PBSC Discussion Paper.

Document Purpose

The paper provides comments on concerns and issues that have been raised in recent presentations and papers regarding the use of REFCLs to reduce bushfire start risk from powerlines in Victoria.

Concerns and Issues Raised

Most of these related to the implementation, operation and costs of REFCLs. The implementation issues were reviewed and have either been or are being resolved. The operational issues raised are known and are being managed and include issues such as the increased difficulty in locating faults. The cost increase issues are noted. The issues raised in these categories will therefore not be discussed further.

Some issues raised in presentations are not related to REFCLs e.g. the installation of additional weather and fire monitoring for the fire authorities by the distribution businesses, community engagement, safe community centers, coordination between authorities and fuel load reduction. These were considered and actioned where deemed necessary by the Victorian Government as part of its response to the Black Saturday fires. They are not considered further.

The remaining issues regard the ability of the REFCL to reduce fire start risk and alternative approaches to reduce network fire risk and are considered in this paper.

REFCL Performance Concerns

Concerns Raised	Comments
• Cross country faults (7-37% p.a. over 15 year period and these can cause fire starts. • Non-metallic screened HV ABC a cross country fault risk. • Cross country faults can happen at any time.	Cross country faults are being addressed by hardening the network involving the selective replacement of equipment likely to fail such as some surge diverters, voltage transformers and the replacement or isolation of older cables. During the commissioning process for REFCLs the network is tested to check the remaining equipment's ability to operate with a REFCL in service. The operation of the REFCL during the full year means that any failures that may occur are distributed throughout the year as the type of equipment failures are not prone to increase in probability due to the environmental conditions experienced on TFB days. This reduces the probability that a cross country fault will occur on a TFB day.

Concerns Raised	Comments
	Experience to date with REFCLs in service in Victoria has not indicated that cross country faults are a significant issue.
• Multiple high impedance faults (e.g. trees brushing) can still lead to arcing in high fire risk in high fire risk days.	This is mitigated by not allowing REFCL's on TFB days to compensate for long periods and instead isolating any permanent faults as soon as possible. Enhanced inspection and tree clearing requirements since Black Saturday reduces the risk of tree branches brushing 22kV multiphase and SWER lines.
• Phase to phase faults not compensated	Agreed for phase to phase faults clear of earth. In the highest fire risk (prescribed) areas the strategy is to replace the bare conductors with underground or covered conductor over time to mitigate this risk.
• Phase to phase to earth and backfed faults difficult to manage	REFCL will not fully mitigate the risk for phase to phase to earth faults but has a higher mitigation probability in cases involving a high impedance vegetation fault. Back-fed faults can be detected and cleared by a REFCL.
• Cannot compensate for phase to phase faults – line clashing.	Conductor clearance design standards have been chosen to reduce the risk of line clashing due to wind and the expected temperatures during operation. Audits of lines and inter-circuit conductor clearances have been undertaken to identify areas where the construction does not confirm to standards. Conductor clashing due to high fault currents caused by a downstream fault is reduced with REFCL technology as it reduces the phase to earth fault current to a level where clashing would not occur. The REFCL also reduces the chances of a phase to earth fault evolving into a phase to phase to earth fault and therefore reduces the risks of conductors upstream clashing. Clashing due to downstream faults is also considerably less likely in many fire risks areas as the fault levels are generally considerably lower than in the metropolitan area.
• Hardening the system causes an increase in insulation deterioration rate.	While this concern is not directly a performance issue it could lead to an increase in failures so has been included. There is the potential for failures of equipment that is already in a deteriorated state. Commissioning tests are designed to bring

