DMA and MTN Zone Substation Rapid Earth Fault Current Limiter (REFCL) Installation – JUSTIFICATION STATEMENT

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JUSTIFICATION STATEMENT

This document justifies capital expenditure on the United Energy network.

REPEX Road Map

1. Asset replacement – Modelled

a. 6 modelled asset categories

2. Asset replacement – Modelled & Unmodelled

a. Pole top structures + SCADA/protection

3. Other Repex - Unmodelled

a. ZSS Primary Asset Replacement

    (i) CEES - Capacitor Banks + Earth Grid + Neutral Earthing Resistors

    (ii) CEES - Buildings

b. Non VBRC Safety Projects

    (i) Intelligent Secure Substation Asset Management (ISSAM) – UE PL 2401 e.g.CCTV

c. Operational Technology

    (i) OT Safety

    - Service Mains Deterioration Field Works – PJ1385
    - In Meter Capabilities IMC) – PJ1386
    - Light Detection and Ranging (LiDAR) Asset Management – PJ1400
    - OT Security – PJ1500
    - DNSP Intelligent Network Device – PJ5002

    (ii) OT Reliability

    - Distribution Fault Anticipation Data Collection and Analytics (DFADCAA) – PJ1599
    - Fault Location Identification and Application Development – PJ1600

    (iii) OT Other

    - Dynamic Rating Monitoring Control Communication (DRMCC) – PJ1413
    - Test Harness – PJ1398
    - Pilot New and Innovative Technologies – PJ1407

d. Network Reliability Assessment UE PL 2304 – Projects

    (i) Automatic Circuit Re-closers (ACRs) and Remote Control Gas Switches (RCGSs)

    (ii) Fuse Savers

    (iii) Rogue Feeders

    (iv) Clashing

    (v) Animal Proofing

    (vi) Communications Upgrade

e. CEES – Environment

f. CEES – Power Quality Maintained

g. Terminal Station Redevelopment HTS and RTS - UE-DOA-S-17-002 & UEDO-14-003

4. VBRC Projects

a. HV Aerial Bundled Cable Strategic Analysis Plan - UE PL 2053

b. DMA and MTN Zone Substation Rapid Earth Fault Current Limiter (REFCL) Installation

c. Other VBRC projects

TABLE OF CONTENTS

1. EXECUTIVE SUMMARY

Faults on overhead powerlines can result in ground fires. Some of these fires may result in major bushfires that result in loss of life, property and livestock. Every distribution business with electricity assets in hazardous bushfire risk areas (HBRA) have an obligation to implement programmes to reduce the number of fires started from its assets, particularly in HBRA.

There are several regulatory obligations that require United Energy (UE) to eliminate the source of risk, and where elimination is not reasonably practicable, the identification of treatments or controls so that residual risks are reduced to as low as reasonably practicable (ALARP). These regulations include the Electricity Safety Act, the Occupational Health and Safety Act and Australian Standard AS 5577–2013.

In accordance with UE's obligations and as part of UE's risk management policy, UE has undertaken a bushfire mitigation ALARP assessment. This work has identified and assessed many options that have the potential to reduce the likelihood of the network causing a bushfire. A total of 75 options were identified and each option was assessed in regards to effectiveness and feasibility. The ALARP risk assessment identified Rapid Earth Fault Current Limiters (REFCLs) as one of the most effective controls available. This document presents a detailed study of REFCLs in support of the bushfire mitigation ALARP assessment.

Based on the latest available fire loss consequence mapping data, the value of the bushfire risk reduction provided by the REFCL technology is comparable to the capital cost at two zone substations, namely Mornington (MTN) and Dromana (DMA). Deployment of REFCLs at the highest risk zone substations is a practicable means of lowering bushfire risk. On this basis, UE believe that installing REFCLs at MTN and DMA zone substations constitutes a reasonable approach.

