
AMS – Victorian Electricity Transmission Network

Secondary Systems

(Protection, Control, Monitoring & Metering
Assets) (PUBLIC VERSION)

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1 Executive Summary

Protection assets are combined in systems to detect electrical faults on the transmission network and, via the operation of circuit breakers, rapidly disconnect faulted circuits from sound circuits. Protection systems are designed to protect operators and the public from hazardous electrical conditions, limit damage to network equipment and maintain the network's electrical operating parameters within selected limits to ensure reliable energy supplies to consumers.

Secondary assets include devices to measure the network's electrical operating parameters and monitor the function and condition of selected primary network assets. This data is essential for the effective tactical operation of the network, fulfilling commercial agreements between connected parties and the strategic management of primary assets. Examples include revenue metering, power quality monitoring, transformer loading and temperature measurement, circuit breaker operation, and monitoring insulating oil degradation and prevailing weather.

Control assets are arranged in systems to provide automatic or remote manual control of the function of primary assets. These systems are essential for the effective and efficient control of power flows within the network and include functions such as transformer voltage regulation and cooling system control, reactive voltage control, load shedding and runback schemes.

Secondary system technologies evolve rapidly. In a relatively short period of time electromagnetic technology was superseded by analogue electronics, then by digital electronics and further by microprocessors which integrated multiple functions. Intelligent electronic devices with flexible integration, programmability and configurability are now in use.

Secondary assets become obsolete within a typical timeframe of 15 years when they are no longer supported by manufacturers, are technically incompatible with interfacing equipment or are no longer able to provide the functionality established in industry standards or regulation.

1.1 Key Strategies

An overarching strategy is to integrate secondary asset modernisation projects within Terminal Station rebuild projects or major primary asset replacement projects wherever economic. This approach ensures better technical and economic outcomes with efficient design, coordinated delivery and fewer circuit outages during implementation. Stand-alone secondary projects are initiated only where no suitable Terminal Station rebuild project or primary asset replacement project is planned in an appropriate timeframe and asset condition warrants replacement or augmentation.

Key strategies for the secondary systems assets include:

- Develop standard schemes and procure new assets with the capability for simultaneous operation of IEC61850 and DNP3 communication protocols ensuring compatibility with existing systems on brownfield sites and appropriate communication speeds for modern IP-based equipment.
- Continue asset inspection and maintenance in accordance with PGI 02-01-02.
- Review and update PGI 02-01-02 by 2018.
- Integrate secondary asset modernisation projects within terminal station rebuild projects or major asset replacement projects wherever economic.
- Ensure stand-alone secondary projects are initiated only where no suitable major projects is planned in an appropriate timeframe.
- Review the secondary assets condition and update the asset management systems by 2019.
- In conjunction with the annual review of network contingency plans review spares requirement for critical relays and maintain stock levels.

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2 Introduction

2.1 Purpose

This asset management strategy applies to all secondary systems asset located within terminal stations in the Victorian transmission network. The broad classes of secondary assets are as follows:

Protection Assets:

- Transformer Protection.
- Bus Zone Protection.
- EHV Line Protection.
- HV Line (Feeder) Protection.
- Reactive Plant Protection for Static Var Compensators (SVC), Synchronous Condensers, Capacitors and Reactors).

Station & Network Control Assets:

- Circuit Breaker Management & Control.
- Transformer Voltage Regulation.
- Transformer Cooling Control.
- Transformer auto close schemes.
- Reactive Plant Control (SVC, Synch Comp, Capacitor).
- Load Shedding Schemes.
- Special Network Control Schemes such as Very Fast Runback and Emergency Tripping schemes.

Monitoring & Metering Assets:

- Revenue Metering.
- Weather Stations.
- High Speed Monitoring.
- Power Quality Monitoring.
- Network Disturbance Recorders.

Secondary Infrastructure Assets:

- Station System Control and Data Acquisition (SCADA) (Remote Terminal Units (RTUs) Human Machine Interfaces (HMI) and Station Control and Information Management Systems (SCIMS).
- Secondary Cabling.
- TRESIS Relay Database.

This strategy does not cover DC Power Supplies (Batteries, Chargers & DC/DC Converters). These assets are included in a separate Asset Management Strategy document (AMS 10-52).

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This strategy does not cover the communications systems for peer-to-peer communication in protection systems and communication between protection systems and remote engineering locations. Strategies for communications systems are included in AMS 10-56 (Communication Systems).

2.2 Objectives

The objective of this strategy is to assist personnel involved in managing assets, meeting regulatory obligations and informing other stakeholders by:

- Presenting an overview of AusNet Services' protection and control systems currently in service throughout the Victorian electricity transmission network;
- Identifying business and network risks associated with secondary systems and providing guidance for their prudent and efficient management;
- Identifying emerging performance risks and providing guidance for efficient management of those risks; and
- Economic management of secondary system assets throughout their life-cycle achieving network performance targets taking account of risk, costs and customer expectations.

2.3 References

This asset management strategy forms part of a suite of documentation that supports the management of AusNet Services' assets. Other documents within the suite pertinent to the management of secondary assets include:

AMS 01-01	Asset Management System – Overview.
AMS 10-01	Asset Management Strategy – Transmission Network.
AMS 10-19	Plant and Equipment Maintenance.
AHR 10-68	Asset Health Report for Secondary Systems (Protection and Control Relays and Remote Terminal Units) and Revenue Metering.

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3 Asset Summary

The data in this section is current as of September 2014.

3.1 Protection Assets

The underlying technology of protection relays can generally be classified as either electro-mechanical, microprocessor-based or Intelligent Electronic Devices (IEDs).

- **Electromechanical:** Electromechanical relays are single function relays with mechanical measurement registers, rotating disc mechanisms, mechanical bearings and spring-based energy storage. Electromechanical relays represent the oldest relay technology.
- **Analogue Electronic:** Analogue Electronic relays are usually single function relays that use discrete analogue electronic components including transistors and integrated circuits, and employ capacitors for measurement.
- **Microprocessor-based:** Microprocessor-based relays can be single- or multi-function devices in which measurement is carried out by an analogue to digital conversion. This type of relay uses numerical algorithms and digital signal processing to implement protection functions.
- **Intelligent Electronic Devices (IEDs):** An IED is an advanced type of microprocessor-based relay. They are multi-function devices with sophisticated digital programming and configuration capabilities, fault recording and digital communications. IEDs represent the most modern relay technology.

3.1.1 Transformer Protection

Transformer protection is provided by duplicated independent (X and Y) relays that may include a number of protection functions, the chief one being differential protection. Differential protection compares the currents in the High Voltage, Medium Voltage and Low Voltage transformer connections and scales them appropriately for magnitude and phase angle so that the normal net sum of the currents is zero under healthy circuit conditions. If the current sum is not zero; differential protection schemes send tripping signals to relevant circuit breakers. An internal restraint circuit prevents tripping upon transformer energisation. Modern intelligent transformer relays can also provide overload detection on any connection and receive signals from external devices such as Buchholtz (oil surge) relays and temperature sensors. The relays are connected to SCADA and provide instrumentation and event information to the control centre. Intelligent relays record currents during transformer faults and are of great value in analysing a transformer failure, allowing faster repair and remedial action to prevent similar failures on other transformers.

There are 652 transformer protection relays in service at terminal stations within the AusNet Services electricity transmission network. Figure 1 below illustrates the proportion of electro-mechanical, electronic, microprocessor and IED devices in service.

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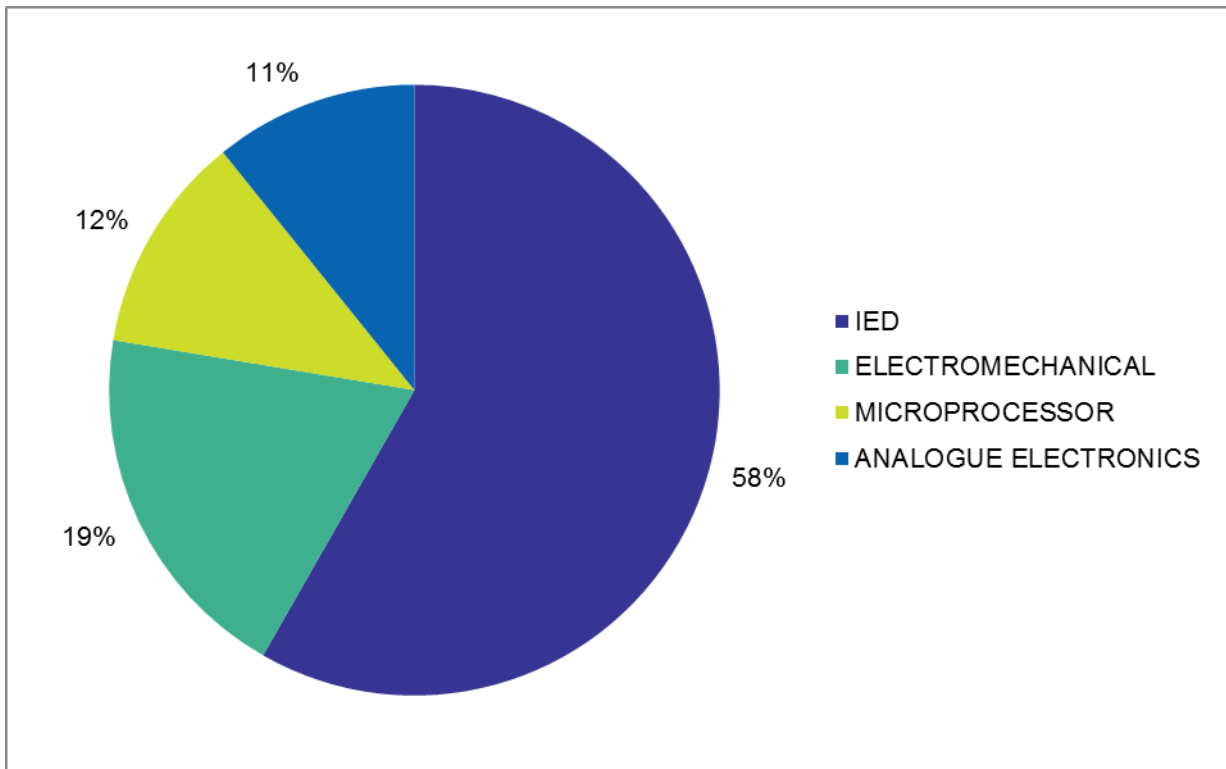


Figure 1 – Transformer Protection Assets by Technology

Figure 2 below illustrates the service age profile of electro-mechanical, electronic, microprocessor and IED transformer protection relays in service.

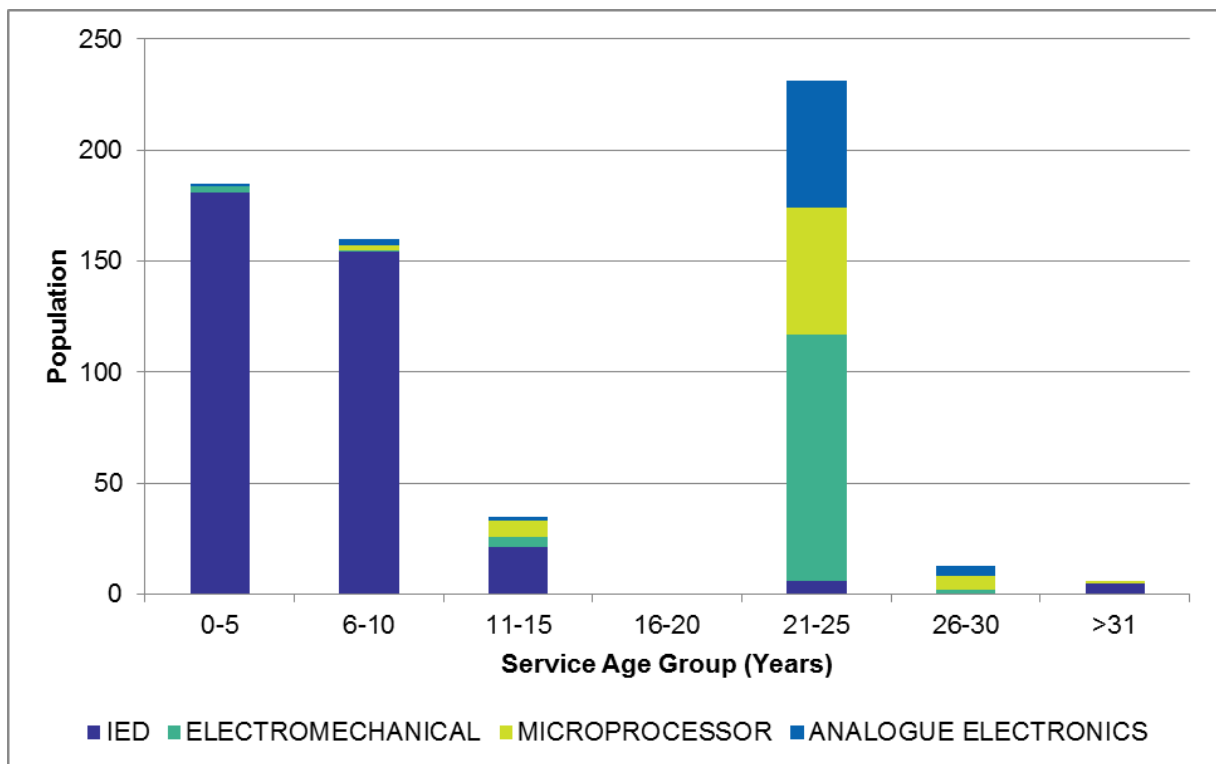


Figure 2 – Transformer Protection Asset Age Profile

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3.1.2 Bus Protection

Bus protection consisting of duplicated protection (X and Y) may be applied to primary circuit busbars at all voltage levels (11 kV, 22 kV, 66 kV, 220 kV, 275 kV, 330 kV and 500 kV) within terminal stations. The most commonly employed bus protection schemes are high impedance differential protection and overcurrent protection.

There are 562 bus protection relays in service at terminal stations of Victorian electricity transmission system; a majority of these are Electro-mechanical relays. Figure 3 below illustrates the proportion of electro-mechanical, electronic, microprocessor and IED devices in service. Electromechanical relays are preferred for used in high impedance bus protection schemes even in modern installations due to their robust construction and inherent operating stability. This accounts for the high population of electromechanical relays compared to other technology types for bus protection. Although the population of IEDs is expected to increase, in bus protection applications it is expected that a high proportion of electromechanical relays will remain in service for some time.

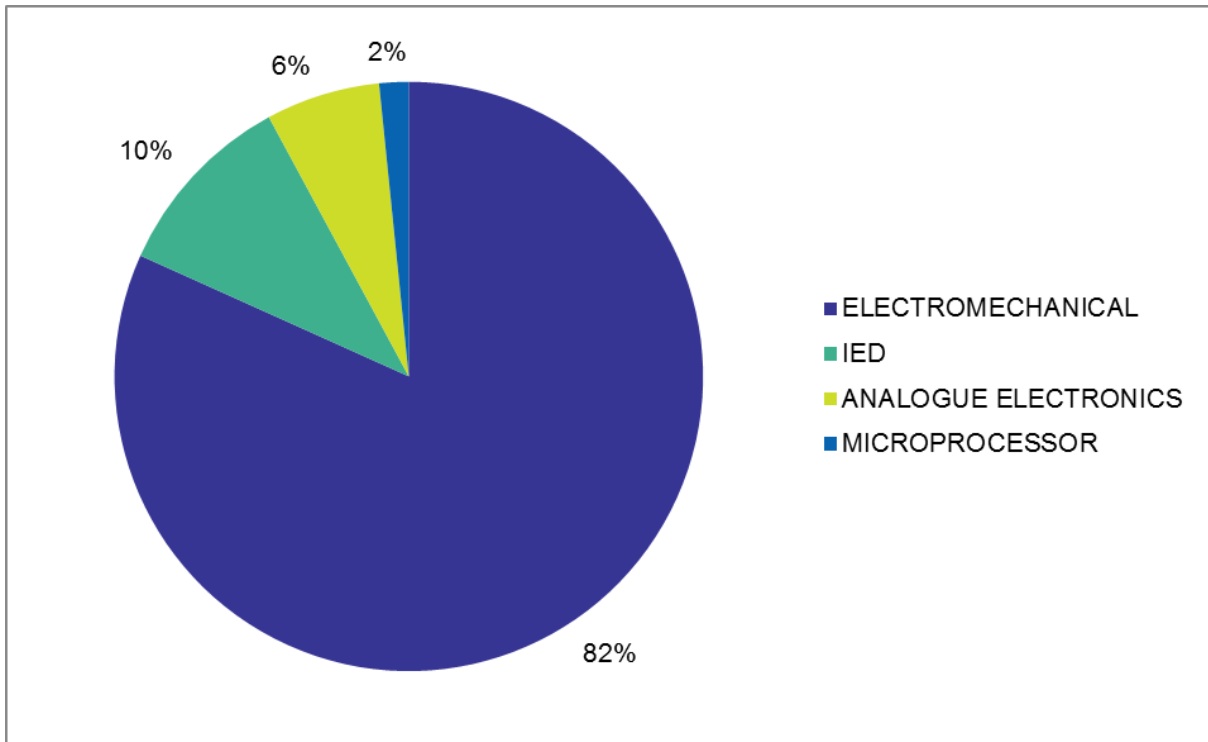


Figure 3 – Bus Protection Assets by Technology

Figure 4 illustrates the age profile of bus protection relays currently in service. Approximately 60% of bus protection relays are between 21 and 25 years.

