5.13.G

Project justifications for switchgear replacement programs

Ausgrid

Content

1 INTRODUCTION

1.1 Switchgear on our network

Switchgear is an integral part of Ausgrid's distribution and transmission network. When used in conjunction with protection systems, switchgear allows for the automatic protection of the power system and provides fast and efficient fault clearing. Switchgear also provides switching capability for power flow management and isolation points for maintenance, repair or network augmentation or during supply restoration.

Switchgear helps to maintain the reliability and security of the network. Examples of the types of switchgear on Ausgrid's network include:

- Circuit breakers
- Fuses
- Isolating switches.

As at June 2017, Ausgrid had approximately 159,000 units of switchgear on the network. There are many manufacturers and models of switchgear as this equipment type is generally long lived. For example, Ausgrid currently has approximately 50 different types of air break switches on the network. The volume and variety of legacy assets present a significant challenge to mitigating the risks of these assets.

Most assets that are the subject of replacement programs are either obsolete, have condition issues which can lead to a safety risk in the event of a failure and, in many cases, exceed their standard technical life. Degradation related failures can sometimes be corrected by repairing the asset where spare components, or the modern equivalent of the components, are available. Due to the age of the majority of the equipment, spare parts are often unavailable. Components sometimes may be re-used from similar switches that have been removed from service but, due to their age, it is commonly found that suitable components cannot be salvaged. Also, the repair of older switchgear does not mitigate the inherent risks associated with their design.

1.2 Changes in technology

The switchgear that Ausgrid is currently installing is technically advanced compared to the assets they are replacing. The technical advances for the different switchgear types include:

- The use of sulphur hexafluoride (SF6) gas, vacuum bottles or air for arc control when the switchgear operates
- The use of SF6, air or polymeric materials for electrical insulation
- 'Arc rated' cladding, 'load break heads' and enclosed switches to protect workers and the public against uncontrolled arcing during switching
- Capability for remote operation.

1.3 Working out what we need to replace

Ausgrid has developed planned replacement programs to address the degraded condition and obsolescence of many of these assets. A planned replacement approach is preferable to a reactive or conditional replacement approach due to:

- Their condition issues being well known and understood
- The time required to procure and install equipment operating at 33kV or higher voltages

- The high customer impact associated with failure of LV or 11kV switchgear caused by a lower level of redundancy in the network at those voltage levels
- The ability of new technologies to mitigate the inherent risks associated with older designs.

Replacement works under planned programs are prioritised so assets which pose the highest risk are replaced first.

1.4 Summary of programs

In total Ausgrid expects to spend $126.8 million ($, real FY19) on replacing switchgear during the 2019-24 regulatory period.

The following programs are discussed in further detail below:

- 11kV overhead switches ($12.3 million)
- 415V switchgear ($24.4 million)
- 11kV ground switches ($58.9 million)
- 11kV circuit breakers ($19.1 million)
- Subtransmission circuit breakers ($5.6 million)
- Subtransmission isolating switches ($6.5 million).

2 11KV OVERHEAD SWITCHES

2.1 Program description

The planned replacement programs address issues associated with degradation of overhead 11kV switches and fuses. Overhead 11kV switches are located on poles and exposure to the elements over their operating life plays a key role in their degradation. Degradation of overhead 11kV switches causes safety risks to the public, customers and workers, and loss of supply risks, if the:

- Switch or fuse components fail and fall to the ground
- Switch or fuse components jam and cannot be operated in an emergency condition
- Switch or fuse components fail and uncontrolled discharge of electricity occurs.

The planned programs are for replacement of high priority overhead 11kV switch types. The four programs are:

- 11kV Essantee HS641 air break switches (REP_04.02.32)
- 11kV Taplin D571 air break switches (REP_04.02.36)
- 11kV Haycolec air break switches (REP_04.02.43)
- ABB 11kV series V Expulsion Drop Out (EDO) fuse carriers (REP_01.02.57).

Ausgrid is planning to replace 3,872 overhead 11kV switches and fuses at a total cost of $12.3 million in direct costs ($, real FY19) across the four programs during the 2019-24 regulatory period. The existing assets are replaced with modern equivalent units that have been designed to overcome the failure modes with past switchgear types including those associated with these high priority types.

The age profile highlighting the identified programs for replacement against the total population of 11kV overhead switches on the network is shown in Figure 1 below.

The Haycolec air break switches, Taplin air break switches and the ABB 11kV Series V EDO fuse carriers identified for replacement in 2019-24 are being replaced prior to reaching their standard technical life due to known condition issues.

2.2 Background

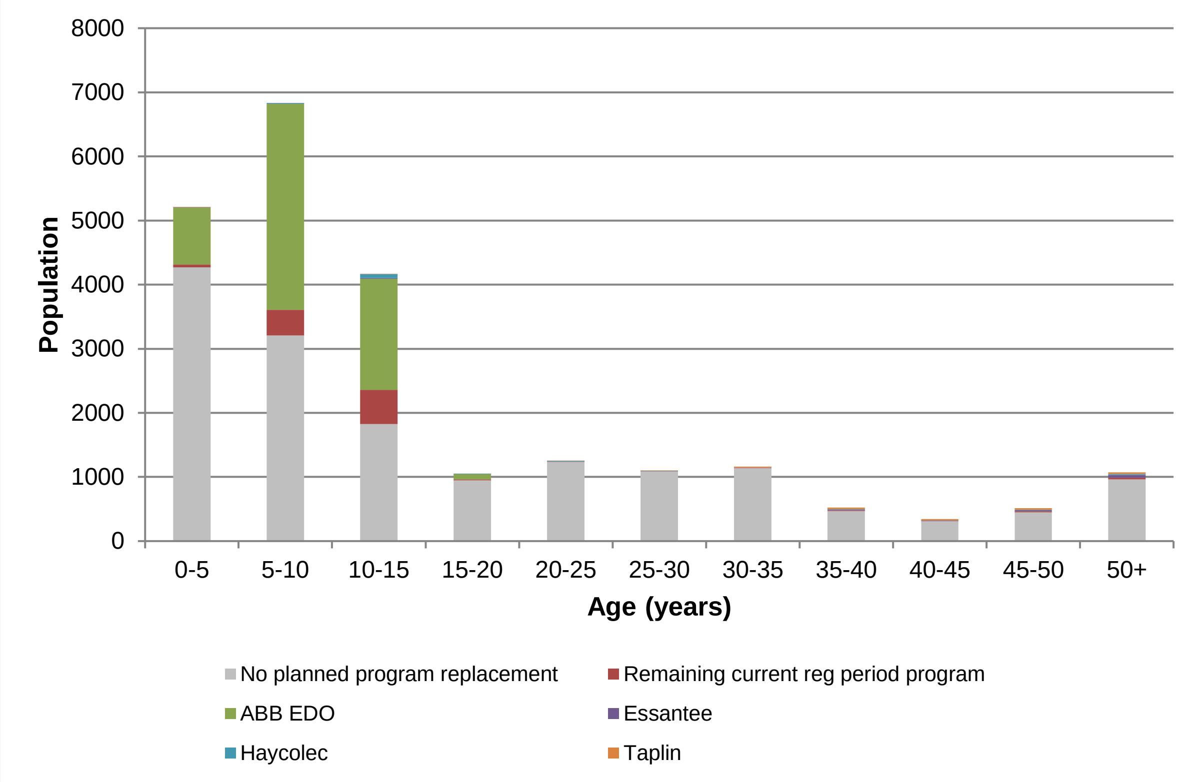
Ausgrid began the installation of air break switches in the 1960s. There are approximately 7,500 installed on the network. The three identified types of air break switches have a high number of failures relative to other types on the network and have caused safety risks to Ausgrid workers and the public due to their known failure modes.

The primary function of an air break switch is to safely control Ausgrid's overhead network. They are required to be safe;

- When they are manually opened or closed during network switching
- At all other times when they are not being opened or closed.

The age profile of the 11kV air break switch and fuse carriers population is shown in Figure 1 below. The majority (72%) of 11kV air break switches and fuse carriers on the network are less than 15 years old due to concerted efforts over previous periods to address known failure modes which have caused safety risks to the public, customers and workers, as well as restricting network operability under normal and emergency operating circumstances. The assets identified for replacement in the current and 2019-24 periods are shown in the chart.

Figure 1. Age profile of 11kV overhead switches (as at 30 June 2017)



The age profile shows a high proportion of air break switches and fuse carriers are less than 15 years of age. There are a number of reasons for this:

- Condition issues associated with Haycolec air break switches were identified in approximately 2003 (11 years after Ausgrid began installing them) and their targeted replacement was initiated
- Field audits were undertaken in some Ausgrid regions between approximately 2004 and 2007 because asset data had not been accurately recorded due to historical processes
- Ausgrid mandated in 2007 that conditionally or functionally failed HV underslung links (another type of overhead switch) were to be replaced with air break switches following safety incidents related to underslung links during network switching
- Condition issues associated with Essantee HS641 air break switches were identified in approximately 2007 and their targeted replacement was initiated
- Reactive replacement of other older air break switches which had failed and were beyond repair.

The primary function of an air break switch is to safely control Ausgrid's overhead network.

EDO fuse carriers are primarily associated with pole top substations. They provide a means for manual isolation and fused protection of the substation.

2.3 Risks – Consequence and likelihood

The key consequences that can result from a loss of function of an air break switch are shown in Table 1 below.

Table 1. Consequences from loss of function for 11kV overhead switches

Consequences	Description
Harm to the public, communities and workers	Cracked insulators may cause injury (electric shock) or a fatality (electrocution). Electric shock 'near misses' have occurred for Ausgrid workers and pole inspection contractors.
	Failed porcelain insulators may fall and cause physical injury. Physical injury 'near misses' have occurred for Ausgrid workers from both insulators and switching arms.
	Fires caused by degraded electrical contacts or conductor connections may spread from the pole and cause injury (burns) or a fatality.
	Safety issues as a result of loss of supply are detailed below.
Damage to property	Failed porcelain insulators may cause physical damage to buildings, infrastructure or vehicles.
	Buildings, property or critical infrastructure may be damaged by fires (including bushfires) caused by degraded electrical contacts or conductor connections.
Damage to the environment	Fires caused by electrical equipment failures may damage the natural environment.
Loss of supply	Interruptions to electricity supply can affect a single customer or whole communities in the form of transport systems, traffic controls, emergency services, business and communication systems, critical infrastructure and vulnerable customers including those on life support systems.
	Functional failures on poor performing feeders may result in SAIDI or SAIFI impacts that do not meet minimum performance levels and lead to intervention by our regulator.

Spatial factors can also increase the likelihood or consequences of an air break switch or fuse carrier failure. These factors include if they are:

- Located in areas with high pedestrian / vehicle activity or in close proximity to public amenities
- Located in salt affected areas
- Located in areas prone to bushfire.

