AMS – Electricity Distribution Network

MV Switches and ACRs

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Disclaimer

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1 Executive Summary

This strategy forms part of a comprehensive asset management strategy for the AusNet Services electricity distribution network. Its purpose is to identify issues, analyse options and outline the strategy for maintaining network reliability, safety and security through effective and efficient management of medium voltage (MV) switches and Automatic Circuit Reclosers (ACRs).

The primary function of MV switches and ACRs is to isolate sections of the network either for operational purposes or in response to fault events. MV switches may be pole- or ground-mounted, and use oil, SF6 gas, vacuum or air as the insulating and/or breaking medium.

ACRs and a small proportion of MV Switches known as sectionalisers (a type of automated gas switch), are able to operate both autonomously, and manually via remote or local controls. These devices form the basis of distribution feeder automation (DFA) systems that minimise customer outages in case of network fault events. ACRs and sectionalisers represent approximately 20% of the total population of MV switches and ACRs. Significant numbers of three-phase ACRs have been installed or replaced as part of DFA systems within the last decade. Improved bushfire mitigation protection philosophies, including the introduction of REFCL technologies, continues to drive bulk upgrade, replacement and the installation of new units.

The majority of MV switches can only be operated locally (at the switch location) by trained staff as required to facilitate network operations. Proactive management will continue to be required to optimise the ongoing transition from a low-customer-density overhead network controlled by manually operated, pole-mounted switches to a network with significant high-customer-density underground circuit switches by SCADA-controlled metal clad switchgear in both pole and ground-mounted installations.

The subset of MV Switches and ACRs considered critical to network switching requirements are known as “key switches”. Switches considered necessary for operational reasons but not critical to network switching requirements are known as “auxiliary switches”. Some switches considered surplus to network switching requirements, are referred to as “redundant switches”. The categorisation of a switch location as “key”, “auxiliary” or “redundant” can change as the network evolves. As maintenance of pole-mounted switches is a labour intensive activity, ad hoc and corrective maintenance of non-key switches, as required to facilitate safe and efficient network operations, is considered the most economic management approach. Replacement on failure of key and auxiliary switches is anticipated to be a primary contributor to CAPEX in this area.

1.1 Strategies

1.1.1 New Installations

- Continue to design and install new and replacement assets in accordance with the distribution design manual (30-4142)
- ACR and sectionaliser control box configurations shall comply with current control configuration standards.

1.1.2 Maintenance

- Continue to maintain MV Switches and ACRs in accordance with SOP 70-03
- Maintain SOP 70-03 consistent with Enhanced Data-Driven Asset Management (EDDAM) studies

1.1.3 Obsolescence and Spares Management

- Continue to maintain adequate spares to ensure ongoing availability of key switches, as per the distribution critical spares strategy SOP 28-02

1.1.4 Replacement

- In accordance with the outcomes of asset inspections and individual feeder reliability reviews, selectively retire or replace air break switches with gas switches
- Prioritise proactive replacement of high criticality, poor condition key switches
- Replace approximately 40 ACRs and gas sectionalisers each year on condition, prioritising the highest criticality assets
- Replace all oil insulated ACRs by 2025
- In accordance with SOP 70-03, replace failed or poor condition non-key switches only if required to facilitate network operations

1.1.5 Systems and Processes

- Update key switch policy and introduce processes for regular review and update
- Consolidate system data with key switch policy
- Record asset condition in Asset Management System

1.1.6 Research and Development

- Extend scope of Enhanced Data Driven Asset Management (EDDAM) studies to incorporate MV switches and ACRs
- Research and develop automated processes for identification and management of key switches

2 Introduction

2.1 Purpose

The purpose of this document is to outline the inspection, maintenance, replacement and monitoring activities identified for economic life cycle management of MV Switches and ACRs. This document is intended to be used to inform asset management decisions and communicate the basis for activities.

In addition, this document forms part of our Asset Management System for compliance with relevant standards and regulatory requirements. It is intended to demonstrate responsible asset management practices by outlining economically justified outcomes.

2.2 Scope

The assets covered by this strategy include:

- Pole-top MV Automatic Circuit Reclosers (ACRs) including all switchgear, instrumentation and control components
- MV manual and automatic switches, including remotely controlled and automated sectionalisers
- Fuse Savers

The following assets are not covered by this strategy:

- Primary or secondary infrastructure located within zone substation boundaries
- Communications infrastructure beyond the installed switch location – refer AMS 20-81
- Power Quality and Revenue Meters – refer AMS 20-15
- Pole infrastructure including the pole, conductors, insulators, cross-arms, transformers, fuses and other non-switching related equipment
- SCADA systems
- Non-Regulated assets
- LV switching infrastructure including LV pillars
- MV Fuse Switch Disconnectors – refer AMS 20-61

2.3 Asset Management Objectives

As stated in *AMS 01-01 Asset Management System Overview*, the high-level asset management objectives are:

- Comply with legal and contractual obligations;
- Maintain safety;
- Be future ready;
- Maintain network performance at the lowest sustainable cost; and
- Meet customer needs.

As stated in *AMS 20-01 Electricity Distribution Network Asset Management Strategy*, the electricity distribution network objectives are:

- Improve efficiency of network investments;
- Maintain long-term network reliability;
- Implement REFCL's within prescribed timeframes;
- Reduce risks in highest bushfire risk areas;
- Achieve top quartile operational efficiency; and
- Prepare for changing network usage.

3 Asset Description

3.1 Asset Function

The electricity distribution network in eastern Victoria employs several types of medium voltage (MV) switches to facilitate network operation. The main function of these switches is to isolate sections of the network either for operational purposes or in response to fault events. MV switches may be pole- or ground-mounted, and use oil, SF6 gas, vacuum or air as the insulating and/or breaking medium. Some MV switches have load and/or fault current breaking capabilities, while others can only be operated after the network has been de-energised.

ACRs and a small proportion of MV Switches known as sectionalisers (automated gas switches), are able to operate both autonomously, and manually via remote or local controls. Automatic and remote operation of these devices is facilitated by a control box installed at the switch location. These devices form the basis of distribution feeder automation (DFA) systems that are designed to minimise customer outages in case of network fault events.

The majority of MV Switches however can only be operated manually. They are operated locally (at the switch location) by trained staff as required to facilitate network operations.

A subset of MV Switches and ACRs are considered critical to network switching requirements. These switches are known as “key switches”. Switches considered necessary for operational reasons but not critical to network switching requirements are known as “auxiliary switches”. Some switches are considered surplus to network switching requirements, and are referred to as “redundant switches”. The categorisation of a switch location as “key”, “auxiliary” or “redundant” can change as the network evolves.

3.2 Asset Population and Age Profile

MV Switches and automatic circuit reclosers (ACRs) are considered to be (distribution) line assets. They are installed on 6.6 and 22kV (MV) feeders, usually as pole top devices but also as part of indoor, ground mounted or kiosk substations.

MV Switches and ACR equipment types are reported under a combination of categories in the RIN.

The switch component of MV Automatic Circuit Reclosers (ACRs) are reported under the “ > 11kV & < = 22kV ; Circuit Breaker” RIN category (total 1586 assets; RIN 2017). ACRs account for 48% (approximately 760) of the listed assets.

ACR and sectionaliser control boxes are included in the “FIELD DEVICES” RIN category (total 5859 assets; 2017 RIN). MV ACR and sectionaliser control boxes account for 39% (almost 2,300) of the listed assets.

All non-control infrastructure associated with MV switches (excluding ACRs) are reported under the “ < = 11 kV ; Switch” or “> 11kV & < = 22kV ; Switch” categories (total 140,900 assets; 2017 RIN). MV Switches, including sectionalisers, account for 11% (approx. 15,500) of the listed assets.

Approximately 78% of MV switches are less than 20 years old. Less than 9% of in-service assets have been in service for more than 40 years.