Concerns Raised	Comments
	forward these failures. Evidence to date has not supported an increase in failures due to REFCL operation once hardening of the network was undertaken. In some cases, isolation of older cable networks has been undertaken to address this issue.
• Changes in network configuration during compensation period can lead to arc re-ignition.	Compensation period on total fire ban days is short and the fault isolated before any network configuration change occurs. After reconfiguration the REFCL will retune to the reconfigured network.
• SWER incompatible with REFCL: costly to reconfigure, under grounding best option yet still challenges. • ACR's provide some benefit.	New ACRs are being used to reduce the fire risk of SWER lines. New on-line monitoring technology offers the potential to reduce risk of many equipment and conductor failure types and identify vegetation touching a line. However, it is currently not designed to detect and trip a line and will therefore not prevent a fire start from a tree falling on a line. Replacement over time of bare conductor with cable or covered conductor is being used in the highest risk (prescribed) areas.
• Single-phase incompatible with REFCL	This is not correct.
• Residual current compensation not instantaneous, and capacitor discharge not seen at source substation can take 40-80ms.	The required capacity specifications were determined from the results of many REFCL fire start tests. The fault voltage reduction and energy release restrictions necessary to mitigate against a fire start do not require instantaneous compensation.
• Harmonic sources may not be effectively compensated.	Harmonic levels are being addressed.
• LV and > 33kV line no compensation	The LV fire risk has been mitigated by the use of spreaders and in highly vegetated areas LV ABC. LV was not found to be a high fire start risk. 66kV and above lines were found to be a very low fire risk.
• REFCL's reduce likelihood of an earth fault created fire by some 60-70% at the most optimistic estimate. and • Aim is to stop extreme bushfire events caused by electrical network	The numerous fire start tests undertaken and its analysis suggests that this level of fire start risk reduction is not optimistic. A REFCL can also reduce the risk of a fire start risk due to some phase to phase to earth faults and back-fed faults. This neglects the targeted approach adopted in Victoria where the level of fire risk reduction is aligned to the level of fire start consequences.

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not just reduce by 50% or maybe 60%.	
• Cigre C2-24. Strategies to mitigate fire risk	Cigre sub-committee (C2-24) falls under CIGRE (C2) “System Operation and Control” committee. It therefore would consider operational and control issues and strategies. The preemptive de-energising of parts of the network is not Victorian Government policy.

Alternative Network Fire Start Risk Reduction Options

One presentation also included information from a research paper (Williamson[1] 2015) into the use of household PV combined with battery storage and the de-energisation of the associated powerline in order to mitigate fire start risk from powerlines on high fire risk days.

The paper noted that de-energising powerlines potentially results in grave community impacts and that this practice was not adopted in Victoria.

The report assessed the feasibility and cost effectiveness of installing PV and batteries capable of providing up to 3 days of energy supply to households in order to cover their energy needs over consecutive high risk TFB days. The SWER lines would not be removed.

The approach differs from the RAPS trails undertaken in Victoria as the powerlines would remain for use at all other times so a large RAPS system is not required. It would potentially be more acceptable to customers than the RAPS systems as the customer is not being removed totally from the network and does not require a diesel generator as backup in winter.

The required capacity of the PV and battery system was determined by evaluating historical Victorian data on TFB days to determine the likely number of consecutive TFB days, the likely energy generation by solar cells in this period and the energy consumption on high risk feeders over hottest summer months to determine average energy consumption per household.

The paper considered that the feasibility of using PV with battery storage on 22kV multiphase line was doubtful. But it considered that while challenging to implement it is likely to be feasible for SWER lines in high fire risk areas and is a low-cost mitigation strategy. The paper also noted that the costs are likely to reduce as the cost of battery storage reduces.

The cost estimate for the implementation of various options to reduce the fire start risk from powerlines, including the PV/battery options, are shown in the following table from the paper:

[1] Application of Distributed Solar Photovoltaics and Energy Storage to Mitigate Bushfire Risk in Victoria, Australia. Michael Williamson, Loughborough University.

Alternative approaches

Williamson (2015)

Technology Option	Mean Customer Density/ km	NPC (Incremental $/km) Lifetime	Risk Reduction	Lifespan (years)	Status
A) New generation SWER ACRs	2.4	$1,229	50%	38	deployed under existing measures
B) REFCLs on multi-wire	13.9	$8,798	70%	38	deployed under existing measures
C) Convert SWER to multi-wire (REFCL)	2.4	$163,897	63%	70	not implemented
D) SWER – insulated wire	2.4	$284,253	90%	30	not implemented
E) SWER – underground	2.4	$366,998	99%	45	deployed for high risk powerlines
F) Multi-wire – insulated wire	13.9	$341,887	90%	30	not implemented
G) Multi-wire – underground	13.9	$567,468	99%	45	no information on implementation
H) PV/Storage on SWER	2.4	$22,302	99%	20	no planned implementation
I) PV/Storage on multi-wire	13.9	$129,167	99%	20	feasibility doubtful
J) SWER ACR plus PV/Storage	2.4	$23,531	99%	20 to 45	no planned implementation
K) Stand alone PV/storage - remove SWER line	2.4	$137,964	99%	20	not implemented

The paper argues that only options that reduce the risk by 90% to 100% should be considered but did not consider that it is possible to implement a suite of measures that are tailored to reduce the risk by different amounts depending on the fire start risk level of the location.

