Rapid Earth Fault Current Limiter (REFCL) Program

Compatible Equipment – Line Hardening Strategy

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1 PURPOSE AND BACKGOUND

1.1 Purpose

The purpose of this supporting document is to explain AusNet Services' line hardening strategy, which addresses the voltage stress that occurs on line equipment when a Rapid Earth Fault Current Limiter (REFCL) responds to an earth fault.

REFCLs are to be installed on AusNet Services' network in response to new bushfire mitigation regulations. Line hardening work is one of 5 work streams that comprise the REFCL installation program.

1.2 Background

AusNet Services' network operates in a unique geographical location, which is exposed to extreme bushfire risk. These conditions warrant significant investment to mitigate the bushfire risk.

The 2009 Victorian Bushfire Royal Commission made several recommendations with respect to fires initiated from distribution electricity networks. Subsequently, the Victorian Government established the Powerline Bushfire Safety Program to research the optimal way to deploy REFCLs for bushfire prevention. This research led the Government to introduce Electricity Safety (Bushfire Mitigation) Amendment Regulations 2016.

For AusNet Services, the regulations require each polyphase electric line originating from 22 selected zone substations to comply with mandated voltage reduction performance standards by 1 May 2023. In the timeframes specified in the regulations, the installation of REFCLs is the only feasible technological solution.

The REFCL installation program will be managed in three Tranches. This line hardening strategy is focused on Tranche 1, which will be completed by 30 April 2019. At this stage, it is expected that the strategy will remain valid to Tranches 2 and 3. However, this will be confirmed prior to the commencement of these later Tranches.

The 'line hardening' work stream is concerned with the replacement of 22kV surge arrestors that are known to be incompatible with the new REFCL technology.

Surge arrestors are used throughout our 22kV network to provide impulse protection from faults. Surge arrestors have been designed for low impedance or solidly earthed networks to provide insulation coordination with other equipment on our network such as pole top transformers, switches and cables.

Surge arrestors fitted to a REFCL protected network (high impedance) must be capable of sustaining the elevated voltages which occur on healthy phases in response to a phase to ground fault. Sustained over-voltages are experienced regularly and repeatedly during REFCL operation.

4,913 line surge arrestor sites have been identified as requiring replacement in Tranche 1.

1.3 Strategy objective

The objective of this line hardening strategy is to:

- describe the issues associated with the operation of surge arrestors on a network utilising REFCLs; and
- demonstrate that a prudent and efficient approach has been taken to the selective replacement of surge arrestors on AusNet Services' network.

2 Investment need

The Electricity Safety (Bushfire Mitigation) Amendment Regulations (2016) specify the installation and operation of the voltage reduction required on a polyphase line when a phase-to-ground fault occurs, and the fault current levels that must be achieved. These specifications can only be met safely where under-rated rated line equipment such as surge arrestors are replaced.

The need for this 'line hardening' investment was highlighted in the REFCL trials:

> *"When an earth fault occurs, the REFCL response creates voltage stress on network equipment connected to un-faulted phases, which can lead to a second fault. Outcomes can be worse than if a REFCL were not installed.[1] "*

The 'second fault' results from the exposure of a surge arrestor to the high voltages that arise from REFCL operation. These 'second faults' are also known as 'cross country faults' i.e. they occur at a location on the feeder other than the site of the initial fault which caused the REFCL to operate.

As noted in the above excerpt, the outcome of the second fault can be worse than if a REFCL were not installed due to the potential for both the original fault and the failing surge arrestor to ignite a fire. Furthermore, the REFCL will not operate when two faults have occurred on the network and therefore no protection is provided by the REFCL following the second fault. It is therefore imperative that incompatible surge arrestors are replaced through a systematic 'line hardening' work stream as part of the REFCL installation program.

3 Options analysis and preferred approach

The installation of REFCLs on the existing network requires the establishment of cost effective method to replace surge arrestors to achieve compliance with the Regulations. As already noted, this work is essential for REFCL technology to operate safely i.e. to operate without increasing the likelihood of bushfire ignition.

Historically, AusNet Services' line surge arrestors catered for phase to ground voltages up to 19kV. Following the installation of REFCL technology, they must now cater for elevated phase to ground voltages up to 24.2kV (i.e. 22kV plus 10%).

The following activities have been completed in order to evaluate options:

- Desktop and field identification of surge arrestor types and population currently on the network; and
- Sample testing at elevated voltages to identify surge arrestor types that cannot withstand elevated voltages.

Preliminary sample testing has assessed each surge arrestor type against its rated operating voltage and rated temporary over voltage whilst ensuring no thermal runaway exists when subject to the new voltage requirements. This objective is to minimise the risk of failure following REFCL operation.

