Using High-Resolution Time-Stamped Data to Improve System Operations
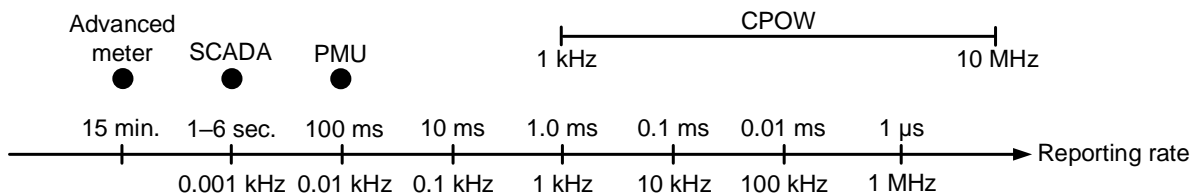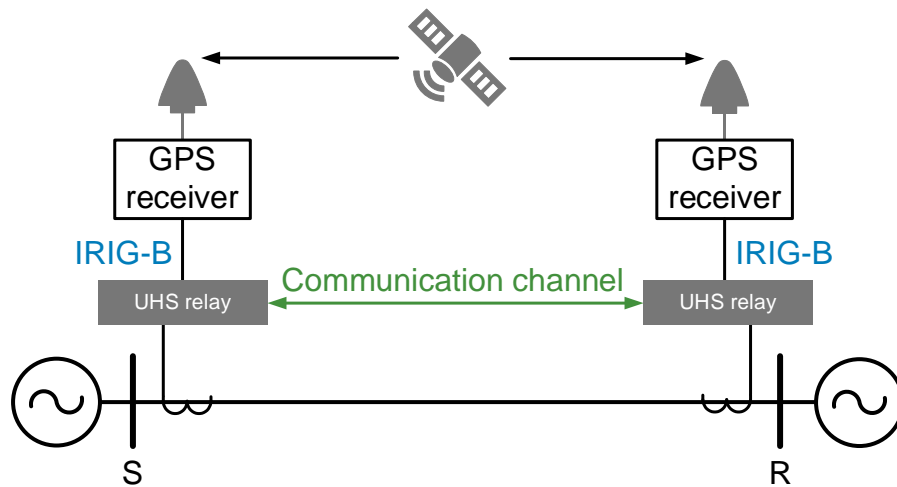

Wide-area ultra-high-resolution CPOW
Continuous point-on-wave measurements

- 1 MHz ultra-high-resolution CPOW streaming
- 1 µs resolution waveform sampled data
- High availability, streamed from protective relays
- UTC precise time-stamped time source

Advanced meter	SCADA	PMU		CPOW	
			1 kHz		10 MHz

15 min.	1–6 sec.	100 ms	10 ms	1.0 ms	0.1 ms	0.01 ms	1 µs	Reporting rate
	0.001 kHz	0.01 kHz	0.1 kHz	1 kHz	10 kHz	100 kHz	1 MHz	

