

C37.114-2014 IEEE Guide for Determining Fault Location on AC Transmission and Distribution Lines (Revision of IEEE Std C37.114-2004)



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Overview

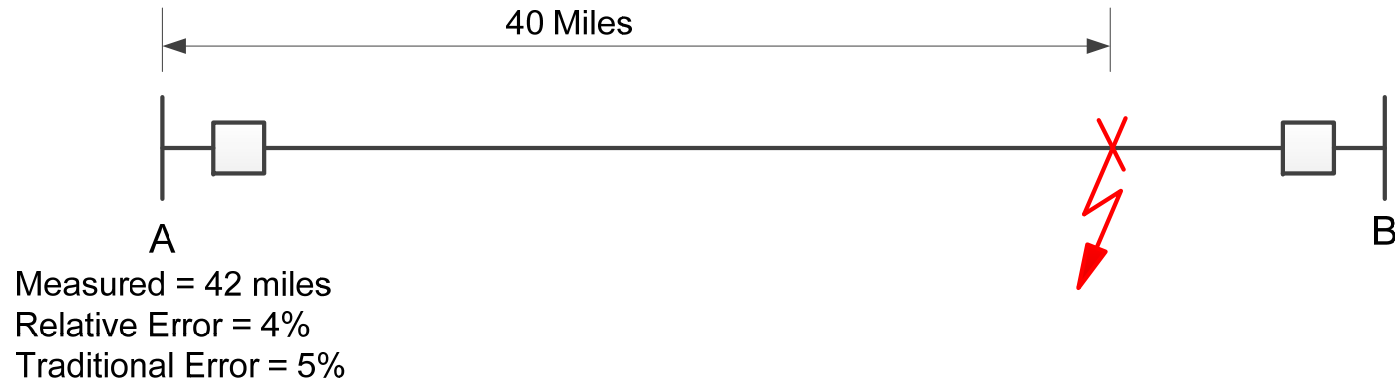
- Guide outlines the techniques and application considerations for determining fault location on ac transmission and distribution lines
- Reaffirmation ballot in 2009 had negative comments
- WG formed to address negative ballot comments and to update material on fault locating technologies/applications

Determination of FL Error

- Relative Error Based Upon Line Length: $\frac{|m_m - m_t|}{L}$
- Traditional Relative Error: $\frac{|m_m - m_t|}{m_t}$
- Relative error based upon line length provides a “normalized” value with respect to the end that is being evaluated
- Traditional error can give significantly different error values at each end of the line

Error Calculation Example

50 Mile Line



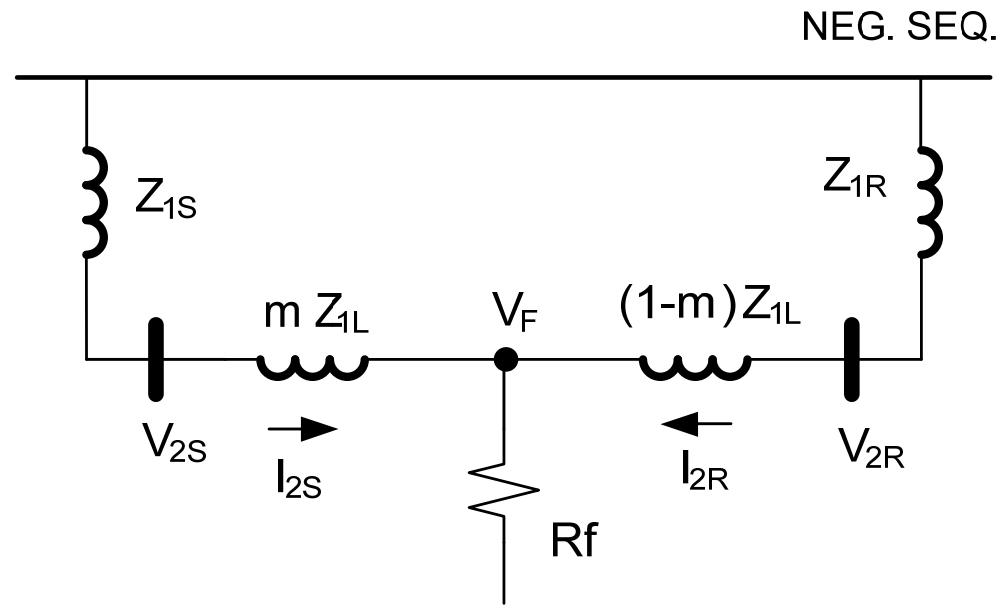
Synchronized versus Un-synchronized Phasors for Fault Locating

