 onwards. Protection is one of the most critical components within our asset base. An analysis has identified that the reduction in reported capitalisation for the last financial year is essentially due to the initiation of a significant number of new Secondary System Renewals, most of which will not commence capitalisation before FY2021/22. It is noted that expenditure since FY2017/18 has decreased in alignment with our strategic objectives of capital expenditure reductions which has seen the reprioritisation of investment options to meet capital constraints.

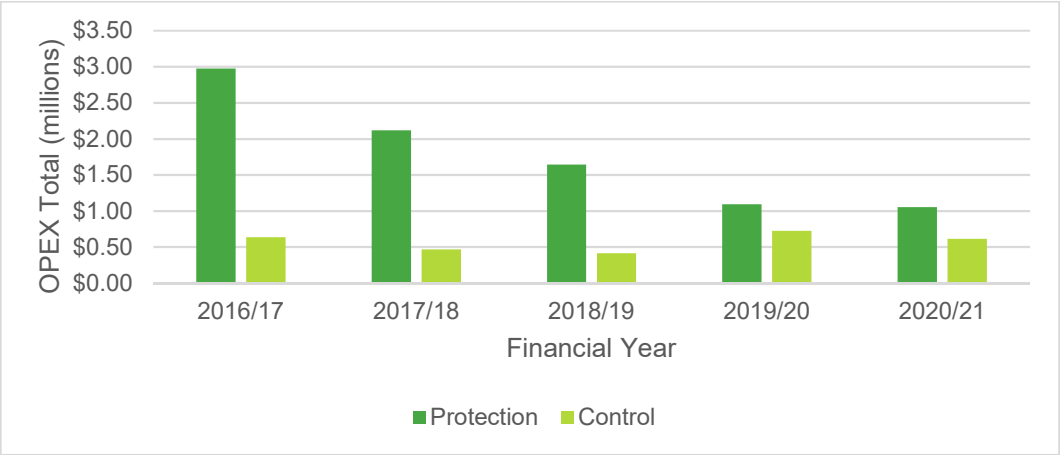
Figure 4 Total Historical CAPEX



3.1.1.2. Operating Expenditure

Previous initiatives had targeted a reduction in overall operating expenditure of the AMPOW. These reductions have been achieved through efficiency gains in maintenance delivery to reduce overall costs. These have been targeted through a review of maintenance activities and their frequencies. This has resulted in the historical downward trend of Operating Expenditure over the last four years.

Figure 5 Total Historical OPEX



The reductions in total expenditure highlighted above are a result of several factors. FY2017/2018 introduced in-service protection maintenance for all feeder and busbar protection schemes, resulting in a reduction of effort and outages required to deliver maintenance while ensuring that our protection schemes are capable of performing their stated function in meeting NER critical clearance times and maintaining the reliability and security of the network.

Since FY2019/20 we have seen an increase in control system corrective expenditure. Initial investigations have identified an emerging issue, potentially affecting a particular fleet, with controllers failing in a dormant lockout position that prevents its functionality. This has resulted in urgent emergency works to bring the controller back online with a firmware upgrade being required. See section 5.8 for further details.

A review of maintenance performance for protection and metering and cyber security (due to reporting challenges), actual versus budget costs, for FY2021 is shown in Table 8 below.

Table 8: Automation maintenance expenditure FY2021

	Actual $	Budget $	Variance $
Routine Maintenance	$1,351,133	$2,422,580	-$1,071,447
Inspections	$19,278	$27,537	-$8,259
Condition	$405,318	$475,000	-$69,682
Defect	$892,920	$952,222	-$59,302
TOTAL	**$2,668,649**	**$3,877,339**	**-$1,208,690**

Operating Expenditure constraints in FY2020/21 required the reprioritisation of maintenance activities. This had a direct impact on the overall planned maintenance for protection schemes whereby self-checking systems could have their activities delayed out of the financial year. This approach did not affect metering systems, which are part of the above summaries and did not place the network at significant risk.

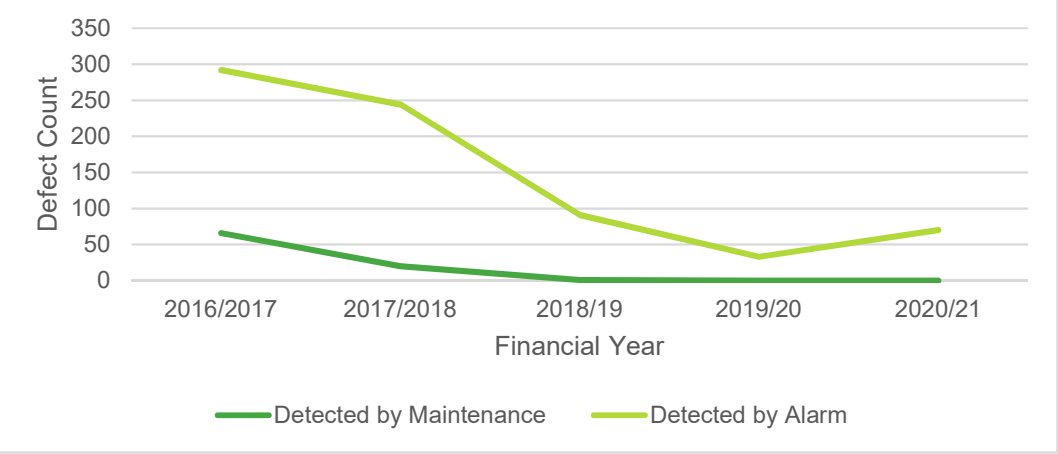
3.1.2. Review of Renewal and Maintenance Initiatives

Delivery of the existing Renewal and Maintenance initiatives has continued to target the strategic objectives of Transgrid where the investment:

- can be shown to be in the best interest of consumers
- is required to add or maintain value to our stakeholders
- protects network performance and maintains our license
- supports future value and creates further opportunity

The historical investment in modern technology, particularly self-checking components, has allowed us to move from a reliance on preventative maintenance to identify issues. New assets offer a higher availability of diagnostics and real time notification of issues.

Figure 6 Historical Protection Issue Detection



As can be seen, issues detected during preventative maintenance activities has reduced significantly throughout the last five years. As more assets are upgraded to modern technologies and standards, we are no longer waiting the length of a maintenance interval to discover issues with the assets. This means there is higher confidence in the availability of our protection assets within the network.

In particular, since 2016/17 where we have seen an increasing rate of delivery of our technology driven site wide upgrades, there is a downward trend in defects in general as the entire site infrastructure has been upgraded and delivers a more reliable installation.

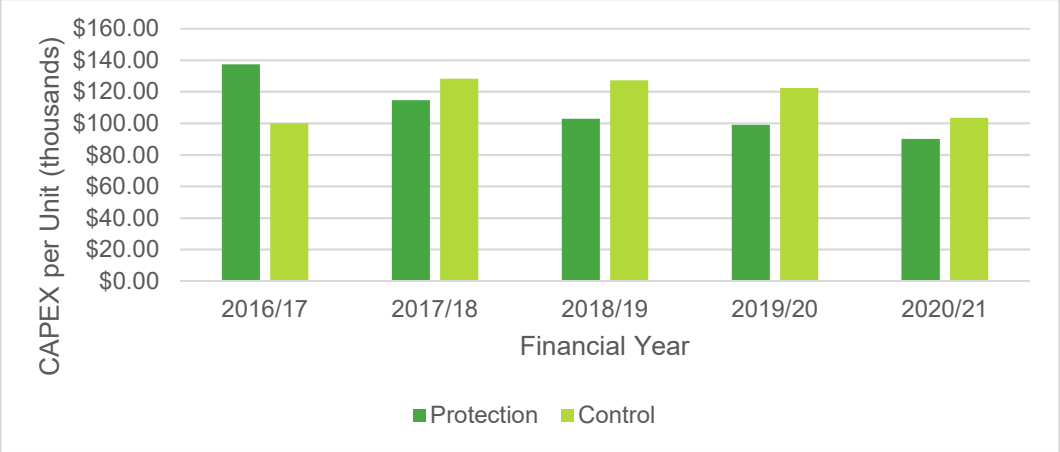
3.1.2.1. Capital Expenditure

FY2018/19 has seen the initiation of several major secondary system renewals. The year has seen the successful completion of targeted Asset Renewal Strategies such as Protection, Windows XP and 415V AC systems

When assessing the capital costs on a per asset basis, trends are increasing for control systems which is as expected due to the complexities of updating obsolete standards to modern standards. From a protection perspective, there is an increase in per unit costs between FY 2015/2016 to FY 2016/2017 while recent initiatives in the development of new standards and freedom given to design teams to identify opportunities to deliver the greatest value to the organisation while meeting strategic objectives in collaboration with the Asset Management team has resulted in overall reductions in expenditure.

As we have attempted to move to site wide asset renewals which allow the upgrade of all associated infrastructure to maximise value from the latest technology and capabilities, there is a portion of unitised costs which reflect the additional infrastructure works incurred as part of these upgrades. This increment can be seen between FY2015/2016 and FY2016/2017.

Figure 7 Unitised Historical CAPEX



Overall protection unit expenditure has remained stable and generally this can be attributed to two major contributors:

- Standardisation of the entire suite of relays deployed
- Replacement of microprocessor based systems is believed to be quicker due to similar wiring and configurations being available

Unit replacement costs for control systems has remained steady for over 3 years, this has been attributed to the delivery of Control system renewals under SSR projects only and minor renewal programs covering simpler systems namely, Data Concentrators and HMIs.

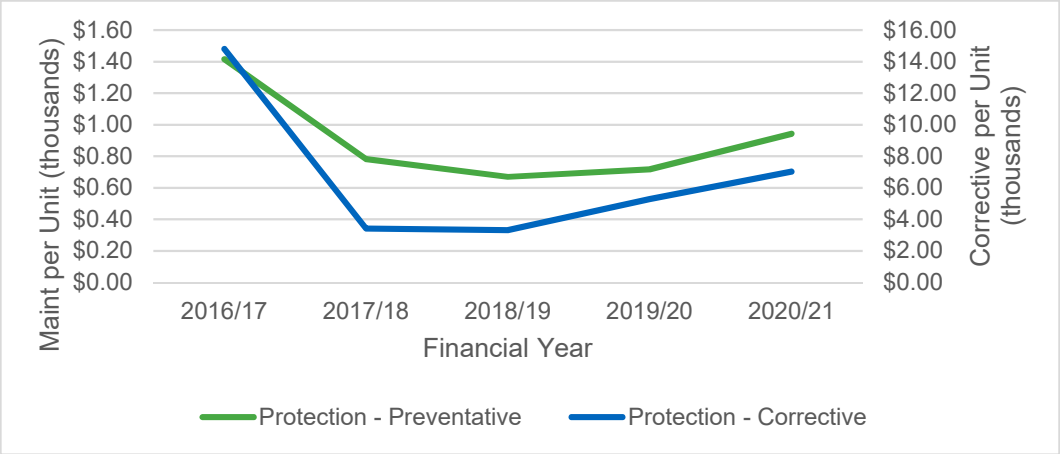
3.1.2.2. Operating Expenditure

Operating expenditure target reductions from the previous Strategy and Objectives have been met through the existing maintenance initiatives. This has been a result of several factors:

- Efficiencies in the delivery of maintenance tasks to maximise value from the assets
- Corrective maintenance cost reductions due to new technologies resulting in a faster and more cost effective return to service.
- Reductions in maintenance activity rates based on cyclical standard job analysis.

Protection related maintenance activities have seen an increase in unitised costs per maintenance task across both preventative and corrective activities. This has largely been attributed to the inclusion of support costs into the AMPoW.

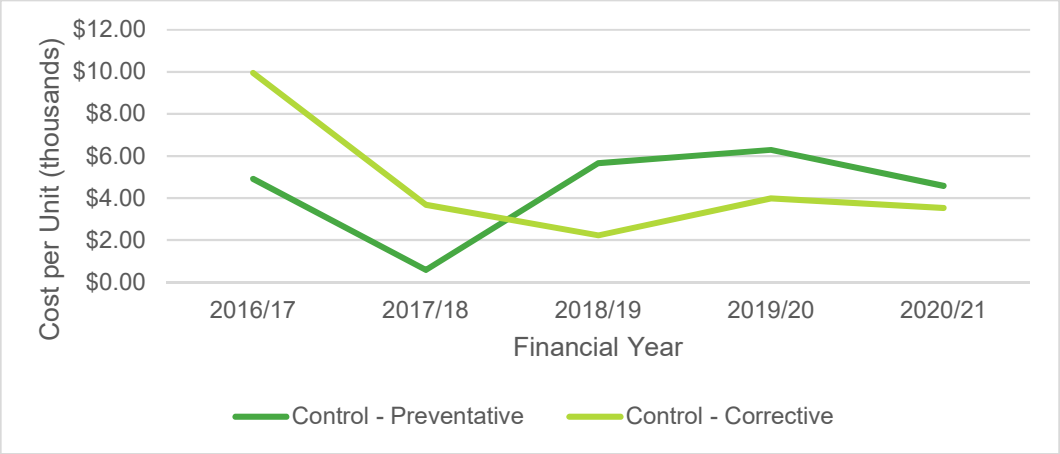
Figure 8 Historical Protection OPEX



Control related maintenance activities have seen a decrease in unitised costs for corrective and preventative maintenance activities. A review of costs has identified the cause:

- Defect only maintenance for a vast majority of control components
- Upgrades of control systems to modern standards which result in their integration into protection systems.
- Majority of control systems being modern systems with a reduced effort in rectification.

Figure 9 Historical Control OPEX



3.1.3. Past Performance – Asset Management Performance Indicators

The KPIs that demonstrate the effectiveness of this Renewal and Maintenance strategy to mitigate the network related safety, reliability environment, financial, compliance and reputational risks in support of the achievement of the asset management targets and objectives are the number of Key Hazardous Events. These measures have been maintained at a low level historically, indicating the Renewal and Maintenance strategies have been effective at mitigating the risks and achieving the asset management objectives.

KPIs are represented across both prescribed and non-prescribed assets. Across all outage types excluding Transmission Line & Cable Fault Outage Rates, Digital infrastructure assets have performed below the five year average for this asset class.

Historical KPIs and objectives are shown in Table 9 below. Updated Objectives and KPIs are shown in Section 4.

Table 9: Asset management objectives and performance indicators – Automation Systems

Transgrid Strategic Theme	Asset Management Objective	Asset Management Performance Indicators
Deliver safe, reliable power	Manage Network Safety Risk	• Maintain Network Safety LTIs and Fire starts at zero *Achieved in FY2021.* • Maintain 5 year average level of Key Hazardous Events: - Uncontrolled discharge of electricity *Achieved in FY2021 – see Section 3.1.3.*
Deliver safe, reliable power	Manage Network Safety Risk	• No red reports in key result indicators provided to BARC regarding Bushfire, Reliability and Public Safety *Achieved in FY2021.*

Transgrid Strategic Theme	Asset Management Objective	Asset Management Performance Indicators
Deliver safe, reliable power	Maintain network reliability	• Maintain 5 year average level of loss of supply events due to substation faults *Achieved in FY2021 – see Section 3.1.3.*
Deliver safe, reliable power	Maintain network reliability	• Achieve CY2021 STPIS result of $5.3m *STPIS performance for CY2021 is forecast to meet target.*
Create an efficient high performing business	Manage assets efficiently to deliver security holder and consumer value	• 7.8% reduction in AMPoW delivery FY2021 *AMWP budget outcome was met in FY2021. For asset class specific performance see Table 8 in Section 3.1.1.2.* • Achieve efficiency on regulated capital spend FY2021 *Targeted capital efficiency was achieved in FY2021 and reinvested into the business.*

3.1.3.1. Fault Outage Rates

Digital infrastructure assets have met and exceeded the 5 year average for all Forced outages.

