Synchro-waveforms: Application opportunities in electric power transmission systems

Chester Li, Hydro One Inc
Chester.li@hydroone.com

Scope of this presentation

- **Introduction--Hydro One**
- **From waveforms to synchro-waveforms**
  - When waveforms are not necessary in engineering judgment
  - When waveforms are necessary in troubleshooting
  - When synchro-waveforms are necessary
- **Discussions**

Introduction – Hydro One

ONE OF THE LARGEST PURE PLAY ELECTRIC TRANSMISSION AND DISTRIBUTION COMPANIES IN NORTH AMERICA

26% of Ontario's distribution customers

98% of Ontario's transmission capacity

1.6M Poles

>80 industrial customers

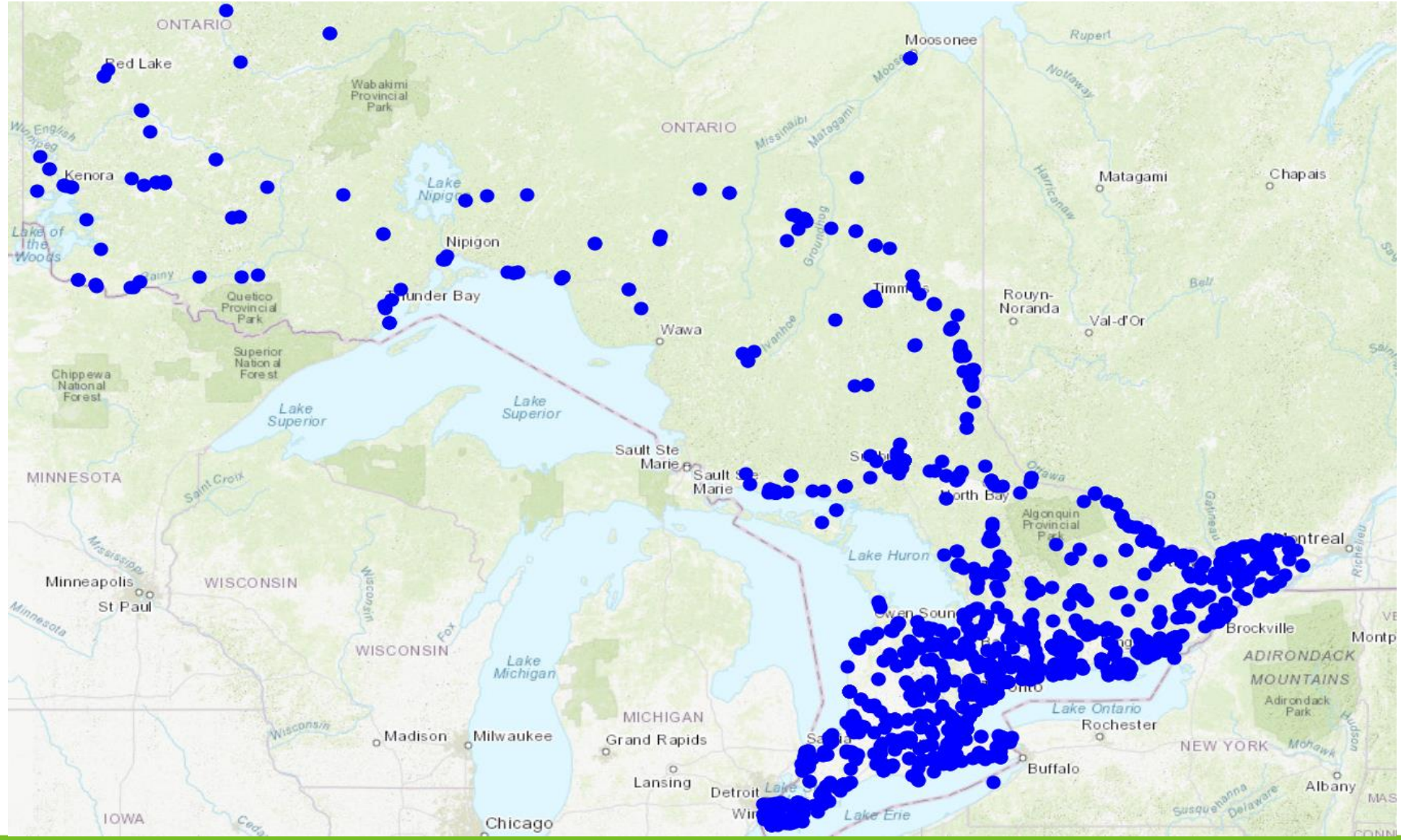
8,800 skilled and dedicated employees

~1.4M residential and business customers served by our local distribution business

Leadership in ESG

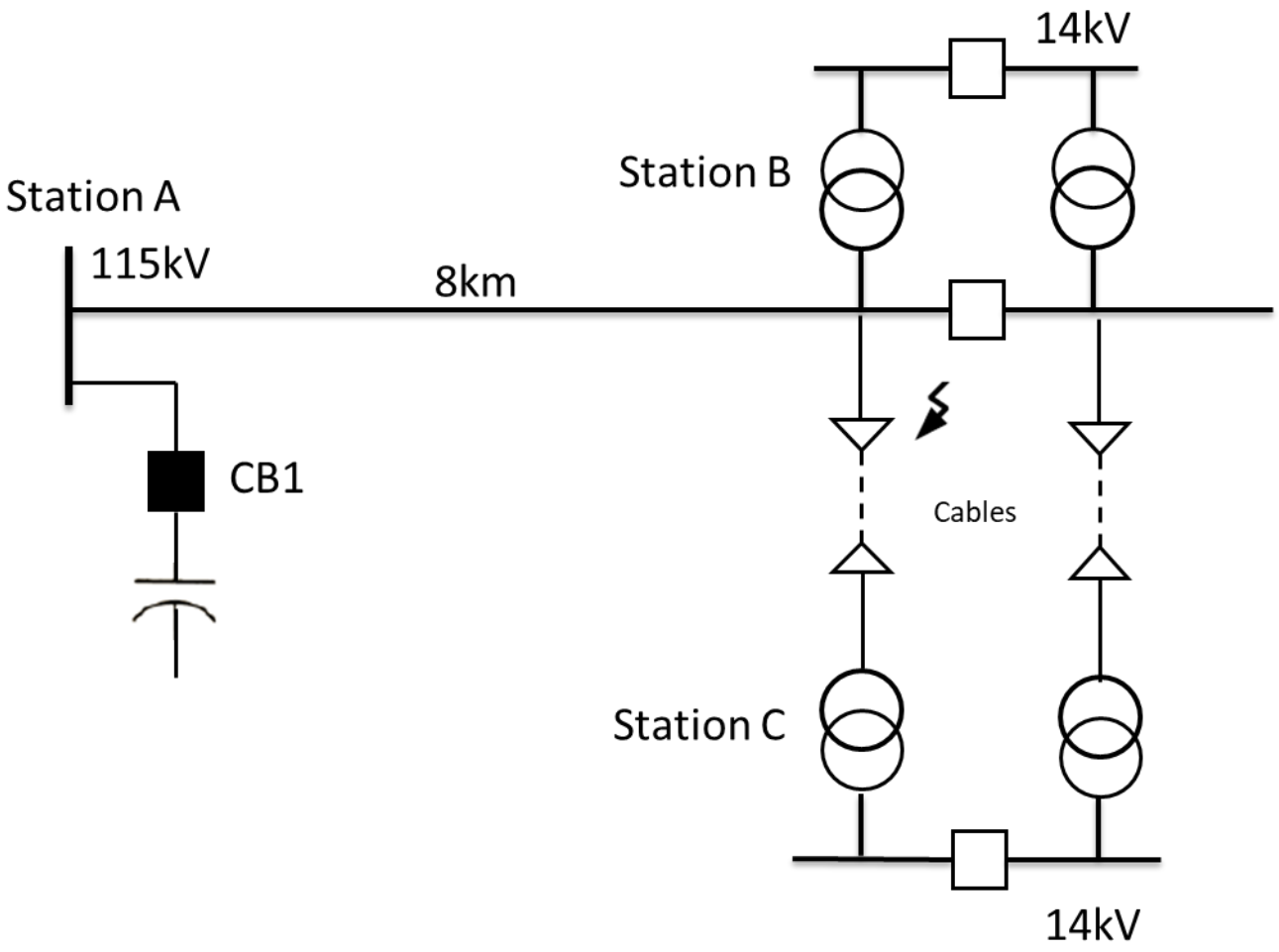
Approximately 7,200MW wind/solar, 2022 peak demand around 23,000MW

