5.13.D

Project justifications for underground cables replacement programs

Ausgrid

Content

1 INTRODUCTION

1.1 Underground cables and equipment on Ausgrid's network

Ausgrid has 15,761km of underground cables on the network. The cable operating voltages range from low voltage (LV) operating at 240V through to subtransmission cables operating at 132kV. These underground cables are predominantly located in urban areas.

These cables require other components to ultimately distribute electricity to customers. These other components operate at voltages from LV to 132kV and include:

- More than 32,700 connections used to link an underground cable to overhead mains
- More than 56,000 pillars used to access and operate LV cables
- More than 10,000 pits used for making connections and accessing or pulling cables
- More than 8km of cable tunnels in the CBD and urban areas
- More than 35km of spare 33kV, 66kV and 132kV cables for emergency situations.

1.2 Changes in technology

Ausgrid installed cables with paper insulation and a lead covering (PILC cables) for many decades as they were the main cable technology historically available. PILC cables were used for voltages from LV to 33kV. Ausgrid also installed fluid filled cables (FFC's) and gas pressure cables on circuits operating at 33kV or 132kV – both of these cable technologies required pressure monitoring systems to ensure safe operation.

These cable technologies have been superseded by cables which utilise polymeric insulation, including cross-linked polyethylene (XLPE) insulation and ethylene propylene rubber (EPR) insulation. Cables with XLPE insulation are used at all voltages however cables with EPR insulation are only used at 11kV. Some FFC's which are planned to remain in service for a number of years will have their pressure alarms systems replaced with a modern digital technology which allows for remote monitoring of cable fluid pressures in a real-time basis.

Pillars have been used for many decades to provide access to LV cable terminations and to house network switches or fuses. Older versions of pillars often had housings made from steel and pose public safety risks due to degraded internal components. Modern pillars have a plastic housing which provides protection for the public from the electrical components within it.

Ausgrid currently installs underground to overhead connections (UGOH's) with polymeric insulated terminations and fittings as opposed to the compound filled terminations with porcelain insulators and fittings used in the past. Compound filled terminations are prone to moisture entry resulting in catastrophic failure of the porcelain insulators and fittings – these failures cause safety risks to the public and workers as well as loss of supply risks

1.3 Working out what we need to replace

The condition of low voltage underground cables and the underground equipment cannot be cost effectively monitored. In weighing up the risks of asset failure, Ausgrid plans to gradually replace all the assets identified in these problematic asset classes. Replacement is undertaken in planned programs

1.4 Summary of programs

In total we expect to invest $116.6M on underground cables and equipment as part of planned replacement programs during the 2019-24 regulatory period. Ausgrid has a 'run to failure' approach for other underground cables and equipment which are not demonstrating systemic condition issues and these are only replaced following failure (refer to Part K (Reactive programs) for further details). Planned replacement of underground cables is also undertaken as major projects (typically for 33kV and 132kV cables) - refer to Attachment 5.14.2 for further detail in regard to these projects.

The following programs are discussed in further detail below:

- Low voltage cable replacement ($104.2 million)
- Underground equipment replacement and modification ($12.4 million).

2 LOW VOLTAGE CABLES

2.1 Program description

The planned replacement programs for LV cables address known safety and loss of supply issues associated with cable degradation. LV cable degradation causes risks to the public, customers and workers if:

- Electrical current escapes from the cable in an uncontrolled way
- The electricity supply loses the 'neutral' connection.

The two planned programs related to the replacement of LV cables are:

- LV CONSAC mains (km) (REP_04.02.05)
- LV HDPE mains (km) (REP_04.02.06).

These programs are continuing from the current regulatory period. Ausgrid plans to replace 76km of Consac cable and 25km of high density polyethylene insulated (HDPE) cable during the 2019-24 period at a cost of $104.2 million. All other underground cable replacements are captured either under Area Plans or reactively as detailed in Part K (Reactive programs).

2.2 Background

The primary function of an LV cable is to provide a safe and reliable electricity supply to customers. Ausgrid has approximately 6,160km of LV cables which supply electricity from distribution substations to customers. Consac and HDPE cables are two types of LV cables. Consac and HDPE cables form approximately 14% of the LV cable population (845km) and are installed on more than 9,900 LV circuits supplied from almost 5,200 distribution substations.

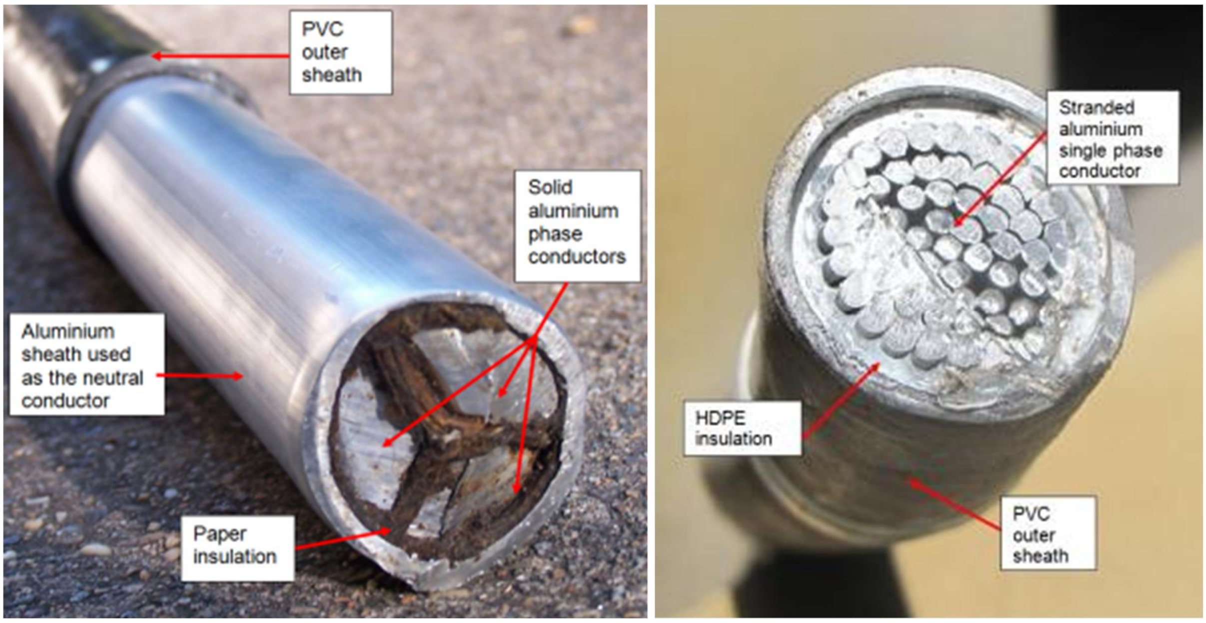
The two types of LV cables targeted in these programs are described in Table 1.