For strategic purposes, MV Switches and ACRs may be separated into five operational types: ACRs, air break switches, gas switches (including manual gas switches and automatic sectionalisers), indoor or ground mounted switches and Fuse Savers. Each of the operational types represent distinct operational technologies and constructions, display different functions, criticalities, performance characteristics and condition profiles, and as a result incur slightly different management strategies. Figure 1 provides an overview of the in-service population, separated into operational types.

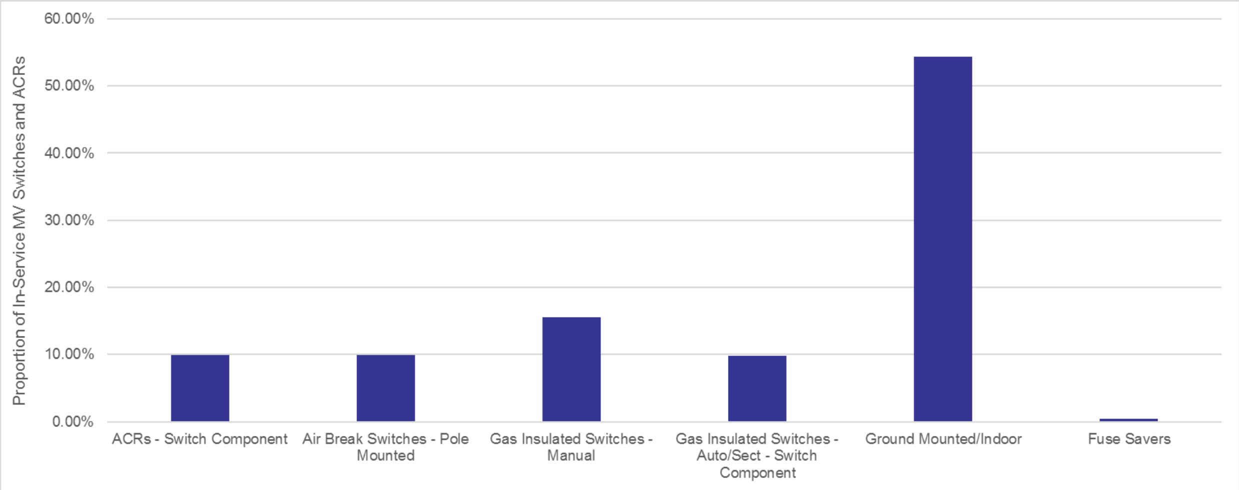


Figure 1: MV Switches and ACRs - Operational Types

3.2.1 Automatic Circuit Reclosers (ACRs)

ACR's are installed on both three-phase feeder backbones and single wire earth return (SWER) circuits to form an integrated distributed feeder automation (DFA) system. They facilitate the normal remote operation and re-configurability of the network, with the added capability of automatic fault detection and isolation. Combined in systems with automated sectionalisers (Section 3.2.3), ACR's facilitate rapid, automated reconfiguration of the network in response to faults, that minimises the extent of supply outages.

ACR control boxes may be replaced/managed independent of the primary switch component, although the compatibility of the control unit and primary equipment does need to be considered. Control that is more sophisticated functions, for example, those used in conjunction with REFCL technologies to provide fault isolation, require that the switch component is fitted with matching, calibrated CTs for implementation of higher resolution sensitive earth fault (SEF) protection than traditionally applied. For this reason, the age profile of ACR control boxes and switch components are well correlated.

Within the last decade, significant numbers of three-phase ACRs have been installed or replaced as part of DFA systems. Improved bushfire mitigation protection philosophies, including the introduction of REFCL technologies, continues to drive bulk upgrade, replacement and the installation of new units, as reflected in Figure 2.

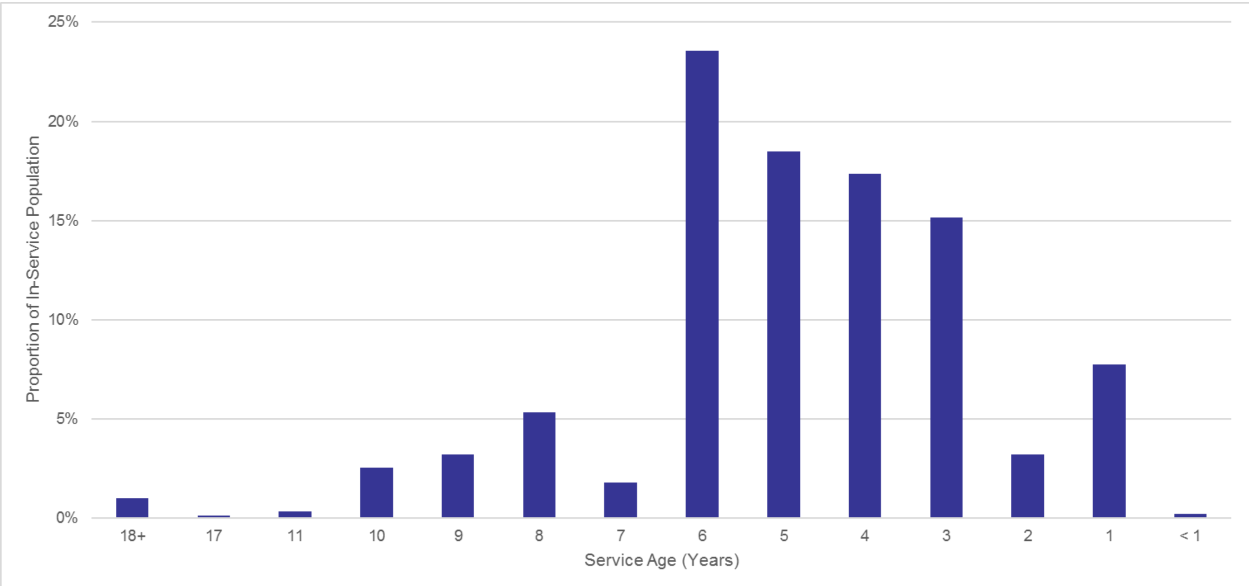


Figure 2: ACR Control Box Age Profile

3.2.2 Pole Mounted Air Break Switches (ABS)

Air-break switches (ABS) are used on the overhead distribution network to provide manual switching functionality. These types of switch use air as the insulating medium and, with an average service age of 28 years, are one of the oldest in-service switch types.

Including isolators, pole mounted air break switches currently make up 10% of the MV switch population although the total population of air-break switches will decrease significantly over the next 10 years. Only a very small proportion of air break switches are considered key switches, and gas switches will replace these devices by 2020. Air break switches are no longer installed (new), and, with the exception of key switches, are not actively maintained or operated. They are instead routinely replaced by gas switches as required to facilitate network operations.

3.2.3 Gas Insulated Switches

There are two (2) types of gas-insulated switches currently in service: manual gas switches, and remotely controlled or automated gas switches (also referred to as sectionalisers). Both manual and remotely controlled or automatic gas switches use SF6 as the insulating medium. The only difference between the two types is that remotely controlled gas switches and sectionalisers are equipped with an auxiliary control box to facilitate automatic and remotely controlled operation. The only difference between sectionalisers and remotely controlled gas switches is the complexity of the applied controller settings.

Representing the most modern type of MV switch currently used by AusNet Services, gas switches are relatively young compared to other switch types. Although the first generation of gas switches were installed in 1994, the majority of switches currently in service have been in operation for less than 12 years. Significant volume of gas-insulated switches have been installed within the last decade to facilitate distribution feeder automation. All new and replacement MV switches installed on the distribution network are gas switches.

Manual gas switches account for almost 16% of the MV switch population. The proportion of manual gas switches will continue to increase as older model air break switches are replaced by gas switches.

Sectionalisers, in conjunction with ACRs, are used to rapidly reconfigure the network in case of fault to restore supply to customers. They are designed to operate in the “dead time” between fault and subsequent reclose operations. The sectionaliser counts the number of attempted recloses upon the circuit and will “lock out” (i.e. isolate the downstream network) once the ACR has attempted a designated number of reclose operations. This allows for the safe re-energisation of the upstream network pending line works to clear the downstream fault.