Introduction – Hydro One

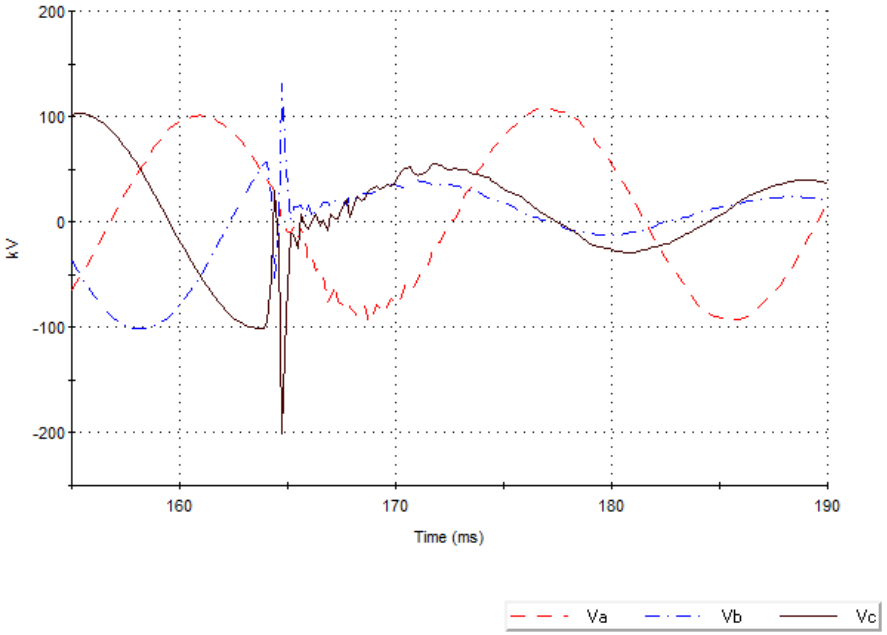


~1500 PQ meters

Engineering judgement when waveforms are unnecessary

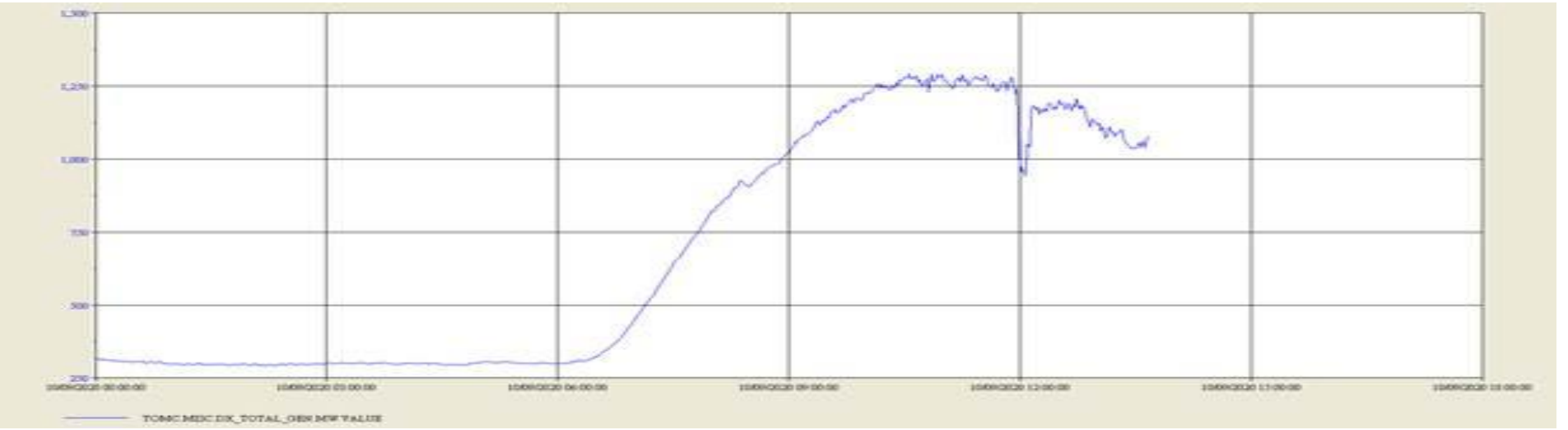


- **A 115kV shunt capacitor was switched off by opening CB1 @ Station A**
- **The line was tripped upon breaker switching and fault annunciated**
- **So what to check?**



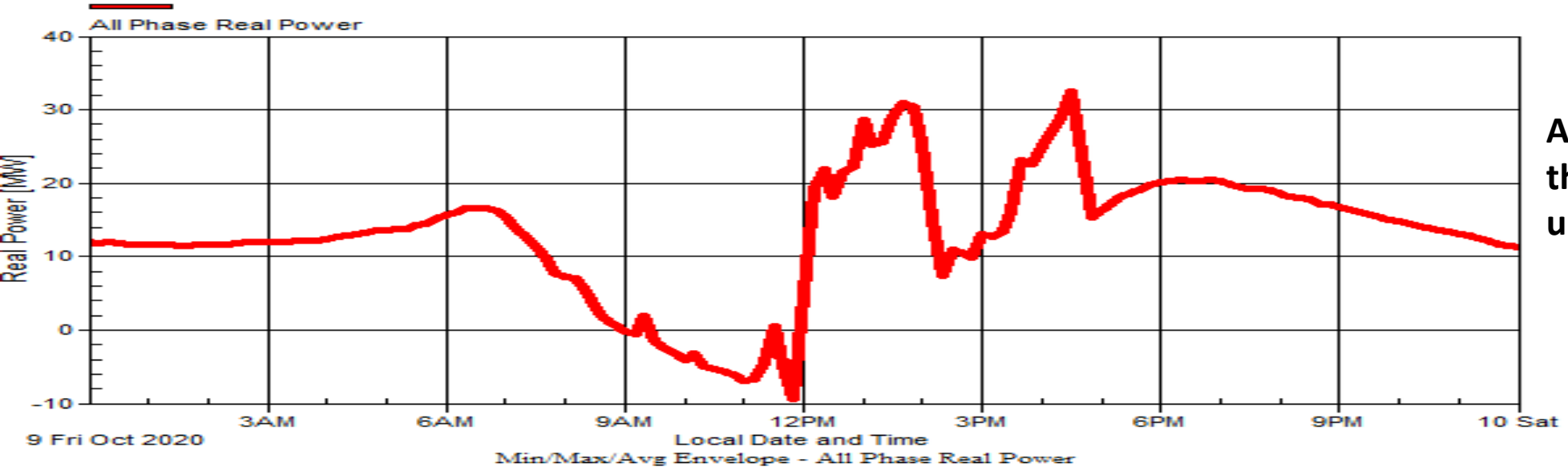
Voltage waveforms @ Station B,
Nice to have but not necessary

Examples where waveforms are necessary



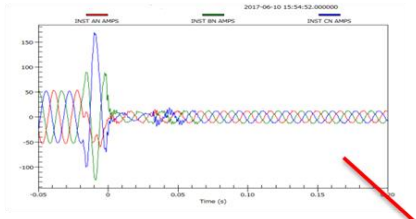
Total D-connected Solar MW trend under a 500kV fault