All air break switch and fuse carrier configurations have failure modes which are generally deteriorating in nature and therefore present an increased likelihood of failure as a product of time (i.e. as the assets age). Detecting failures before they occur and applying treatments maintains air break switches in a serviceable condition and mitigates the potential consequences. The key failure modes for each identified type of air break switch and the EDO fuse carriers are shown in Table 2 below.

Table 2. Key failure modes by identified 11kV overhead switch type

Pole Material Type	Key Failure Modes
Essantee HS641 (Installed from 1966-1974)	Uncontrolled discharge of electricity during normal operation due to corroded supports pins cracking insulators.
	Insulator failure during switching operations due to corroded supports pins cracking insulators.
	Pole top fires or arcing due to loss of spring pressure in contacts.

Pole Material Type	Key Failure Modes
Haycolec (Installed from 1992-2003)	Uncontrolled discharge of electricity during normal operation due to corroded support pins cracking insulators.
	Insulator failure during switching operations due to corroded supports pins cracking insulators.
	Pole top fires or arcing due to poor rotating contact design.
Taplin D571 (Installed from 1973-1986)	Uncontrolled discharge of electricity during normal operation due to corroded supports pins cracking insulators.
	Insulator failure during switching operations due to corroded supports pins cracking insulators.
	Pole top fires or arcing due to contact misalignment caused by twin crossarm design.
	Pole top fires or arcing due to poor conductor connection design.
EDO fuse carriers	Corroded bolt connections due to inappropriate material used during manufacturer leading to mechanical failure.

Other failure modes associated with the ground level operating handle, earthing system and operating down rods are also relevant to these and other types of air break switches.

In the five year period from 2012/13- 2016/17 there were a total of 1,837 conditional and functional failures of 11kV air break switches. The failure modes are generally consistent with those experienced by other organisations in the Australian electricity industry. The average annual failure rate has been decreasing over recent years due to the concerted effort to replace the types with known condition issues and despite an increase in the population.

An investigation was launched following five failures of the terminal connection of the ABB Series V 11kV EDO fuse carriers on the Central Coast of NSW. One of these failures was a near miss where the fuse carrier fell and almost struck a worker during operation. The manufacturer has advised that the grade of stainless steel used for the bolt and nut combined with the heavy pollution environment along coastal areas has led to the corrosion and premature failure of this bolt and nut connection.

2.4 Treatment analysis

Assessment of the treatment solutions considered for the identified air break switch and fuse carrier types is shown in Table 3 below.

Table 3. Treatment options for managing 11kV overhead switches

Treatment options	Treatment overview
1 Repair the switch or fuse	Repair the asset prior to failure using like-for-like components.
2 Modify the switch or fuse	Modify the components of the asset which have known failure modes with their modern equivalent.
3 Replace the switch or fuse	Replacement is implemented based on a risk-prioritised list of assets.

The different treatment options are all utilised at different points in the asset's lifecycle. A repair may be completed where practical and efficient; however components are not generally available and are not suitable for re-use due to degradation. A refurbishment treatment with modern equivalent components requires design changes and the inherent risk of the degraded asset is not addressed. A replacement allows for a modern design with improved safety features and durable materials to be installed.

2.5 Options

The options shown in Table 4 below have been considered in relation to managing the safety and loss of supply risks.

Table 4. Program options for managing 11kV overhead switches

Program need options	Option overview
1 Reactive treatment	Implement treatment such as repair or replacement when the asset fails.
2 Conditional treatment	Implement treatment to inspect assets on a routine basis to identify problems with their condition. Assets are treated when a condition issue has been identified.
3 Planned treatment	Implement planned treatment such as modification or replacement prior to assets failing.

The serious safety and electricity supply risks to the public, communities and workers makes a 'run to failure' reactive approach unacceptable. Repair and modification options for these identified types of air break switches are limited due to their age, lack of manufacturer support or availability of suitable spare components.

The modern air break switches and EDO fuse carriers have improvements to their design and materials. The benefits of planned replacement therefore include:

- The avoided cost of maintaining the asset
- Minimising the cost of reactive failures
- The avoided cost of potential injury, fire and damage to the equipment
- The additional safety outcomes gained through the installation of a modern switch with improved insulator materials.

The decision to replace the ABB 11kV Series V EDO fuse carriers was due to the potential serious risks associated with these assets failing. This decision was informed by internal investigations that raised concerns about the type of steel used for EDO nuts and bolts. On this basis, reactive treatment is not a credible option. Replacement of the equipment is on a like for like basis for the current fuse carrier assembly on a long term period based contract.

The planned replacement programs address the identified types with known systemic condition issues. Other types of air break switch or fuses may also fail due to other failure modes. In these circumstances reactive replacement occurs following a breakdown of the asset or where unrepairable defects are identified by field staff when operating equipment. Refer to Part K for details in regards to reactive replacement requirements for other air break switches.

2.6 Costing and volumes

The forecast replacement volume is expected to sustainably manage the risks associated with the deteriorating asset population in a prioritised order so those of highest risk are completed first. Balancing the risk and delivery practicality, Ausgrid has prioritised EDO fuse carrier work based on their location and an initial inspection. The intention is to replace approximately 700 annually from mid-FY17, to remove all of these assets within 10 years based on a reasonably practicable timeframe. EDO fuse carriers account for 3% annually of the population within these asset classes.

These programs form part of the overall investment being proposed for the replacement of overhead switches, they can also be captured as reactive failures. Refer to the Ausgrid Reset RIN template '2.2 REPEX' for details in regard to the overall investment proposed for this asset category during 2019-24.

The estimated unit cost for air break switch and fuse carrier replacement is shown in Table 5 below. Ausgrid is proposing to replace 0.3% annually of the population within the overhead switch asset class. Ausgrid predominantly delivers this work utilising internal resources, however some replacement is undertaken by accredited service providers in conjunction with contestable projects.

The implied Ausgrid unit cost determined in the replacement expenditure (repex) modelling reflects the significant variation in unit rates for the different types of 11kV switches which Ausgrid is replacing, as this includes both overhead switches and oil filled ground switches. The implied Ausgrid unit cost in this repex asset category is not reflective of an appropriate cost to replace an overhead switch due to the variety of switches captured in this category.

The summary forecast for these replacement programs is shown in Table 5 below. The costs shown are direct costs only.

Table 5. Forecast for 11kV overhead switches

Direct Costs (real $FY19)	FY20	FY21	FY22	FY23	FY24
11kV Essantee HS641 air break switches					
Volumes for replacement	50	50	22	0	0
Unit cost	$12,356	$12,298	$12,267	$0	$0
Total costs ($m)	**$0.62**	**$0.61**	**$0.27**	**$0**	**$0**
11kV Taplin D571 air break switches					
Volumes for replacement	25	25	25	25	25
Unit cost	$14,334	$14,269	$14,237	$14,217	$14,178
Total costs ($m)	**$0.36**	**$0.36**	**$0.36**	**$0.36**	**$0.35**
11kV Haycolec air break switches					
Volumes for replacement	25	25	25	25	25
Unit cost	$11,173	$11,125	$11,099	$11,082	$11,051
Total costs ($m)	**$0.28**	**$0.28**	**$0.28**	**$0.28**	**$0.28**
ABB 11kV series V EDO fuse carriers					
Volumes for replacement	700	700	700	700	700
Unit cost (per set of 3)	$2,207	$2,194	$2,186	$2,180	$2,171
Total costs ($m)	**$1.55**	**$1.54**	**$1.53**	**$1.53**	**$1.52**

3 415V SWITCHGEAR

3.1 Program description

Ausgrid has two programs related to the replacement of low voltage 415V switchgear in substations. The purpose of these programs is to mitigate risks associated with deteriorating low voltage switchgear which can lead to loss of supply and safety risks.

The two key programs related to 415V switchgear are:

- Network protectors (REP_01.03.06)
- Low voltage air circuit breakers (REP_01.03.02).

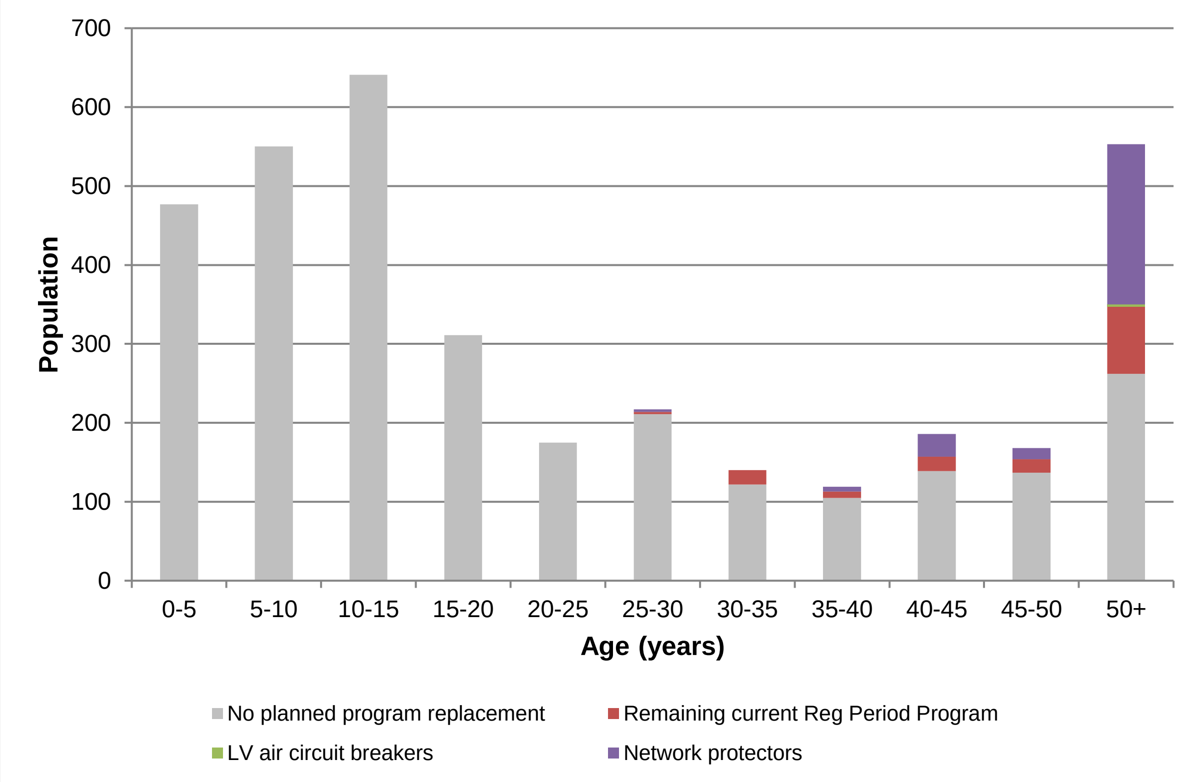
These programs have continued from the current regulatory period. Ausgrid expects to replace 258 of these assets in the 2019-24 regulatory period. The total value of these programs is expected to reach $24.4M in direct costs (real $FY19) during the 2019-24 period.

