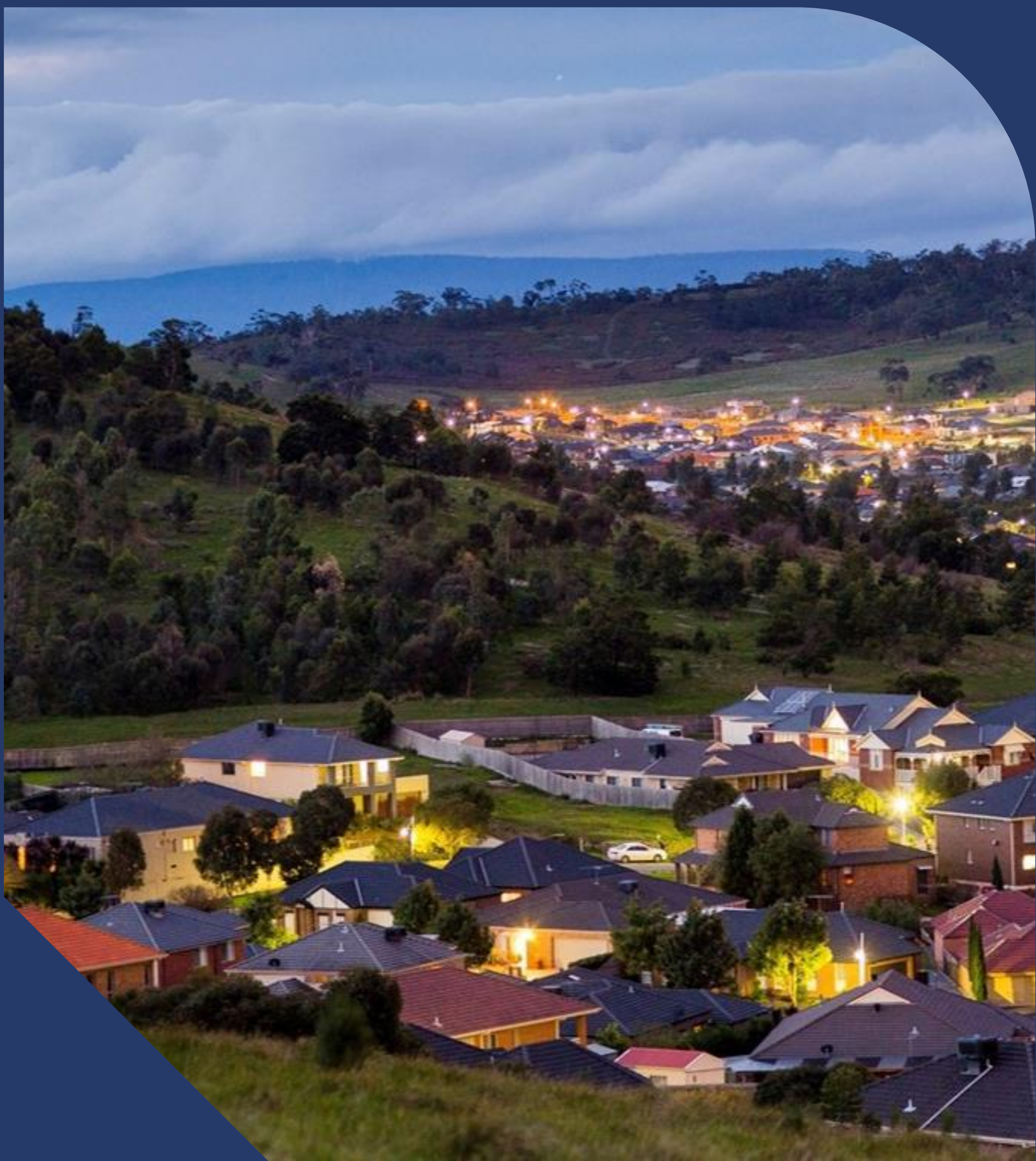
AusNet

Early Fault Detection (EFD) Program

AMS – Electricity Distribution Network

Wednesday, 29 January 2025



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1. Executive summary

AusNet Electricity Services Pty Ltd (AusNet) is a regulated Victorian Distribution Network Service Provider (DNSP) that supplies electrical distribution services to more than 802,000 customers. Our electricity distribution network covers eastern rural Victoria and the fringe of the northern and eastern Melbourne metropolitan area.

This document is part of the suite of Asset Management Strategies relating to the AusNet electricity distribution network. The purpose of this strategy is to consider ways in which technology can be used to manage fire risk from unidentified defects. Unidentified defects on the network pose a fire risk. Defects can go unidentified for a variety of reasons, including failure to identify a defect during inspection of an asset, an interference by a third party (human, animal or environmental) that affects the condition of the asset between inspections, or an internal or invisible defect inside the asset or on the surface but indiscernible to the inspector. These types of defects can and do manifest at undetermined locations and points in time.

AusNet is seeking to, as far as practicable, combat against undetected defects, which can (in rare cases) have catastrophic consequence failure events. While AusNet has investigated and implemented various programs, such as corona and thermography surveys, aerial inspections programs, ground-based inspection programs, vegetation inspection and cutting programs, an effective, technically feasible solution to date has not been available to fully identify asset defects that are difficult to detect using conventional techniques. It may never be the case that this risk can be minimised to zero. The biggest risks of undetected defects are bushfire and electric shock. This strategy concentrates on high bushfire areas and high customer numbers as a metric used to define a fire loss consequence area, as these are the highest risk areas from potential asset failures.