This may not tell the full story

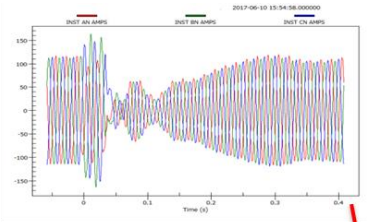


A 230kV station MW flow through step-down transformer under the 500kV fault

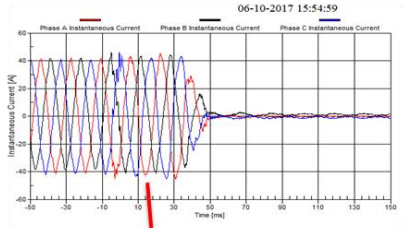
Examples where waveforms are necessary



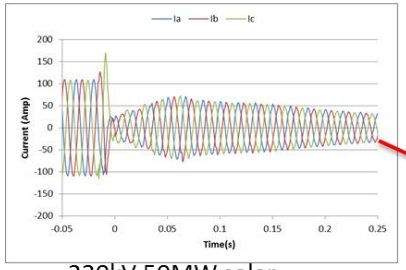
44kV 30+MW solar



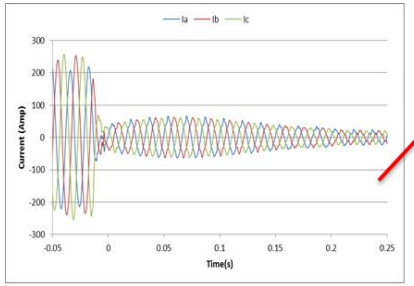
44kV 30MW solar



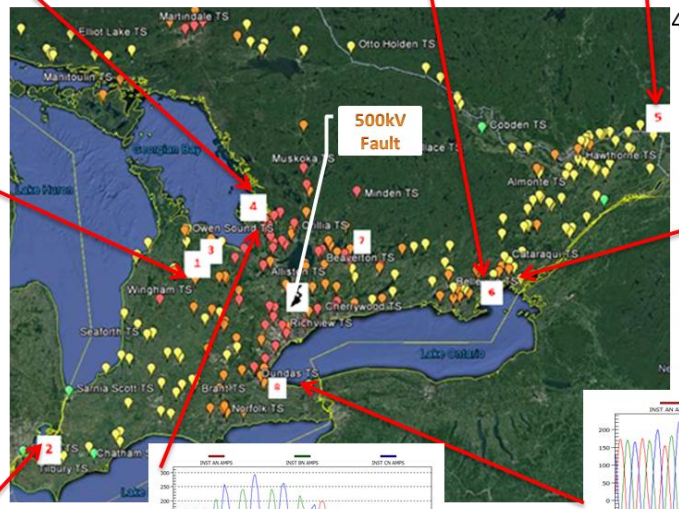
44kV 27MW solar

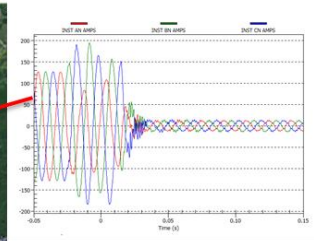


230kV 50MW solar

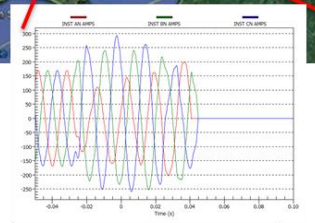


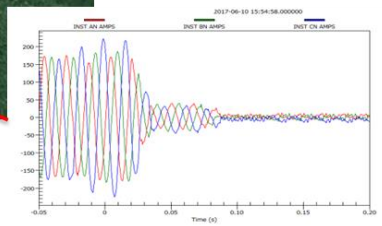