The age profile highlighting the identified programs for replacement against the total population of 415V switches on the network is shown in Figure 2.

3.2 Background

Ausgrid has approximately 100,000 items of 415V switchgear installed across the network ranging from links on distribution network poles, distribution panels in substations and circuit breakers installed within substations. The age profile of the population of 415V switchgear, including assets identified for replacement is shown in Figure 2 (assets associated exclusively with a reactive strategy such as overhead links have been excluded from the graph). Most of the substation based 415V network protectors and air circuit breakers identified for replacement in the 2019-24 period are over (or approaching) the standard technical life of 40 years.

Figure 2. Age profile of 415V switchgear (as at 30 June 2017)



The primary function of substation based network protectors and circuit breakers is to safely disconnect electrical supply due to a detected fault on the distribution network.

The need for treatment of these assets is considered by asset category and shown in Table 6 below.

Table 6. Asset overview for 415V switchgear

Asset	Overview
Network protectors	Network protectors are an obsolete specialised design used in the triplex network chamber substations specific to the Sydney CBD. There are six different manufacturers and models. Some types have been identified as containing asbestos. The specialised nature of the network protectors and their underground location means that the costs associated with maintaining these assets is high. These assets are unique within the Australian industry and require specialised skills and technical support to maintain. The cost of maintaining air circuit breaker technology is approximately 35% less expensive than maintaining these network protectors.
Low voltage air circuit breakers	The low voltage air circuit breakers program was initiated following an investigation into failures with certain types, specifically Westinghouse DS532 & British Thomson Houston VJ types. The air circuit breakers identified for replacement have an obsolete design or, safety and technical reliability concerns. Other issues include overheating contacts due to the lack of contact spring pressure and high contact wear. The current program targets the two models of obsolete low voltage air circuit breakers.

3.3 Risks – Consequence and likelihood

The key consequences that can result from a loss of this function are shown in Table 7 below.

Table 7. Consequences from loss of function for 415V switchgear

Consequences	Description
Harm to the public, communities and workers	Fire caused by a loss of insulation, further propagated by the presence of highly flammable oil within the circuit breaker tank and adjacent transformers.
	Structural damage to substation as a result of over-pressure within the circuit breaker tank leading to a tank rupture.
	Safety issues as a result of loss of supply as detailed below.
	Delay of a circuit breaker in the clearing of a downstream fault has the potential to put the general public at risk (for example if a line falls to the ground but the power is not rapidly disconnected via the switchgear).
	Asbestos containing materials are present in the majority of these obsolete network protectors and require specialised handling. Any inadvertent release of asbestos fibres has the potential to impact the public and workers.
Harm to the environment	Mineral oil spills can lead to environmental issues.
Damage to property	Damage to surrounding property and other substation equipment as a result of a circuit breaker explosion or fire.
Loss of supply	Interruptions to electricity supply can affect a single customer or whole communities in the form of transport systems, traffic controls, emergency services, business and communication systems, critical infrastructure and vulnerable customers including those on life support systems.

Network protectors in basement and underground substations in the Sydney CBD present significant risks in the event of a functional failure. Network protector failures can cause considerable damage to the substation if the failure causes a fire. For example in 2009, a network protector failure resulted in a CBD substation fire which caused extensive damage to the surrounding equipment and privately owned building.

Some of these substations are housed in concrete chambers located beneath roadways in the Sydney CBD and have entrance hatches in the footpath at each end of the chamber. These substations are classed as ‘confined spaces’ and access is restricted under Workplace Health and Safety (WH&S) obligations. WH&S obligations require that access into confined spaces use fall arrest devices where vertical ladders are in place and that rescue personnel remain adjacent to the top of the access hatch whenever work is undertaken in the chamber. The access issues, in association with the high traffic densities in the CBD, contribute to the high costs associated with operating, maintaining and replacing these assets.

The key failure modes for network protectors and low voltage air circuit breakers are shown in Table 8.

Table 8. Key failure modes by identified 415V switchgear type

Switch Type	Key Failure Modes
Network protector	Operating mechanism failure.
	Burnt out motor.
	Master relay failure.
	Operating mechanism failure.

Switch Type	Key Failure Modes
Low voltage air circuit breaker	Worn contacts.
	Lack of spring pressure.

The lack of spare parts and technical support for these aged assets extends the time to repair when there is a failure.

Over the five year period from 2012/13 to 2016/17, there were 37 network protector conditional and functional failures representing the inherent failure rate with an asset base of 329 units. The network protectors are beyond their designed serviceable life and the risk of failure increases each year a unit remains in service. There were 51 low voltage air circuit breaker conditional and functional failures representing the inherent failure rate with an asset base of 2,692 units.

3.4 Treatment analysis

Assessment of the treatment solutions considered for 415V switches is shown in Table 9.

Table 9. Treatment options for managing 415V switchgear

Treatment option	Treatment overview
1 Repair the 415V switchgear	Undertake repairs to the 415V switchgear as conditional issues are identified.
2 Refurbish the 415V switchgear	Components such as contacts are able to be replaced, as well as any asbestos barrier board removed.
3 Replace the 415V switchgear	Replacement is implemented based on the asset condition.

The different treatment options are all utilised at different points in the asset's lifecycle. A repair may be completed where practical and efficient, particularly where insulation has been compromised. A repair or refurbishment treatment does not remove the inherent risk associated with the switchgear design and is therefore not the preferred option.

3.5 Options

The program options considered to mitigate the risks associated with network protectors and air circuit breakers are assessed in Table 10.

Table 10. Program options for managing 415V switchgear

Program need options	Options overview
1 Reactive treatment	Implement treatment such as repair, refurbishment or replacement when the 415V switchgear fails.
2 Conditional treatment	Implement treatments to repair, refurbish or replace 415V switchgear when inspections/testing identify they have deteriorated to the point of conditional failure based on a set of criteria.
3 Planned treatment	Implement planned treatment prior to 415V switchgear assets failing. Individual assets are built into a priority list of assets to be treated.

The analysis of options in relation to low voltage switchgear takes into consideration the availability of spares, technical support and WH&S requirements. In particular, network protectors on the Ausgrid network are beyond their designed service life and obsolescence is a significant risk.

The preferred option for network protectors is to replace them with modern equivalent air circuit breaker technology in a planned program. The planned replacement of network protectors addresses the condition, safety and performance issues associated with these assets that are at the end of their serviceable life. In particular, replacing with modern equivalent technology such as an air circuit breaker overcomes the current issues associated with lack of spare parts and technical support.

The preferred approach for 415V air circuit breakers is to replace the Westinghouse DS532 and British Thomson Houston VJ assets in a planned program. This planned replacement program will end in 2022 and transition to condition-based replacement program for the remainder of assets within this category. A condition-based approach provides time to procure and plan for the replacement which is more cost effective than a reactive approach due to the high cost associated with unplanned treatment.

Each site will be assessed individually to determine the most cost effective option to remove these air circuit breakers from the network. Options may include bypassing the circuit breaker and retiring in situ, rebuilding the low voltage board or complete substation replacement.

3.6 Costing and volumes

Ausgrid is planning to replace all of the remaining network protectors over the 2019-24 regulatory period. The network protectors have been identified, assessed conditionally and placed on a priority list.

Ausgrid is proposing a substantial increase in planned replacement volumes for network protectors to mitigate the rising cost associated with maintaining and repairing these assets as they age. The remaining small population of targeted air circuit breakers are planned to be replaced in a sustainable manner through the remainder of the regulatory period. These programs represent an annual replacement volume of 1.4% of the population of 415V switchgear assets.

These programs form part of the overall investment being proposed for the replacement of 415V switches, they can also be captured as reactive failures. Refer to the Ausgrid Reset RIN template ‘2.2 REPEX’ for details in regard to the overall investment proposed for this asset category during 2019-24.

Due to the age and general poor condition of Sydney CBD basement and underground substations, Ausgrid considered the feasibility of complete replacement of substations. In most cases, replacement of these substations was not considered a cost effective way to mitigate the risk of asset failure.

In the case of some early models, either the replacement of the low voltage board or replacement of the substation with a kiosk may also be credible approaches to address the risk.

The implied unit cost determined from repex modelling reflects the significant variation in unit rates for the different switch types as the RIN category includes all switches less than or equal to 11kV. Due to the significant variation between the voltages and installation locations of switches captured in the category, the forecast unit cost for the RIN category and the benchmark unit rate for this asset category is not reflective of an appropriate cost to replace low voltage switchgear.

The summary forecast for these replacement programs is shown in Table 11 below. The costs shown are direct costs only.

Table 11. Forecast for 415V switchgear

Direct Costs (real $FY19)	FY20	FY21	FY22	FY23	FY24
Network protectors					
Volumes for replacement	50	50	50	50	50
Unit cost (per breaker)	$95,229	$94,888	$94,737	$94,655	$94,470
Total costs ($m)	**$4.76**	**$4.74**	**$4.74**	**$4.73**	**$4.72**
Low voltage air circuit breakers					
Volumes for replacement	2	2	2	1	1
Unit cost (per breaker)	$82,717	$82,535	$82,374	$82,257	$82,065
Total costs ($m)	**$0.17**	**$0.17**	**$0.16**	**$0.08**	**$0.08**

4 11KV GROUND SWITCHES

4.1 Program description

Ausgrid has a number of programs to replace 11kV ground switches with known condition issues. These switches are primarily located in distribution substations. The need to replace these switches has been triggered by the safety risks they pose to the public, customers and workers, however the proposed approach is also the most cost effective and provides additional network flexibility.

The replacement programs related to 11kV oil filled fuse and ring main switches are:

- Statter, ALM and Godfrey fuse switches (REP_01.02.45)
- Reyrolle JKSS ring main isolators with compound filled end boxes (REP_01.02.47)
- Obsolete oil-filled ring main units and fuse switches (REP_01.02.52).

The replacement programs related to other technology types are:

- Hazemeyer ring main units – harsh environment (REP_01.03.17)
- Bass, Clain and Saunders isolate and earth switches (REP_01.03.13).

