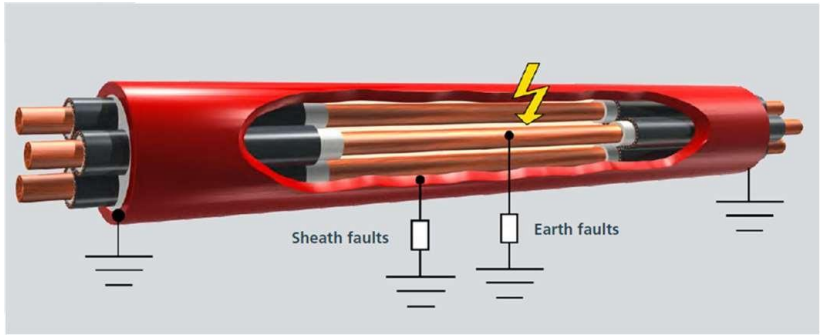
PPA 2022:



Appropriate Cable Fault location for the Pacific Island Networks

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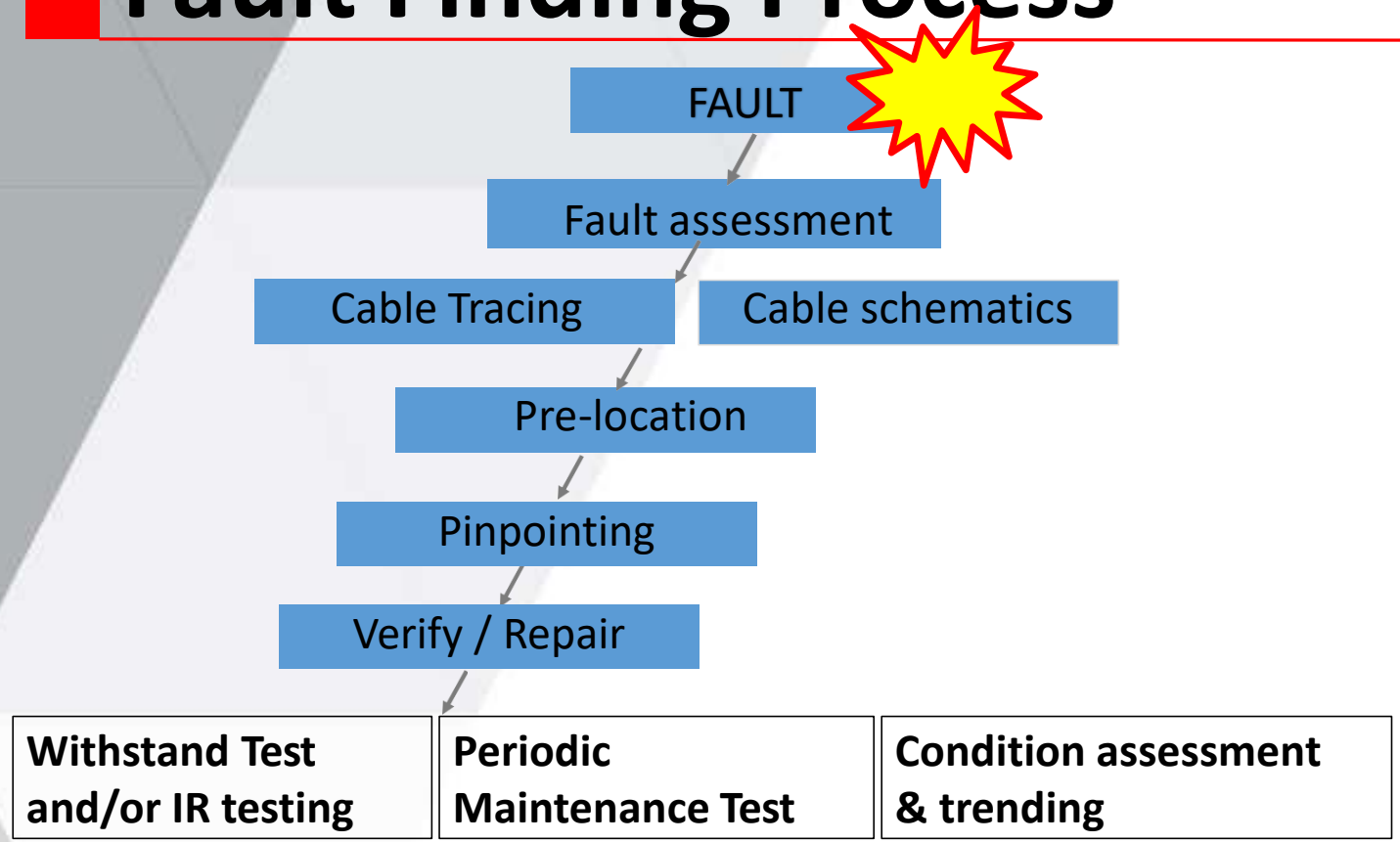
Fault Finding Process



