Synchro-waveform Measurements from IBR Rich Grids (A Case Study)

NASPI Meeting, October 16, 2024

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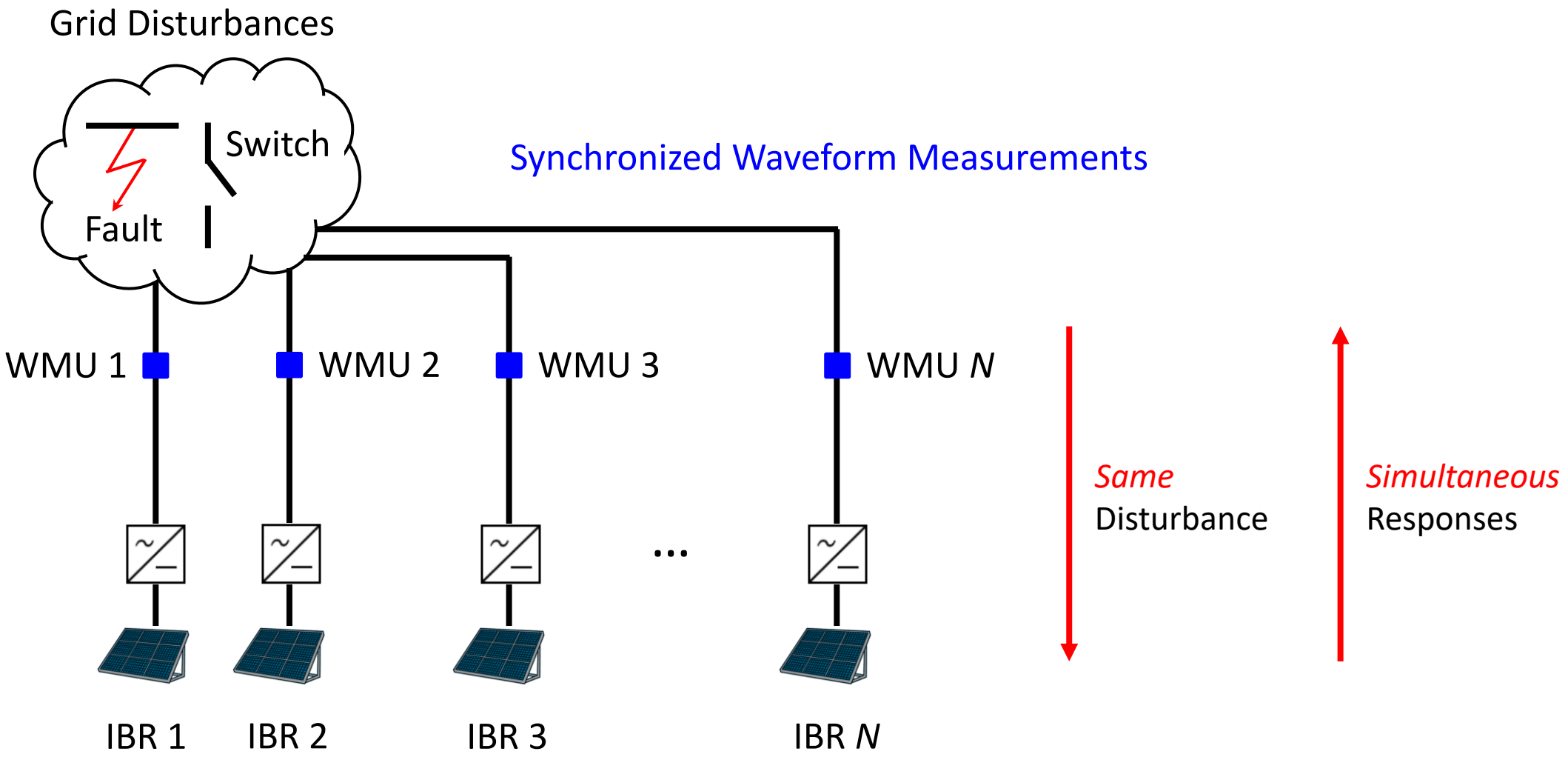
University of California, Riverside