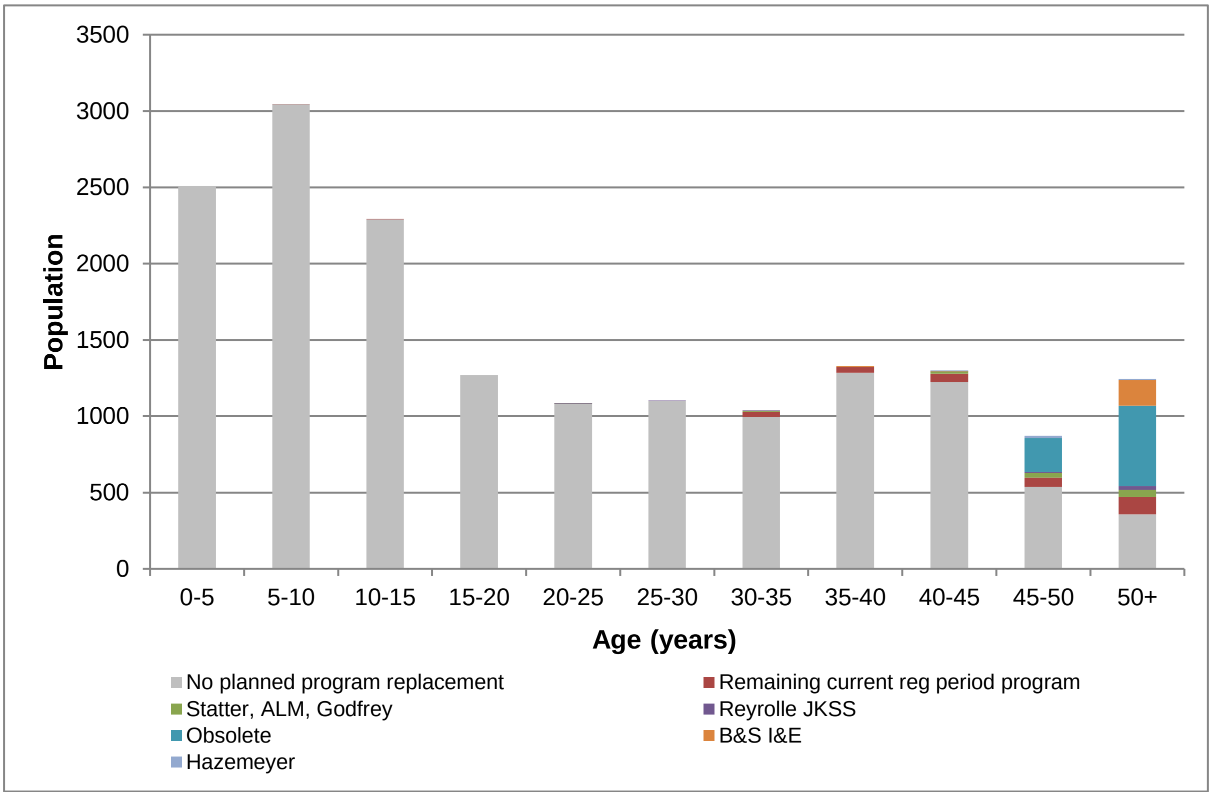
Four of these programs are continuing from the current regulatory period and one, the Obsolete oil-filled ring main units and fuse switches program (REP_01.02.52), is changing from a reactive to a planned program. In total, Ausgrid expects to spend $58.9M in direct costs (real $FY19) on replacing these assets.

The age profile highlighting the identified programs for replacement against the total population of 11kV switches on the network is shown in Figure 3.

4.2 Background

Ausgrid has approximately 17,000, 11kV ground switches across the network. This switchgear is generally located in distribution substations and consists of ring main units, fuse switches and isolate and earth switches. Their function is to isolate sections of the network for work to be undertaken and to protect network components through fuse operation when faults occur. They must remain in a safe condition to perform these functions. An age profile of these assets is shown in Figure 3 below and the assets identified for replacement in the current and 2019-24 periods are shown in the chart.

Figure 3. Age profile of 11kV ground switches (as at 30 June 2017)



The 11kV ground switches on the Ausgrid network have over 20 different manufacturers and multiple configurations of these types of assets. Each manufacturer and model has its own specific condition or inherent design issues, age profile and failure modes that require management.

The need for treatment of these assets is considered by asset category and shown in Table 12 below.

Table 12. Asset overview for 11kV ground switches

Asset	Overview
Ring main units and fuse switches	Ring main units have three switches allowing sections of the network to be isolated for work. Fuse switches allow connection of a substation or High Voltage customer through a feeder “tee off” from the main feeder cable. Both configurations also have fuses which provide feeder protection in the event of a fault. These are available in three insulation technologies: • Oil • Air • Gas (SF6). Switch condition information is collected primarily through oil quality testing for oil switches and visual inspections for the remainder. For air insulated switches environmental factors, such as high pollution and salt spray in coastal areas, have affected the condition of these assets. SF6 switch issues to date have only been due to low gas from gas leaks. This has led to Ausgrid identifying poor performing sub populations (i.e. by manufacturer or model) and deeming them conditionally failed resulting in planned replacement.
Isolate and earth switches	11kV isolate and earth switches are predominantly installed on the Sydney CBD triplex network. This equipment is used to de-energise and earth the system to allow for maintenance, repair or network augmentation of the associated 11kV CBD feeder, distribution transformer or network protector / low voltage circuit breaker. Approximately 80% of the assets identified for replacement are over 40 years old.

4.3 Risks – Consequence and likelihood

The key consequences that can result from a loss of this function are shown in Table 13

Table 13. Consequences from loss of function for 11kV ground switches

Consequences	Description
Harm to the public, communities and workers	Fire or catastrophic rupture of the tank during localised operation caused by a loss of insulation, further propagated by the presence of highly flammable oil within the switch tank. In 2015, a tank rupture in Western Australia resulted in two fatalities and two serious injuries.
	Safety issues as a result of loss of supply as detailed below.
Harm to the environment	Mineral oil spills can lead to environmental damage.
Damage to property	Damage to surrounding property and other substation equipment as a result of a switch explosion or fire.
Loss of supply	Network interruption to customers supplied through the switch. Interruptions to electricity supply can affect a single customer or whole communities in the form of transport systems, traffic controls, emergency services, business and communication systems, critical infrastructure and vulnerable customers including those on life support systems.

Failures of these assets have a high consequence as the vast majority of this switchgear is opened and closed manually posing significant WH&S risks due to worker exposure. Much of this switchgear is installed in substations that are located in residential and high traffic commercial areas and if not managed properly can pose serious public safety risks.

All 11kV switches have failure modes which are generally deteriorating. Detecting potential failures before they occur and applying treatments maintains 11kV switches in a serviceable condition and mitigates the potential consequences. Maintenance of oil filled switches includes the high cost periodic replacement of oil requiring an outage and placing the network in an abnormal state. The key failure modes that require management for each targeted switch are shown in Table 14.

Table 14. Key failure modes by identified 11kV ground switch type

Switch Type	Key Failure Modes
Oil insulated fuse switches and ring main units	Corroded support structures and main tank.
	Oil degradation and leaks.
	Operating mechanism failure.
Air insulated fuse switches and ring main units	Contaminated insulators.
	Corroded support structures.
	Contact arcing.
SF6 insulated fuse switches and ring main units	Rupture of seals and subsequent gas leaks.

Switch Type	Key Failure Modes
Isolate and earth switches	Oil degradation and leaks.
	Deterioration of gaskets.
	Cracking of the porcelain bushings.

In 2015, an oil insulated switch failed in Western Australia resulting in two fatalities and also two workers receiving serious injuries. In the five year period from 2012/13 to 2016/17, there were a total of 1,152 conditional and functional failures with the potential to inhibit the operation of the 11kV switches. A review of the failure rates indicates an increasing rate of failure and an aging population. As a result of the known condition issues and safety risks Ausgrid is proposing to increase replacement work in this asset class for the highest risk switches.

4.4 Treatment analysis

Assessment of the treatment solutions considered for 11kV switches is shown in Table 15 .

Table 15. Treatment options for managing 11kV ground switches

Treatment option	Treatment overview
1 Repair the 11kV switches	Undertake repairs to the 11kV switches as conditional issues are identified. This is an operational task.
2 Refurbish the 11kV switches	Major components such as contacts and seals are able to be replaced and new oil replacing old oil.
3 Replace the 11kV switches	Replacement of the entire switch with a modern 11kV switch.
4 Replace the substation	Replacement is implemented based on the condition of the switch and other components within the substation. As this is complex to evaluate it is assessed reactively and determined on a case by case basis.

The different treatment options are all utilised at different points in the asset's lifecycle. A repair may be completed where practical and efficient, particularly where insulation has been compromised. A repair or refurbishment treatment does not remove the inherent risk of the oil and costs a similar order of magnitude and is therefore not the preferred option.

The change from oil to gas insulation in fuse switches represents a significant reduction in safety risk reducing the risk of fire and catastrophic failure and also removes the need for periodic oil changes (currently performed every 25-30 years), reducing outages and maintenance costs. Where the replaced switch has the technology to be remotely controlled it also minimises the risk exposure for network operators.

4.5 Options

Each of the proposed switchgear programs has undergone an assessment of options to mitigate risks associated with the asset failing. The serious safety and electricity supply risks to the public, communities and workers makes a 'run to failure' reactive approach unacceptable. The remaining options applied to each switchgear manufacturer or model combination are summarised in Table 16.

Table 16. Program options for managing 11kV ground switches

Program need options	Option overview
1 Reactive treatment	Implement treatment such as repair, refurbishment or replacement when the 11kV switchgear fails.
2 Conditional treatment	Implement treatments to repair or replace 11kV switchgear when inspections/testing identify they have deteriorated to the point of conditional failure based on a set of criteria.
3 Planned treatment	Implement planned treatment prior to 11kV switchgear assets failing. Individual assets are identified in a priority list of assets to be treated. Assets are replaced in a systematic and cost efficient way, starting from the most risky assets.

A high number of identified 11kV ground switches are beyond the standard technical life, are leaking and have known condition issues with tank corrosion supporting a planned treatment approach.

The switch manufacturers recommend a periodic oil change be undertaken at less than 10 years to mitigate the risk of catastrophic failure due to degraded oil condition. However, given the significant cost to undertake this maintenance, Ausgrid's Maintenance Requirements Analysis (MRA) process has determined that in our operating environment and with our pre-operation procedures, a periodic oil replacement in oil filled fuse switches is undertaken every 25-30 years.

The number of replacement works and hence the replacement rate for this equipment has been determined by balancing the costs of continuing ongoing maintenance against the cost of replacement. The assets identified for replacement are then replaced prior to requiring their second periodic maintenance activity as they are not expected to be serviceable beyond 60 years of age due to support needs for age based degradation of key components. The benefit of planned replacement therefore includes:

- The avoided cost of maintaining the asset
- The avoided cost of potential injury or fatality, fire and damage to the equipment
- The additional flexibility and safety outcomes gained through the installation of a modern switch with remote switching capability.

Ausgrid has determined that a planned treatment at 45-50 years is appropriate to reduce the risk of catastrophic failures and the higher operating costs associated with oil filled units than gas filled units.

The remainder of these switchgear assets will follow a reactive or conditional treatment approach that will be initially managed within the maintenance program. There will be a small number of reactive treatments due to the cost inefficiency of a purely planned approach and where a full switch replacement is required due to a failure or identified condition issue. These will be managed through the reactive capital programs of work and are captured in Part K (Reactive programs).

4.6 Costing and volumes

Ausgrid is proposing planned replacement volumes for oil switches in line with the new strategy to remove the oil risk and reduce the need for additional maintenance expenditure as these assets age.