Source: NASPI-2020-TR-004
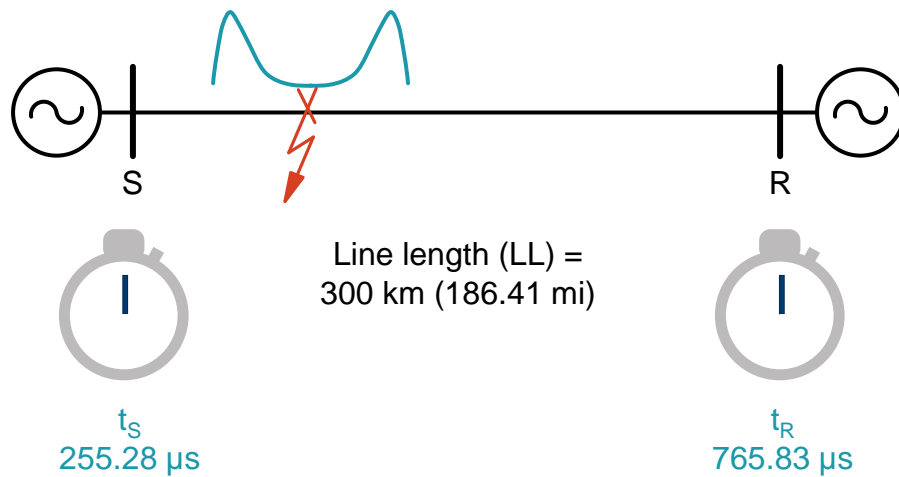
1

Submicrosecond time source
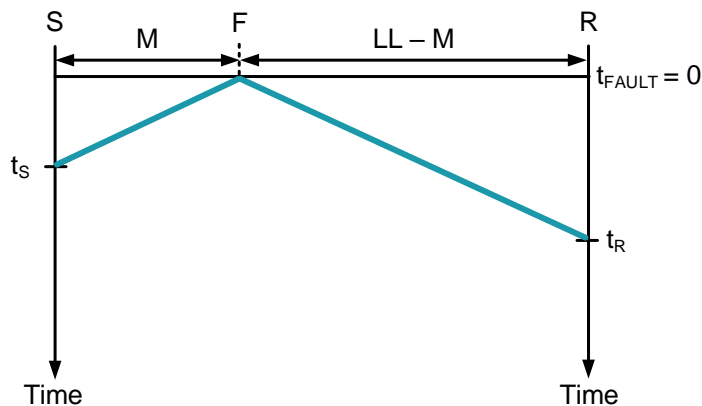

Submicrosecond timekeeping

- Antenna connected satellite-synchronized clock time source
- IRIG-B clock with IEEE C37.118 time code extensions
- IRIG-B signal 100 Hz edge jitter under 500 ns
- Time source time error of less than 10 µs

Fault launches traveling waves

Fault at 75 km (46.6 mi) from Terminal S

S

R

Line length (LL) =
300 km (186.41 mi)