Gas sectionalisers currently account for almost 10% of in-service MV switches.

All gas sectionalisers currently in service consist of two components: a standard, gas-insulated MV switch and a GSS100-type control module supplied by [C.I.C]. The control module, as an electronic component, has a significantly reduced service life expectation compared to the switch component. The control module may be replaced independent of the primary switch component, however compatibility of the control unit and primary equipment does need to be considered. The majority of GSS100 control modules are less than 10 years old, as indicated in Figure 3.

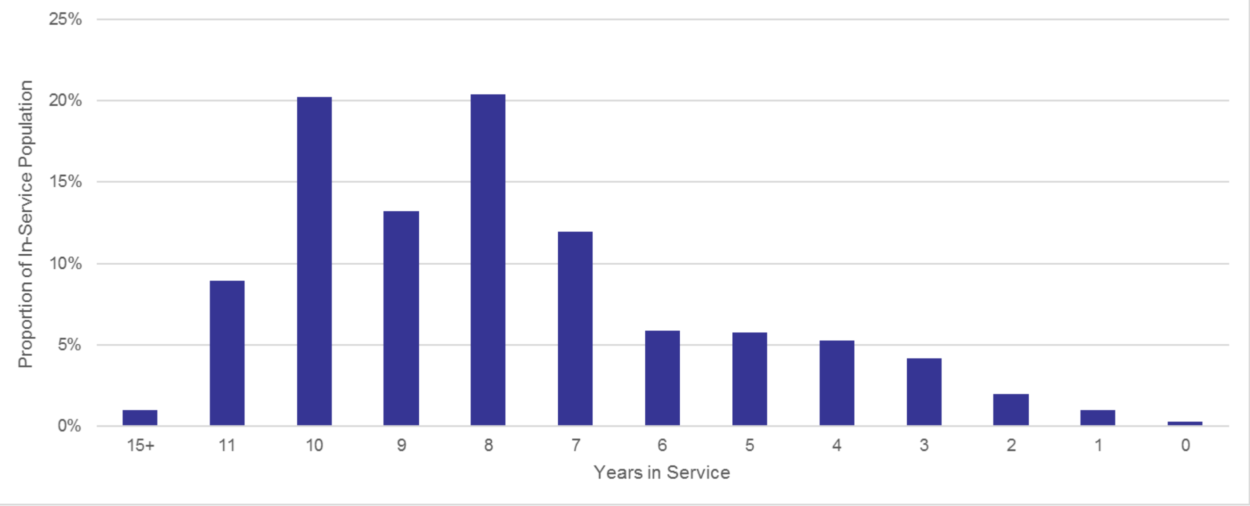


Figure 3: GSS100 Service Age Profile

Remotely controllable gas switches are mostly installed on network open points. They have local and remote open/close functionality, which represents a step up from manual gas switches, but do not use the same complex logic implemented on gas sectionalisers.

3.2.4 Ground Mounted Switches

Ground mounted and indoor switches currently represent just over 50% of MV switches in service throughout the AusNet Services distribution network. Typically located within indoor or kiosk substations, they are used both to switch the underground cable network, and as a connection point between underground and overhead network sections.

The majority of these switches are installed in "ring-main" and "interconnector" configurations with the capability of making and breaking load currents on the underground distribution network.

More than 90% of these switches are SF6 gas insulated [C.I.C] as illustrated in Figure 4. The remainder are a mix of air break, gas insulated and bulk-oil types from several different manufacturers including [C.I.C].

The majority of ground-mounted switches currently in service are less than 15 years old.

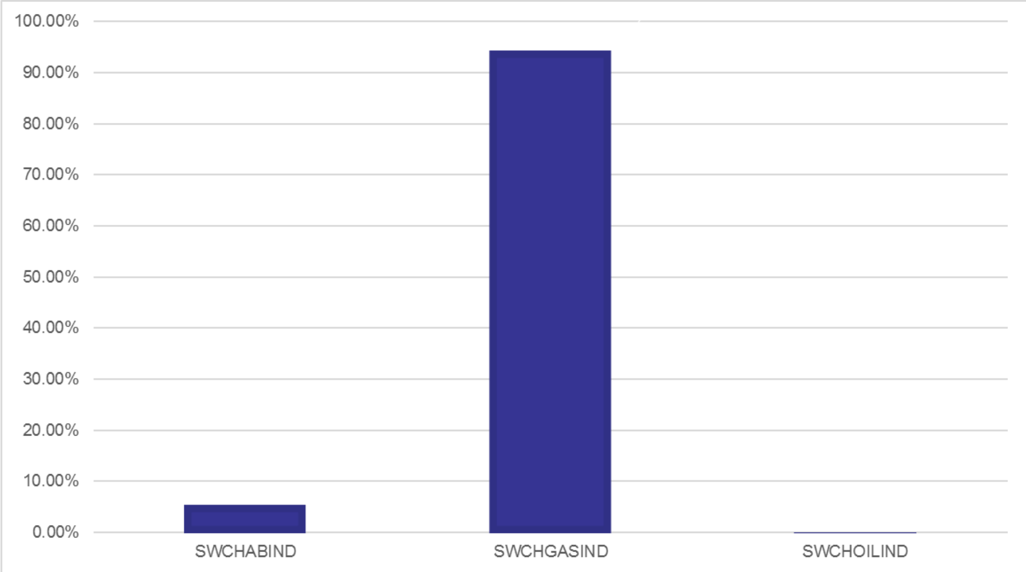


Figure 4: Types of in-service ground mounted and indoor MV switches

3.2.5 Fuse Savers

A fuse saver is a self-powered, electronically controlled, single-phase fault-interrupting device that works in partnership with a fuse to protection a lateral or spur line from both transient and permanent faults. The fuse saver is capable of detecting, opening and clearing a fault in less time than it takes a fuse to melt. Fuse Savers are used sparingly on the distribution network, representing less than 1% of the MV switch population, and have an average service age of 6 years.

3.3 Asset Condition

The condition of MV Switches and ACRs is determined via application of a formal condition assessment framework.

The condition of ACRs and automated gas sectionalisers is dictated primarily by the condition of the associated control infrastructure, which has a much shorter service life expectation than the primary switch component. The switch and control box infrastructure must be compatible for satisfactory operation, and it is not always possible to replace just the control infrastructure while maintaining the switch component in service. The assigned condition score is thus primarily dependent upon the functional capability, degree of obsolescence and overall historic reliability of the switch control system.

Pole-mounted, metal enclosed switches have been purchased on the basis that they are maintenance free with an estimated service life of between 30 and 45 years. Care has been taken in the specification of the external surfaces to ensure they have maximum corrosion resistance. However, as these switches are connected to the overhead line network they are subject to environmental influences, including lightening and animal damage. The overall asset condition deteriorates as the service life increases. The condition of manual switches is thus dictated by service age, location, duty and operability. Figure 5 provides an overview of the condition profile of MV Switches and ACRs.