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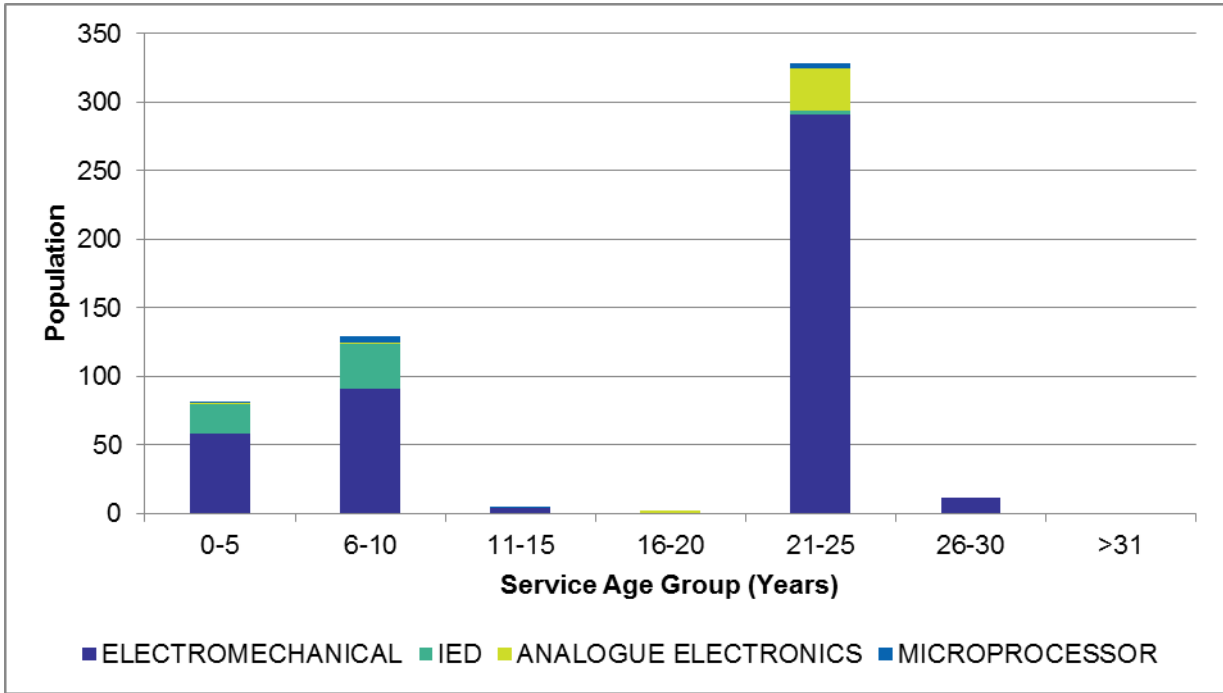


Figure 4 – Bus Protection Asset Age Profile

3.1.3 EHV Line Protection (220 kV, 275 kV, 330 kV and 500 kV)

Protection for 220 kV and higher voltage (EHV) lines is provided by duplicated independent (X and Y) relays. It is an Australian Energy Market operator (AEMO) requirement that except for an eight hour maintenance period, both relays must be in service at any one time or the line may have to be taken from service. There are two main operating principles: distance (impedance) and current differential. Distance relays are connected to the line current and voltage transformers and measure the line impedance; they operate if the impedance is lower than the actual line impedance. The distance relays at each end of the line must be interconnected by a communications link to ensure that the AEMO specified fault clearance times are met.

Current Differential relays are connected to current transformers (CTs) on the line and continuously compare the currents at each end of a line via a high speed digital communications link. These relays operate to trip the line if a difference between the terminal currents is observed. Current differential protection offers a more clearly defined protected zone than distance protection and is applied when a suitable communications link is available between the stations.

Present generation relays may include both distance and current differential operating principles included with either or both in service. The latest relays are also able to undertake line instrumentation functions for SCADA.

There are 832 relays protecting EHV lines in the electricity transmission network. Figure 5 below illustrates the proportion of electro-mechanical, electronic, microprocessor and IED devices in service and Figure 6 below illustrates the service age profile.

The population of IEDs is expected to increase going forward as older assets reach the end of their technical and economic lifecycles. IEDs provide superior functionality for line protection applications and are deployed as standard for all new and replacement installations.

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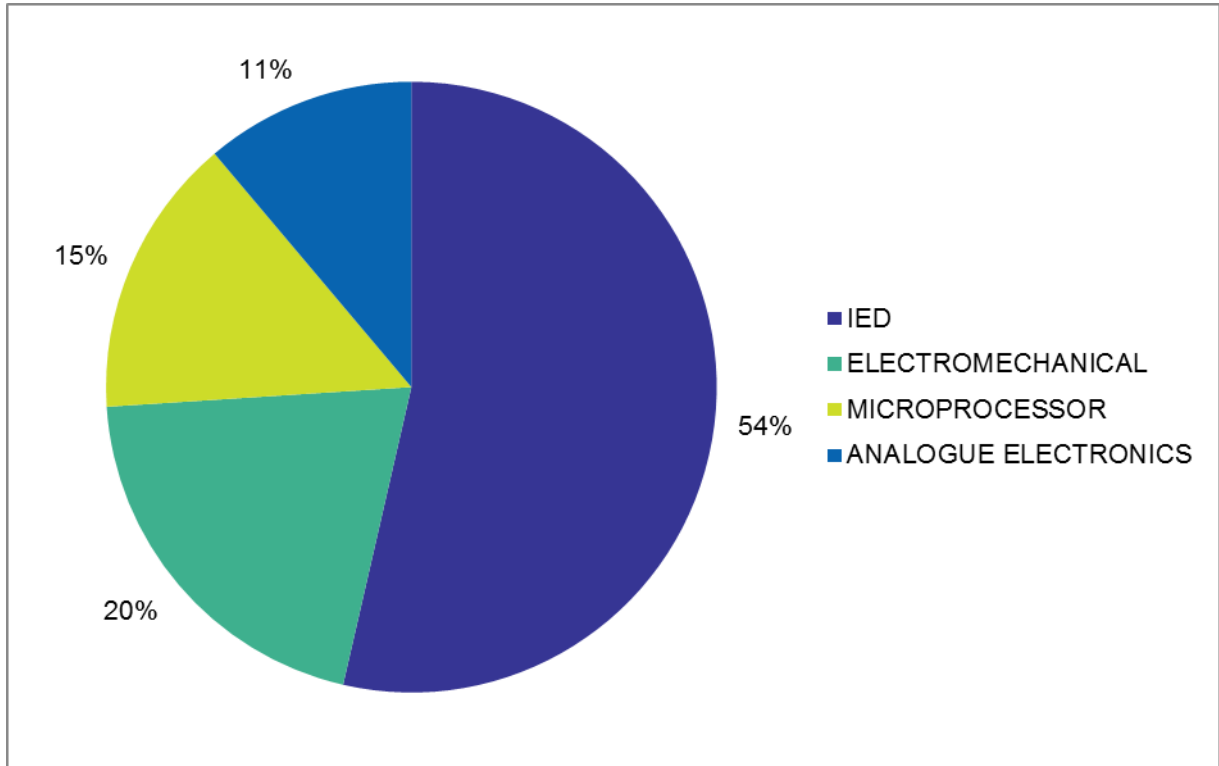


Figure 5 – EHV Line Protection Assets by Technology

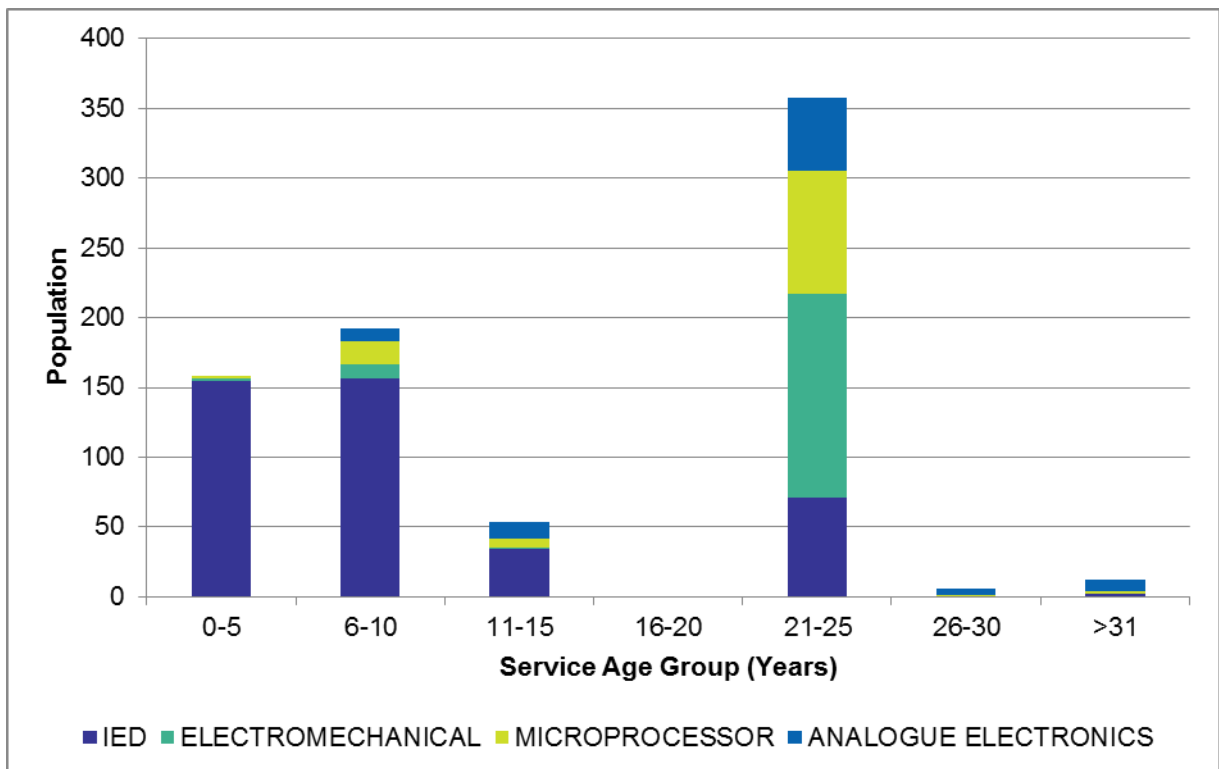


Figure 6 – EHV Line Protection Asset Age Profile

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3.1.4 HV Line Protection (66 kV and 22 kV)

Protection for 66 kV lines is provided by duplicated independent (X and Y) relays. As with the EHV protection, there are two main operating principles: distance (impedance) and current differential. The protection clearance times for HV lines are less stringent than for EHV lines and communications links between stations are generally not necessary when distance protection is used. However, there are significant benefits associated with grading of protection schemes when differential schemes are used, and for this reason current differential protection is preferred when a suitable communications link is available

Overcurrent and/or pilot wire protection is used for some older feeders. Pilot wire protection is similar to current differential protection, but uses electro mechanical relays and analogue communication over dedicated copper telephone wires.

The present generation protection schemes for 66 kV feeders have two intelligent relays (X and Y) each including distance and/or differential, but with the additional functions of CB Failure detection, CB control, automatic reclose and instrumentation. In some applications, distance protection is required to ensure adequate backup protection is provided for downstream assets.

There are 829 relays located in terminal stations to protect high and medium voltage lines from terminal stations to zone substations owned by distribution network service providers (DNSP). Figure 7 below illustrates the proportion of electro-mechanical, electronic, microprocessor and IED devices in service and Figure 8 below illustrates the service age profile.

The population of IEDs is expected to increase in the future as older assets reach the end of their technical and economic lifecycles. IEDs provide superior functionality for line protection applications and are deployed as standard for all new and replacement installations.

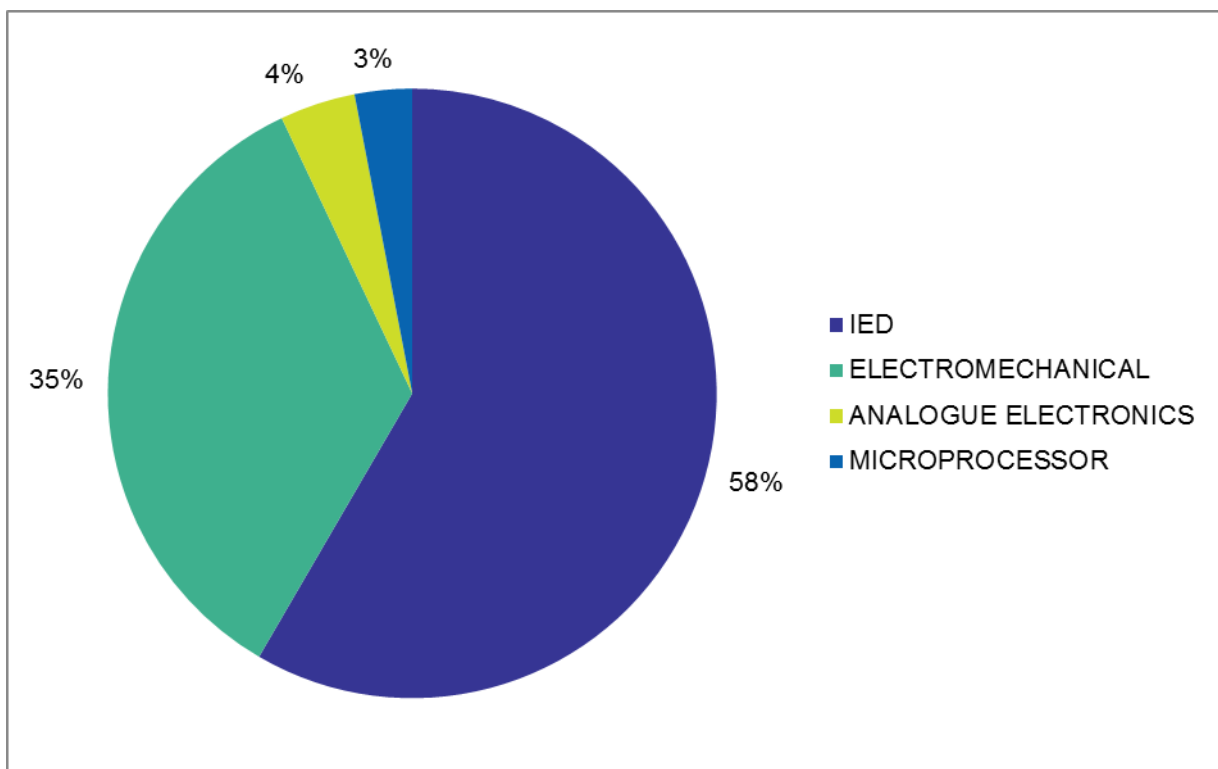


Figure 7 – HV Line Protection Assets by Technology

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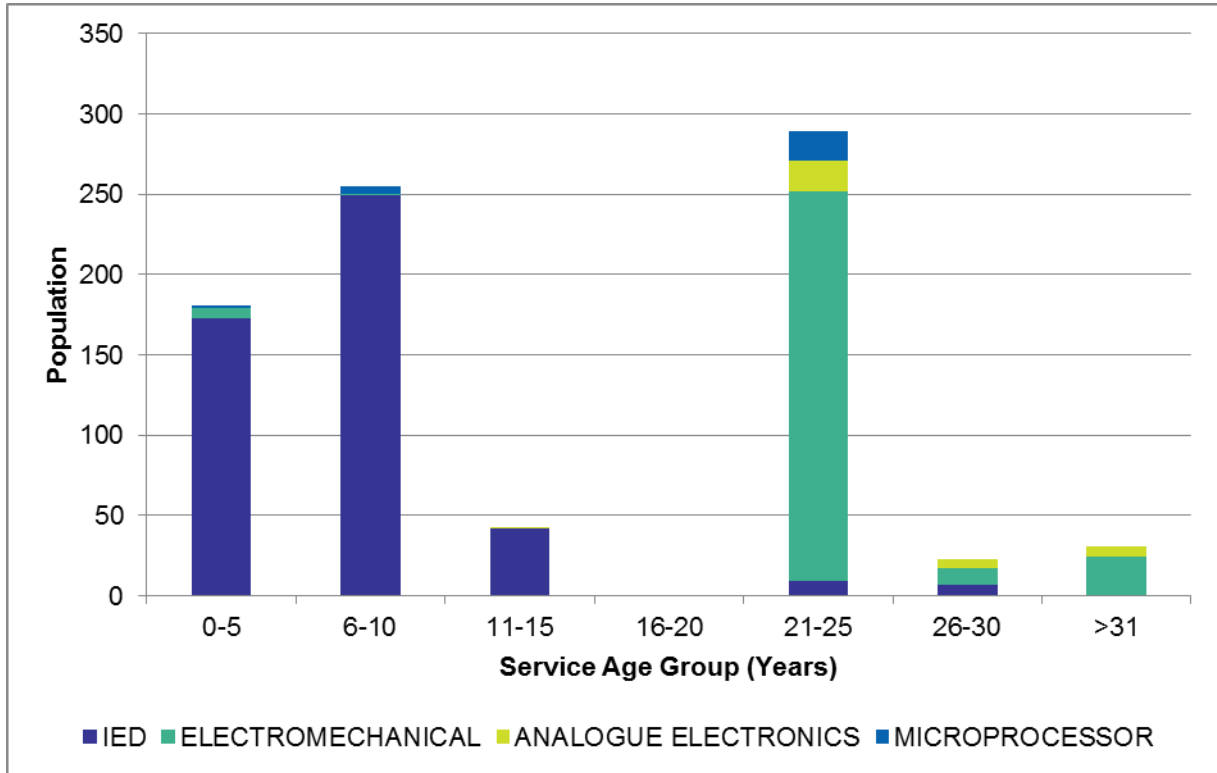


Figure 8 – HV Line Protection Asset Age Profile

3.1.5 Reactive Plant Protection

Reactive plant includes fixed capacity Capacitors and Reactors, and variable capacity Synchronous Compensators and Static Var Compensators.