t_S
255.28 µs

t_R
765.83 µs

Double-ended TW fault locator

S   M   F   LL − M   R

$t_{FAULT} = 0$
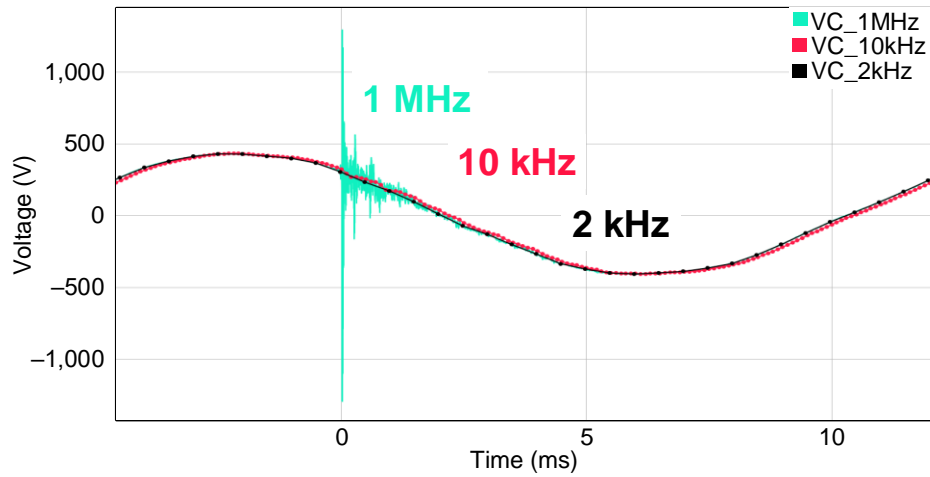
t_S

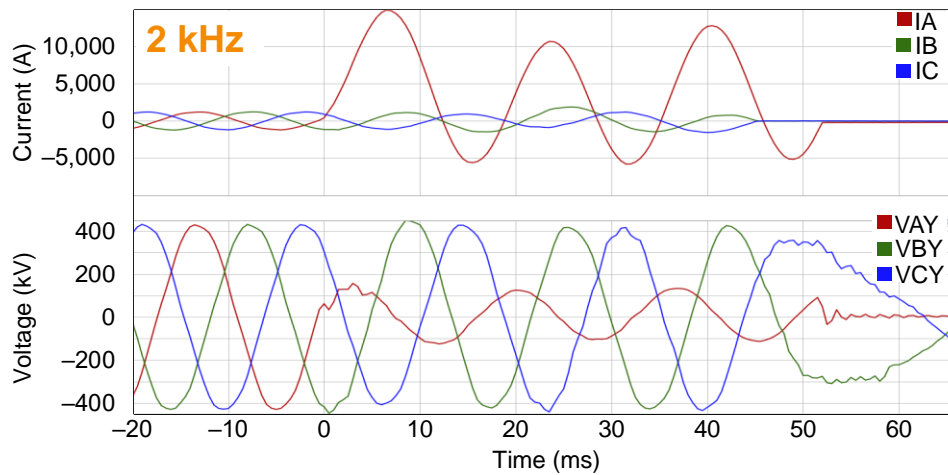t_R

Time   Time

$$M = t_S \cdot \frac{LL}{TWLPT}$$

$$LL - M = t_R \cdot \frac{LL}{TWLPT}$$

$$M = \frac{LL}{2} \cdot \left(1 + \frac{t_S - t_R}{TWLPT} \right)$$
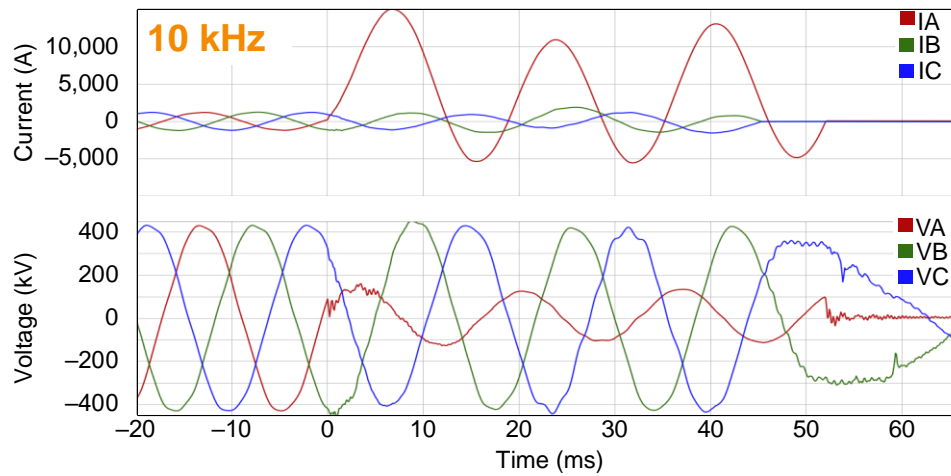
Huge voltage transients visible at 1 MHz are invisible at 2 kHz (2 ms) and 10 kHz (0.1 ms)
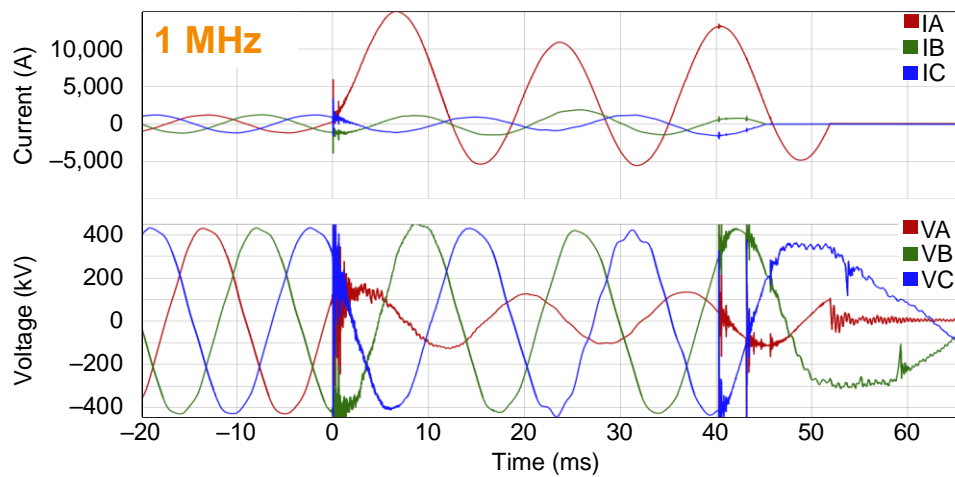
Huge voltage transients visible at 1 MHz are invisible at 2 kHz (2 ms)

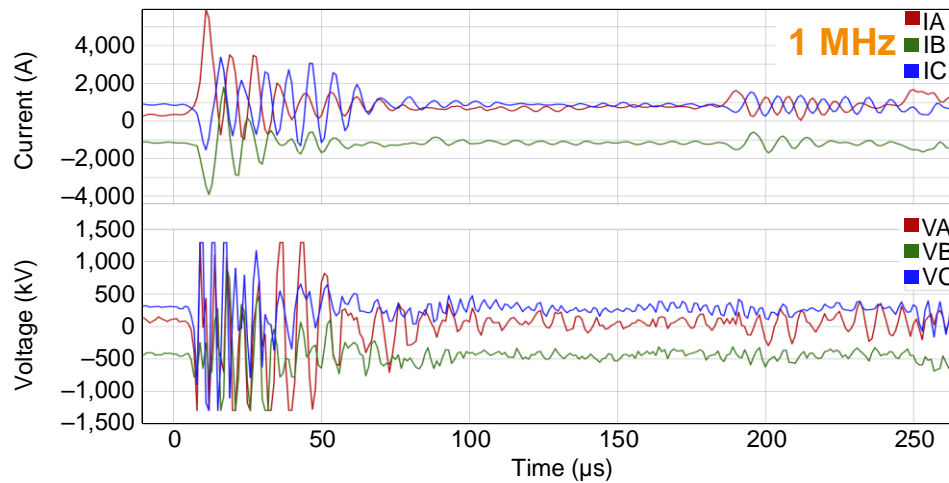# Huge voltage transients visible at 1 MHz are invisible at 10 kHz (0.1 ms)
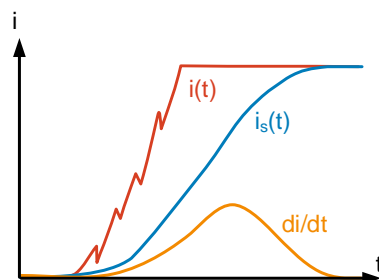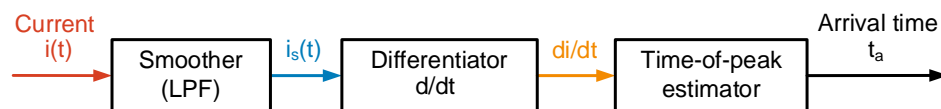