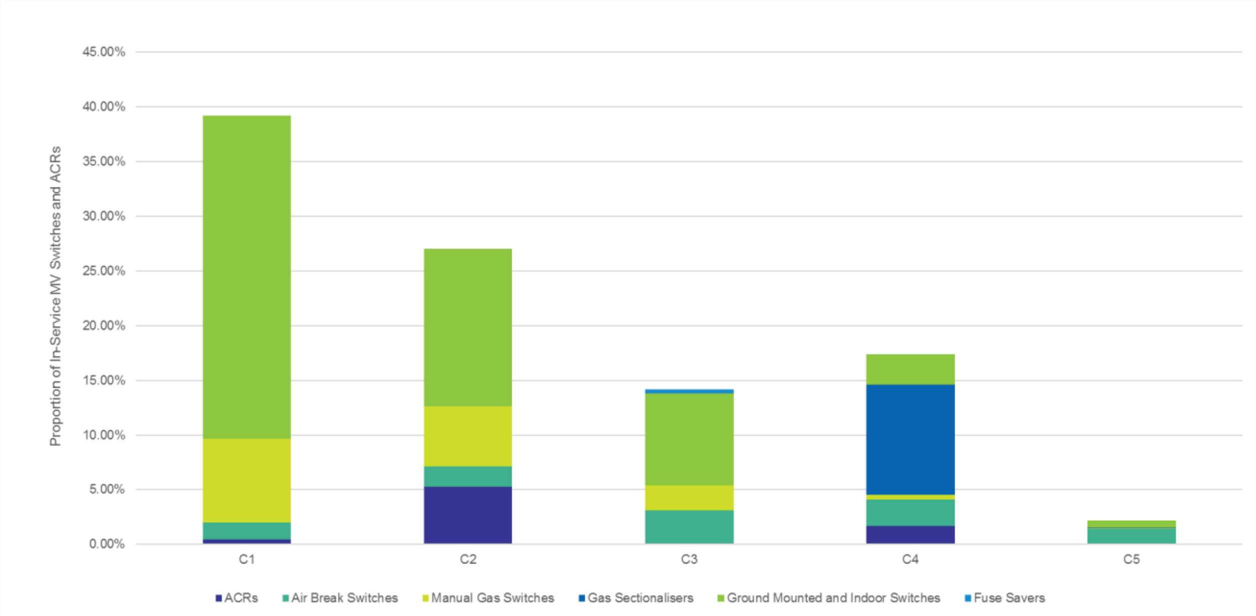


Figure 5: Condition Profile of In-Service MV Switches and ACRs

More than 65% of in service MV Switches and ACRs are considered to be in “Good” (C2) or “Very Good” (C1) condition. Less than 3% of assets are considered to be in “Very Poor” condition.

A significant proportion (17%) of assets are considered to be in condition C4. In particular, it is noted that all gas sectionalisers are considered to be in condition C4. This is attributed to significant reliability issues associated with GSS100 controllers, for which there has not been a suitable alternative available until very recently. A number of potential alternatives have recently been identified and are currently being assessed for use in place of the GSS100.

The majority (more than 96%) of manual gas switches are considered to be in acceptable condition, between C1 (“Very Good”) and C3 (“Average”). Similarly, more than 94% of ground mounted and indoor switches are considered to be in condition C3 (“Average”) or better.

3.4 Asset Criticality

As discussed in Section 3.1, the high level relative criticality of any MV Switch or ACR is described by the assigned functional category – those switches identified as key switches are the most critical, followed by auxiliary switches, whilst the relative criticality of redundant switches is minimal.

All ACRs and gas sectionalisers are classified as key switches owing to their central role in the DFA system. The criticality of individual ACRs and gas sectionalisers may be compared via consideration of the potential impact (in terms of customer outages and fault clearance times) of device failure in case of a network fault event.

Figure 6 and Figure 7 provide an overview of the relative criticality of in-service ACRs and gas sectionalisers, where criticality is defined as indicated in Table 1.

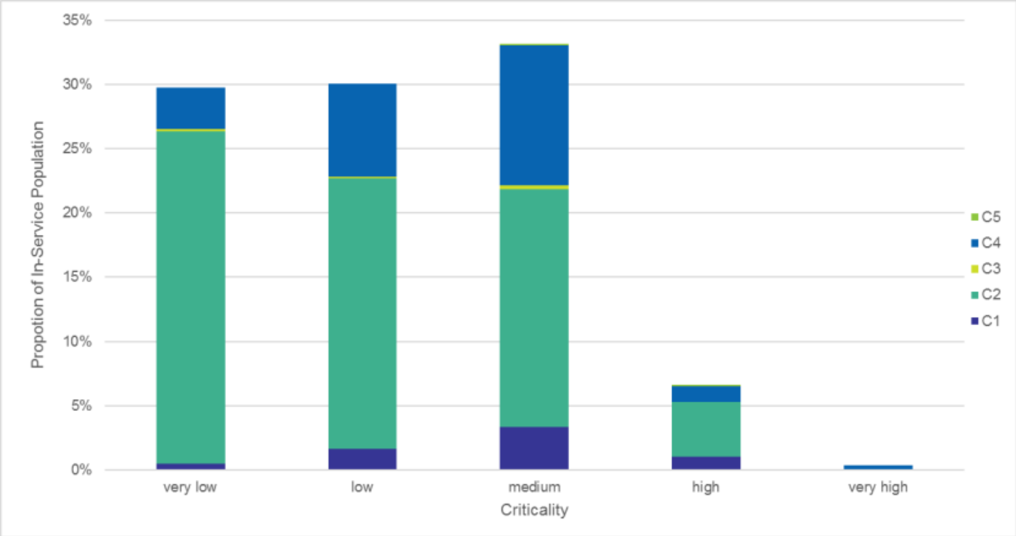


Figure 6: Criticality of In-Service ACRs

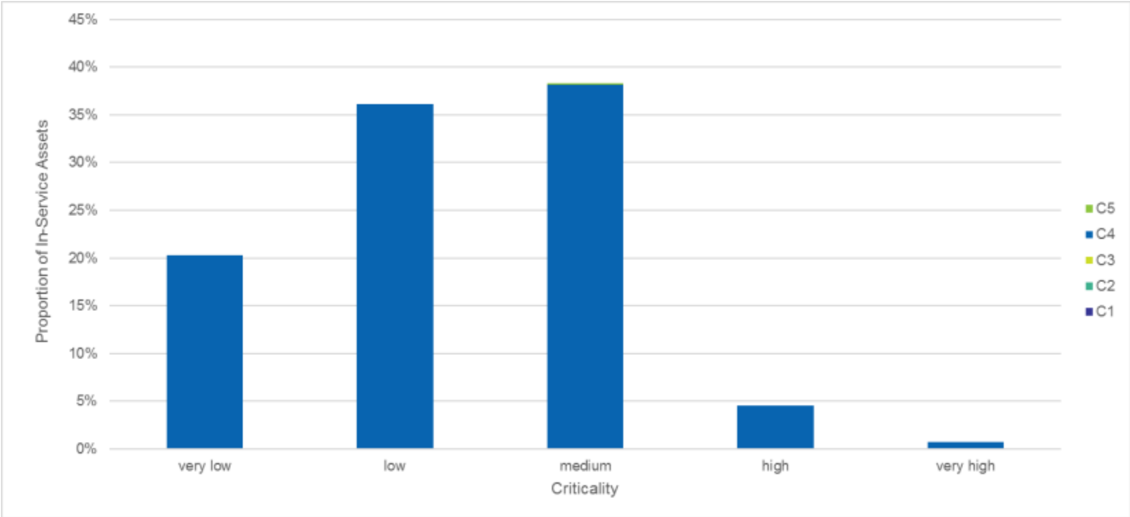


Figure 7: Criticality of gas sectionalisers

Table 1: Interpretation of asset failure criticality - ACRs and gas sectionalisers

Criticality	Criticality Bands	Definition
Very Low	1	Total failure effect cost < 1 times Replacement Cost
Low	2	Total Effect Cost is between 1-3 times of replacement cost
Medium	3	Total Effect Cost is between 3-10 times of replacement cost
High	4	Total Effect Cost is between 10 -30 times of replacement cost
Very High	5	Total Effect Cost exceeds 30 times of replacement cost

3.5 Asset Performance

3.5.1 Failure Modes

The following failure modes are essentially random in nature and are common to most forms of pole-mounted switchgear:

- Lightning damage – direct lightning strike or transient over-voltage in excess of the specified Lightning Withstand Impulse level of (normally open) switch insulation
- Birds and animals – initiation of arcing faults between or across MV bushings or connections resulting in thermal insulation damage
- Vandalism – unauthorised operation or wilful damage by thrown projectiles or rifle fire
- Mechanical damage due to the impact of falling vegetation or motor vehicles
- Low insulating gas due to leakage

Rust or corrosion of switch components is a common age-related determinate of the end of economic life for pole mounted switchgear. The rate of corrosion is dependent upon the location of the asset, and a particular problem in coastal environments due to airborne salt spray, but also in areas subject to increased atmospheric pollution, including the Latrobe valley, where coal dust is a contributing factor, and in agricultural areas with high concentrations of fertilizer dust.