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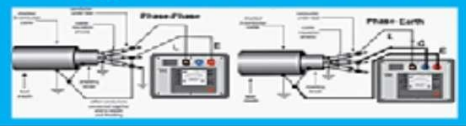
Type of faults and traditional approaches

Megger Insulation Test



Also qualifies the voltage dependence of the fault

Fault Diagnosis
(Determine Identical Phase)

Typical High Resistance Fault
Lower Value (1MΩ - 3MΩ)
Highest value (4MΩ - 99MΩ)

Dead Short Fault
0-1Ω

Open Fault
Ideal = ∞ (Normal)

Low Resistance Fault
Short Fault (1 - 99Ω)

TDR
Waveform
Upside down

Both End
Phase
Short

Measurement
Comparison
End

TDR Only
Time Domain Reflectometer

Surge Generator

High Voltage / High Resistance Bridge

This is typically required if the fault does not break down at low voltage

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TDR only summary:

- Fast
- Safe and non-destructive (LV DC pulse <50 volts)
- Portable
- Good for open circuit faults and short-circuited faults. (Especially in multi-core cables)
- Economic option
- Pre-location only (No pinpointing)
- Not suitable for high resistance faults (>100 ohms)

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Surging/Thumping only summary:

Fault finding with thumping only?

- Major disadvantage: No pre-location
- Breaks down a high resistance or “flashing” fault making it possible to listen for the fault (pinpointing the fault) by using EMF + acoustic equipment to enhance hearing.

Challenges and warning:

- Use on longer cables without pre-location leads to long thumping episodes
- Single stage thumpers require higher voltages to enable higher joules *(next slide)*
- Over-thumping can change the condition of the fault and possibly damage the global insulation condition of the cable.