Huge voltage transients visible at 1 MHz

Huge voltage transients visible at 1 MHz
1 µs reporting rate

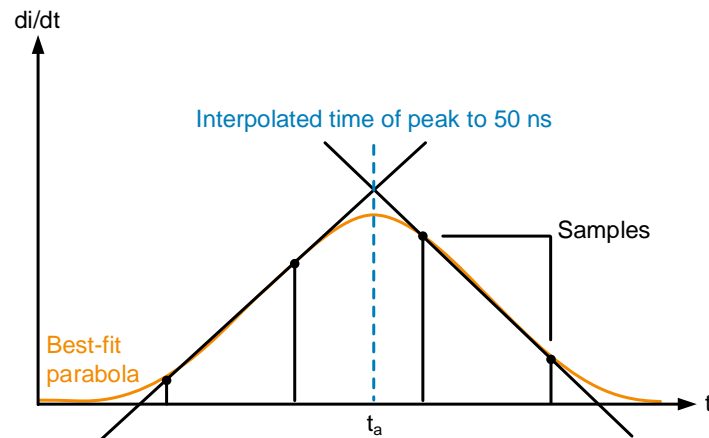# Signal processing with differentiator-smoother
Radar "leading edge tracking" method

Traveling waves are sharp changes between two quasi steady-state signal levels

Submicrosecond accuracy time stamps
Interpolation for the arrival time of traveling waves