- Protection for fixed capacity reactors is similar to that used for transformers: differential, overcurrent and Buchholtz (gas).
- For fixed capacitors, overcurrent protection that operates from the total current into the capacitor is used. A separate sensitive current balance overcurrent circuit is also provided to detect failure of pre-determined number of capacitor cans in each phase of a capacitor bank. Detection of the unbalanced current and subsequent tripping of the capacitor bank will prevent further failure of remaining capacitor cans due to overvoltage. Some relays also have a thermal overload function based on an internal model of the capacitor characteristic.
- Synchronous Compensators, all with over 40 years of service, are fitted with individual relays providing overcurrent, overvoltage and current differential protection, together with additional items for Hydrogen Gas coolant, starting motor, voltage control and synchronising.
- Static Var Compensators (SVC) comprise of individual capacitor and reactor elements switched by thyristors. Protection for the capacitors and reactors is by individual overcurrent, overvoltage and differential relays, comprising up to 20 individual relays. The high voltage thyristors are connected in series, with their combined rated voltage limit greater than the system voltage. Each thyristor is monitored so that when failure of one thyristor is detected, the SVC will be turned off to prevent overvoltage failure on the remaining thyristors. There are also protection circuits to detect failure of the water cooling systems for the thyristors.
- A special case is the Series Capacitor installations on the two DDTs-SMTS 330 kV lines. The Series Capacitors are effectively part of the lines and protection against primary insulation failure is provided by the 330 kV line protections. However, special protection is needed to detect sudden high currents during 330 kV line faults. Excessive voltage across the series string of 180 cans triggers an arc in the air gap provided. This arc effectively shunts the cans and protects them from overvoltage failure. The short circuit provided by the spark gap is immediately backed up with the closure of a Bypass CB. A separate monitoring circuit integrates ambient temperature, current and time to prevent thermal overload.

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There are 384 relays protecting extra high voltage (EHV) and high voltage (HV) capacitors located in terminal stations throughout the electricity transmission network. These relays provide overcurrent and earth fault protection for reactive plant.

Figure 9 below illustrates the proportion of electro-mechanical, electronic, microprocessor and IED devices in service and Figure 10 below illustrates the service age profile. The population of IEDs is expected to increase in the future as older assets reach the end of their technical and economic lifecycles. IEDs provide superior functionality for reactive plant protection applications and are deployed as standard for all new and replacement installations.

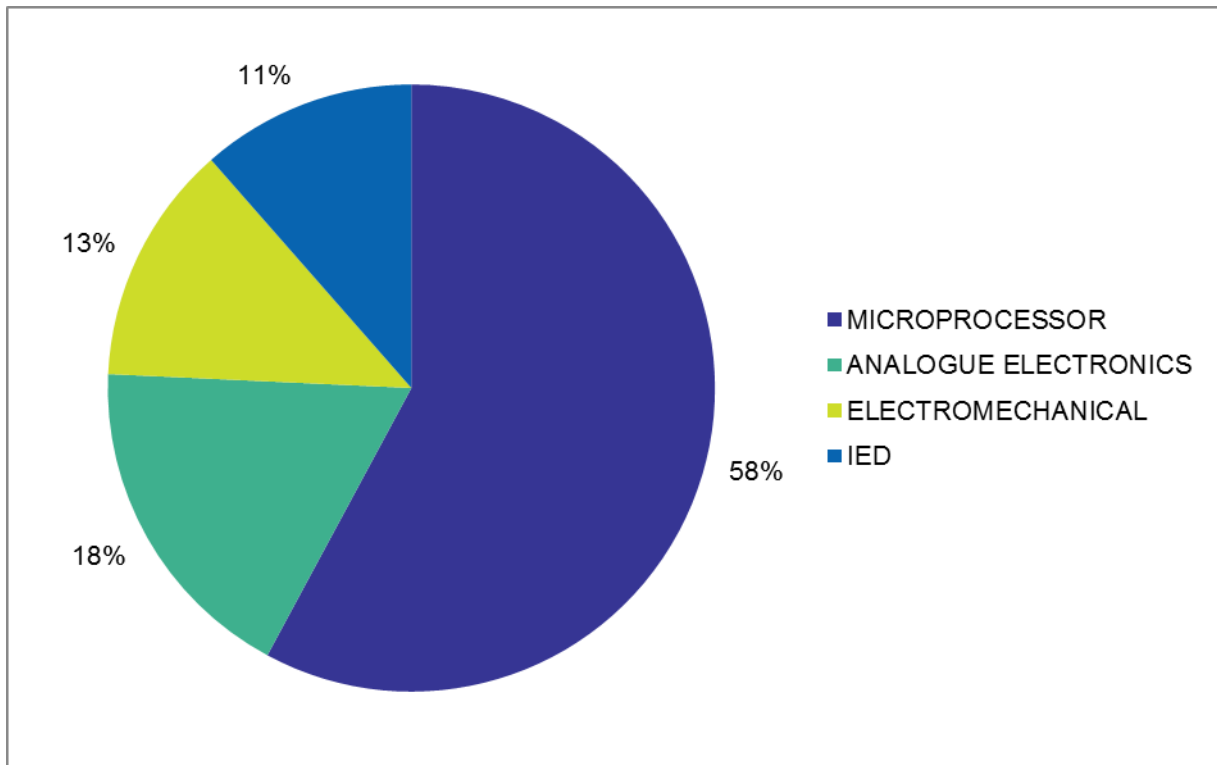


Figure 9 – EHV & HV Capacitor Protection Assets by Technology

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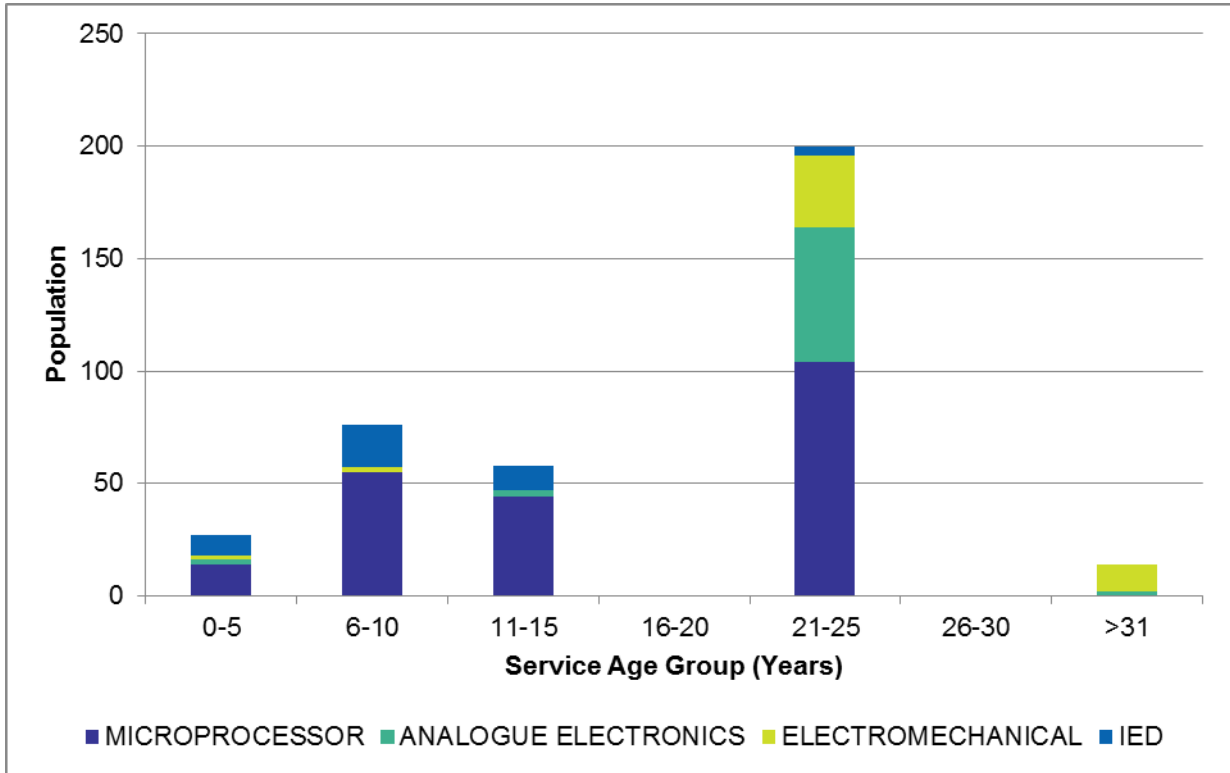


Figure 10 – EHV & HV Capacitor Protection Asset Age Profile

There are 36 relays protecting current limiting reactors in the electricity transmission network. Figure 11 below illustrates the proportion of electronic, microprocessor and IED devices in service and Figure 12 below illustrates the service age profile.

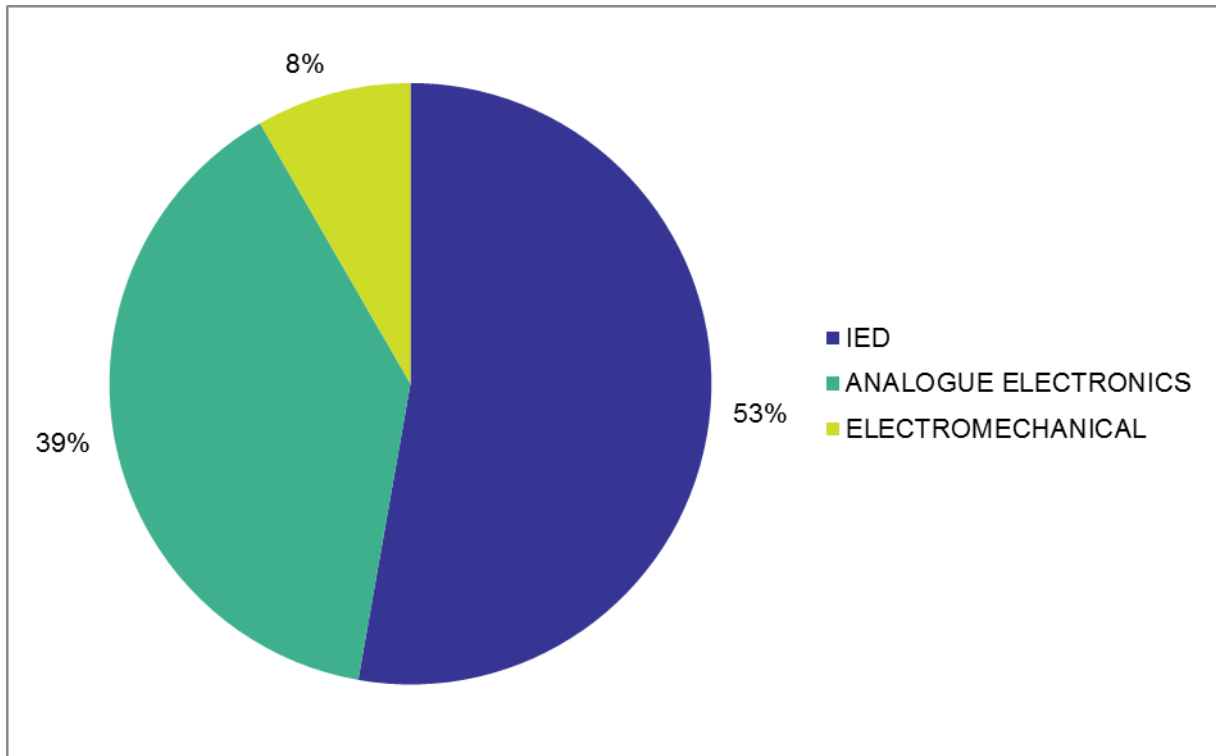


Figure 11 – Reactor Protection Assets by Technology

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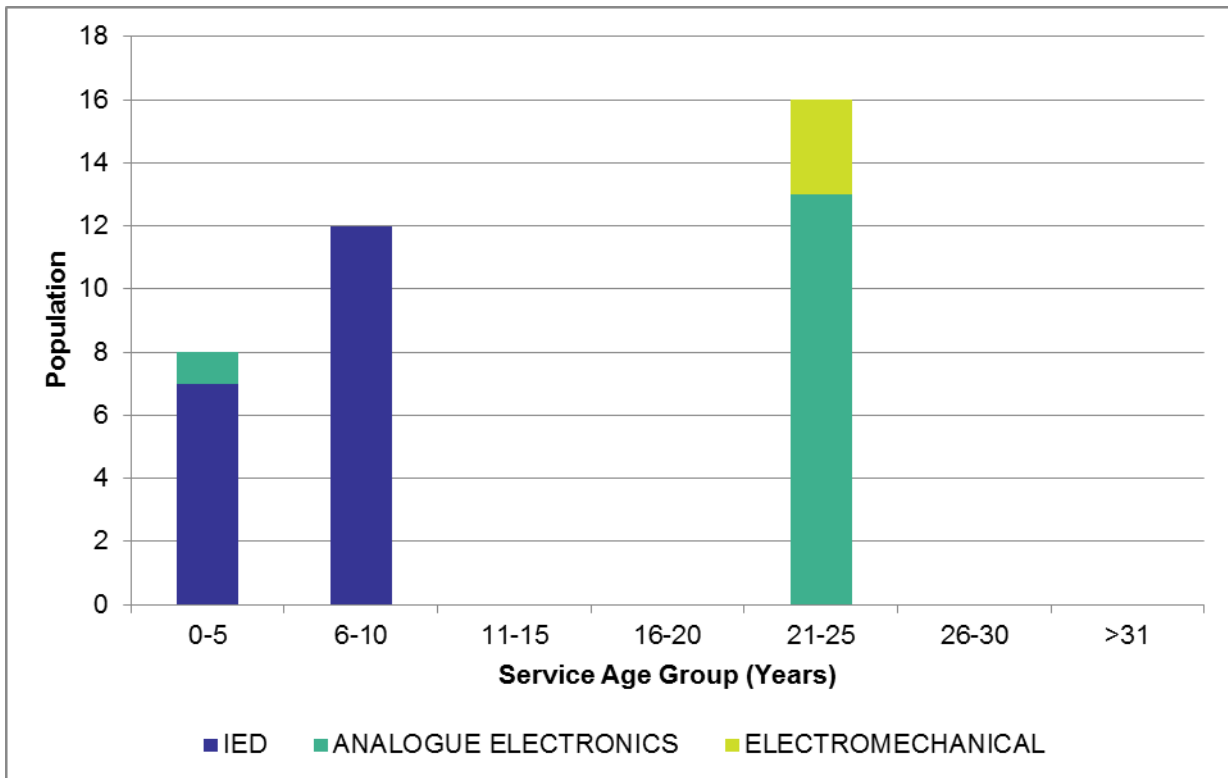


Figure 12 – Reactor Protection Asset Age Profile

There are 133 relays protecting Synchronous Compensators and Static Var Compensators in the electricity transmission network.

Figure 13 below illustrates the proportion of electro-mechanical, electronic and IED devices in service. Figure 14 illustrates the service age profile.