There are a number of concerns with this study.

Firstly, it assumes that a study of the SDG&E network into the number of network outages undertaken by Mitchell[2] with different wind gust speeds will be the same in Victoria. The paper states that for the SDG&E network the outages increased 10 fold for every 25 km increase in wind gust speed but the data does not entirely fit this approximation. Overall it concludes that there was a 10,000 increase in outages from the outage level with wind gusts of up to 8 km/hr to that with wind gusts of 97 km/hr. The data also showed that the increase did not change once wind gust speeds increased beyond 97 km/hr up to the maximum of 113 km/hr in the study.

It is highly likely that this analysis would not be transferable for use in Victoria as the behaviour of a network under high wind speeds depends on many factors such as the technology and specifications of the equipment, the construction standards used for powerlines, asset inspection and maintenance practices, asset replacement policies, vegetation clearances to powerlines and the management of these clearances, operational practises and the use of on-line monitoring to enable the early detection of defects.

The other concern is that the outage rate variation will not necessarily correlate to the level of increase in fire start risk. The cause, time and location of the outages needs to be considered and if any fire start mitigation measures are in place to reduce the risk of a fire start from the cause of the outage. The report also notes that at higher wind speeds the risk of fire start from a fault may reduce due to the effects of the strong wind.

The household energy consumption does not reflect the much higher consumption in the very hot conditions on TFB days due to air conditioning and evaporative cooling energy requirements as the study used an average of household energy consumption over the peak

[2] "Power line Failures and catastrophic wildfires under extreme weather conditions", Mitchell J. W., Engineering Failure Analysis 35 2014, pp 726-735

summer months. It also did not consider the potentially higher energy consumption requirements of farms and other small businesses that can be connected to SWER lines.

The RAPS trial in Victoria highlighted that the installation costs can increase considerably due to the need to undertake repairs or improvements to the existing electricity switchboard or wiring in some households in order to bring it up to acceptable modern standards.

Some households in the high fire risk areas will have restricted access to solar radiation due to surrounding trees and an alternative safe energy source would be needed or significantly larger capacity batteries.

The paper argues that a suitable financial incentive be offered to households to install the PV/battery installations. However, some households may not wish to participate or may not be able to afford to pay for the remaining cost of the installation. Therefore, an incentive scheme may not work.

The paper recognises that there would need to be a method to determine which SWER lines are to be included, when they are to be switched off and when it is safe to be restored. It proposes the use of a Bayesian Belief Network to evaluate the criteria for de-energising a line. This may provide an input to the evaluation of a criteria but any rules and probability of switching of supply would need to be clearly understood well in advance so that preparations can be made.

The report also does not identify the safety issue with restoring supply after a period of de-energisation as the condition of the line will be unknown. Restoration can take a considerable time if the area of the SWER line is remote.

While there are a number of issues with the evaluation and the implementation of this option would be challenging, it is technically feasible and could provide another means to reduce fire start risk from SWER lines in the highest fire risk areas

Summary

There have been a number of concerns raised regarding the operation and performance of a REFCL however there are a number of errors and misunderstandings in these. They also do not provide evidence to suggest that REFCLs are not an appropriate fire risk mitigation option for wide spread application in Victoria.

The option of using solar PV and batteries in households to enable de-energising a powerline does not accurately reflect the conclusions of the researcher as it was regarded as unlikely to be feasible for 22kV multiphase lines but feasible but challenging for SWER lines. Therefore, this did not apply to the use of REFCLs.

The use of PV and batteries in households on SWER lines in the highest fire start risk areas is a technically feasible option and may be a means to reduce fire risk in these areas. It is an option that is worth considering but has many implementation challenges.