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Project justifications for SCADA control protection replacement programs

Ausgrid

Content

1 INTRODUCTION

1.1 SCADA, network control and protection systems on our network

Supervisory Control And Data Acquisition (SCADA), network control and protection systems are an essential part of Ausgrid's distribution and transmission network required to operate the network effectively and safely. The primary function of these assets is to monitor the state of the network in real time and respond to emergencies. This category is broadly defined as secondary systems assets and includes a variety of equipment:

- Protection systems including relays
- Communications links and associated hardware
- Control and monitoring systems
- Batteries and associated chargers
- Wholesale metering equipment.

As at June 2017, there were approximately 77,000 SCADA, network control and protection systems devices across the Ausgrid network. There are many manufacturers and models of SCADA, network control and protection systems. The volume and variety of legacy assets presents a significant challenge to mitigating the risks of these assets.

The majority of assets included in replacement programs are obsolete, and in many cases exceed their standard technical life. Spare parts are often unavailable, the equipment is no longer supported by the manufacturer, and is incompatible with other new equipment. Repairing or upgrading this type of equipment is often not possible or cost effective and does not mitigate the inherent risks associated with some of the designs.

1.2 Changes in technology

The development of electronic components and microprocessors has had a major impact on the technology in this category. Early equipment consisted of electromechanical devices with moving parts. Equipment involving discrete electronic components followed. Current technology is microprocessor based which allows more functionality from a single unit. Modern systems also enable enhanced integration between devices and can have their full potential realised when used in combination with an Advanced Distribution Management System (ADMS).

1.3 Working out what we need to replace

Assets in this category are degrading and legacy systems are obsolete and incompatible with new systems. Asset condition is leading to increased failure rates and there are limited options to repair. Where ‘like for like’ replacement options exist, they are expensive as they are generally only manufactured for Ausgrid. Ausgrid’s approach is to enable the future technology where benefits exist through targeted planned programs, without over investing.

1.4 Summary of programs

Ausgrid has 19 programs targeting the replacement of SCADA, relays, modems, batteries and audio frequency load control systems. In total, Ausgrid plans to spend $78.7 million in direct costs ($, real FY19) on replacement programs in the 2019-24 regulatory period.

The following programs are discussed in further detail below:

- Relays ($29.7 million)
- SCADA equipment ($18.3 million)
- Modems ($18.2 million)
- Batteries ($4.7 million)
- Audio frequency load control ($3.0 million)
- Wholesale metering equipment ($4.6 million).

2 RELAYS

2.1 Program description

Ausgrid has nine planned programs to replace and upgrade legacy protection schemes and relays. A subset of Ausgrid's population of protection schemes have been identified as having known potential for hidden failure modes with the potential to compromise the operation of Ausgrid's network leading to the development of replacement programs.

The programs address assets at end of life and obsolete equipment that have been superseded by new technology and have limited options for repair.

The planned replacement programs are:

- Protection schemes – zone substations (REP_02.02.51)
- Protection schemes – sub-transmission substations (REP_03.02.39)
- Protection relays – zone substations (REP_02.03.08)
- Protection relays – sub-transmission substations (REP_03.03.05)
- High impedance busbar protection – zone substations (REP_02.02.61)
- High impedance busbar protection – sub-transmission substations (REP_03.02.60)
- Voltage regulation equipment – zone substations (REP_02.03.10)
- 11kV switchboard protection – zone substations (REP_02.02.60)
- Intertripping schemes – distribution substations (REP_01.02.61).

The total value of these programs in the 2019-24 regulatory period is $29.7 million in direct costs ($FY19).

The age profile highlighting the identified programs for replacement against the total population of relays on the network is shown in Figure 1.

Programs with specific additional drivers are outlined below:

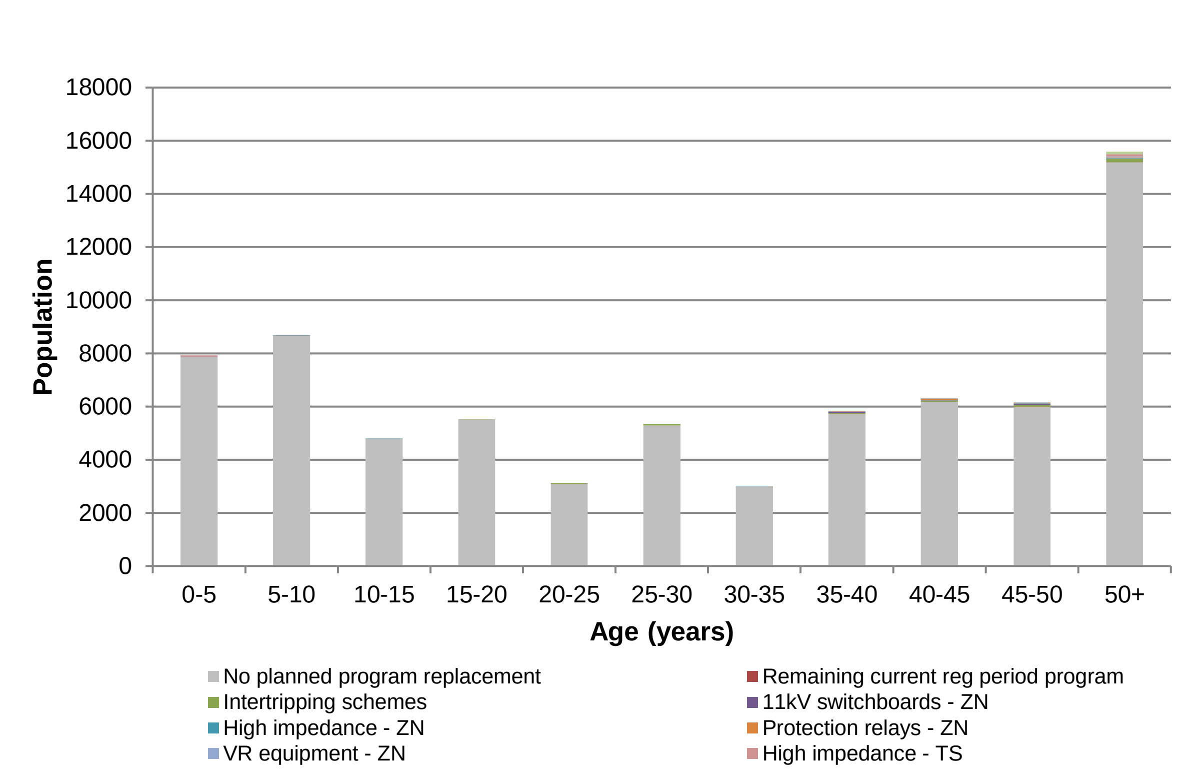
- The 11kV switchboard protection program was driven by the need to ensure the reliable protection of 11kV switchboards that have had vacuum circuit breakers retrofitted to enable their ongoing operation
- Intertripping schemes are completely dependent upon the degrading pilot wire network. The failure modes of pilot wires are hidden and remain undetected until required to operate. These assets also experience high levels of degraded insulation and mechanical damage. These assets are considered to be at the end of their standard technical life.