AusNet is proposing to install Early Fault Detection (EFD) devices on the network in Codified[1] and High Bushfire Risk Areas (HBRA) as part of the bushfire safety program. EFD devices are a relatively new innovative technology aimed at proactively identifying potential asset failures, allowing networks to deploy field personal to address the identified potential asset failure before a failure occurs and potentially creates a hazard, including bushfire risk.

The EFD devices detect partial discharges that occur from early signs of a fault (for example deteriorating insulator material, conductor degradation). Data regarding the early signs of fault are communicated to AusNet via the device's inbuilt cellular communications module. As such, the technology helps detect and pinpoint defects (with an accuracy of ±10 metres) in electrical infrastructure before they develop into electrical faults that cause equipment damage, permanent outages, and public safety threats such as fallen wires and bushfires.

Since the inception of EFD, AusNet has installed 310 EFD units through various trials, with the latest trial of the singe-wire earth return (SWER) Firesafe EFDs installed across the codified areas. The trials have established these devices can detect latent defects on the network. However the data presented by [C.I.C] through the portal includes substantial numbers of alerts which are not operationally viable to follow up with site visits. More work is required to enhance the alerts and provide confidence in dispatching resources to the site following an alert.

[1] Codified = 'Electric Line Construction Area' as defined within the *Electricity Safety (Bushfire Mitigation) Regulations*. ELCAs are the highest fire loss consequence areas where insulated medium voltage networks are mandated.

1.1. Bare Conductor Network

1.1.1. Bare Conductor Network configuration

AusNet owns and operates an electricity distribution network across a service area of approximately 80,000 square kilometres and supplies energy via 45,000 kilometres of overhead conductors with a mix of covered and bare conductor. The overhead network of conductors is held above ground by an infrastructure of 318,000 poles. It is the overhead Bare Conductor network residing in Hazardous Bushfire Risk areas that AusNet will concentrate the deployment of the EFD system. Table 1 provides a view of the conductor across the various voltages. The voltages of interest in this program are medium voltage (MV) 6.6kv to 22kV.

Table 1: All overhead conductors (excludes underground cables) by circuit length in ,000km - December 2024

,000km	All Conductor			Bare Conductor	
Voltage	All Areas	HBRA		All Areas Bare Conductor	HBRA Bare Conductor
66kV	2.43	2.09		2.43	2.43
22kV	22.42	19.63		22.21	19.43
12.7kV	6.36	6.36		6.36	6.36
11kV	8.03	8.03		8.03	8.03
6.6kV	0.052	0.046		0.017	0.011
<1kV	5.97	2.59		5.02	1.95
	45.26	38.74		44.06	38.21

Source: AusNet

1.1.2. Inspections on the Network

AusNet manages the integrity of the Overhead Network through a number of interval-based asset inspection and condition monitoring programs that are established practices used within the industry. These include;

- visual inspection of asset condition using high resolution photography via ground and aerial based inspection methods,
- vegetation clearance assessment through ground-based patrol or aerial based LiDar survey,
- thermal and corona surveys, and
- timber pole testing and treatment program.

The visual inspection of asset condition is approved by Energy Safe Victoria as satisfying the requirement for inspections and intervals contained in the *Electricity Safety (Bushfire Mitigation) Regulations 2023* (Vic), as amended or replaced from time to time. Details of inspection cycles can be found in Bushfire mitigation Plan – Electricity Distribution Network BFM 10-01 and Bushfire Mitigation Manual BFM 21-79 and *30-4111 Asset Inspection Manual*

The Thermography and Corona Program is run annually and covers all 66kV conductors (station to station) and all 22kV feeders for the first 10km out from its starting point at the individual zone substations across the network. The vegetation inspections cover all voltages and inspection is performed annually.

Inspection and testing intervals have been developed to cost effectively monitor network condition and identify defects that are based upon asset failure modes and intervals for which the inspection methods are effective in detecting.

1.1.3. Challenges of latent defects

The inspection programs that AusNet applies to the Network are robust and as far as practicable, effective. However, there are challenges with certain equipment failure modes that can and do occur on the Network in-between inspections. AusNet seeks to identify these latent defects before they have a chance to form into a fault. As failure intervals may be as short as hours or days, it is not practicable to increase inspection frequencies to identify these defects. In addition, some failure modes of latent defects may not be detected through established inspection methods. Accordingly, adoption of new technologies and innovation, such as EFD, are monitored to identify opportunities to cost effectively enhance established asset condition monitoring and inspection techniques.