- Two-Ended Method
- With synchronized phasors, fault location is independent of fault resistance characteristic (i.e., variable resistance versus constant)
- If fault resistance is constant, synchronized sampling is not needed
- Synchronized sampling provides better results

Synchronized Phasors for Fault Location

- Per unit distance to fault (m) from Bus S is given by:

$$m = \frac{V_{2S} - V_{2R} + Z_{1L} \times I_{2R}}{Z_{1L} \times (I_{2S} + I_{2R})}$$



Un-synchronized Phasors for Fault Location

- V_{2S} , I_{2S} , V_{2R} , and I_{2R} phasors reach constant magnitude & phase angle in the fault steady state
 - Synchronous measurements are not necessary
 - Even with a time interval between measurements, we can solve for m in the equation below to yield an accurate fault location

$$\frac{|V_{2S} - m \times Z_{1L} \times I_{2S}|}{\left| \frac{V_{2R}}{I_{2R}} - (1 - m) \times Z_{1L} \right|} = |I_{2R}|$$

Synchrophasors and Synchronized Sampling

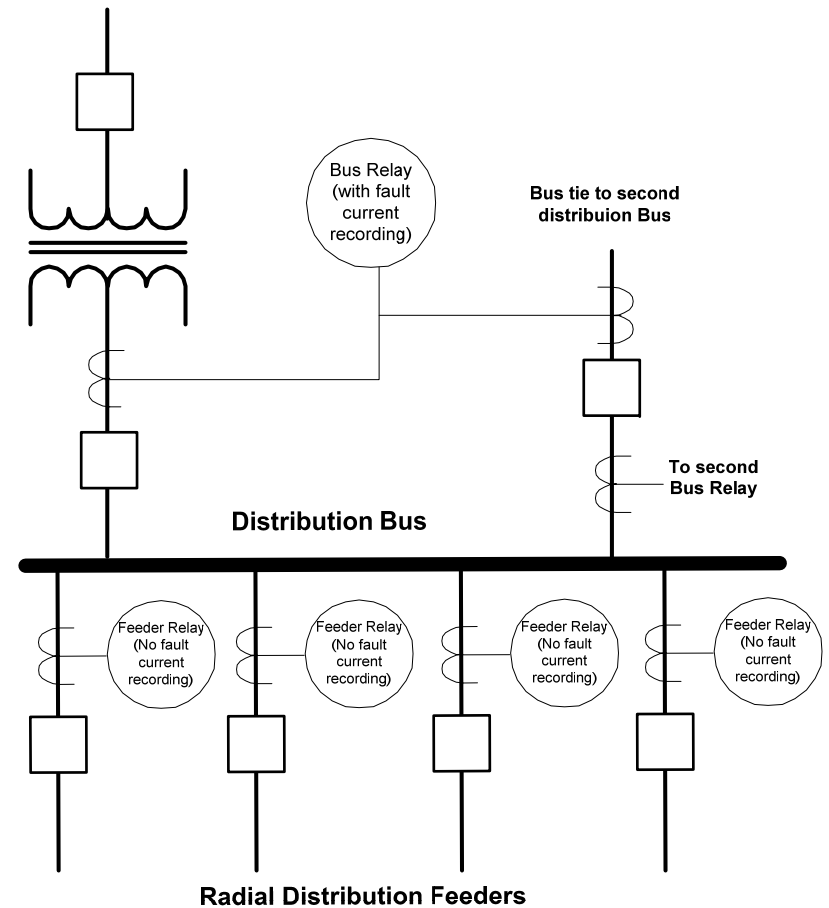
- Synchrophasors in fault location
 - Filtering system must be same at all terminals for accuracy
 - Acquisition rate is important
 - Longer data windows result in less accuracy
- Synchronized sampling in fault location
 - Advantages over synchrophasors
 - Same filtering technique is applied at all terminals => better fault location during transient response
 - Sample rate can be under the control of the user
 - Use highest sampling frequency possible; error is inversely proportional to sampling frequency

Distribution Line/Feeder Fault Locating

- Challenges with Distribution Feeder Fault Locating
 - Conductor sizes change
 - Multiple feeder taps and laterals
 - Limited IEDs and/or communication with IEDs, particularly outside the substation
- Distribution Fault Locating has traditionally been accomplished through physical indications and field methods without the use of IED fault measurements.
- Using only the IEDs to “calculate” fault distances often not accurate due to non-homogeneous feeder configuration and limited communication with remote devices.
- Using IED Data (Fault Currents and/or Fault Impedances) in conjunction with feeder modeling tools can be used for more accurate Distribution Fault locations