REFCLs act as soon as a single phase to earth fault occurs, very quickly reducing the fault current to such low values that electrical arcs are extinguished before a sustained fire can start. The technology is relatively new to the industry in Australia and continues to undergo development in its ability to reduce the risk of powerline faults causing bushfire. UE has played a key role in assisting the Victorian state government undertake research and development in 2014 and 2015 using its REFCL in Frankston South (FSH) to demonstrate the capability of the technology and to make improvements. With the latest developments, a risk reduction of 90% for phase to earth faults on 22kV lines is achievable providing an overall reduction in the risk of distribution network assets causing major bushfires by as much as 60%. REFCLs are one of the few options identified that can deliver a significant reduction in bushfire risk.

A number of REFCL technologies and operating modes have been considered and UE has concluded that the preferred REFCL for the UE network is a type that deploys active fault compensation through the use of a residual current compensator. This technology offers the maximum possible reduction in bushfire risk as identified by the 2014 and 2015 research. UE shall only consider other REFCL technologies if the preferred technology is unavailable or unreliable.

The capital cost of installing the two REFCLs is estimated at $7.5M ($3.75M unit cost) and the present value benefit of the bushfire risk reduction is estimated at $3.9M in 2015 dollars. The upfront capital cost is not disproportionally high compared to the value of the risk reduction and therefore the installation of REFCLs is necessary to reduce the bushfire risk to ALARP. Furthermore this cost is efficient in comparison to the average unit cost of $6.26M to install REFCLs throughout regional Victoria as published in the regulatory impact statement for the bushfire mitigation regulations amendment.

The installation of REFCLs at MTN and DMA zone substations is included in UE's current Fire Prevention Plan (as published on the UE website) and will become a mandatory obligation once approved by Energy Safe Victoria in early 2016.

2. BUSHFIRE RISK MITIGATION

2.1 Bushfire background

Victoria is one of the most fire-prone regions in the world with a long history of bushfires. Some of the most serious bushfires include 7 February 2009, 16 February 1983, April 1980, 12 February 1977 and 8 January 1969. These fires have resulted in considerable loss of life, property and livestock. Smaller bushfires occur annually and require enormous resources to manage.

Evidence shows that faults on distribution network powerlines are a significant cause of fire starts on days of extreme bushfire risk when temperatures and wind speeds soar, fuel is dry and humidity is low. In all the major fires listed above more than half were started by powerlines. On 7 February 2009 (Black Saturday), 121 of the 173 deaths were the result of powerline ignited bushfires.

Of all the risks associated with operating the UE network the risk assessed with the largest consequence is a fault on an electricity asset starting a major bushfire. The risk is ever present despite continuing efforts to mitigate it.

Fire loss consequence mapping for Victoria reveals that the UE network only represents 0.50%[1] of the total state risk.

Within UEs territory, there are some areas considered of moderately high risk such as the areas supplied by Mornington (MTN) and Dromana (DMA) zone substations around Red Hill, Arthurs Seat and Mornington that contain a disproportionate fraction of the risk. These two areas represent 56% of UE's total fire loss consequence (MTN=29% and DMA=27%) and require special attention.

2.2 Bushfire residual risk with existing controls

UE has a comprehensive bushfire mitigation plan that incorporates a range of strategies designed to control the risk of powerline assets starting bushfires. On the whole this existing plan is sufficient to maintain risks to acceptable levels. There are however some areas, particular those areas supplied by Mornington (MTN) and Dromana (DMA) zone substations where the residual risk after the application of existing controls remains 'Very High' as defined by UE's risk management policy.

For these reasons, UE has undertaken a revised risk assessment to identify additional controls that can be introduced to reduce the bushfire risk to as low as reasonably practicable (ALARP). Some of these programmes are already underway. Among the programmes implemented, UE already has a RECFL in service at Frankston South (FSH) zone substation. The trial has been largely successful in its aim of preventing fire starts caused by network faults. The installation of similar devices at Mornington (MTN) and Dromana (DMA) would be one of the most effective controls that UE could introduce to reduce risk in its highest risk areas.