Colombia – 230 kV, 260 km (161.6 mi)
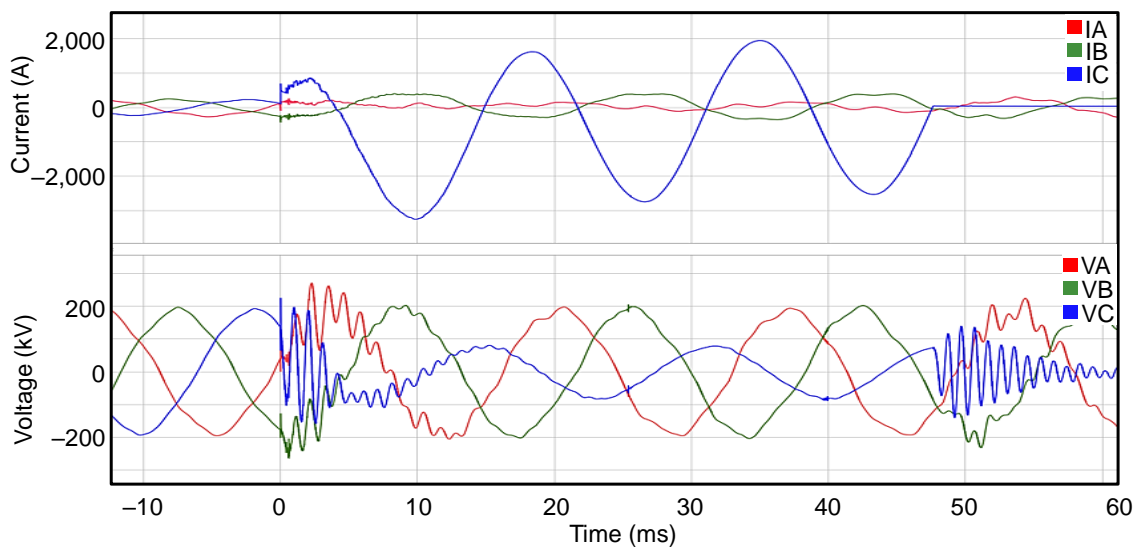## Chivor-to-Rubiales transmission corridor
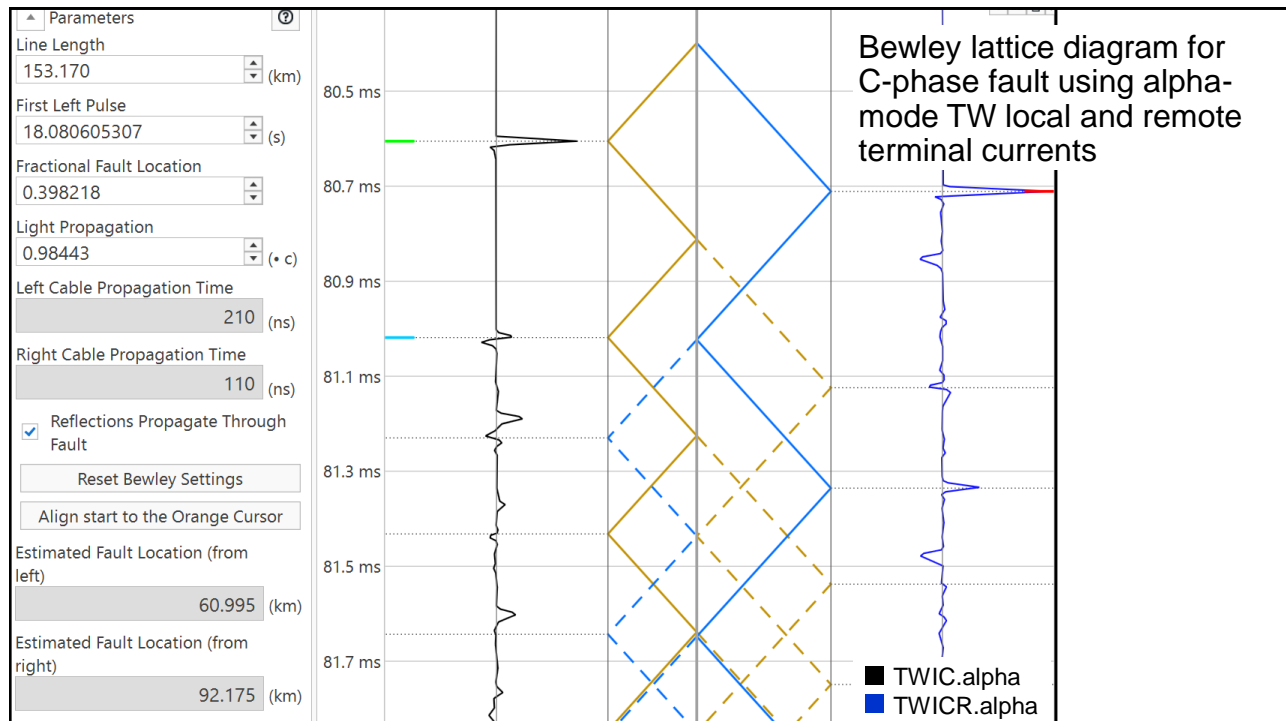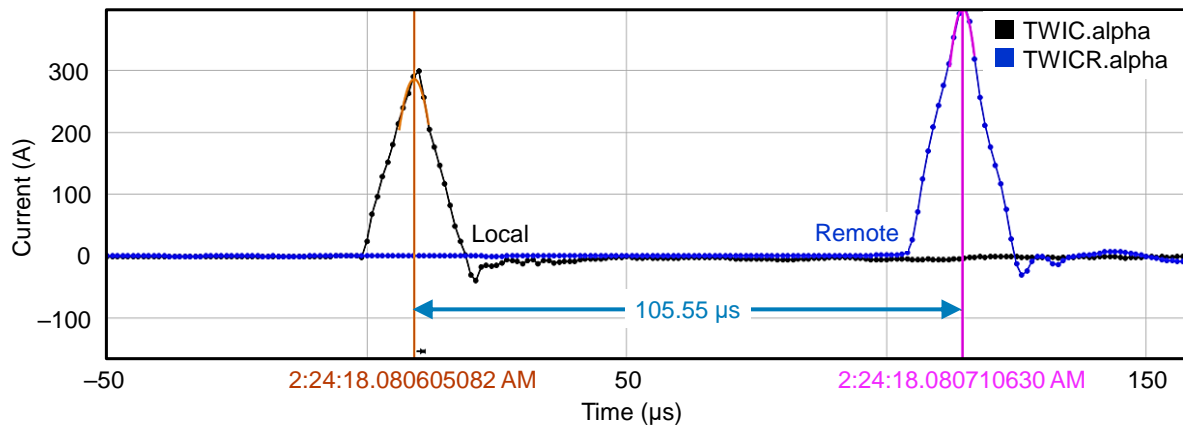
Colombia – 230 kV, 260 km (161.6 mi)