Not all defects can be detected from inspections

Some defects in electrical equipment are internal and do not produce an outward facing visual indicator that they are in danger of failure. These types of defects can be found in new and older installed electrical apparatus. Some examples are:

- Surge diverter internal faults
  - Example causes = lighting, manufacturing batch defects, loose connections etc
- MV fuses – candling
  - Example causes = lighting, manufacturing batch defects, moisture ingress etc
- Insulator tracking
  - Example causes = coastal salt spray, industrial pollution, vehicle exhaust fumes
- Conductor strand fracture
  - Example causes = lighting, Aeolian vibration, third party contact
- Conductor strand breaks
  - Example causes = lighting, Aeolian vibration, third party contact
- Conductor joint deterioration
  - Example causes = lighting, moisture ingress, incorrect application (sizing)
- Conductor connection faults
  - Example causes = loose connection, coastal salt spray,
- Transformer internal failures
  - Example causes = Insulation break down, fault in manufacturing process, lighting.

These types of defects require specialist detection equipment. This equipment is typically radio frequency detection equipment looking for abnormal signals that would indicate a defect is present. The difficulty of using this equipment is it is handheld and is only effective if the defect is emitting signals at the time the operator is on site. Most defects give off intermittent signals.

Visible defects develop between inspections

Given the robustness of the two-stage inspection process for identifying defects most defects and emerging defects are found during the inspection process. Faults are generally a result of an interference by a third party (human, animal or environmental) that affects the condition of the asset between inspections and there is the human error risk that an emerging defect might be missed at inspection. Typical examples of visible defects that can lead to failure are"

- Conductor strand breaks
  - Example causes = Lighting, Aeolian vibration, third party contact
- Conductor joint deterioration
  - Example causes = Lighting, moisture ingress, incorrect application (sizing)
- Conductor connection faults
  - Example causes = Loose connection, coastal salt spray,
- Vegetation encroachment
  - Example causes = Rapid growth, tree top failure
- Tree Bark contact
  - Flying bark landing on conductors and contact phase to phase or phase to structure
- Bird and animal contact
  - Bridging earthed structure to electrical equipment/conductor
- Cracked insulator
  - Example causes = lamination of insulator sheds, lighting, third party contact

As with above, these defects require an operator to be on site to detect. While these are visible defects, it is difficult, given the network service area is 80,000 square kilometres, 318,000 poles and 45,000 route kilometres to cover. Success is never guaranteed even if the network was patrolled monthly as the defect could manifest at any time between visits.

Some of these challenges can be addressed through the use of the EFD devices, as described below.

2. Early Fault Detection (EFD)

2.1. EFD development Background

Latent defects in high voltage line hardware and equipment prompted a Melbourne University to explore the development of early fault detection equipment.

Some defects such as fractured conductors are not always detectable using traditional inspection methods. As a result of these type of defects and the inability to successfully detect visually, research into other detection methods was undertaken by a university in Melbourne. Research uncovered that defects such as this emitted abnormal radio frequencies that can be identified and isolated from normal operating frequencies. Research found that using IoT and machine learning, a defects attribute library of varying types could be developed. By measuring energy and time, a location and probable cause of defect can be pinpointed to an accuracy of ±10 metres. Specialist inspection resources could then be deployed to identify the physical equipment in question and undertake remedial works before the defect developed into an asset failure.

Off the back of this research –IND Technology patented the EFD technology in 2013 and subsequently was successful in obtaining grants from the Victorian government for trials of EFD devices with AusNet and Powercor. The EFD has proven reliable and effective in identifying defective equipment giving off invisible signals. The EFD is now deployed in countries with similar bushfire challenges to that of AusNet. The United States and Canada have deployed thousands of these units and, given their success, are increasing their programs.

With Rapid Earth Fault Current Limiter (REFCL) technology deployed to approximately 62% of AusNet's polyphase network, IND-T's latest trial of SWER EFD technology and final report[2] has focussed on deployment across Victoria's SWER networks as a key priority in cost effectively applying additional controls to further reduce the risk of bushfire associated with overhead powelines.

2.2. Early Fault Detection System

Broken/damaged electrical equipment produces an abnormal radio frequency signal. This disruptive radio frequency (RF) signal emitted by the damaged equipment can travel through the air as electromagnetic radiation or along the powerline. EFD data collection units detect these signals and measure their energy and arrival time to a high degree of accuracy using the GPS satellite network. EFD data collection units send this data every second to the EFD portal server where algorithms calculate the location of signal sources and their attributes.

The EFD sensor units are installed at intervals of 3.5km along the feeder. Radio frequency anomalies are measured between the sensor units. The RF telemetry that is gathered is then analysed to provide a likely magnitude of discharge and range to the source. Potential sources can include vegetation in proximity/contact to a powerline or internal component discharge events. The current version of the EFD unit, generation 4, includes additional hardware and software filters to remove unwanted interference from undesirable RF sources such as AM/FM radio transmitters.

The EFD can be seen as the network's "ears" on the network, operating on a 24/7 basis and informing the network operator when something is emerging.

Figure 1: Early Fault Detection (EFD) System.

[2] IND-T FireSafe SWER EFD Trial, Final Report, November 2024

[C.I.C]

Figure 2: SWER Early Fault Detection (EFD) Device.

[C.I.C]

From the trials AusNet has confirmed, the source location provided by the EFD units has proven to be highly reliable with the claimed accuracy of ~10m holding true for most cases. This has proven to be invaluable in identifying what types of issues the EFD regularly detects as well as sources of interference. See section 4 for more information on the trials.