Figure 10 Transmission Line & Cable Fault Outage Rate

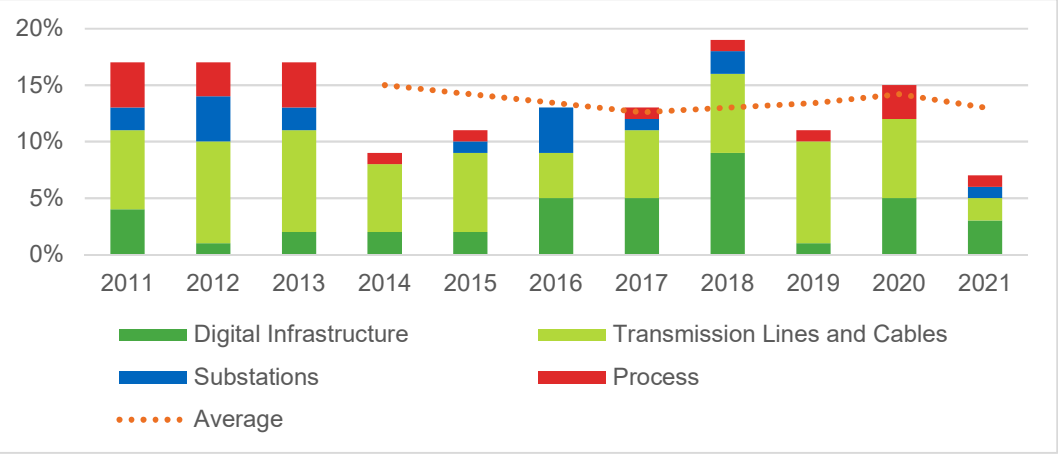


Figure 11 Transformer Fault Outage Rate

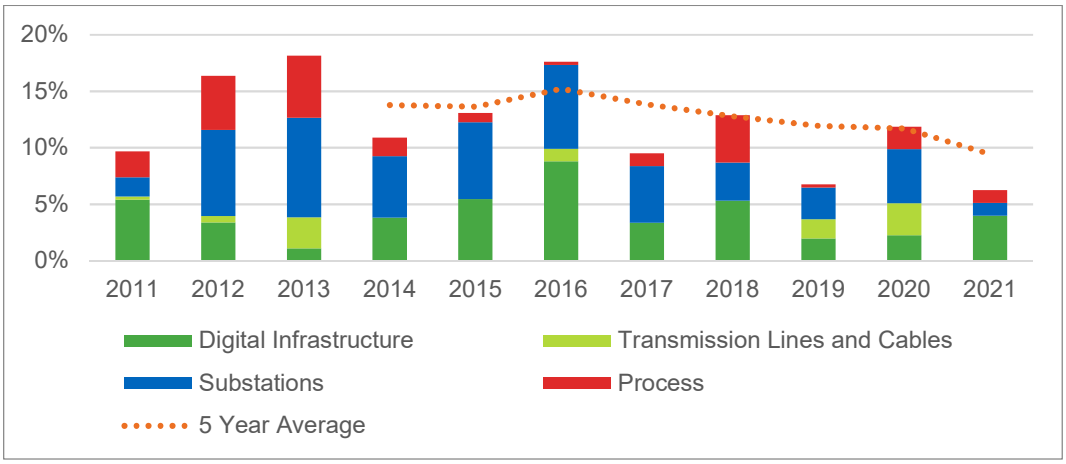
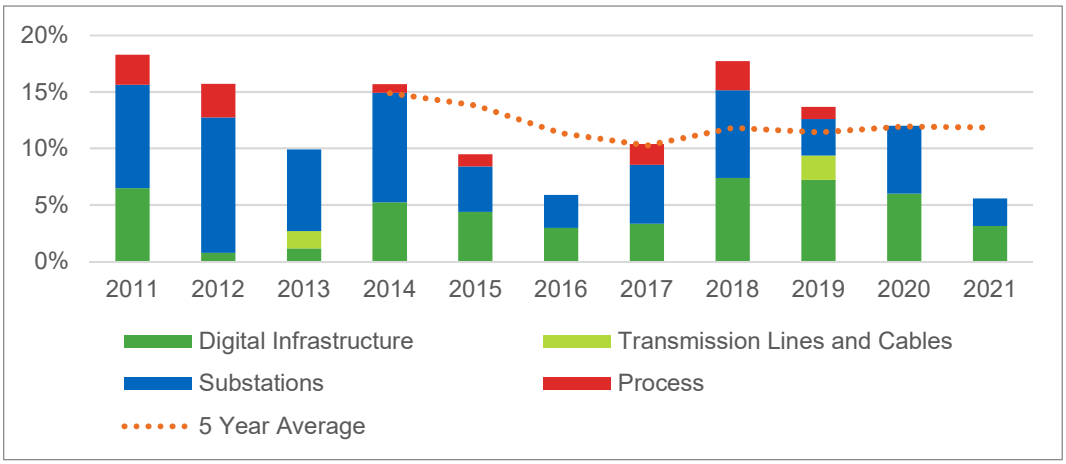


Figure 12 Reactive Plant Fault Outage Rate



3.1.3.2. Forced Outage Rates

Digital infrastructure assets have met and exceeded the 5 year average for all Forced outages.

Figure 13 Transmission Line & Cable Forced Outage Rate

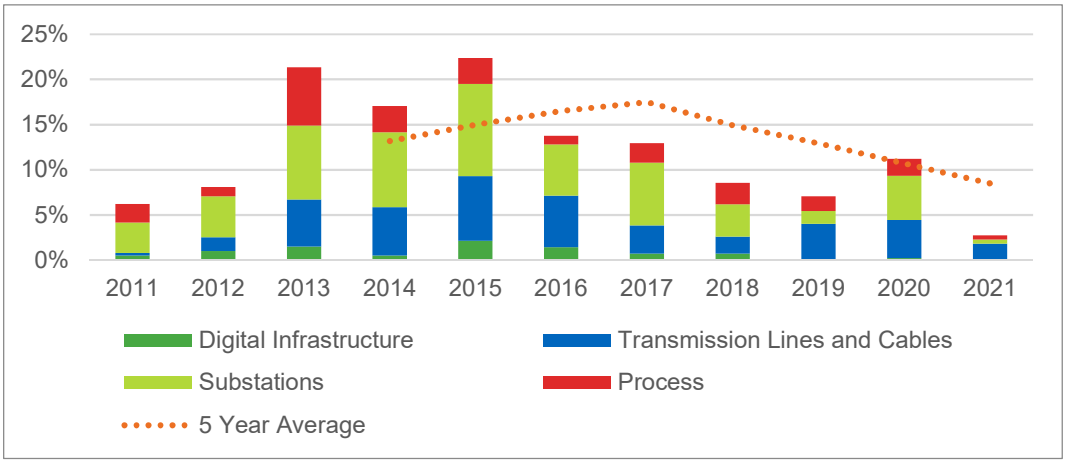


Figure 14 Transformer Forced Outage Rate

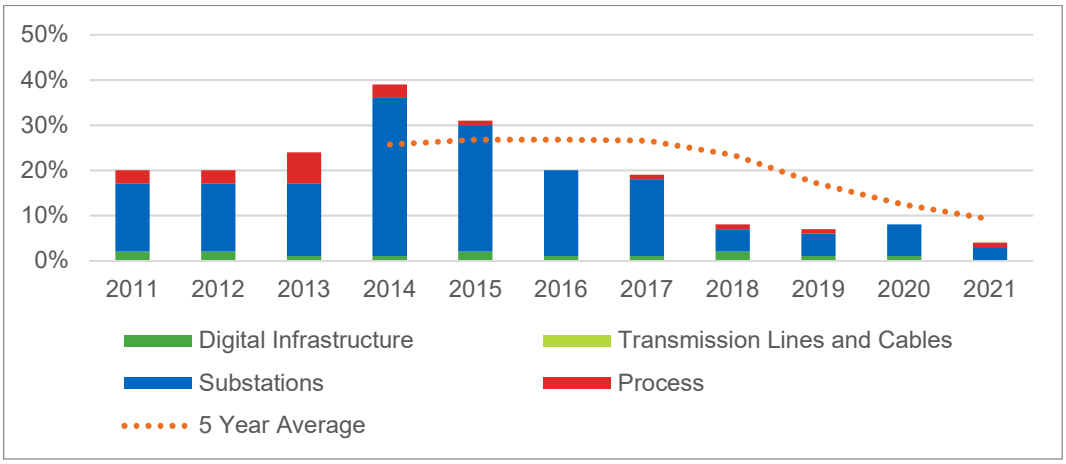
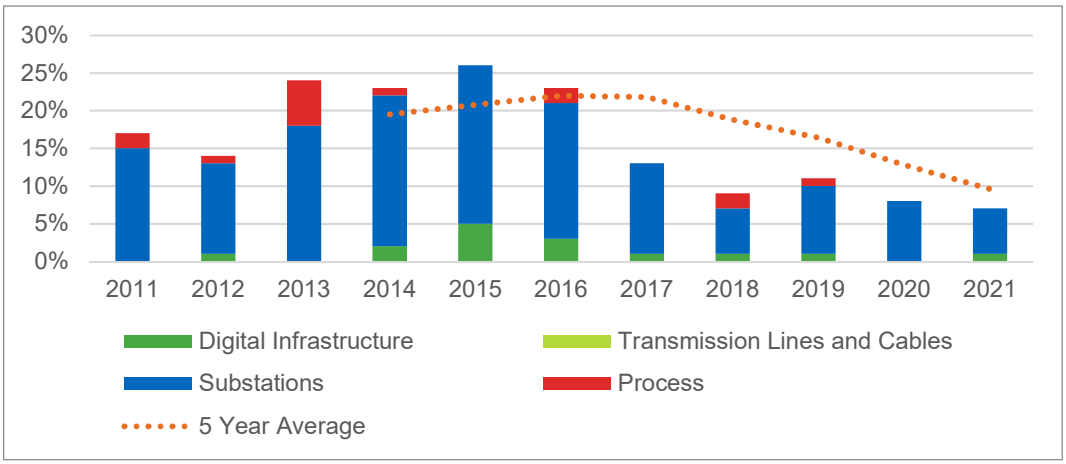


Figure 15 Reactive Plant Forced Outage Rate



3.1.3.3. System Minutes

There have been no System Minute events in 2021.

Figure 16 ENS >0.05 System Minute Event Count

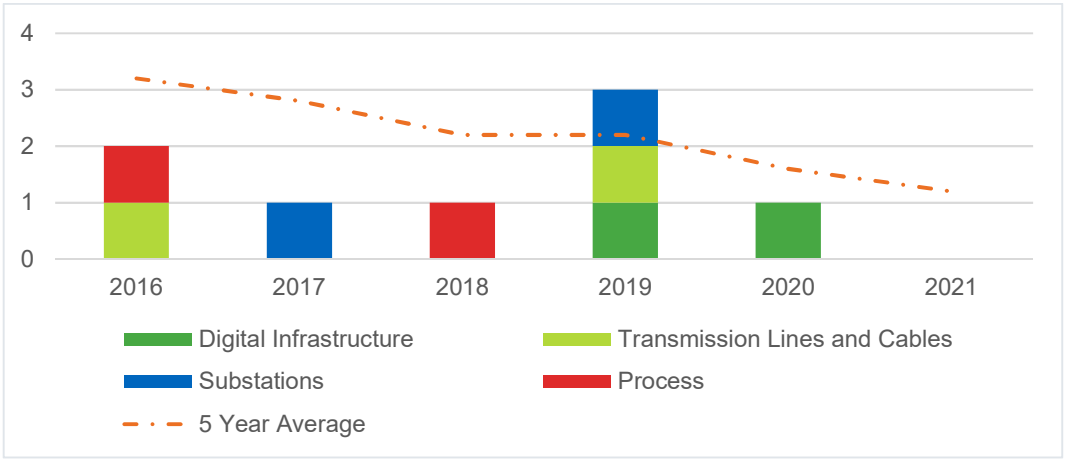
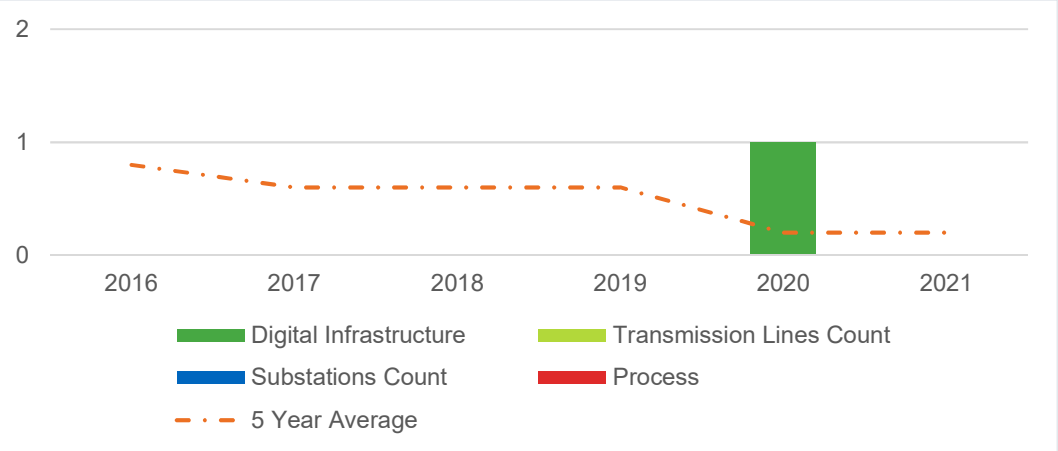


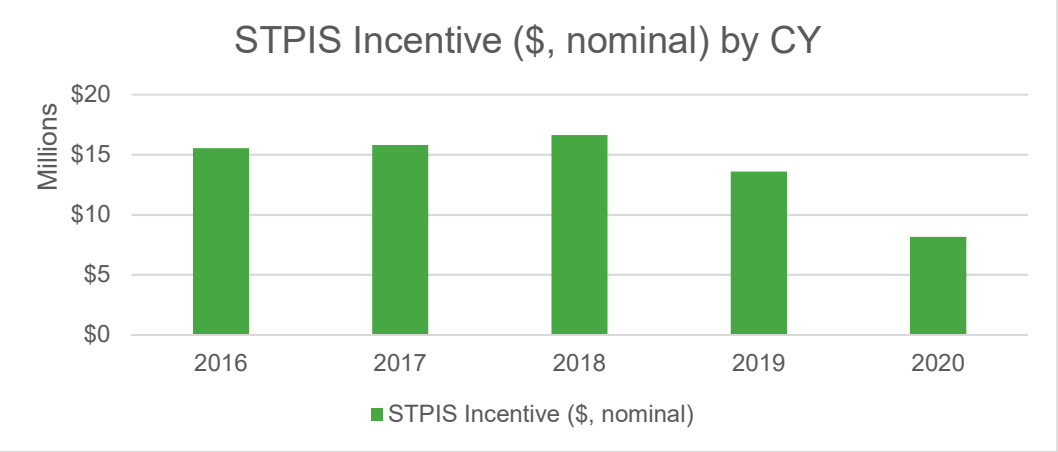
Figure 17 ENS >0.25 System Minute Event Count



3.1.4. STPIS Performance

Annual STPIS performance is summarised below.

Figure 18 Annual STPIS Outcome Trend



To meet the incentives certain initiatives have been undertaken by the Digital Infrastructure Asset Manager to maximise the availability of assets on the Network, we have not identified any issues with these initiatives over the last year and will maintain the previous direction.

3.2. Review of Strategic Initiatives

The status of relevant strategic initiatives from the Network Asset Strategy and other asset class specific strategic initiatives is provided in Table 8.