Table 1. LV cables for replacement overview

Asset	Overview
Consac	Consac is a three phase cable with aluminium conductors and paper insulation and utilises the aluminium sheath as the neutral conductor as opposed to having a fourth conductor.
HDPE	HDPE is a single phase cable with aluminium conductor and HDPE insulation – each circuit has four separate cables (3 phases and a neutral).

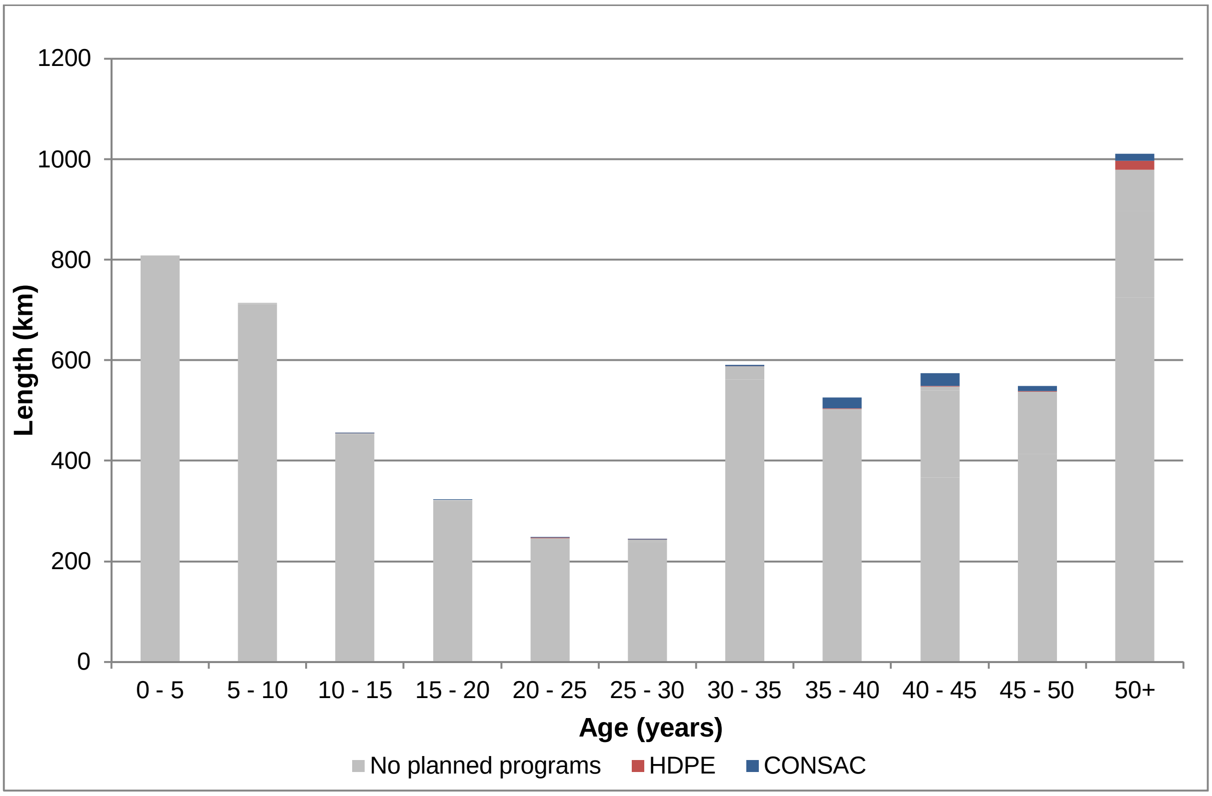
Figure 1 shows the components of a three phase Consac cable and a single phase HDPE cable.

Figure 1. Components of three phase Consac cable (left) and single phase HDPE cable (right)



The age profile for all LV cables on Ausgrid's network, including Consac and HDPE cables, is shown in Figure 2.

Figure 2. Age profile of LV underground cables (as at 30 June 2017)]



The need to replace these cable types has been triggered by condition and inherent design issues. These cable types have a higher failure rate than other types of LV cables on the network and have caused safety risks to the public, customers and workers, as well as loss of supply risks, due to their known failure modes.

2.3 Risks – Consequence and likelihood

The key consequences that can result from a loss of function for Consac or HDPE cables are shown in Table 2 below.

Table 2. Consequences from loss of function for Consac and HDPE cables

Consequence	Description
Harm to the public, communities and workers	Loss of the electricity supply neutral may cause injury (electric shock) or a fatality (electrocution). Electric shocks have occurred at customer installations due to degraded Consac cables.
	Uncontrolled discharge of electricity may cause injury (electric shock or burns) or a fatality (electrocution or fire). Ausgrid workers and public workers have received electric shocks due to degraded HDPE cables.
	Safety issues as a result of loss of supply are detailed below.
Damage to property	Poor electricity supply quality or voltage spikes caused by uncontrolled discharge of electricity may damage appliances installed within customer premises. Ausgrid may be held liable for their replacement.
	Uncontrolled discharge of electricity may damage buildings, property, critical infrastructure or natural environments
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.
	Failures associated with these cable types may result in large numbers of supply interruptions and penalties or intervention by our regulator.
Increased public or political scrutiny	Multiple interruptions to the electricity supply at high profile locations may result in widespread media coverage and political intervention. Multiple interruptions to the electricity supply to the tourist strip at Bondi Beach resulted in these outcomes.