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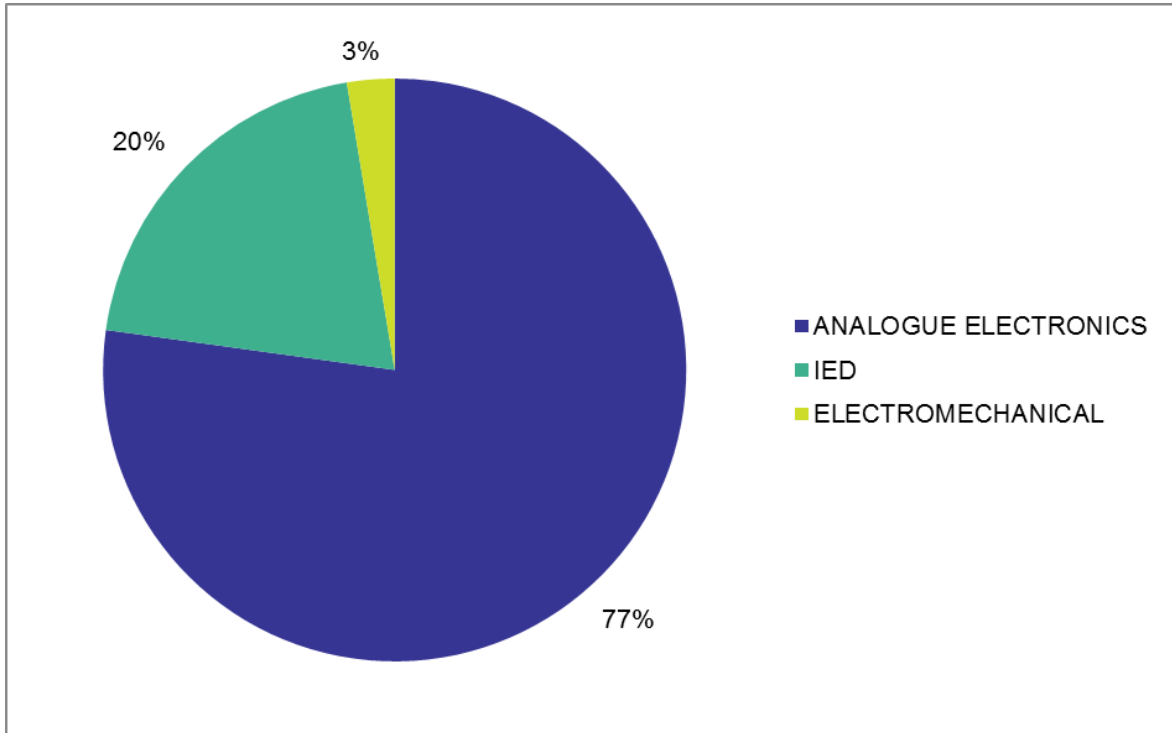


Figure 13 – SC & SVC Protection Assets by Technology

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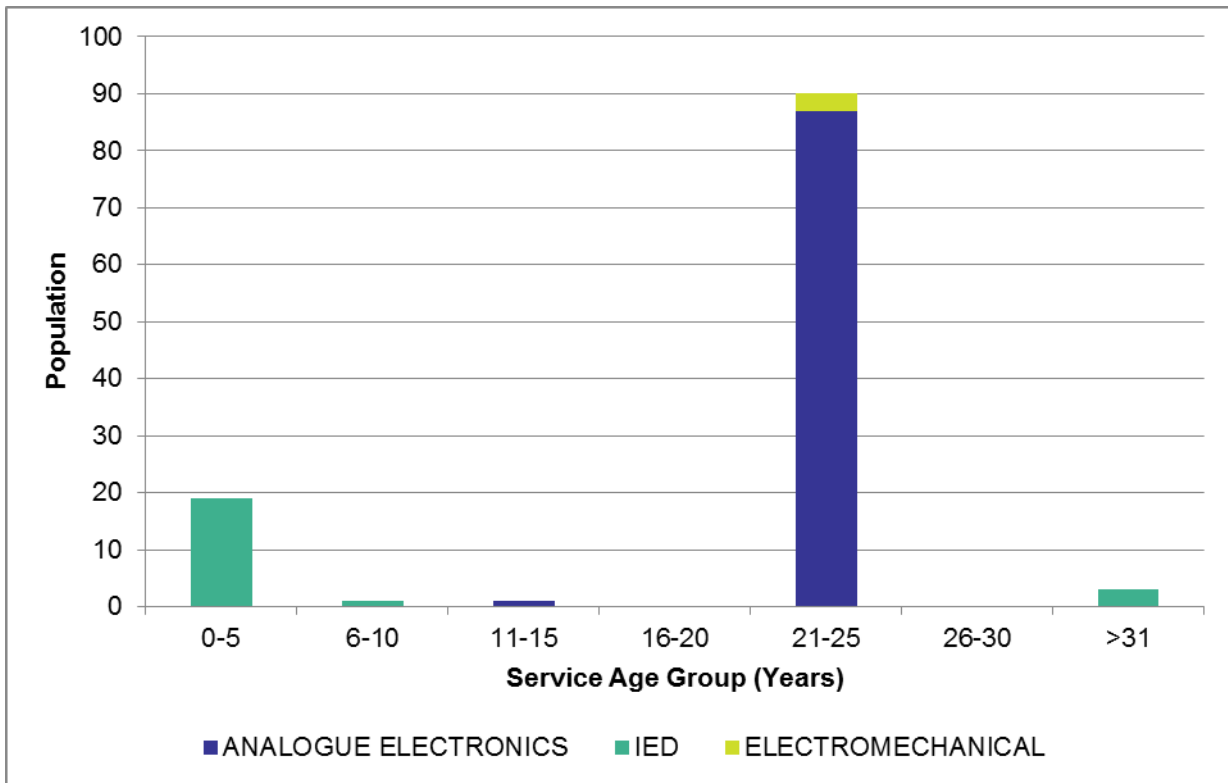


Figure 14 – SC & SVC Protection Asset Age Profile

3.2 Station & Network Control Assets

3.2.1 Circuit Breaker Management & Control

Circuit breaker management relays provide CB fail, auto reclose, local and remote control and instrumentation functionality for circuit breakers within one device. CB management relays are used in modern schemes in place of discrete control and instrumentation devices. Strategic integration of these devices throughout the transmission network facilitates progressive retirement of analogue instrumentation and obsolete control infrastructure whilst maximising operational capability for the network.

Circuit breaker management relay and control equipment has the intelligence to control the CB itself, providing statuses and alarms information to local HMI and the control centre. It also provides the synchronism check function to the CB to interlock the CB Close command with pre-determined system voltage conditions.

They also provide CB Failure protection function that opens adjacent CBs when the CB concerned has failed to open during fault incidents.

The CB Management relay is connected to the CB current transformers, voltage transformers on both sides of the CB, CB control circuits and trip circuits for adjacent CBs.

Figure 15 below illustrates the percentages and numbers of CBs with modern CB Management and Control utilising SCIMS (SCADA). Figure 16 illustrates the age profiles of relays in service.

Population of IEDs expected to increase as the older assets reach the end of their technical and economic lifecycles.

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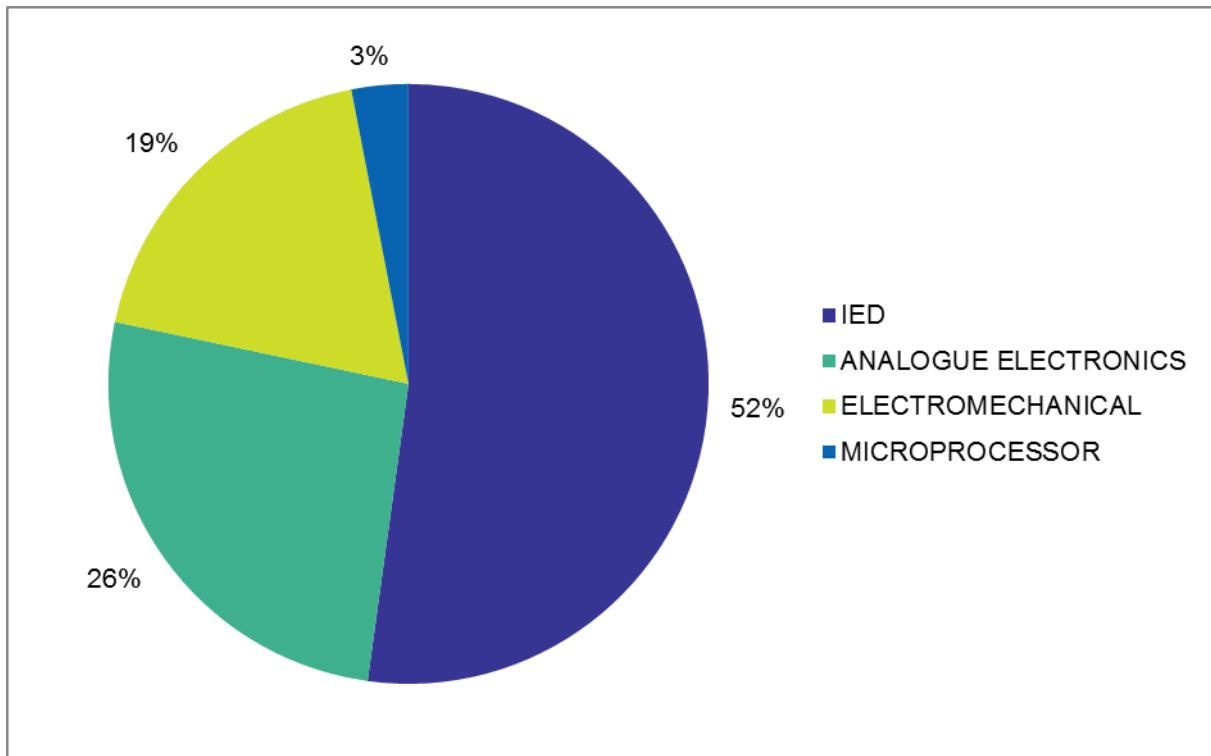


Figure 15 – Circuit Breaker Management Assets by Technology

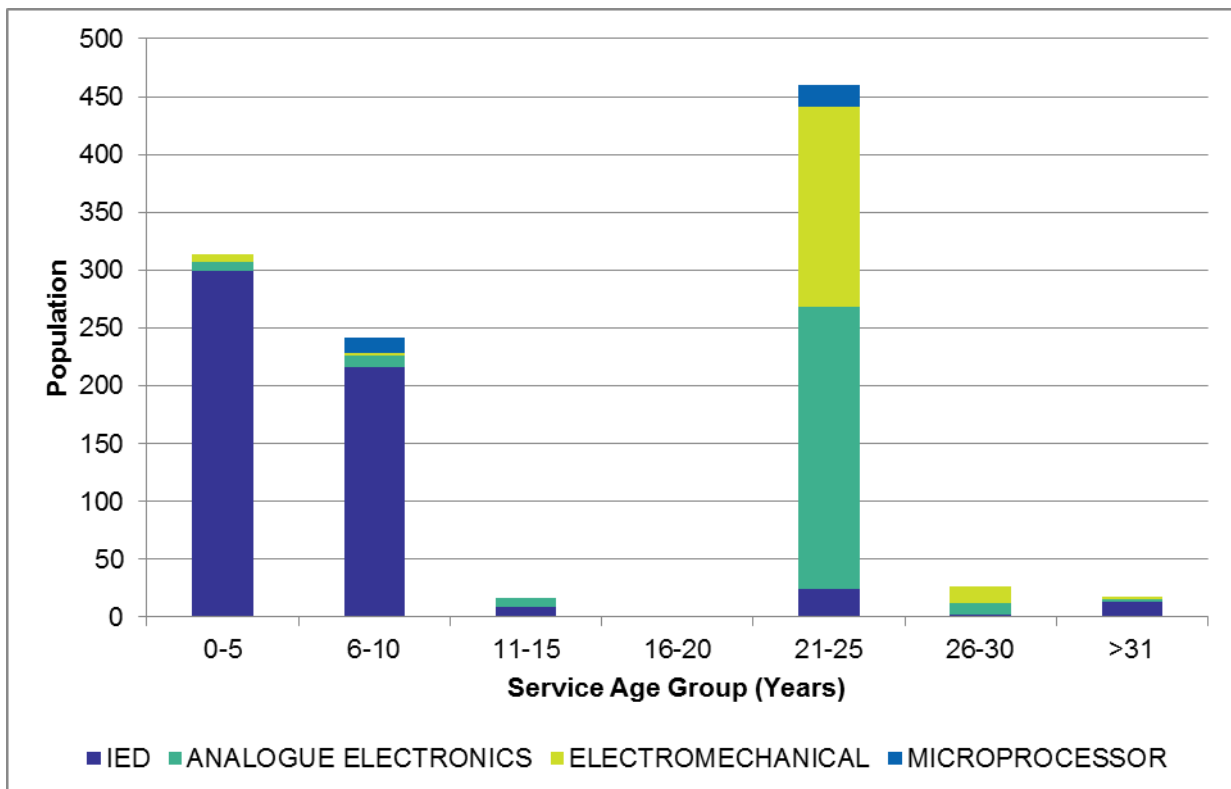


Figure 16 – Circuit Breaker Management Asset Age Profile

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As shown in Figure 17, there are 721 Control and/or CB fail assets in service. The majority (58%) of these assets are older technology Microprocessor types while the remainder are of latest technology IED devices (40%). There are very few (2%) of Analogue Electronics assets in service. The age profile of relays in service is shown in Figure 18 below.

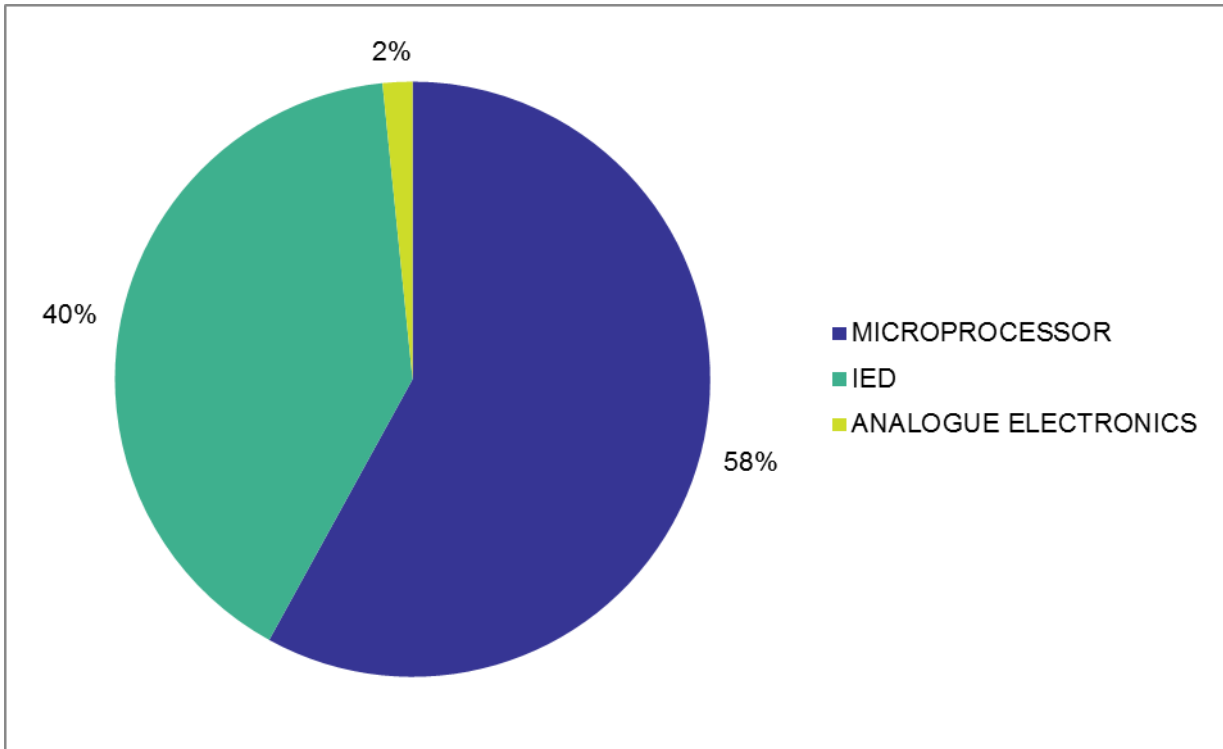


Figure 17 – Circuit Breaker Management and Control Assets by Technology

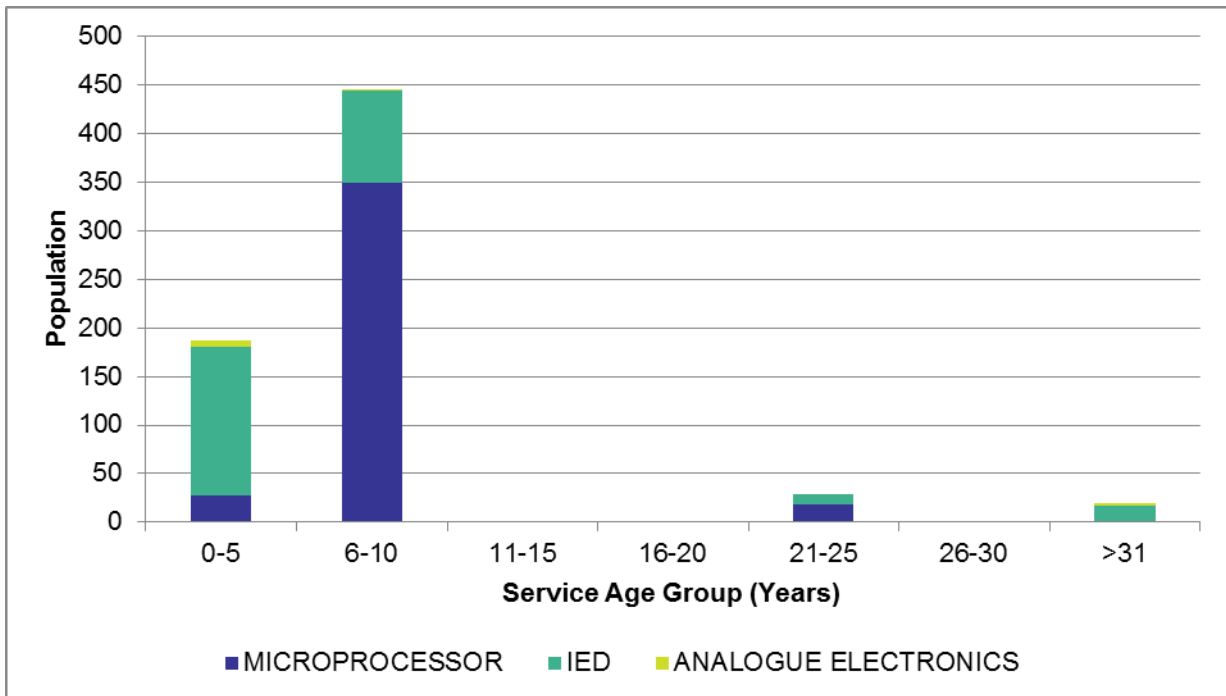


Figure 18 – Circuit Breaker Management and Control Assets Age Profile

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3.3 Monitoring & Metering Assets