Table 10 Strategic Initiative Status

Network Asset Strategy Objectives	Initiatives / Reference	Status
Deliver safe reliable power		

Network Asset Strategy Objectives	Initiatives / Reference	Status
Manage Network Safety Risk Maintain network Reliability	Implement a technical authority framework supported by competency assessment processes.	Scope of activities covered by the Technical Authority Framework has been developed. Technical Design competency framework developed with assessment process development underway.
	Review and revise Risk Assessment Methodologies to ensure our ability to quantify risk is both appropriate and balanced defensibly.	Risk Assessment Methodology has been updated and is under continuous improvement.
	Implement Critical Control Management for key areas of the business.	Ongoing
	Minimise numbers of deployed systems that pose safety risk	Ongoing
Create an efficient high performing business		
Ensure accessible, relevant asset management information is available to inform business wide decisions	Continued collection of detailed asset condition data in AIM. Ready access to this data and integrating into the AAIT should empower the Asset Manager to make informed decisions. Improve asset performance monitoring through defect and AIM issue dashboards and analysis to inform asset strategies. Utilise newly implemented failure coding in AIM to allow better analysis and decision making.	Ongoing
Manage assets efficiently to deliver security holder and consumer value.	Control Assurance Reviews (CAR's) to identify weakness and non-conformances in cable asset management practices.	Two CAR's completed in FY2020/21.
	Development of information dashboards that provide relevant information to stakeholders to ensure asset management performance is accessible	Strategic risk dashboards have been implemented across operational and Executive committee meetings with further measures to be included in future iterations.

Network Asset Strategy Objectives	Initiatives / Reference	Status
Invest in Transmission to support the energy transition		
Support sustainable growth of the asset base by developing the right infrastructure	Supporting the development of the Integrated System Plan and Renewable Energy Zone projects.	Ongoing - providing trusted advice for the development, procurement and design of new assets to achieve lowest lifecycle cost. Review and update of standard design manuals and IUSA functional specifications.
Support growth in our unregulated business		
Support growth as the service provider of choice to the non-regulated market	Supporting the development of non-regulated projects.	Ongoing - providing trusted advice for the bid and development of non-regulated opportunities. Non-prescribed maintenance plan developed. Works in progress to develop a non-prescribed spares plan.

4. Strategy

4.1. Strategy and Objectives

All strategic initiatives with respect to Transgrid's prescribed Automation 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.

Table 11 Asset management objectives and performance indicators – Automation Asset Classes

Transgrid Strategic Theme	Asset Management Objective	Asset Management Performance Indicators
Deliver safe, reliable and low cost power	Manage Network Safety Risk	• Maintain Network Safety LTIs and Fire starts at zero • Maintain 5 year average level of High Potential Incidents (HPI): - Uncontrolled discharge of electricity - Third Party Activity resulting in asset damage / public injury • No red reports in key result indicators regarding Bushfire, Reliability and

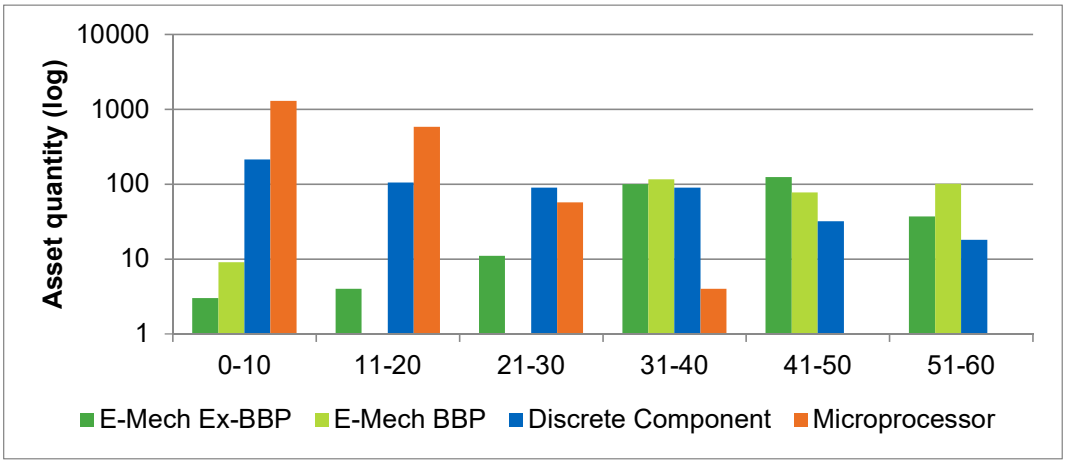
Transgrid Strategic Theme	Asset Management Objective	Asset Management Performance Indicators
		Public Safety Principal Risk Dashboards
Deliver safe, reliable and low cost power	Manage Network Safety Risk	Maintain 5 year level of environmental incidents
Deliver safe, reliable and low cost power	Maintain network reliability	Maintain 5 year average level of loss of supply events
Deliver safe, reliable and low cost power	Maintain Network Reliability	Target improvements to performance of the STPIS measures
Create an efficient high performing business	Manage assets efficiently to deliver security holder and consumer value	Deliver AMPoW within +/- 5% Delivery Capital Program within +/-5% Target capital efficiency improvements

5. Renewal and Maintenance Initiatives

5.1. Protection Assets Review

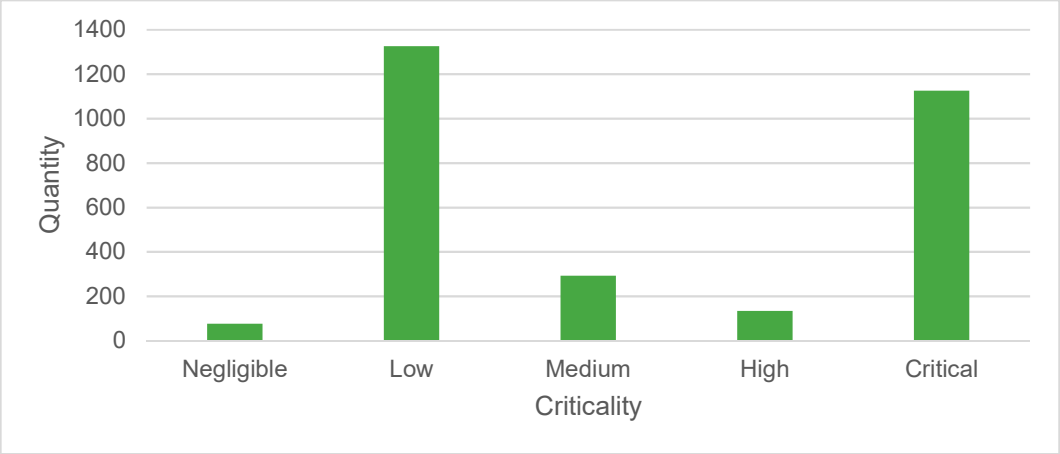
The current age profile of various protection technologies when compared to their estimated technical lives, identify a reasonable number of assets that have exceeded their life. Many of these end of life assets, excluding electromechanical Busbar Protection assets, have been identified for renewal.

Figure 19 Protection Age Profile



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:

Figure 20 Protection Criticality



5.1.1. Electromechanical Assets Excluding Busbar Protection

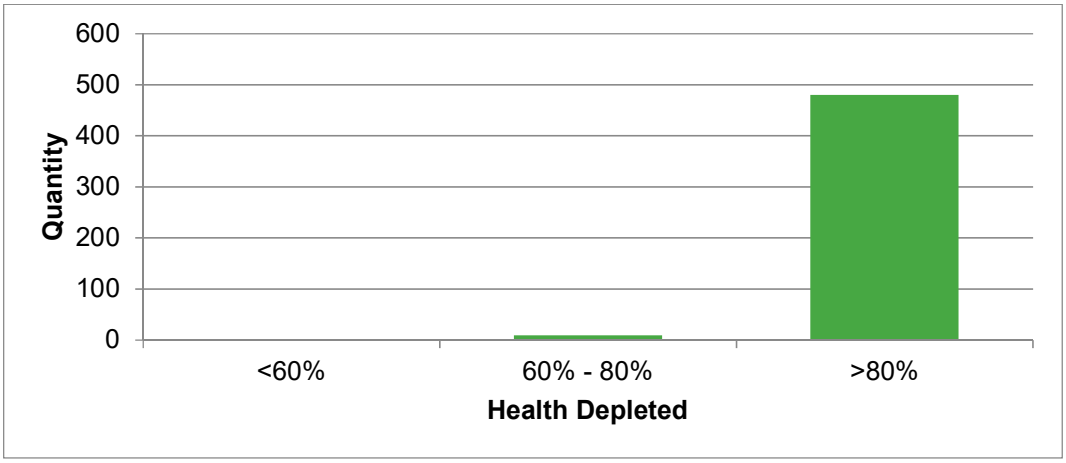
The use of electromechanical relays has been phased out of all new installations except for some auxiliary functions. This is mainly due to the low value they provide us compared to the capabilities of modern microprocessor based assets.

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 their quality. 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.

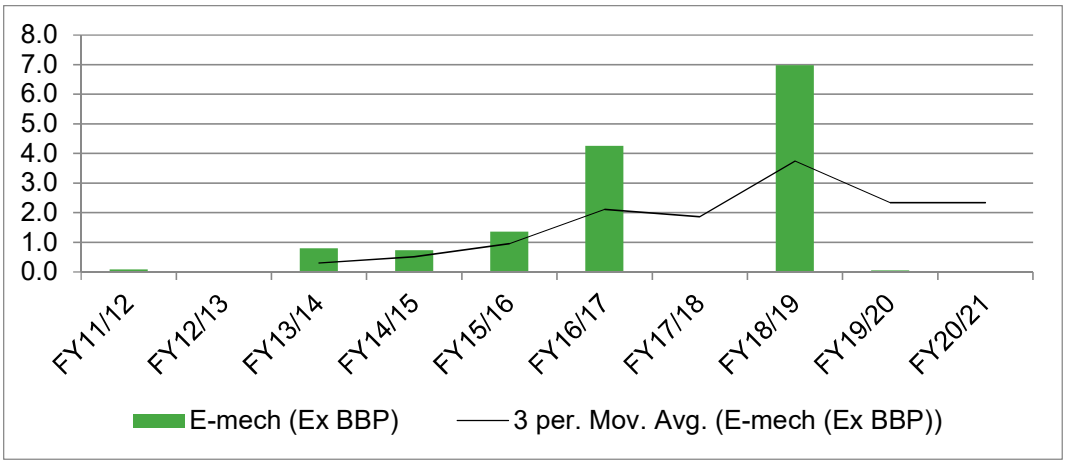
The health of these assets varies and is primarily dependant on manufacturer support, spares availability, forecast defect rates, age and the technical life of the assets. The health index has been used to identify the assets that require investigation for renewal through our Capital Investment Governance Process.

Figure 21 Electromechanical ex-BBP Health Index



A review of historical defect rates with a three year rolling average highlighting a flattened trend. However, the spike in FY2018/19 and subsequent decay in defects is aligned with a 4 yearly maintenance cycle, with dormant failures difficult to detect with no alarming functionality. Addressing these issues is a priority for us to meet our strategic objectives.

Figure 22 Electromechanical ex-BBP Historical Defect Rates (%)



5.1.2. Electromechanical Busbar Protection Assets

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.

The health index of these assets has depleted and is primarily dependant on manufacturer support, spares availability, forecast defect rates, age and the technical life of the assets. The health index has been used to identify the assets that require investigation for renewal through our Capital Investment Governance Process.

Due to the unique nature of High Impedance Busbar Protection, in that they have simple connections and are relatively simple to upgrade with newer units, no active renewal initiatives have been put in place to address the end of life characteristics of these assets.

Figure 23 Electromechanical BBP Health Index

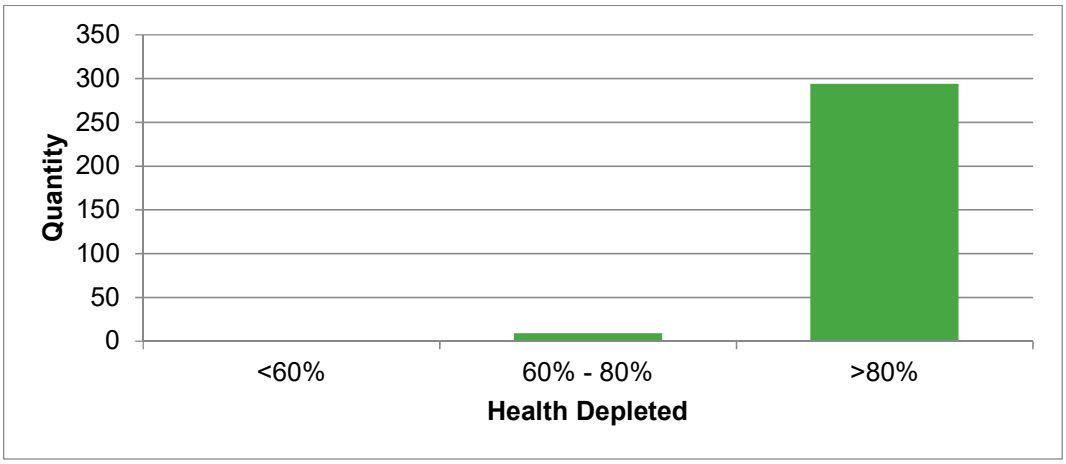
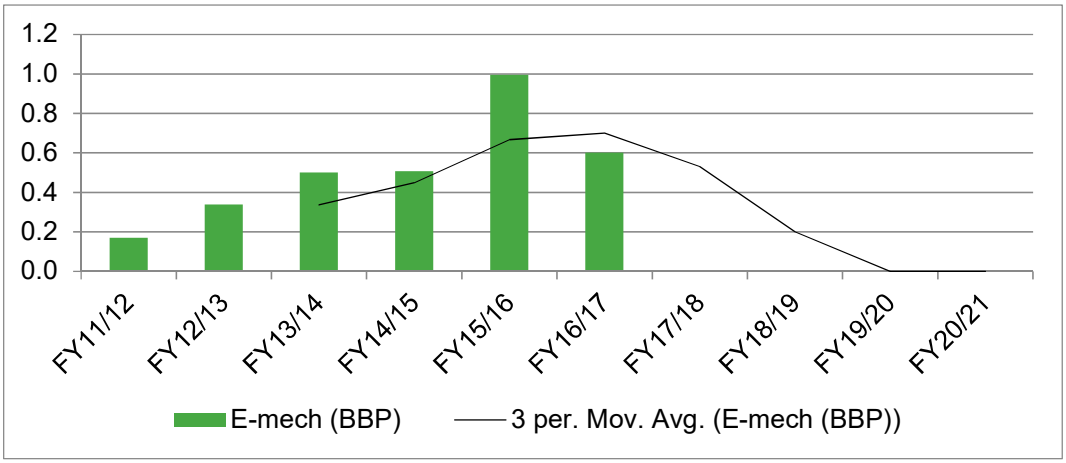


Figure 24 Electromechanical BBP Historical Defect Rates (%)



5.1.3. Discrete Component Protection Assets

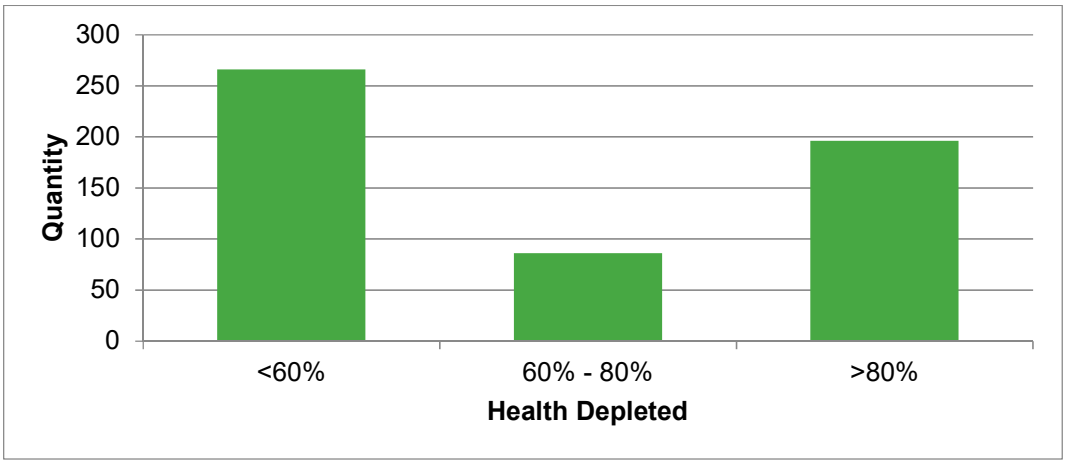
Early electronic Protection systems based on discrete electronic components installed on printed circuit boards. The majority of these systems were installed between 1970 and 1995. The installations are displaying signs of degradation due mainly to capacitor dielectric issues resulting in calibration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

We do 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.