2.2.1. Web Data Portal

All data collected by the EFD units is accessible through a Tableau web portal. Several dashboards are preconfigured:

- **AusNet Dashboard**

  For a broad summary of the installed devices, the Dashboard provide a geographical display, during the analysis of faults, this was found to be useful as an initial summary however the Deep Dive pages showing discharge energy were preferred for identifying locations of interest.

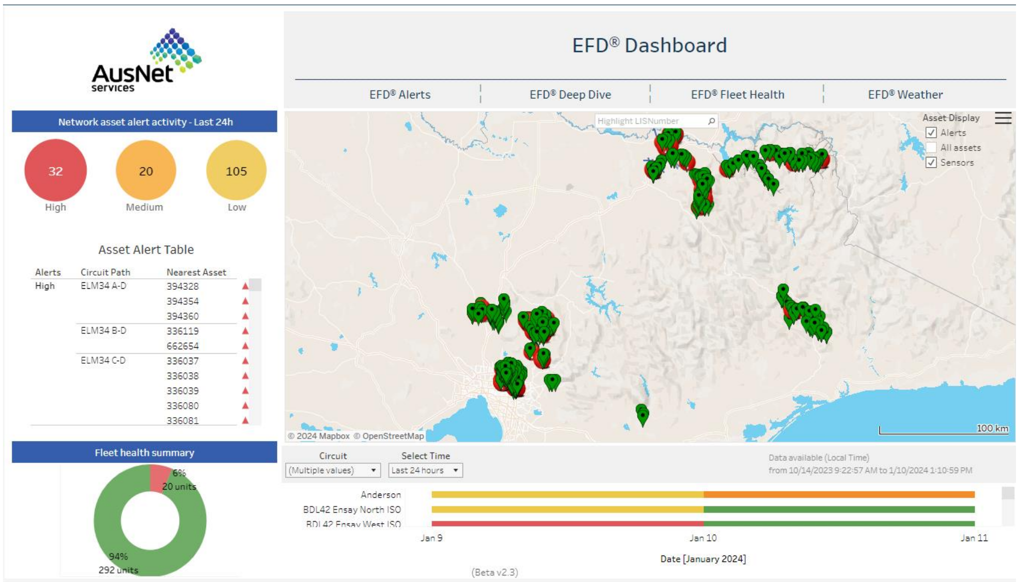


Figure 3: Dashboard View

- **EFD Alerts**

  Provides a Table summary of all Alerts produced by the EFD units

- **EFD Deep Dive Analysis**

  Provides a set of graphs allowing for filtering on Detection Energy, Source, Energy Profile and several other similar breakdowns.

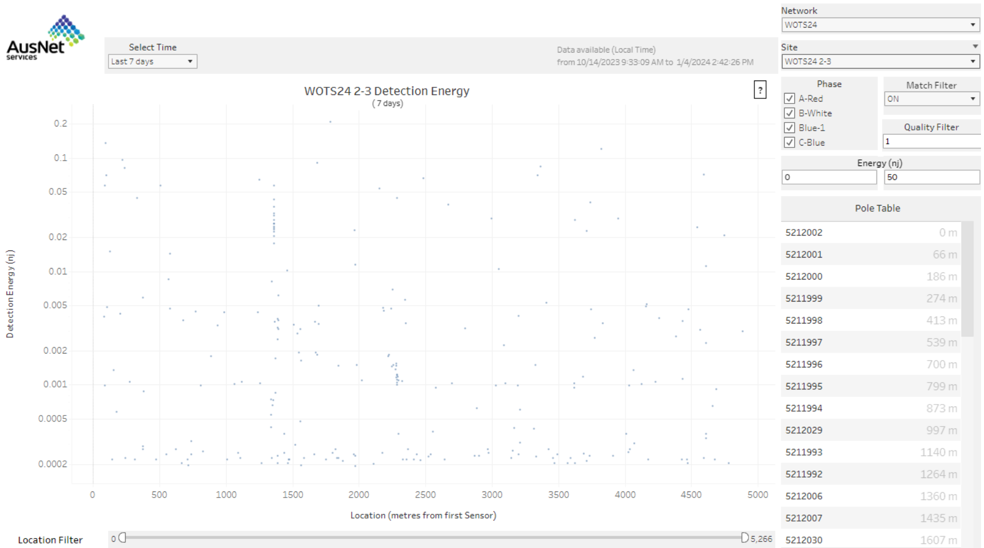


Figure 4: DeepDive View

- **EFD Fleet Health**

  Provides Status of all EFDs connection and internal device alarms for maintenance purposes.
  As of June 2024, IND advises this functionality has been decommissioned for Australian Users with a replacement advised to arrive in late 2024.

- **EFD Weather**

  Provides an overlay of EFD Data and Geographical Weather including Temperature, Windspeed and Rainfall.

3. Early Fault Detection Trials

3.1. Installations

AusNet currently has a total of 310 EFD units installed across 14 feeders. Of these units, the 39 'SWER' units are the oldest and are set to be retired due to the decommissioning of the 3G network. The (new) FireSafe SWER (FSS) units are all installed on SWER networks, the remaining Gen3B & Gen4 units are 22kV installations.