115kV 50MW solar





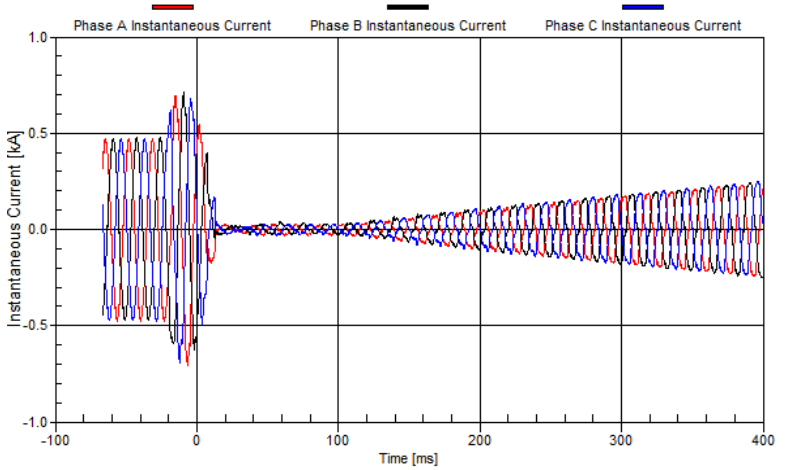
44kV 10MW solar

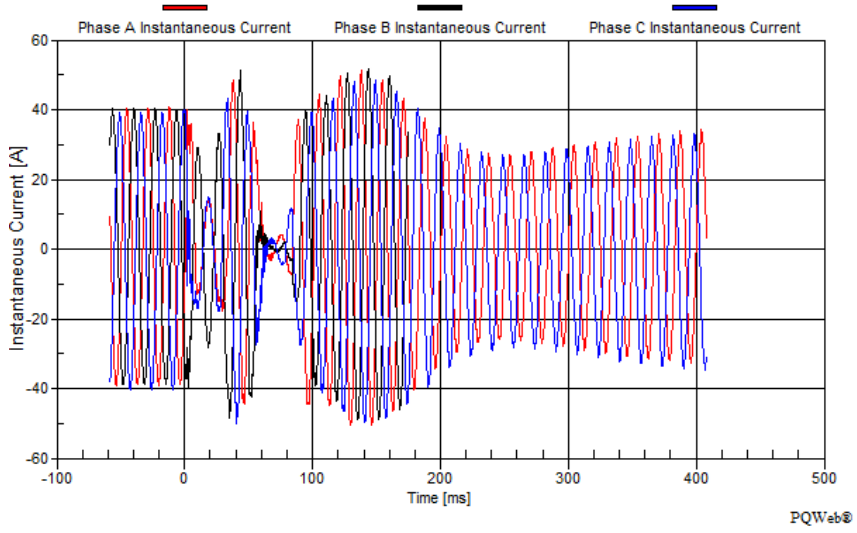




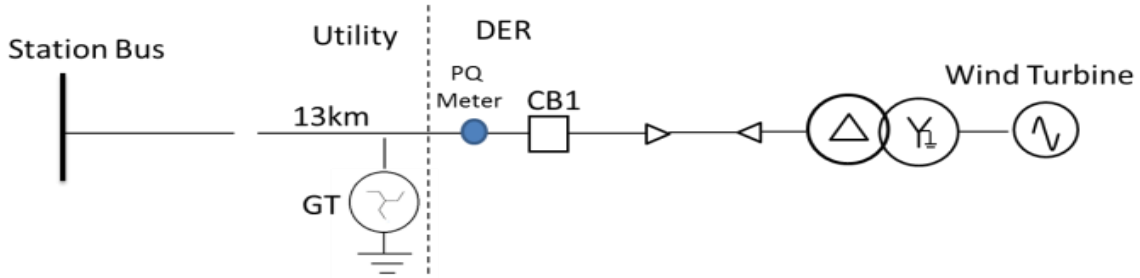
44kV 18MW wind

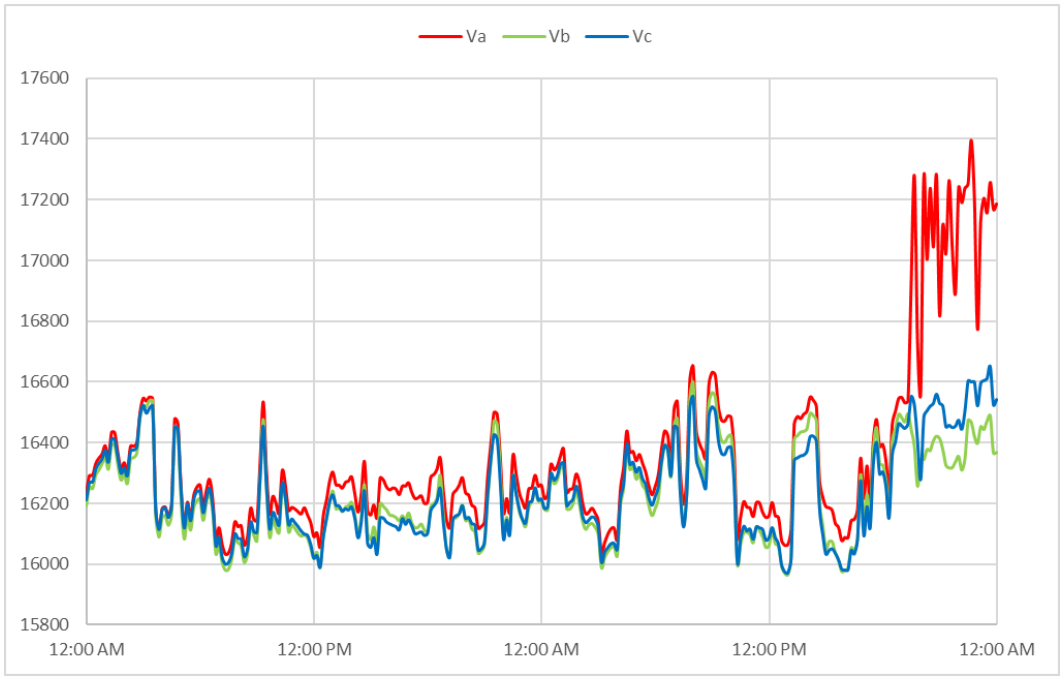
28kV 10MW wind

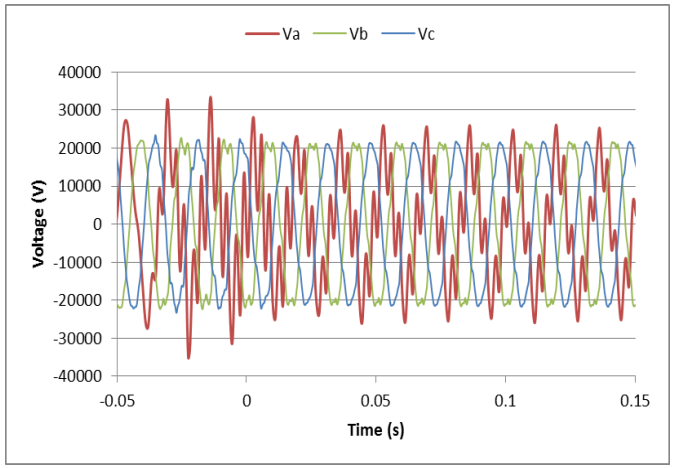


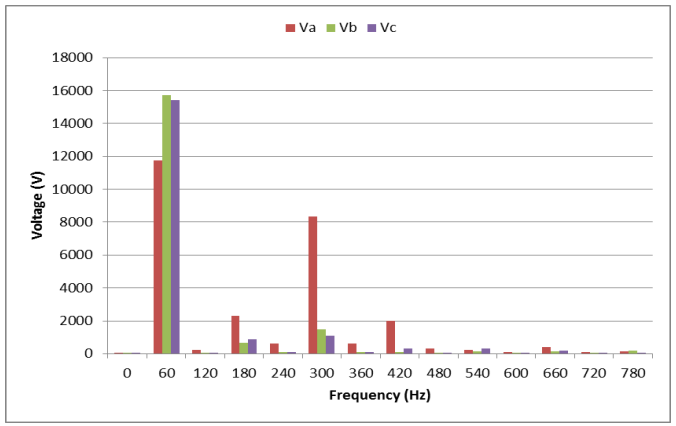


where waveforms are necessary



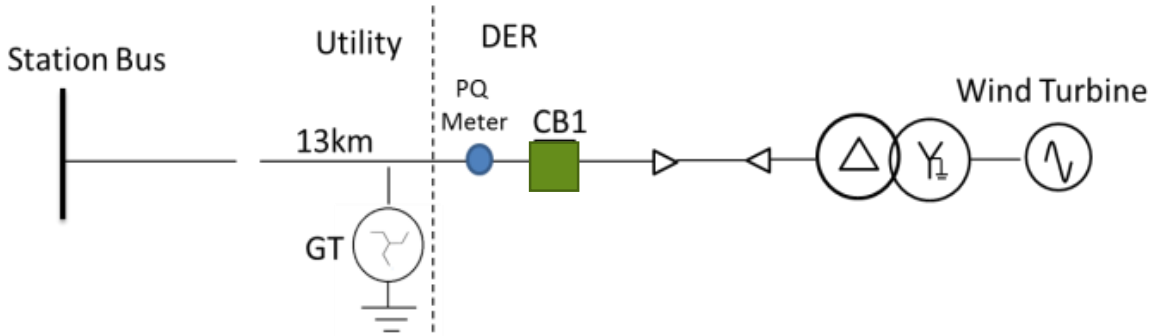


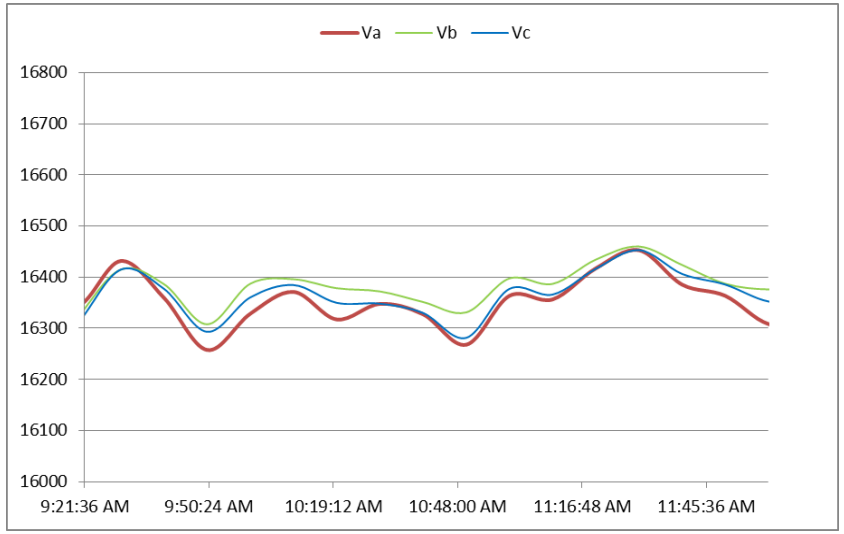


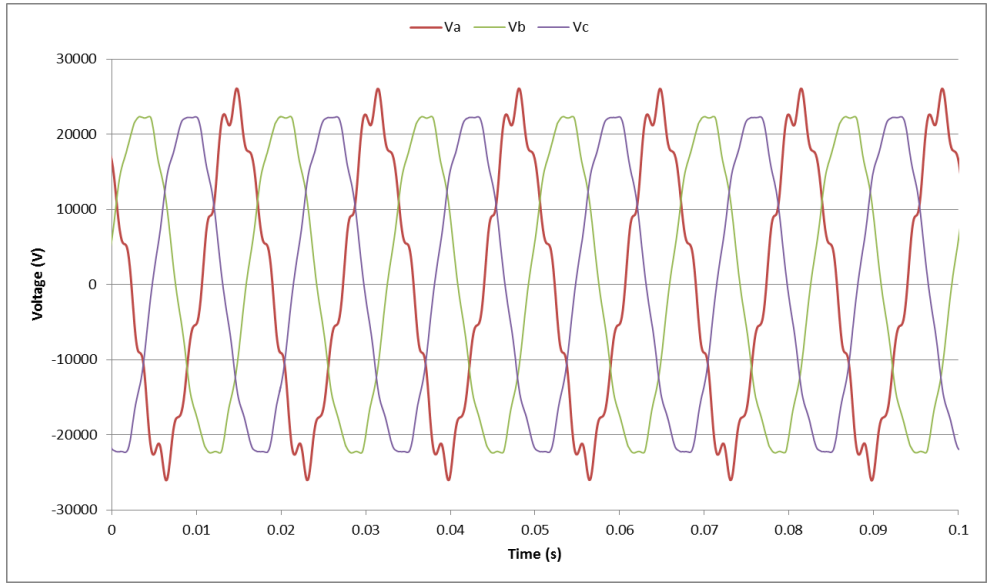


Voltage trend, waveforms and spectra under wind farm repetitive attempt to startup