The consequences and likelihood of low voltage cable failure can increase due to factors including:

- Their inherent design (particularly for Consac and HDPE cables)
- Being in areas with high pedestrian / vehicle activity or in close proximity to schools
- Supporting circuits which supply critical customers, infrastructure or economic hubs
- Being in salt affected areas (coastlines) due to water penetration into the ground.

The failure modes associated with Consac and HDPE LV cables are generally deteriorating in nature and therefore present an increased likelihood of failure over time. The predominant failure modes for Consac and HDPE cables are shown in Table 3.

Table 3. Key failure modes identified by LV cable type

Cable Types	Key failure modes
Consac cable	Corrosion of the aluminium sheath resulting in loss of the electricity supply neutral.
	Degradation of soldered neutral connections at the customers' installation resulting in loss of the electricity supply neutral.
	Moisture ingress through corroded aluminium sheath or degraded joint cover resulting in degraded paper insulation (conditional failure).
	Moisture related degradation of the paper insulation resulting in uncontrolled discharge of electricity within the cable causing interruptions to electricity supply.
	Moisture related degradation of the paper insulation resulting in uncontrolled discharge of electricity within the cable causing fires within pillars.
HDPE cable	Corrosion of the aluminium conductors resulting in loss of the electricity supply neutral or poor electricity supply quality (voltage unbalance).
	Moisture related degradation of the insulation and aluminium conductors resulting in uncontrolled discharge of electricity within the cable.
	Moisture related degradation of the insulation and serving materials resulting in uncontrolled discharge of electricity from the cable.

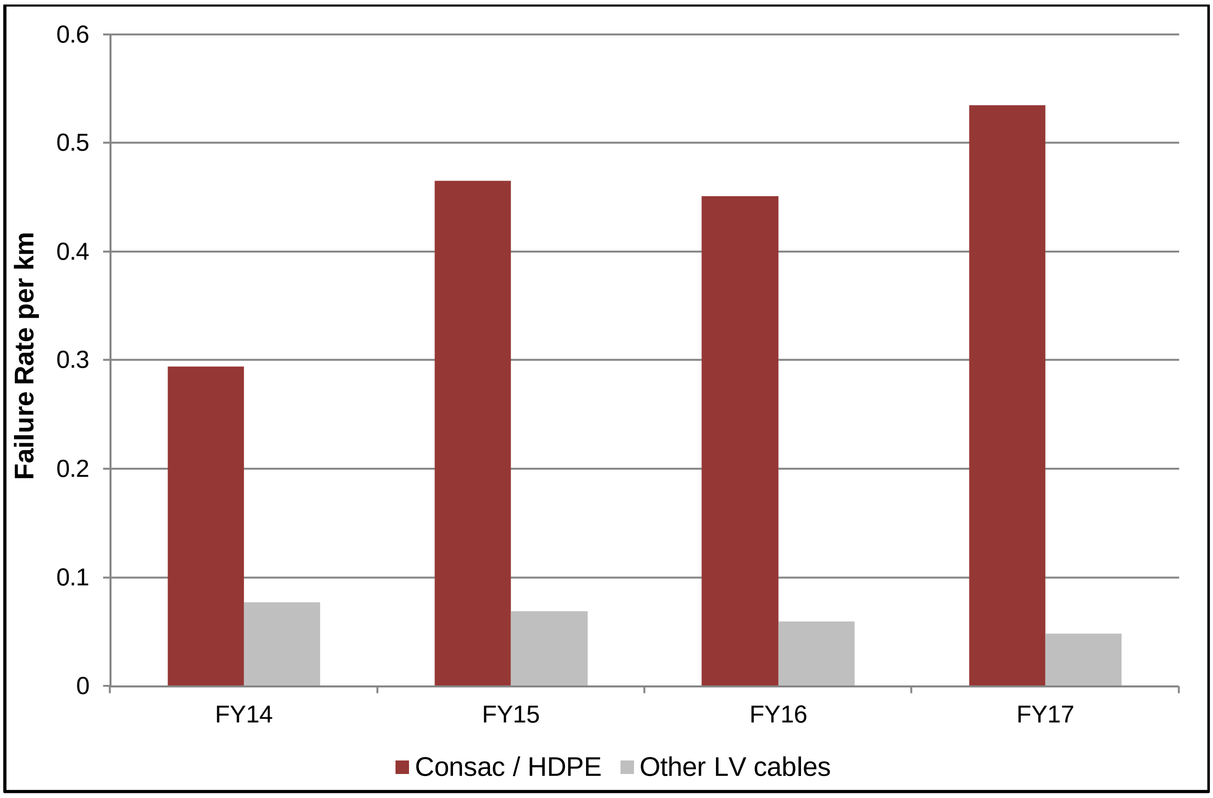
Ausgrid experienced approximately 500 or more LV cable functional failures per year from 2013/14 to 2016/17 at an average cost of approximately $20,000 per failure. Functional failures result in interruptions to the electricity supply to customers. The quantity of functional failures generally increases in years with higher rainfall.

The failure rate per km for Consac and HDPE cables is significantly higher (two to eight times higher) than all other LV cable types over recent years even with the concerted effort over this time to replace these cables. The deterioration of the materials in these cables is predominantly caused by moisture finding its way into the cables and joints over their operating life because they were installed directly in the ground (and not in ducts).