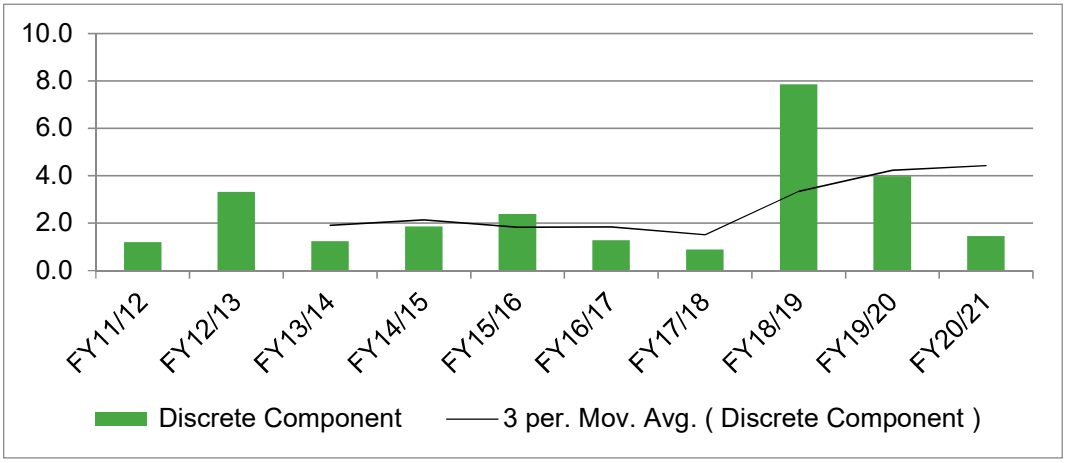
The health of these assets varies and is primarily dependant on manufacturer support, spares availability, forecast defect rates, age and the technical life of the assets. The health index has been used to identify the assets that require investigation for renewal through our Capital Investment Governance Process.

Figure 25 Discrete Component Health Index



A review of historical defect rates with a three year rolling average highlighting a flattened trend. However, the spike in FY2018/19 and subsequent decay in defects is aligned with a 4 yearly maintenance cycle, with dormant failures difficult to detect with no alarming functionality. These assets require immediate attention to address the emerging issues.

Figure 26 Discrete Component Historical Defect Rates (%)



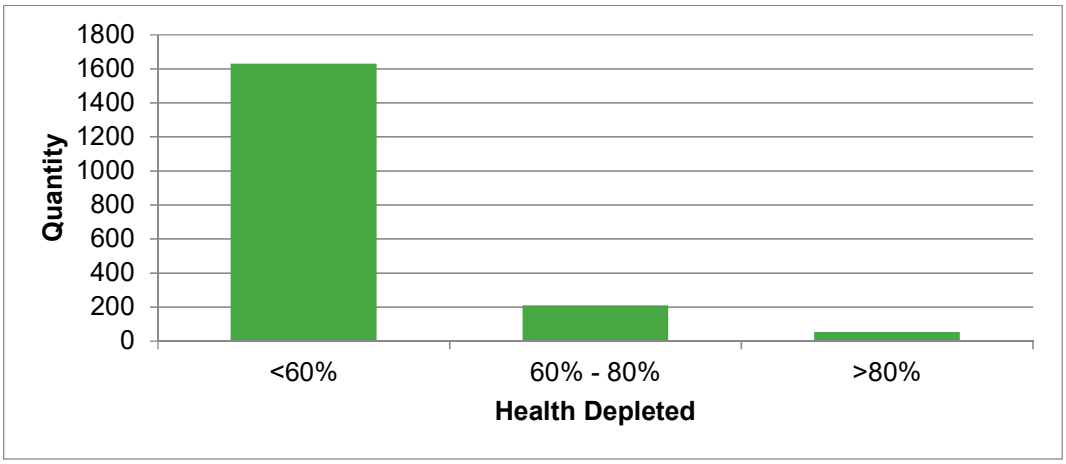
5.1.4. Microprocessor Protection Assets

Microprocessor based protection assets are the current standard for the protection of all network elements with the exception of Busbars. These assets provide significant value to us and our strategic objectives. These assets are capable of complex configurations and incorporate an internal watchdog which will alarm when the asset detects any issues, minimising the need for frequent preventative maintenance activities. These assets form the majority of our protection population.

The current implementation of microprocessor standards additionally leverages communications channels to connect directly to our SCADA systems, this provides additional confidence in the early detection of relay failures.

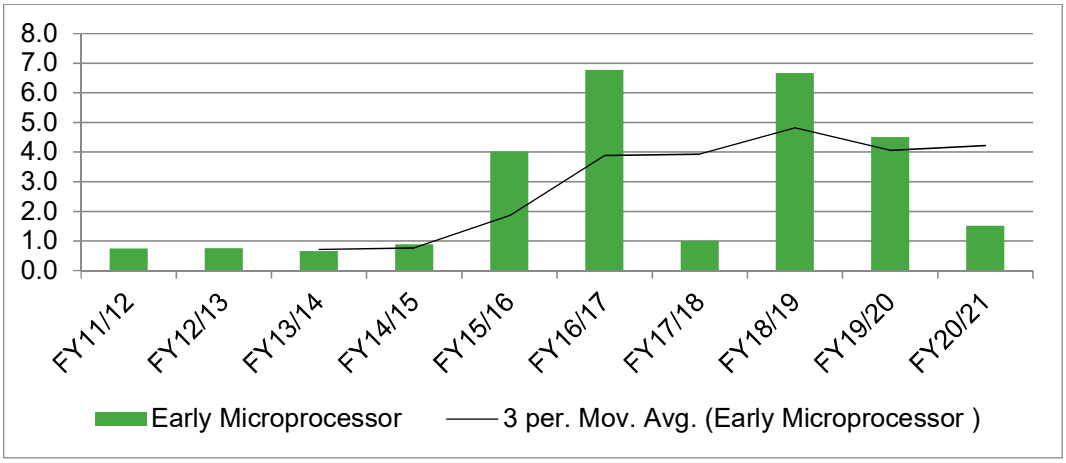
The health of these assets varies and is primarily dependant on manufacturer support, spares availability, forecast defect rates, age and the technical life of the assets. The health index has been used to identify the assets that require investigation for renewal through our Capital Investment Governance Process.

Figure 27 Microprocessor Health Index



Early microprocessor models (pre-2000) are assessed separately as they are a simpler device inclusive of their internal watchdog feature. They compose 348 assets out of the entire population. These assets face issues with spares availability due to the withdrawal of manufacturer support. There are additional complications associated with manufacturer support surrounding the inability to patch or update relay programming software. There is an increasing trend in defect rates and these issues have been targeted in our renewal initiatives.

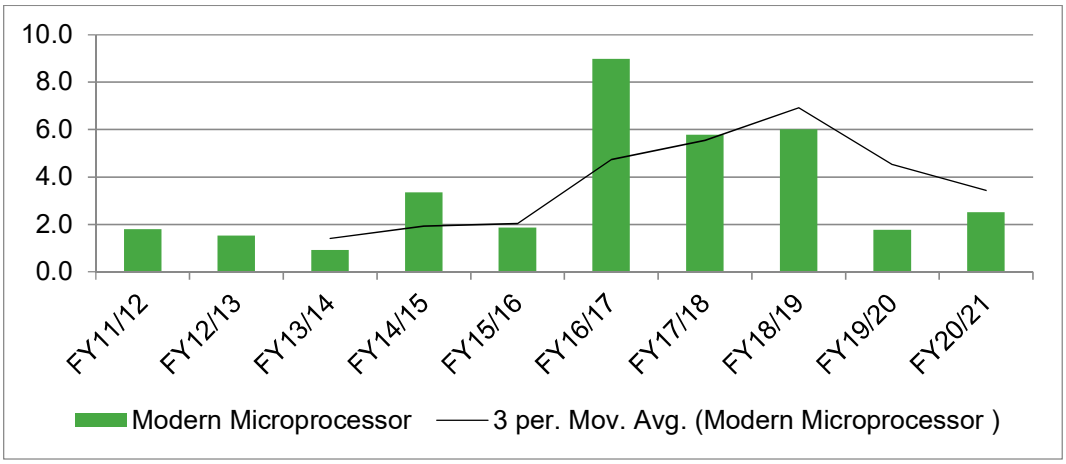
Figure 28 Early Microprocessor Historical Defect Rates (%)



Modern microprocessor assets (post 2000) have increased watchdog capability and functionality. Their defect rates are generally higher, but they are capable of detecting many issues and are considerably easier to replace and retest than other types of assets. While the defect rates are higher, many result in simple resets of the asset or worst case a direct new for old swap during the response.

There have been a significant number of defects raised historically due to a particular model range of assets, these have been targeted as part of the previous strategies and the majority of targeted assets have been renewed between FY2017/18 and FY2018/19. In the last year the defect rate for modern microprocessors has returned to a acceptable rate, comparable to pre-FY15/16, demonstrating the successful implementation of our renewal initiatives.

Figure 29 Modern Microprocessor Historical Defect Rates (%)



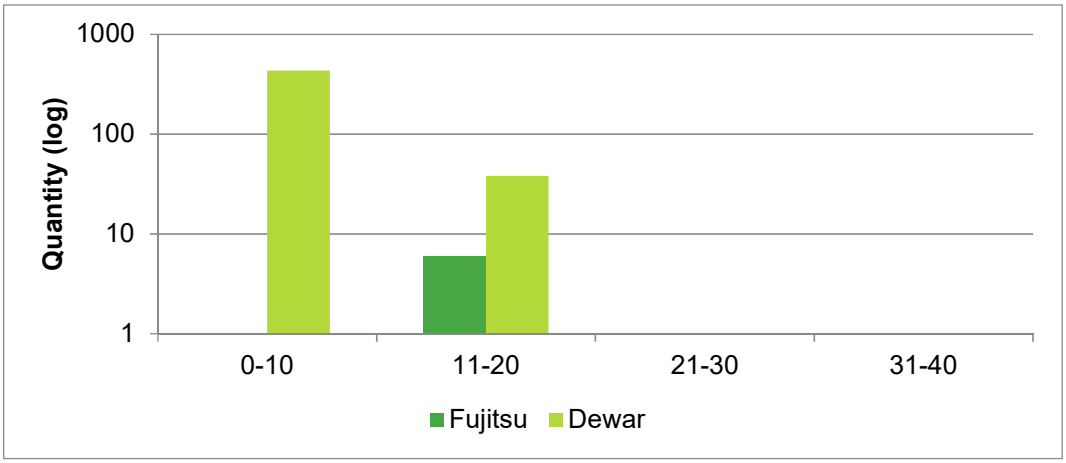
5.2. Tele protection Assets

5.2.1. Population Review

Tele protection assets are comprised of almost all modern day Dewar systems with just 8 remaining Fujitsu units in the network. These assets are in good condition with a proportion reaching the end of their technical lives. The asset's age profiles indicate a steady increase in ages which require standard addressing.

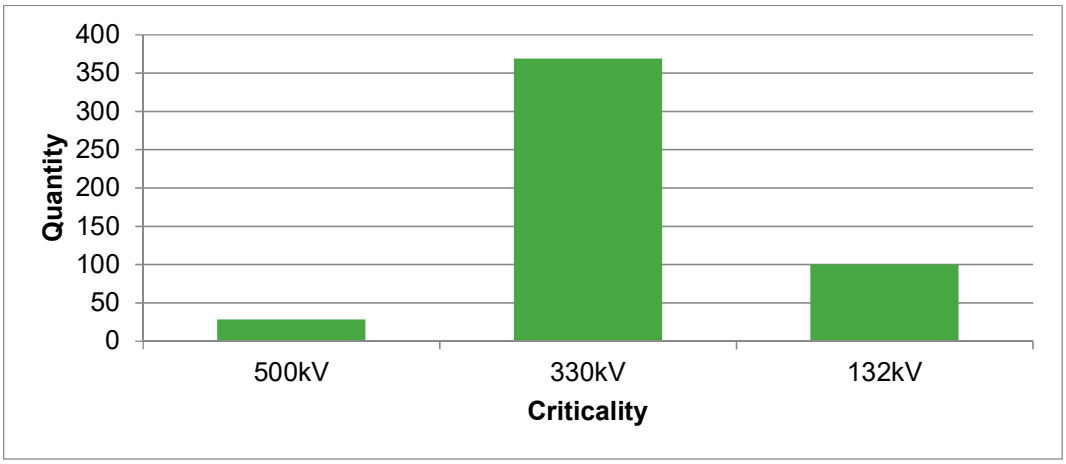
Fujitsu teleprotection signalling equipment was in common use before the adoption of the current fleet of teleprotection signalling systems. This equipment was installed over a 20 year period culminating in the late 1990's/early 2000's. It has been very reliable but is no longer supported and is beginning to show signs of ageing.

Figure 30 Tele protection Age Profile



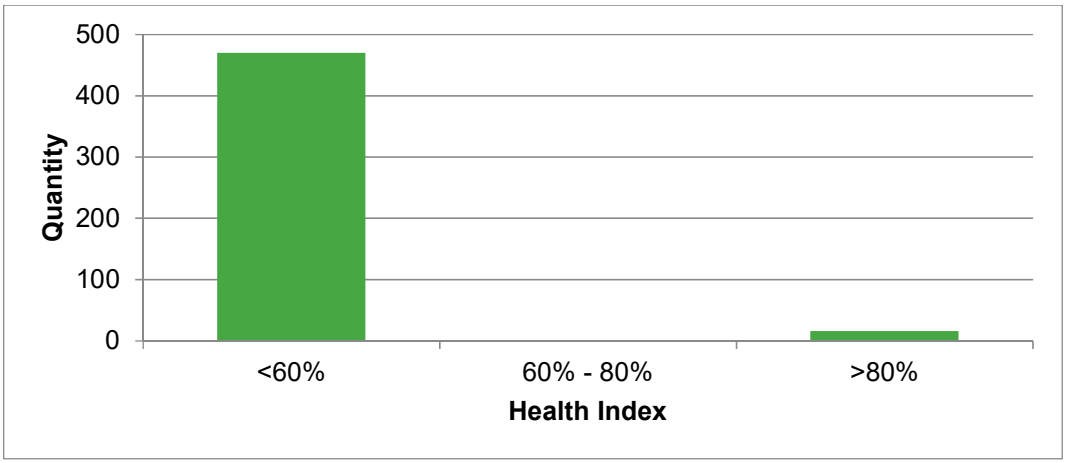
Due to the need for teleprotection to provide high speed remote end clearance of transmission line faults. Scoring is applied in accordance with brackets of voltage level protected. This is due to the potential network stability impacts and clearance time requirements at different voltage levels.

