NEW TECHNOLOGY TO CUT VICTORIA'S POWERLINE FIRE RISK

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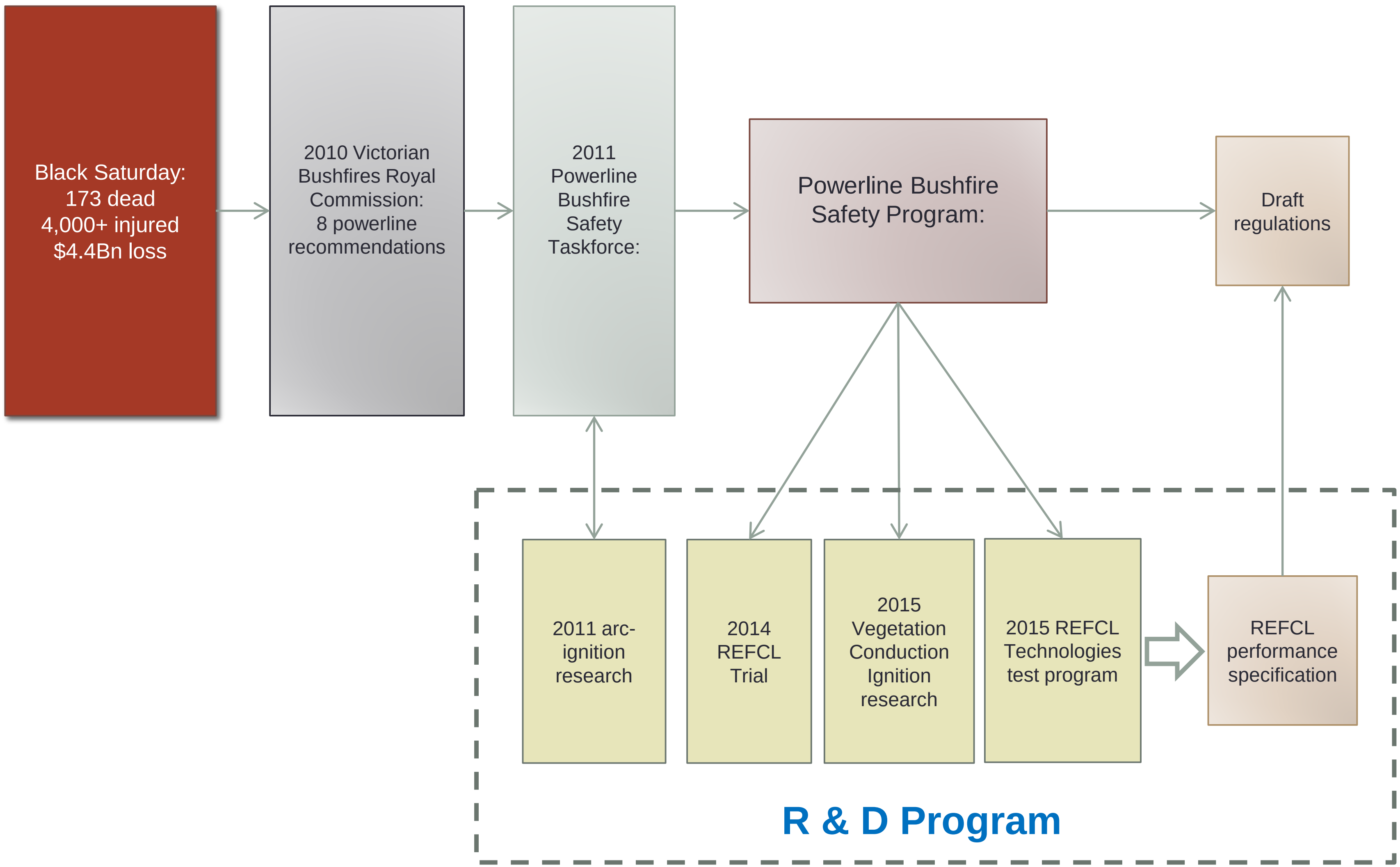
5 December 2016

Seven years of careful, focused work



Things we have learned

2011 metal-metal arcs near dry grass:

- Arcs and how they behave
- How arcs ignite dry grass
- The performance required to prevent fires in ‘wire hits rail’ faults

2013 auto-reclose settings for metal-metal arcs near dry grass:

- The minimum auto-reclose delay needed to minimise fire risk

2014 REFCL Trial at Frankston – metal-soil arcs through dry grass:

- How arcs into soil behave
- The performance required to prevent fires in ‘wire down’ faults

2015 Vegetation Conduction ignition test program at Springvale:

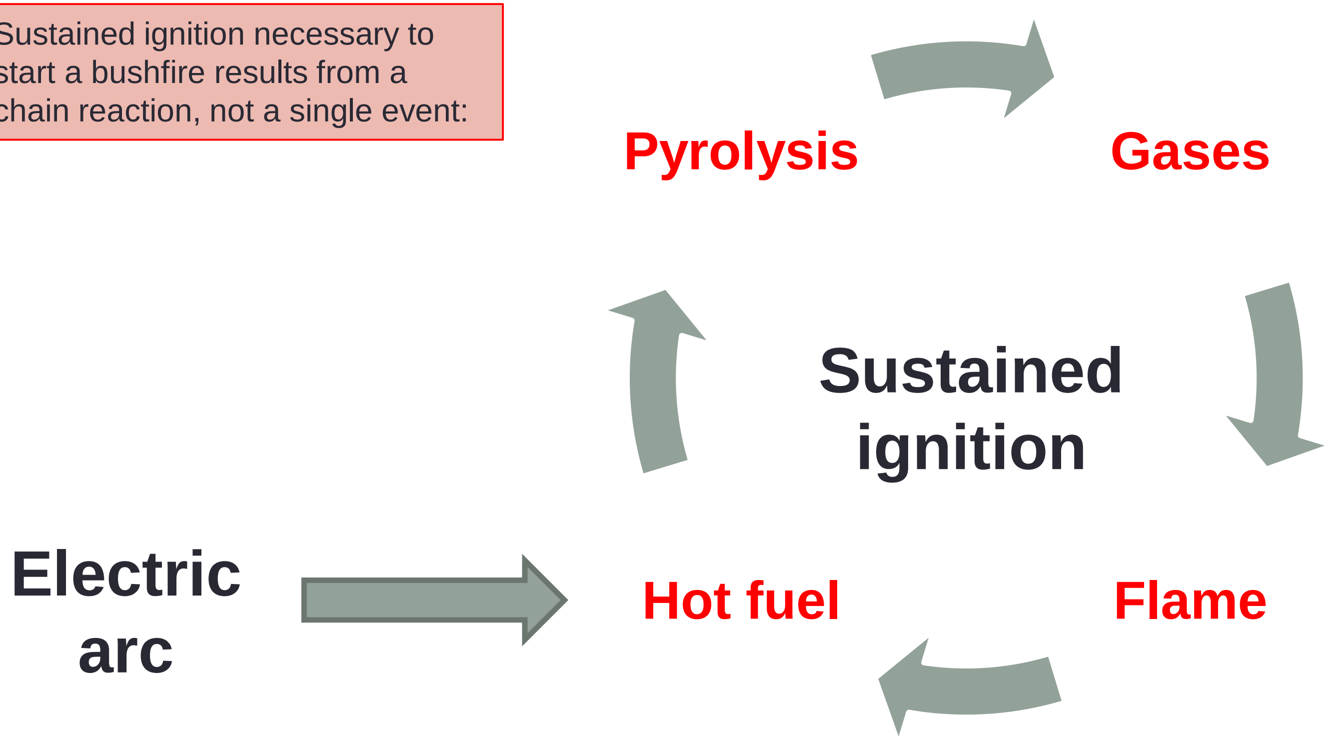
- How electric current through branches causes fires
- The performance required to prevent fires in tree/bush faults

2015 REFCL technologies trials at Kilmore:

- The performance standard is sound and conformance can be tested
- REFCLs cut fire risk in both ‘wire down’ and tree/bush faults
- At least one REFCL technology can meet the performance standard