The failure modes for Consac cables are generally consistent with those experienced by other organisations in the Australian electricity industry as well as internationally. The failure modes associated with HDPE cables are less widely known outside of Ausgrid however similar failure modes have been seen by other organisations.

Figure 3 compares the failure rate per km for Consac and HDPE cables against all other cable types from 2013/14 to 2016/17.

Figure 3. Failure rate per km for Consac and HDPE compared to all other LV cables



2.4 Treatment analysis

Assessment of the treatment solutions considered for Consac and HDPE cables is shown in Table 4.

Table 4. Treatment options for managing Consac and HDPE cables

Treatment options	Treatment overviews
1 Repair the cables	Repair the cables prior to failure using like-for-like components. This is an operational task.
2 Modify the cables	Modify the components of the cables which have known failure modes with their modern equivalent.
3 Replace the cables	Replace the cables with their modern equivalent.

Repairs (Option 1) may be completed where practical and efficient, or as a short term fix until planned replacement can be undertaken. Repairs do not return the cables to an 'as new' condition and do not address risks associated with the inherent design of these cable types.

Modification of the cables (Option 2) would involve extensive excavation to remake joints and modifying the full cable length is impractical. Modification also does not remove the inherent risk of the cable design and costs a similar order of magnitude as replacement and is therefore not the preferred option.

Ausgrid believes the replacement of Consac and HDPE cables (Option 3) to be the most appropriate treatment option as it provides a balance between the risks and costs so far as is reasonably practical and addresses the cause of these risks, the design of the cables.

Analysis of present values for these treatment options suggests that cable replacement of the entire distributor should be undertaken after an initial failure has occurred.

It is not reasonably practical to repair, modify or replace all of the cables in a short timeframe due to the size of the cable population. Repair and modification involves significant expenditure and does not return the asset to an 'as new' condition due to the inherent design of the cables.

2.5 Options

The program options shown in Table 5 have been considered in relation to managing the safety and loss of supply risks associated with Consac and HDPE cable. These options are based on the need to undertake work on these assets.

Table 5. Program options for managing Consac and HDPE cables

Program need options	Option overviews
1 Reactive treatment	Implement treatment such as replacement when the cable fails.
2 Conditional treatment	Implement treatment to replace the cable when inspections or testing identify that they have deteriorated to the point of conditional failure.
3 Planned treatment	Implement planned treatment such as replacement prior to cables failing.

The analysis of the treatment options suggests replacement following an initial failure as the most cost effective treatment, however this analysis only considered costs in regard to the cable replacement. Conditional or functional failures of Consac and HDPE cables pose safety and loss of supply risks to the public, customers and workers as described in Table 2 and also require reallocation of resources from other planned works to undertake the initial failure response (for example, switching the network or undertaking temporary repairs to restore supply to customers) and to design / implement the cable replacement works. Reallocation of resources from other planned works also results in additional costs and delays in those planned works. As these risks and additional factors accumulate over time, this could lead to a significant uplift in safety incidents, increasing and unsustainable levels of reactive replacement work and an accompanying step change in capital expenditure. These risks and additional factors were not included in the analysis of treatment options but need to be considered when determining the appropriate program option for managing the significant and ageing population of Consac and HDPE cables. Due to these risks and additional factors, an approach that only manages these assets in a reactive manner (Option 1) is unacceptable for Consac and HDPE cables however is broadly considered acceptable for other LV cable types.

Conditional treatment (Option 2) would require a significant inspection or testing program. Due to the excavation costs, customer outages and resource requirements needed to fully inspect and test the full length of cables prior to determining whether replacement is required, this option is considered impractical. Condition issues may be identified when other works are being undertaken on the cable (for example, jointing for a pillar replacement).

The preferred option for Consac and HDPE cables is planned treatment (Option 3). The planned treatment option provides a prioritised and systematic approach to address the safety and loss of supply risks associated with these cables so far as is reasonably practicable.

This planned replacement approach optimises the management of risk rather than the long term sustainability of the LV cable population (average age). Ausgrid believes this to be the most appropriate approach as it defers short to medium term investment for customers, particularly where new technologies may lead to changes in the configuration and design of the network of the future.

These planned replacement programs address the LV cable types with known systemic condition issues, however other types of LV cable may also fail. As safety risks are not as prevalent on other LV cable types due to their design, Ausgrid accepts a run to failure approach for them. Refer to Part K for details in regards to reactive replacement requirements for other LV cables.

2.6 Costing and volumes

The total populations of Consac and HDPE cables have been identified for replacement in a planned program. These programs have been extended from previous periods and will continue into subsequent periods due to the size of the asset populations. The forecast replacement volume is expected to sustainably manage the risks associated with an ageing asset population in a prioritised order so those of highest risk are completed first.

Historically, internal resources have been wholly responsible for the design and construction of Consac and HDPE cable replacement projects. Contracted resources were managed by internal resources for the cable laying component of these projects – these contract resources accounted for approximately 70% of project costs. Going forward, Ausgrid plans to enhance this ‘blended delivery’ approach – the revised approach will result in half of the Consac and HDPE cable replacement project volume being fully outsourced to the market as ‘design and construct’ projects and the remaining half of the replacement volume still the responsibility of internal resources to deliver (including managing external resources for cable laying). This revised approach results in external resources being utilised for delivery of 85% of the program forecast.

Based on analysis of available industry information, replacement costs for LV cables range from approximately $396,400 to $1,009,000 per km. The Ausgrid average replacement cost for LV underground cables has been estimated as approximately $1,026,380 per km. Ausgrid recognises that this cost is high compared to industry averages however notes that replacement costs vary within the Ausgrid supply area and range from $463,100 per km in townships, $664,500 to $1,030,000 per km in urban residential and commercial areas and up to $1,450,400 per km in high density residential, commercial and tourist areas.

