Synchro-waveforms: Application opportunities in electric power transmission systems

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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
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

TRV With Different Bypass Timing

- No Bypass
- 1ms Bypass Margin
- 2ms Bypass Margin
Telecom based transfer-bypassing---three terminal timing coordination

Racing: telecom delay + CapThor operation time $\rightarrow$ this must win vs. terminal breaker interruption time,
Naturally Occurred Fault Result

- Bus Voltage on faulted phase @ Station A
- Line current on faulted Phase @ Station A
- Opening resistor current
- Fault clearing
- Series capacitor discharging current @ Station C
- Line current on faulted Phase @ Station B
Synchro-waveforms: 3-terminal line differential
Synchro-waveforms: Travel Wave based fault location

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

- \( L \): line length
- \( t_L \): TW arrival time at L side
- \( t_R \): TW arrival time at R side
- \( TWPT \): 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