2.3 Bushfire Risk ALARP methodology

The bushfire risk ALARP methodology involved identifying all opportunities or potential opportunities for new or enhanced controls that can prevent UE assets from starting bushfires. All opportunities were identified regardless of their practicability. To ensure all opportunities were identified a workshop was held that included experts on the subject matter including internal UE staff, the Mornington Council, the Country Fire Authority (CFA) and the Victorian State Government. All opportunities were then ranked to estimate their expected effectiveness and practicability taking cost, time and resources into consideration. Refer to the documented bushfire mitigation ALARP assessment for further detail on the methodology[2].

[1] Source: CSIRO data used in the Regulatory Impact Statement for the amendments to the Electricity Safety (Bushfire Mitigation) Regulations 2013.

[2] Refer to UE PR 2511 for UE's Bushfire Mitigation ALARP Risk Assessment.

2.4 Results from the ALARP assessment

The ALARP assessment identified REFCLs as the control that can provide the single largest reduction in risk with the exception of the widespread undergrounding of powerlines. Furthermore unlike options to insulate all overhead powerlines, or place them underground, REFCLs are affordable and therefore a potentially practical means of controlling bushfire risk. Final endorsement to proceed with REFCLs was subject to a more detailed assessment to evaluate the cost and benefits of the technology, to select the type of technology and to determine where best to install it. Together with work undertaken in the UE REFCL strategic direction analysis plan, this document forms part of that detailed assessment.

2.5 REFCL Options Considered

There are several possible REFCL options to consider:

- Scale of deployment e.g. target REFCL deployment in all areas that supply hazardous bushfire risk areas (HBRA) or only the highest risk HBRA.
- Selection of REFCL technology e.g. deployment using active REFCLs that provide the highest performance or alternatives such as passive REFCLs or REFCLs with rapid trip that might be lower cost but not perform as well.

2.5.1. Scale of deployment

In order for a strategy to be developed based on the ALARP risk assessment principles it is necessary to identify the bushfire risk by zone substation and to compare this risk with the cost.

Fire loss consequence mapping undertaken for Victoria by the CSIRO currently provides the most accurate breakdown of risk by zone substation. The zone substation in the UE network with the highest risk are tabled below:

Zone substation	Share of UE network bushfire risk
Mornington (MTN)	28.8%
Dromana (DMA)	27.1%
Glen Waverley (GW)	9.4%
Rosebud (RBD)	7.5%
Hastings (HGS)	5.6%
Other	21.6%

The zone substation which stand out as having the greatest risk are MTN (29%) and DMA (27%). Together they shoulder more than half (56%) of UE's fire loss consequence.

Glen Waverley (GW) has the next highest fire loss consequence but the risk is limited to a region of bush and parkland from Dandenong Valley Parklands in the north to Shepherds Bush and Jells Park in the south. There are very few electricity assets in the parks with most overhead powerlines in low risk urban areas. Furthermore these areas are easy for emergency services to access and therefore it is easier to control any fire that might start in this region compared to those in difficult terrain.

The area with the next highest fire loss consequence is Rosebud (RBD) at 7.5% which contains powerlines in some high risk areas. Local knowledge would suggest the risk at RBD zone substation is higher than GW ZSS but relative to MTN and DMA is considerably lower.

The estimated value of the total UE network bushfire risk is $595k per annum[3]. On this basis the risk per zone substation is valued at:

[3] Source: Section 3.2.4 of the Regulatory Impact Statement for the amendments to the Electricity Safety (Bushfire Mitigation) Regulations 2013 estimates the Victorian risk for the period 2000-2034 is $119M/annum. The CSIRO estimate the UE network represents 0.50% of the total state risk.