The forecast for the 2019-24 period equates to replacement of 1.8% of the 11kV oil-filled ground based switch population annually and also reflects Ausgrid's intention to mitigate the risks associated with oil in substations. Some replacement works are also completed as part of substation replacement programs detailed in Part H (Distribution substations). Continuing this replacement rate would mean that the population of oil-filled ground based switches is replaced over a period of 54 years. Replacement of oil-filled ground based switches will continue to be targeted in subsequent periods due to the size of the asset population and expected increasing volume of identified condition issues as the asset population continues to age.

The delivery timing for the isolate and earth switch program has been based upon the poor condition of the assets, their operation beyond their standard life and the application of a risk prioritisation process. Ausgrid is proposing to replace the entire remaining population of Bass, Clain and Saunders isolate and earth switches during the 2019-24 period. These switches are oil-filled and are often located in difficult to access and load critical sites. Their replacement is planned to mitigate the rising cost associated with maintaining and repairing these assets as they age.

The volumes of Hazemeyer proposed for replacement are 0.3% of the population of Hazemeyer switches installed on Ausgrid's network. A number of the replacement substations in Part H (Distribution substations) have Hazemeyer switches installed.

These programs form part of the overall investment being proposed for the replacement of 11kV ground switches, they can also be captured as part of other programs or as a reactive failure. Refer to the Ausgrid Reset RIN template '2.2 REPEX' for details in regard to the overall investment proposed for this asset category during 2019-24.

In some cases with 11kV switches the modern standard switch footprint may be too large to fit in the existing substation kiosk. In these cases, an assessment of the whole kiosk is undertaken to determine whether to replace the entire kiosk substation with the current standard substation or to continue to accept a higher level of risk and maintenance expenditure. In these circumstances, where the risks are not acceptable, replacement is funded from reactive funding for obsolete substations. An assessment of the footprint of the assets was undertaken as part of the development of the program to prevent the potential for duplication across programs.

The implied Ausgrid unit cost determined in the repex modelling reflects the significant variation in unit rates for the different types of 11kV switches which Ausgrid is replacing, as this includes both overhead switches and oil filled ground switches. The implied Ausgrid unit cost in this repex asset category is not reflective of an appropriate cost to replace a ground based switch due to the variety of switches captured in this category.

The summary forecast for these replacement programs is shown in Table 17. The costs shown are direct costs only.

Table 17.   Forecast for 11kV ground switches

Direct Costs (real $FY19)	FY20	FY21	FY22	FY23	FY24
Statter, ALM and Godfrey fuse switches					
Volumes for replacement	20	20	20	20	20
Unit cost	$40,390	$40,328	$40,361	$40,432	$40,465
Total costs ($m)	**$0.81**	**$0.81**	**$0.81**	**$0.81**	**$0.81**

Direct Costs (real $FY19)	FY20	FY21	FY22	FY23	FY24
Reyrolle JKSS ring main isolators with compound filled end boxes					
Volumes for replacement	17	17	0	0	0
Unit cost	$49,536	$49,467	$0	$0	$0
Total costs ($m)	**$0.84**	**$0.84**	**$0**	**$0**	**$0**
Obsolete oil-filled ring main units and fuse switches					
Volumes for replacement	150	150	150	150	150
Unit cost	$49,536	$49,467	$49,519	$49,619	$49,672
Total costs ($m)	**$7.43**	**$7.42**	**$7.43**	**$7.44**	**$7.45**
Hazemeyer ring main units – harsh environment					
Volumes for replacement	5	5	5	5	5
Unit cost	$41,788	$41,688	$41,686	$41,721	$41,713
Total costs ($m)	**$0.21**	**$0.21**	**$0.21**	**$0.21**	**$0.21**
Bass, Clain and Saunders isolate and earth switches					
Volumes for replacement	33	33	33	33	24
Unit cost (per switch)	$96,858	$96,296	$95,988	$95,769	$95,399
Total costs ($m)	**$3.20**	**$3.18**	**$3.17**	**$3.16**	**$2.29**

5 11KV CIRCUIT BREAKERS

5.1 Program description

The purpose of the 11kV circuit breaker replacement program is to replace degraded and obsolete circuit breakers installed in distribution and zone substations. These circuit breakers use oil as the insulation medium for the breaking mechanism which poses an environmental and fire risk.

Ausgrid has three planned programs to replace 11kV circuit breakers.

- High voltage (11kV) oil circuit breaker (REP_01.02.43)
- Single circuit breaker switchgear (REP_01.03.04)
- 11kV air insulated switchboards – vacuum circuit breakers (REP_02.02.01).

In total, the three programs are forecast to cost $19.1M in direct costs (real $FY19) over the 2019-24 period. These programs are continuing from the current regulatory period.

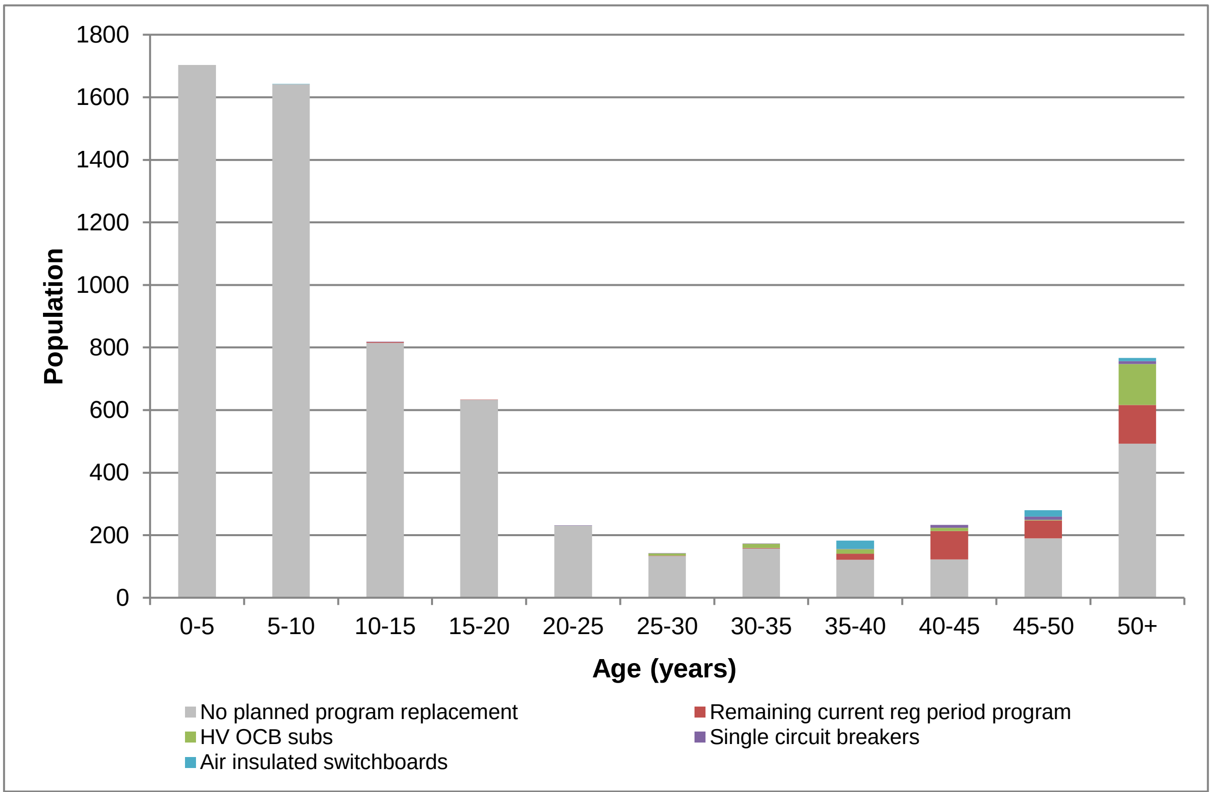
The age profile highlighting the identified programs for replacement against the total population of 11kV switches on the network is shown in Figure 4 below.

5.2 Background

Ausgrid has approximately 6,800, 11kV circuit breakers across the network. These consist of modern models as well as those from previous network utilities that have now amalgamated to constitute Ausgrid. This means there are a large variety of manufacturers, models and ages on the network with varying risks and performance levels. Prior to the early 1990s, the majority of high voltage circuit breakers used oil as an insulation medium. More recently, vacuum circuit breakers have become the standard.

The age profile of the total population of 11kV circuit breakers is shown in Figure 4 below below. A high proportion of the assets planned for replacement are over the 45 year standard technical life.

Figure 4. Age profile of 11kV circuit breakers (as at 30 June 2017)



The equipment is designed to quickly disconnect supply in fault circumstances and minimise damage to other assets including 11kV feeders, transformers and low voltage boards. Circuit breakers also provide switching functions (including remote switching) and isolation points on the 11kV network to allow for planned maintenance, repairs and network augmentation and restoring load in emergencies. Previous network design and equipment selection from predecessor organisations has led to Ausgrid having an uncommon arrangement with a significant number of 11kV circuit breakers installed in distribution substations.

Conditional information collected during maintenance and testing provides a good understanding of the internal condition of the equipment.

The current population of oil circuit breakers is deteriorating and spare components are becoming difficult to source. Ausgrid also has a strategy of progressively removing oil filled equipment, including switchgear, from substations. The replacement of bulk oil circuit breakers installed in air insulated switchboards within zone substations. This allows the life of the switchboard to be extended by removing the risks associated with oil switchgear.

Single circuit breaker substations form an obsolete substation and switchgear design which was used in the 1960s. It requires communications to an upstream substation and circuit breaker to allow faults to be disconnected from the network. These communications utilise copper pilot cables and have high failure rates as they are of a similar age to the substation equipment. Locating and repairing defects on these underground communications cables is expensive due to the need to excavate roads to access the cable for repair.

5.3 Risks – Consequence and likelihood

The key consequences that can result from a loss of this function are shown in Table 18.

Table 18. Consequences from loss of function for 11kV circuit breakers

Consequences	Description
Harm to the public, communities and workers	Fire caused by a loss of insulation, further propagated by the presence of highly flammable oil within the circuit breaker tank.
	Structural damage to substation as a result of over-pressure within the circuit breaker tank and subsequent tank rupture.
	Safety issues as a result of loss of supply as detailed below.
	Delay in disconnecting supply from a downstream fault of a circuit breaker has the potential to put the general public at risk (for example if a line falls to the ground but is not rapidly disconnected).
Harm to the environment	Mineral oil spills can lead to environmental issues.
Damage to property	Damage to surrounding property and other substation equipment as a result of a circuit breaker explosion or fire.
Loss of supply	Network interruption to customers connected to the substation. Interruptions to electricity supply can affect a single customer or whole communities in the form of transport systems, traffic controls, emergency services, business and communication systems, critical infrastructure and vulnerable customers including those on life support systems.

The safe and reliable operation of this equipment ensures that the 11kV network remains stable and faults are disconnected in time to prevent injury to Ausgrid personnel and the public and prevent secondary damage to equipment.

The failure modes, risks and consequences are similar across all 11kV oil circuit breakers. The main failure modes for 11kV circuit breakers are shown in Table 19 below.