2.2 Background

Ausgrid has over 72,000 relays installed across the network in sub-transmission, zone and distribution substations. Relay technology on Ausgrid’s network includes electromechanical, static (constructed from discrete electronic components) and microprocessor based relays.

The age profile of protection relays on Ausgrid’s network is shown in Figure 1**Error! Reference source not found.** below.

Figure 1. Age profile of relays (as at 30 June 2017)



The relays that are being targeted for replacement are beyond the standard technical life. Electromechanical relays have a standard technical life of 45 years. This is significantly higher than modern digital / micro-processor based relays which have a standard technical life of 15 years. Electromechanical type relays are older technology and 36% of Ausgrid's electromagnetic relays are beyond 45 years and are approaching end of life. The electromagnetic relays are being replaced with modern standard micro-processor based relays.

Microprocessor based relays represent the modern standard in relay technology and offer wider benefits including reduced maintenance (through self monitoring) and interoperability (i.e. "plug and play" components that enable parts to be replaced easily if they fail). Modern relays also enable more data collection as Ausgrid transitions to an ADMS as they have the ability to capture and communicate real time data. Modern relays also allow multiple functions to be combined into a single unit reducing the number of relays required.

Relays functions and schemes are summarised below in Table 1.

Table 1. Asset overview for relays

Type	Overview
Protection relays	Protection relays are a component of the overall protection scheme that detects and initiates control signals to clears faults on the electrical network. The types of equipment protected by these schemes include conductors, busbars, and reactive plant such as transformers, capacitors and reactors.
Voltage regulation relays	Voltage regulating relays are installed within schemes in Ausgrid's zone and sub-transmission substations to maintain the voltage levels on the distribution network within limits specified in the National Electricity Rules (Clause S5.1.5). This requirement forms part of Ausgrid's operating licence conditions (Clause 3).

Type	Overview
11kV switchboard protection	Frame leakage and busbar protection schemes are commonly installed in zone substations to detect and clear faults on 11kV switchboards.
High impedance busbar protection	High impedance busbar protection is employed on indoor and outdoor switchboards at zone and subtransmission substations to provide rapid clearing of faults.
Intertripping schemes	In some of Ausgrid's legacy distribution substation designs, a dedicated circuit breaker or switch was not used for each transformer and feeder. Rather a copper pilot was used to provide a communications medium to allow a circuit breaker at a remote location to be operated in the event of a fault.

2.3 Risk – Consequence and likelihood

The key consequences that can result in a loss of this function are shown in Table 2.

Table 2. Consequences from loss of function for relays

Consequences	Description
Harm to the public, communities and workers	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 operation of the relay and switchgear).
	Safety issues as a result of loss of supply as detailed below.
Damage to property	Damage to surrounding property and other substation equipment as a result of a delayed protection operation.
	Customer equipment can be damaged due to voltages fluctuating outside of acceptable limits.
Loss of supply	Network interruption to customers connected to the substation. Interruptions to electricity supply for an extended period 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.

Failure to maintain adequate protection of the electricity network is a breach of the National Electricity Rules and Ausgrid's operating licence. Electromechanical relays are being targeted for replacement and the failure rates of this type of relay are:

- 50 recorded conditional and functional failures of protection relays over a five year period from 2012/13 to 2016/17, these were found as part of maintenance and network events
- 86 recorded conditional and functional failures of voltage regulation relays over a five year period from 2012/13 to 2016/17, these were found as part of maintenance and network events.

Other relay types are treated with conditional or reactive programs and are included in Part K of this document with other reactive programs. These records do not include all failures of the relays as corrective maintenance activities are often repaired in the field and are not recorded as a failure.

The key failure mode for electromechanical relays is a failure of moving parts due to seizing and wear. These are often recorded as:

- Failure to operate
- Jammed contacts.

A significant portion of Ausgrid's relays utilise electromechanical technology. These fail predominantly in a manner that is not immediately detected (i.e. hidden failure modes). The implication of hidden failure modes is that they remain undetected until the asset is required to operate at which time the relay fails to perform its function. Furthermore, many of the older relays are no longer supported by manufacturers, spare parts are not readily available, and a reactive replacement would require a technology change which is time consuming to implement as it often requires redesign.

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

2.4 Treatment analysis

Assessment of the planned treatment solutions considered for relays is shown in Table 3 below.

Table 3. Treatment options for managing relays

Treatment option	Option overview
1 Repair the relay	Undertake repairs to the relay as conditional issues are identified.
2 Refurbish the relay	Components such as springs can be rewound and the relay recalibrated.
3 Replace the relay	Replacement of the relay with a modern equivalent.

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 the skills required to undertake this refurbishment are specialised and the cost compared to organisational benefit is prohibitive. Replacement removes the inherent design risks associated with these assets and enables additional monitoring and network control.

Improvements in the technology of modern microprocessor relays means advantages including inbuilt supervisory, fault detection and multi-functionality can be realised at the same time. This allows the detection and communication of some internal failures of the relay and the consolidation of multiple legacy relay functions into one.

2.5 Options

The options considered in relation to the treatment of legacy relays and schemes are summarised in Table 4 below.

Table 4. Program options for managing relays

Program needs options	Option overview
1 Reactive treatment	Implement treatment such as repair or replace when the relay fails.
2 Conditional treatment	Implement treatments to repair or replace relays when inspections or 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 relay 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.

A planned replacement of these identified assets is the preferred option. Electromechanical relays have known condition issues, hidden failure modes and most are beyond their standard life. A planned replacement approach ensures that all the assets will be replaced in an efficient manner with the lowest customer impact.

2.6 Costing and volume

Approximately 0.1% of the relay population is to be replaced as part of replacement programs each year due to the risks and average age of these assets. Historically assets were replaced as part of other programs and Area Plan projects. The forecast volume supports Ausgrid's strategy to leverage automation functionality within the network for customer benefit as it adopts an ADMS. These programs form part of the overall investment being proposed for the replacement of relays, and 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.

Ausgrid establishes period contracts for the procurement of relay equipment. This is market tested by a competitive tender process, which allows for standardisation and reduces the time and effort required for each installation as the relays are pre-configured. The total population of specific relay types has been identified for replacement in planned programs. When combined with the impact of planned Area Plan projects, the forecast replacement program volumes are expected to sustainably manage the risks associated with a deteriorating asset population in a prioritised order so those of highest risk are completed first.