Zone substation	Value of annual bushfire risk
Mornington (MTN)	$171k
Dromana (DMA)	$161k
Glen Waverley (GW)	$56k
Rosebud (RBD)	$45k
Hastings (HGS)	$33k
Other	$129k

The best data available based on the 2014 and 2015 research suggests that REFCLs have the potential to reduce this risk by up to 60%[4]. Thus a REFCL at MTN zone substation reduces bushfire risk valued at $103k/annum.

The average cost to install a REFCL on the UE network is estimated at $3.75M which is approximately equivalent to an annual cost of $230k. On this basis the cost of installing REFCLs at MTN and DMA is not disproportionately higher than the risk reduction. At GW and RBD the cost is around 7 times the value of the risk reduction and therefore for these locations the cost is considered disproportionate to the risk reduction benefit. On this basis the ALARP assessment recommends REFCLs at MTN and DMA. At this time UE cannot justify an installation at GW or RBD.

Installing REFCLs at MTN and DMA zone substation will also provide an additional benefit. UE has installed significant amounts of HV aerial bound cable (ABC) on MTN and DMA 22kV feeders to manage bushfire risk however over the past 3 years UE has experienced an increase in HV ABC faults. Some of these faults have started ground fires. The risk in this region is therefore higher than the state average where these faults are not so prevalent. The CSIRO fire loss risk analysis does not factor in the additional risk in this area. Although the plan is to replace all HV ABC with known issues this will take several years and REFCLs will help to alleviate this risk in the interim.

The analysis shows that the installation of two active REFCLs has the ability to reduce the total bushfire risk in the UE network by a significant 35%. There are however a number of REFCL technologies to consider and a number of alternative ways to operate REFCLs which are also worthy of consideration.

2.5.2. Selection of REFCL technology

Passive REFCLs have been used for many years in Europe and consist of a simple arc suppression coil that is installed between the transformer neutral and earth. Fault current is reduced to around 10A. There are several manufacturers of the coils, control systems and protection relays. The technology is mature and simple. The 2014 research in Frankston demonstrated the bushfire risk reduction traditional passive REFCLs can provide however the risk reduction was much less than for active REFCLs.

Active REFCLs also use an arc suppression coil but in addition incorporate a residual current compensator that provides active control of the voltage on the network once a fault is detected. It has much higher performance than the passive REFCL and can reduce the current to virtually zero for most faults.

REFCLs can be operated in a number of operating modes. One possible mode is for the protection to immediately trip once a fault is detected. This provides maximum bushfire risk reduction and may not require the replacement of as many surge arresters thus having lower implementation costs. Unfortunately immediately tripping for all faults is not always possible if the fault cannot be located. Furthermore tripping for transient faults will result in a large drop in supply reliability. If employing an active REFCL it is possible to compensate for the fault without tripping the feeder and special algorithms enable the circuit containing high impedance faults to be located. This provides the best possible bushfire risk reduction without impacting supply reliability.

Other types of REFCLs or variants of the above are possible.

[4] Source: CSIRO estimate the reduction in likelihood of polyphase powerlines starting a bushfire with a REFCL as 48-60%. Refer to Table 2 in the Regulatory Impact Statement for the amendments to the Electricity Safety (Bushfire Mitigation) Regulations 2013. Based on the Frankston and Kilmore research, UE expect performance at the upper end of this range if REFCLs are used that comply with the performance regulations contained within the Regulatory Impact Statement.

UE has experience with the active REFCL incorporating the residual current compensator and this is the only system which has been demonstrated as complying with the performance standards to be introduced into the Victorian Electricity Safety (Bushfire Mitigation) Regulations 2013. Therefore the active REFCL is currently UE's preferred technology despite some concerns over its reliability and dependence on a single supplier.

2.5.3. Comparison of Options Considered

A considerable number of options for controlling the risk of UE assets starting bushfires have been evaluated as part of the bushfire mitigation ALARP assessment. This document only considers two REFCL options compared with business as usual i.e. the status quo.