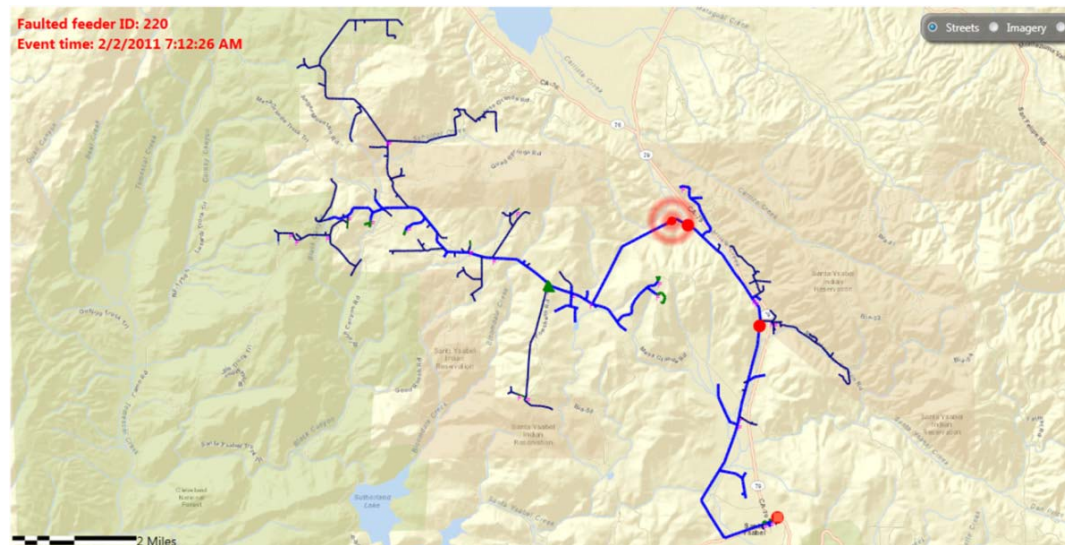
Distribution Fault Locating User Application

- Distribution system faults often have minimal fault impedance
 - Actual fault current from Bus or feeder IEDs can be compared to the feeder model's bolted fault current
- Multiple fault locations may be provided
 - Protected taps and laterals can be eliminated (if they coordinate).
 - FCI (Faulted Circuit Indicator) and physical verifications can further eliminate unprotected taps
 - Downstream IED status and fault information can refine locations (if available)



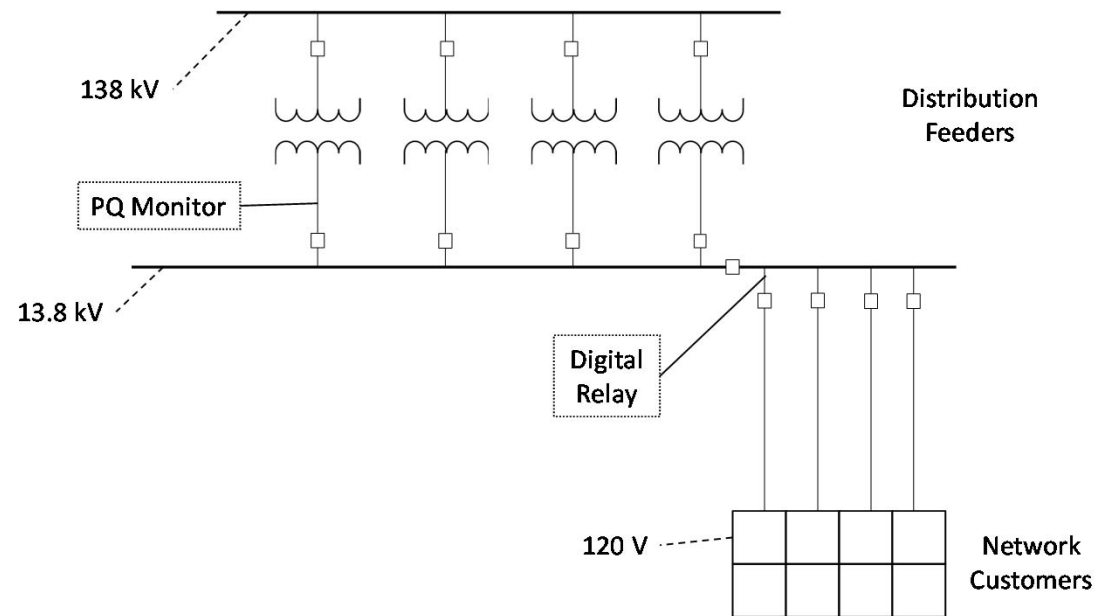
Distribution Line/Feeder Fault Locating

- Comparison between IED Fault Data and Feeder Model can be manual or automatic
 - Manually compare IED Fault Current and fault type to the feeder's short circuit model to determine fault location(s). Tables and other tools can speed up this evaluation
 - A detailed feeder model and feeder IED fault data can be imported to commercially available distribution system analysis software using a search algorithm to automatically identify fault locations.