The failure of an ACR to operate in response to protection commands or remote or local control commands may usually be attributed to contact wear, trip or close coil failure, controller software failure, electronic component failure or low voltage supply/battery failures in the controller.

Failures of air break switches are commonly attributed to cracked or mis-aligned arc chutes and flicker blades, bent pick-up and reset brackets or drive shaft, burnt main contacts, inadequate contact penetration and cracked or broken insulators.

An emerging issue with the newest model ACRs is propensity for birds to chew polymeric bushings, necessitating bushing replacement. Bushing covers may be retrofitted to prevent or reduce animal damage.

SF6 insulating gases can be lost to the atmosphere following damage to gas switch enclosures or through leaking gas seals around gas switch operating shafts. A major contributor to increasing unwanted leakage is attributed to corrosion of sealing flanges that jack apart due to corrosion by-product build up, or gradual hardening of rubber seals. SF6 leakage is a major driver for corrective gas switch assembly replacements, which currently maintains the SF6 leakage rate from MV switches at less than 1% per annum.

The potential for asset failure leading to fire start is analysed with reference to the number of fire starts that have occurred across all assets. In 2011, “F-Factor” was introduced as a scheme to incentivise distribution businesses to proactively reduce the incidence of asset and ground fires occurring on the network. The significant change in fire ignitions recorded since 2010 may be attributed to replacement of a large volume of oil-filled circuit breakers, and to a lesser extent to the volumes of ACRs and ABS replaced under DFA programs and proactive bushfire mitigation programs. Since the introduction of the F-Factor scheme, an average of less than a single ignition per annum attributed to an MV switch or ACR failure has been recorded.

3.5.2 Failure Rates

Figure 8 and Figure 9 provide an overview of the types of corrective maintenance activities performed on MV Switch components (Figure 8) and ACR and sectionaliser control boxes (Figure 8: Corrective Activities Performed between 2015 and 2018 on MV Switch Components

) between 2015 and 2018. In both cases, the dominant corrective maintenance activity was replacement (counts include both minor component and entire assembly replacements). A significant number of ACR and sectionaliser control boxes were adjusted in this time – this reflects bulk setting and configuration changes incurred by network evolution and firmware upgrade activities.

MV Switches and ACRs

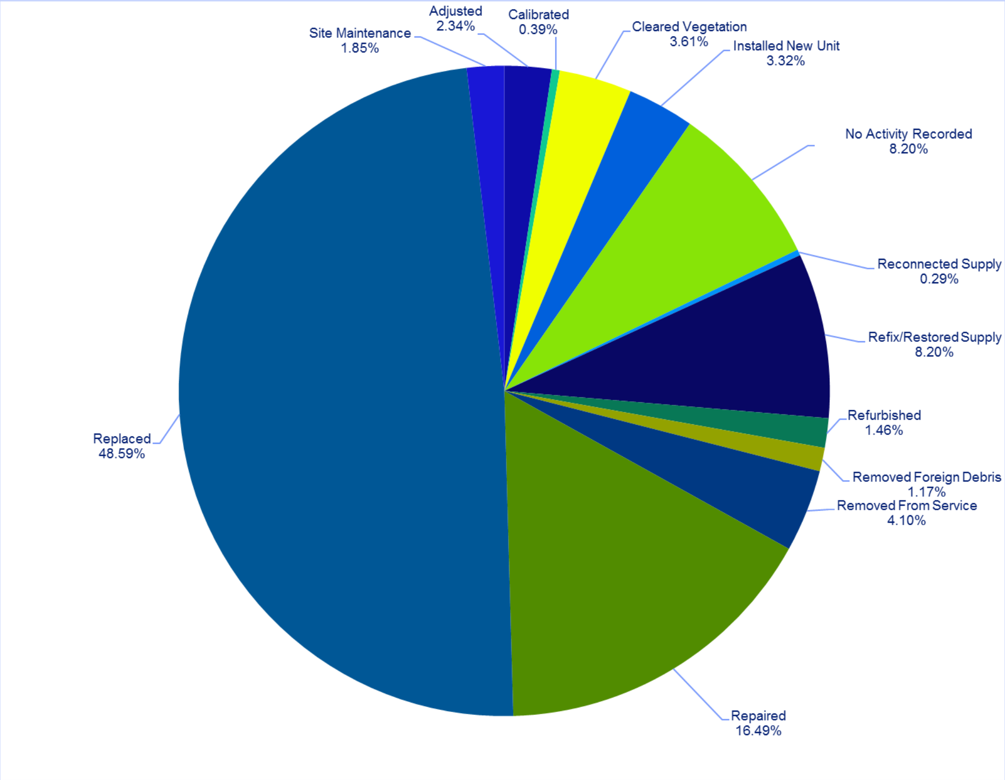


Figure 8: Corrective Activities Performed between 2015 and 2018 on MV Switch Components

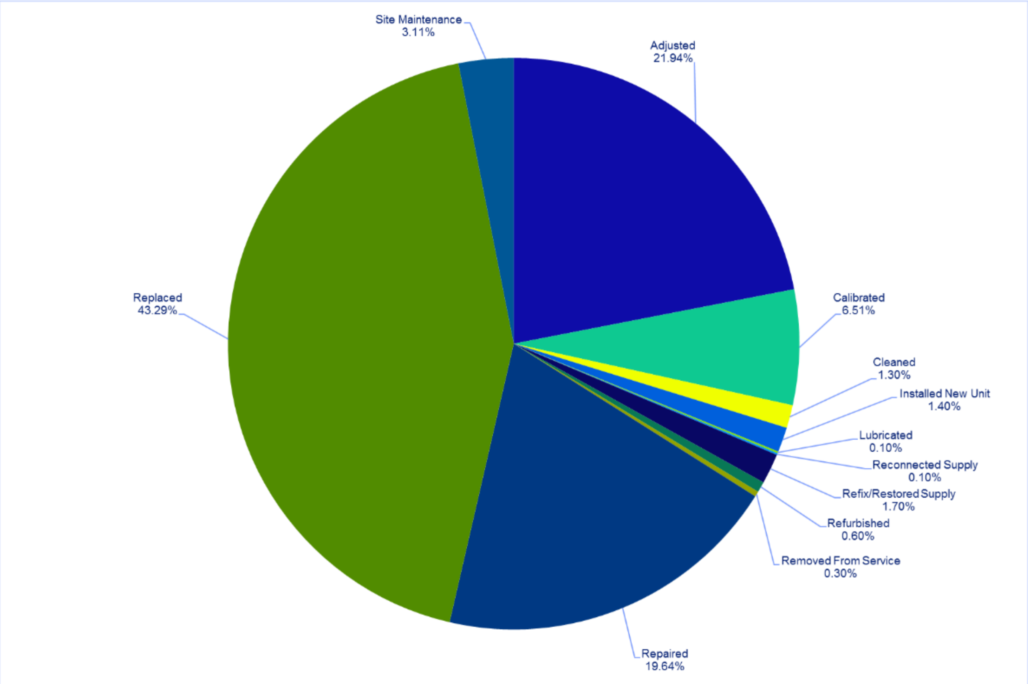


Figure 9: Corrective Maintenance Activities Performed on ACR and sectionaliser Control Boxes between 2015 - 2018

provides a summary of asset failures necessitating corrective replacement (excluding minor component replacements) over the last 3 years, and includes a forecast of replacement volumes based on the observed historic trends. It is clear that corrective replacement of control boxes is a dominant contributor to total replacement volumes. This may be attributed to unreliability of GSS100 control boxes. Very few corrective replacements of ground mounted or indoor switches have been observed. This may be attributed to the relatively young service age of this population of switches, and their location within relatively protected environments.