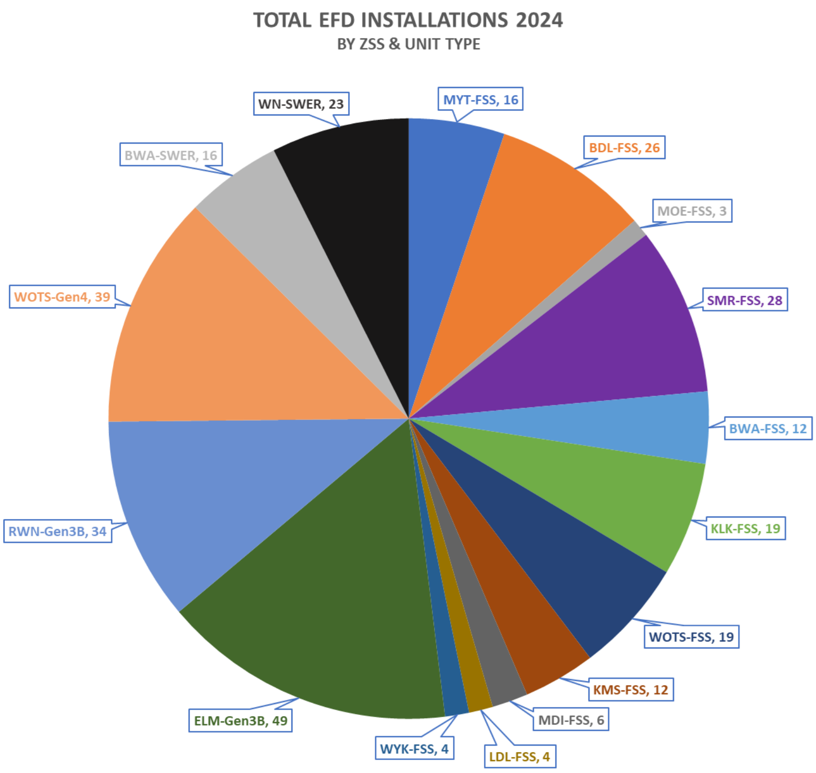


Figure 5: Units per network section

WOTS Network

In April 2023, AusNet received a technical exemption from Energy Safe Victoria to isolate a part of the WOTS24 network from REFCL protection using an Isolation Transformer. One condition of this exemption was the requirement to install and operate Early Fault Detection equipment along 193km of the WOTS24 network.

A total of 39 EFD units were installed on the isolated section of WOTS24 [C.I.C]

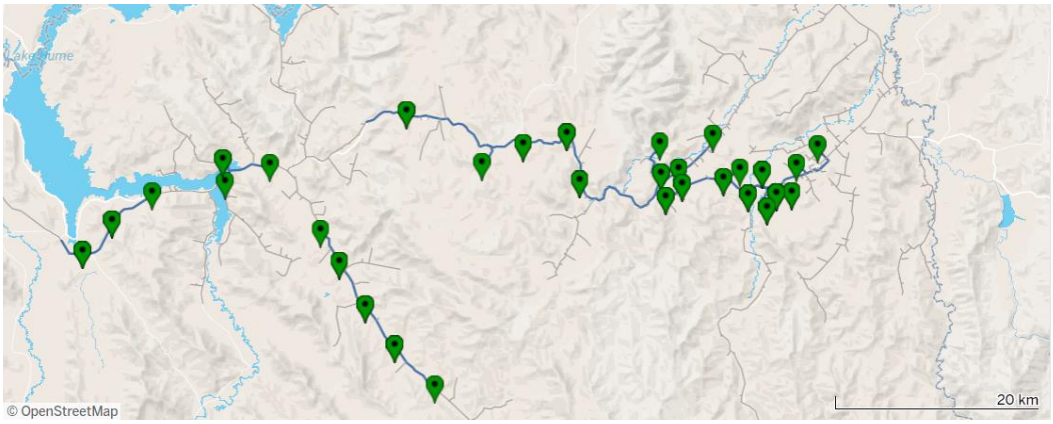


Figure 6: Example showing most WOTS24 EFD Installations

3.2. SWER in Codified areas

In 2022, a joint trial between IND-Technology (supported by Victorian State Government grant), Powercor and AusNet was kicked off to trial the newly designed FireSafe SWER EFD. AusNet has installed 310 EFD units over a number of trials which commenced in 2017. The first SWER units installed in the first trial 2017 are now obsolete due to shutdown of the 3G network and are being removed from the network.

The FireSafe EFD trial installed 150 units covering all SWER lines in codified areas.