Chivor-to-Rubiales transmission corridor

Chivor

San Luis de Gaceno

Jagüey

Bogota

Puerto Gaitán

Corocora

Villavicencio

Quifa

Rubiales

1 MHz ultra-high-resolution signals

Local and remote C-phase TW arrival times

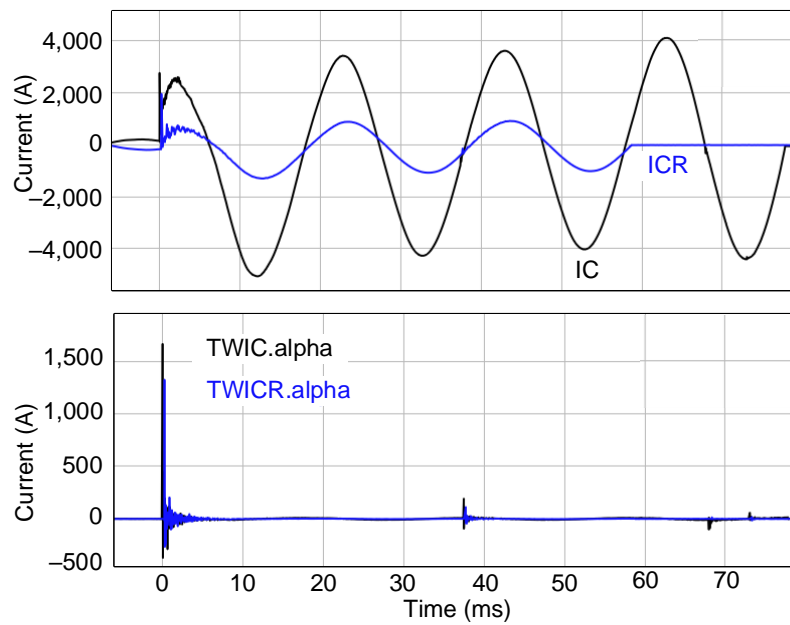Bewley lattice diagram for C-phase fault using alpha-mode TW local and remote terminal currents
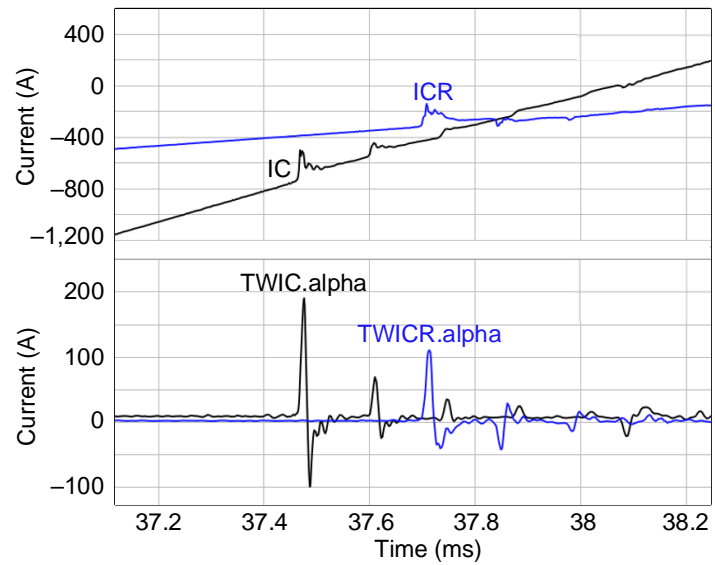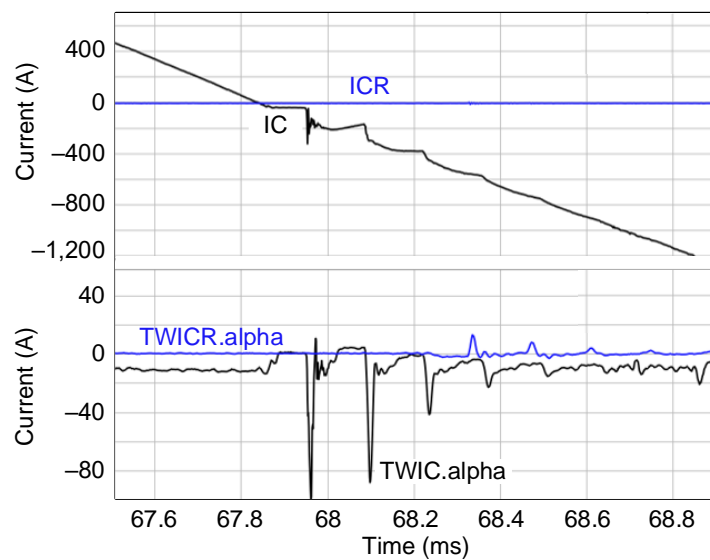
Circuit breaker reignition