where waveforms are necessary

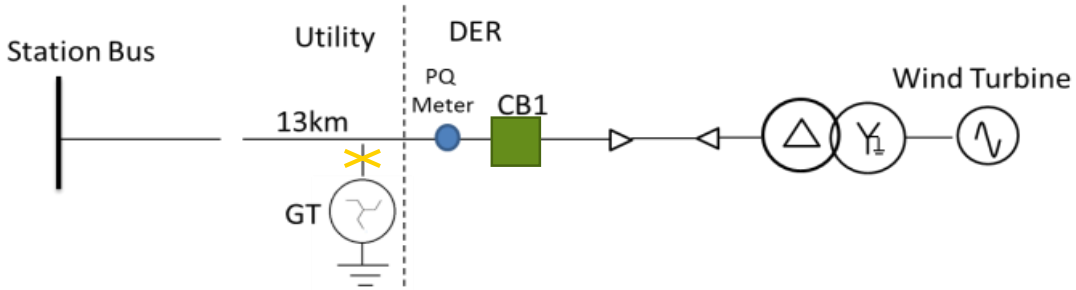


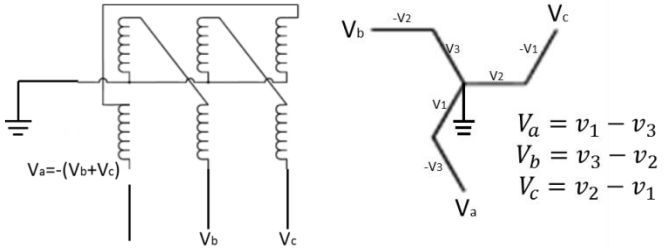


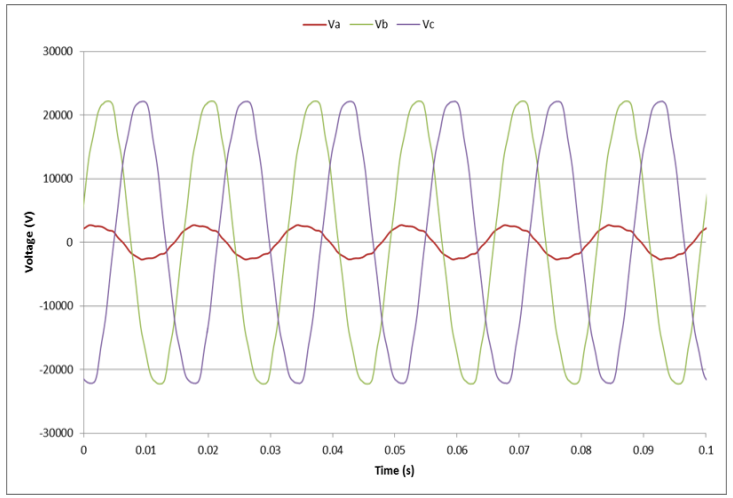


Voltage waveforms, spectra and rms trend with WF isolated

where waveforms are necessary



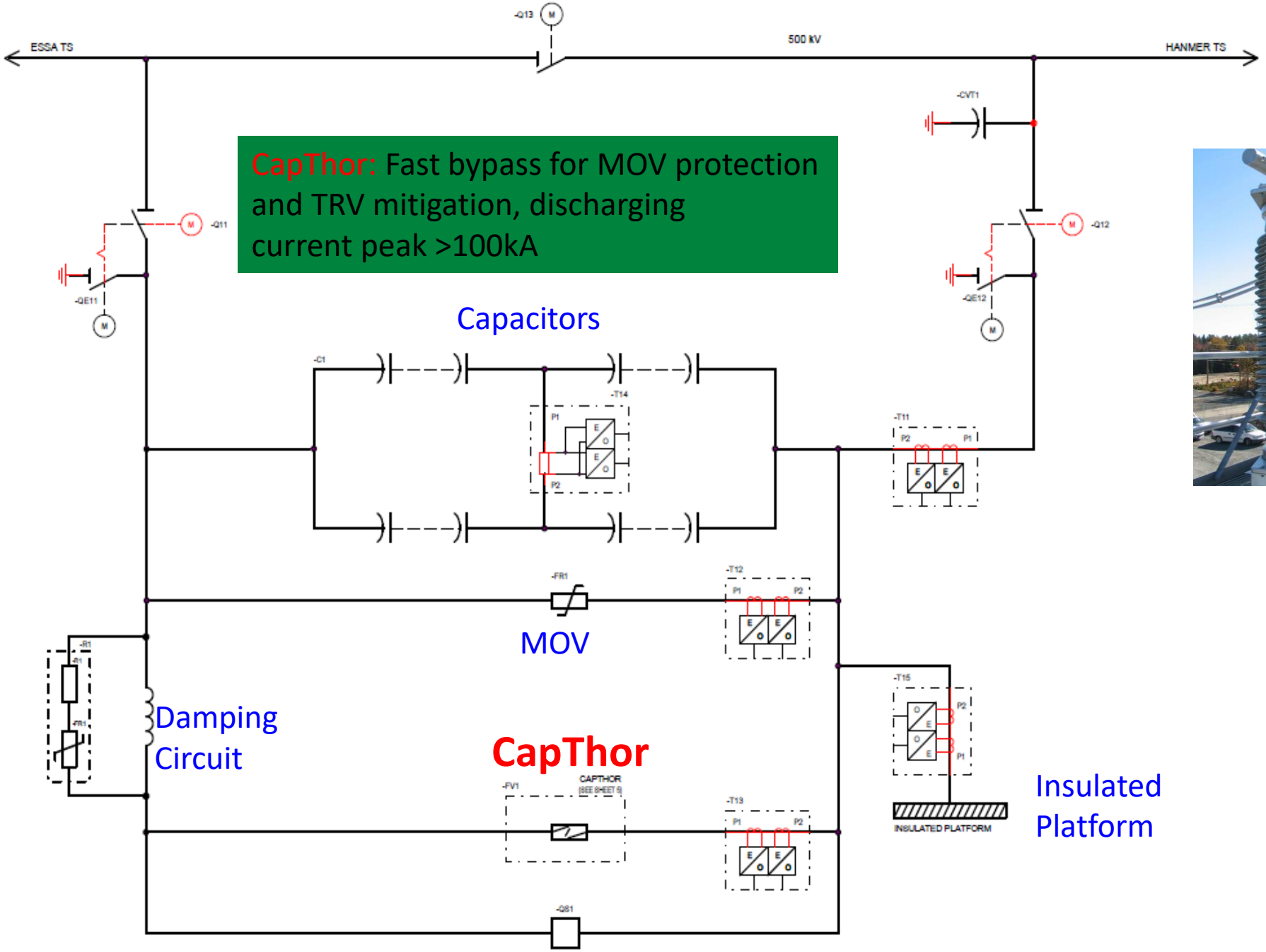