The Consac and HDPE cables being replaced are predominantly laid directly in the ground and therefore replacement involves installation of new infrastructure (conduits, pillars and pits) in established areas and changeover of existing services to the new cable, as opposed to the comparatively easier task of installing cables in ‘green field’ development areas or replacing existing cables if they were installed in conduits. In addition to this, efficiencies of scale are achieved with replacement of longer circuits and are broadly proportional to the length of cable being replaced. The average replacement length per project during the 2015-19 period was 190m, however this is reducing to an average of 140m during the 2019-24 period, which is expected to reduce scale efficiencies achieved during the current period. These factors have also contributed to the higher than benchmark replacement cost.

The 2019-24 summary forecast for these replacement programs is shown in Table 6. The costs shown are direct costs only. The forecast equates to replacement of 2.4% of the Consac and HDPE cable population annually (0.33% of the LV underground cable population) – this replacement rate results in removal of these cable types over a 40 year period. Due to the size of the asset population and expected increasing volume of failures as the asset population continues to age, the replacement rate will be reassessed periodically and may also lead to increases in future periods.

These programs form part of the overall investment being proposed for the replacement of underground cables. 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.

Table 6. Forecast for Consac and HDPE cable

Direct Costs (real $FY19)	2019/20	2020/21	2021/22	2022/23	2023/24
Replace LV CONSAC mains (km)					
Volumes for replacement (km)	15.5	15.1	15.0	15.0	15.2
Unit cost	$1,020,390	$1,021,043	$1,025,299	$1,031,021	$1,035,719
Total costs ($m)	**$15.82**	**$15.40**	**$15.42**	**$15.55**	**$15.77**
Replace LV HDPE mains (km)					
Volumes for replacement (km)	5.0	5.0	5.0	5.0	5.0
Unit cost	$1,047,846	$1,047,089	$1,050,048	$1,054,488	$1,057,684
Total costs ($m)	**$5.24**	**$5.24**	**$5.25**	**$5.27**	**$5.29**

3 UNDERGOUND EQUIPMENT

3.1 Program description

The underground equipment discussed in this section supports the safe and reliable functioning of underground cables and the connection between underground and overhead circuits. The replacement programs for equipment associated with underground cables address known condition and inherent design issues. These issues cause safety and loss of supply risks to the public, customers and workers, and also environmental risks, if:

- An uncontrolled discharge of electricity occurs, or
- Cable fluid unknowingly leaks into the environment.

The four planned programs for equipment associated with underground cables are:

- Cable pressure alarm replacement (REP_05.02.12)
- 11kV Underground to overhead terminations (UGOHs) replacement (REP_04.02.11)
- 33kV Underground to overhead terminations (UGOHs) replacement (REP_05.02.30)
- Modification of Menai type LV pillars (DOC_11.03.74).

These programs are continuing from the current regulatory period. Ausgrid expects to invest $12.4 million replacing this underground equipment during the 2019-24 period. All other underground equipment replacements are captured either under Area Plans or reactively as detailed in Part K (Reactive programs).

3.2 Background

The primary function of underground equipment is to safely distribute electricity from subtransmission supply points to customers. The underground equipment types targeted in the underground equipment programs are detailed in Table 7.

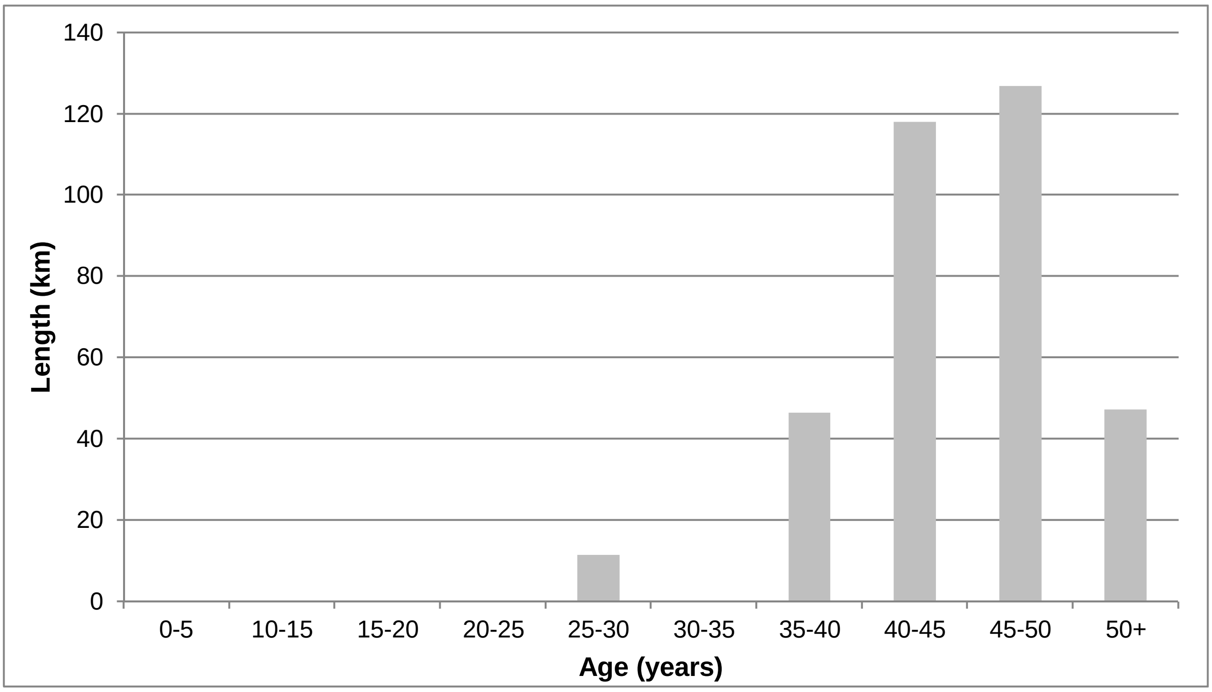
Table 7. Underground equipment for replacement or modification overview