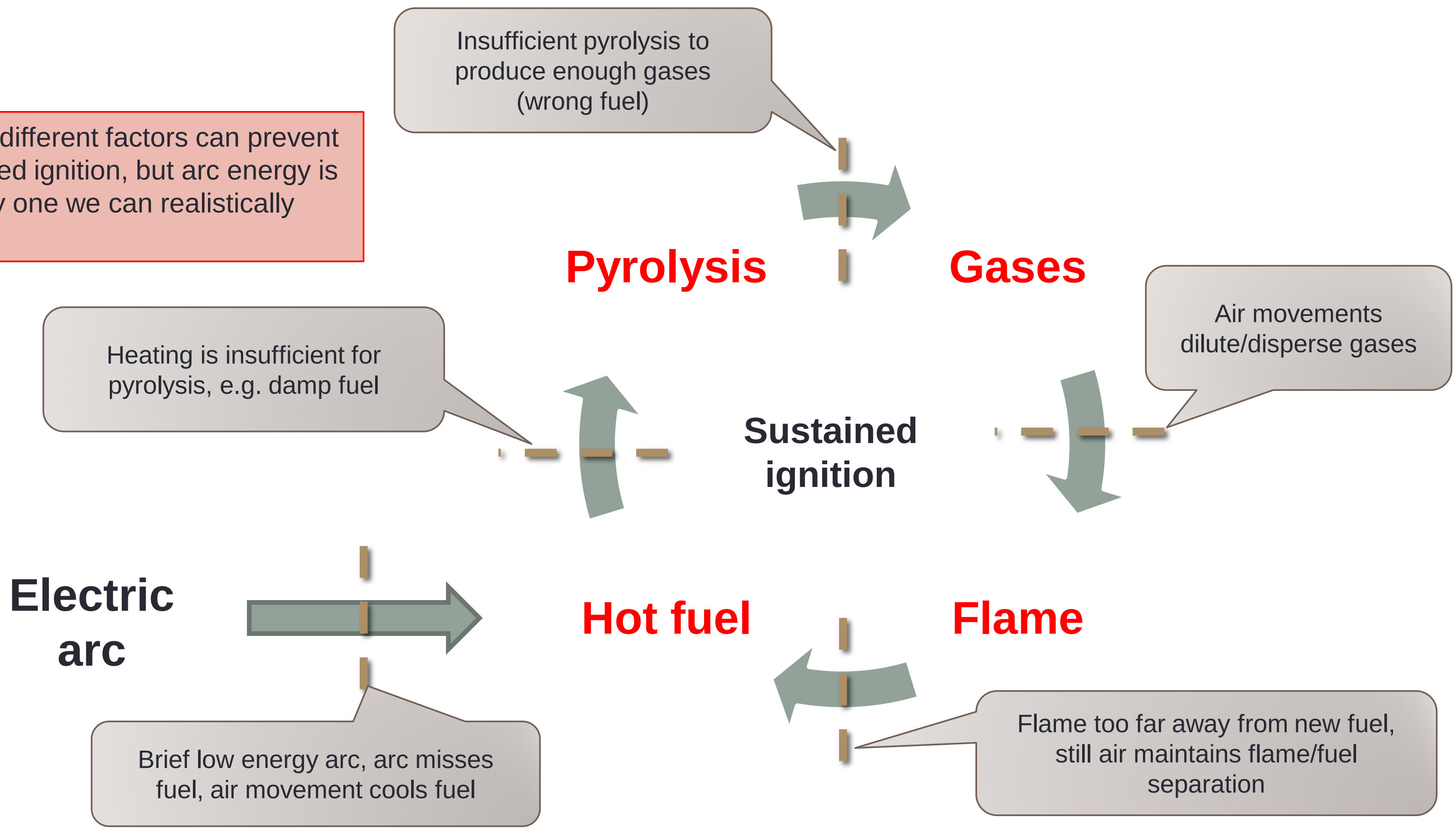
The process of sustained ignition

Sustained ignition necessary to start a bushfire results from a chain reaction, not a single event:



Barriers to sustained ignition exist

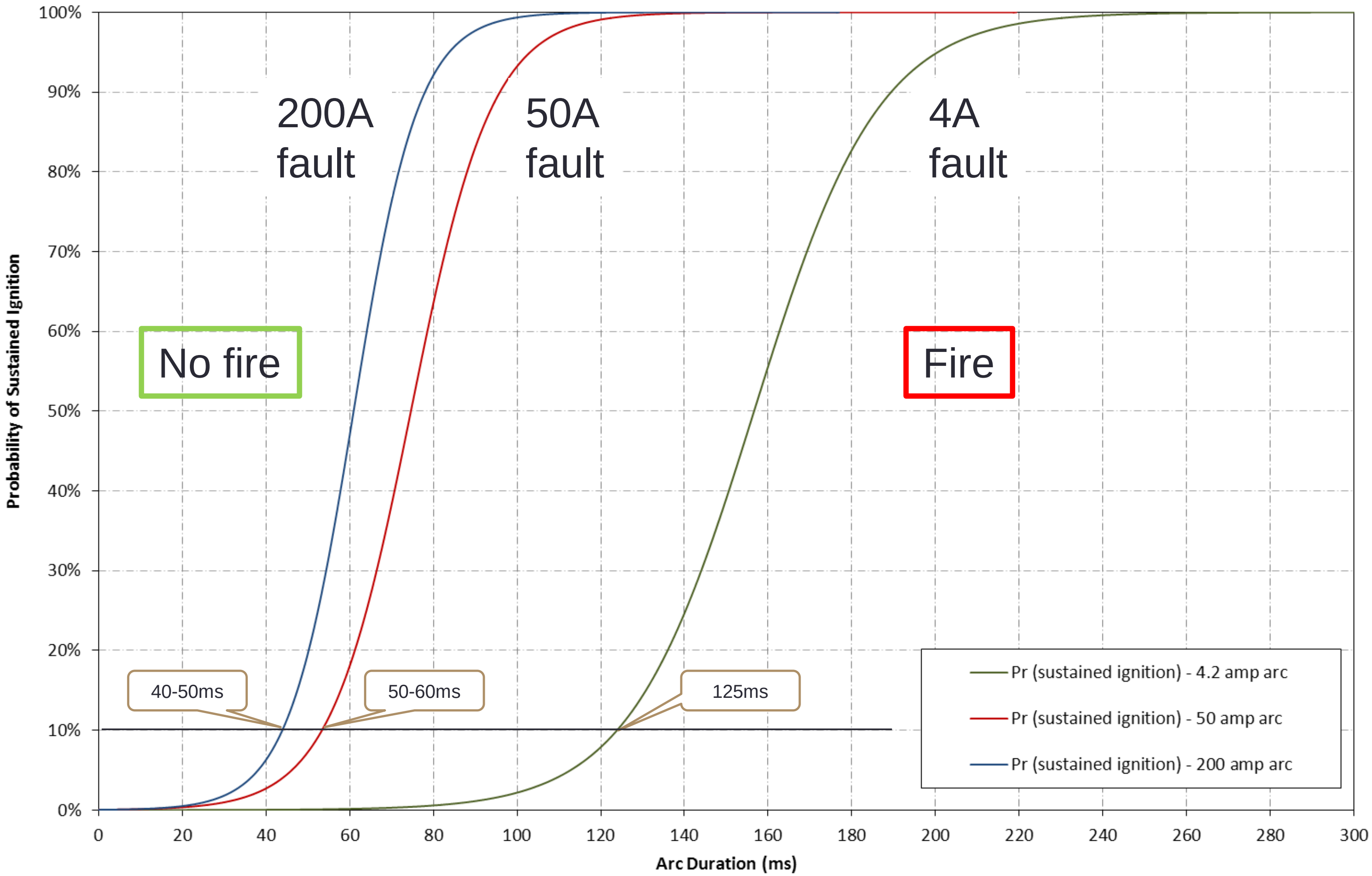
Lots of different factors can prevent sustained ignition, but arc energy is the only one we can realistically control:



Electric arcs are complex and chaotic

1. Low current arcs extend upwards but readily blow with the wind and sometimes blow out.
2. High current arcs are chaotic and driven by the magnetic forces generated by their own current, but even a 200 amp arc will respond to wind though it is almost impossible to blow out.
3. Arcs have a thin extremely hot core (the thread) surrounded by a lower temperature sheath and they shed super-heated air upwards.
4. Less than 15% of the arc's energy is released as radiation.
5. For arcs to cause ignition, actual contact with fuel is necessary unless the fuel is just above the arc.
6. Arcs can ignite dry grass provided they contact it and last long enough:
   - TCA Test 285 200A 70ms no fire
   - TCA Test 284 200A 100ms fire

Performance required to prevent fires



2014: REFCLs can prevent fires

1. 'Wire down' powerline fault ignition tests
2. 'Line drop' tests confirmed test simulation.
3. 259 tests on a real network – 220km of 22kV lines and cables with 24,000 connected customers
4. Custom built test facility 8km from substation FSH Frankston South

REFCLs make a dramatic difference

1. In most ‘wire down’ faults (those with a fault current of more than a few amps), the effect of the REFCL is startling – arc energy is reduced to the point where ignition cannot occur:
   - Without a REFCL
   - With a REFCL
2. But after the fault, diagnostic tests must determine if the fault is permanent or transient and identify which powerline it is on. The first REFCL tests showed this was a weakness.
3. The particular REFCL under test (Swedish Neutral’s GFN) has firmware-defined functionality, so improvements were made and confirmed in tests at Kilmore South:
   - REFCL with soft fault-confirmation test

The vegetation conduction ignition test facility

Ignition in powerline tree faults

In powerline tree faults, the heating source is not an electric arc, but resistive heating from conduction of electric current through the tree branch.

1000+ tests on 16 species at a custom built test facility at Springvale in early 2015 showed:

1. There are four (overlapping) phases of vegetation conduction ignition faults leading to ignition:
   - Phase 1: development of contact between the branch and the wire
   - Phase 2: expulsion of water from the branch
   - Phase 3: charring/flame progressively extending down the branch
   - Phase 4: flashover (if it’s a ‘branch across wires’ fault)
2. Fire risk varies by species but can be cut on average by more than 90% if fault current is limited to 0.5 amps.

The vegetation conduction ignition test rig

A mechanically simpler rig than for 'wire down' faults, but much greater complexity in tests due to all the extra variables associated with vegetation.

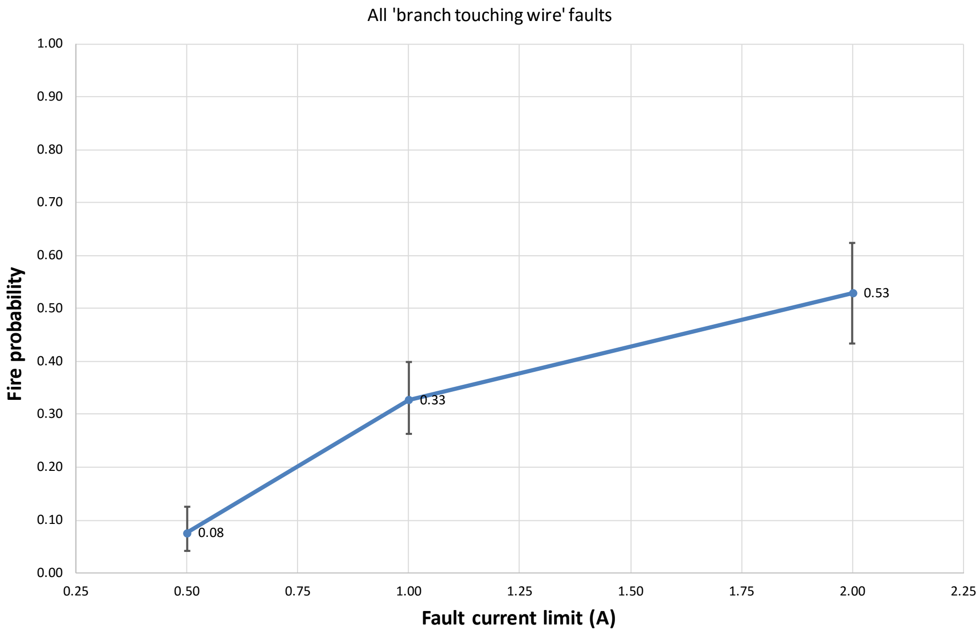
Springvale test 426 Manna Gum
Springvale Test 426 infrared

