Victorian Electricity Supply Industry REFCL Technical Working Group Position Paper Response to Recommendation E of the 2020 REFCL Functional Performance Review

Executive Summary

The Victorian Electricity Supply Industry (**VESI**) Rapid Earth Fault Current Limiter (**REFCL**) technical working group (**TWG**) has reviewed recommendation E of the REFCL functional performance (**FP**) review which recommended that distributors explore methods to better predict damping values. Recommendation E has now been implemented through improvements to the existing method. The VESI REFCL TWG is of the view that this method most appropriately balances cost, time constraints, reliability and accuracy.

Who we are

The VESI is an industry group comprised of the five distribution businesses (CitiPower, Powercor, AusNet Services, Jemena and United Energy) and the main transmission network business (AusNet Services) in Victoria, collectively referred to as Major Electricity Companies (**MEC**) in the *Electricity Safety Act 1998* (Vic) (**ESA**). In 2016 VESI established the REFCL TWG as a forum to share knowledge and experience in delivering the mandated REFCL program. ESV has also been represented as a permanently invited guest of the VESI REFCL TWG since its inception.

Background

In 2020, Energy Safe Victoria (**ESV**) engaged Power Systems Consultants (**PSC**) to undertake an independent FP review of REFCL technology (following the implementation of the first tranche of the delivery program). The review considered input from ESV, AusNet Services, Powercor, United Energy, Jemena, the Department of Environment, Land, Water and Planning (**DELWP**) and other stakeholders.

The report[1] concluded that *"the operational performance of the installed REFCLs is meeting expectations in relation to bushfire risk mitigation. In some instances, the installed REFCLs have exceeded these expectations by responding to more complex faults and reducing bushfire risk"*. The report also made eight recommendations (A-H) intended to improve the community benefit from the program.

ESV, AusNet Services, Powercor, United Energy and Jemena responded to each of the recommendations[2]. In July 2021 ESV received the Minister's Statement of Expectations[3] (**SOE**) for the period 1 July 2021 to 1 July 2023 that included an expectation that ESV implement each of the FP review recommendations. ESV's response[4] committed to working with industry to meet this expectation.

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[1] Accessible here: https://esv.vic.gov.au/wp-content/uploads/2021/01/REFCL-Functional-Performance-Review.pdf
[2] The report and response are accessible here: https://esv.vic.gov.au/about-esv/reports/technical-reports/rapid-earth-fault-current-limiter-reports/
[3] The Minister's SOE is accessible here: https://esv.vic.gov.au/wp-content/uploads/2021/08/Letter_from_Minister_ESVSOE_2021-23.pdf
[4] ESV's response is accessible here: https://esv.vic.gov.au/wp-content/uploads/2021/08/Letter_to_Minster_ESVSOE_2021_Response.pdf

Purpose

The intent of this paper is to address recommendation E of the 2020 REFCL FP review:

"It is recommended that the distributors explore methods to better predict damping values accurately, and remove the reliance on the bounded range currently adopted to mitigate the risk to the program and to maintaining compliance."

Initial Responses to Recommendation E

The following provide direct quotes of each organisation's response to recommendation E of the 2020 REFCL FP review.

ESV response

"This recommendation relates to delivery and economic risks that are a matter for distribution businesses (DBs) to manage. ESV will submit this recommendation to distribution businesses for their formal reply. ESV agrees that a method for more accurately determining network damping would assist DBs to perform network planning activities more efficiently that may result in lower delivery costs. Once a REFCL is installed, network damping can be measured directly and changes can be made to address this issue if the true damping values exceed initial estimates. Therefore DBs should consider whether investment in developing a method for accurately determining network damping before a REFCL is installed will be offset by associated network planning and augmentation savings. ESV will continue to oversee the industry's development of improvements/solutions to this and several other technical issues through its involvement in the Victorian Electricity Supply Industry REFCL Technical Working Group."

United Energy Response

"United Energy does not see the value in developing a model for accurately determining network damping before a REFCL is installed particularly where there may be alternative strategies to maintain / improve REFCL performance. Network damping can be measured directly once a REFCL is installed.

UE will continue to monitor REFCL performance and action remedial or improvement initiatives As Far As Practicable."

Powercor Response

"Powercor has completed installing REFCLs at sixteen zone substations so far, with fourteen accepted as complying substations by ESV. Damping prediction has not impacted our ability to deliver the first two tranches of the program. Powercor agrees with ESV's assessment that:

- *this recommendation relates to delivery and economic risks that are a matter for distribution businesses (DBs) to manage; and*
- *Once a REFCL is installed, network damping can be measured directly.*

Powercor does not see any value at this stage of the program in developing a model for accurately determining network damping before a REFCL is installed."

Jemena Response

"Jemena supports this recommendation, although we believe it could be difficult to achieve as experience to date suggest damping values can only be confirmed once the ASC is installed and tuned. Nevertheless, we see the benefit in this recommendation to manage our risk in maintaining compliance and would work with ESV and other DBs to explore viable options in the REFCL Technical Working Group."

AusNet Services Response

"AusNet Services agrees with the benefits of being able to accurately estimate and predict damping. It does however acknowledge; this is a complex problem facing many utilities worldwide. We have initiated a small study whereby the resistive losses of common line equipment are being measured. This program is in its early stages.

We agree, leveraging the resources of the Victoria Electricity Supply Industry REFCL Technical Working Group is an appropriate way to further investigate prediction of damping."