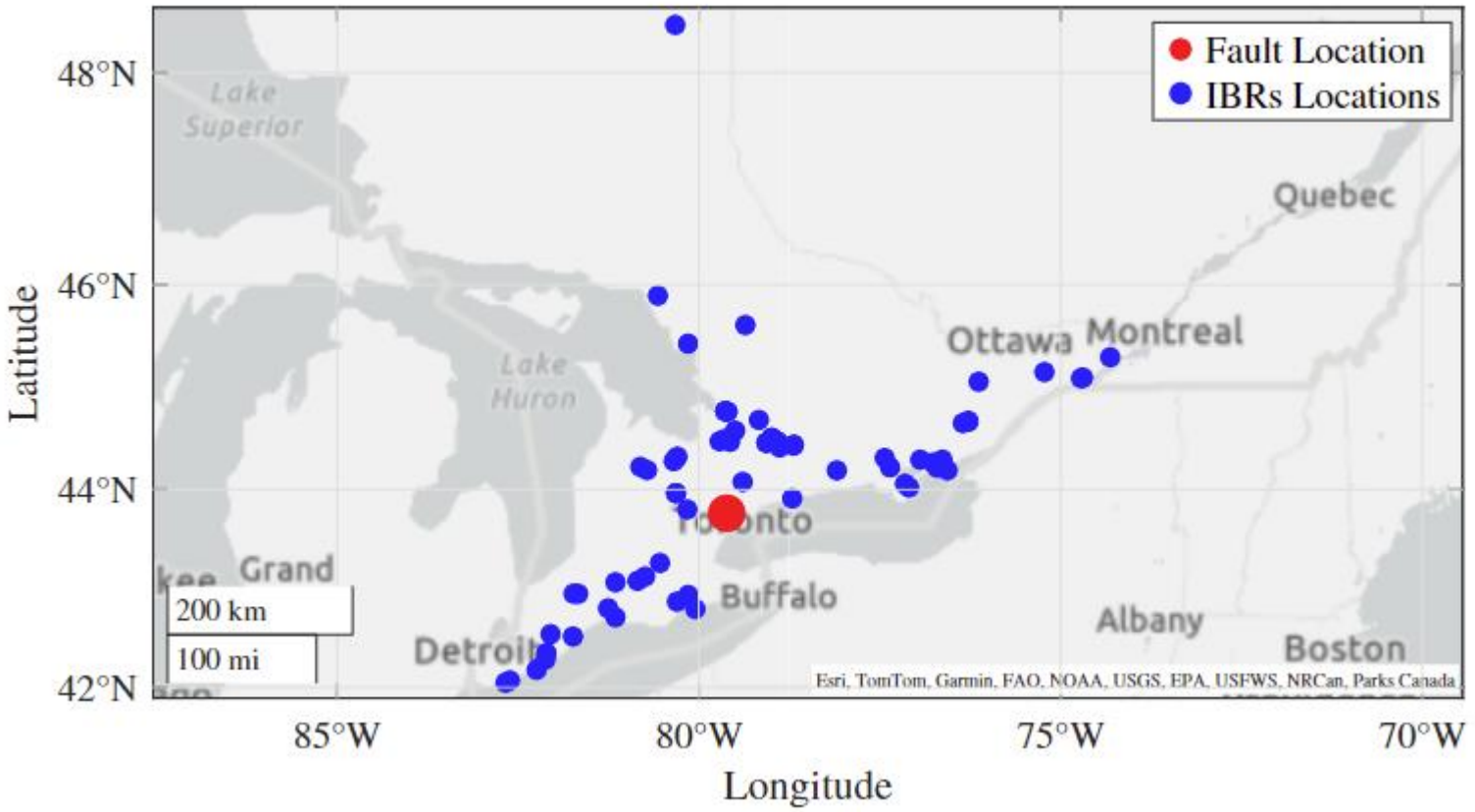
Collaborators: Hossein Mohsenzadeh-Yazdi (UCR) and Chun Li (Hydro One)

Monitoring IBRs with WMUs (Waveform Measurement Units)