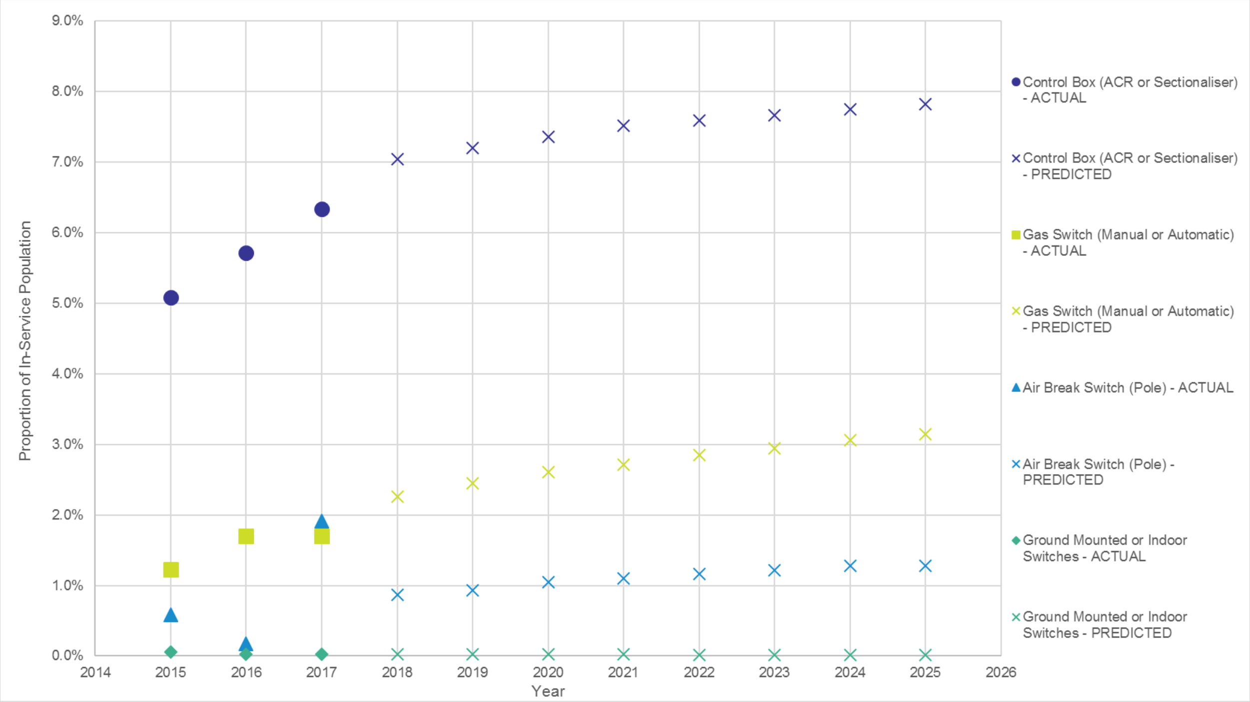


Figure 10: Actual and Predicted Annual Corrective Replacement Volumes by asset type

4 Other Issues

4.1 Regulatory Requirements and Legislation

As an Electricity Distribution Network Service Provider (DNSP) in Victoria, AusNet Services must meet the following obligations:

4.1.1 Electricity Safety Act (Section 98(a))

The Electricity Safety Act (section 98(a)) requires AusNet Services to "*design, construct, operate, maintain and decommission its supply network to minimise, so far as practicable, the hazards and risks to the safety of any person arising from the supply network; having regard to the:*

a) Severity of the hazard or risk in question; and
b) State of knowledge about the hazard or risk and any ways of removing or mitigating the hazard or risk; and
c) Availability and suitability of ways to remove or mitigate the hazard or risk; and
d) *Cost of removing or mitigating the hazard or risk*"

4.1.2 Electricity Distribution Code (Section 3.3.1(b))

As per Section 3.3.1 (b) of the Electricity Distribution Code, AusNet Services are required to:

"*Develop and implement plans for the acquisition, creation, maintenance, operation, refurbishment, repair and disposal of its distribution system assets and plans for the establishment and augmentation of transmission connections:*

- *To comply with the laws and other performance obligations which apply to the provision of distribution services including those contained in this Code;*
- *To minimise the risks associated with the failure or reduced performance of assets; and*
- *In a way which minimises costs to customers taking into account distribution losses*"

4.1.3 National Electricity Rule (Clause 6.5.7)

Clause 6.5.7 of the National Electricity Rules requires AusNet Services to propose capital expenditures necessary to:

- "*meet or manage the expected demand for standard control services over that period;*
- *Comply with all applicable regulatory obligations or requirements associated with the provision of standard control services;*
- *Maintain the quality, reliability and security of supply of standard control services; and*
- *Maintain the reliability, safety and security of the distribution system through the supply of standard control services*"

4.2 Enhanced Performance Requirements

4.2.1 Recommendations from 2009 Victorian Bushfires Royal Commission

On 16 February 2010, Counsel Assisting the 2009 Victorian Bushfires Royal Commission, lodged a submission[1] in which it proposed that:

"…the evidence supports the conclusion that significant changes should be made to Victoria's electricity distribution infrastructure, and to the way in which that infrastructure is operated and managed, in order to reduce the risk of bushfires on catastrophic fire days"

With respect to the operation of Automatic Circuit Breakers in particular, Counsel Assisting proposed that:

"…the reclose function on the Automatic Circuit Reclosers (ACRs) on all SWER lines should be disabled for the duration of every fire season"

"…the reclose function on the ACRs on all 22 kV feeders should be adjusted on all total fire ban days so as to permit only one reclose attempt prior to lockout (whether or not a neutral earth resistor has been installed at the zone substation from which the feeder originates)"

These requirements necessitated the bulk upgrade and replacement of ACRs across AusNet Services Distribution network over the last decade and will continue, in the context of the Electricity Safety (Bushfire Mitigation) Amendment Regulations 2016 (refer Section 4.2.2) and AMS 20-13 (AusNet Services Distribution Network Enhanced Safety Strategy) to influence asset management decisions.

4.2.2 Electricity Safety (Bushfire Mitigation) Amendment Regulations 2016

Subsequent to the 2009 Victorian Bushfire Royal Commission, the Victorian Government established the Powerline Bushfire Safety Program to research the optimal way to deploy Rapid Earth Fault Current Limiters (REFCLs) for bushfire prevention. This research led the Government to introduce the Electricity Safety (Bushfire Mitigation) Amendment Regulations 2016.

The need to upgrade or replace incompatible equipment, including ACRs, was addressed in the REFCL trial report:

"Some network equipment currently used in Victoria is not compatible with REFCL operation and must be upgraded or replaced with equipment that is compatible…Incompatible equipment can prevent correct REFCL operation and may produce dangerous network conditions with a REFCL in service"[2]

The Electricity Safety (Bushfire Mitigation) Amendment Regulations (2016) specify the installation and operation of the voltage reduction required on a polyphase line when a phase-to-ground fault occurs, and the fault current levels that must be achieved. These specifications can only be met where existing ACRs are upgraded or replaced.

AusNet Services has developed a dedicated strategy for undertaking REFCL-driven ACR replacements (REF 20-18: "Compatible Equipment – Automatic Circuit Recloser Strategy"), and modifying existing DFA systems (REF 20-13: "Distribution Feeder Automation Strategy"). The bulk of ACR and gas sectionaliser replacement and upgrade activities anticipated over the next decade will be undertaken as part of the REFCL program consistent with those strategies.

All new and replacement ACR units installed throughout the distribution network, regardless of whether or not the target feeder is supplied from a zone substation where REFCL has been installed, will comply with specifications and standards necessary for REFCL operation. This will ensure efficient spares management and streamline design (in particular, control configuration design) standardisation.