Network Damping

Damping represents the zero sequence energy losses of the unfaulted network. These losses comprise:

- Energy losses from leakage current to earth on all network components
- Energy losses within the Arc Suppression Coil (ASC)
- Energy losses in the series resistances of overhead lines and underground cables

Initial deployment

Damping is one of several network characteristics that must be controlled in order for the *required capacity* to be achieved. This is because high network damping constrains fault detection sensitivity. When a MEC is planning to implement REFCL protection for a particular distribution network, the level of network damping must be estimated in order to determine the necessary:

- Size and quantity of arc suppression coil(s) to be installed
- Nature and extent of network augmentation works

As discussed in the 2020 REFCL FP review, from past experience, MECs assume a typical network damping value for their networks. Experience has shown that this has been effective. If following REFCL installation, network damping is found to be unusually high, MECs now have several options to resolve the issue, including:

- Assessing the network to identify and replace faulty assets that may be the source of high damping
- Isolating underground cable sections from REFCL-protection; a general exemption was granted by the Governor in Council on 1 October 2020 to all affected MECs, which removes the obligation for underground cables to have the *required capacity*.
- Isolate overhead network sections and install a remote REFCL to ensure the *required capacity* is still achieved.

- Transferring network sections to adjoining REFCL-protected networks to ensure the *required capacity* can be achieved on all network sections.
- Applying to the Minister and ESV for a technical exemption, which may involve alternative initiatives to reduce the bushfire risk

AusNet Services' Kinglake network was an exception noted in the 2020 REFCL FP review, where its unique network configuration led to unusually high network damping. The Kinglake network consists of two short feeders and one long feeder with a high proportion of underground cable at its extremities. Kinglake was one of AusNet Services' first REFCL installations and thus stimulated heightened concern regarding damping predictions. At that time the aforementioned solutions had not been well developed.

To resolve the Kinglake issue AusNet Services implemented upgrades to the REFCL system to improve performance, moved the open point of the feeder that connects to the REFCL-protected Woori Yallock zone substation and isolated multiple underground cable sections. From this experience MECs have identified that long feeders with a high proportion of underground cable at their extremities are associated with high network damping. This has since been validated in theoretical studies and experience on other networks.

Following completion of the 2020 REFCL FP review:

- REFCL technology has continued to improve, allowing the *required capacity* to be achieved on networks with higher damping,
- MECs have gained experience with various network configurations that enables them to better identify networks that may have higher damping. While this doesn't allow MECs to predict damping with high accuracy, it does enable them to identify and allow for additional mitigation works in the planning phase, thus reducing delivery and compliance risk.

Due to these advancements and experience, MECs are now able to:

- Better predict network damping prior to REFCL installation
- Implement solutions to address network damping that exceeds the initial prediction
- Limit compliance risk by implementing established solutions that avoid exemptions where possible

Changes over time

Network damping is not a static measure and may change over time due to:

- Wet conditions at the time of measurement due to free water on insulators creating additional conductive paths to ground
- Network growth increasing series losses of the network (especially where it involves a higher proportion of underground cable located remote from the source substation)
- Replacement of the Arc Suppression Coil (ASC) with a different capacity unit
- Other changes to network components that may introduce different losses

Experience across all Victorian REFCL-protected networks has shown that wet weather can lead to dramatic increases in damping, but this is a temporary effect. Since wet weather cannot be controlled and is not conducive to times of heightened bushfire risk, it has been accepted that failure to demonstrate the *required capacity* in these conditions is not indicative of a compliance issue, and does not represent a safety concern for the community.

More permanent network changes over time due to natural expansion (i.e. additional network to connect new residential or commercial developments) or replacement of overhead line with underground cable represent a greater concern. Experience to date has shown that the associated change in network damping due to these changes is typically small, is being actively modelled by MECs and can generally be predicted with high accuracy. Notwithstanding this, there will be instances where increased damping triggers significant network investment, such as the installation of a third REFCL at Powercor's Colac zone substation in 2021.

Alternative approach

Network damping is notoriously difficult to predict with great accuracy. This is because it requires detailed understandings of the losses associated with all components that make up the network and how these losses combine and are affected by varying load and other external influences. Furthermore, many of the energy loss mechanisms involved are second-order effects that are not specified in the design of network components.

For some particularly challenging networks MECs have developed detailed models to identify solutions to high damping and other technical challenges. This has involved developing models of all network components to build a virtual twin of the network, involving significant effort and cost. However these models have been developed post REFCL installation and have required real-world validation to improve their accuracy and to build confidence in their outputs. In this case they are modelling known issues, or known-unknowns.

In order to model unknown-unknowns (networks pre-REFCL deployment) designers would be required to accurately identify and model all network components and other influencing factors that may affect network damping. For this reason MECs have not historically had great confidence in the output of these models.

For these reasons we are not confident that it is possible to develop a method to more accurately predict network damping that can provide rapid predictions, at low cost, with high reliability and accuracy, using this approach. Therefore, we are of the view that the existing approach, which has improved over time, most appropriately balances cost, time constraints, reliability and accuracy.

Benefit of a new approach

Construction works have already begun to establish REFCL protection at the final prescribed substations. Therefore establishing a new method to better predict network damping will not provide any benefit to the delivery of the mandated REFCL program. While further REFCL installations may occur in the future, the high uncertainty of success makes the business case for developing a new method undesirable.

Position

The VESI REFCL TWG is of the view that:

- Significant improvements to the accuracy of network damping predictions have been achieved since the initial REFCL installations in Victoria were completed
- The improved methodology satisfactorily meets the needs of MECs in regard to cost, time constraints, accuracy and reliability
- This improvement meets the intent of recommendation E of the REFCL functional performance review.