3.3.1 Revenue Metering

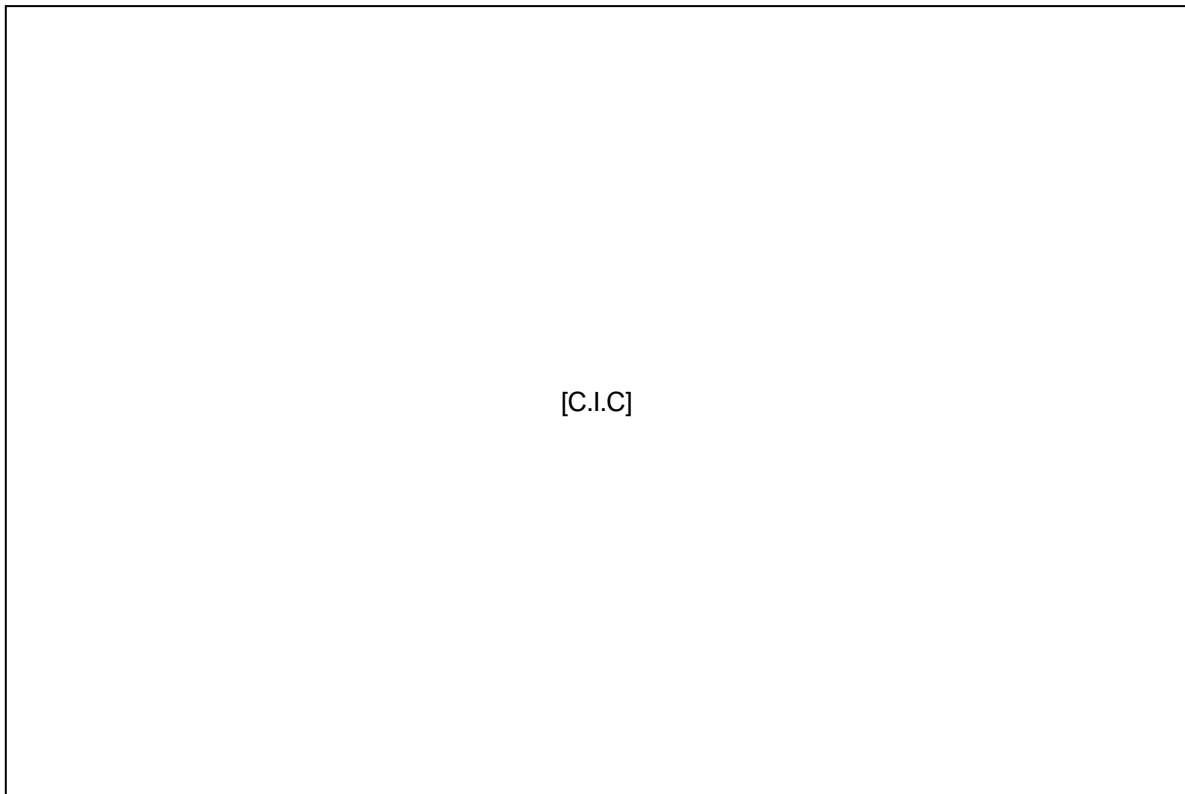
AusNet Services has an installed base of 635 Transmission Revenue Meters and provides *Responsible Person Services* under the National Electricity Rules (NER). These revenue meters monitor wholesale energy flows, and facilitate invoicing amongst National Electricity Market (NEM) participants. AusNet Services also provide Meter Provider and Meter Data Provider Services via a subsidiary company Select Solutions.

As shown in **Error! Reference source not found.** below the vast majority of meters in service are [C.I.C] meters (607 units); with the remainder being older [C.I.C] meters (28 units). The meters and their associated CTs and VTs are tested to the requirements of the NER. The age profile of revenue meters are shown in **Error! Reference source not found.**



[C.I.C]

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Although the [C.I.C] meter has been declared obsolete by the manufacturer, some limited spare parts are still available. The sourcing of a replacement for [C.I.C] meters has commenced.

Table 1 summarises the AusNet Services metering installations by type as defined by the National Electricity Rules:

NER METER TYPE	DEFINITION	NUMBER INSTALLED
TYPE 1	Annual Energy Throughput greater than 1,000 GWh	53
TYPE 2	Annual Energy Throughput between 100 and 1,000 GWh	233
TYPE 3	Annual Energy Throughput from 0.75 GWh to less than 100 GWh	155
TYPE 4	Annual Energy Throughput less than 0.75 GWh	10
CHECK Meters	Check Meters for Type 1 and 2 Installations	184
TOTAL		635

Table 1 – Revenue Meters by Type

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3.3.2 Tower Weather Stations

Represented in Table 2, AusNet Services maintains eight combined weather and line tension installations on 220 kV transmission lines at the following locations:

LINES	TOWER
MLTS-BATS1	T71
MLTS-BATS 2	T112
KTS-GTS	T137
YPS-ROTS 5/6	T177
YPS-ROTS 7/8	T93
HWPS-ROTS 1/2	T267
BETS-SHTS	T570
BETS-SHTS	T672

Table 2 – Tower weather station locations

These weather stations provide the following information to AEMO:

- Wind speed;
- Wind direction;
- Ambient temperature;
- Humidity; and
- Line tension.

The previous generation of weather stations are being replaced due to unsatisfactory performance. Their shortcomings include:

- The units do not provide reliable information due to damage from water ingress and moisture.
- GPRS modems are at the end of life and no longer available from Telstra or other telecommunication companies.
- The main unit controller being no longer supported by the manufacturer.

There are no spare parts or in-house knowledge for maintenance of the stations. Three tower weather stations have been replaced under Project XB51. Project 006A – “Replace weather stations on 5 transmission towers”, is currently in progress to upgrade the five remaining older generation weather stations. Under this project, the older generation weather stations will be replaced by devices using improved sensors and improved central control box construction more suitable for application in for exposed locations.

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3.3.3 Terminal Station Weather Installations

There are 22 weather monitoring installations located within AusNet Services' terminal stations. They are located at:

- BATS
- BETS
- DDTS
- EPS
- GNTS
- GTS
- HOTS
- HWTS
- HYTS
- KGTS
- KTS
- Mary St
- MBTS
- MLTS
- RCTS
- ROTS
- RTS
- SHTS
- SVTS
- TGTS
- WOTS
- YPS

These weather monitoring stations were installed in 2005 to provide AEMO the following information via Remote Terminal Units:

- Wind speed via Anemometer and Ultrasonic measurements;
- Wind direction;
- Ambient temperature;
- Barometric pressure.

They have worked well since installation, however not all stations transmit all available data to the Network Control Centre. Table 3 summarises the sensors installed and data available at the Network Control Centre.

They are expected to have a remaining service life of 12 to 15 years.

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No	Station	Temperature		Anemometer Wind Speed		Ultrasonic Wind Speed		Barometric Pressure		Wind Direction	
		Sensor	NOC	Sensor	NOC	Sensor	NOC	Sensor	NOC	Sensor	NOC
1	BATS	√	√	√	√	√	√	√	√	√	√
2	BETS	√	√	√	√	√	√	√	√	√	√
3	DDTS	√	√								
4	EPS	√		√		√		√	√	√	
5	GNTS	√	√	√	√	√	√	√	√	√	√
6	GTS	√	√	√	√	√	√	√	√	√	√
7	HOTS	√	√	√	√	√	√	√	√	√	√
8	HWTS	√	√	√	√	√	√	√	√	√	√
9	HYTS	√	√								
10	KGTS	√	√	√	√	√	√	√	√	√	√
11	KTS	√	√	√	√	√	√	√	√	√	√
12	Mary St	√	√								
13	MBTS	√	√	√	√	√	√	√	√	√	√
14	MLTS	√	√	√	√	√	√	√	√	√	√
15	RCTS	√	√								
16	ROTS	√	√	√	√	√	√	√	√	√	√
17	RTS	√	√								
18	SHTS	√	√	√	√	√	√	√	√	√	√
19	SVTS	√	√	√	√						
20	TGTS	√	√					√	√		
21	WOTS	√	√								
22	YPS	√	√	√	√	√	√	√	√	√	√

Table 3 – Weather Sensors and data availability to Network Control Centre

Secondary Systems

3.4 Secondary Infrastructure Assets

3.4.1 Station SCADA (RTUs / HMI / SCIMS)

There are 119 RTUs (Remote Terminal Units) providing SCADA (Supervisory Control and Data Acquisition) services at stations in AusNet Services' electricity transmission network. The SCADA systems gather remote station data such as instrumentation (volts, amps, frequency, Watts, VARs, transformer temperature, conductor strain, environmental monitoring, etc.) circuit breaker and plant status, station alarms, etc, interprets it and displays information to operations personnel to guide control of the network.

SCADA assets can be categorised into six technology types: Electronic (oldest), First Generation Microprocessor, Second Generation Microprocessor, Third Generation Microprocessor, Current Generation Microprocessor and PC-based Microprocessor.

Figure 19 below shows the SCADA assets by technology. The majority of SCADA systems in service throughout the electricity transmission network are First Generation Microprocessor and Third Generation Microprocessor assets. The remaining 12% of in service SCADA assets are Electronic assets.

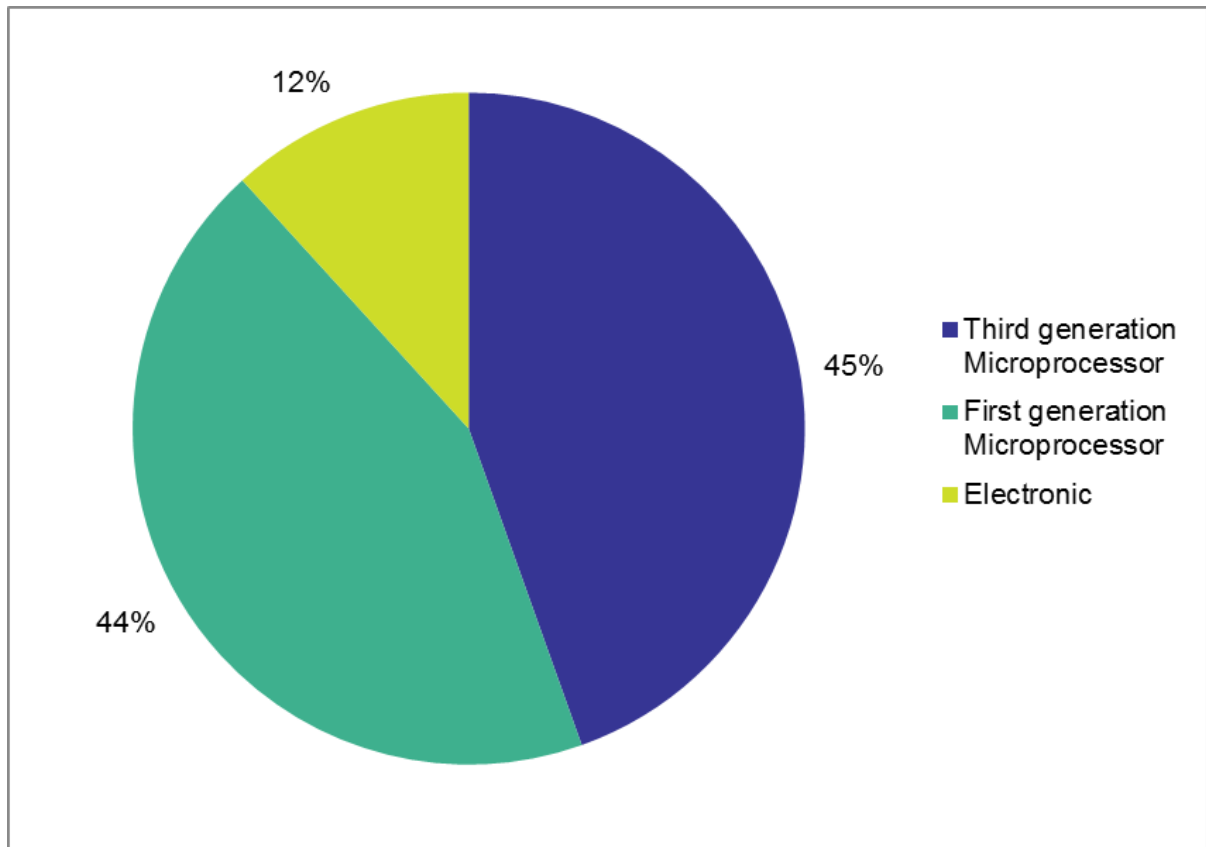


Figure 19 – SCADA Assets by Technology

Secondary Systems

As shown in the Figure 20 below more than 30% of SCADA assets are older than 25 years. Most of the oldest SCADA assets are Electronic SCADA assets.

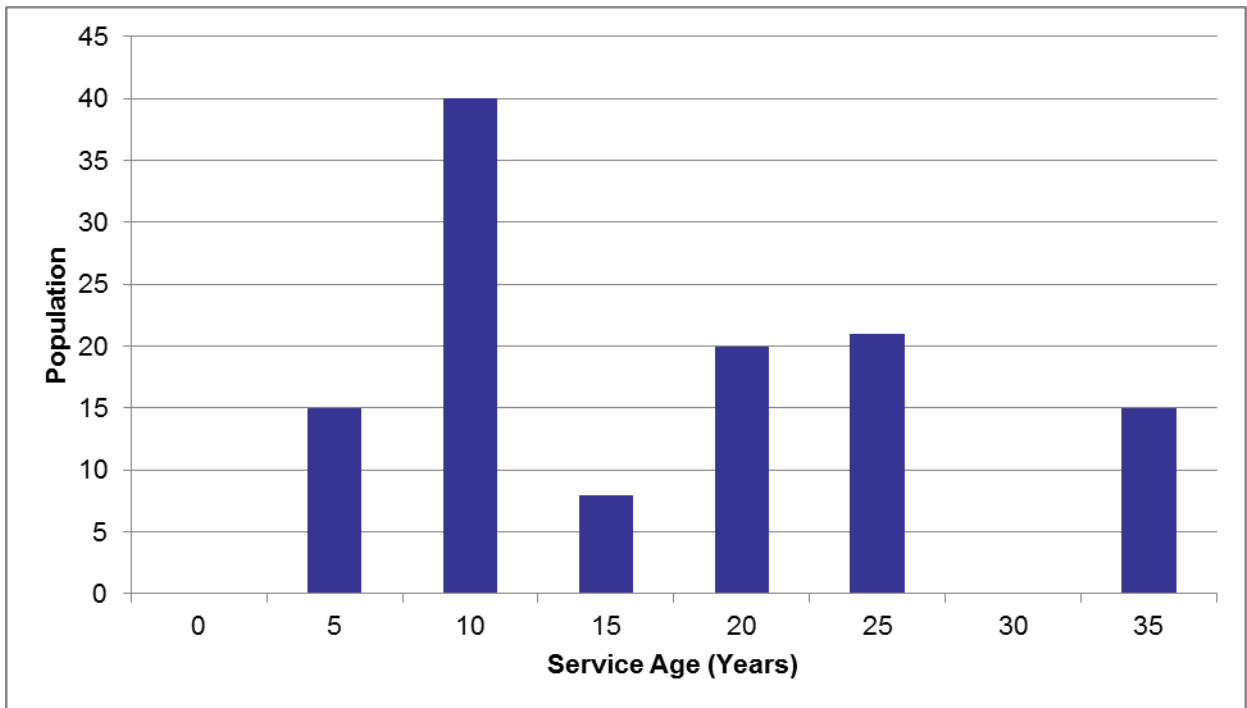


Figure 20 – SCADA Asset Age Profile

Secondary Systems

4 Strategic Drivers

Secondary Equipment (inclusive of Protection and Control, RTU and Revenue Metering) replacement has three key drivers:

- **COMPLIANCE:** These criteria apply to RTU and Revenue Metering assets and are determined by compliance with NER and AEMO's specifications.
- **OBSOLESCENCE:** These criteria determine the functionality of inadequate, failing, aged and/or unsupported and reflects the overall usability and maintainability of the relay. A secondary asset is considered to be obsolete if it is no longer economical to maintain due to abnormally high operating costs, scarcity of qualified personnel to service the asset, lack of manufacturer support, not compatible with modern assets or not capable of delivering expected services due to restricted functionality.
- **MODERNISATION:** These criteria determine the strategic fit of an asset in progression towards a modern, standardised design for station equipment using intelligent devices and the IEC61850 standard, consistent with network and business strategies and regulatory requirements. An asset may be considered to be a higher priority for replacement if it is no longer compatible with core operational systems (including communications equipment and SCADA) or if it has insufficient functionality to meet evolving network operational requirements (including, for example, bushfire mitigation requirements).

In addition, some replacement is driven by customer requirements and, where these requirements extend beyond the level of prescribed transmission services, they are funded by the customer.

Please refer to "AHR10-68 Asset Health Report Victorian Electricity Transmission Network Secondary Systems (Protection and Control Relays and Remote Terminal Units) and Revenue Metering" for further details.

Secondary Systems

5 Condition

The asset condition of Primary Plants such as transformers, transmission lines and circuit breakers can be assessed in terms of physical condition (rust, oil leaks, insulation strength or mechanism wear). However Secondary Systems generally do not exhibit external signs of deterioration and thus assessments must rely on reports of difficulties in obtaining and maintaining calibration or settings, mal-operations or failures to operate as intended and functionality.

For the purposes of this AMS, the ability of a Secondary System to reliably deliver its expected function has been assessed according to strategic replacement criteria outlined in Section 4 (Strategic Drivers) above namely Compliance, Obsolescence and/or Modernisation.

5.1 Protection & Control Assets

For the purpose of condition assessment of protection and control assets, the capability of a protection or control relay to deliver its expected function appropriately has been assessed according to Obsolescence and Modernisation¹.

Table 4 below provides a definition of the various condition scores and recommended action for protection and control assets.