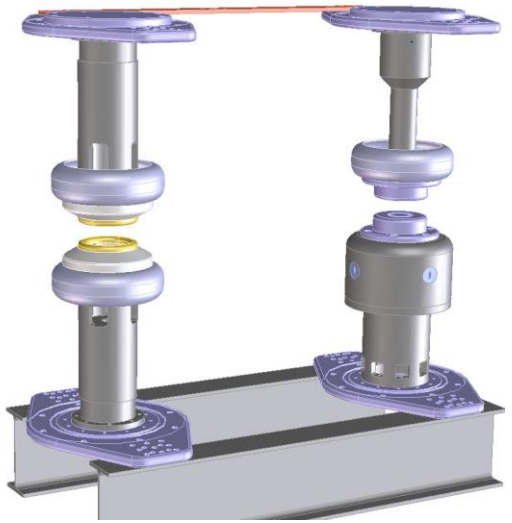


Voltage waveforms after GT isolated indicating loss of phase A

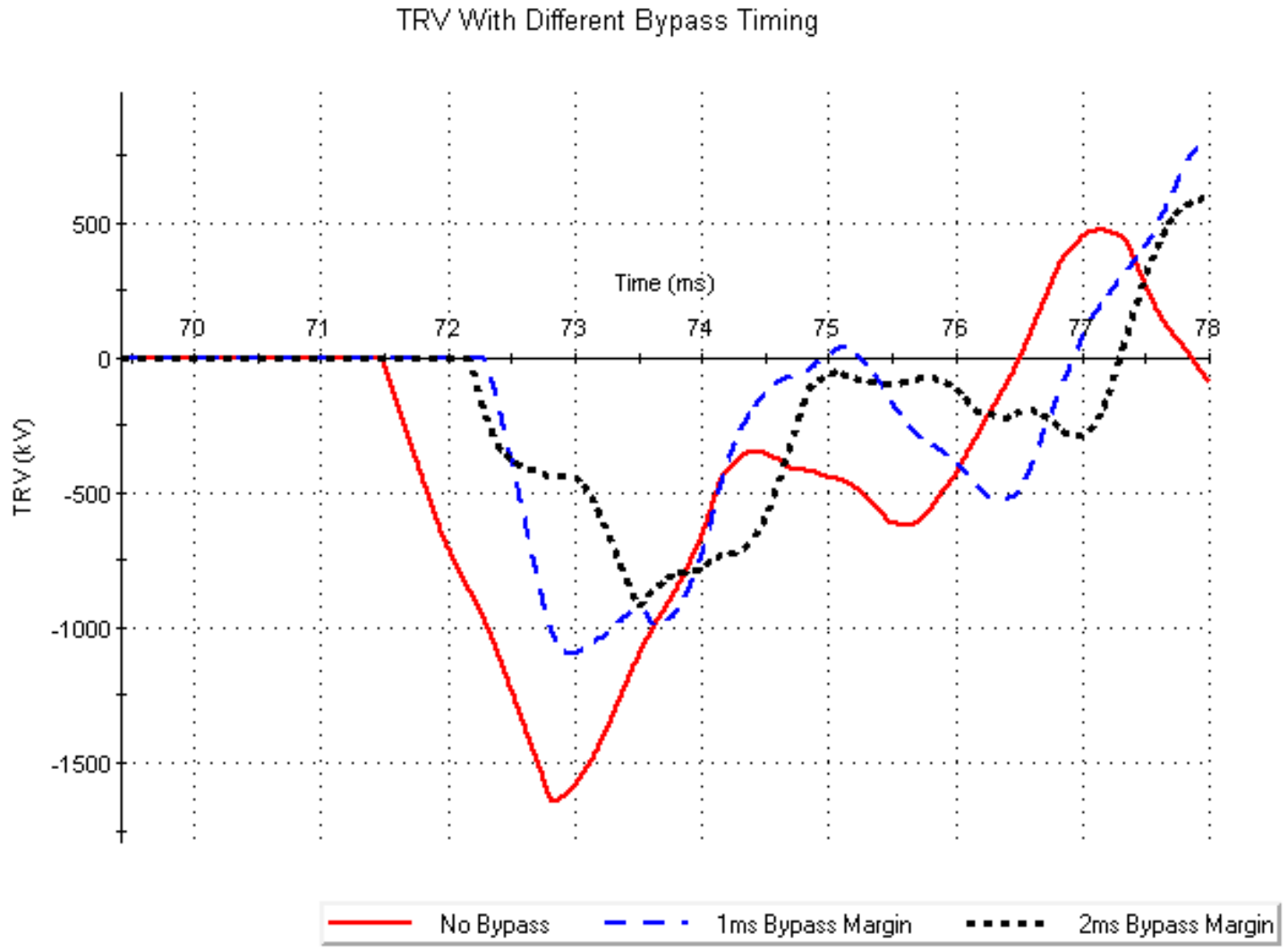
Example when Synchro-Waveforms are necessary – Series Capacitor Bypass Control Validation

CapThor: Fast bypass for MOV protection and TRV mitigation, discharging current peak >100kA