Figure 31 Tele protection Criticality



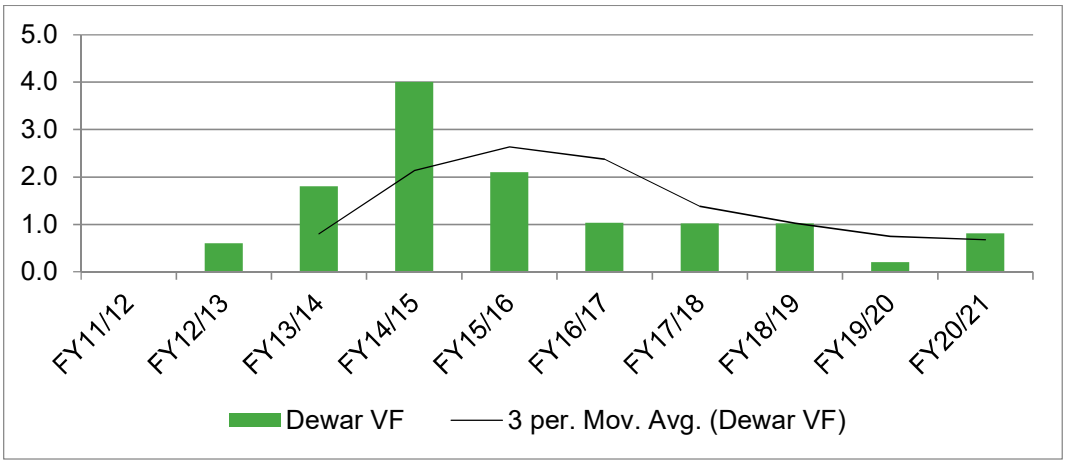
The health of these assets varies and is primarily dependant on manufacturer support, spares availability, forecast defect rates, age and the technical life of the assets. The health index has been used to identify the assets that require investigation for renewal through our Capital Investment Governance Process.

Figure 32 Tele protection Health Index



The Dewar asset defect rates indicate good performance overall with numbers below the 4% rate for several years. These are considered to be relatively reliable assets.

Figure 33 Dewar Tele protection Defect Rates (%)



Defect rates for the Fujitsu assets have dropped for the last few years, it is noted that a population of 8 would produce very low or very high defect rates. There are no longer spares and support available for these assets and we are reliant on re-acquired spares from major projects therefore a failure may result in extended outages of the protective asset to allow an upgrade to modern standards.

5.3. Analysis Assets

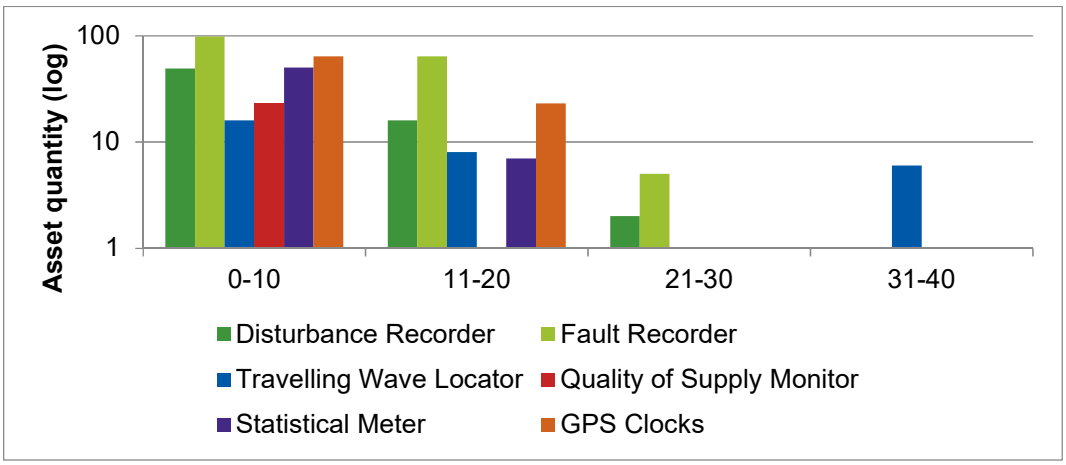
Analysis equipment assets are utilised to review and analyse performance of the network. The vast majority of these assets are microprocessor based and are utilised to support the operation of the network. These assets provide operational value to ensure responses to network events are quickly analysed leading to shorter outage times.

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.

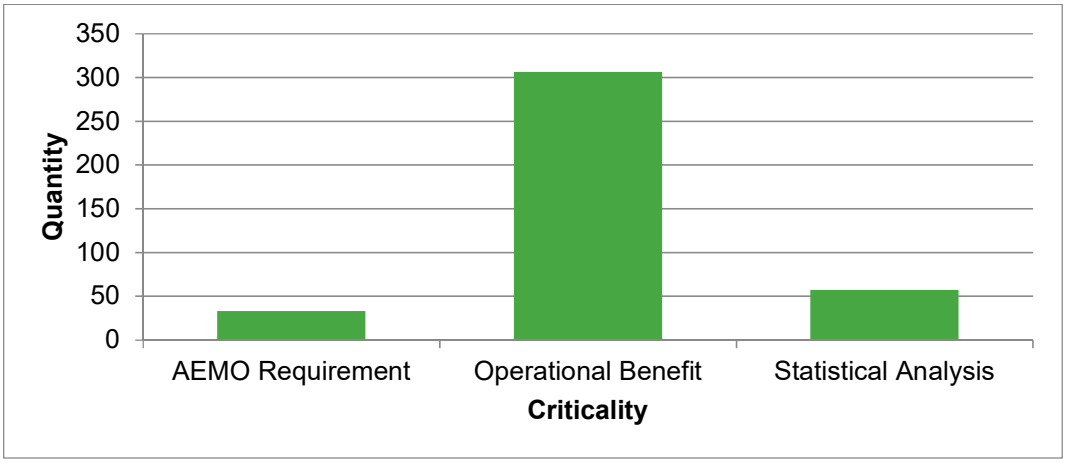
- GPS Clocks – Microprocessor based timing units utilised to coordinate accurate timestamping across multiple devices. These devices assist in ensuring all incidents across the network can be traced and a sequence of events can be established

Figure 34 Analysis Age Profile



Analysis assets fall under three main categories, AEMO directed installations, operational benefit installations and statistical analysis. Two categories are of value to us in maintaining a reliable and secure electricity supply in an efficient manner that is of benefit to consumers. Statistical Analysis components are generally metering installations that have had status changed from Market Metering to statistical. These are kept in service due to the expense of withdrawal and disposal. These types of installations are not maintained and no renewal initiatives are undertaken unless their status is changed to Market Metering again.

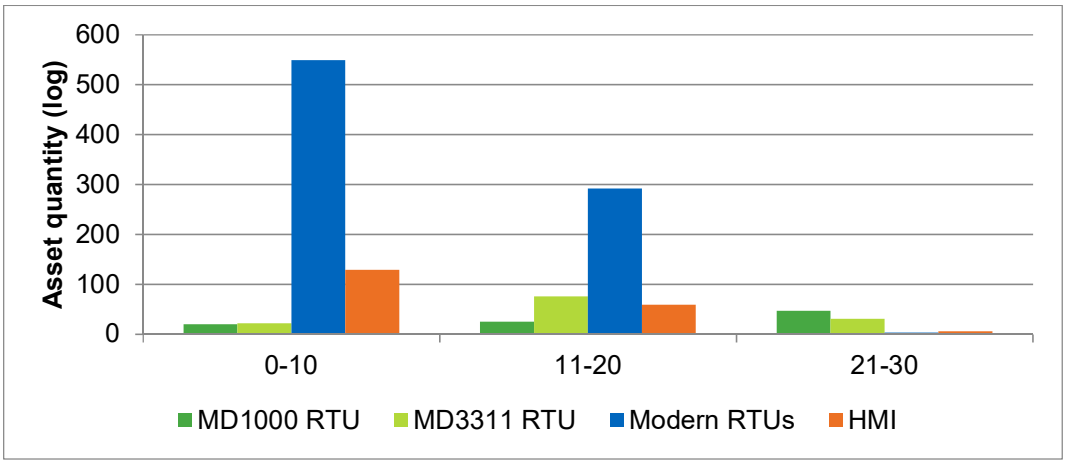
Figure 35 Analysis Criticality



5.4. Control Assets

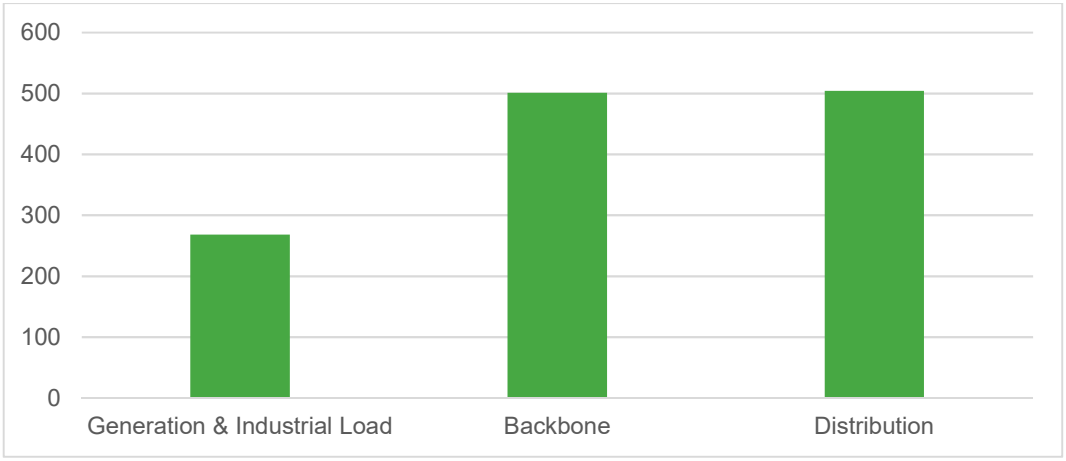
Control Assets are used for the remote monitoring and control of elements within an unmanned substation or switching station. These assets allow us to increase value to our stakeholders by minimising the labour required to ensure the correct operation of the Network. Some functions such as automatic reclose of breakers is automated, while other functions are centrally monitored and controlled from the SCADA Control Rooms.

Figure 36 Control Age Profile



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.

Figure 37 Control System Criticality



5.4.1. MD1000 RTU

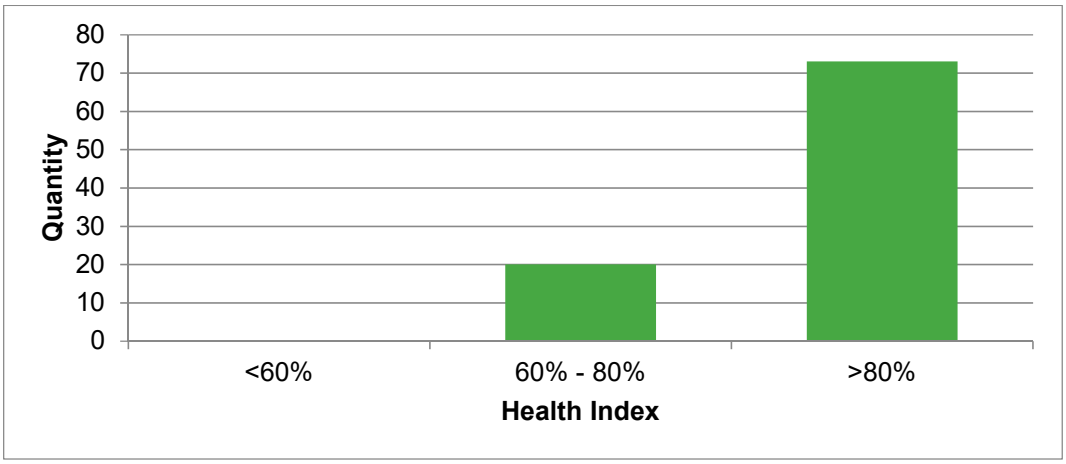
The MD1000 family of RTUs are of the earliest generation of controllers utilised in the Transgrid network. These assets were used in a centralised controller philosophy where there is a single brain and multiple IO points for the various primary assets controlled. These assets are microprocessor and 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.

The health of these assets varies and is primarily dependant on manufacturer support, spares availability, forecast defect rates, age and the technical life of the assets. The health index has been used to identify the assets that require investigation for renewal through our Capital Investment Governance Process.

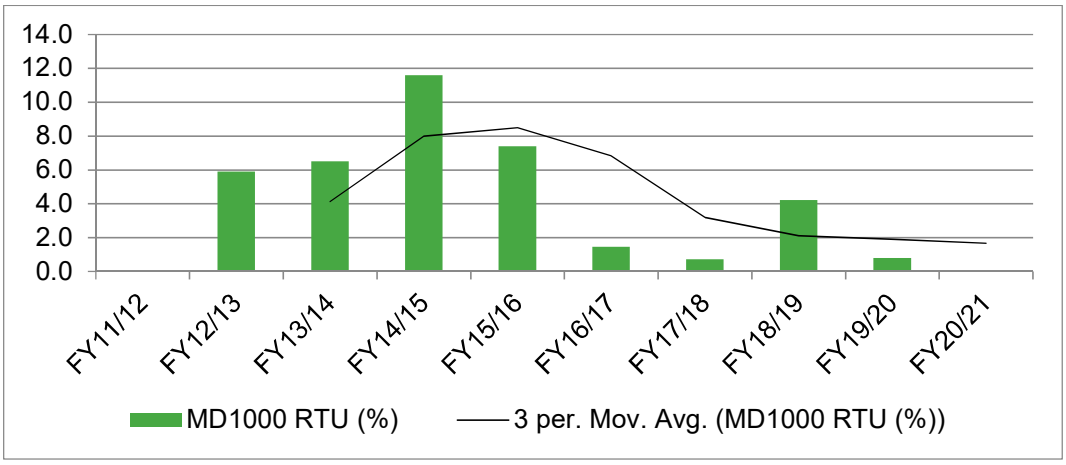
It is noted that MD1000 components are well beyond their technical life and the little spares that are available are comprised primarily of refurbished or repaired units.

Figure 38 MD1000 Health Index



The trend of defect rates for this asset has reduced over the past few years, this is largely due to a reduced number of assets and therefore a lower population to detect defects against. It is however difficult to maintain these assets as they are reliant on an obsolete, manufacturer specific communications protocol. With spares depleted and a heavy reliance on re-acquired spares from major renewal projects, we cannot provide value to our stakeholders by keeping this asset in service.

Figure 39 MD1000 Defect Rates (%)



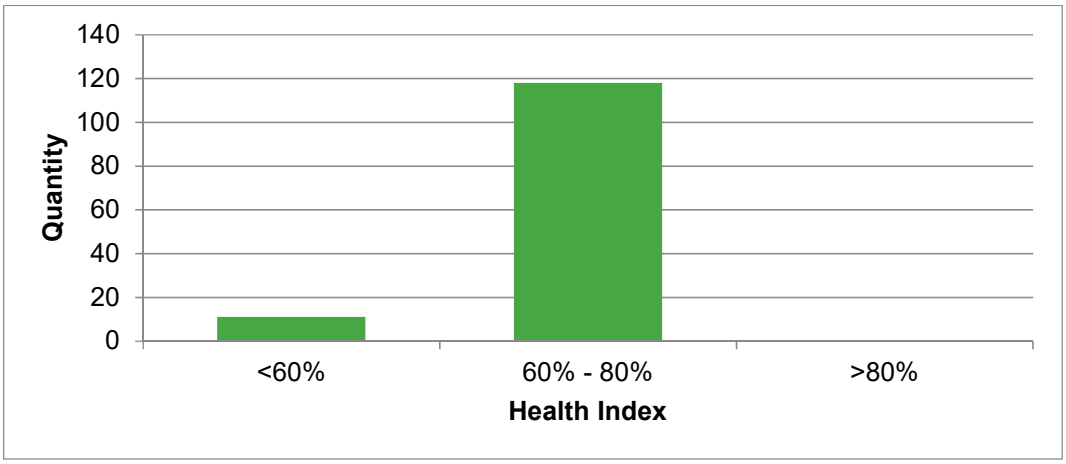
5.4.2. MD3311 RTU

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.