Tests have determined two particular types of line surge arrestors are capable of withstanding the increased voltages associated with the operation of a REFCL. AusNet Services is not proposing to upgrade these surge arrestors, which comprise 60% of the surge arrestor population for the first tranche.

[1] Dr Anthony Marxsen, REFLC Trial: Ignition Tests, Marxsen Consulting Pty Ltd, Monday 4 August 2014, page 93.

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The options considered to ensure that line surge arrestors are capable of operating at elevated voltages are:

1. Staged program to replace the 40% of surge arrestors that sample testing has determined will not operate satisfactorily at elevated voltages.
2. Replace all surge arrestor types that do not have a minimum designed operational limit of 22 kV. This will involve replacement of some surge arrestors which performed satisfactorily in testing but were not originally manufactured to operate at 22 kV.
3. Retrofit existing three phase surge arrestor sets with an additional surge arrestor in a 'Neptune' configuration. In addition, replace single and two phase surge arrestor sets that sample testing has determined will not operate satisfactorily at elevated voltages.
4. Do not proactively replace surge arrestors allowing the existing surge arrestors to run to failure when exposed to REFCL operating voltages.

The option of removing, rather than replacing, some surge arrestors was not evaluated as AusNet Services analysis indicates that surge arrestors should be installed on distribution transformers in high bushfire risk areas (and the REFCL installations are targeted at these areas). Further, there is little cost saving resulting from the removal of surge arrestors as the largest cost component of surge arrestor replacement is labour, and labour cost will still be incurred to visit the site and remove existing surge arrestors.

A summary of our analysis in relation to each of these options is shown in Table 1.

Table 1: Options evaluated

Option	Advantages	Disadvantages
1. Identify surge arrestors not capable of withstanding the elevated voltages (based on test results) and replace accordingly.	Ensures REFCL operating compliance on a risk-based approach. Reduces volume of work required. Ensures cost efficiency.	Risk still exists of cross country faults should surge arrestors be incorrectly identified or missed during replacement program.
2. Replace all surge arrestors.	Uniform approach. One hundred percent replacement of tranche one surge arrestors would reduce the risk associated with line surge arrestors being missed during the planning and delivery stages of the project.	Increases volume of work required. Option would not minimise direct project costs and therefore fails to maximise community benefits, assuming the risk of cross country faults can be eliminated.
3. Retrofit an additional surge arrestor in a Neptune configuration.	Reduces costs of surge arrestor replacement.	Many differing mounting brackets would need to be developed for each different transformer/ switch/ pole/ surge arrestor combination. More expensive to develop brackets than replace surge arrestors. Each installation site would require a design component. Not technically feasible in many

Option	Advantages	Disadvantages
		instances due to clearance requirements.
4. Allow existing surge arrestors to fail when exposed to REFCL operating voltages.	Less up-front capex.	Likely to result in additional fire starts (defeating the purpose of the REFCL program). Poor network reliability would result due to multiple outages from cross country faults affecting whole feeders (as REFCL will trip feeder CB). Significant increased risk of fire and or harm for the general public.

Option 1 is the preferred option as it is evident from the above table it is:

- It is the lowest cost option, providing that the risk of cross country faults can be mitigated;
- It is strongly preferred to Option 3, which is not feasible;
- It is strongly preferred to Option 4, which exposes the community to unacceptable safety risks and reliability outcomes; and
- Meets the objective of safe compatible operation with REFCL technology.

3.1 Preferred Option Risks

The key risk associated with replacing only tested surge arrestor types is that the risk of a cross-country fault still exists. Although a pragmatic approach, surge arrestors may be missed in the replacement works, as it will be heavily reliant on the validating internal database information against field inspections. This risk is mitigated by testing during the commissioning phase of the REFCL and annual insulation tests which aim to identify and rectify any failing or missed assets.

A further risk arises from selecting surge arrestors to be replaced utilising sample testing. It is possible that some surge arrestors that passed the sample testing will fail in operation. This risk has been mitigated by selection of a statistically significant test sample size.