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

Table 5. Forecast for relays for 2019-24

Direct Costs (real $FY19)	FY20	FY21	FY22	FY23	FY24
Protection schemes – zone substations					
Volumes for replacement	0	0	3	3	0
Unit cost	$0	$0	$182,052	$181,551	$0
Total costs ($m)	**$0**	**$0**	**$0.55**	**$0.54**	**$0**
Protection schemes – sub-transmission substations					
Volumes for replacement	0	0	3	3	0
Unit cost	$0	$0	$182,053	$181,552	$0
Total costs ($m)	**$0**	**$0**	**$0.55**	**$0.54**	**$0**
Protection relays – zone substations					
Volumes for replacement	17	17	17	17	17
Unit cost	$71,501	$71,122	$70,900	$70,734	$70,470
Total costs ($m)	**$1.22**	**$1.21**	**$1.21**	**$1.20**	**$1.20**
Protection relays – sub-transmission substations					
Volumes for replacement	21	21	21	20	20

Direct Costs (real $FY19)	FY20	FY21	FY22	FY23	FY24
Unit cost	$16,797	$16,683	$16,617	$16,567	$16,488
Total costs ($m)	**$0.35**	**$0.35**	**$0.35**	**$0.33**	**$0.33**
High impedance busbar protection – zone substations					
Volumes for replacement	3	3	3	3	3
Unit cost	$203,539	$202,740	$202,274	$201,924	$201,367
Total costs ($m)	**$0.61**	**$0.61**	**$0.61**	**$0.61**	**$0.60**
High impedance busbar protection – sub-transmission substations					
Volumes for replacement	2	2	2	2	2
Unit cost	$203,539	$202,740	$202,274	$201,924	$201,367
Total costs ($m)	**$0.41**	**$0.41**	**$0.40**	**$0.40**	**$0.40**
Voltage regulation equipment – zone substations					
Volumes for replacement	16	16	16	16	16
Unit cost	$100,155	$99,512	$99,512	$98,855	$98,407
Total costs ($m)	**$1.60**	**$1.59**	**$1.59**	**$1.58**	**$1.57**
11kV switchboard protection – zone substations					
Volumes for replacement	2	3	2	3	2
Unit cost	$284,955	$283,836	$283,183	$282,693	$281,914
Total costs ($m)	**$0.57**	**$0.85**	**$0.57**	**$0.85**	**$0.56**
Intertripping schemes – distribution substations					
Volumes for replacement	6	6	6	6	6
Unit cost	$115,057	$114,482	$114,147	$113,895	$113,494
Total costs ($m)	**$0.69**	**$0.69**	**$0.68**	**$0.68**	**$0.68**

3 SCADA EQUIPMENT

3.1 Program description

These programs have been developed for the replacement and upgrading of SCADA equipment that has reached the end of its standard technical life. These replacement works are largely driven by obsolescence and lack of supportability. The planned programs are:

- SCADA equipment – distribution substations (REP_01.02.59)
- SCADA schemes – zone substations (REP_02.02.46)
- SCADA equipment – zone substations (REP_02.02.62)
- SCADA schemes – sub-transmission substations (REP_03.02.34)
- SCADA equipment – sub-transmission substations (REP_03.02.61).

The total value of these programs in the 2019-24 regulatory period is $18.3 million in direct costs ($, real FY19). These programs have been reactive in the current regulatory period and are changing to planned due to the volume of assets over standard life and the need to manage supportability issues and cybersecurity requirements in License Conditions. Ausgrid is proposing to split these programs into those able to be replaced by Remote Terminal Unit (RTU) equipment replacement compared to those that require a replacement of the entire scheme.

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

Ausgrid has numerous unsupported proprietary SCADA systems and components installed in sub-transmission, zone and distribution substations that are now beyond their standard technical life. In all cases the maintenance and support (including replacement parts) has ceased for these legacy systems (those identified for replacement) as the hardware components are obsolete.

Ausgrid's legacy proprietary SCADA equipment cannot support modern feeder protection relays and will not support the enablement of future network capability including the integration into an ADMS.

3.2 Background

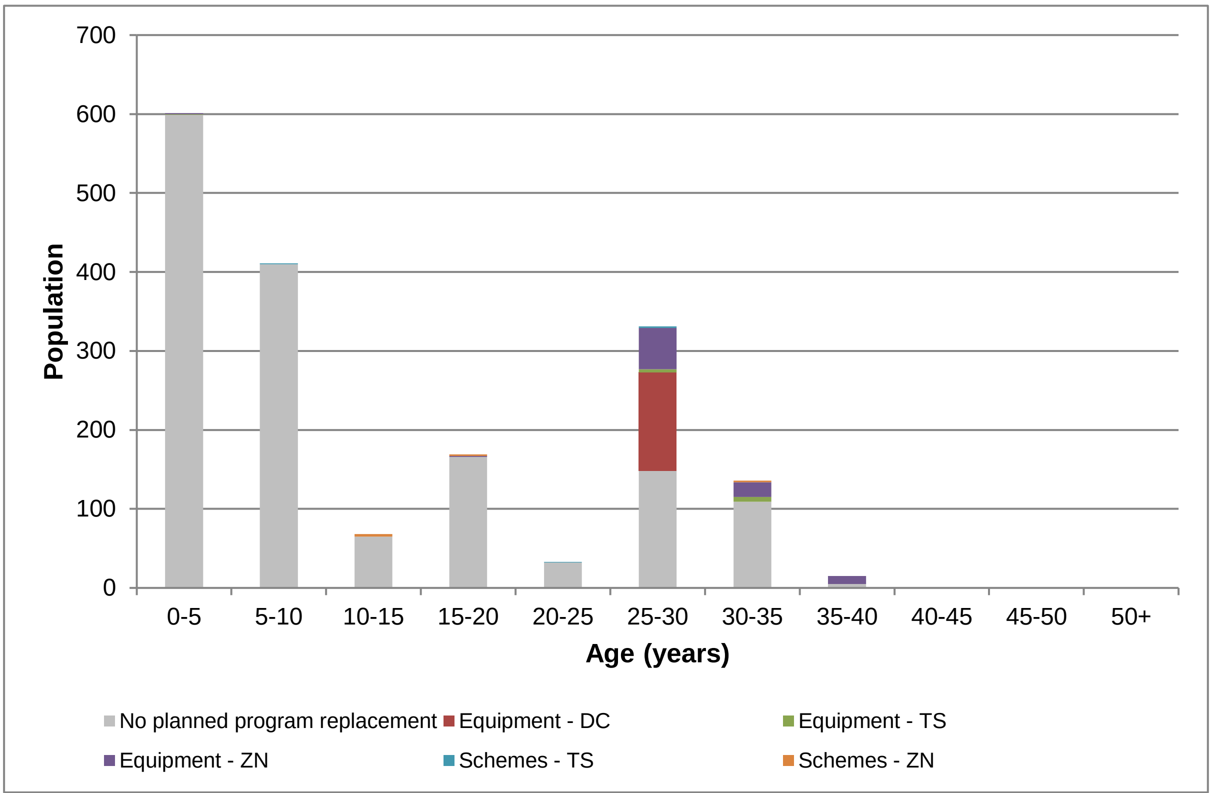
Ausgrid's network system comprises a large number of interconnected assets. In order for these assets to be safely and reliably managed, SCADA equipment is used to locally and remotely monitor and control electrical equipment and to collect data on asset performance.