Table 19. Key failure modes by identified 11kV circuit breaker type

Switch Type	Key Failure Modes
Oil insulated circuit breaker	Corroded support structures and main tank.
	Oil degradation and leaks
	Operating mechanism failure.

Failures recorded as conditional and functional failures represent the indicative inherent failure rate with an average of 185 failures per year for the five year period between 2012/13-2016/17. Analysis of the failure rate is observed to be decreasing, highlighting the positive affect of Ausgrid's previous replacement programs.

Due to the age of these older assets, spare parts and technical support for these circuit breakers is limited. The lack of spare parts hinders the ability to properly maintain these circuit breakers and also increase the reliability risk as time to restore is increased.

Specific to the single circuit breaker switchgear program; these assets rely on a degraded copper pilot cable communications network. This pilot network is significantly deteriorated and failures on this network are increasing.

5.4 Treatment analysis

Assessment of the treatment solutions considered for 11kV circuit breakers is shown in Table 20 below.

Table 20. Treatment options for managing 11kV circuit breakers

Treatment option	Treatment overview
1 Repair the 11kV circuit breakers	Undertake repairs to the 11kV circuit breakers as conditional issues are identified.
2 Refurbish the 11kV circuit breakers	Components such as contacts are able to be replaced.
3 Replace the 11kV circuit breakers	Replacement of the circuit breaker.

The different treatment options are all utilised at different points in the asset's lifecycle. A repair may be completed where practical and efficient, particularly where insulation has been compromised. A repair or refurbishment treatment does not remove the inherent risk of the oil and costs a similar order of magnitude and is therefore not the preferred option.

When a replacement treatment occurs assets are replaced with modern design with improved safety features and more durable materials. Replacement removes the inherent design risks associated with these assets. The strategy to change from oil to vacuum or gas insulation in circuit breakers represents a significant reduction in safety risk reducing the risk of fire and catastrophic failure. Where the replaced switch has the technology to be remotely controlled it also minimises the exposure risk for workers.

5.5 Options

Each of the proposed switchgear programs has undergone an assessment of options to mitigate risks associated with the asset failing. The serious safety and electricity supply risks to the public, communities and workers makes a 'run to failure' reactive approach unacceptable. The remaining options applied to each 11kV circuit breaker are summarised in Table 21 below.

Table 21. Program options for managing 11kV circuit breakers

Program need options	Option overview
1 Reactive treatment	Implement treatment such as repair, refurbish or replacement when the 11kV switchgear fails.
2 Conditional treatment	Implement treatments to the 11kV switchgear when inspections/testing identify they have deteriorated to the point of conditional failure based on a set of predetermined criteria.
3 Planned treatment	Implement planned treatment prior to 11kV switchgear assets failing. Individual assets are built into a priority list of assets to be treated. Assets are replaced in a systematic way starting from the highest priority.

The planned replacement of these assets is the preferred approach until the backlog of poor performing circuit breakers and obsolete equipment is managed at which point a conditional replacement approach will be implemented.

The benefits of planned replacement include:

- The avoided cost of maintaining the asset
- The avoided cost of potential injury/fatality, fire and damage to the equipment
- The additional flexibility and safety outcomes gained through the installation of a modern switch with remote switching capability.

For conditional treatment decisions that are informed by Ausgrid's Maintenance Requirements Analysis process, periodic inspection and testing of the insulation is undertaken to enable assessment of the asset condition. This condition information is used to determine the timing for corrective action to enable rectification prior to catastrophic failure, giving consideration to a reasonably practicable timeframe to plan and complete rectification works.

5.6 Costing and volumes

Ausgrid is proposing to replace the remaining population of single circuit breaker switchgear during the 2019-24 period. Replacing these assets allows a number of issues to be addressed which is a result of the obsolete design of this style of substation as well as removing the risks associated with Oil-filled Circuit Breakers (OCBs). The switchgear used at these sites is often retrofitted zone style circuit breakers which have been fitted to the distribution network. This program is continuing from the current regulatory period and the proposed volumes will complete the remainder of the replacement works.

The forecast for the 2019-24 regulatory period for HV OCBs equates to replacement of 0.2% of the 11kV circuit breaker population annually and also reflects Ausgrid's intention to mitigate the risks associated with oil in substations. These circuit breakers are replaced using a conditional program with testing criteria informing replacement decisions. Replacement of OCBs will continue in subsequent periods due to the size of the asset population and expected increasing volume of identified condition issues as the asset population continues to age.

For zone substation circuit breaker replacement works the forecast for replacement was based on identifying all OCBs in air insulated switchboards in zone substations and cross referencing this to the Area Plan projects list. Any air switchboard forecast to be in service at the end of the 2019-24 regulatory period was assessed as reasonable to complete a vacuum circuit breaker conversion. This is to mitigate the primary risks associated with OCBs. This program is continuing from the current regulatory period and the proposed volumes are to complete the remainder of the replacement work.

Ausgrid is proposing a substantial decrease in planned replacement volumes for 11kV circuit breakers in line with the change to a more conditional replacement program and the completion of a large program of vacuum circuit breaker conversion across zone substations.

These programs form part of the overall investment being proposed for the replacement of 11kV circuit breakers, they can also be captured during Major Projects or as a reactive failure. Refer to the Ausgrid Reset RIN template '2.2 REPEX' for details in regard to the overall investment proposed for this asset category during 2019-24.

The preferred replacement option for high voltage oil circuit breaker and single circuit breaker switchgear is with the current standard ring main fuse switch units (SF6 insulated) within the existing chamber where equipment ratings allow. This is due to the lower lifecycle cost when compared to a circuit breaker arrangement. In some cases this is not practical so other options such as installation of a ring main circuit breaker or replacement of the whole substation are assessed. This is evaluated on a case by case basis.

In the case of 11kV air insulated switchboards with oil filled circuit breakers, the scope of the replacement program includes replacing the 11kV bulk oil circuit breaker with an equivalent 11kV vacuum circuit breaker in the existing housing.

The implied unit cost determined from the repex modelling reflects a variation in unit rates for the different circuit breaker types. Using the benchmark unit rate for this asset category is not reflective of an appropriate cost to replace an 11kV circuit breaker. Ausgrid in the previous regulatory period completed a large number of vacuum circuit breaker conversions which has led to a lower historical unit cost for this RIN category. This also impacted the implied benchmark unit rate. A large number of targeted 11kV circuit breakers are installed in distribution substations which due to their complexity can be of a higher unit cost.

The summary forecast for these replacement programs is shown in Table 22 below. The costs shown are direct costs only.

Table 22. Forecast for 11kV circuit breakers

Direct Costs (real $FY19)	FY20	FY21	FY22	FY23	FY24
HV OCB Subs					
Volumes for replacement	12	12	12	12	12
Unit cost	$193,648	$192,954	$192,668	$192,529	$192,175
Total costs ($M)	**$2.32**	**$2.32**	**$2.31**	**$2.31**	**$2.31**
Single Circuit Breaker Switchgear					
Volumes for replacement	10	10	10	7	0
Unit cost	$175,496	$174,875	$174,635	$174,535	$0
Total costs ($M)	**$1.75**	**$1.75**	**$1.75**	**$1.22**	**$0**
11kV Air Insulated Switchboards - Vacuum CB – ZN					
Volumes for replacement	41	0	0	0	0
Unit cost	$26,786	$0	$0	$0	$0
Total costs ($M)	**$1.10**	**$0**	**$0**	**$0**	**$0**

6 SUBTRANSMISSION CIRCUIT BREAKERS

6.1 Program description

Ausgrid has planned programs targeting the replacement of subtransmission circuit breakers in zone and sub-transmission substations. The purpose of these programs is to address risks associated with assets that are in poor condition and remove risk to the safety of workers and reliability of supply to customers. The programs are:

- 33kV Circuit breakers – General – Sub-transmission (TS) substations (REP_03.04.03)
- 132kV Circuit breakers – General – Zone (ZN) substations (REP_02.03.01).

66kV circuit breakers have no identified systemic issues and are managed through reactive programs which are outlined in Part K (Reactive replacement programs).

Assets are replaced with modern equivalent standards. The total value of these two programs is expected to be $5.6M in direct costs ($, real FY19) for the 2019-24 period.

The age profile highlighting the identified programs for replacement against the total population of subtransmission circuit breakers on the network is shown in Figure 5. The majority of assets identified for replacement are over the standard technical life of 45 years. Ausgrid has had an intense program of replacing degraded circuit breakers over recent regulatory periods which has reduced the average failure rate. Despite this replacement program, 18% of the subtransmission circuit breaker population is over the 45 year standard technical life.

These programs include 33kV circuit breaker equipment not classed as bulk oil including air blast live tank and minimum oil live tank circuit breakers. The bulk oil circuit breakers were targeted for replacement in the current regulatory period and any remaining units will be treated reactively. These programs also include circuit breakers of obsolete design with identified condition issues as shown in Table 23 below below.

Table 23. Asset overview for subtransmission circuit breakers

Program	Overview
33kV Circuit breakers	Targets a particular site that uses obsolete orphan technology (last of its type left on network) of air blast circuit breakers. Ausgrid has experienced catastrophic failures with this technology and a serious injury to an Ausgrid worker. The costs of maintaining these assets are high due to the need to have an associated air system (consisting of pumps, pipework, pressure vessels and gas bottles) to maintain air pressure for operation.
132kV Circuit switches	Replacement of the outdoor early generation SF6 circuit switches that have reached the end of their serviceable life. These are only able to operate load currents but not fault currents which reduces operational flexibility. Ausgrid only has four remaining on the network.