Condition Score	Condition Description	Summary of Details of Condition Score	Recommended Action
C1	Very Good	Relays in this category are of the IED technology type. They are still in production and are supported by their manufacturers. C1 rated relays incorporate IEC61850 and feature GOOSE messaging. They also host a number of functions and capabilities to support network modernisation.	No Action Required
C2	Good	Relays in this category are mostly of the IED technology type. They are still in production and are supported by their manufacturers. C2 rated relays do not feature IEC61850 or GOOSE messaging. Instead, serial is the inherent communication platform. These relays generally host functions and capabilities similar to C1 rated relays.	Routine Maintenance and Condition Monitoring
C3	Average	Relays in this category are mostly of the microprocessor and electronic technology type. They are no longer in production but are still supported by their manufacturers. C3 rated relays feature a very limited number of functions and capabilities to support network modernisation.	Routine Maintenance and Condition Monitoring. Expected service life greater than 5 years.
C4	Poor	Relays in this category are mostly electro-mechanical but do include some relays from all 3 remaining technology types. They are obsolete with no manufacturer support. A limited number of spares are stocked in stores. C4 rated relays offer no functions or capabilities to support network modernization. Their limited functionality may also restrict full implementation of current standards.	Remaining Service Life less than 5 years

¹ For more information refer to AHR 10-68 Asset Health Report Victorian Electricity Transmission Network Secondary Systems (Protection and Control Relays and Remote Terminal Units) and Revenue Metering.

Secondary Systems

Condition Score	Condition Description	Summary of Details of Condition Score	Recommended Action
C5	Very Poor	Relays in this category are mostly electro-mechanical but do include some relays from all 3 remaining technology types. These relays are obsolete with no manufacturer support and there are no spares available. C5 rated relays offer no functions or capabilities to support network modernization.	Replace as soon as reasonably practical

Table 4 – Condition Score Definition and Recommended Action of Protection and Control Assets

5.1.1 Transformer Protection

Figure 21 below demonstrates the condition profile of transformer protection assets. More than 58% of assets are in “Good” (C2) or “Average” (C3) conditions. Majority of these assets are IED devices. More than 35% of transformer protection assets are in “Very Poor” (C5) condition. Most of the assets in C5 condition are oldest generation Electro-mechanical relays while others are either analogue electronic relays or microprocessor relays.

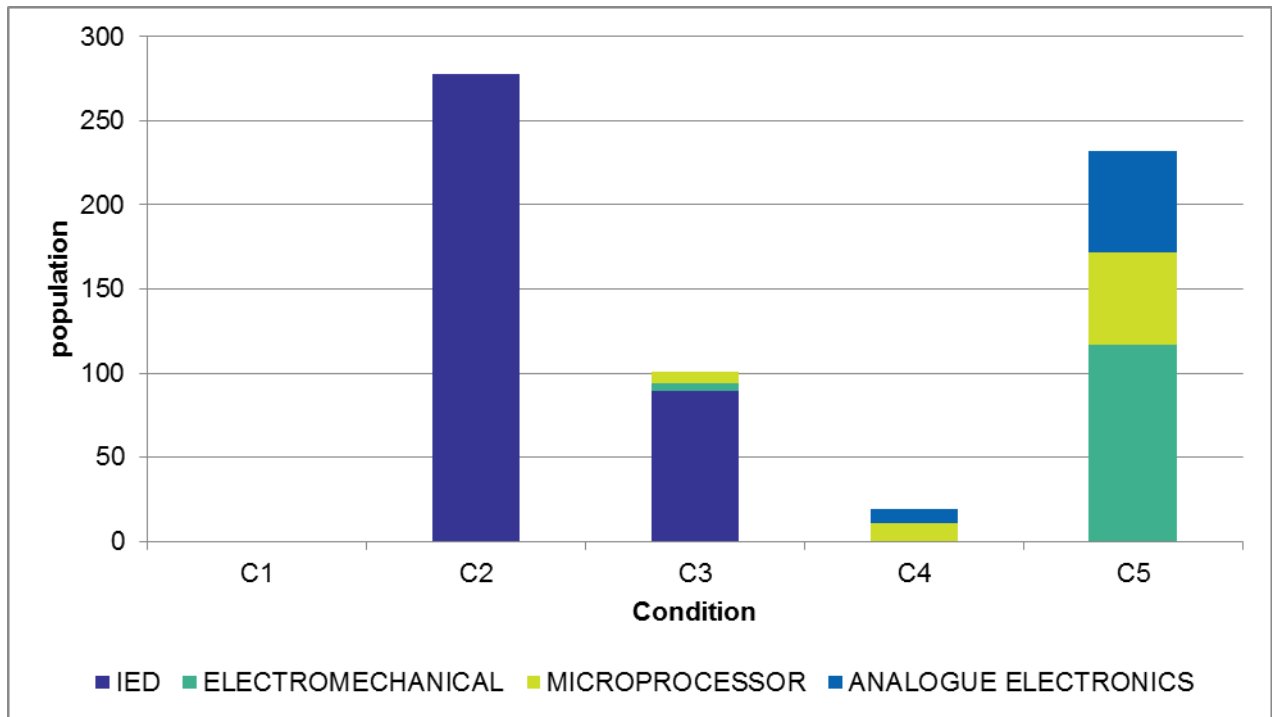


Figure 21 – Transformer Protection Asset Condition Profile

5.1.2 Bus Protection

Figure 22 below illustrates the condition profile of bus protection relays. Approximately 40% of bus protection relays are in either “Good” (C2) or “Average” (C3) conditions. More than 58% of relays providing bus protection are in “Very poor” (C5) condition. Most of them are oldest type Electro-mechanical replays and the rest is either Analogue Electronics or Microprocessor types.

Secondary Systems

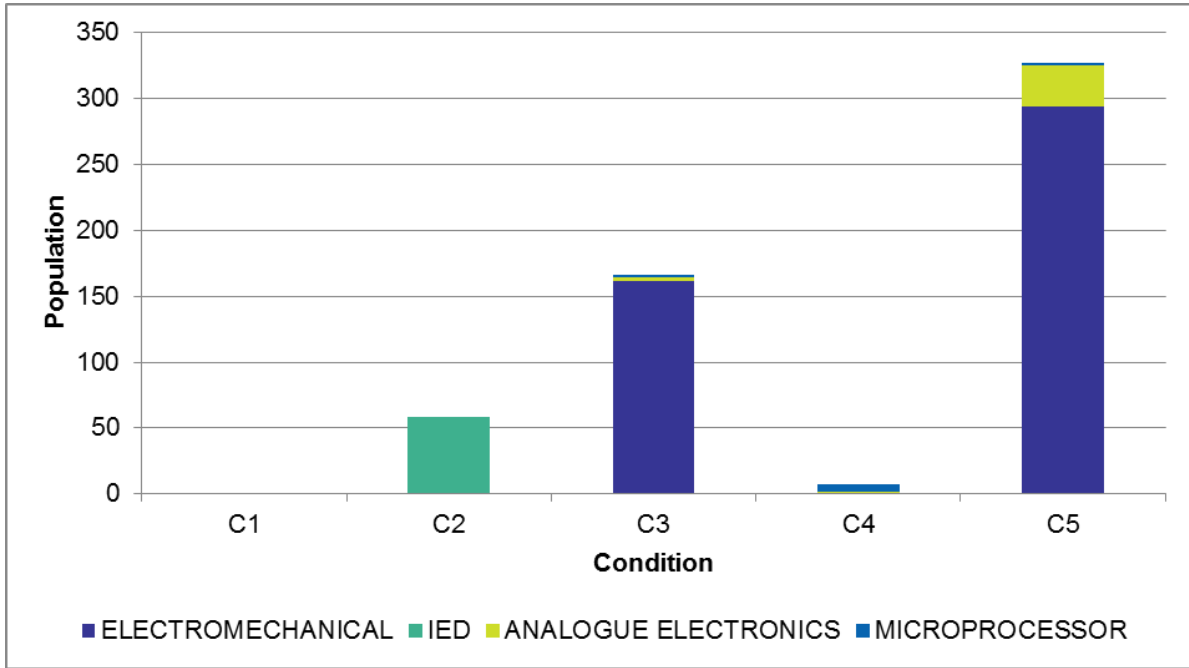


Figure 22 – Bus Protection Asset Condition Profile

5.1.3 EHV Line Protection (220 kV, 275 kV, 330 kV and 500 kV)

Figure 23 illustrates the condition profile of EHV line protection assets. Approximately 41% of assets are in “Good” (C2) condition and all these are IED devices. More than 31% of EHV line protection assets are in “Very poor” (C5) condition while another 21% are in “Poor” condition approaching C5 condition within next five years. Majority of EHV line protection assets in C5 condition are electro-mechanical relays while the rest are either analogue electronic relays or microprocessor relays.

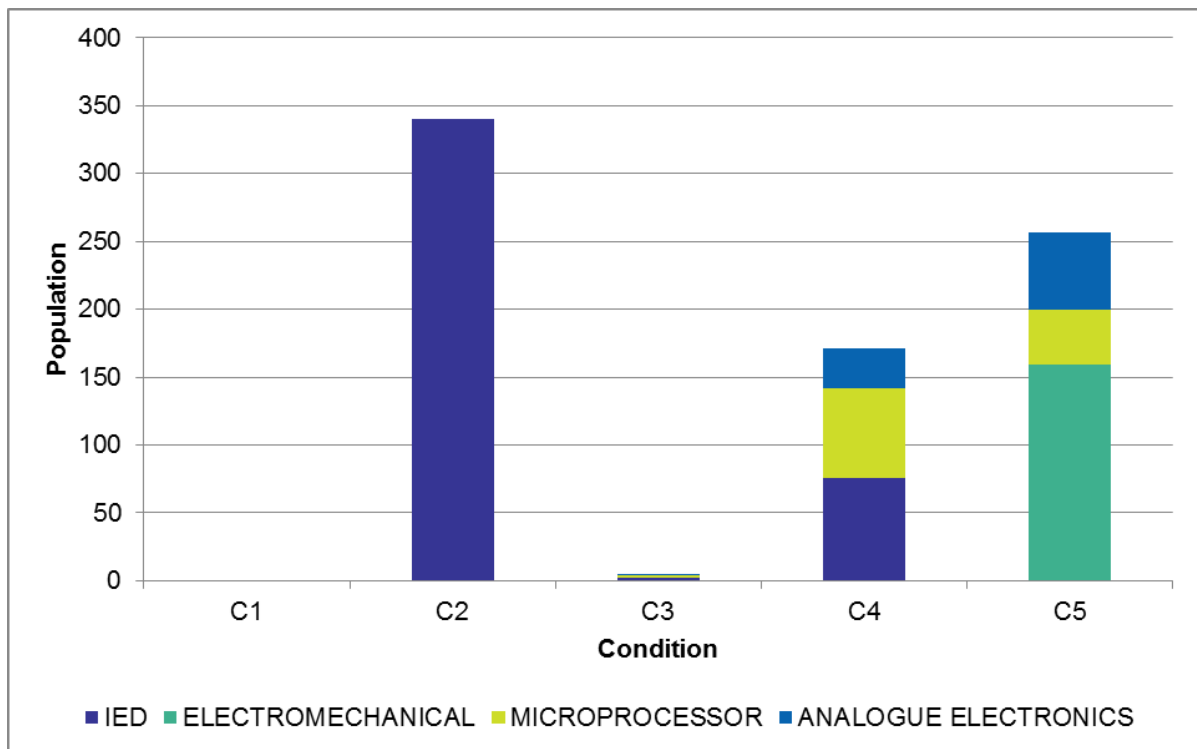


Figure 23 – EHV Line Protection Asset Condition Profile

Secondary Systems

5.1.4 HV Line Protection (66 kV and 22 kV)

Figure 24 provides condition profile of HV line protection assets. More than 52% of HV line protection assets are in “Good” (C2) condition and all of them are IED devices. More than 36% assets are in “Very poor” (C5) condition. Approximately 93% of HV line protection assets in very poor condition are electro-mechanical relays. These relays are obsolete with no manufacturer support and there are no spares available.

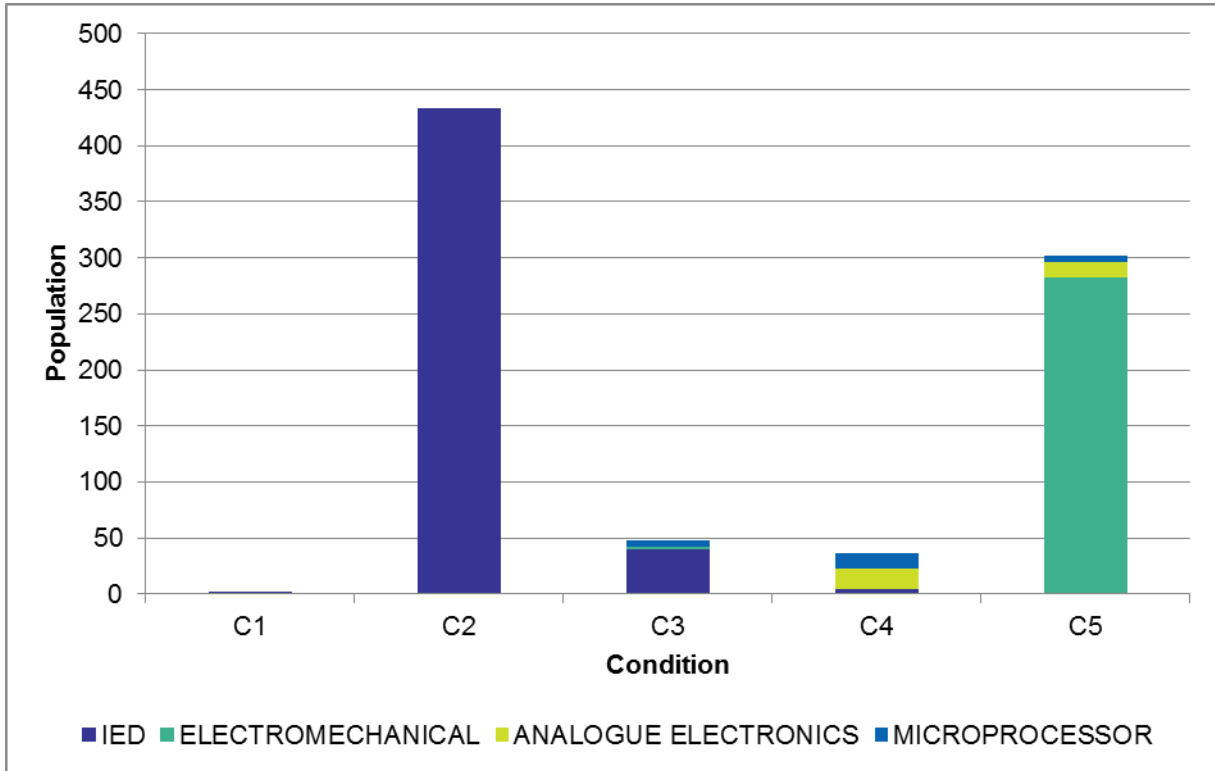


Figure 24 – HV Line Protection Asset Condition Profile

5.1.5 Reactive Plant Protection

Figure 25 to Figure 27 below provides the condition profiles of protection assets of reactive plants in the Victorian transmission system. Figure 25 shows the condition profile of EHV and HV capacitor protection assets. Approximately 64% of assets are in “Poor” (C4) condition approaching “Very poor” (C5) condition in near future. About 17% of capacitor protection assets are already in C5 condition and most of them are electro-mechanical relays. More than 56% of capacitor protection assets are microprocessor relays and most of them are in “poor” condition. Overall, most of the capacitor protection relays are nearing the end of their service life.