4 Efficient and prudent program delivery

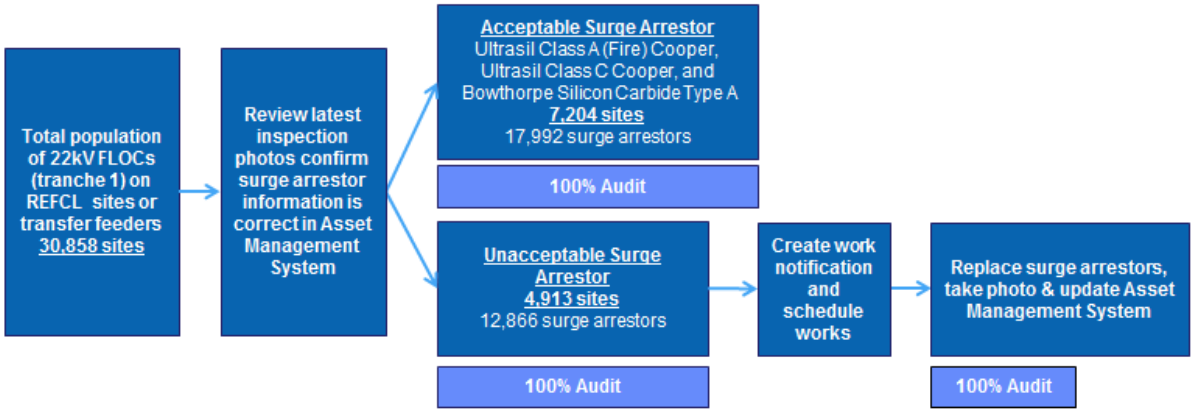
Approximately 60% of line surge arrestors do not need to be replaced due to the outcomes of testing.

In accordance with this strategy, 344 surge arrestors must be replaced on the Woori Yallock network, which were not replaced as part of the original Woori Yallock REFCL project. The 344 sites relate to 3 surge arrestor types which have been exposed as having thermal runaway at operating voltages under 24kV. If not replaced these sites run the risk of failure in the near term. The replacement of these surge arrestors are therefore included in Tranche 1 works.

Surge arrestor replacement activities will be completed on a staged feeder by feeder basis. The first sites to be finalised will be Rubicon A, Barnawartha and Woori Yallock, including Woori Yallock's transfer feeders to Lilydale and Kinglake. The timely completion of these locations will allow the REFCLs to be commissioned and network hardening tests to occur in 2017. Where

possible, surge arrestor work will be integrated with other REFCL, maintenance, bushfire mitigation or safety program works.

The number of line surge arrestors to be replaced is validated to ensure all 'unacceptable surge arrestors' are identified and the likelihood of missing unacceptable surge arrestors is reduced. This process also ensures surge arrestors deemed acceptable are not replaced. A 100% photo audit is conducted at three stages throughout the validation process. This validation further reduces the likelihood of surge arrestors being incorrectly assessed as either acceptable or unacceptable. The process is shown below:



4.1 Risk management

The risks associated with delivery of the program of surge arrestor replacement are shown in the table below.

Risk	What could occur	Actions & controls
Interference / clashes with other project(s) and project scope creep.	Delivery delays leading to non- compliance with Bushfire Mitigation Regulations and the approved Bushfire Mitigation Plan. Down time for construction crews	Continual engagement with Network Planning Teams and delivery partners. Network Programs constant review of Portfolio projects. Dedicated Program Sponsor Team established.
Delivery delays and timelines not met to meet REFCL regulatory obligation	Delivery delays leading to non- compliance with Bushfire Mitigation Regulations and the approved Bushfire Mitigation Plan.	Monthly reporting of the progress of the project from delivery partners through to the Program Team / Steering Committee and Energy Safe Victoria. Regular updates of Asset Management System enabling progress to be tracked real-time. Well planned schedule of works. Early engagement with Control Energy Operations Team (CEOT), delivery partners and field personnel to ensure resourcing availability.

4.2 Procurement

Surge arrestors to be installed are standard stock items. These items have been procured utilising AusNet Services' standard procurement and governance processes which include competitive tendering to ensure the cost per unit is efficient.

4.3 Works delivery

The volume of unacceptable surge arrestors requiring replacement in tranche one of the REFCL program varies between zone substations.

The number of surge arrestor replacements is largely proportional to the number of customers the respective zones substation serves. Larger customer numbers lead to more transformers, and in turn a larger surge arrestor population. Wonthaggi, Seymour and Wangaratta serve the most customers and have the highest volume of surge arrestors requiring replacement.

The surge arrestor work will mainly be constructed using established external delivery partner relationships. Internal resources may be utilised for integration opportunities with other required works on 22kV feeders where appropriate.