Asset	Overview
Cable pressure alarms	Ausgrid has more than 350km of fluid filled cables (FFCs) on 76 different circuits which operate at either 33kV or 132KV. These cables are pressurised with fluid (mineral oil or manufactured insulating fluids) and it is critical that this pressure is monitored and maintained by cable pressure systems (including alarms) to prevent cable failure. There are over 240 cable pressure monitoring / alarm points. The cable pressure alarm replacement program addresses safety risks to the public, customers and workers, as well as loss of supply and environmental risks associated with FFC pressure alarm failures
UGOHs	UGOHs are used for the transition from an underground cable to overhead conductors. They are mounted on poles in public areas. Ausgrid has more than 6,700 network UGOHs operating at voltages from 11kV to 132kV. The cable terminations on the UGOHs can be either three single phase arrangements (known as ‘sealing ends’) or three phase arrangements (known as ‘pot heads’). Older terminations were made of metal or aluminium and have porcelain insulators and porcelain surge arrestors.
Menai type pillar	Ausgrid has over 56,000 LV pillars. Pillars are used to provide access to, and house, LV cable terminations, network switches and service cable connections for customers or fuses. They are located in public areas. While modern pillars typically have a plastic cover to mitigate public safety risks, older versions of pillars often had housings made from steel and pose public safety risks due to degraded internal

Asset	Overview
	components energising the steel cover. 'Menai' pillars are one type of LV pillar with steel covers. A number of public safety incidents related to this pillar type occurred in 2013. There are approximately 1,850 Menai pillars on the Ausgrid network and they were largely installed in association with Consac cable installation.

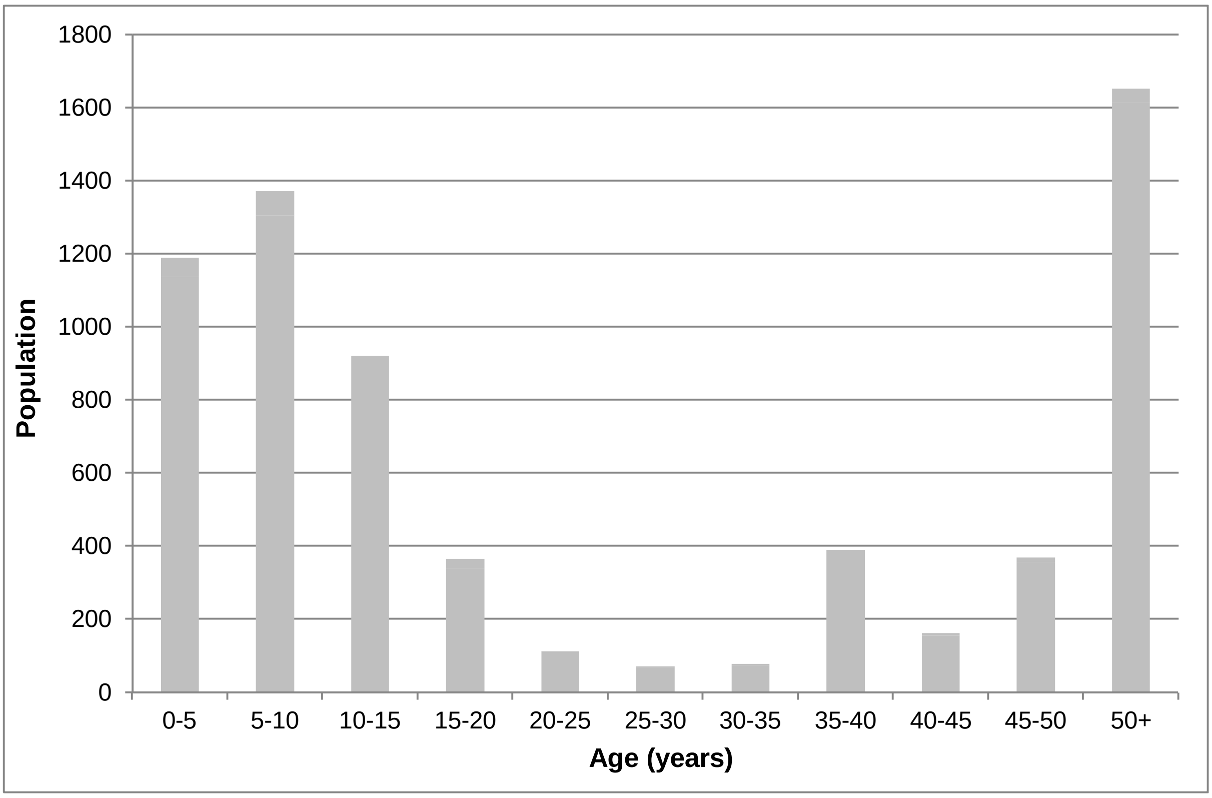
The age profile for FFCs (and their pressure alarm systems) is shown in Figure 4. The average age of FFCs is 40 years, with 50% over their standard technical life of 45 years.

Figure 4. Age-profile of fluid filled cables (as at 30 June 2017)



The age profile for all 11kV and 33kV UGOHs is shown in Figure 5. Their average age is 18 years and 25 years respectively.

Figure 5. Age-profile of 11kV and 33kV UGOHs (as at June 2017)



3.3 Risks – Consequence and likelihood

The key consequences that can result from a loss of function of underground equipment are shown in Table 8.