[1] SUBM.501.001.0002 2009 Victorian Bushfires Royal Commission Letters Patent issued 16 February 2009 SYSTEMIC ISSUES ELECTRICITY SUBMISSIONS OF COUNSEL ASSISTING
[2] Dr Anthony Marxsen, REFCL Trial: Ignition Tests, Marxsen Consulting Pty Ltd, Monday 4 August 2014, page 94

5 Risk and Options Analysis

5.1 Risks

5.1.1 Reliability of Customer Supply

Distribution Feeder Automation (DFA) systems play a key role in maintaining customer supply reliability when network faults occur. Failure or incorrect operation of component ACRs and gas sectionalisers can disrupt operation of these systems, resulting in additional and extended customer outages than otherwise necessary to isolate the faulted network section.

With the introduction of REFCL technologies in 22 zone substations across the distribution network, ACRs and sectionalisers will continue to play an important role in the location and isolation of faulted network sections. Failure of these devices will result in larger and extended repair outages in case of network fault.

Manual switches are necessary to facilitate network operations, including isolation of network sections to facilitate repair works or vicinity activities. A sufficient number of operable manual switches minimises the effect of necessary network isolations on customer supply reliability, whilst supporting network flexibility. Failure or inoperability of a manual switch may result in a requirement to take larger outages than otherwise necessary to facilitate network or vicinity works.

5.1.2 Occupational Health and Safety

Suitable trained personnel must locally operate manual switches. Failure of a switch during operation can pose a physical risk to the operator due to falling debris or arc by-products. This is a particular risk with air-break switches and the primary reason why air-break switches requiring frequent or occasional operation are routinely replaced by gas switches.

Automatic Circuit Recloser (ACR) protection settings include specialised setting groups for use when live line activities are being undertaken on the connected feeder. These settings are intended to minimise risk to personnel undertaking live line works by preventing reclose in case of network faults. Failure of these settings to be applied, or failure of these settings to operate correctly, can increase risk to line workers.

5.1.3 Protection Reliability

ACRs provide network protection functions in case of (downstream) network faults. Failure of an ACR to operate correctly in response to a target fault condition necessitates that an upstream protection device operates to isolate the fault in its place. This not only increases the outage zone, but also extends the fault clearance time. Similarly, spurious or incorrect operation of an ACR (operation in the absence of a network fault) results in unnecessary customer outages.

5.1.4 Environmental

Failure of a switch upon operation, particularly air break switches, can present a fire ignition risk due to arcing and the expulsion of debris. Mechanical failure of gas switch isolation tanks can result in atmospheric release of varying quantities of SF6 gas, while failure of oil-insulated switch tanks can result in oil leakage.

Correct operation of ACR protection settings minimises any fire ignition risk associated with network fault events, compliant with recommendations resulting from the 2009 Victorian Bushfire Royal Commission (refer Section 4.2.1).

5.2 Options Analysis

5.2.1 Maintenance

MV Switches and ACRs are maintained in accordance with SOP 70-03 “Standard Maintenance Guidelines – Distribution and Sub-Transmission Lines and Associated Assets”. Key switches, including all ACRs and gas sectionalisers, are maintained on a time-based cycle, or if a defect is reported during operation. Auxiliary switches are not maintained on a cyclic basis. Rather, they are maintained prior to switching if required for planned operational purposes. Redundant switches are not actively maintained. If they are located on a feeder backbone on an interconnected system, the switches are removed and bridged.

Maintenance of low resistance to ground is a necessary expense for key switch earths to ensure rapid and reliable operation of the high voltage protection systems and thus reduce risks associated with step and touch potentials, flying objects and fire ignition.

Operators make a visual assessment of each MV switch prior to manual operation to ensure that the switchgear has not been damaged since its last inspection or operation and in particular that any exposed switching components have not been damaged or fouled by debris. These assessments are essential for pole-mounted air break switches in particular as the operating position can be exposed to the by-products of high voltage arcs if the switch should fail during operation. As the detailed components of the arc control mechanisms are located, at least 8 metres from the operating position, visual assessment of air break switches can be difficult in low light conditions.

Operators also make a visual assessment of each switch after operation to ensure that maintenance items are identified and remedied before subsequent switch operation is required. In particular, a visual inspection of the main contact penetration and correct latching of exposed interrupters in pole mounted air break switches is important.

As proactive maintenance of pole-mounted switches is a labour intensive activity, ad hoc and corrective maintenance of non-key switches, as required to facilitate safe and efficient network operations, is considered the most economic management approach.

ACR and sectionaliser control boxes are maintained in accordance with PGI 02-01-04.

5.2.2 Replacement

A poorer condition asset is associated with both an increase in the likelihood of failure, and a decreased capability for repair in case of failure.

The replacement strategies applied to the different types of MV switches and ACRs varies according to the criticality of the switch. As discussed in Section 3.4, the criticality of a switch is dependent upon:

- The impact of switch failure on network operability (i.e. whether the switch is considered to be a key, auxiliary or redundant switch)
- In the case of ACRs and sectionalisers, the potential impact of DFA system failure on customer supply reliability

The safety risk presented by the switch to a local operator is also considered when assessing a switch for replacement.

Manual MV switches are replaced only on failure, and only if considered necessary for operational purposes. Corrective replacement (i.e. replacement on failure) is considered the most economically appropriate management strategy for manual MV switches. As per SOP 70-03 (refer Section 5.2.1), non-key air break switches are routinely replaced by gas switches, but only if they are required to be operated.

Replacement of ACRs and automated sectionalisers occurs both reactively (in response to a fault), or (increasingly) as a way of managing obsolescence and/or capability limitations of the associated control software. All ACRs and automated sectionalisers are replaced in case of failure, as they are all considered necessary for operation of the electricity network.

The introduction of REFCL technologies throughout the distribution network will continue to drive bulk upgrade and/or replacement of ACRs and automated sectionalisers over the next 5 to 10 years. In addition, allowance is made for replacement of the highest criticality, poorest condition ACRs and sectionalisers installed on non-REFCL feeders.

Key switches are prioritised for replacement via application of a semi-quantitative risk-based decision matrix. This approach is intended to identify the poorest condition, highest criticality assets. In populating the decision matrix, the economic value of potential energy at risk in case of failure is estimated assuming a nominal 4-hour service restoration time and the primary risk associated with the pole/substation at which that asset is located. The primary risk component considers the fire-start and safety implications of asset failure. The total risk is compared to the unit replacement cost (URC) to generate a decision matrix. Applying this approach to the current population of ACRs and sectionalisers generates the decision matrix shown in Figure 11.

		Condition – ACR				
		1	**2**	**3**	**4**	**5**
Criticality Band	5	11.7%	2.4%	0.7%	0.8%	0.0%
	4	23.81%	5.46%	2.21%	1.05%	0.58%
	3	24.04%	2.32%	0.35%	0.81%	0.23%
	2	11.38%	0.93%	0.35%	0.12%	0.00%
	1	9.41%	0.58%	0.23%	0.35%	0.12%

		Condition – Gas Sectionalisers				
		1	**2**	**3**	**4**	**5**
Criticality Band	5	0.00%	0.00%	0.00%	0.72%	0.00%
	4	0.00%	0.00%	0.00%	4.52%	0.00%
	3	0.00%	0.00%	0.09%	38.03%	0.18%
	2	0.00%	0.00%	0.00%	36.13%	0.00%
	1	0.00%	0.00%	0.09%	20.23%	0.00%

Plan for proactive replacement within 5 years
Plan for proactive replacement within 10 years
Plan for proactive replacement within 15 years
Maintain in service