Table 4-1: Summary of zone substation data and works required

	22kV Network Size (km)	Customers	22kV Feeders	22kV Transfer Feeders (from zone substations that will not have a REFCL installed in Tranche 1)	Unacceptable Surge Arrestor Sites Requiring Replacement	
					Transformer sites	Switch and cable head sites
Wonthaggi	1,023	23,263	8	3	610	120
Myrtleford	529	7,434	4	1	325	66
Barnawartha	295	1,861	4	-	150	30
Kilmore South	439	8,495	2	1	268	44
Rubicon A	514	4,883	3	-	592	59
Kinglake	184	2,435	3	-	137	22
Wangaratta	1,475	17,430	7	-	874	158
Seymour	1,006	10,395	6	-	665	170
Woori Yallock	659	17,535	4	1	448	175
Total	**6,124**	**93,731**	**41**	**6**	**4069**	**844**

Source: AusNet Services

4.4 Program costs

The Lines Hardening Strategy preferred option has been costed in accordance with our standard costing methodology, as detailed in supporting document: Cost Estimating, unit rates and program delivery.

The costs detailed below in Table 4-2 include:

- Evaluation and type testing of existing surge arrestor fleet;
- Photo verification of all 22kV surge arrestor sites determining whether they are acceptable or unacceptable;
- Works planning and governance activities;
- Construction works for surge arrestor sites (transformer, switch and cable head locations);
- Project management; and
- Auditing.

Table 4-2: Summary of capital expenditure requirements

	Unacceptable Surge Arrestor Sites Requiring Replacement		Unacceptable Surge Arrestor Units Requiring Replacement	Costs $000s 2016 direct
	Transformer sites	Switch and cable head sites		
Wonthaggi	610	120	1,912	1,796
Myrtleford	325	66	1,024	962
Barnawartha	150	30	471	443
Kilmore South	268	44	817	768
Rubicon A	592	59	1,705	1,602
Kinglake	137	22	416	391
Wangaratta	874	158	2,703	2,539
Seymour	665	170	2,187	2,054
Woori Yallock	448	175	1,631	1,533
Total	**4069**	**844**	**12,866**	**12,088**

Source: AusNet Services

To demonstrate the efficiency and prudency of our proposed expenditure, we must have regard to available benchmark information. We note that the Regulatory Impact Statement (RIS) prepared by ACIL ALLEN for the Victorian Government in 2015 provided the variation in the quantities for surge arrestors units (referred to as 'Feeder Lightning Arrestors').

The RIS estimate forecast[2] 0 - 8,224 surge arrestor units per zone substation requiring replacement at $1,000 each.

AusNet Services replacement program, as detailed above, is 416 - 2,703 surge arrestor units per zone substation requiring replacement at $940 each, which is a considerable saving compared to the RIS estimates. This outcome provides further assurance that AusNet Services' cost forecasts are prudent and efficient.

It is also important to emphasise that the cost forecasts presented in this contingent project application reflect a detailed scope of work for each zone substation installation in accordance with the AER's 'trigger event' definition. As such, AusNet Services' forecasts are fully substantiated having regard to the actual conditions at each zone substation whereas the RIS estimate adopted a broader estimating approach that was unavoidably less comprehensive.

4.5 Program governance

While the line surge arrestor replacement program will be managed using the AusNet Services' Portfolio Framework, an overarching REFCL Program Governance Framework has been established in order to provide end-to-end Program oversight and accountability, to identify and manage program level risks.

The REFCL Program Governance Framework aligns to AusNet Services' values and commitment to mission zero with:

- Clear accountabilities, reporting and robust risk and issue management;
- Sustainable, long term, reliable, economical and workable whole of life designs;
- Delivery as per agreed timelines without compromising reliability and other service standards;
- Integration where possible with the rest of the AusNet Services work program;
- Compliance with required obligations;
- Strong relationships with all stakeholders in order to successfully manage change;
- Development of internal capability in order to facilitate the transition to business as usual; and
- Use of business as usual processes and resources where possible.

5 Concluding comments

This supporting document has explained that:

- The proposed scope of surge arrestor replacements is the lowest cost and highest community benefit option for addressing the specific issues on REFCL protected networks;
- A standard approach to estimating the costs of surge arrestor replacements has been used;
- We have identified the key risks in relation to surge arrestor replacements and taken appropriate risk mitigation measures; and
- Our replacement volumes are within the Government's estimated range in the RIS, and our forecast unit costs are lower.

[2] Regulatory Impact Statement, Bushfire Mitigation Regulations Amendment, ACIL ALLEN Consulting, Table 14, Page 69. It should be noted that the RIS costs are expressed in $2015 while our costs are expressed in $2016. Strictly speaking, for comparison purposes the RIS costs are approximately 1.5 per cent higher than indicated here.

In addition, it should be noted that our forecast expenditure for surge arrestor replacement has been subject to our standard business case review and approval processes. This work will also be subject to our project management and governance arrangements.

For these reasons, we regard the forecast expenditure for surge arrestor replacement as prudent and efficient, in accordance with the Rules requirements relating to contingent projects.