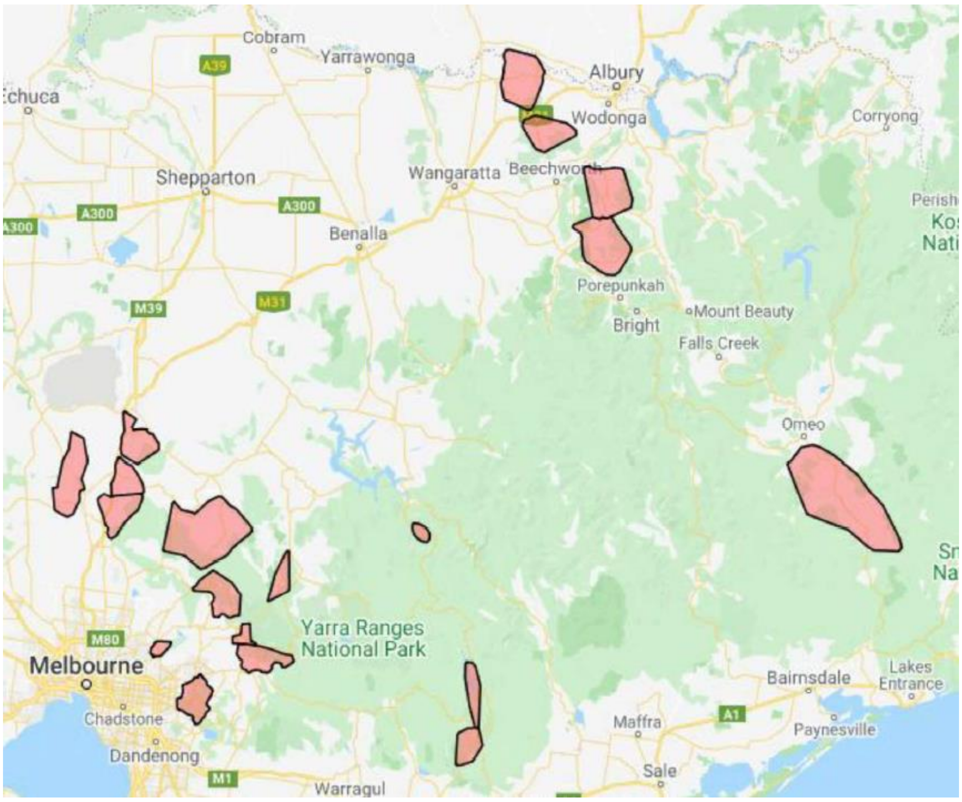


Figure7: SWER Network supplying Codified areas formed the basis of trial for Fire Safe SWER installations

3.3. EFD Trial 2022-2023 findings

AusNet trialled 310 [C.I.C] Early Fault detector units across fourteen networks between 2017-2024. In addition to our initial SWER trial units (2017), FSS & Gen3B units (2020-2022), newer generation 4 models were required to be installed on WOTS24 as part of a REFCL exemption in 2023.

3.3.1. Analysis Challenges

The main challenge is effectively analysing EFD data and sifting through the Alerts to determine what required immediate Action. The provided Alert system raised a considerable number of false positives and Alerts for issues that are not indicative of network issues such as Alerts during periods of rainfall or for what is suspected to be dirty insulators.
For example, in Month of July 2024, the following Alerts were raised:

- 1026 Alerts across Risk Score, Burst & High Energy
- 304 Alerts if omitting early gen SWER units
  - 152 unique locations
  - 5 undefined locations
- 96 Alerts on WOTS24 alone
- 9340 Alerts if omitting early gen SWER units
  - 1533 unique locations

    - 37 undefined locations
- 209 Alerts on WOTS24 alone
    - 45 unique locations

When looking at a larger picture of the first 6 months of 2024 it rapidly becomes clear that the frequency of alerts on the network far exceed the capacity of an inspection team to verify.

- 10996 Alerts across Risk Score, Burst & High Energy
    - 107 unique locations

As a result, all analysis must be done manually by checking the sensors through the 'EFD Deep Dive' page. This process is time consuming and does not resolve the issues of erroneous detection events.

3.3.2. Analysis and onsite inspections by AusNet [C.I.C] on WOTS24

In October 2023, AusNet identified sixty-one locations on WOTS24 with varying levels of RF discharge magnitude and frequency. On 8th November 2023, the top ten priority sites as identified through internal processes were visited by the Asset Inspection team. Both Visual inspection and corona camera were used and no abnormalities at or around the listed locations were identified.

Following the news of the AusNet Inspection results, a follow-up inspection was undertaken with [C.I.C] present 22nd Jan 2024. This inspection utilised both corona cameras and FLIR Acoustic cameras to attempt to identify the sources of the measured discharge. The additional expertise of [C.I.C] in identifying potential sources was beneficial in providing insight to potential sources. From the 14 Inspected sites on the 22nd, the following was noted:

- No clear Vegetation encroachment near identified inspection areas, suspect strong wind may cause Vegetation proximity to one location resulting in detections.
- The pole assets & conductors appear to be in good or excellent operational condition
- 11/14 Identified locations did not have a clear source of discharge, speculation that source may be dirty or mossy insulators
- At one location, conductor jointing sleeves were in proximity, potentially the source.
- At one location, the source was identified as minor discharge across an insulator but was already covered by a plastic insulating cap
- At one location, the source of RF was mid-span with no clear cause.

4. EFD Strategy

4.1. EFD Program

The EFD program will have 3 stages spread across three separate regulatory periods.

Stage 1 - 2026-2031, centres on the SWER Network and a portion of polyphase. – key objective is operationalising the attributes library and workflow.

Stage 2 and 3 centre on Polyphase Networks and are wholly contingent on the success and viability of stage 1 to achieve operational maturity. – key objective to roll out across the Network as an economic Fire and outage prevention method.