- Overall this approach *on its own* is not recommended

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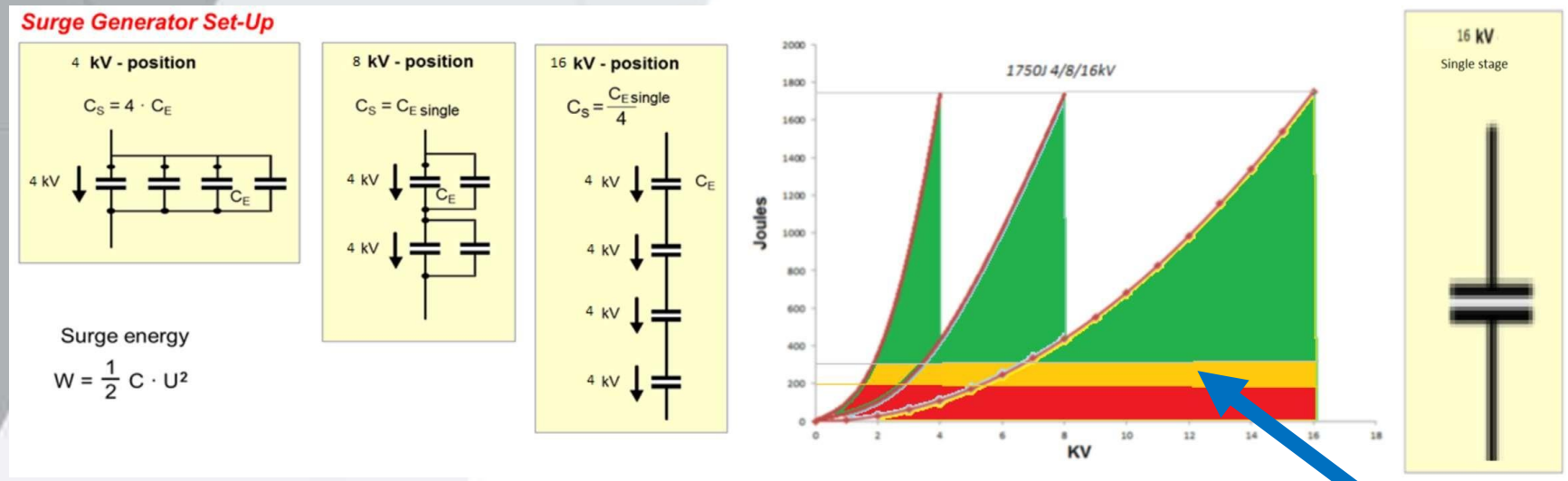
A discussion…
Multi-stage Surge Wave Generator



Such an architecture:

- Permits more suitable combinations of energy and joules
- Improves operational effectiveness, also lessening over voltage exposure damage to cables

Note: Audible threshold for faults typically 250 Joules

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Importance of balancing joules (energy) & impulse voltage…

- It is important when selecting a capacitive discharge impulse generator (thumper) that the right combination of impulse voltage and joules of energy is found for the length and voltage of cable tested.
- The is illustrated in the drawing to the right.
- The art of specifying a cable impulse generator is to balance the correct amount of joules with the cable's rated voltage so that the cable is not damaged in the process of fault location, but the fault is ultimately broken down and located

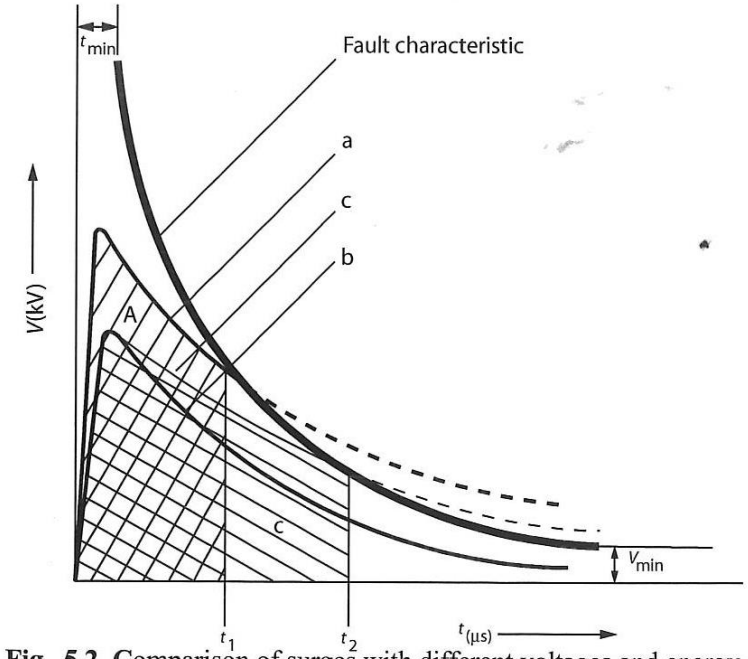

Fig. 5.2 Comparison of surges with different voltages and energy contents

*Courtesy of Barry Clegg

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…Importance of balancing joules (energy) & impulse voltage

By way of illustration:

- The impulse generator energy = **½ CV²** (…expressed in **Joules**)
- Assume we only have 1000J thumper rated at 16kV and wish to use it on a 400V cable at up to 4kV impulse.
- Applying a 4kV impulse, the joules available will be $1000/(4/16)^2 = 62.5J$… This is below the audible threshold and will be unlikely to break down the fault...
- Thus the temptation to increase the voltage in order to achieve a breakdown, but at the expense of the cable being severely damaged *(V knob is not volume a control!!!)*
- Hence impulse generators with multiple capacitance options are now seen as best practise, balancing energy and voltage specifications
- **Note 1 – cable length is also a vital factor in this discussion… recognising the cables "fault characteristic" curve and the requirement to intersect this curve to break down the fault**
- **Note 2: Best to try to keep V 'minimal' & Joules maximised**

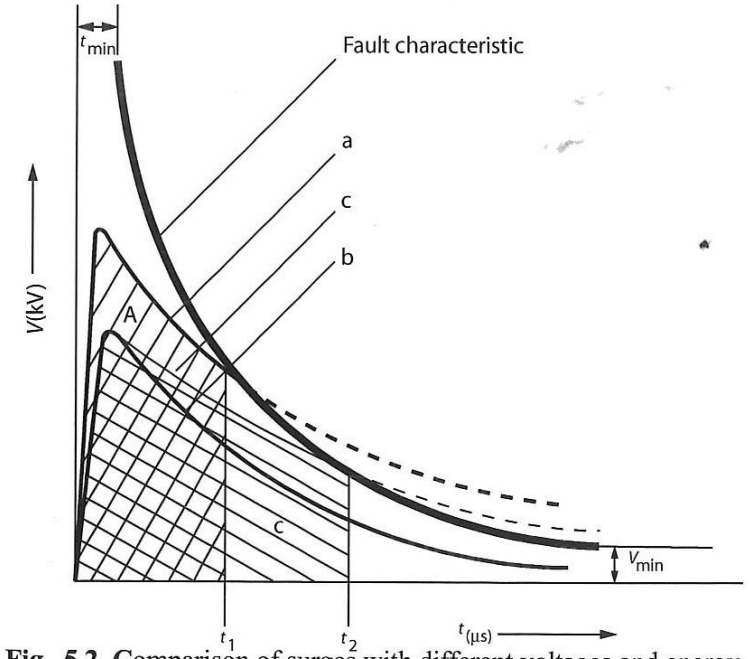

Fig. 5.2 Comparison of surges with different voltages and energy contents

*Courtesy of Barry Clegg

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High Resistance / High Voltage Bridge only

- Ideal for high resistance faults
- Also suited for sheath fault location
- Modern versions offer simpler operation than previous generation Inverted Murray Loop Bridge

- Limited contribution if fault is combined with a spark gap (“flashing fault”) …unless the bridge has an HV source included (more common now)
- But…a significant investment for only a partial coverage of the potential cable fault location requirements