1 MHz data reveals two post-fault disturbances

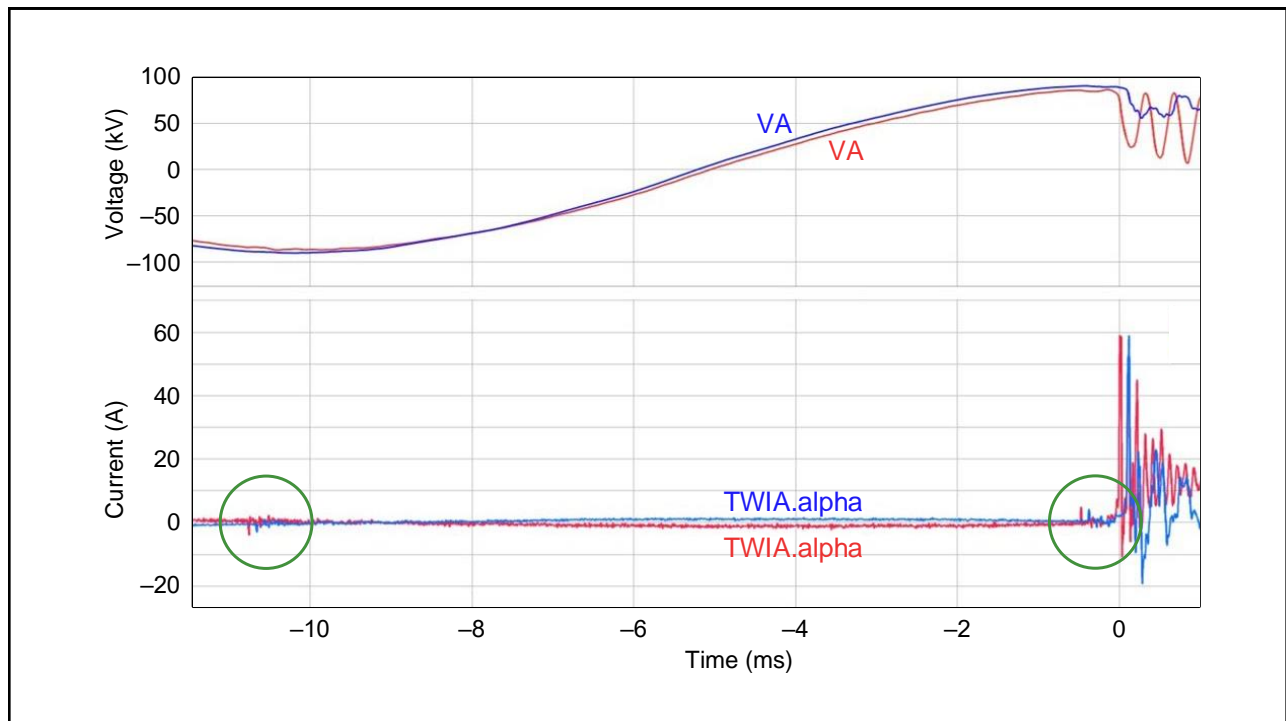## Use off-line software tool to investigate further
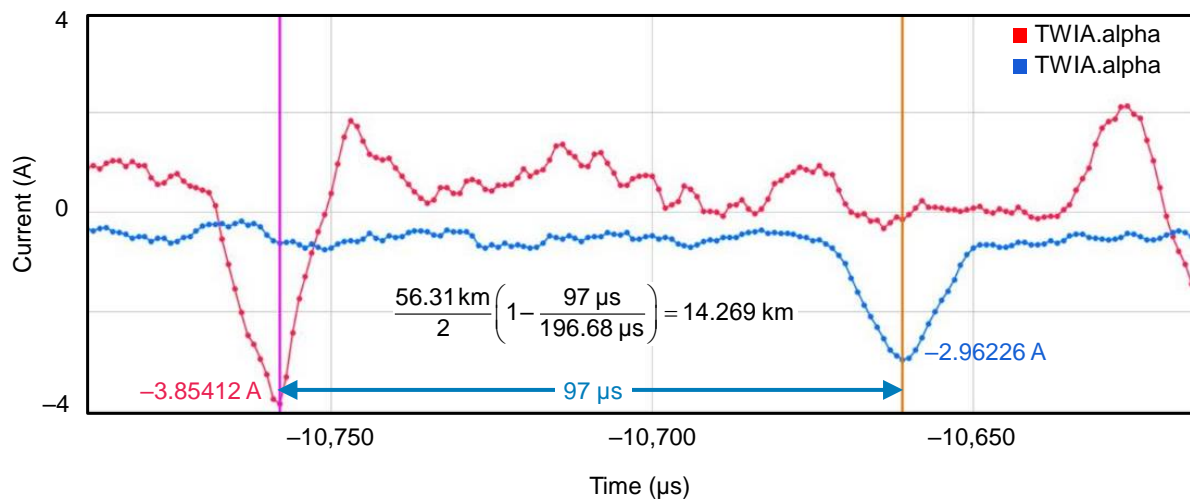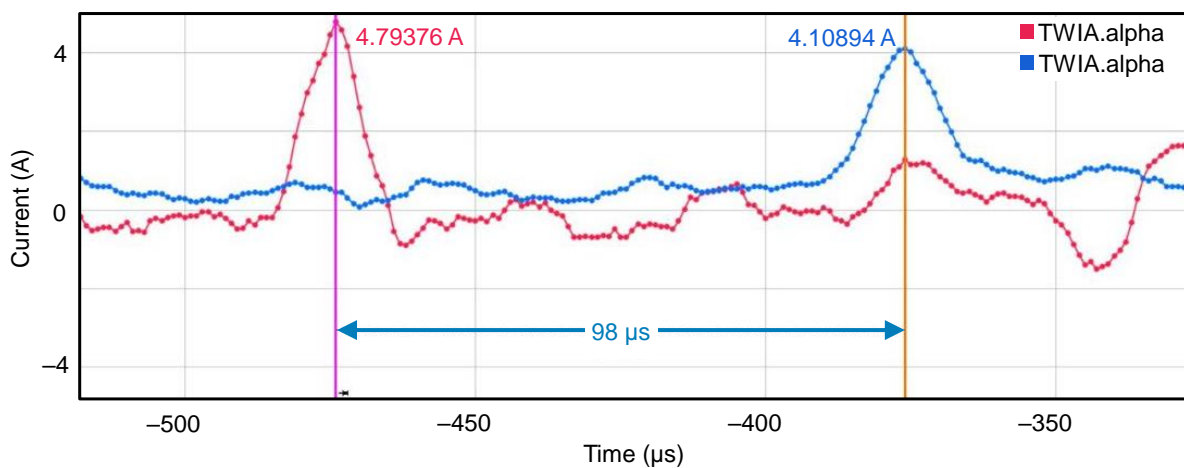