Option 1 – Status Quo

No new controls to reduce the risk of UE assets causing bushfire.

The advantages and disadvantages are summarised as follows:

Advantages:

- No additional upfront capital cost or additional final burden placed on energy consumers.
- No new systems or disruptive business impact.

Disadvantages:

- Provides no reduction in the risk of UE assets starting bushfires.
- Does not comply with regulatory obligations when other controls to reduce risk are available which are reasonably practicable.
- Does not provide other benefits such as improvements in public safety.

Option 2 – Passive REFCL using ASC only

The passive REFCL is mature with several manufacturers providing the components required to construct the system. The passive REFCL significantly reduces the fault current for phase to earth faults and thereby provides an effective way of managing bushfire risk over a wide network area. Unlike the active REFCL it is unable to actively control voltage and requires a minimum amount of sustained fault current to keep the voltage on the faulted phase low. This current will in some cases cause fires thus the technology is not quite as effective as active REFCLs. The technology has less scope for further improvement unless faulted phase earthing can be developed and added to the passive REFCL. It also does not provide any benefit for phase to phase faults.

The advantages and disadvantages are summarised as follows:

Advantages:

- Passive REFCL systems significantly reduce the energy released into phase to ground faults reducing step and touch potentials and generally reducing the risk associated with electric arc, current burns and electrocution. Furthermore passive REFCL systems provide extremely sensitive fault detection, about 5 times more sensitive than traditional SEF. For high impedance phase to ground faults, such as 'wire on ground', the voltage on the faulted phase can remain high (many thousands of Volts) until the system trips the feeder containing the fault thus it may take several seconds before a 'wire on ground' fault is de-energised.
- Research has proven that passive REFCL systems can prevent a significant number of 'wire on ground' faults on 22kV networks from starting fires under extreme fire risk conditions.
- The number of fires started from 22kV phase to earth powerline faults on high fire risk days could be reduced by approximately half.
- Passive REFCL systems reduce the number of momentary interruptions customers experience. Due to the reduction in damage that occurs during faults there is also a reduction in the number of sustained faults.

Disadvantages:

- This technology is not effective against phase to phase faults.
- This technology has not been used on any electricity distribution network in Australia previously although it is commonly used in other parts of the world.
- It requires network hardening to ensure the network can withstand the elevated phase to earth voltages that occur during a phase to earth fault.
- Passive REFCL technology is not as effective in the fault current limiting capability of active REFCLs.
- Passive REFCL technology offers less scope for further improvement when compared to active REFCLs.

This option is not recommended as long as active REFCL technology is viable.

Option 3 – Active REFCL using ASC and RCC

Active REFCLs employ a residual current compensator to enable the voltage on the faulted phase to be actively controlled and reduced to prevent a fire.

A summary of the advantages of the preferred option is as follows:

Advantages:

- Active REFCL systems significantly reduce the energy released into phase to ground faults reducing step and touch potentials and generally reducing the risk associated with electric arc, current burns and electrocution.
- Active REFCL systems provide extremely sensitive fault detection, about 5-10 times more sensitive than traditional SEF.
- For high impedance phase to ground faults, such as ‘wire on ground’, the voltage on the faulted phase is reduced to low levels within several cycles once the fault is detected. It is equivalent to or exceeds all other technologies for its ability to make single phase faults on bare overhead lines as safe as possible.
- Research has proven that active REFCL systems can prevent a significant number of ‘wire on ground’ faults on 22kV networks from starting fires under extreme fire risk conditions.
- An active REFCL scheme will provide maximum bushfire mitigation for UE’s HBRA.
- Active REFCL systems reduce the number of momentary interruptions customers experience and because of the reduction in damage that occurs during faults there is also a reduction in the number of sustained faults.
- Active REFCL systems will substantially reduce the number of fires started on high fire risk days. A 60% reduction in the number of fires started on high fire risk days is expected.