Table 8. Consequences from loss of function for underground equipment

Consequence	Descriptions
Harm to the public, communities and workers	Uncontrolled discharge of electricity may cause injury (electric shock, physical injury or burns) or a fatality (electrocution or fire). Failures of Menai pillars have resulted in fires and electric shocks to the public and workers. Failures of 11kV and 33kV UGOH terminations have resulted in a number of 'near miss' public safety incidents.
	Safety issues as a result of loss of supply are detailed below.
Damage to property	Poor electricity supply quality or voltage spikes caused by uncontrolled discharge of electricity may damage appliances installed within customer premises. Ausgrid may be held liable for their replacement.
	Uncontrolled discharge of electricity may damage buildings, property or critical infrastructure. Failure of UGOH terminations and cable pressure alarms has resulted in damage to vehicles due to explosive failure of underground equipment components.
	Uncontrolled or unknown discharge of fluid from FFC's may damage buildings or property. Ausgrid has had incidents where fluid from FFC's has leaked into building basements.
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

Consequence	Descriptions
	those on life support systems.
	Failures associated with these cable types may result in large numbers of supply interruptions and penalties or intervention by our regulator.
Damage to the environment	Uncontrolled discharge of electricity may cause fires which damage the natural environment.
	Uncontrolled or unknown discharge of fluid from FFC's may pollute waterways or other natural environments. Ausgrid has received a formal warning and an official caution from the NSW Environmental Protection Authority in regard to uncontrolled leakage from FFCs.
Increased public or political scrutiny	Multiple interruptions to the electricity supply at high profile locations or uncontrolled discharge of fluid from an FFC may result in widespread media coverage and political intervention.

The consequences and likelihood of underground equipment failure can increase due to factors including:

- Their inherent design and obsolete technology (for example cast iron UGOHs)
- Being in areas with high pedestrian / vehicle activity or in close proximity to schools
- Supporting circuits which supply critical customers, infrastructure or economic hubs
- Being in areas prone to bushfire or areas of environmental sensitivity (for example, near waterways)
- Being in areas that are salt affected (coastlines) or highly polluted.

The failure modes associated with these types of underground equipment are generally deteriorating in nature and therefore present an increased likelihood of failure over time. The inherent design of the equipment also contributes to the failures which are occurring. The main failure modes for this underground equipment are shown in Table 9.

Table 9. Key failure modes by identified underground equipment types

Equipment Type	Key failure modes
Cable pressure alarms	False activation of alarms due to drift in calibration, VF filter degradation, water ingress and degradation of wiring and pilot cables (causing short circuits).
	Non-operation of alarms due to drift in calibration, VF filter degradation, water ingress and degradation of wiring and pilot cables (causing open circuits).
	Uncontrolled discharge of electricity within the cable due to fluid starvation following non-operation of alarms.
UGOH terminations	Moisture entry into the termination due to age related degradation of gaskets / seals or corrosion of the metal housing.
	Explosive failure of the termination housing and porcelain components due to moisture entry into the termination.
	Explosive failure of the termination housing and porcelain components due to lightning strike, pollution related degradation of the insulators or animal contact.
Menai type pillars	Moisture entry into the pillar due to corrosion of the metal cover.

Equipment Type	Key failure modes
	Uncontrolled discharge of electricity to the steel housing due to incorrect positioning of insulating components, moisture entry or internal component degradation.
	Uncontrolled discharge of electricity to the steel housing due to pillar being struck / third party damage.
	Fire within the pillar due to uncontrolled discharge of electricity.

Ausgrid responded to approximately 630 FFC low pressure alarms between 1/7/2013 and 30/6/2017. Each alarm results in a field investigation of the cause of the low pressure to ensure that the FFC is not at the point of functional failure due to reduced fluid pressure. 280 of these low pressure alarms (45%) were false indications caused by defects in the pressure alarm system. One pressure alarm system failure resulted in a cable failure which required significant cable replacement and cost more than $1 million to return it to service.

In the period from 2013/14 to 2016/17, Ausgrid experienced approximately 46 termination failures per year on 11kV UGOHs and 5 termination failures per year on 33kV UGOH's. Failures of older UGOH terminations typically involve explosive fragmentation of the porcelain and metal housing components which can be projected for distances of up to 20 metres. Some types of 11kV and 33kV UGOH terminations have a higher failure rate than other types of UGOH terminations on the network and have caused safety risks to the public, customers and workers, damage to property and loss of supply risks.

Ausgrid's asset management practices for underground equipment provide an understanding of their condition and therefore the likelihood of failure. Detecting failures before they occur and applying treatments to maintain underground equipment in a serviceable condition limits the likelihood of failure and mitigates the potential consequences described above.

3.4 Treatment analysis

Assessment of the treatment solutions considered for underground equipment is shown in Table 10.

Table 10. Treatment options for managing underground equipment

Treatment options	Treatment overviews
1 Repair the underground equipment	Undertake repairs to the underground equipment like for like as conditional issues are identified.
2 Modify the underground equipment	Modify the underground equipment using modern equivalent components.
3 Replace the underground equipment	Undertake replacement with modern equivalent components.

The different treatment options are all utilised at different points in the asset's lifecycle. The treatment solution selected varies for these underground equipment types. One solution will not resolve all of the various known failures modes due to the different purposes and operating voltages of the equipment.

For FFC pressure alarm systems a repair (Option 1) may be completed for short term defect mitigation where practical and efficient. Modifications (Option 2) are impractical due to the obsolete technology and lack of manufacturer support for the alarms systems. Repairs or modification do not address the failure modes associated with the inherent design of the pressure alarm system. The preferred option for FFC pressure alarms is to replace them with a modern technology which allows remote 'real time' monitoring of cable fluid pressures. The benefits of replacement of the full alarm system with a technology which allows remote 'real time' monitoring of cable fluid pressures include:

- Efficiencies in network operations due to the reduced quantity of reactive responses to pressure alarms and reduced maintenance costs for the remaining life of the FFC
- More effective pressure monitoring as pressure reductions can be tracked by software and intervention timeframes forecast and planned
- Mitigation of the safety, loss of supply and environmental pollution risks caused by the poor performance of the existing pressure alarm systems.