How bushfires start from tree faults

The conceptual model:

- First ignition occurs at height (typically 8-10 metres)
- Embers drop to the ground
- Dry grass on the ground ignites
- Wind builds the grass fire into a bushfire

Interrupting supply before embers fall prevents the fire.



Fire risk can be cut by more than 90% if the supply is interrupted when the fault current reaches 0.5 amps

‘branch touching wire’ – species ranking

There are some species that do not belong near powerlines.

Species	Average fire probability at 1.0 amp fault current limit
Salix sp. (Willow)	100%
Fraxinus Angustifolia (Desert Ash)	58%
Acacia Mearnsii (Black Wattle)	57%
Pinus Radiata (Radiata Pine)	55%
Eucalyptus Baxteri/Obliqua (Stringybark)	53%
Eucalyptus Viminalis (Manna Gum)	50%
Acacia Melanoxylon (Blackwood)	23%
Cotoneaster Glaucophyllus (Cotoneaster)	21%
Acacia Pycnantha (Golden Wattle)	10%
Pittosporum Undulatum (Native Daphne)	7%
Allocasuarina Verticillata (Drooping Sheoak)	5%
Schinus Molle (Peppercorn)	0%

What makes a species 'worst case'?

Not simply 'ignite-ability'. Not simply 'time to ignite'

Regardless of how long it takes, will fire risk occur before powerline protection systems remove the voltage? The worst case species was that which produced the highest fire risk at a particular current limit.

The method adopted was:

- Tests stopped at a current limit (0.5/1.0/2.0/4.0 amps)
- Fire risk was monitored using infrared video of fallen embers

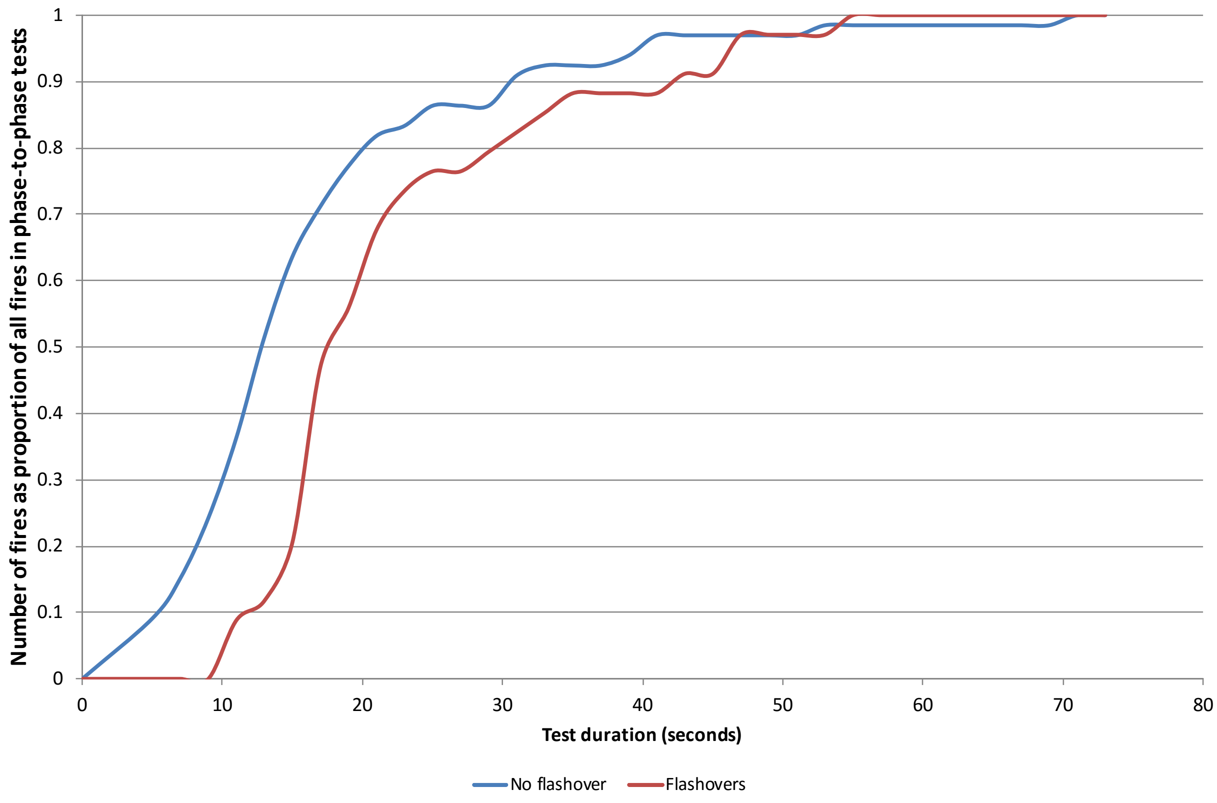
A Salix test (limit 1.0A): Springvale Test 307 Springvale Test 307 IR