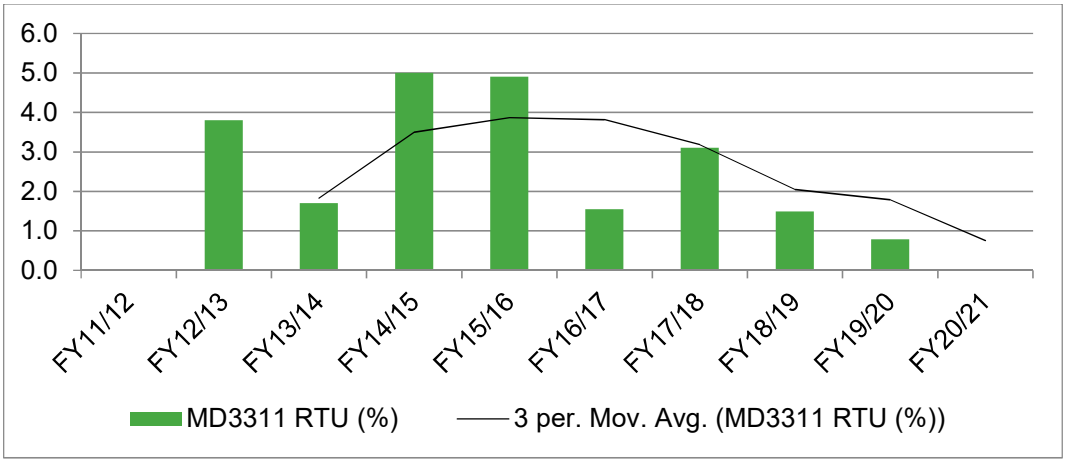
The health of these assets varies and is primarily dependant on manufacturer support, spares availability, forecast defect rates, age and the technical life of the assets. The health index has been used to identify the assets that require investigation for renewal through our Capital Investment Governance Process.

Figure 40 MD3311 Health Index



The rolling average of defect rates for these assets has been relatively steady for the past few years. Ongoing monitoring and review is in place for these assets.

Figure 41 MD3311 Defect Rates (%)

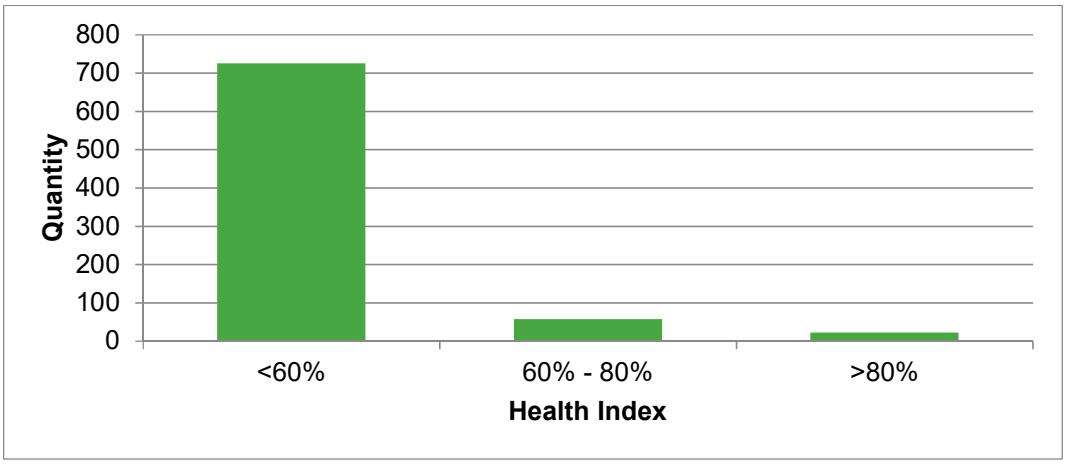


5.4.3. Modern RTU

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.

The health of these assets varies and is primarily dependant on manufacturer support, spares availability, forecast defect rates, age and the technical life of the assets. The health index has been used to identify the assets that require investigation for renewal through our Capital Investment Governance Process.

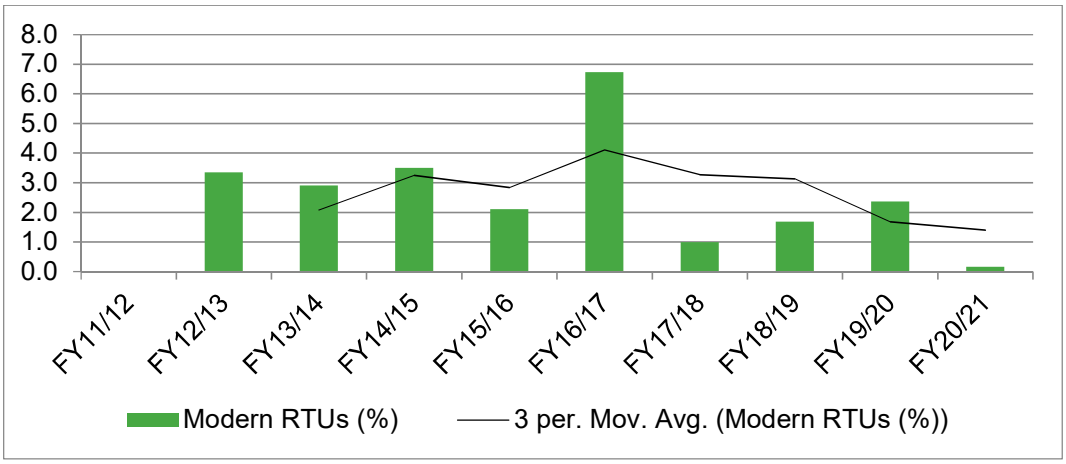
Figure 42 Modern RTU Health Index



Modern RTU rolling average defect rates have been trending slightly upwards, this is being monitored and reviewed regularly as to the causes. So far we have established that it is mainly attributable to the increase in quantities installed leading to more defects in the network.

We have identified an issue with the MD300 series of modern RTUs whereby the internal software of the device is prone to locking up. We are in the process of planning a direction to address this very specific issue.

Figure 43 Modern RTU Defect Rates (%)



5.4.4. Modern IED Controllers

Current standards have moved to the utilisation of Intelligent Electronic Devices for control functionality. These standards are in early stages of deployment with two solutions available:

Integrated control within the protection device

Dedicated protection device carrying out control functionality only

Both approaches are leveraging IEC61850-7 and IEC61850-8 to deliver Interdev ice messaging as required for the operation of a substation.

Continual monitoring of these deployments will be carried out to ensure long-term viability.

5.4.5. HMI

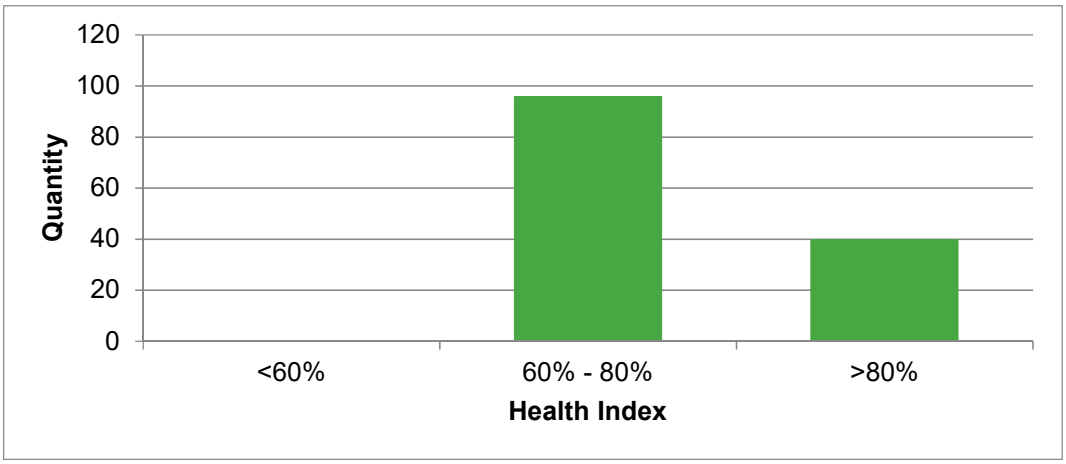
HMIs are based on an industrial PC package utilising Serck SCX6 as the software interface platform. The systems operate on the Windows XP operating system.

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.

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.

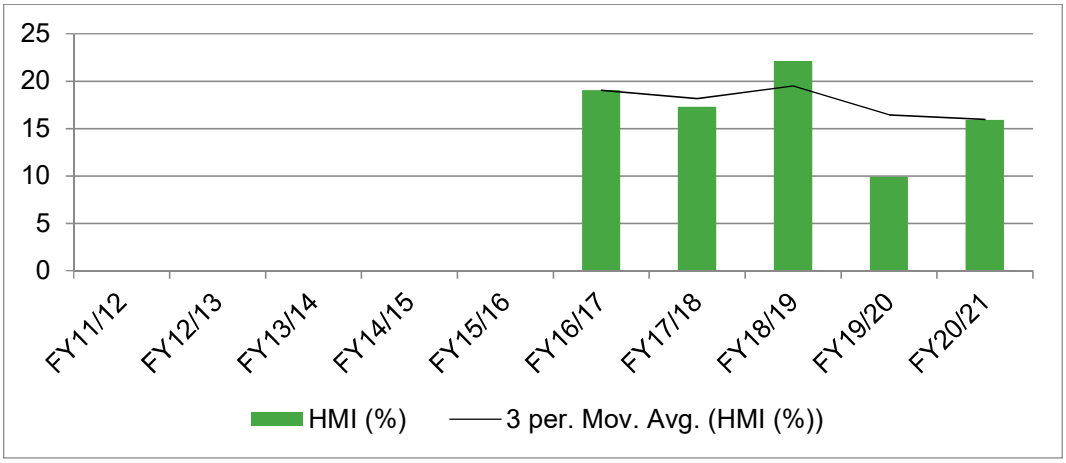
The health of these assets varies and is primarily dependant on manufacturer support, spares availability, forecast defect rates, age and the technical life of the assets. The health index has been used to identify the assets that require investigation for renewal through our Capital Investment Governance Process.

Figure 44 HMI Health Index



HMI rolling average defect rates have seen a decrease last year. These assets have been targeted for renewal as part of a security upgrade project to bring the underlying operating system of the HMI software to modern standards and hardware. The result of replacements can be seen with a change to a more robust hardware platform likely attributing to the decrease in defects.

Figure 45 HMI Defect Rates (%)



5.5. Point on Wave Systems

Historical deployments for Point on Wave systems (POW) have been allowed to be set by the circuit breaker manufacturer. This has led to unique situation whereby we have several models of POW relay installed within the network with no feasible upgrade path.

We have commenced engagement with the key stakeholders for POW devices to establish a way forward.

Our current strategic direction is the investigation and investment into the development of a standalone, Circuit Breaker agnostic POW device that facilitates the standardisation of deployments, configuration and maintenance of these systems. Whilst this direction would provide capital and operating expenditure efficiencies related directly to the POW asset fleet, wider considerations with the coupled HV plant, for example manufacturer warranty and support, remain a work in progress.

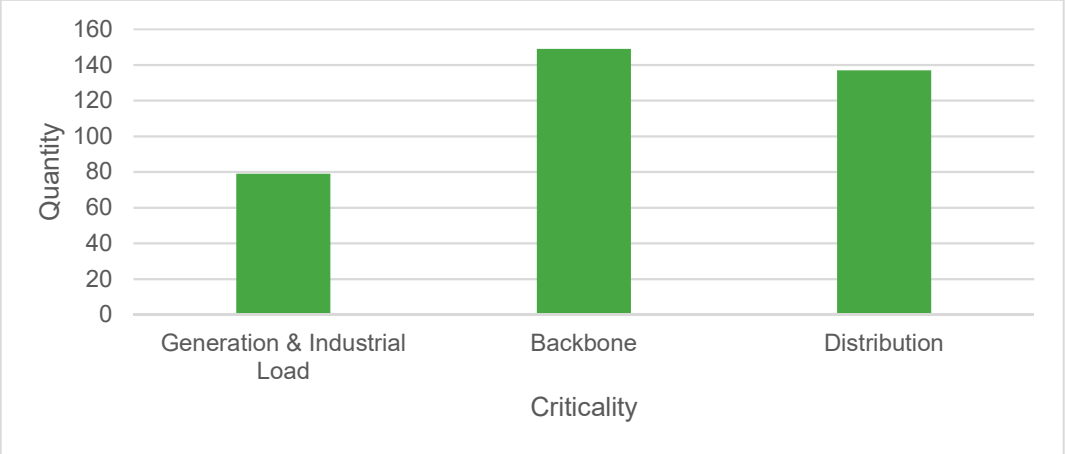
The POW system fleet is noted to have significant asset data deficiencies. Rectifying this is of paramount importance so as to make informed strategic asset decisions, and as such data remediation activities will be undertaken within the upcoming 2 years in preparation for the regulatory control period FY2023/24 – 2027/28.

5.6. DC Supplies

DC supplies provide backup power to allow the control and protection systems at an unmanned substation or switching station continued operation. This is a critical component of the network to allow us to respond to network outages which may lose supply to the station affected.

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.

Figure 46 DC Supply Criticality



5.6.1. NiCd Batteries

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 and metering schemes installed as well as control and HMI systems.

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

The health of these assets varies and is primarily dependant on manufacturer support, spares availability, forecast defect rates, age and the technical life of the assets. The health index has been used to identify the assets that require investigation for renewal through our Capital Investment Governance Process.

NiCd Battery rolling average defect rates have held relatively steady over the past few years. With a technical life of 20 years and an age profile with a significant number of assets in that age, it is as expected.

5.6.2. NiCd Chargers

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.

The health of these assets varies and is primarily dependant on manufacturer support, spares availability, forecast defect rates, age and the technical life of the assets. The health index has been used to identify the assets that require investigation for renewal through our Capital Investment Governance Process.

Defect rates for NiCd chargers has been dropping over the last few years. Our renewal initiatives have been adjusted accordingly with expenditure targeted more at the batteries than at the chargers.

5.6.3. VRLA Systems

Current practices have moved to the utilisation of VRLA DC supply systems. These systems have only been implemented at 2 sites thus far and no data exists as yet regarding their performance. These systems are heavily utilised within the telecommunications space and have seen no adverse performance issues. These systems mitigate maintenance activities required to meet standards for the deployment of NiCd systems.

5.7. Backup Diesel Generators

There are multiple diesel generator systems installed at various sites throughout the network for alternate 400V AC supply.

Asset data and asset condition are being acquired and structured. The current financial year shall finalise asset data build and asset performance requirements.

Current practice s to maintain to manufacturer specifications.

5.8. Control Room SCADA

There are two Operational Control Rooms in operation within our network, these are located at the Sydney West (primary control room) and Newcastle regional centres.

5.8.1. SCADA Terminal Equipment

Control room SCADA assets are currently being replaced as part of a renewal program driven by age, manufacturer support, OT security requirements and License compliance obligations.

Asset data is being acquired and structured as the new system is brought online. The current financial year shall finalise asset data build and asset performance requirements in collaboration with the Operations team.

Aside from urgent hardware upgrade works in FY19/20 resulting from a manufacturer product notice affecting SCADA network switches, there are currently no reportable issues with the current SCADA assets that requires attention at this time.

5.8.2. SCADA AC Supplies

There are no emerging issues with these assets.

5.8.3. SCADA DC Supplies

There are no emerging issues with these assets.

5.9. Emerging Issues and Renewal and Maintenance Initiatives

The emerging issues and renewal and maintenance initiatives to address them are summarised in Appendix A.

5.9.1. Protection Systems

Auto reclose checks are performed annually and provide a confirmation that our systems will maintain network reliability, particularly during bushfire season when our lines are more susceptible to transient faults from flames and smoke. These activities are costly and challenging to resource and we will be reviewing their value proposition with the deployment of combined protection and control schemes which have eliminated multiple failure points from the auto-reclose components.

A number of sites within bushfire prone areas have been identified as having legacy non-remote auto reclose enable/disable functionality. Remediation options to enable remote functionality are currently being investigated, however preliminary findings to date have noted upgrade solutions will be very capital intensive. Investigations are planned to continue.