The initial stage will centre of the enhancement of the product to achieve the operational needs of AusNet so latent defects can be clearly identified and managed. This must be operational as 11,000 alerts from 300 units multiplies significantly as hundreds and eventually thousands come online.

4.1.1. EFD Development

Since the inception of EFD, AusNet has installed 310 EFD units through various trials, with the latest trial of the SWER Firesafe EFDs installed across the codified areas.

The trials have established these devices can detect latent defects on the Network. The trials have also uncovered that the data presented by [C.I.C] through the portal does not currently discern what is a defect and what is a non-defect.

The trials also demonstrated the device sensitivity, as the slightest disruption to the Electromagnetic Field will initiate an alert; ie; a cobweb stuck to a conductor, debris floating past the line, local radio interference etc.

The first 6 months of 2024 a sum of 10996 Alerts across Risk Score; Burst & High Energy, were detected from 310 in service EFDs. The ability to travel to site to investigate this volume is not operationally viable. More work is required to further develop automated analytical tools for the data flowing back to AusNet. This highlights the importance of the attribute's library or more precisely the sensitivity of the device.

AusNet believes the devices have the ability to detect latent defects, but the attributes library and workflow assignment requires significant work to become integrated into 'business as usual' operations.al and fit for purpose. A project will be required to develop a robust useable product. It is expected vast increased amounts of data will be required to feed in and with the aid of AI and machine learning the attributes Library can be refined to enable an operational viable application of the product. The project will enhance the attributes Library and provide confidence to AusNet in dispatching resources to the site of an alert. To gather confidence and refine the model the following initiatives need to be enacted.

1. A dedicated project team will be required to further enhance the accuracy of the Attributes Library.
2. A large volume of devices is required to gather a significant data load required to refine the Attributes Library.
3. In-field site inspection tools and skills to enhance latent defect detection rates

4.1.2. Coverage

As Rapid Earth Fault Current Limiter (REFCL) technology has been deployed across approximately 62% of AusNet's Hazardous Bushfire Risk Areas of the polyphase network[3], deployment of SWER EFD devices across the SWER network is considered the most cost-effective option for deployment of EFD technology in further mitigating bushfire risk, together with enhancing network reliability and safety.

As operational experience and the defect attributes library are developed, opportunities to cost effectively deploy EFD technology on the polyphase network will be investigated.

4.1.3. Timing

[3] REFCL only operates on polyphase networks and therefore offers no additional electrical protection to SWER networks

A progressive program rolled out over a number of regulatory periods. AusNet will target the SWER Network in the 2026-2031 regulatory period. This allows a measured approach to minimising impact on customer cost, provides time to enhance Attributes Library to minimise false positives and maximise response efficiency.

4.1.4. Enhancements

AusNet will partner with [C.I.C] to develop a user friendly EFD dashboard that removes the need for Engineering skill sets to review current and historical activity for each alert, minimising the need to understand data nuances and establish links. The intent is to dedicate a project team to improve the attributes Library using a proportionate volume of data and in field verification to improve machine learning and automate the work flow to dispatch resources to find and remediate actual defects. This will streamline the inspection and operational approach to better target faults in an expedient manner. Integration of this platform with AusNet Asset systems will further improve response and efficiency.

4.1.5. Dedicated resource

AusNet will explore to adoption of local service agents to provide a rapid response. The local agents will be strategically situated to cover the EFD feeders. They will be equipped with visual and hand-held tools required for validating and finding defects after an EFD detection. Types of tools required for field inspections:

- Stabilised Binoculars
- Optical camera (DSLR)
- Acoustic camera (FLIR Si-124),
- Infrared cameras
- Parabolic Reflector (ultrasonic sensor)

4.2. Electricity Safety Act

AusNet's obligations under Section 98, 'General Duties', of the Electricity Safety Act 1998 (**the Act**) are to;

> '*…design, construct, operate, maintain and decommission its supply network to minimise* ***as far as practicable***—
>
> *(a) the hazards and risks to the safety of any person arising from the supply network; and*
>
> *(b) the hazards and risks of damage to the property of any person arising from the supply network; and*
>
> *(c) the bushfire danger arising from the supply network.*

The definition of 'practicable' under the Act means to have regard to;

> *(a) the severity of the hazard or risk in question; and*
>
> *(b) the state of knowledge about the hazard or risk and any ways of removing or mitigating the hazard or risk; and*
>
> *(c) the availability and suitability of ways to remove or mitigate the hazard or risk; and*
>
> (d) *the cost of removing or mitigating the hazard or risk*.

In compliance with its obligations under the Act, AusNet has actively engaged in a program to trial EFD technology that has demonstrated its capacity to detect latent defects and observed the increasing uptake of the technology by other utilities, particularly in North America, that face similar bushfire risks to that of AusNet.

The development of EFDs as a new control to manage hazards 'as far as practicable'(**AFAP**) has resulted in the Melbourne based company (IND-Technology) developing a SWER specific devices that has significantly reduced cost relative to those devices used for polyphase networks. The cost of SWER EFD deployment has been modelled against benefits to customers and the community through reduction of bushfire risk and increased network reliability and safety. A key factor influencing future benefits is the degree of subjectivity associated with determining potential consequences of an increasing asset age profile and climate change increasing the frequency of high fire danger days.