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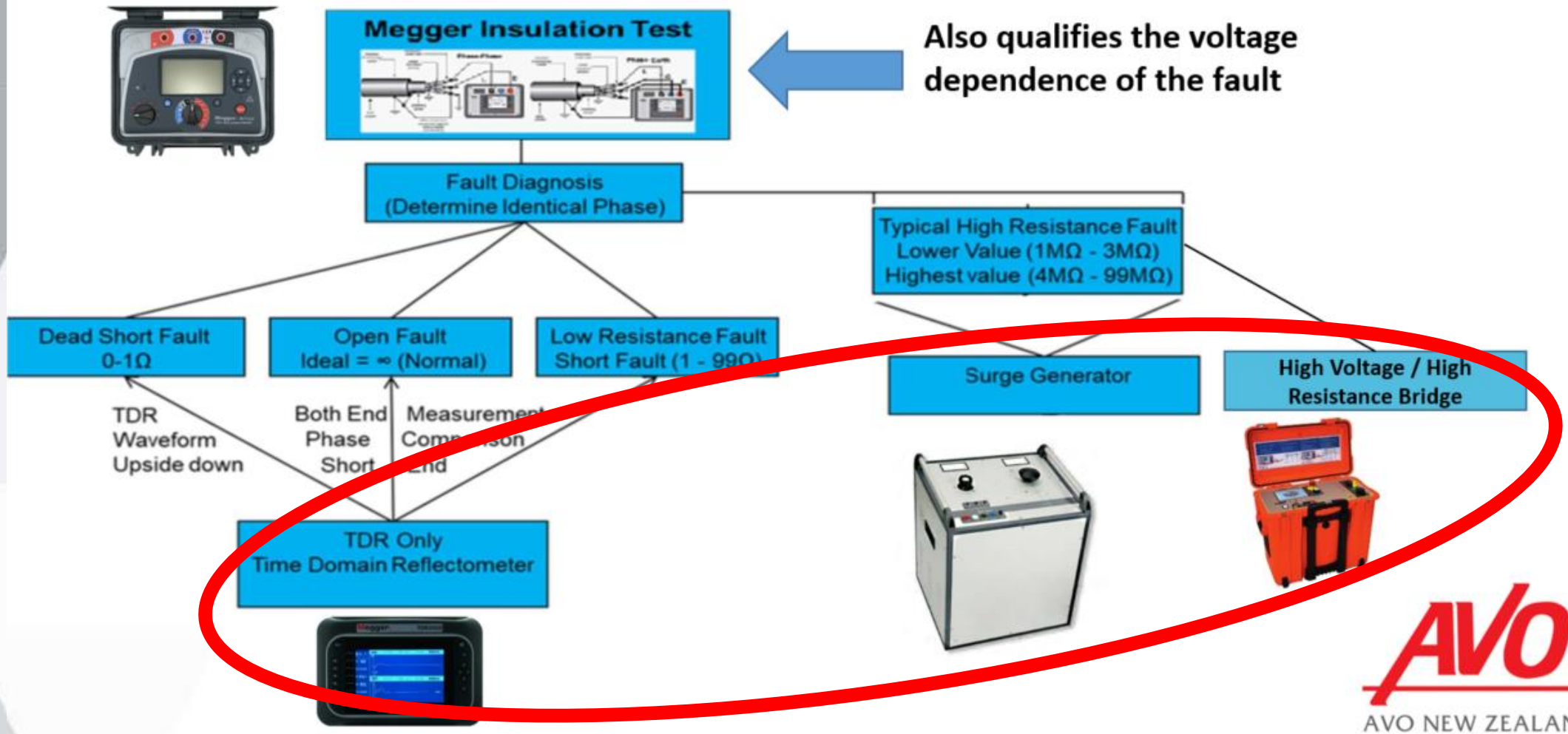
Combining all three technologies Surging, High resistance, and TDR…



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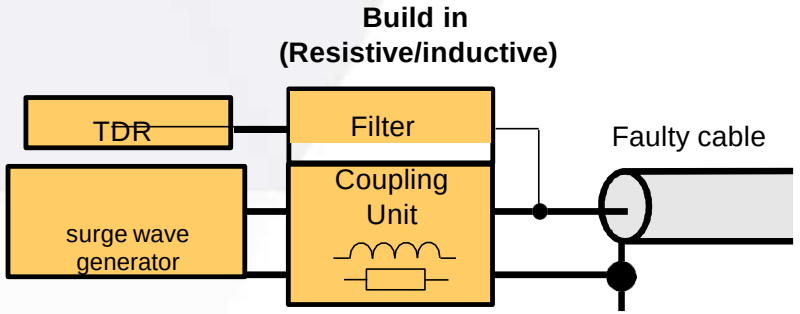
…Introducing the “modern” combined Multi-voltage cable fault location system

These devices typically include:

- Arc Reflection Measurement (ARM) (…next slide)
- TDR of high resistance faults
- High resistance fault measurement
- …achieved via a suitable coupling unit and enhanced processing and display technology