SCADA is a system of hardware and software which is used to gather and process real time data from the network for the purpose of monitoring and controlling network equipment. The capability of SCADA for monitoring and operation of network equipment in real time enables Ausgrid to:

- Respond to faults and outages in a timely manner
- Facilitate compliance with reliability targets under the licence conditions
- Mitigate the safety risks associated with operating an electricity network.

The age profile of the approximately 1,760 SCADA equipment items is shown in Figure 2 below. All SCADA equipment on the network is less than 40 years old reflecting the period in the 1970s when SCADA was introduced onto Ausgrid's network. The standard technical life of SCADA assets is 30 years, with 9% of the recorded population being over this age.

Figure 2. Age profile of SCADA equipment and schemes (as at 30 June 2017)



Examples of equipment which can be controlled remotely using SCADA systems include transformers, circuit breakers and protection systems. SCADA can also receive data on voltage and current levels, circuit breaker status and metering data as well as other equipment.

3.3 Risks – Consequence and likelihood

The key consequences that can result in a loss of this function are shown in Table 6 below.

Table 6. Consequences from loss of function for SCADA equipment and schemes

Consequences	Description
Harm to the public, communities and workers	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.
	If SCADA is not available, electronic circuit breaker operation will not be available. Workers will be required to operate the network manually at the local site putting them at greater potential for harm as well as increased delay in switching to restore the network.
Breach of National Electricity Rules	Ausgrid is required to maintain visibility of the status of the network at a number of sites that form the transmission network.
Damage to property	Damage to substation or mains equipment as the result of overload due to status and load being unknown.

The equipment in the proposed planned programs no longer has the manufacturer's support for maintenance as numerous hardware components are obsolete. A large proportion of the current SCADA equipment is not compatible with the protection relays or protocols of equipment being installed.

Over the five year period between 2012/13 to 2016/17, there have been 76 recorded conditional and functional failures affecting Ausgrid's SCADA assets.

3.4 Treatment analysis

Assessment of the planned treatment solutions considered for SCADA systems is shown in Table 7 below.

Table 7. Treatment options for managing SCADA equipment and schemes

Treatment option	Treatment overview
1 Repair the SCADA system	Undertake repairs to the SCADA system as conditional issues are identified.
2 Refurbish the SCADA system	Removable cards within the devices are able to be replaced if compatible equivalents can be obtained.
3 Replace the SCADA system	Replacement of the SCADA system

The different treatment options are all utilised at different points in the asset's lifecycle. A repair may be completed where practical and efficient. Due to the general poor condition, age and lack of certainty about length of life this would achieve, a refurbishment is not considered practical or viable.

3.5 Options

The assessment of the available options to manage the risks associated with Ausgrid's SCADA systems is set out in Table 8.

Table 8. Program options managing SCADA equipment and schemes

Program needs options	Option overview
1 Reactive treatment	Implement treatment such as repair, refurbish or replacement when the SCADA assets fail.
2 Conditional treatment	Implement treatment for the SCADA assets when inspections or 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 SCADA 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.

There is no practical way to determine when a degraded SCADA system is pending failure. Recent installed versions monitor their health and send a warning alarm, e.g. in the event of a fan failure within the power supply. A planned replacement of these identified assets is the preferred option. Improvements in the technology of modern microprocessor SCADA equipment means advantages including inbuilt supervisory or fault detection can be realised at the same time. Over time as these new devices are installed, Ausgrid will be able to transition to a conditional replacement program.

Having correctly functioning SCADA equipment is a compliance requirement under the National Electricity Rules and the Ausgrid licence conditions so a planned replacement approach is the most prudent approach for the older style units identified.

3.6 Costing and volume

The forecast replacement quantities of SCADA equipment and schemes have been based on the historical identification of conditional and functional failures. This forecast is expected to sustainably manage the risks associated with technology changes and an aging asset population.

The SCADA assets are approaching end of life and therefore a more proactive replacement strategy was deemed appropriate as opposed to the historical reactive treatment. SCADA equipment has been historically captured as part of Area Plan projects or reactive work.

Approximately 2.9% of the SCADA population is planned to be replaced each year due to the average age of these assets, this will manage the population to slightly above standard technical life. The forecast volume supports Ausgrid's strategy for leveraging automation capability within the network for customer benefit as it adopts an ADMS. These programs form part of the overall investment being proposed for the replacement of SCADA equipment, and 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.

Ausgrid has undertaken detailed analysis on the different equipment utilised as part of SCADA systems and determined that there are two distinct scopes; as such, this has resulted in the schemes and equipment programs:

- The equipment programs are targeted at replacing the central RTU hardware at these locations with a modern equivalent
- The scheme programs are for a small number of sites that require a complete rework of the hardware, software and sensing devices due to incompatibility of the existing installation with currently available equipment.

The summary forecast for these replacement programs is shown in Table 9. The costs shown are direct costs only.

Table 9. SCADA equipment replacement forecast

Direct Costs (real $FY19)	FY20	FY21	FY22	FY23	FY24
SCADA equipment – distribution substations					
Volumes for replacement	25	25	25	25	25
Unit cost	$61,062	$60,822	$60,682	$60,577	$60,410
Total costs ($m)	**$1.53**	**$1.52**	**$1.52**	**$1.51**	**$1.51**
SCADA schemes – zone substations					
Volumes for replacement	1	1	1	1	1
Unit cost	$468,077	$466,137	$465,003	$464,153	$462,807
Total costs ($m)	**$0.47**	**$0.47**	**$0.47**	**$0.46**	**$0.46**
SCADA equipment – zone substations					

Direct Costs (real $FY19)	FY20	FY21	FY22	FY23	FY24
Volumes for replacement	15	15	15	15	15
Unit cost	$61,062	$60,822	$60,682	$60,577	$60,410
Total costs ($m)	**$0.92**	**$0.91**	**$0.91**	**$0.91**	**$0.91**
SCADA schemes – sub-transmission substations					
Volumes for replacement	1	1	1	1	1
Unit cost	$468,077	$466,137	$465,003	$464,153	$462,807
Total costs ($m)	**$0.47**	**$0.47**	**$0.47**	**$0.46**	**$0.46**
SCADA equipment – sub-transmission substations					
Volumes for replacement	5	5	5	5	5
Unit cost	$61,062	$60,822	$60,682	$60,577	$60,410
Total costs ($m)	**$0.31**	**$0.30**	**$0.30**	**$0.30**	**$0.30**

4 MODEMS

4.1 Program description

The third generation (3G) mobile cellular network, which is used by Ausgrid's modems, is planned to be retired by Telstra from 2020 onwards. Before this occurs, the affected modems need to be replaced. Ausgrid has two programs targeted at replacing the population of modems. Both replacement programs are driven by an obsolescence of the 3G technology.

The two replacement programs are:

- Modems – distribution substations (REP_01.02.60)
- Modems – distribution mains (REP_04.02.48).