In December 2023, AusNet submitted a draft updated Electricity Safety Management System (ESMS) to Energy Safe Victoria (Energy Safe) for review. As at 31 January 2024, AusNet is engaging with Energy Safe on the draft ESMS.

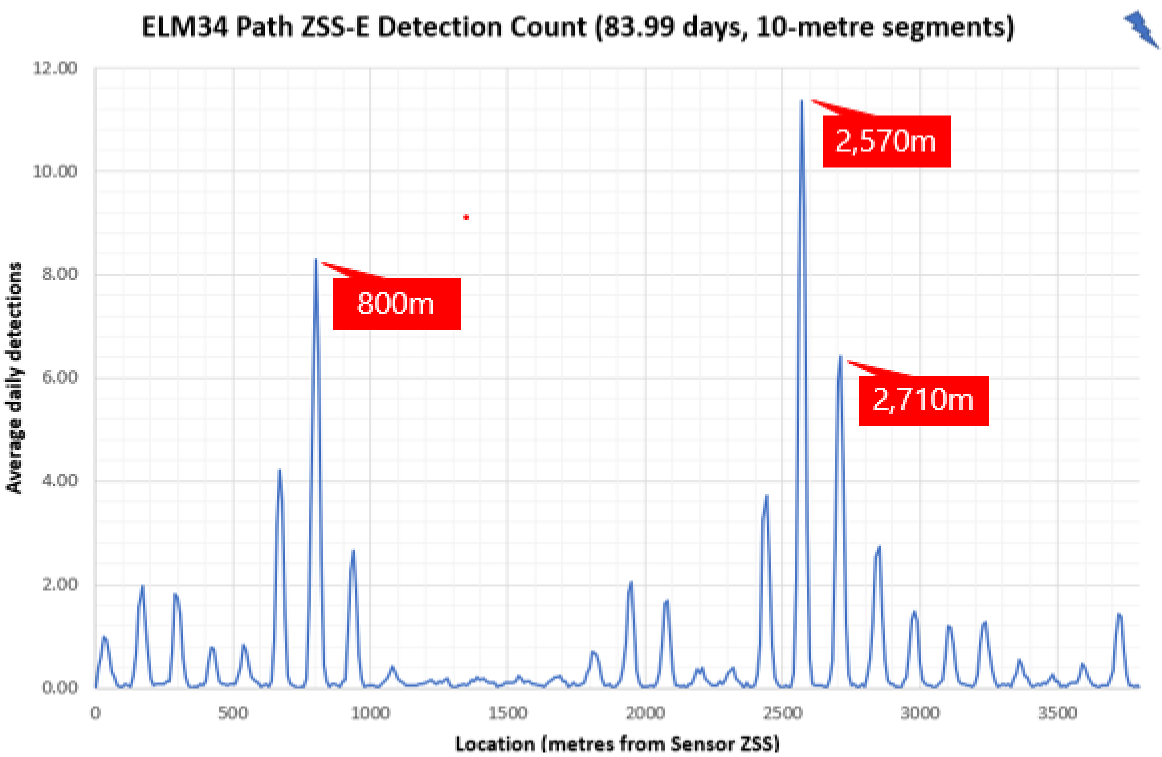
4.3. Conclusion

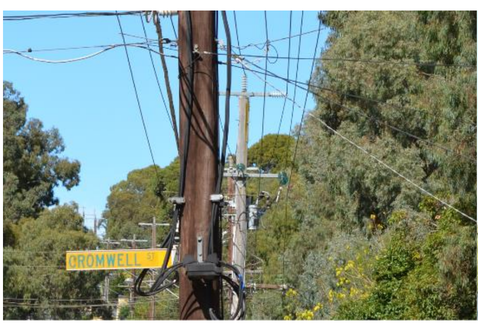
AusNet believes this innovative product will mitigate bushfire danger AFAP as it progresses to a mature state with greater deployment providing opportunity to develop the defects attributes library.

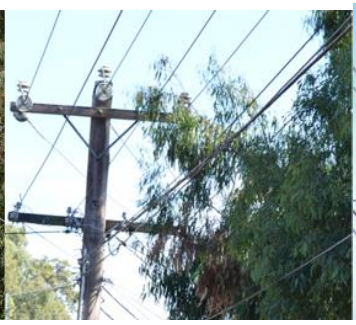
As will be observed from the modelling the benefit is low due to the very low customer density of SWER and given the Probability of Failure is low due to the strong condition of the network. The potential to detect latent defects through EFD technology that are not detectable through current inspection and monitoring practices, provides an opportunity for AusNet to further manage hazards and risk AFAP in compliance with it's legislative obligations.

A staged implementation of EFD across the Network to build knowledge and process is a prudent objective to operationalising the product to make it viable. Once operational the customers who ultimately pay for this innovation will receive the benefits of the technology, not only for bushfire mitigation, but also improved community safety and system reliability.

Appendix A – Vegetation Encroachment identified by EFD on ELM







Location 800m Contact during Windy conditions	Location 2,510m Vegetation Contact	Location 2,710m Vegetation Contact

5. Schedule of revisions

ISSUE	DATE	AUTHOR	DETAILS OF CHANGE
1	30/01/2025	D McCrohan	Initial draft

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