5.9.2. Analysis Systems

It has been recently determined that records of fault and disturbance recorders and their requirements as set by AEMO are subject to errors. This has initiated a review of all recorder installations and their requirements as well as their recording in a traceable format.

5.9.3. Control Systems

A dormant failure mode has been identified in the MD300 series of RTU within the network. Due to the significant install base of this asset and the rare occurrence of such failures, the direction has been established for the rectification of a site's RTUs upon detection of a single failed unit. This approach was deemed the most efficient for the business in addressing an identified problem in a controlled manner.

5.9.4. NiCd Systems

NiCd systems require regular maintenance to ensure their functionality. Furthermore, these systems carry an explosion risk which is legislated with a variety of Standards applicable to maintain safety for our staff.

Recent developments in the VRLA space and the successful roll-out of VRLA 110V systems for our non-prescribed projects has established the validity of these deployments in our prescribed asset base.

VRLA systems provide the following benefits:

- No regular maintenance requirements
- Systems are self-monitoring
- No specialised battery room requirements
- Cheap and effective ventilation solution has been identified and confirmed with a variety of manufacturers
- Applying a substitute which carries significantly lower risks

6. CAPEX Forecasts

6.1. Ten Year CAPEX Profile

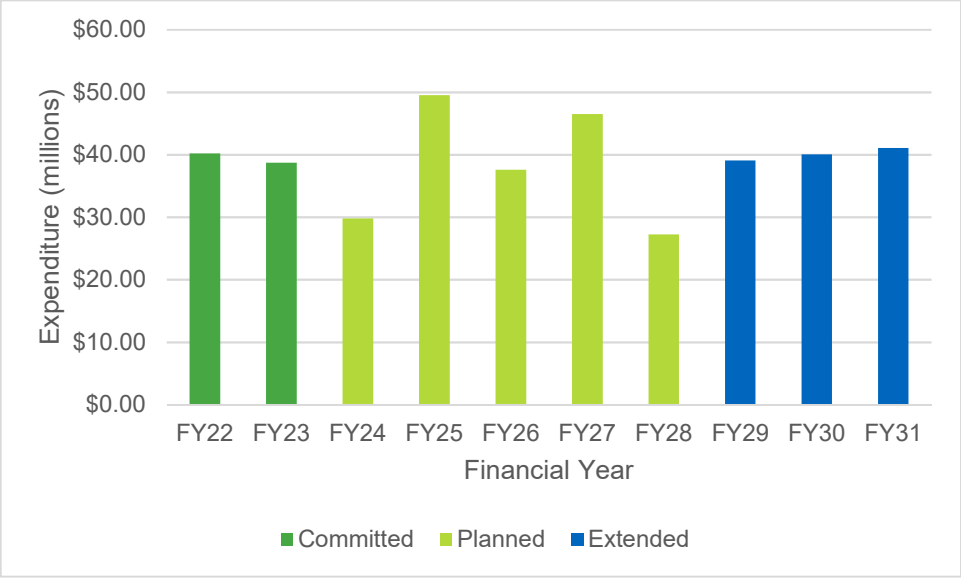
There has been a recent increase in projected capital expenditure due cost estimation updates and emerging issues. This has led to a CAPEX value exceeding our determination. The projects within the digital infrastructure area of control are continually reviewed and adjusted to address evolving capital constraints.

Currently the ten-year CAPEX profile covers all replacement expenditure forecast for Automation assets including:

- Targeted asset renewal programs
- Automation component of site wide secondary systems renewals

The forecast is a bottom up build of all capital expenditure currently in the Capital program of works and the forecast works planned as part of the Revenue Submission for Regulatory Control Period FY2023/24 – 2027/28.

Figure 47 Ten Year CAPEX Forecast



6.2. Anticipated Changes to the Asset Base

The anticipated changes to the asset base have been illustrated in this section for two scenarios where data and modelling allow:

- All committed investments proceedings
- No investments from this strategy proceeding

6.2.1. Protection Assets

Figure 48 Protection - Forecast Age Profile

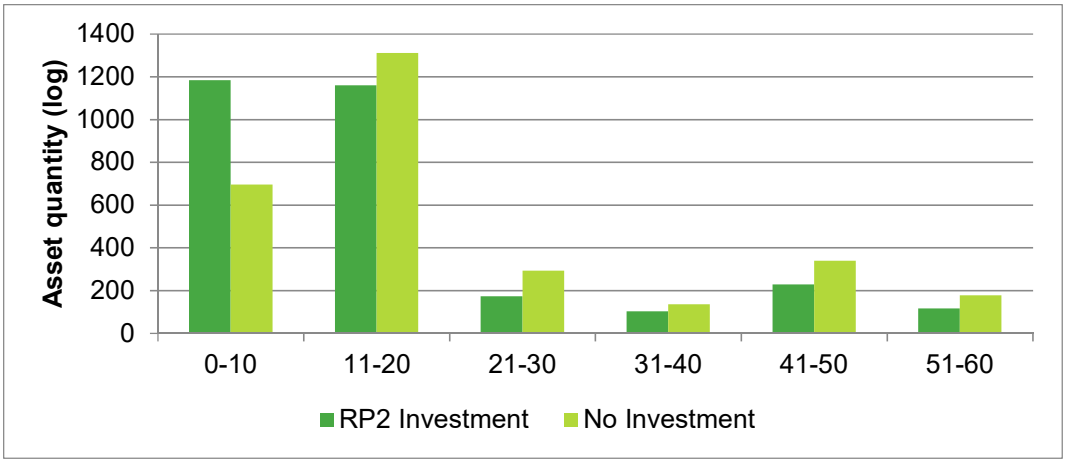
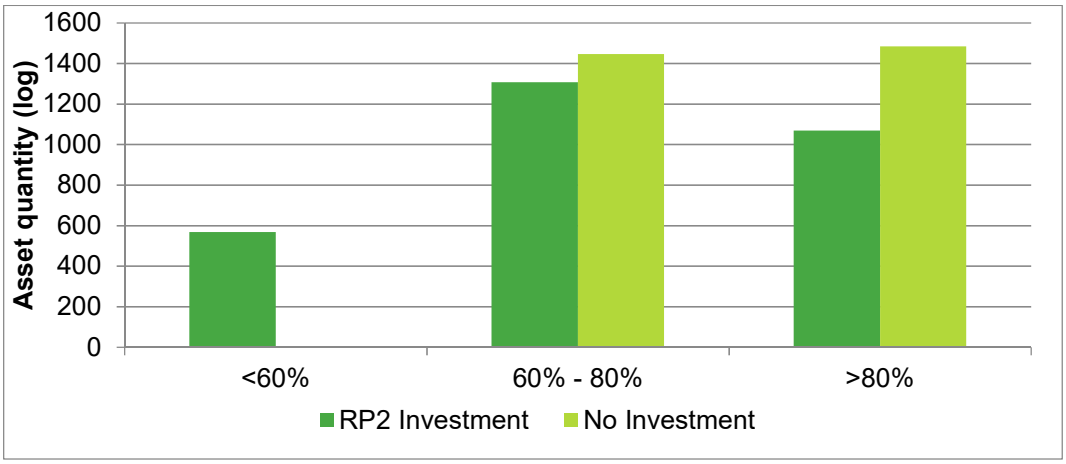


Figure 49 Protection - Forecast Health Index



6.2.2. Tele protection Assets

Figure 50 Tele protection - Forecast Age Profile

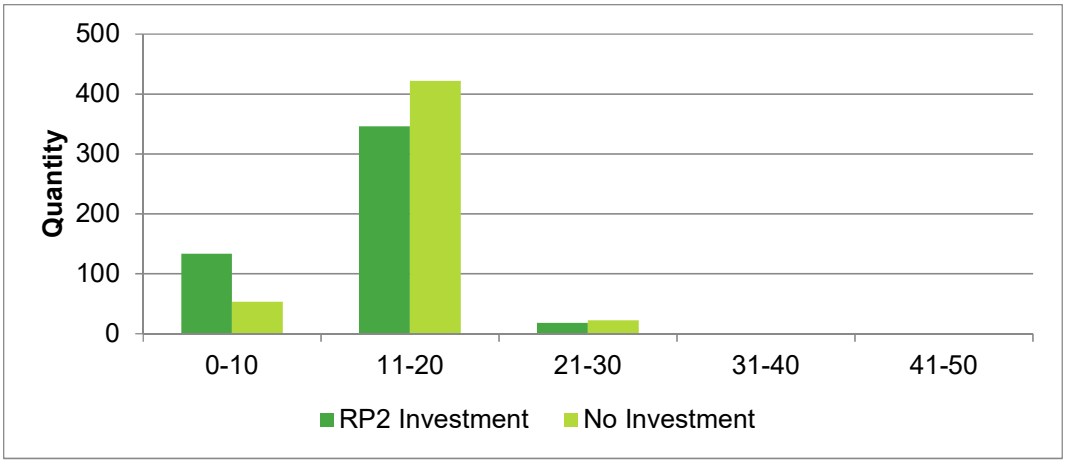
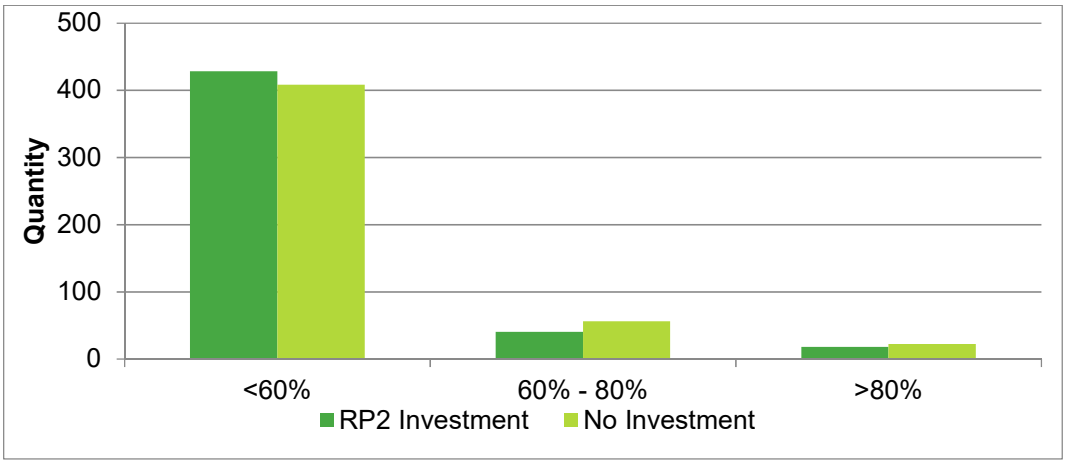


Figure 51 Tele protection - Forecast Health Index



6.2.3. Control Assets

Figure 52 Control - Forecast Age Profile

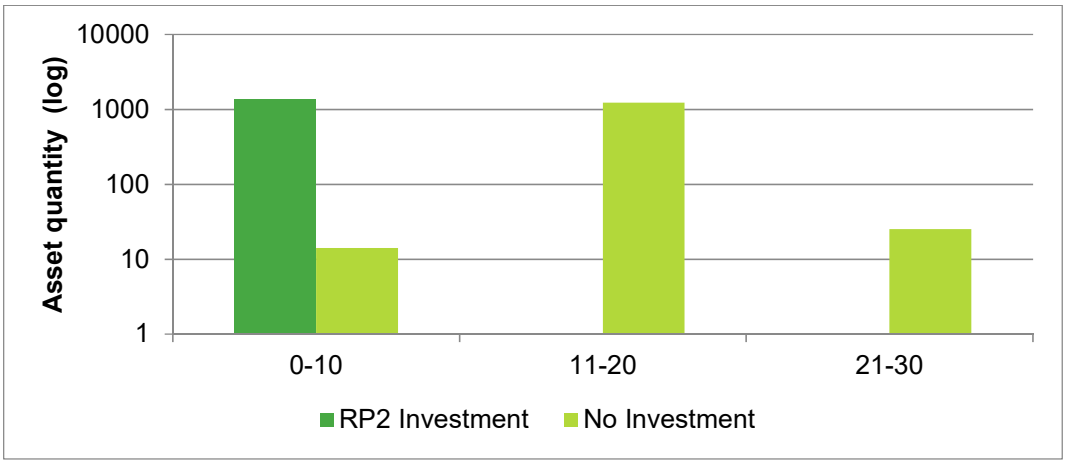
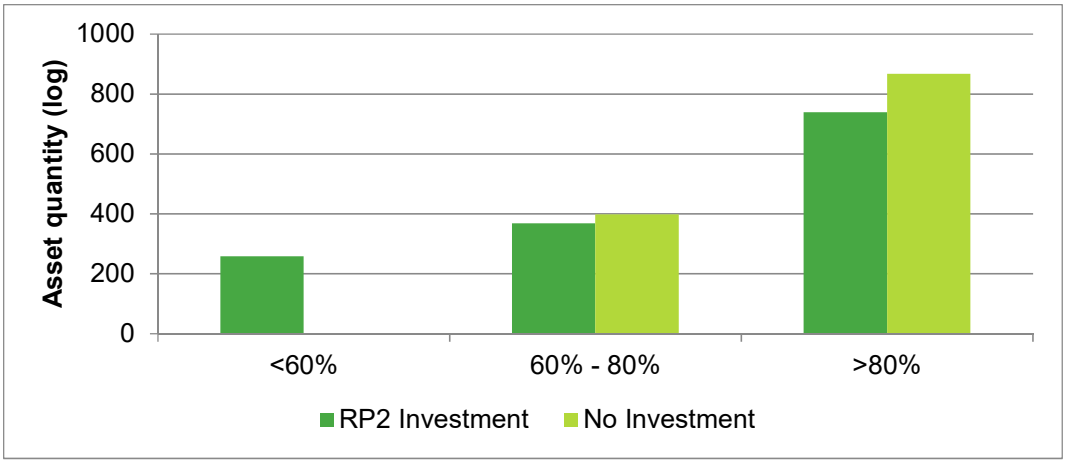


Figure 53 Control - Forecast Health Index



6.3. Long Term - REPEX Investment Framework

The 50 Year REPEX model is used by Transgrid to create a 50 year forecast, which is based on expected asset lives, standard deviations and unit costs. The assumptions within the model are based on industry standard information. This forecast includes REPEX volumes, costs and consequential average life profiles but no other consequential inputs/outputs (such as reliability and asset health). It also doesn't include augmentation expenditure.

Figure 54 Automation Systems Long Term CAPEX

RP2 (FY2018/19 – FY2022/23) has been excluded as it is currently in an active system with committed works using a bottom up approach through our asset analytics tool using a number of financial and non-financial (risk) inputs.

7. OPEX Forecasts

7.1. Discussion of significant changes to Maintenance Plan

We are currently maintaining our assets as a leader in terms of frequencies. When comparing to Australian and International benchmarks (RIN and ITOMS), TNSPs are maintaining assets at a higher frequency to Transgrid. We are still reviewing and realising the benefits from recent initiatives and will continue to monitor effectiveness.