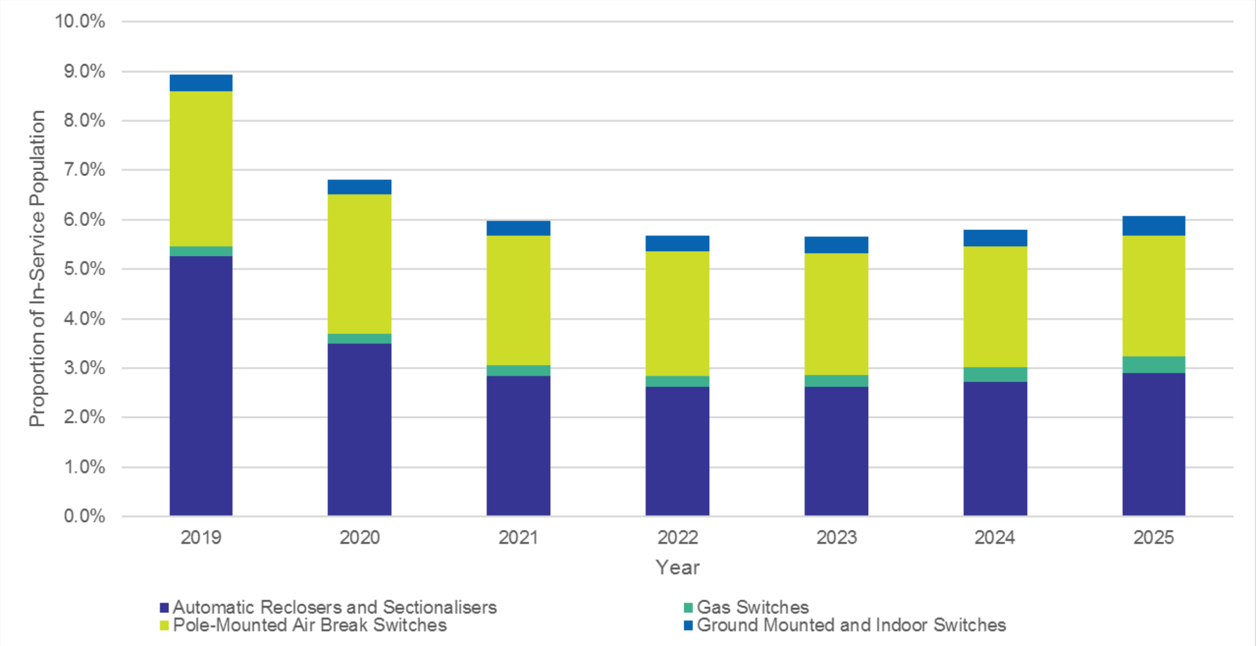
Figure 11: Decision matrix used to identify and prioritise the highest criticality, poorest condition assets for replacement

Once assets have been identified and prioritised for replacement, a detailed cost-benefit analysis is performed to ensure that the proposed activity is the most economically appropriate option, taking into consideration obligations detailed in Section 4.

5.3 Comparison with REPEX model outputs

The AER's REPEX model was used to provide a top-down estimate of expected asset replacement volumes, using asset age profiles extracted from SAP. A mean asset life of 20 years was assumed for control boxes, and 45 years for switch assemblies. Recommended replacement volumes are indicated in Figure 12.

Figure 12: Output of REPEX model - MV Switches and ACRs



Actual replacement volumes of ACRs and sectionalisers is expected to exceed REPEX model outcomes in order to meet obligations discussed in Section 4.2. Even excluding REFCL-driven replacements, the actual forecast replacement volumes across all categories (Figure 13) is expected to exceed REPEX model predictions, particularly for gas switches. This may be attributed to corrective replacement activities of gas sectionalisers driven by reliability issues currently experienced with GSS100 control boxes, and gas switch replacements necessary to address SF6 leakage risks. Fewer replacements of air break and ground mounted switches are expected as only those assets requiring operation are replaced (Section 5.2.2).

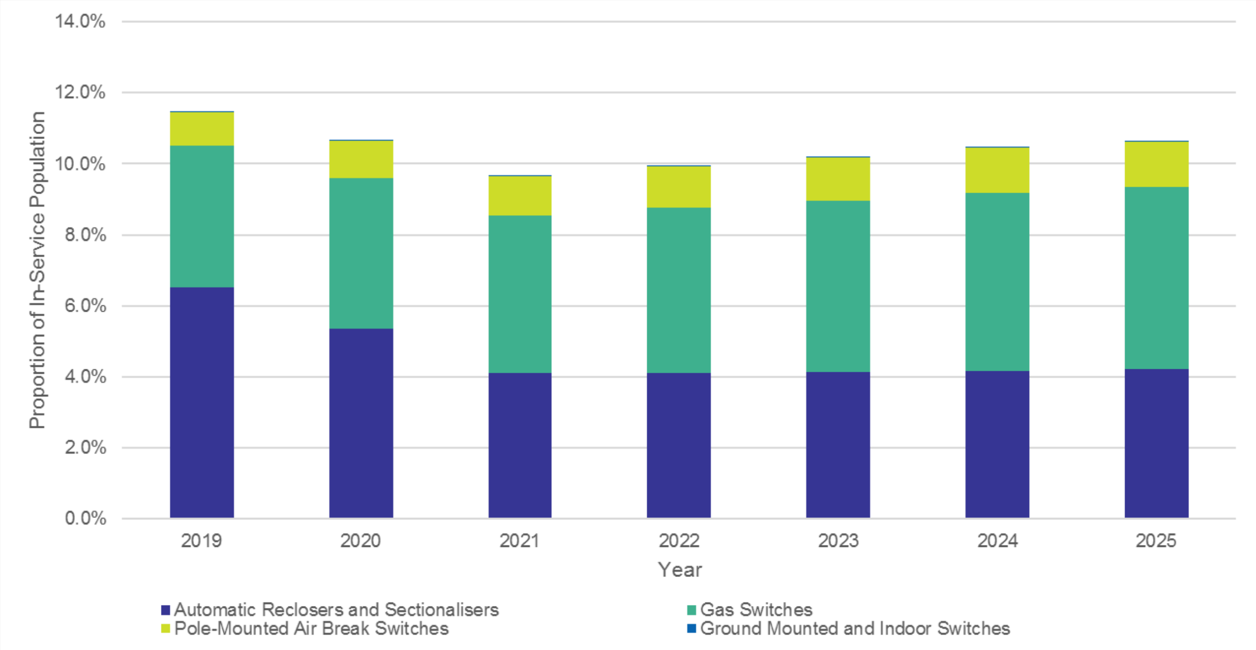


Figure 13: Actual Forecast Replacement Volumes - MV Switches and ACRs (excluding REFCL-driven replacement of ACRs and gas sectionalisers). The primary driver of replacement volumes is corrective replacement (replacement in case of failure)

6 Asset Strategies

6.1 New Installations

- Continue to design and install new and replacement assets in accordance with the distribution design manual (30-4142)
- ACR and sectionaliser control box configurations shall comply with current control configuration standards.

6.2 Maintenance

- Continue to maintain MV Switches and ACRs in accordance with SOP 70-03
- Maintain SOP 70-03 consistent with Enhanced Data-Driven Asset Management (EDDAM) studies

6.3 Obsolescence and Spares Management

- Continue to maintain adequate spares to ensure ongoing availability of key switches, as per the distribution critical spares strategy SOP 28-02

6.4 Replacement

- In accordance with the outcomes of asset inspections and individual feeder reliability reviews, selectively retire or replace air break switches with gas switches
- Prioritise proactive replacement of high criticality, poor condition key switches
- Replace approximately 40 ACRs and gas sectionalisers each year on condition, prioritising the highest criticality assets
- Replace all oil insulated ACRs by 2025
- In accordance with SOP 70-03, replace failed or poor condition non-key switches only if required to facilitate network operations

6.5 Systems and Processes

- Update key switch policy and introduce processes for regular review and update
- Consolidate system data with key switch policy
- Record asset condition in Asset Management System

6.6 Research and Development

- Extend scope of Enhanced Data Driven Asset Management (EDDAM) studies to incorporate MV switches and ACRs
- Research and develop automated processes for identification and management of key switches