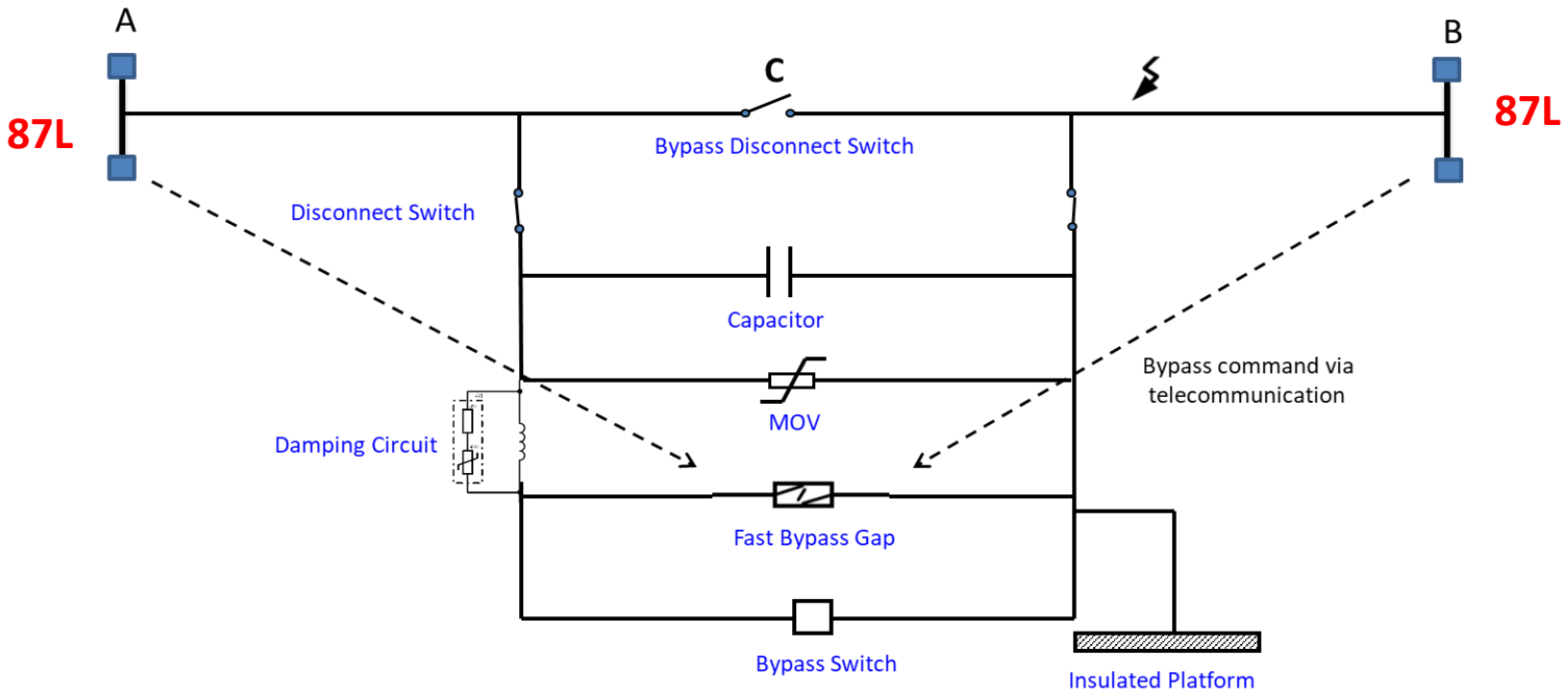




TRV----Fast bypassing is required



Telecom based transfer-bypassing---three terminal timing coordination

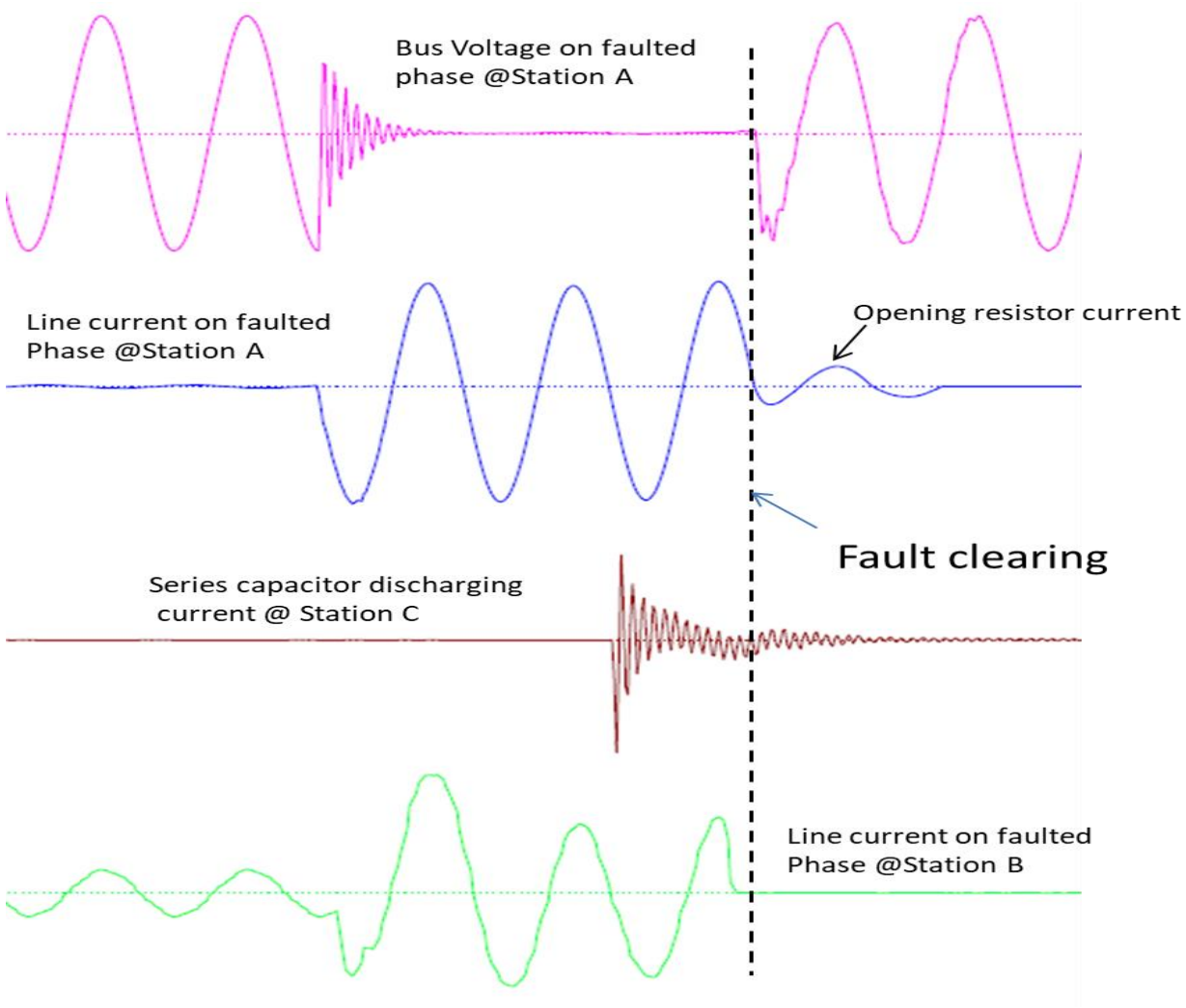


Racing: telecom delay + CapThor operation time →this must win

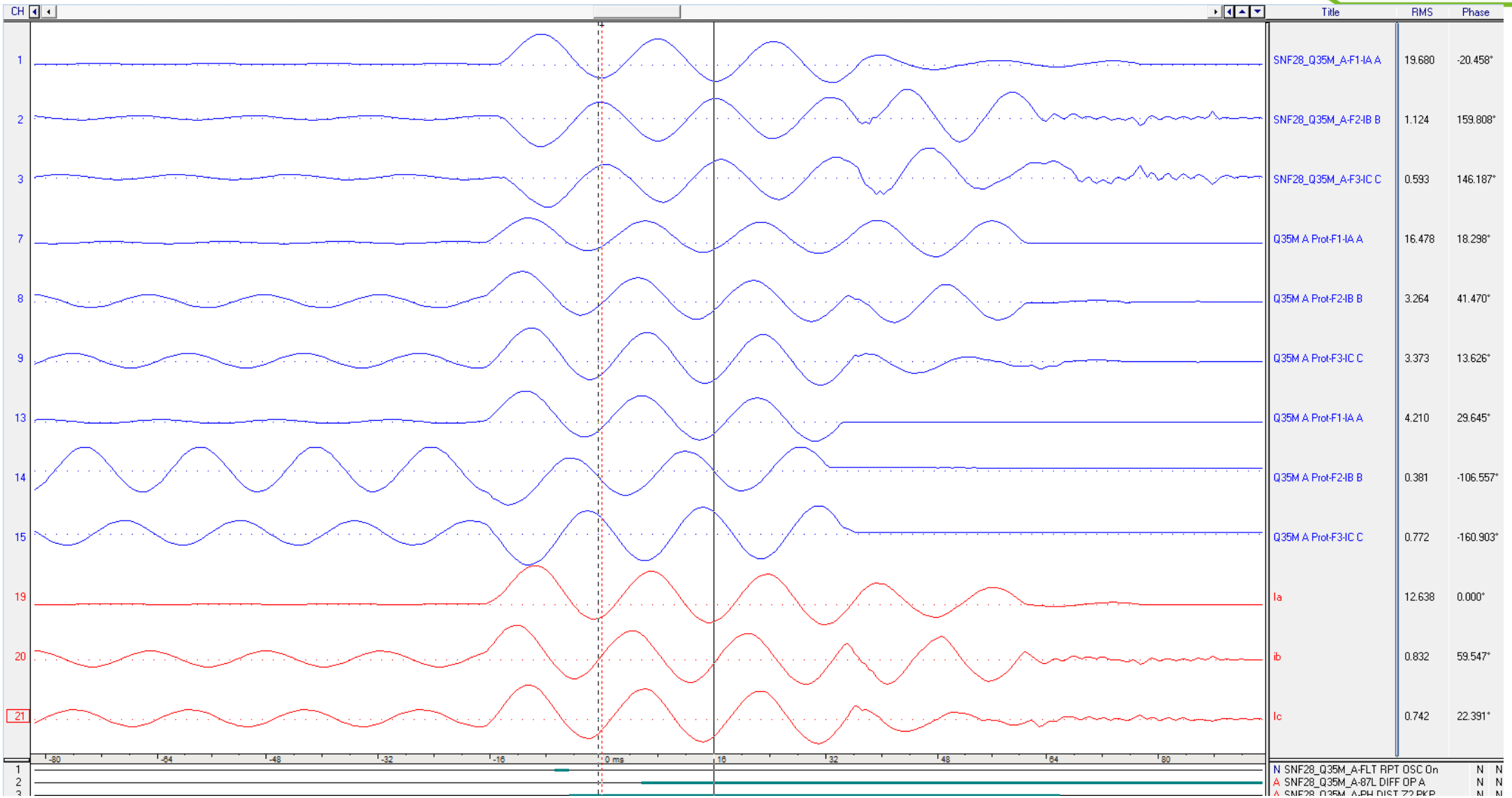
vs.