For 11kV and 33kV UGOHs, repair of existing terminations (Option 1) could be undertaken however this would not remove the safety and loss of supply risks associated with their inherent design as failures would still occur due to lightning strikes, pollution or animal contact. Terminations are able to be modified (Option 2) with non-fragmenting components. This is the preferred solution as it mitigates the safety risks associated with termination housing and porcelain component failure at the lowest cost. Full UGOH replacement (Option 3) may be required where electrical safety clearances (to current standards) cannot be achieved when modifying the UGOH.

For Menai pillars, repair of internal components (Option 1) may reduce the likelihood of a failure occurring however does not reduce the safety consequence of a failure due the presence of the steel covers. Modification of these pillars with a plastic cover (Option 2) is the preferred solution as it mitigates the risk of electric shocks to the public and workers to a level equivalent to that posed by modern pillar designs at a lower cost than full pillar replacement. Full pillar replacement (Option 3) may be required if the steel frame which supports the internal components within the pillar is corroded but this is not expected to be the typical outcome.

3.5 Options

The program options available when considering management strategies for these types of underground equipment are summarised in Table 11.

Table 11. Program options for managing underground equipment

Program needs options	Option overviews
1 Reactive treatment	Implement treatment such as modifying or replacing the underground equipment when it fails.
2 Conditional treatment	Implement treatment to modify or replace assets when inspections or condition assessments identify that they have deteriorated to the point of conditional failure based on a set of criteria.
3 Planned treatment	Implement planned treatment such as modifying or replacing the underground equipment prior to the asset failing.

The consequence of these underground equipment types failing poses serious safety risks to the public, customers, workers and the community as described above. Due to these risks, an approach that only manages these assets in a reactive manner (Option 1) is unacceptable. This option would defer capital expenditure in the short term, but would not adequately manage the existing risks associated with the identified underground equipment types. As these risks accumulate over time, this could lead to a significant uplift in public safety incidents, reactive replacement work and an accompanying step change in capital expenditure. Due to the significant and ageing population of the existing assets, overcoming this in the future would require a significant increase in capital expenditure.

Ausgrid's preferred approach for managing these types of underground equipment is to undertake a planned approach to address the known failure modes currently posing safety, loss of supply and environmental risks. All other types of underground equipment will be managed by an approach where their condition is assessed against condition criteria to determine the most efficient treatment and timing, or they will be replaced at end of life.

The preferred approach optimises the management of risk rather than the long term sustainability of the asset population (average age). Ausgrid believes this is the most appropriate approach as it defers short to medium term investment for customers particularly where new technologies may lead to further efficiencies or changes in the configuration and design of the network of the future.

3.6 Costing and volumes

The total populations of these specific underground equipment types have been identified for replacement or modification. These programs commenced in the current period and some will continue into subsequent periods due to the size of their populations. The forecast volumes are expected to sustainably manage the risks associated with an ageing asset population and in a prioritised order so those of highest risk are completed first. Underground equipment has been aligned to the 'Underground cables - Other' category in the Ausgrid Reset RIN template '2.2 REPEX' so benchmarking of unit costs is difficult and not directly comparable with other DNSP's as it is not known what underground assets they have aligned to this category and whether comparison can be made like for like.

The work related to the underground equipment programs is primarily performed by Ausgrid internal resources however may be carried out by external resources or ASP's in association with contracted cable or pole replacement work or with contestable projects.

The 2019-24 summary forecast for these replacement programs is shown in Table 12. The costs shown are direct costs only.

The forecast for cable pressure alarm replacement during the 2019-24 period equates to approximately 4% of the pressure monitoring points on FFC's annually - the monitoring points targeted for pressure alarm replacement are typically on FFC's which are not defined for replacement under Area Plan projects during the 2019-24 period. In addition to these replacements, 36% of the population of pressure monitoring points will be retired under Area Plan projects for FFC's during 2019-24.

The forecast for 11kV and 33kV UGOH modification equates to approximately 0.4% of the 11kV UGOH population and 1.9% of the 33kV UGOH population annually. The programs target UGOH's of highest risk based on current failures. For 33kV UGOH's it is expected that those of highest risk (porcelain insulators) will all be modified by the end of the 2019-24 period. It is expected that replacement of high priority 11kV UGOH's will continue into subsequent periods due to the size of the asset population and their increasing age.

The forecast for Menai pillars equates to modification of approximately 0.4% of the LV pillar population annually. The public safety risks associated with this type of pillar will be further mitigated by full pillar replacement in association with Consac and HDPE cable projects or other cable projects. With this modification and replacement approach for these assets, it is expected that mitigation of the reasonably foreseeable public safety risks associated with Menai pillars will be completed by the end of the 2019-24 period.

These programs were funded by separate reactive programs prior to 2017/18 and now form part of the overall investment being proposed for the replacement of underground cables.

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.

Table 12. Forecast for underground equipment

Direct Costs (real $FY19)	2019/20	2020/21	2021/22	2022/23	2023/24
Cable pressure alarm replacement					
Volumes for replacement	10	10	10	10	10
Unit cost	$78,123	$77,935	$77,911	$77,947	$77,909
Total costs ($m)	**$0.78**	**$0.78**	**$0.78**	**$0.78**	**$0.78**
11kV UGOH replacement					
Volumes for replacement	25	25	25	25	25
Unit cost	$30,719	$30,583	$30,524	$30,494	$30,422
Total costs ($m)	**$0.77**	**$0.76**	**$0.76**	**$0.76**	**$0.76**
33kV UGOH replacement					
Volumes for replacement	4	4	4	4	4
Unit cost	$207,314	$207,090	$207,567	$208,321	$208,830
Total costs ($m)	**$0.83**	**$0.83**	**$0.83**	**$0.83**	**$0.84**
Modification of Menai type LV pillars					
Volumes for modification	200	200	200	200	200
Unit cost	$513	$510	$514	$521	$527
Total costs ($m)	**$0.10**	**$0.10**	**$0.10**	**$0.10**	**$0.11**