Secondary Systems

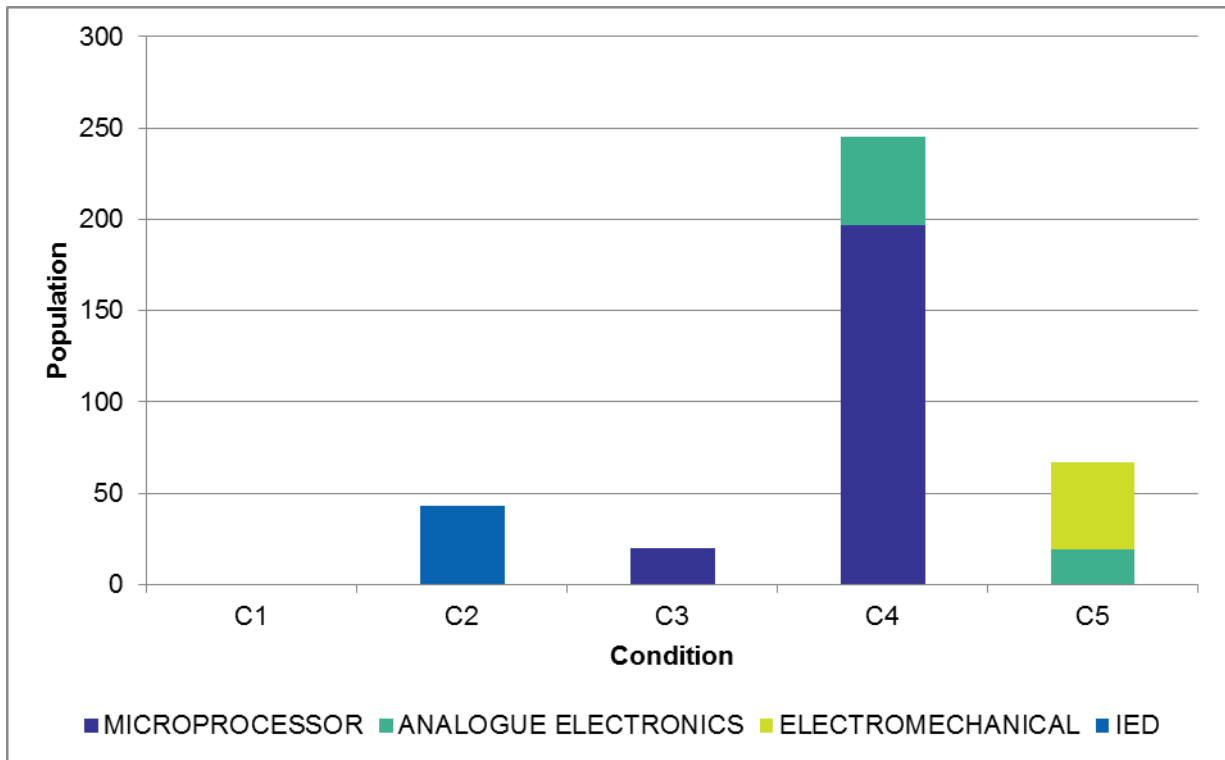


Figure 25 – EHV & HV Capacitor Protection Asset Condition Profile

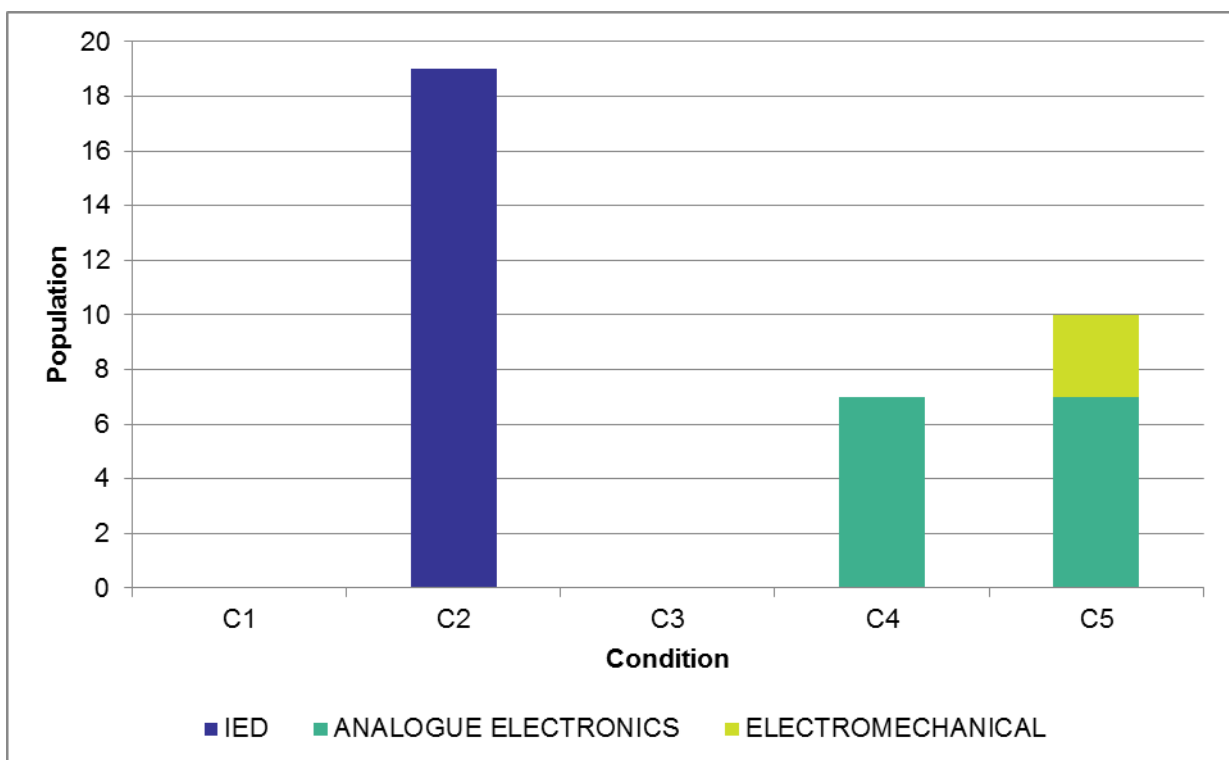


Figure 26 – Reactor Protection Asset Condition Profile

Secondary Systems

Figure 26 above demonstrates the condition profile of reactor protection assets. More than 52% of reactor protection assets are in “Good” condition (C2) and they all are IED devices. Approximately 28% of assets are in “Very poor” (C5) condition and they are either electro-mechanical or analogue electronic relays. There are no microprocessor relays in the reactor protection systems.

Figure 27 illustrates the condition profile of protection assets of Synchronous Compensators (SC) and Static Var Compensators (SVC). Approximately 67% of assets are in “Poor” (C4) condition approaching “Very poor” C5 condition within next few years. All the assets in C4 condition are analogue electronic relays. More than 10% of assets are already in “very poor” condition. The majority of the assets in poor and very poor condition are analogue electronic relays while the rest are electro-mechanical relays.

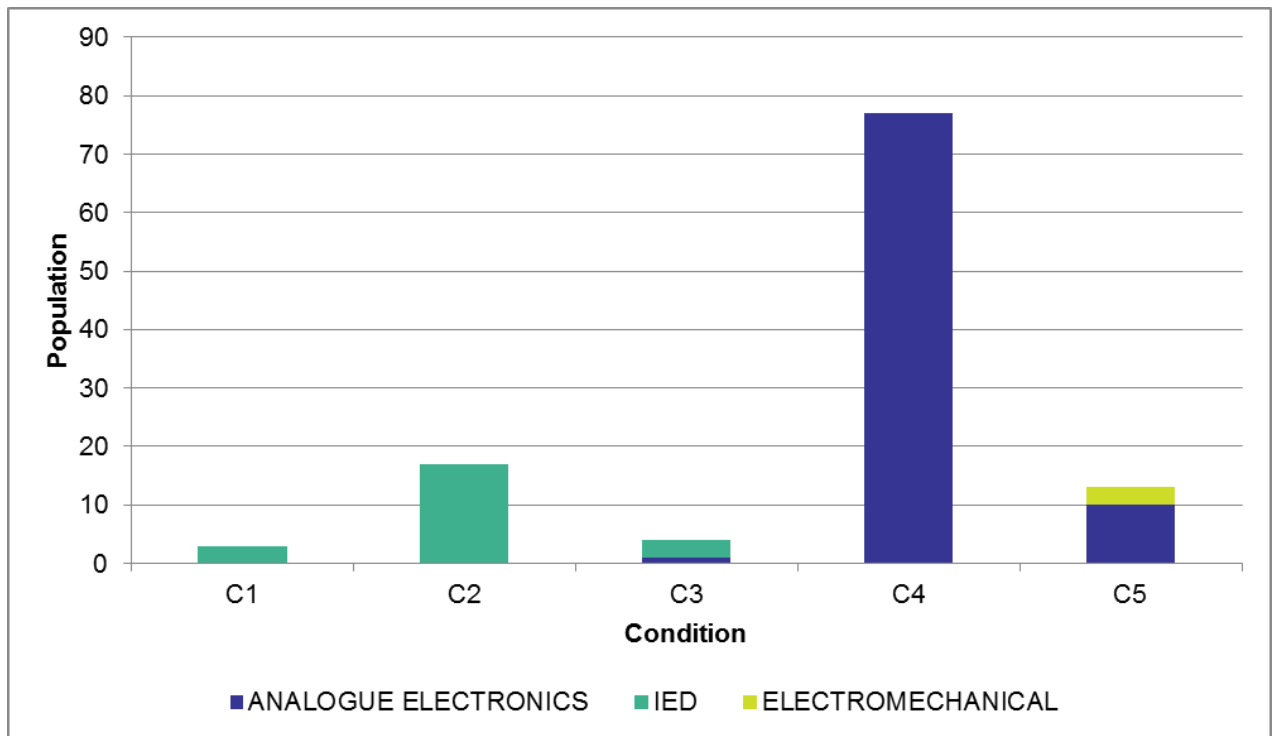


Figure 27 – SC & SVC Protection Asset Condition Profile

5.1.6 Circuit Breaker Management & Control

Figure 28 below shows the condition profile of circuit breaker management assets. Of 1109 CB management assets, more than 50% are in “Good” (C2) condition and all of them are IED devices. Approximately 26% of assets are in “Very poor” (C5) condition while another 20% that are in “Poor” condition reaching their end of service life within next five years. The majority of these relays are either old technology Electro-mechanical relays or Analogue electronics relays.

Secondary Systems

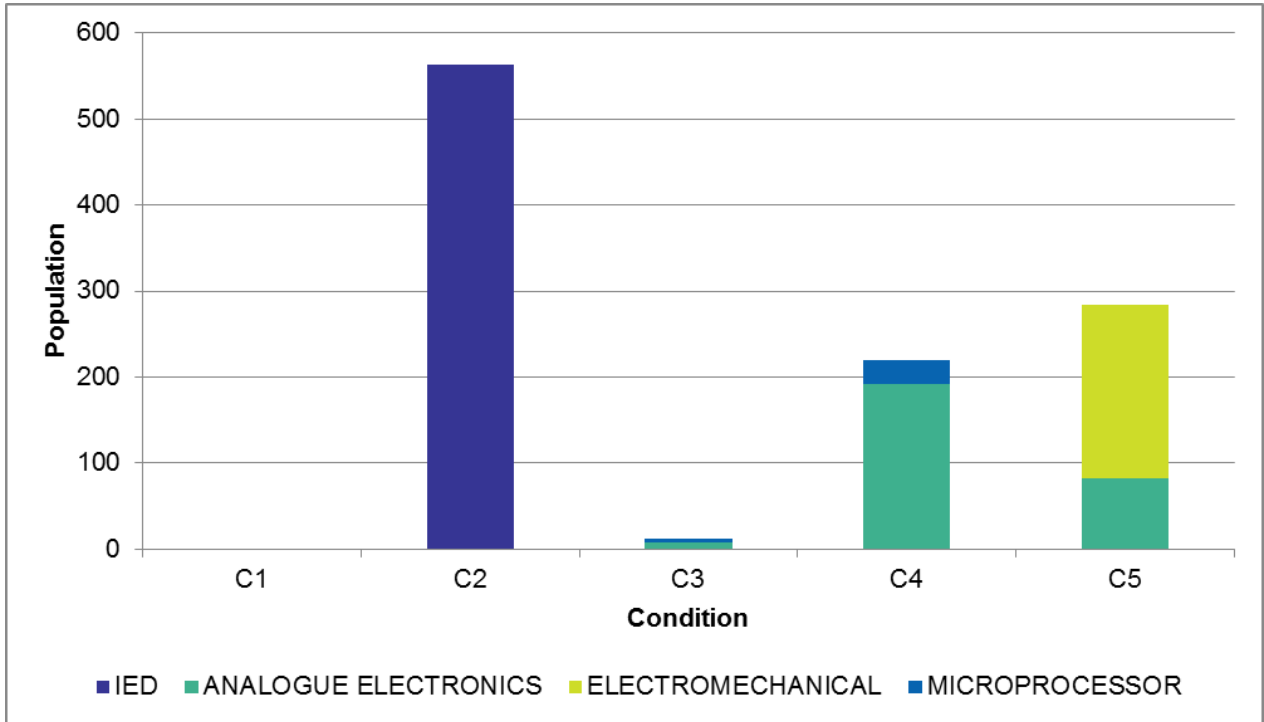


Figure 28 –Condition Profile of Circuit Breaker Management Assets

Figure 29 demonstrates the condition profile of Control and/or CB fail assets. More than 55% of assets are either in “Poor” condition (C4) or “Very poor” condition (C5). Almost all of these relays are Microprocessor relays.

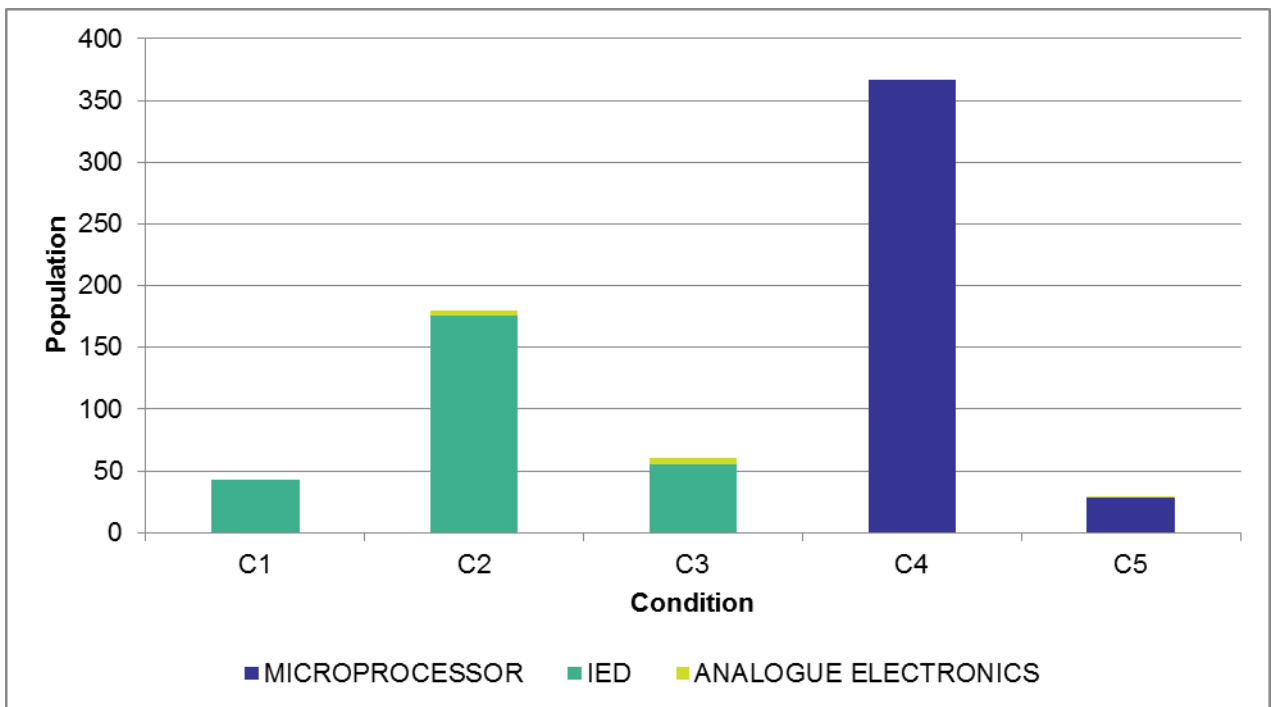


Figure 29 –Condition Profile of Control and/or CB Fail Assets

Secondary Systems

5.2 Monitoring and Metering Assets

The condition score of monitoring and metering assets was determined based on three assessment criteria; Compliance, Modernisation and Obsolescence as explained in the section 4 above. A weighted average of the score applied for each set of criteria was used to determine the overall condition score.

The product obsolescence considers the age, production and support continuity of the revenue metering.

Limited or no spare availability for a defective meter will increase the risk of non-compliance. If any of the meters fail, an exemption in terms of compliance from AEMO is required for any outages and or repair. The production and support examines the in-production and support from suppliers as well as the level of product spares available in the system.

The modernisation criteria considers the capability of revenue metering providing power quality functionalities as well as enhanced hardware capabilities such as independent DNP port. Other criteria such as remote access, network connections refer to the software and hardware ability of the revenue metering product to meet industry requirement.

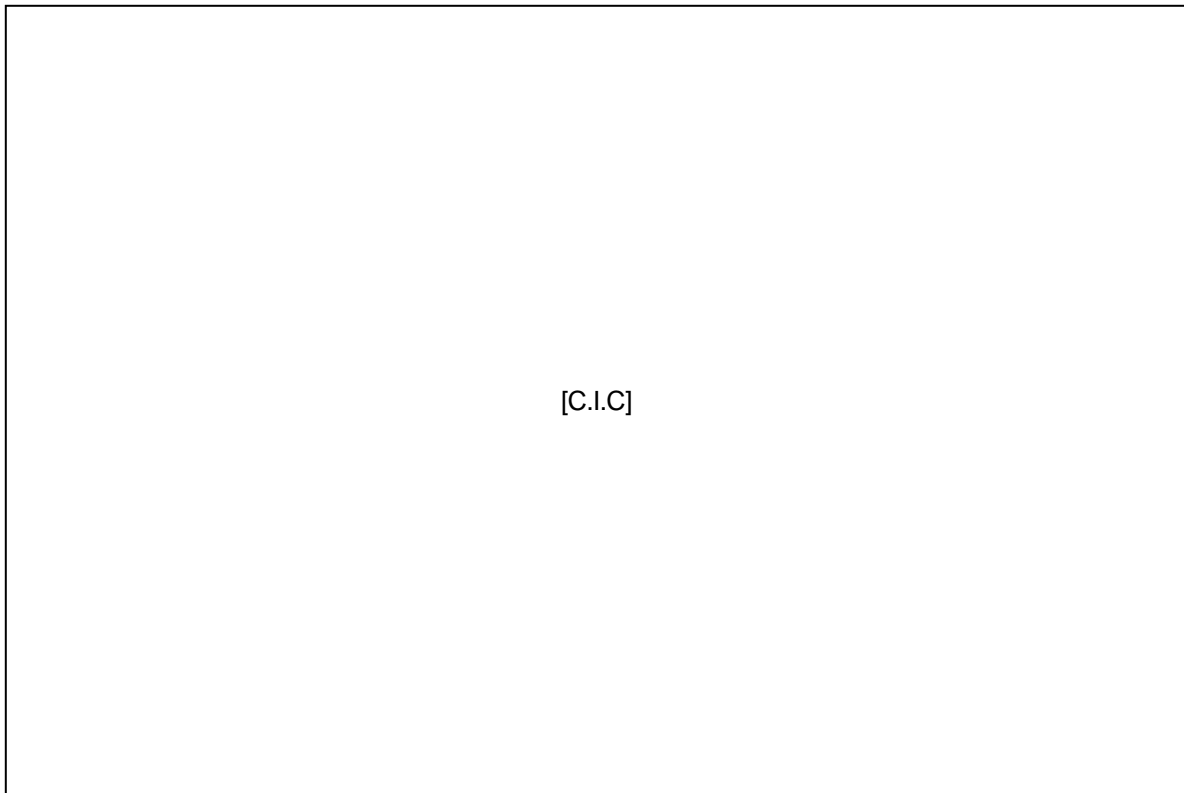
Table 5 provides a definition of the various service scores and recommendations for monitoring and metering assets.