These replacement programs will commence in the 2019-24 regulatory period. The combined value of these programs in the 2019-24 regulatory period is $18.2 million in direct costs ($, real FY19).

Ausgrid has been advised by Telstra that the 3G mobile network will be retired. The existing population of modems will not function after the 3G cellular network is decommissioned and the planned modem replacement programs is required to address this.

Telstra has announced a plan to begin the retirement from 2019/20[1]. Table 10 information has been supplied to Ausgrid by Telstra in regards to the remaining life of 3G and fourth generation (4G) devices.

Table 10. Telstra Mobile Technology 2020-30

Telstra Mobile Technology	2020	2022	2025	2028	2030
3G HSPA	Available	Likely available	50/50 available	Unlikely available	Not available
4G LTE	Available	Available	Available	Available	Likely available

4.2 Background

As at 30 June 2017, there were approximately 6,600 modems installed throughout Ausgrid's network area. Modems are hardware devices which can transmit and receive digital information sent over a fixed or wireless network operated by a telecommunications provider. Modems are used to establish a communications link with equipment capable of monitoring and controlling network assets. More specifically, Ausgrid relies on modems at:

- More than 5,900 distribution substations
- Over 700 line locations (pole top reclosers, voltage regulators, etc)
- Seven zone substations.

The plan is to replace all affected modems in the 2019-24 regulatory period.

Modems are used to communicate the status and load profiles of Ausgrid's distribution network to enable better planning and visibility of the network. In some instances a modem is used to operate and control switching devices either in substations or mounted on poles.

[1] Telstra, November 2016 Investor Day Presentation, 17 November 2016.

Modems are utilised in high bushfire periods to disable recloser operations to minimise bushfire risk.

The entire population of Ausgrid's modems (as at 30 June 2017) relies on the 3G cellular network to transmit and receive digital information. Telstra's announcement presents a need for these modems to be replaced with modems capable of connecting with an available network technology such as 4G. Ausgrid is also considering the need to be compatible with the fifth generation (5G) cellular network as part of these programs.

In addition to addressing obsolescence, the installation of modems with 4G or higher compatibility will allow Ausgrid to implement end-to-end encryption of data sent and received between substations, field devices and Ausgrid's control room. This will provide greater security for the power system against cyber-attacks and other forms of intrusion into Ausgrid's communication systems to comply with the National Electricity Rules.

4.3 Risks – Consequence and likelihood

The key consequences that can result in a loss of this function are shown in Table 11 below.

Table 11. Consequences from loss of function for modems

Consequences	Description
Harm to the public, communities and workers	Reclosers functionality is required to be altered in high bushfire periods to minimise the risk of bushfires from recloser actions.
	Interruptions to electricity supply for an extended period 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.
	Workers will be required to operate the network manually at the local site putting them at greater potential for harm.
Damage to property	Damage to substation or mains equipment as the result of overload due to status and load being unknown.

Ausgrid will not be able to remotely receive data from the network equipment installed in distribution substations and lines once Telstra's 3G network is retired.

4.4 Treatment analysis

Assessment of the planned treatment solutions considered for modems is shown in the following table.

Table 12. Treatment options for managing modems

Treatment option	Treatment overview
1 Repair the modem	No practical option.
2 Refurbish the modem	No practical option.
3 Replace the modem	Replacement of the modem.

Due to the volume of modem assets across the network, Ausgrid is proposing that they be replaced during the 2019-24 period.

4.5 Options

The assessment of the available options to manage the risks associated with Ausgrid's SCADA systems is set out in Table 13.

Table 13. Program options for managing modems

Program needs options	Option overview
1 Reactive treatment	Implement treatment such as replacement when the modem fails.
2 Conditional treatment	Implement treatments to repair or replace modem assets 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 modem assets failing.

Due to the timeframe for Telstra to decommission the 3G network, a planned replacement is the most appropriate option to ensure network services are upgraded in advance of the 3G shutdown dates to minimise risk of disruption to the network. Any modem failures will be treated reactively.

4.6 Costing and volume

Due to the potential unavailability expected of Telstra's 3G network from 2020 (refer to Table 10 above), it is planned that all modems using 3G as the communications medium be replaced during the 2019-24 regulatory period. As this program is driven by the telecommunication availability changes and not previously required, this is a new program which addresses all modems in a timely fashion prior to the planned start of disconnection of devices. Experience gained from the National Broadband Network rollout has highlighted that coordinated replacement works are difficult to achieve with telecommunication's companies. Ausgrid experienced unexpected disconnections during the process of transition. A planned replacement ahead of the proposed start of the 3G disconnection ensures availability of critical services.

This program forms part of the overall investment being proposed for the replacement of modems, refer to the Ausgrid Reset RIN template '2.2 REPEX' for details on the overall investment proposed for this asset category during 2019-24.

The summary forecast for these replacement programs is shown in Table 14. The costs shown are direct costs only.

Table 14. Forecast for modems

Direct Costs (real $FY19)	FY20	FY21	FY22	FY23	FY24
Modems – distribution substations					
Volumes for replacement	1200	1200	1200	1200	1200
Unit cost	$2,728	$2,722	$2,718	$2,716	$2,712
Total costs ($m)	**$3.27**	**$3.27**	**$3.26**	**$3.26**	**$3.25**
Modems – distribution mains					
Volumes for replacement	127	127	127	127	126
Unit cost	$3,038	$3,027	$3,021	$3,017	$3,009

Direct Costs (real $FY19)	FY20	FY21	FY22	FY23	FY24
Total costs ($m)	**$0.39**	**$0.38**	**$0.38**	**$0.38**	**$0.38**

5 BATTERIES

5.1 Program description

Ausgrid has two planned programs to replace substation batteries that are at the end of their technical life. The planned replacement programs are:

- Batteries and battery charging equipment – zone substations (REP_02.03.11)
- Batteries and battery charging equipment – sub-transmission substations (REP_03.03.08).

The total value of these programs is expected to be $4.7 million in direct costs during the 2019-24 regulatory period. These programs will continue from the current regulatory period.

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

The primary function for the battery systems is to provide a source of auxiliary power so that the SCADA, protection relays and circuit breaker coils can continue to function if required during a loss of power to the substation (credible contingency event). A functional battery is required to support Ausgrid's legal obligation to plan for the safe operation of the network in foreseeable abnormal circumstances or during significant disruption to normal operation.

All batteries exhibit wear out due to internal chemical degradation processes. Batteries that have degraded are unable to hold charge and will not operate when required. The degradation of battery systems means that they need to be replaced to provide the required function. Battery chargers are matched to the battery technology and therefore need to be replaced upon battery technology change to maintain compatibility.