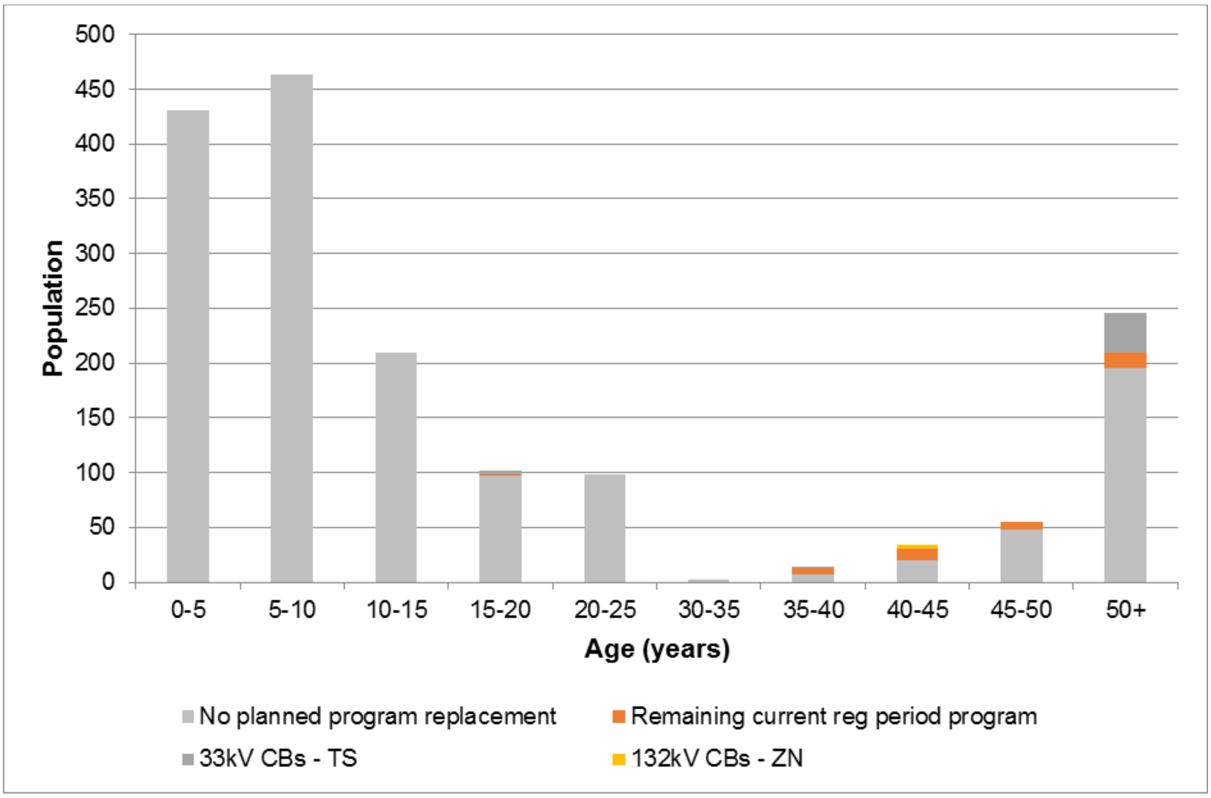
The circuit breakers in the zone and sub-transmission substations are replaced 'like-for-modern like' (utilising either vacuum or SF6 gas as the breaking medium). Modern circuit breaker design significantly reduces the safety risk associated with oil or air technology and has lower maintenance costs.

6.2 Background

Circuit breakers act as an electric switch for 'making' or 'breaking' the electric circuit and when used in conjunction with protection systems, interrupt electrical faults that may develop on the system. Conditional information collected on circuit breakers during preventative maintenance is a good indicator of the internal condition.

Ausgrid has approximately 1,650 circuit breakers at 33kV and above. The age profile of these assets is shown in Figure 5.

Figure 5. Age profile of subtransmission circuit breakers (as at 30 June 2017)



In many cases, the condition of these high voltage assets is considered in conjunction with other site condition or load issues. In these circumstances, and where appropriate, an Area Plan (major) project is issued. This usually occurs where there are multiple issues that are required to be addressed together to understand the least cost solution. For example, the replacement of 33kV bulk oil outdoor circuit breakers in sub-transmission substations are generally conducted under Area Plans projects due to the scale of these rebuilds (and some installations such as indoor configurations make replacement in situ impractical).

6.3 Risks – Consequence and likelihood

The key consequences that can result from a loss of this function are shown in Table 24 below.

Table 24. Consequences from loss of function for subtransmission circuit breakers

Consequences	Description
Harm to the public, communities and workers	Fire caused by a loss of insulation, further propagated by the presence of highly flammable oil within the circuit breaker tank.
	Structural damage to substation as a result of over-pressure within the circuit breaker tank leading to a tank rupture.

Consequences	Description
	Safety issues as a result of loss of supply as detailed below.
	Delay in the disconnection of a downstream fault by a circuit breaker has the potential to put the general public at risk (for example if a line falls to the ground but is not rapidly disconnected).
Harm to the environment	Mineral oil spills can lead to environmental issues.
Damage to property	Damage to surrounding property and other substation equipment as a result of a circuit breaker explosion or fire.
Loss of supply	Network interruption to customers connected to the substation. Interruptions to electricity supply can affect a single customer or whole communities in the form of transport systems, traffic controls, emergency services, business and communication systems, critical infrastructure and vulnerable customers including those on life support systems.

Due to a number of factors, such as deterioration of internal and external components, increasing fault levels, increasing maintenance requirements and inherent equipment design problems these breakers are in poor condition and cannot meet their operational requirement. The failure modes are shown in Table 25.

Table 25. Key failure modes by identified subtransmission circuit breaker type

Switch Type	Key Failure Modes
33kV air blast circuit breaker	Air system leaks.
	Operating mechanism failure.
	Cracking of porcelain.
132kV circuit breaker (switcher design)	SF6 gas leaks.

The inherent failure rate for these circuit breakers is an average of 95 failures per year for the five year period from 2012/13-2016/17 for a population of 1,650 circuit breakers.

Whilst a typical circuit breaker operation would have minimal impact on the network, in the event of a circuit breaker failure there is typically a higher consequence due to a backup protection scheme being required to operate. This results in a larger network impact with a delayed time to disconnect, leading to increased potential for adverse outcomes from the originating fault. Circuit breaker functional failure in sub-transmission and zone substations can cover a large geographic area affecting a larger number of customers.

6.4 Treatment analysis

Assessment of the treatment solutions considered for subtransmission circuit breakers is shown in Table 26 below.

Table 26. Treatment options for managing subtransmission circuit breakers

Treatment Option	Treatment overview
1 Repair the circuit breaker	Undertake repairs to the circuit breaker as conditional issues are identified.

Treatment Option	Treatment overview
2 Refurbish the circuit breaker	Components such as contacts are able to be replaced and the insulating medium renewed.
3 Replace the circuit breaker	Replacement of the circuit breaker.

The different treatment options are all utilised at different points in the asset's lifecycle. A repair may be completed where practical and efficient, particularly where insulation has been compromised. A repair or refurbishment treatment does not remove the inherent risk of the oil and costs a similar order of magnitude and is therefore not the preferred option.

6.5 Options

Ausgrid has considered several options in relation to managing subtransmission circuit breakers. These options and the assessment are set out in Table 27 below.

Table 27. Program options for managing subtransmission circuit breakers

Program need options	Options overview
1 Reactive treatment	Implement treatment such as replacement when the circuit breaker fails.
2 Conditional treatment	Implement treatments to repair or replace circuit breaker equipment when inspections/testing identify they have deteriorated to the point of conditional failure based on a set of criteria.
3 Planned treatment	Implement planned treatment prior to circuit breaker assets failing. Individual assets are built into a priority list of assets to be treated. Assets are replaced in a systematic way starting from the most risky assets.

Ausgrid uses condition information from maintenance and testing activities to determine the overall condition of circuit breaker populations and is able to define individual circuit breakers or classes of circuit breakers as conditionally failed and therefore apply a treatment.

Circuit breakers of vacuum or SF6 breaking medium will be replaced in a conditional manner where inspection and testing can identify issues within the conditional to functional failure warning period. The remaining population of 33kV air blast circuit breakers is located in one substation (Surry Hills) location and are intended to be replaced via a planned approach due to the obsolete nature of this technology. Replacement, in accordance with a priority list, minimises risk and further failures while the population of assets are being replaced.

The option of reactive treatment does not address WH&S issues and potentially increases operating costs in the long term. In the event of a failure, switching parts of the network to manage the outage has a detrimental impact on Ausgrid's ability to operate in an effective and efficient manner.

The remainder of the subtransmission circuit breaker assets will follow a reactive or conditional treatment approach and will be initially managed within the maintenance program. These will be managed through the reactive capital programs of work and are captured in Part K – Reactive programs.

6.6 Costing and volumes

The quantities proposed for 2019-24 for 33kV circuit breakers are sufficient to replace the obsolete 33kV air blast circuit breaker technology used at one substation location (during FY20). The quantities proposed for 2019-24 for 132kV circuit breakers are sufficient to replace the remaining quantity of outdoor installed circuit switches across Ausgrid's network that are approaching end of life.

These programs form part of the overall investment being proposed for the replacement of 33kV and 132kV circuit breakers, they can also be captured during Major Projects or as a reactive failure. Refer to the Ausgrid Reset RIN template '2.2 REPEX' for details in regard to the overall investment proposed for this asset category during 2019-24.

These programs cover the 'like-for-modern' replacement of the 33kV and 132kV circuit breakers. Where reconfigurations of the substation are considered, these works are developed into Area Plan projects and have associated and detailed cost-benefit analysis undertaken.

The implied unit cost determined from the repex modelling reflects a variation in unit rates for the 33kV circuit breaker. The 33kV circuit breakers targeted are a different design to those historically replaced and are all located at one site. This results in a lower unit cost and also impact the implied benchmark unit rate. For the 132kV circuit breakers the unit rate is consistent and no 66kV circuit breakers are targeted as part of the proposed planned programs.

The summary forecast for these replacement programs is shown in Table 28. The costs shown are direct costs only.

Table 28. Forecast for subtransmission circuit breakers

Direct Costs (real $FY19)	FY20	FY21	FY22	FY23	FY24
33 kV Circuit Breakers – General – TS					
Volumes for replacement	41	0	0	0	0
Unit cost	$108,039	$0	$0	$0	$0
Total costs ($m)	**$4.43**	**$0**	**$0**	**$0**	**$0**
132kV Circuit breakers – General – ZN					
Volumes for replacement	2	2	0	0	0
Unit cost	$281,489	$279,789	$0	$0	$0
Total costs ($m)	**$0.56**	**$0.56**	**$0**	**$0**	**$0**

7 SUBTRANSMISSION ISOLATING SWITCHES

7.1 Program description

Ausgrid has a number of planned programs targeting the replacement of subtransmission isolating switches in zone and sub-transmission substations. The purpose of these programs is to address risks associated with assets that are in poor condition and remove risk to general safety of workers and reliability of supply to customers.

The programs are:

- 33kV Essantee isolate and earth switches – Zone (ZN) substations (REP_02.02.35)
- 33kV Isolate and earth switches - Zone (ZN) substations (REP_02.02.38)
- 132kV Motorised I & E Switches – ZN (REP_02.03.02)
- 132kV Motorised I & E Switches – TS (REP_03.03.02).

The above listed programs are long-standing replacement programs, 66kV isolating switches have no identified systemic issues and are managed through reactive programs which are outlined in Part K. In May 2016, the program to replace 33kV isolate and earth switches in Zone Substations was changed from a reactive to planned replacement program following a serious functional failure in a zone substation which resulted in a safety near miss. Assets within these programs are replaced with modern equivalent standards. The total value of these four programs is expected to be $6.5M in direct costs (real $FY19) for the 2019-24 period.

Ausgrid has two programs to replace standalone 33kV switches in zone and subtransmission substations. Both the 33kV types of switches currently being replaced are located in outdoor locations, and have experienced a number of safety incidents due to failures over the last 12 months. The 33kV Essantee Isolator switch was first introduced into the Ausgrid network in 1941 with the majority of the population commissioned during the 1960s. Switches in indoor locations do not have the same failure modes and are not included in this program.