Disadvantages:

- This technology is not effective against phase to phase faults.
- This technology is currently only available from a single supplier.
- UE has experienced reliability problems with its active REFCL. Such problems are common with new technologies. (Performance has improved in 2015).
- It requires network hardening to ensure the network can withstand the elevated voltages that occur when the REFCL compensates for a fault.
- Passive REFCL technology offers less scope for further improvement when compared to active REFCLs.

2.5.4. Summary of the REFCL options:

Option	1	2	3
Description	**Status Quo**	**Passive REFCL using ASC only**	**Active REFCL using ASC and RCC**
Technically Viable	Yes.	Yes.	**Yes.**
Practicable	Yes.	Some areas.	**Some areas.**
Residual risk	**Very High.**	**High.**	**High.**
Comments	Provides no reduction in the risk of UE assets starting bushfires. Does not comply with regulatory obligations when other controls to reduce risk are available which are reasonably practicable.	An adjustable reactor (Arc Suppression Coil or ASC) is inserted between the neutral and ground and the inductance of this reactor is tuned to match the capacitance of the network reducing fault current to low levels, typically as low as 10A. This is expected to prevent about half of phase to earth faults on 22kV overhead lines from starting fires. Provides about 50% of the risk reduction compared with active REFCLs therefore passive REFCLs are inferior compared to active REFCLs.	Reduces the risk of phase to earth faults on 22kV lines causing fire by up to 90%. Could reduce the risk of distribution network initiated bushfires by over 60%. May not be economic in areas of low bushfire risk. Provides a number of additional network benefits. In this option an adjustable reactor (Arc Suppression Coil or ASC) is inserted between the zone substation transformer neutral and ground. The inductance of this reactor is tuned to match the capacitance of the network reducing fault current to very low levels, typically as low as 10A depending upon how well the coil is tuned, the amount of damping on the network and the amount of capacitive unbalance between phases on the network. An additional component known as a residual current compensator (RCC) is also installed which is able to inject an arbitrary voltage/current into the neutral enabling the voltage on the faulted phase to be precisely controlled and reduced close to zero once a fault is detected. Research has demonstrated that this type of REFCL is currently the most advanced system available today and is the most effective at reducing the risk of phase to earth faults on overhead powerlines from starting bushfires.
Recommendation	Not recommended.	Not recommended. Only to be considered if active REFCLs are not commercially available or mature.	**Yes but only in the highest fire risk areas based on the bushfire loss consequence mapping.** **May be used in other areas for other reasons in future.**

3. REFCL BACKGROUND

REFCLs encompass a range of technologies which are able to detect phase to earth faults with considerably higher sensitivity than conventional sensitive earth fault protection and rapidly reduce the current so quickly that it can prevent an electric arc causing a fire. The most common form of REFCL uses resonant earthing and requires the installation of a tuned coil to be installed between the transformer neutral and earth.

UE commissioned a REFCL in the form of a ground fault neutraliser (GFN) from Swedish Neutral at Frankston South (FSH) zone substation as part of an initial trial of the technology. Its primary benefit is for bushfire mitigation and safety. Given that the RECFL significantly reduces the energy into a single phase to ground fault, it inherently reduces the risk of fire starts.

During the first half of 2014 a field test facility was designed and built on the UE network and a comprehensive research programme of 259 tests, including 118 ignition tests under rigorously controlled conditions, was carried out on the only Australian public electricity distribution network protected by a REFCL.