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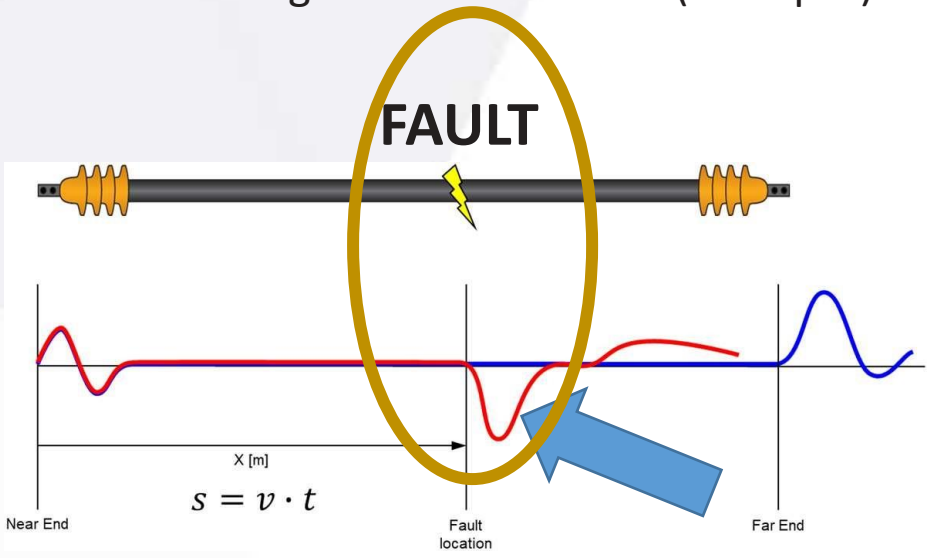
Pre location via ARC Reflection – an explanation

Arc reflection method (ARM) is a two-step-process:

A ***differential*** overlay of 2 traces;

- LV Reference TDR measurement
- HV impulse fault measurement from Surge Wave Generator (thumper)



LV trace – blue

HV trace – red

(shows clear difference at fault site)

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Advancements in portability and software:

Users now have unprecedented access to powerful and effective combinations of features in their cable fault location devices. The selection process is now a choice between two main architectures:

- A versatile single-box multi-voltage multi-Joule CFL device, typically:
  - 80-120kg (typically van-mounted)
  - 2000 Joules per voltage range selected (sufficient for most cable lengths)
  - 4/8/16/32kV (allows strong coverage from LV to 66 kV cable)

- Smaller compact, cost-effective devices designed for specific cable voltage and fault characteristic curves:
  - 30kg single person lift
  - 4kV 500J for LV cables, and 12kV 500J for up to 2.5km of 11kV cable
  - Battery-powered operation…no need for mains voltage power source
  - Simple, common intuitive operator interface, permitting easy transition from LV to HV models
  - Well suited for Pacific Islands network requirements

Acoustic and electromagnetic impulse detectors for ‘pin-pointing’ faults

After pre-location, acoustic and electro magnetic impulse detectors are the vital ‘next step’ in the cable fault location process.

Advances made include:

- Enhanced combination of electromagnetic detection capabilities and optimised geophone design to avoid stray noise pickup
- Offers a high level of user comfort and convenience
- Optional facility for sheath fault location in some brands

Note: minimise HV impulses on cable during this phase of cable fault location!

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Summary
Cable fault finding pre-location:

- With combined TDR & Arc Reflection Method devices, both high and low resistance faults can be pre located and pinpointed. This will minimize surging and avoid over-thumping of cables.
- Modern impulse generator permit the optimum combination of energy (joules) and test voltage to suit a wide variety cable voltage types and lengths
- By combing **intuitive operating software** and the advancements in the performance of **acoustic EMF pinpointing** equipment, the combined benefits result in smarter, faster, lighter, more effective, and safer cable fault finding….while avoiding adverse impact to the cable life in the process.

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Questions?

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