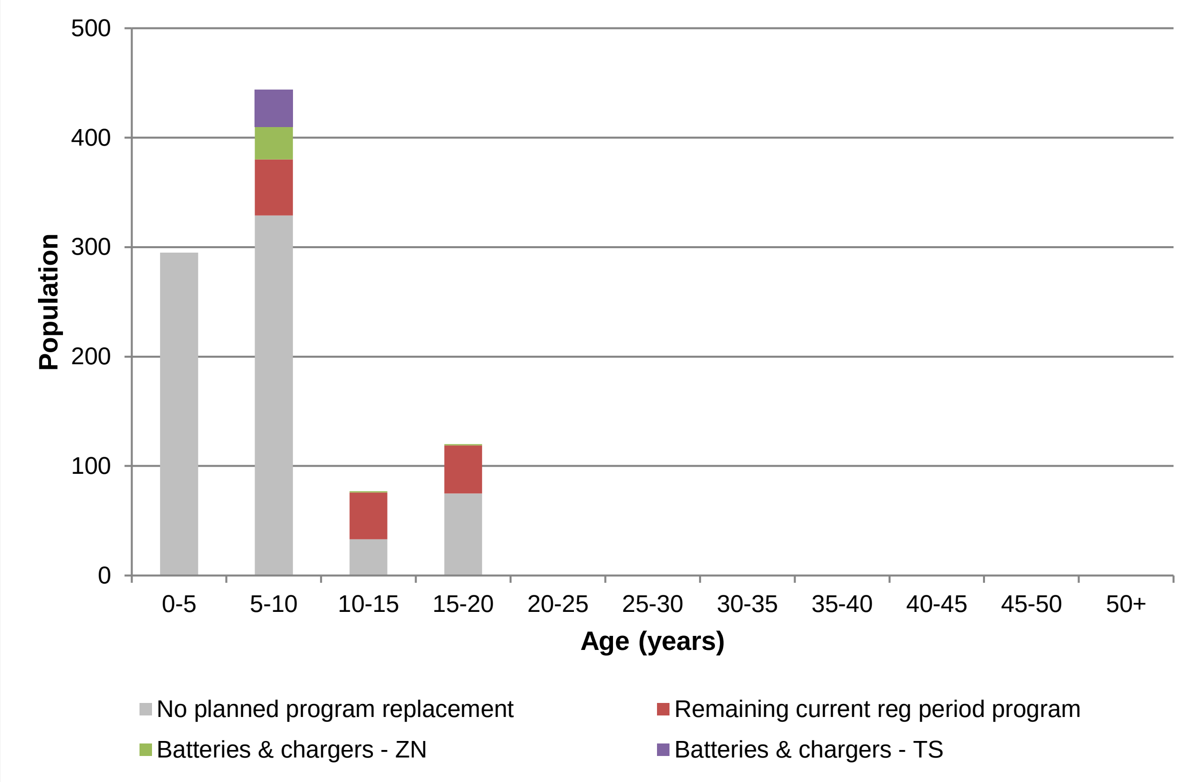
5.2 Background

There are approximately 3,000 battery and charger assets installed on Ausgrid's network. Ausgrid requires battery installations in zone and subtransmission substations to provide an auxiliary power source in the event of loss of network supply to the substation. The batteries provide power to the SCADA, protection relays and circuit breaker coils to enable it to remotely function during a loss of network supply to the substation. This equipment is normally supplied by the battery charger as they are DC operated components. In some cases the fire and security systems are also supported by the batteries in the event of a loss of network supply.

Since 2009, Ausgrid's preferred battery technology for battery installations in zone and subtransmission substations is valve regulated lead acid (VRLA). The current battery supplier specifies a standard technical life of 12-15 years for their product. This replaced a previous battery technology that had a standard technical life of 20 years, however this was significantly more expensive.

The age profile for all the batteries and battery chargers on Ausgrid's network is shown in Figure 3.

Figure 3. Age profile of batteries and charging equipment (as at 30 June 2017)



5.3 Risks – Consequences and likelihood

The key consequences that can result in a loss of this function are shown in Table 15.

Table 15. Consequences from loss of function for batteries and charging equipment

Consequences	Description
Harm to the public, communities and workers	Interruptions to electricity supply for an extended period 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.
	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).
	Auxiliary supply will not be available so electronic circuit breaker operation will not be available. Workers will be required to operate the network manually at the local site putting them at greater potential for harm and increase network restoration times.
Breach of National Electricity Rules	Ausgrid is required to maintain visibility of the status of the network at a number of sites that form the transmission network.
Damage to property	Damage to surrounding property and other substation equipment as a result of a delayed protection operation.

If a degraded battery is not replaced, the capacity to provide auxiliary supply when called upon will be inadequate and the functions of operation through protection or remote operation will be lost.

The key failure modes for the batteries are:

- Loss of capacity (cell internal fault)
- Degraded contacts.

The key failure mode for the battery charger is that the electronic components fail.

Over the five year period from 2012/13 to 2016/17, there have been 643 recorded conditional and functional failures affecting Ausgrid's battery and charger assets.

5.4 Treatment analysis

Assessment of the planned treatment solutions considered for batteries and battery chargers is shown in Table 16.

Table 16. Treatment options for managing batteries and charging equipment

Treatment option	Treatment overview
1 Repair the battery system	Undertake repairs to the battery system as conditional issues are identified.
2 Refurbish the battery system	Battery cells can be regenerated through refilling the electrolyte and reconditioning contacts.
3 Replace the battery system	Replacement of the battery and/or battery charger.

The different treatment options are all utilised at different points in the asset's lifecycle. A repair may be completed where practical and efficient. Repair does not remove the risk of obsolete technology.

Due to the sealed nature of valve regulated lead acid batteries, refurbishment is not considered practical. Refurbishment is practical for Nickel Cadmium style batteries which are used in distribution substations. Replacement removes the inherent risks associated with the obsolete technology of these assets.

5.5 Options

The battery assets experience chemical degradation which increases the rate of failure. A run to failure approach could risk safety, reliability and security of supply on the network. As part of maintenance, battery discharge testing is conducted however this testing is a new approach and the degradation rate is unknown. Further analysis based on experience will allow this option to be realised in the future. The assessment of the available options to manage the risks associated with Ausgrid's battery systems is set out in Table 17 below.

Table 17. Program options for managing batteries and charging equipment

Program needs options	Option overview
1 Reactive treatment	Implement treatment such as repair, refurbish or replacement when the battery systems fail.
2 Conditional treatment	Implement treatment to the battery assets 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 battery systems 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.

Due to the nature of battery technology, the recommended life of 12 to15 years is the accepted industry standard. A planned replacement approach ensures that all the assets will be replaced with the lowest network and customer impact.

Ausgrid use a variety of options to manage batteries:

- Distribution substations batteries – combination of refurbish and replacement reactively
- Distribution substations battery chargers – replaced reactively
- Zone and sub-transmission batteries – planned replacement
- Zone and sub-transmission battery chargers – reactive replacement.

As individual cells are identified as failed as part of condition monitoring (either real-time or during maintenance), they will be reactively replaced or refurbished.

5.6 Costing and volume

These programs form part of the overall investment being proposed for the replacement of batteries, and 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.