The trial was successful with a report to the Victorian Government in August 2014 by Marxsen Consulting finding:

> *"The test program confirmed that under worst case fire conditions, 'wire on ground' powerline earth faults on Victorian rural networks with traditional network protection systems create an inherent risk of fires and that this risk is markedly reduced in a network protected by a REFCL."*

and

> *"Although installation of each REFCL (one per ZSS) including all requisite ancillary works is relatively expensive…, the delivered fire risk reduction benefit per dollar spent is comparatively attractive because each REFCL can provide protection against earth fault fires to all multi-phase (22kV) lines in an entire substation network."*

3.1 REFCL proposed scope

The high level scope of works for the preferred option is to:

- Install the most advanced active REFCL currently available (Swedish Neutral GFN) that enables UE to comply with the performance standards to be introduced into the Victorian Electricity Safety (Bushfire Mitigation) Regulations 2013 made under sections 151, 151A and 157 of the Electricity Safety Act 1998.
- Install high capacity 240A arc suppression coils at each zone substation on suitable foundations and oil bund.
- Install residual current compensators at each zone substation within the control room building inclusive of a 300kVA power supply and cabling to the arc suppression coil.
- Modify or replace the existing NERs and NER CBs to allow the NERs to be switched in and out of service automatically as required for correct REFCL operation.
- Install the REFCL control system that performs all protection, control and monitoring functions including tuning of the arc suppression coil, fault detection and location, control of the NER CB and residual current compensator, tripping of circuits containing faults, health monitoring, alarms and remote/local control of all REFCL functions and operating modes.
- Modify all existing protection schemes at the zone substation and ACRs on the feeders to operate correctly together with the REFCL system including modification to sensitive earth fault schemes.
- Implement full remote SCADA monitoring and control and remote engineering access to the REFCL system to enable remote monitoring of alarms and faults, control of all operating modes and post fault investigation and diagnostics.
- From 22kV distribution feeder surveys identify and replace ACRs as required to allow for increased phase to earth voltages and duration.
- Identify and replace HV customer equipment (such as metering VTs and surge arresters) as required to allow for increased phase to earth voltages and duration.

- Undertake 22kV feeder phase to earth capacitance balancing as required to reduce dissymmetry as required for correct REFCL operation and to achieve required fault detection sensitivity standards.
- Modify the capacitor bank at MTN so that the neutral point is isolated from earth and new protection is installed to detect capacitor can faults causing unbalance. (Note that no capacitor bank works are required at Dromana).
- Survey all 22kV feeders to identify every surge arrester model installed. Either replace or remove non-compliant surge arresters to avoid surge arrester failure caused by over voltage. Line lengths to be surveyed are MTN: 252km overhead and 52km underground; DMA: 223km overhead and 27km underground. Number of surge arrester 3 phase sets to be surveyed: MTN: 770; DMA: 614.

3.2 REFCL cost estimate

The capital cost of the works is estimated as follows. This cost breakdown includes commercially sensitive information and the individual costs are not to be published or shared with equipment suppliers, other distribution businesses or anyone other than regulators who have a need to review and approve costs.

Zone substation	MTN	DMA
Procurement of major REFCL components including the arc suppression coil, residual current compensator, control system and associated installation and commissioning support	$800k	$800k
Other zone substation materials	$370k	$370k
Capacitor bank modifications	$50k	$0k
Design and drafting	$570k	$570k
Installation, testing and commissioning	$620k	$620k
Distribution feeder surveys and updating SAP	$30k	$30k
Balancing of capacitance on individual feeders	$50k	$40k
Repair or replacement of unsuitable assets (ACRs and cable defects identified from cable testing)	$200k	$100k
Surge arrester replacements (based on a 3 phase set unit rate of $2,700)	$1,156k	$845k
Surge arrester removals (based on a 3 phase set unit rate of $1,500)	$93k	$87k
Escalation to 2015 dollars (1.3%)	$51k	$45k
Total budget required	**$3.99M**	**$3.51M**

The above cost estimates are based on UE's experience installing its REFCL at Frankston South and from up to date estimates using 2015 dollars from equipment suppliers and design and construction service providers. UE has estimated the number of surge arrester replacements for MTN and DMA based on the number that needed replacement found from surveys of Frankston, Frankston South and Langwarrin areas. The exact number will not be known until the MTN and DMA feeders are surveyed.