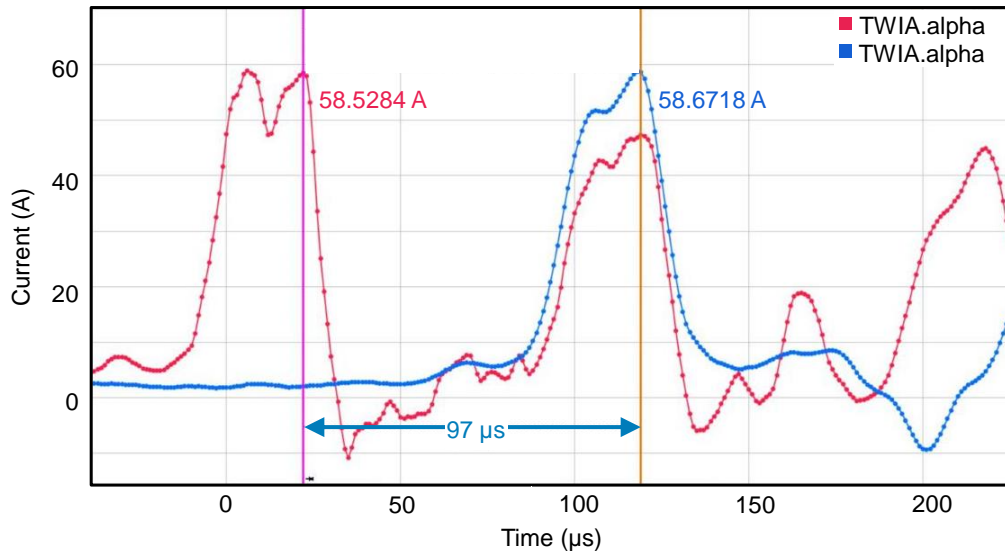## Breaker reignition after C-phase interrupted

Line monitor

Precursors can be located

$$\frac{56.31\,\text{km}}{2}\left(1 - \frac{97\,\mu s}{196.68\,\mu s}\right) = 14.269\,\text{km}$$
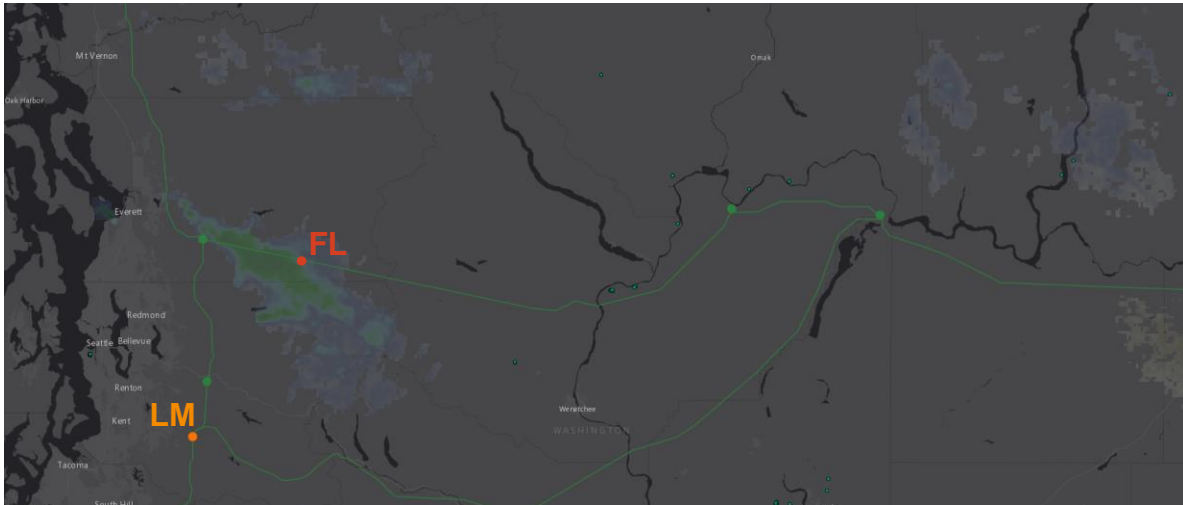
Second precursor

Short circuit

Line monitor counts low-energy and fault events and asserts alarm

- Trigger double-ended TW fault locator, even if no trip occurs
- Calculate event location if no trip occurs, and calculate fault location if trip occurs
- Tabulate event and/or fault locations over time in 0.25-mile or kilometer bins
- Assert alarm or trip on high bin counts

FL result and LM alarm

Fault located by relay using TWFL
(photo courtesy of BPA)

Questions?