Ausgrid has identified efficiencies that can be leveraged with its population of batteries and charging equipment through the installation of real time voltage monitoring connected to the SCADA system. The retrofitting of this monitoring onto the existing population of batteries reduces the likelihood of an increase to maintenance requirements as the batteries age and as this data becomes more mature, will allow a conditional replacement approach to be utilised. Ausgrid is proposing to replace 2.5% of the zone and subtransmission battery population annually in a planned manner to manage the fleet of batteries in a sustainable manner while the organisational knowledge regarding the condition bases replacement approach and parameters required is developed.

The replacement batteries will be sourced using procurement processes to obtain the best market value. The battery technology used in zone and sub-transmission substations is expected to remain constant so the charger is able to be reused rather than replaced which reduces the required expenditure.

The summary forecast for these replacement programs is shown in Table 18. The costs shown are direct costs only.

Table 18. Forecast for batteries and charging equipment

Direct Costs (real $FY19)	FY20	FY21	FY22	FY23	FY24
Batteries and battery charging equipment – zone substations					
Volumes for replacement	10	10	10	10	10
Unit cost	$72,679	$72,370	$72,189	$72,054	$71,838
Total costs ($m)	**$0.73**	**$0.72**	**$0.72**	**$0.72**	**$0.72**
Batteries and battery charging equipment – sub-transmission substations					
Volumes for replacement	3	3	3	3	3
Unit cost	$71,185	$70,779	$70,459	$70,291	$70,204

Direct Costs (real $FY19)	FY20	FY21	FY22	FY23	FY24
Total costs ($m)	**$0.21**	**$0.21**	**$0.21**	**$0.21**	**$0.21**

6 AUDIO FREQUENCY LOAD CONTROL

6.1 Program description

The program for the replacement of audio frequency load control (AFLC) equipment addresses condition issues with existing poor condition equipment which has reached the end of its standard technical life. The planned replacement program is:

- Audio Frequency Load Control Equipment – Zone substations (REP_02.02.64).

The total value of the program is expected to be $3.0 million in direct costs ($, real FY19) during the 2019-24 regulatory period.

The age profile highlighting the identified programs for replacement against the total population of audio frequency load control equipment on the network is shown in Figure 4.

The need to replace these assets is driven by the deteriorating condition of the motor generators and inverters requiring increased maintenance making replacement with a modern equivalent the lowest lifecycle cost approach.

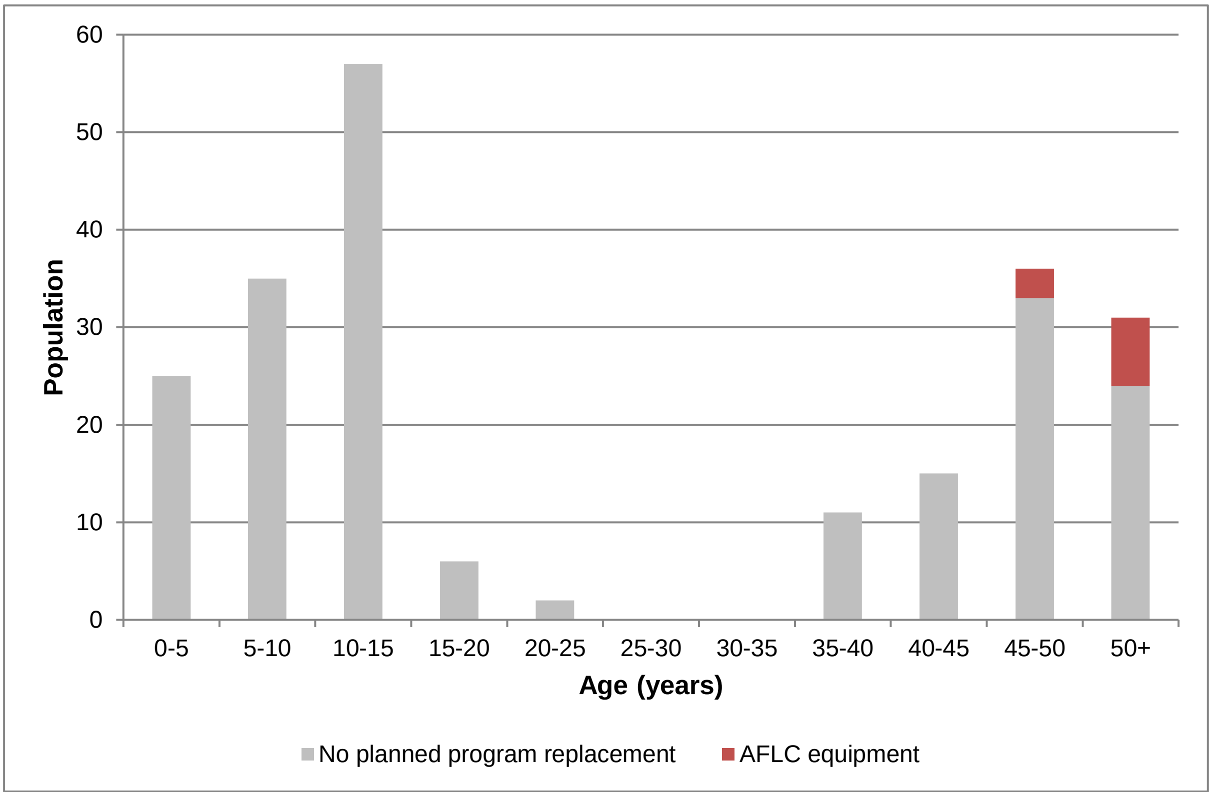
6.2 Background

An AFLC system is a one-way communication method used to switch on and off certain types of equipment generally located at the customers premise. Ausgrid operates an AFLC system where signals are superimposed on the 50Hz supply voltage waveform. The AFLC system is used for remote switching of equipment through the low voltage mains supply such as water heaters, street lighting and metering.

Ausgrid's AFLC equipment is located at zone substations. AFLC cells installed within Ausgrid's network consist of a motor generator set or an inverter connected to a coupling cell. This program covers the replacement of aged motor generators and degrading inverters that compromise the operation of Ausgrid's load control network.

The age profile of the AFLC equipment is shown in Figure 4. Also shown is the age profile of the assets that are planned to be replaced. 31% of AFLC equipment is beyond the standard life of 45 years.

Figure 4. Age profile of AFLC systems (as at 30 June 2017)



6.3 Risk – Consequences and likelihood

The key consequences that can result in a loss of this function are shown in Table 19 below.

Table 19. Consequences from loss of function for AFLC equipment

Consequences	Description
Harm to the public, communities and workers	Interruptions to AFLC systems can affect communities where the local street lighting is switched using this method.
	Workers will be required to attend customers premises to manually turn on load controlled devices (such as hot water) if AFLC supply cannot be restored.
Damage to property	Damage to substation or mains equipment as the result of overload due to inability to switch off controlled loads.
Lack of customer hot water	Where customers utilise off peak hot water systems (approx. 500,000 customers) this will no longer be provided and would not be available until the equipment is repaired or each customer has a worker attend site (this is likely to take weeks).