The cost per project estimated by UE is very efficient when compared to the costs listed in the regulatory impact statement for the amendments to the Electricity Safety (Bushfire) Regulations 2013 in tables 14 and 20. The average cost of the projects listed is $6.26M compared to United Energy's price of $3.75M. The only zone substation which has lower cost is Coolaroo and it does not require any works to replace surge arresters because all surge arresters have already been replaced.

4. COST BENEFIT ANALYSIS

A cost benefit analysis on those options providing the greatest reduction in risk is presented below. Unless indicated otherwise all values are provided on a present value basis calculated over a 20 year period and assume both MTN and DMA REFCLs are installed together.[5]

Option	1	2	3 (Preferred Option)
Description	**Status Quo**	**Passive REFCL using ASC only**	**Active REFCL using ASC and RCC**
Costs:			
CAPEX	$0	$7.8M	$7.5M
OPEX	$0	$0.7M	$0.7M
Benefits:			
Bushfire Risk Benefit	$0	$2.0M	$3.9M
Present Value Ratio	-	0.24	0.48

The preferred option accords UE with a present value bushfire risk mitigation benefit of $3.9M when estimated using the best available data. The preferred option will reduce total UE network bushfire risk by 35%.

The bushfire mitigation benefits were derived by applying data supplied by the CSIRO fire loss mapping research undertaken by the Victorian State government and Regulatory impact statement (RIS) for Victorian legislation. For the RECFL installations at MTN and DMA, the average annual cost of fires caused by electricity assets over the 2000-2034 period in MTN and DMA areas was determined to be $332k. This value was then applied to the overall reduction in the number of fires started using REFCL technology (60%) resulting in an annual bushfire mitigation benefit of $198k, equating to a present value of $3.9M.

There are potential network reliability implications from installing REFCLs that are not listed in the table above but warrant some consideration. Unless a network is hardened to withstand the elevated phase to earth voltages that occur with REFCLs there will be an increase in the number of plant failures and power outages. UE has experienced an increased rate of cable failures at Frankston South (FSH) while the REFCL is operating compared to times when it is not operating. UE has had one ACR fail caused by the REFCL and possibly one surge arrester. Furthermore UE has experienced several faults with the operation of the equipment at Frankston South that have caused power supply outages. Given the known HV ABC issues at DMA and MTN and the mode of failure there is some concern REFCLs could accelerate asset deterioration and negatively impact on reliability. Care will be required, possibly requiring the REFLCs to be limited to operation on high fire risk days until the HV ABC issues are resolved. In the long term as network weaknesses are identified and repaired or assets are replaced the incidence of plant failure will decline.

[5] In practice UE shall not install both REFCLs in the same year due to resource constraints however this does not impact the cost benefit analysis because the costs and benefits do not vary depending upon the project timing. UE will aim to install both REFCLs as quickly as practical.

5. SUMMARY AND CONCLUSION

UE's ALARP bushfire risk assessment has identified that the installation of active REFCLs at Mornington (MTN) and Dromana (DMA) zone substations within the next regulatory period (2016-2020) is a practicable means of reducing bushfire risk and should be part of UE's bushfire mitigation plan. MTN and DMA represent 56% of the total UE risk, significantly higher than any other zone substations. REFCLs at these locations are practicable because they provide an overall UE network bushfire risk reduction of 35% at a cost which is not disproportionately high compared to the value of the risk reduction.

UE has committed to the installation of two REFCLs and included them in UE's fire prevention plan submitted to Energy Safe Victoria. The plan is schedule for approval by ESV in early 2016, upon which it becomes a mandatory obligation for UE to implement.

UE is able to install REFCLs at an average cost per zone substation of $3.75M. This is efficient compared with the average forecast cost of $6.26M for the rollout of the technology across rural Victoria.