Networked Underground System User Application

- Incorporates data from power quality monitors, feeder relays, GIS database, and SCADA
- Automatic routine; data collection and fault location
- Uses impedance for fault locating
- Historical data used to fine tune impedance model
- 80% of faults located to within three manholes





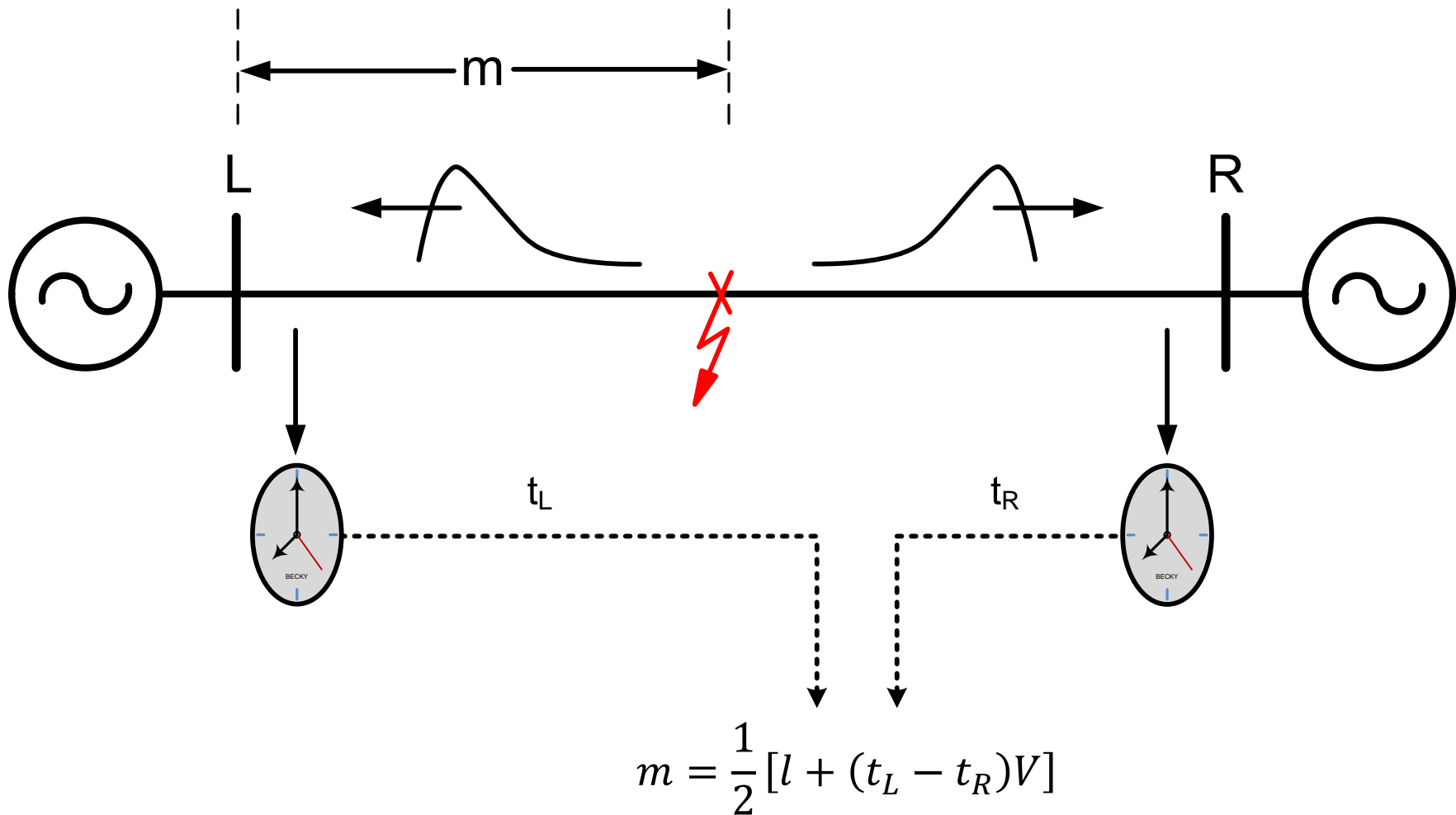
Flushed Insulators Are Hard to Find

Accurately Locate Faults With Traveling Waves

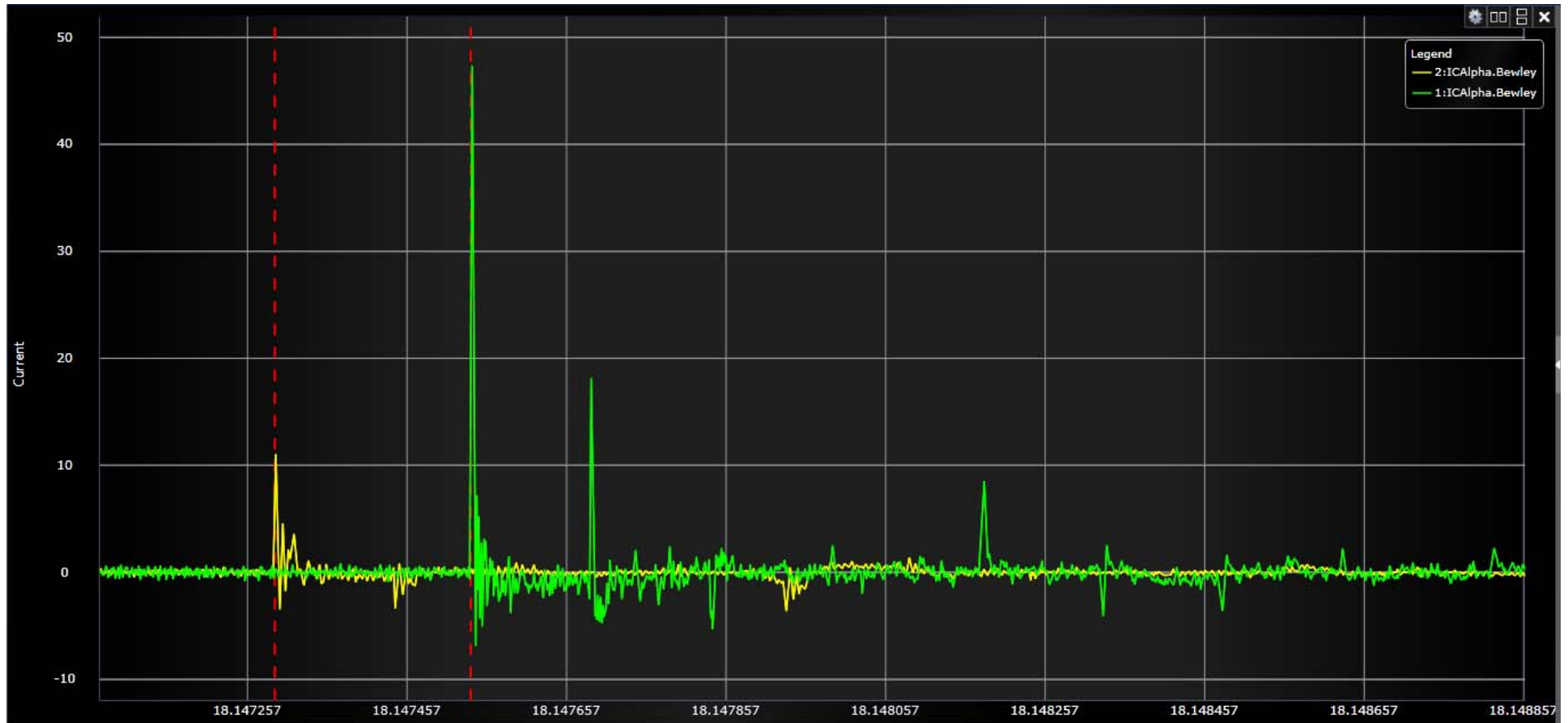
Fault Located at 38.16 miles

Method	Distance (miles)	Difference (miles)
Impedance	34.03	4.13
Traveling wave (TW)	37.98	0.18

Lightning and Faults Launch TW



Travelling Wave Field Event



Real-world Results Using Travelling Wave Fault Locator

Nature of Fault	Line Patrol (miles)	TW (miles)
Flashover	67.91	68.19
Lead projectile	38.16	37.98
Lightning	66.86	67.25
Flashover	61.50	61.42
Flashover	50.18	50.56
Flashover	59.04	59.04

Thank you for your time!

Questions?