There have been 26 recorded conditional and functional failures of AFLC equipment for the five year period from 2012/13 to 2016/17. These records do not include all failures of the AFLC as corrective maintenance activities are often repaired on site and are not recorded as a failure. The main failure modes associated with the population of AFLC equipment are:

- Jammed motor-generator set bearings
- Impulse contactor failures.

6.4 Treatment analysis

Assessment of the planned treatment solutions considered for AFLC equipment is shown in Table 20.

Table 20. Treatment options for managing ALFC equipment

Treatment option	Treatment overview
1 Repair the AFLC equipment	Undertake repairs to the AFLC equipment as conditional issues are identified.
2 Refurbish the AFLC equipment	The contactors are able to be replaced and the bearings in the motor-generator renewed to support continued operation.
3 Replace the AFLC equipment	Replacement of the AFLC equipment with a modern equivalent.

The different treatment options are all utilised at different points in the asset's lifecycle. A repair may be completed where practical and efficient. Due to generally poor condition of the assets and lack of certainty regarding the increased length of life this would achieve, a refurbishment is not considered practical or viable. A refurbishment does not allow for a technological change which will reduce the lifecycle costs.

Replacement removes the moving parts associated with motors and generators and allows for a technological change to a unit with a lower maintenance (static frequency unit).

6.5 Options

The assessment of the available options to manage the risks associated with Ausgrid's AFLC equipment is set out in Table 21 below.

Table 21. Program options for managing ALFC equipment

Program needs options	Option overview
1 Reactive treatment	Implement treatment such as repair, refurbish or replacement when the AFLC assets fail.
2 Conditional treatment	Implement treatment to the AFLC assets 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 AFLC 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.

There is no practical way to determine when a degraded legacy AFLC equipment is pending functional failure. Recent installed versions monitor their health and send a warning alarm, e.g. in the event of a fan failure within the power supply. The degraded legacy installations that consist of the population over standard technical life already have known condition issues and therefore a conditional approach is unsuitable. However as the technology changes and replacement works occur a conditional approach will be implemented.

A planned replacement of these identified assets is the preferred option because improvements in the technology of AFLC equipment means advantages including inbuilt supervisory/fault detection and no moving parts can be realised. Over time as these new devices are installed, Ausgrid will be able to transition to a conditional replacement program.

6.6 Costing and volume

Due to the volume of assets over standard technical life, Ausgrid is proposing to re-initiate a planned replacement program for these assets. The forecast program replacement volumes are expected to sustainably manage the risks associated with a deteriorating asset population. The replacement works will be prioritised so those of highest risk are completed first. Historical replacement volumes are mainly due to a historical replacement program and major projects including substation refurbishments and substation retirements. A review of the AFLC strategy and hardware has resulted in only those captured as part of major projects being replaced during 2016/17 to 2018/19. 1.6% of the legacy motor generator based systems are forecast to be replaced as part of a planned program to remove the risks associated with this ageing equipment. The population of legacy AFLC equipment is expected to be maintained in a sustainable manner.

The ALFC program forms part of the overall investment being proposed for the replacement of AFLC equipment, and 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 replacement AFLC equipment will be sourced using procurement processes so that Ausgrid obtains the best market value for the replacement.

The summary forecast for these replacement programs is shown in Table 22 below**Error! eference source not found.**. The costs shown are direct costs only.

Table 22. Forecast for ALFC equipment

Direct Costs (real $FY19)	FY20	FY21	FY22	FY23	FY24
Audio frequency load control equipment – ZN					
Volumes for replacement	2	2	2	2	2
Unit cost	$306,818	$305,285	$304,391	$303,719	$302,652
Total costs ($m)	**$0.61**	**$0.61**	**$0.61**	**$0.61**	**$0.61**

7 WHOLESALE METERING EQUIPMENT

7.1 Program description

This program is targeted at replacing wholesale metering (Type 4) equipment driven by a regulatory rule change. The planned program is:

- Wholesale Metering Points (REP_02.02.65).

The total value of this program in the 2019-24 regulatory period is $4.6 million in direct costs ($, real FY19). This program is new and will be commencing in the 2019-24 regulatory period.

The Australian Energy Market Commission (AEMC) has determined a rule to reduce the time interval for financial settlement in the national electricity market from 30 minutes to five minutes. The current wholesale metering equipment installed at Ausgrid's transmission network connection and distribution network connection points do not support this function.

Five minute settlement will commence on 1 July 2021, noting that the transitional provisions of the final rule will commence on 19 December 2017. This is a transition period of three years and seven months to allow a sustainable transition.

7.2 Background

Type 4 meters are required at a transmission network connection point or distribution network connection point where the relevant financially responsible market participant will need to record and provide five minute data from 1 July 2021.

At the inception of the National Electricity Market (NEM) in the 1990s, five minute dispatch was considered the shortest operational timeframe practicable. However, different periods for dispatch and settlement were adopted based on limitations in metering and data processing in the 1990s. These limitations no longer exist today.

7.3 Risks – Consequences and likelihood

The key consequences that can result in a loss of this function are shown in Table 23 below.

Table 23. Consequences from loss of function

Consequences	Description
Breach of National Electricity Rules	Ausgrid is required to support the five minute dispatch by 1 July 2021.

7.4 Treatment analysis

Assessment of the treatment solutions considered for metering systems is shown in Table 24 below.

Table 24. Treatment options for managing wholesale metering

Treatment option	Treatment overview
1 Repair the metering system	No practical options.
2 Refurbish the metering system	No practical options.

Treatment option	Treatment overview
3 Replace the metering system	Replace the metering system with modern equivalent.

The replacement of these assets is the preferred (and only practicable) option.

7.5 Options

The assessment of the available options to manage the risks associated with Ausgrid's metering systems is set out in the following table.

Table 25. Program options for managing wholesale metering

Program needs options	Option overview
1 Reactive	Implement treatment such as repair, refurbish or replacement when metering assets fail.
2 Conditional treatment	Implement treatment to the metering assets 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 metering assets failing.

A planned approach is the only practicable option that meets the requirements of the AEMC rule change.

7.6 Costing and volume

This program is planned to be a short term planned replacement program in the two years prior to the AEMC rule change to ensure Ausgrid's wholesale metering equipment are compliant. Once all required metering units have been replaced this program will end. This program forms part of the overall investment being proposed for the replacement of wholesale metering, 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 replacement wholesale meters will be sourced using competitive procurement processes so that Ausgrid obtains the best value for money for the replacement equipment.

The summary forecast for these replacement programs is shown in Table 26. The costs shown are direct costs only.

Table 26. Forecast for wholesale metering

Direct Costs (real $FY19)	FY20	FY21	FY22	FY23	FY24
Wholesale metering equipment					
Volumes for replacement	150	150	0	0	0
Unit cost	$15,594	$15,368	$0	$0	$0
Total costs ($m)	**$2.34**	**$2.31**	**$0**	**$0**	**$0**