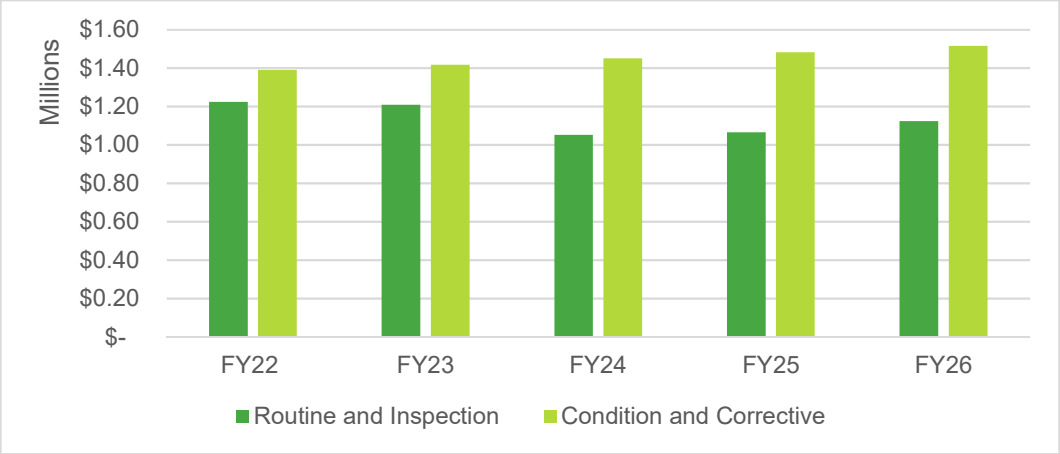
It is anticipated that our OPEX will remain relatively unchanged over the next 1-2 years. Due to reprioritisation of capital portfolio works within other asset classes to meet Transgrid's public safety and bushfire prevention initiatives, it is anticipated that defect costs will likely increase as a result of capital trade-off that has seen the Teleprotection Intertrip renewals delayed until RP3.

7.2. Five Year OPEX Profile

Currently the five year OPEX profile covers all Automation Systems planned preventative activities.

Preventative maintenance follows a non-liner pattern which is driven mainly by maintenance frequencies and their alignment with installation dates. We are targeting a reduction across Digital Infrastructure assets for OPEX, we believe that this target will provide a contribution to meeting our overall AMPoW targets for the organisation.

Figure 55 Automation Systems Planned Preventative Maintenance Forecasts



7.3. Long term OPEX

The current initiatives are foreseen to maintain the long-term OPEX at a relatively consistent rate. It is expected that there will be minor peaks and troughs in expenditure, these fluctuations are the result of maintenance frequencies and convergence of various install dates.

The current and proposed initiatives are aimed at delivering efficiencies in OPEX expenditure through the removal of outage requirements. This will lead to a more predictable and consistent expenditure profile throughout the year and should minimise the probabilities of missed activities due to network constraints.

8. Implementing the Strategies

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

- Maintenance Plan – Automation Systems Assets: 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.

The Asset Manager is responsible for preparation of the maintenance plans and referring the renewal and disposal initiative to the network investment process. Works Delivery/Maintenance Programs is responsible for delivering the maintenance plans as per the Operating Model and Network Planning and Operations/Project Delivery are responsible for delivering the renewal and disposal initiatives detailed in the approved capital works program.

9. Definitions

Table 12 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

Term	Definition
	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.
Fault Outage	AER defined term - Fault outages are unplanned outages (without notice) on the prescribed network from all causes including emergency events and extreme events.
Forced Outage	AER defined term - Forced outages are outages on the prescribed network where less than 24 hours notification was given to affected customers and/or AEMO (except where AEMO reschedules the outage after notification has been provided). Forced outages exclude fault outages.
Asset Management Plans	Documents specifying activities, resources, responsibilities and timescales for implementing the asset management strategy and delivering the asset management objectives.
RP1	Regulatory Period 2014/15 – 2017/18
RP2	Regulatory Period 2018/19 – 2022/23
RP3	Regulatory Period 2023/24 – 2027/28
Preventative Maintenance	Maintenance activities carried out to inspect and prevent assets from failing.
Corrective Maintenance	Maintenance activities carried out to address an asset condition that requires remediation.

10. Document Management

10.1. Monitoring and review

Implementation of the Strategy is monitored and reviewed by the Asset Manager, Head of Asset Management and Investment Review Committee annually.

This document will be reviewed in accordance with the requirements of the relevant document and records management procedure or when a material change occurs that requires its content to be updated.

10.2. 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 Head of Asset Management is responsible for the approval of this strategy.

- The Asset Manager is responsible for the development and regular review of this strategy.

10.3. References

- Asset Management System Description
- Network Asset Strategy
- Prescribed Capital Investment Process
- Spares Policy All Streams

Appendix A – Emerging Issues and Renewal and Maintenance Initiatives

Table 13 Emerging Issues and Renewal and Maintenance Initiatives

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
Protection > Discrete Component > Electro-mechanical	> Manage network safety risk > Maintain network reliability > Manage assets efficiently without compromising security holder and consumer value	> Reduced confidence in assets to protect main elements and clear faults effectively > Unknown condition of asset between maintenance activities due to lack of connectivity	Renewal > Ongoing replacement initiatives to renew remaining assets in the network to modern technologies and standards	Ongoing > Planned completion 2022/23 > 20 Site wide renewals > Approx. 80 targeted renewals	Targeted Renewals > Need 0602 > Need 0604 > Need 0606 > Need 0614 > Need 0615 > Need 0620 > Need 0621 > Need 0622 > Need 0623 > Need 0628 > Need 0634 > Need 0638 > Need 1382 > Need 1383 > Need 1384 > Need 1793 Site wide Renewals > Refer Appendix B
Protection > Microprocessor	> Manage network safety risk > Maintain network reliability > Manage assets efficiently without compromising security holder and consumer value	> Spares and support availability and complexity of wiring requires addressing to maintain operability of protection schemes	Renewal > Ongoing replacement initiatives to renew unsupported assets with modern technology and standards	Ongoing > Planned completion 2022/23 > 20 Site wide renewals > Approx. 400 targeted renewals	Targeted Renewals > Need 0607 > Need 0608 > Need 1356 > Need 1368 > Need 1376 > Need 1377 > Need 1379 > Need 1380 > Need 1381 > Need 1385 > Need 1386 > Need 1387 > Need 1388 > Need 2191 Site wide Renewals > Refer Appendix B

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
Protection > All	> Leverage AM to support new technologies and innovations that improve or grow our business	> Protection assets form the majority of our proposed capital expenditure in renewal initiatives > Traditional standards have approached the end of marginal productivity > To further reduce costs of current renewals of protection assets we would likely rely on a reduction of the quality of output	Design driven > Ongoing work with our Design group to identify new technologies and methodologies as well as areas for improvement that will meet our requirements	In Progress > Planned in service date 2022/23	> Standard Design Manual
Tele protection > All	> Manage network safety risk > Maintain network reliability > Manage assets efficiently without compromising security holder and consumer value	> Assets with high health index require addressing to maintain the reliability and security of the network	Renewal > Ongoing replacement initiatives to renew remaining assets in the network to modern technologies and standards	Ongoing > Planned completion 2022/23 > Approx. 100 targeted renewals	> Need 0635 > Need 1371
Control > All	> Manage network safety risk > Maintain network reliability > Manage assets efficiently without compromising security holder and consumer value	> Previous implementations require a specialised skillset that places a strain on response times due to limited availability of people > Reliability is compromised as the number of components for a single control system results in lower reliability of a single scheme	Renewal > Site wide renewals are upgrading to combined protection and control solutions eliminating the need for independent control schemes > Standalone renewals have been placed on hold with only Liddell progressing due to obsolete communications protocols	Ongoing > Planned completion 2028/2029 > 20 site wide renewals by 2022/23	Site wide Renewals > Refer Appendix B
Control MD300	> Maintain network reliability > Manage assets efficiently without compromising security holder and consumer value	> Dormant failure mode has been identified > Can be determined from the SCADA control room due to freezing of data refreshes > Has only affected less than 10 RTUs so far	> Maintenance > Due to cost implications of technicians attending sites, firmware upgrades shall be completed as part of defect response for any controller at the site.	In progress > Planned by 2021/22	> AMI to be issued
Point on Wave Systems	> Improve capability to support future energy system deployment	> There is no standardised solution for POW systems > There is no configuration record of install base > There are no policy or standard requirements for the deployment of POW > Certain installations do not function correctly	> Policy Review > Establish a deployment policy with Network Planning Develop and deploy a design standard for POW	Ongoing > Planned completion by 2020/21	> Requirements elicitation from stakeholders > Research and Development IWR to be issued
DC Supplies	> Manage network safety risk > Maintain network reliability	> Battery age and condition leading to high defect rates	Renewal > Renewal initiatives in place to target those batteries where their	Ongoing	Targeted Renewals > Need 1360 > Need 1362

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
	> Manage assets efficiently without compromising security holder and consumer value	> Due to the inability to store NiCd batteries there are at times long delays after a failure	age will exceed technical life by 2023	> Planned completion 2022/23	> Need DCN519 > Need DCN515 Site wide Renewals > Refer Appendix B
Protection > Auto-reclose	> Manage assets efficiently without compromising security holder and consumer value > Manage network safety risk	> Auto-reclose checks require a review to their validity with new technological solutions mitigating or eliminating the majority of risk. > Non-remote auto-reclose enable/disable functionality at sites identified within bushfire prone land.	Maintenance > Withdraw auto-reclose checks at a minimum for combined protection and control schemes Renewal > Investigation into options enabling remote functionality	In Progress > Planned 2021/22	> Maintenance Plan – Automation Systems > Targeted Renewals > TBC
Analysis Systems > All	> Manage assets efficiently without compromising security holder and consumer value	> As modern technologies provide additional functionality, the renewal of analysis assets may become unnecessary > These new capabilities form part of other renewal initiatives and so a snapshot in time may not provide insight into the capabilities when these renewals are required.	Maintenance > Replacement of assets as part of defect only response such that available technologies and capabilities can be reviewed at the time of renewal	Ongoing > Started 2019/20	> Maintenance Plan – Automation Systems
Analysis Systems > All	> Maintain network reliability > Manage assets efficiently without compromising security holder and consumer value	> Defect only approach to these types of assets may affect OPEX performance due to the random nature of failures	Maintenance > A review of asset requirements upon failure to ensure only those still adding value for stakeholders are maintained	Ongoing > Started 2019/20	> Maintenance Plan – Automation Systems
Control > RTU assets	> Improve capability to support future energy system development > Manage assets efficiently without compromising security holder and consumer value	> Obsolescence of older models of RTUs may lead to visibility issues in the network > Capital expenditure on an obsolete standard approach	Maintenance > Move to defect only replacements with an equivalent model supplied by CGI. > All new sites incorporate combined protection and control standards, eliminating the need for RTUs	Ongoing > All SSRs implement combined Protection and Control to mitigate RTU risks	> Maintenance Plan – Automation Systems
Tele protection > Dewar	> Manage assets efficiently without compromising security holder and consumer value	> The Dewar teleprotection assets are very reliable with a robust self-checking mechanism > Due to cost estimation issues across a variety of projects, Dewar units have been targeted for a reduction in capital expenditure.	Renewal > Reduction in quantity of assets targeted for renewal. > Maintain a spares portfolio to replace on a defect basis	Complete > Budgeted $1.29m in RP2 Proposal > Reduced by $1.77m under previous strategy	Targeted Renewals > Need 1371
Protection > GE Multilin	> Manage assets efficiently without compromising security holder and consumer value	> Defect rates have dropped significantly and consistently across the GE range for the past few years.	Renewal > Reduction in quantity of assets targeted for renewal.	Complete > Budgeted $40.22 in RP2 Proposal	Targeted Renewals > Need 1379

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
		> Due to cost estimation issues across a variety of projects, GE Relays have been targeted for a reduction in capital expenditure.	> Monitor defect rates ongoing	> Reduced by $3.97m under previous strategy	
Control > SCADA Transducers	> Manage assets efficiently without compromising security holder and consumer value	> Defect rates are disproportionate towards planned maintenance > Here is little value in the testing of these devices	Maintenance > Move to defect only maintenance for these assets	In Progress > Planned Start 2022/23	> Maintenance Plan – Automation Systems
Secondary System Renewals > Tenterfield > Tuggerah > Coleambally	> Manage assets efficiently without compromising security holder and consumer value	> To mitigate significant cost estimate increases, three sites identified for delaying works and reviewing scope	Renewal > Review of scope for three secondary systems renewals	Complete > Tenterfield reprioritised	Site wide Renewals > Need 1194 >
Protection > 132kV Assets	> Manage network safety risk	> Post bushfire review identified potential for improved clearance times on 132kV network	Policy > Investigate implementation of accelerated tripping on all 132kV transmission lines with available communications	Planned > Investigation 2020/21	> Policy review
Control > HMI	> Manage assets efficiently without compromising security holder and consumer value	> Cybersecurity issues with some deployments still reliant on obsolete Operating Systems > Unsupported network infrastructure	Policy > Design philosophy change to leverage latest available technologies.	Complete > New designs under deployment, CLY first site targeted	> IWR N2282
DC Supplies	> Manage network safety risk > Manage assets efficiently without compromising security holder and consumer value	> NiCd battery carry and explosive failure risk > This carries significant burden in maintenance requirements and ancillary systems and standards	Policy > Move to VRLA systems > Mitigate safety risks through substitution with a safer technology > Mitigate maintenance costs > Remove need for battery rooms	In Progress > Applied to all new Secondary System Renewals proposed.	> Standard Design Manual

Appendix B – List of Site Wide Renewals

Table 14 Site Wide Renewals Committed in RP2

Capital Project	Reference Document
Liverpool Secondary Systems Renewal	NS-1599
Gadara Secondary Systems Renewal	NS-1260
Ingleburn Secondary Systems Renewal	NS-1255
Darlington Point Secondary Systems Renewal	NS-1253
Haymarket Secondary Systems Renewal	NS-1493
Muswellbrook Secondary Systems Renewal	NS-1247
Molong Secondary Systems Renewal	NS-1267
Marulan Secondary Systems Renewal	NS-1266
Tuggerah Secondary Systems Renewal	NS-1263
Broken Hill Secondary Systems Renewal	NS-1193
Coleambally Secondary Systems Renewal	NS-1196
Tamworth 330kV Secondary Systems Renewal	NS-1243
Deniliquin Secondary Systems Renewal	NS-1191

Table 15 Site Wide Renewals Planned for RP3

Capital Project	Reference Document
FY24-28 TTF Secondary Systems Renewal	NOSA-1194
FY24-28 YSN Secondary Systems Renewal	NOSA-N2211
FY24-28 SE1 Secondary Systems Renewal	NOSA-N2212
FY24-28 BER Secondary Systems Renewal	NOSA-N2213
FY24-28 ER0 Secondary Systems Renewal	NOSA-N2214
FY24-28 LT1 Secondary Systems Renewal	NOSA-N2405
FY24-28 GNS Secondary Systems Renewal	NOSA-N2406
FY24-28 BRD Secondary Systems Renewal	NOSA-N2407
FY24-28 AR1 Secondary Systems Renewal	NOSA-N2408
FY24-28 KS2 Secondary Systems Renewal	NOSA-N2409
FY24-28 FNY Secondary Systems Renewal	NOSA-N2410
FY24-28 WL1 Secondary Systems Renewal	NOSA-N2411
FY24-28 PMA Secondary Systems Renewal	NOSA-N2419
FY24-28 WW1 Secondary Systems Renewal	NOSA-N2426
FY24-28 RGV Secondary Systems Renewal	NOSA-N2427
FY24-28 CW2 Secondary Systems Renewal	NOSA-N2428
FY24-28 VP1 Secondary Systems Renewal	NOSA-N2429
FY24-28 FB2 Secondary Systems Renewal	NOSA-N2430
FY24-28 NAM Secondary Systems Renewal	NOSA-N2431
FY24-28 GN2 Secondary Systems Renewal	NOSA-N2432

Capital Project	Reference Document
FY24-28 TOM Secondary Systems Renewal	NOSA-N2433
FY24-28 LSM Secondary Systems Renewal	NOSA-N2434
FY24-28 NB2 Secondary Systems Renewal	NOSA-N2435
FY24-28 INV Secondary Systems Renewal	NOSA-N2436
FY24-28 COF Secondary Systems Renewal	NOSA-N2437
FY24-28 NEW Secondary Systems Renewal	NOSA-N2443
FY24-28 KCR Secondary Systems Renewal	NOSA-N2444
FY24-28 BRG Secondary Systems Renewal	NOSA-N2446
FY24-28 MPP Secondary Systems Renewal	NOSA-N2447
FY24-28 DMQ Secondary Systems Renewal	NOSA-N2448