Ausgrid has two programs to replace the manually operated 132kV switches in zone and sub-transmission substations. These switches are approaching end of life and where not associated with a circuit breaker are replaced with a motorised unit to eliminate the need to operate the switch from below the equipment. A portion of the population of these switches have been installed over recent years as manually operated units and will have motors retrofitted under this program.

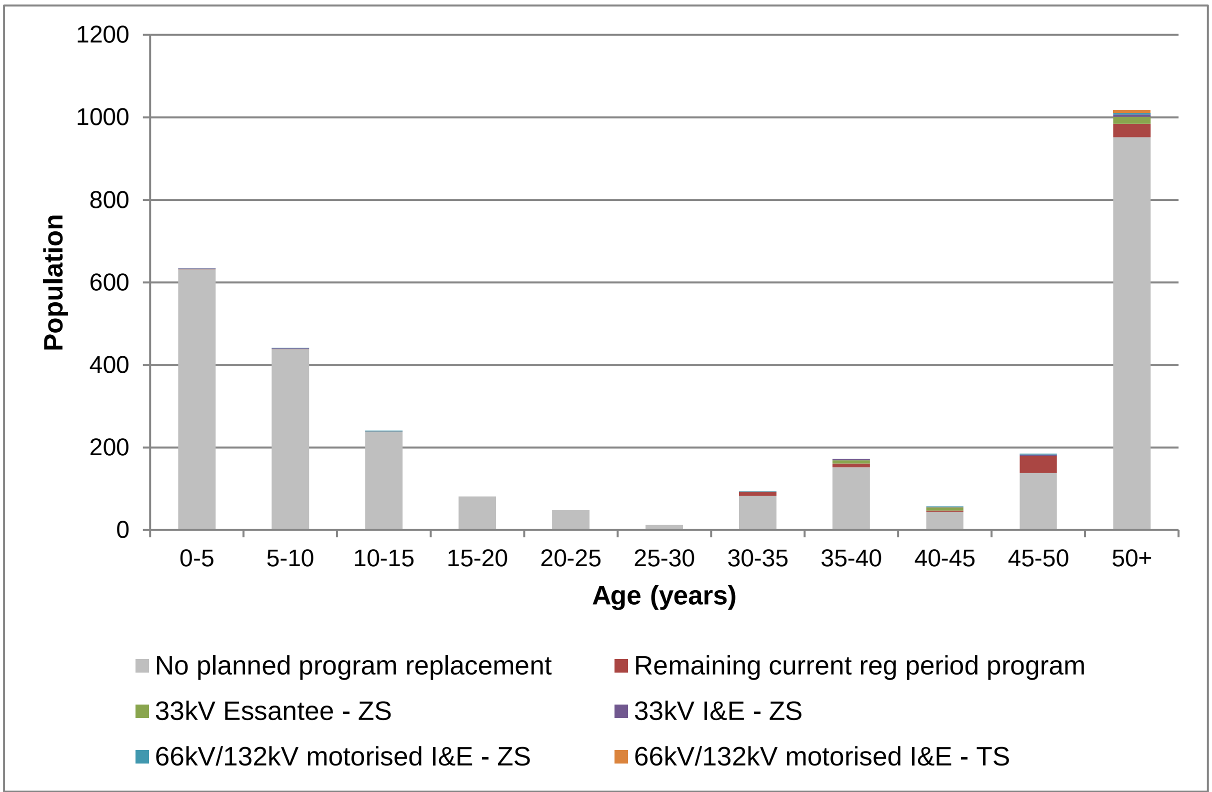
The age profile of assets being replaced in the current and 2019-24 regulatory period is shown in Figure 6 below. The majority of assets identified for replacement are over the standard technical life of 45 years.

7.2 Background

Subtransmission switches provide a point of isolation or connection to the electrical network to allow for the distribution of electricity between transformers, busbars and feeder connections. The switches also provide a functional location for earthing to allow for safe work to occur on various network assets.

Ausgrid has approximately 3,000 subtransmission switches across the network, the age profile is shown in Figure 6 below. Switches are mostly located in outdoor zone and subtransmission substations. These switches are generally operated manually by Ausgrid workers and, as such, there is a safety risk in the event of a failure of the equipment.

Figure 6. Age profile of subtransmission isolating switches (as at 30 June 2017)



In many cases, the condition of these high voltage assets is considered in conjunction with other site condition or load issues. In these circumstances, and where appropriate, an Area Plan project is issued. This usually occurs where there are multiple issues that need to be addressed, to provide a least cost solution.

7.3 Risks – Consequence and likelihood

The key consequences that can result in a loss of this function are shown in Table 29 below.

Table 29. Consequences from loss of function for subtransmission isolating switches

Consequences	Description
Harm to the public, communities and workers	Energised components have the potential to fall on workers during the operation of these devices due to degraded supports.
	Safety issues as a result of loss of supply as detailed below.
Loss of supply	Network interruption to customers connected to the substation. Interruptions to electricity supply can affect a single customer or whole communities in the form of transport systems, traffic controls, emergency services, business and communication systems, critical infrastructure and vulnerable customers including those on life support systems.
Poor network security	Inability to switch the network in response to other failures or planned works due to switches being inoperable.

Ausgrid has a documented history of safety issues associated with the operation of some types of switches. The most common failure modes for the switches are shown in Table 30 below.

Table 30. Key failure modes of subtransmission isolating switches

Switch Type	Key Failure Modes
Switches	Damaged porcelain support isolators.
	Defective operating arms.
	Broken pivot points.
	Corroded support steel work.
	Overheating primary contacts and busbar connections.

The failure rate recorded in the five years between 2012/13-2016/17 is 59 per year which represents the conditional and functional failures of switches installed in zone and subtransmission substations.

The safety consequence of failure of a switch within substations is significant as they require manual operation, placing workers in close proximity to assets during operation.

The 33kV Essantee isolator switches have a history of failures which have impacted reliability of the network and the safety of workers. In 2007, following a series of failures, an investigation to assess the risks posed by 33kV Essantee isolator switches recommended that all outdoor 33kV Essantee isolator switches be replaced according to a recommended priority list.

Since 2016, there have been three safety incidents involving 33kV manually operated "rocker" style switches including a near miss incident where the switch failed while being used by an Ausgrid worker in close proximity. This failure caused live components to dislodge and breach electrical clearances. The contact fell close to live components but did not flash over. Heavy components and molten metals fell close to the worker. This incident triggered a reassessment to vary the program from a reactive to a planned replacement program.

7.4 Treatment analysis

Assessment of the planned treatment solutions considered for these switches is shown in Table 31 below.

Table 31. Treatment option for managing subtransmission isolating switches

Treatment option	Treatment overview
1 Repair the switches	Undertake repairs to the switches as conditional issues are identified.
2 Refurbish the switches	Components such as contacts are able to be replaced, insulators replaced and a motor added.
3 Replace the switches	Replacement is implemented based on a risk-prioritised list of assets. Assets are replaced in a systematic way, beginning with those of highest risk.

The different treatment options are all utilised at different points in the asset's lifecycle. A repair may be completed where practical and efficient, particularly where insulation has been compromised. A repair or refurbishment treatment does not remove the inherent risk of the oil and costs a similar order of magnitude and is therefore not the preferred option.

Replacing the identified degraded switches or installing motors represents a significant reduction in safety risk. Where the replaced switch has the technology to be remotely controlled with a motor it also minimises the exposure risk for operators.

7.5 Options

Ausgrid has considered several options in relation to managing subtransmission switches. These options and the assessment are set out in Table 32 below.

Table 32. Program options for managing subtransmission isolating switches

Program need options	Option overview
1 Reactive treatment	Implement treatment such as repair, refurbish or replacement when the switches fail.
2 Conditional treatment	Implement treatment to switches when inspections/ testing identify they have deteriorated to the point of conditional failure based on a set of predetermined criteria.
3 Planned treatment	Implement planned treatment prior to switch assets failing. Individual assets are built into a priority list of assets to be treated. Assets are replaced in a systematic way starting from the most risky assets.

33kV switches have identified manufacturer and model combinations that are deemed conditionally failed due to conditional issues and the safety risk posed, making a planned replacement approach the most appropriate. Replacement will allow the business to meet WH&S requirements as there is not a viable repair option available.

Deteriorated switches past standard life are to be replaced as part of a planned program. A number of more recent 66kV/132kV switches can have their inherent risk removed by the installation of a motor onto the existing switch as part of a planned refurbishment to allow remote operation.

In the event of a failure, switching of the network to manage the related outage has a detrimental impact on the security of the network as the switches become inoperable and impair Ausgrid's ability to operate in an effective and efficient manner.

7.6 Costing and volumes

The volume of replacement works for 2019-24 for isolating switches allows the replacement of units experiencing condition issues and immediate safety concerns giving consideration to a reasonably practicable timeframe to plan and complete replacement works. The following programs are intended to be completed early in the regulatory period as they are continuing from the current period and are addressing safety concerns:

- 33kV Essantee isolate and earth switches – Zone (ZN) substations (REP_02.02.35)
- 132kV Motorised I & E Switches – ZN (REP_02.03.02)
- 132kV Motorised I & E Switches – TS (REP_03.03.02).

The 33kV isolate and earth switches program addresses emerging issues with this asset style. The forecast for the 2019-24 period equates to replacement of 0.7% of the 33kV isolate and earth switch population annually as part of these programs. Some of these units are replaced as part of Area Plan projects.

These programs form part of the overall investment being proposed for the replacement of 33kV and 132kV isolating switches, they can also be captured during Major Projects or as a reactive failure. Refer to the Ausgrid Reset RIN template '2.2 REPEX' for details in regard to the overall investment proposed for this asset category during 2019-24.

The summary forecast for these replacement programs is shown in Table 33 below. The costs shown are direct costs only.

Table 33. Forecast for subtransmission isolating switches

Direct Costs (real $FY19)	FY20	FY21	FY22	FY23	FY24
33kV Essantee I&Es - ZN					
Volumes for replacement	15	7	0	0	0
Unit cost	$58,431	$57,973	$0	$0	$0
Total costs ($m)	**$0.88**	**$0.41**	**$0**	**$0**	**$0**
33kV I&Es - ZN					
Volumes for replacement	10	10	10	10	10
Unit cost	$58,431	$57,973	$57,610	$57,421	$57,331
Total costs ($m)	**$0.58**	**$0.58**	**$0.58**	**$0.57**	**$0.57**
132kV/66kV Motorised I & E Switches – ZN					
Volumes for replacement	4	0	0	0	0
Unit cost	$167,060	$0	$0	$0	$0
Total costs ($m)	**$0.67**	**$0**	**$0**	**$0**	**$0**
132kV/66kV Motorised I & E Switches – TS					
Volumes for replacement	6	4	0	0	0
Unit cost	$161,946	$160,712	$0	$0	$0
Total costs ($m)	**$0.97**	**$0.64**	**$0**	**$0**	**$0**