Condition Score	Condition Description	Summary of Details of Condition Score	Recommended Action
C1	Very Good	<p>These assets generally provide:</p> <ul style="list-style-type: none"> NMI (National Measurement Institute) pattern provided and verified; Power Quality functionalities such as sag/swell, harmonics up to 50th, flickers, etc; Recording data of 365days of 30 mins for 32points of supplied; Independent Ethernet, Serial and Modem connection ports; Functionality sufficient to meet AEMO requirements. <p>These assets have generally been in production for less than five years and are expected to remain in production for an extended period of time which is estimated in excess of 15 years.</p>	No Action Required
C2	Good	<p>Assets in this category are considered to be in better than average condition. They provide similar hardware, software and functionalities to a C1-rated device, and meet all AEMO requirements. These assets have generally been in service for less than five years, but have been in production for up to 10 years. These assets are not expected to remain in production for an extended period of time.</p>	Routine Maintenance and Condition Monitoring
C3	Average	<p>Assets in this condition are considered to be in an average condition for their respective service age and performance. These assets are either no longer in production, or not expected to remain in production for much longer.</p>	Routine Maintenance and Condition Monitoring. Expected to remain in service for the next 5 years
C4	Poor	<p>This category includes assets which are considered to be in worse than average condition or which are no longer manufactured or supported by suppliers. These assets are potentially at risk of major failure. Any outages and or repair generally require exemption from AEMO in terms of compliance.</p>	Remaining Service Life less than 5 years
C5	Very Poor	<p>This category includes assets which are typically inspection and maintenance intensive. These assets are well beyond the end of economic life. Specialist work is required to manage defects and limited spares are in stock. They generally require exemption from AEMO in term of compliance. These assets are very much less than adequate for current operation and prone to major failure.</p>	Replace as soon as reasonably practical

Table 5 – Condition Score Definition and Recommended Action of Monitoring and Metering Assets

Secondary Systems

Error! Reference source not found. below shows the condition profile of monitoring and metering assets. All the metering assets are either in “Very poor” (C5) condition or “Poor” (C4) condition approaching C5 condition in near future. Metering assets in C5 condition are mainly [C.I.C] meters. [C.I.C] meters are in C4 condition. No metering assets are in “Very Good” (C1) to “Average” (C3) conditions.



5.3 Secondary Infrastructure Assets

The procedure for assessing the current condition of a RTU is based on AEMO’s requirements and operational performance, product obsolescence and modernisation. AEMO requirements for SCADA are predominantly about resolution of information, age of information and reliability of the system. The product obsolescence takes into account the service age, ability to interface and communicate, and in-production, spares availability and support from suppliers. The modernisation criteria considers the capability of RTU in terms of supporting a high number of IEDs and database points, supporting remote access, current computer operating system, management protocol and data storage².

² For more information refer to AHR 10-68 Asset Health Report Victorian Electricity Transmission Network Secondary Systems (Protection and Control Relays and Remote Terminal Units) and Revenue Metering.

Secondary Systems

Table 6 provides a definition of the various service scores and recommendations for secondary infrastructure assets.

Condition Score	Condition Description	Summary of Details of Condition Score	Recommended Action
C1	Very Good	<p>These assets generally provide:</p> <ul style="list-style-type: none"> Advanced functional capability; Physical hardware which is most suitable for the substation environment and eliminates single points of failure in the system; Management and security software suitable for use in the business; Software and functionalities defined in the current substation automation standard (IEC61850); Functionality sufficient to meet AEMO requirements. <p>These assets have generally been in production for less than five years and are expected to remain in production for an extended period of time which is estimated in excess of 15 years.</p>	No Action Required
C2	Good	<p>Assets in this category are considered to be in better than average condition. They provide similar hardware, software and functionalities to a C1-rated device, and meet all AEMO requirements, but do not comply with the current IEC61850 standard. These assets have generally been in service for less than five years, but have been in production for up to 10 years. These assets are not expected to remain in production for an extended period of time.</p>	Routine Maintenance and Condition Monitoring
C3	Average	<p>Assets in this condition are considered to be in an average condition for their respective service age and performance. They typically do not provide system redundancy and lack hardware and functionalities suitable for use with a substation automation system. These RTUs are considered less than adequate for current operation and increase the risk of major failure. In some cases they require special configuration in scanning rate to achieve AEMO requirements. These assets are either no longer in production, or not expected to remain in production for much longer.</p>	Routine Maintenance and Condition Monitoring. Expected to remain in service for the next 5 years
C4	Poor	<p>This category includes assets which are considered to be in worse than average condition or which are no longer manufactured or supported by suppliers. These assets have minimum hardware, software and functionalities for substation automation. They require special configuration in scanning rate to achieve AEMO requirements or exemption from AEMO in term of compliance. Specialist work is required to manage specific defects and limited spares are in stock. These assets are less than adequate for current operation and potentially at risk of major failure.</p>	Remaining Service Life less than 5 years
C5	Very Poor	<p>This category includes assets which are typically inspection and maintenance intensive. These assets are well beyond the end of economic life. Specialist work is required to manage defects and limited spares are in stock. They generally require exemption from AEMO in term of compliance. These assets are very much less than adequate for current operation and prone to major failure.</p>	Replace as soon as reasonably practical

Table 6 – Condition Score Definition and Recommended Action of Secondary Infrastructure Assets

Secondary Systems

Figure 30 below demonstrates the condition profile of secondary infrastructure assets. Approximately 12% are in “Very poor” (C5) condition and all of them are Electronic type. Another 44% First generation microprocessor type RTUs are in “Poor” (C4) condition approaching C5 condition in near future.

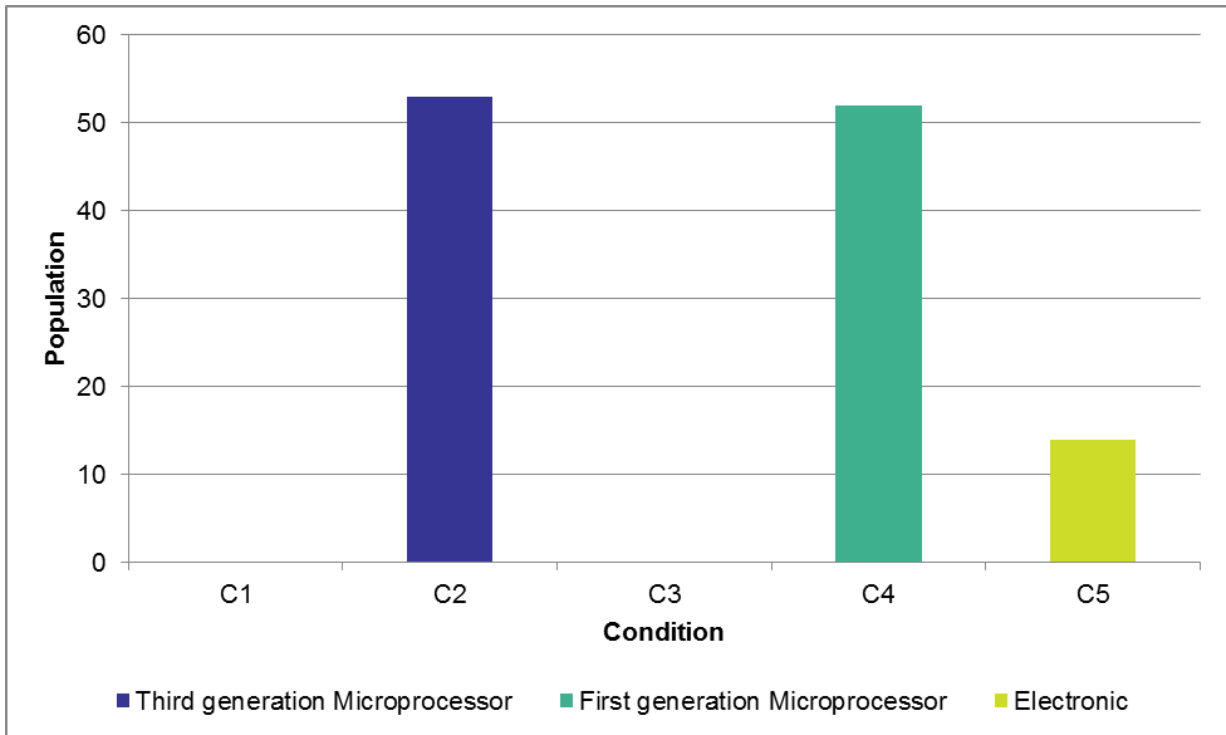


Figure 30 – RTU Condition Profile

5.4 Performance

5.4.1 Protection Systems Failure History

The main objective of having a protection system is to locate and isolate the faulty circuits within the power network rapidly, effectively and safely to minimise threat to worker and public safety, any damage to equipment and risks of network instability. These requirements are defined in Chapter 5 of the National Electricity Rules.

Transmission protection systems are required to be duplicated and fully independent. AusNet Services prepares a Defective Apparatus Report (DAR) for each system failure. Figure 31 below shows the number of DARs prepared for protection systems from 2003. There is general trend of increase over the years. Over the 2012-2014 period there was a 15% increase in reported system failures as shown in Figure 31 below.

Secondary Systems

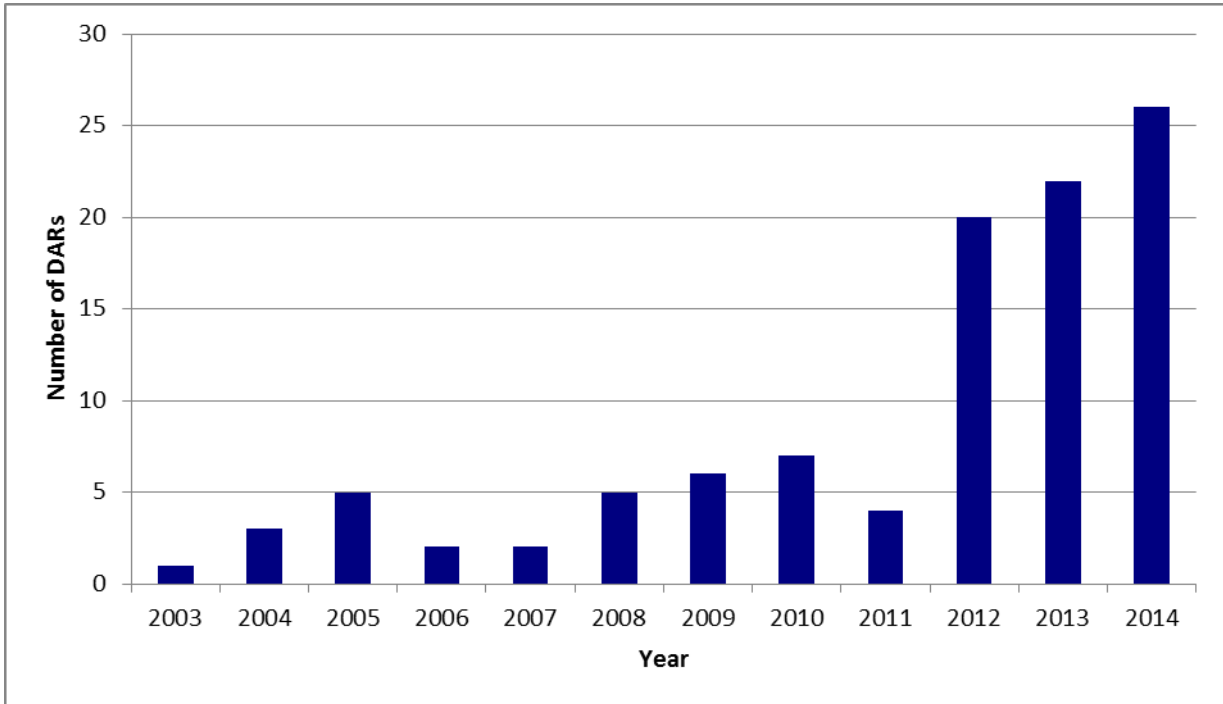


Figure 31 – Defective Apparatus Reports for Protection Systems

Secondary Systems

6 Strategic Factors

The key drivers of secondary asset replacement are covered in detail in Section 4. Some of the strategic factors that underlie these drivers are described below.

6.1 Smart Networks

The increasing availability of “Smart Network” technologies enables network operators to drive the network harder and reduce the need for additional primary plant. This requires investment in network/station control schemes underpinned by faster serial communications protocols, including IEC61850 and GOOSE (Generic Object Oriented Substation Events) messaging.

6.2 Engineering Access

The increasing ability to remotely interrogate relays and remotely apply setting changes provides an opportunity to respond more quickly to network incidents and accelerate service restoration. This is a major benefit of modern IEDs at a time when skilled field staffs are increasingly scarce.

6.3 Complexity of Intelligent Devices

The increased reliability of modern IEDs has enabled the standard maintenance interval to be increased from 3 years to 6 years for digital relays with comprehensive self-supervision capabilities. As multifunctional intelligent devices become more complex, they take longer to commission and maintain; this tends to reduce the cost benefits of longer maintenance intervals. Little hard data is available, but there is some anecdotal evidence to indicate that the cost of commissioning and maintaining IEDs is increasing due to their complexity.

Training tends to focus on newer technologies. The skills required to support older technologies are becoming scarce as staff trained in the 1980s and earlier have either retired or near retirement. The multiplicity of software and range of technologies required to support both old and new relays is a key driver for the replacement of older systems.

6.4 Primary Plant Rebuilds

Replacement of older circuit breakers, transformer replacements and station rebuilds drive secondary asset replacement, but also provide opportunities for creating cost-efficiencies where secondary assets identified for strategic replacement can be replaced at the same time as primary plant. Co-ordinating primary and secondary works minimises undesirable asset outages and also reduces penalties incurred under the performance incentive schemes.

6.5 Network Augmentation

Network augmentation has become a minor driver of Secondary Systems modernisation. For example, the relatively infrequent connection of a new generator to the transmission network may result in new transmission lines or terminal stations being constructed. However, the increasing use of teed lines to connect new assets forces the replacement of older distance-based protection schemes with “three-ended” current differential schemes.

Secondary Systems

7 Strategies

An overarching strategy is to integrate as many secondary asset modernisation projects as possible with Terminal Station rebuild projects or major primary asset replacement projects rather than relying on stand-alone secondary asset replacement projects. This approach ensures better results with more efficiency, fast delivery and better economics. Stand-alone secondary projects are initiated only where no suitable Terminal Station rebuild project or primary asset replacement project is planned in an appropriate timeframe.

7.1 New Assets

- Develop standard schemes for new assets to include the capability for simultaneous operation of IEC61850 and DNP3 communication protocols. Ensure compatibility with existing schemes on brownfield sites and appropriate communication speeds for modern IP-based equipment.
- Develop standards to enable continuous interrogation, self-healing and system health or behavioural monitoring.
- Purchase new and replacement protection assets to current period order contracts.

7.2 Inspection and Maintenance

- Continue the existing inspection and maintenance of secondary assets within AusNet Services' terminal stations for new assets after 12 months and 6 yearly continuous inspection and maintenance for protection relays and on RTUs or Station Gateways in accordance with PGI 02-01-02 "Plant Guidance and Information – Summary of Maintenance Intervals Transmission".
- Continue to update the condition monitoring process for obtaining health indicators for all protection assets.
- Review and update the relevant sections for secondary assets of PGI 02-01-02 by 2018.

7.3 Repairs

- Where economic, return damaged or faulty relays to manufacturers for repair.

7.4 Replacement

- Integrate secondary asset modernisation projects within terminal station rebuild project or major asset replacement projects wherever economic.
- Ensure only stand-alone secondary projects are initiated only where no suitable major projects is planned in an appropriate timeframe.
- Target protection, control, metering and monitoring asset replacement, on deteriorated C4 and C5 condition assets (as per AHR 10-68).
- Where economic the replacement of asset should incorporate the serial communications to IEDs and a local HMI control allowing retirement of the station mimic panels.

7.5 Condition Monitoring

- Provide condition monitoring to secondary assets including secondary cabling where economic.
- Review the condition of secondary assets and update the asset management systems by 2019.

Secondary Systems

7.6 Spares

In conjunction with the annual preparation of network contingency plans and summer preparedness plans:

- Review the need for spares of critical relays (category C3 or C4).
- Ensure prompt procurement of spares when low stock alarm is triggered.
- In case where spares for complex equipment are not available, prepare emergency replacement schemes with marked-up drawings and device settings for use during emergencies.