terminal breaker interruption time,

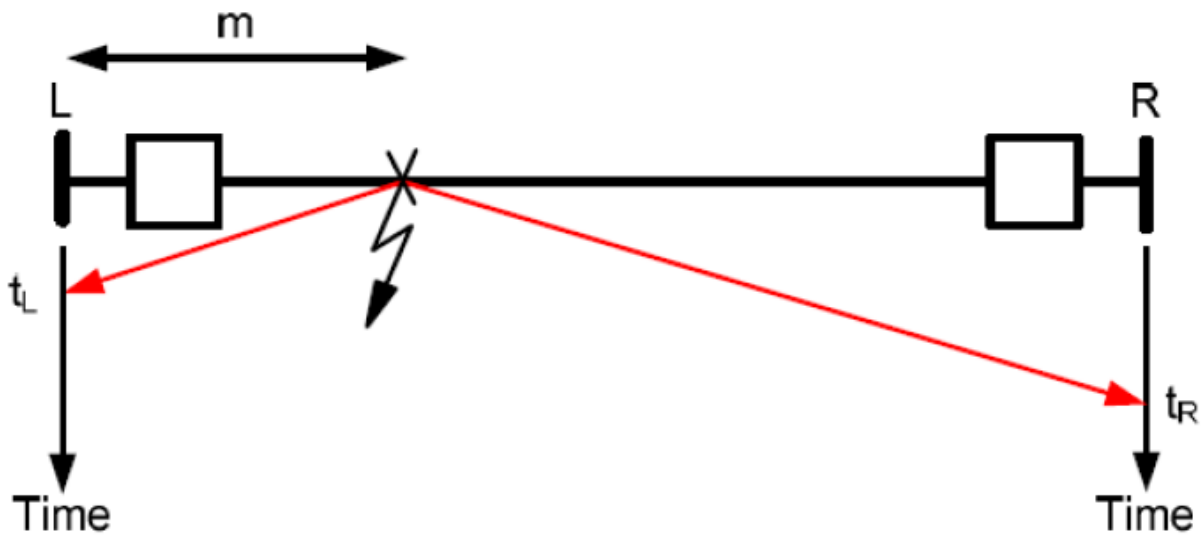
Naturally Occurred Fault Result



Synchro-waveforms: 3-terminal line differential



Synchro-waveforms: Travel Wave based fault location



$$m = \frac{L}{2} \cdot \left(1 + \frac{t_L - t_R}{TWPT}\right)$$

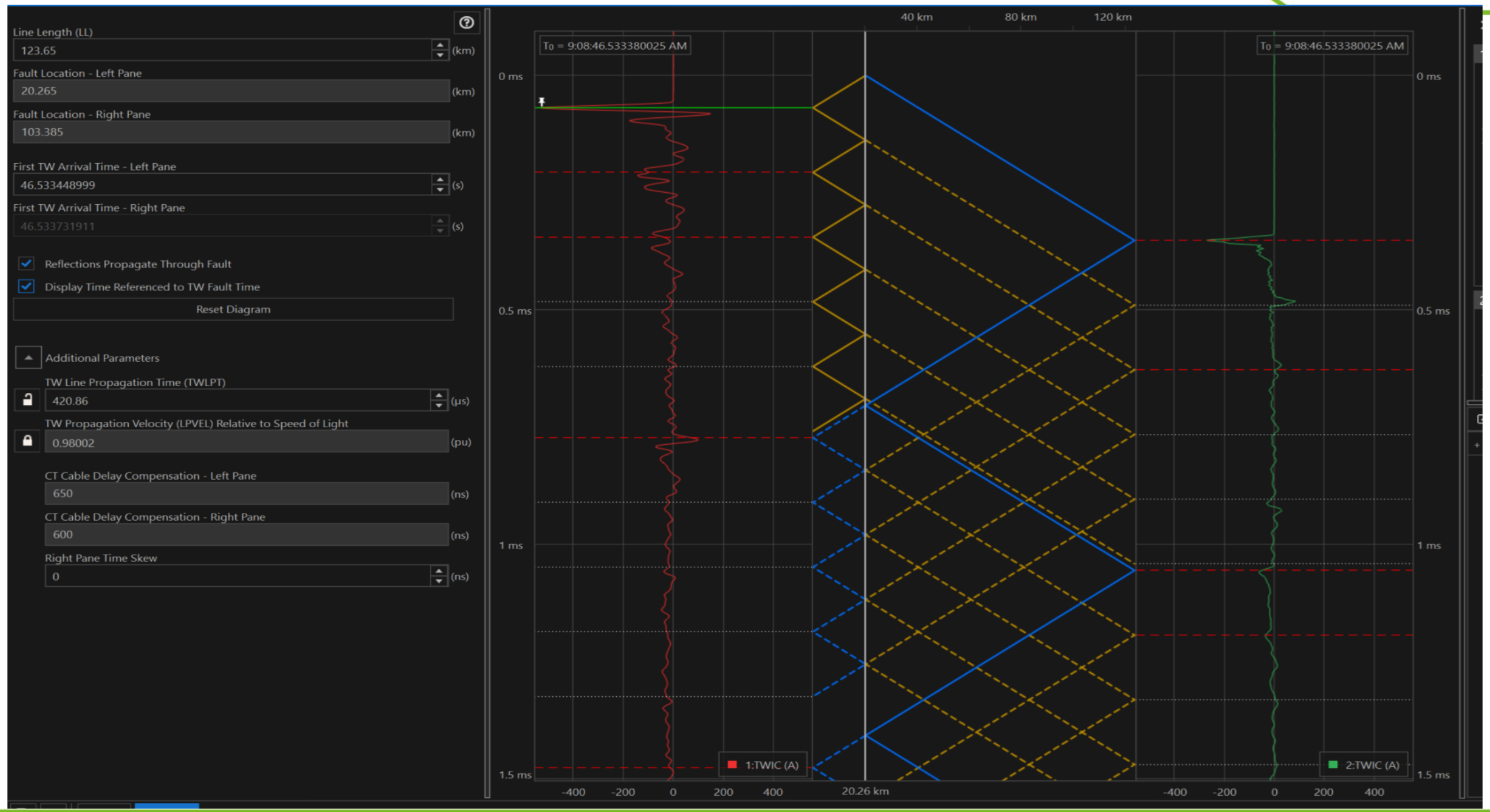
L is the line length

tL is the TW arrival time at L side

tR is the TW arrival time at R side

TWPT is the travelling wave propagation time – the time it takes for the wave to run the entire line

Synchro-waveforms: SEL Travel Wave based fault location



Discussions

1. Hydro One's new standard designs use 1588 PTP for station relay or DFR. New switches support 1588.
2. Time stamping for offline analysis is still the major application, but we are exploring opportunities to exploit the potential from synchro-waveforms.
3. The travel wave based fault location can be used for online line condition monitoring (precursor)

Thank you