The one amp limit does not cut in before flashover: Test 307 current

A Salix test (limit 0.5A): Springvale Test 308 Current: Test 308 current

Even with the worst case species (Salix) a 0.5 amp limit can stop a fire.

Performance required to prevent fires



Fast (<5s) fault detection and response would cut fire risk by 90% (response time for ‘branch touching wire’ faults could be up to four times longer than shown for the same result).

REFCL effects on tree faults

REFCLs offer:

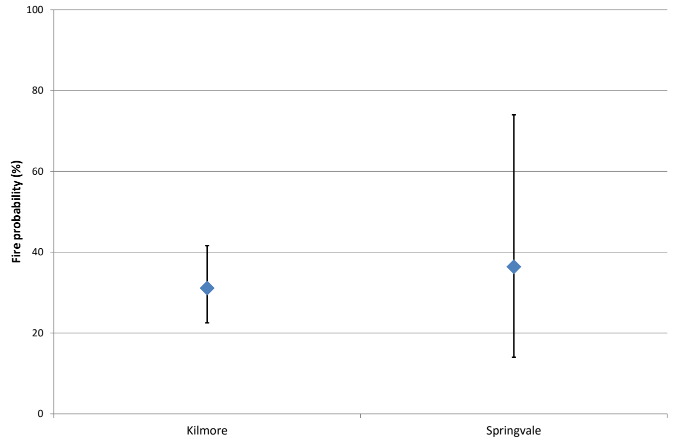
- No benefits for 'detached branch across wires' faults (conductor insulation is the only solution for these faults)
- Major benefits for all other powerline tree fault types ('branch touching wire', 'wire into tree/bush', 'tree across line', 'tree brings line down')

The Springvale tests used an artificial 0.5A fault current limit. These tests were validated at Kilmore South using a REFCL with 0.5A fault detection sensitivity. The Kilmore tests confirmed also that REFCL diagnostic tests for a sustained fault or to identify the faulted powerline did not increase fire risk in tree faults.

However, the REFCL tests has small but important differences to the earlier non-REFCL ones which appeared to help reduce fire risk:

KMS Test 715 Salix 0.5A
KMS Test 715 infrared
KMS Test 715 current

The physical basis for these differences remained unclear but the fire risk benefits of REFCLs in tree faults were confirmed:



The REFCL performance standard

A technology-neutral performance standard:

For a resistive earth fault that would normally draw 0.5 amps:
- Detect the fault in 1.5 seconds
- Within two seconds of the fault, limit conductor voltage to 250V (except during diagnostic tests)
- During diagnostic tests, limit the fault current to 0.5 amps and limit I^2t to 0.1 A^2s.

For a resistive earth fault that would normally draw 32 amps:
- Limit conductor voltage to 1,900V in 85ms, 750V in 500ms and 250V in 2.0 seconds (except during diagnostic tests).

REFCL conformance with this standard will reduce fire risk in all classes of earth faults tested by 90% or more.