Case Study: System-wide Disturbance in an IBR Rich Grid

Ontario, Canada

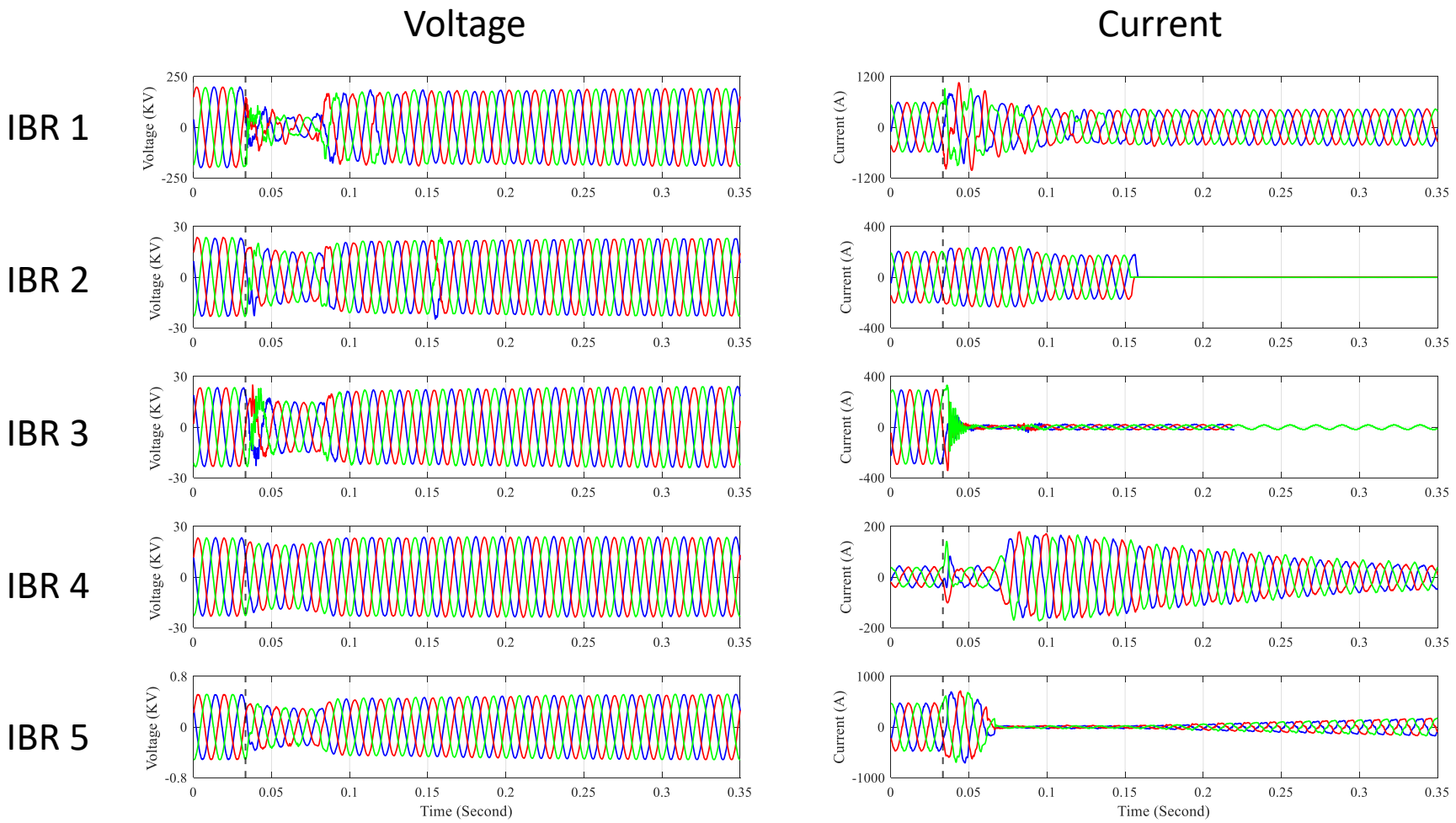


500 kV Fault Causes a System-Wide Disturbance

WMUs at 70 IBRs (Solar and Wind)

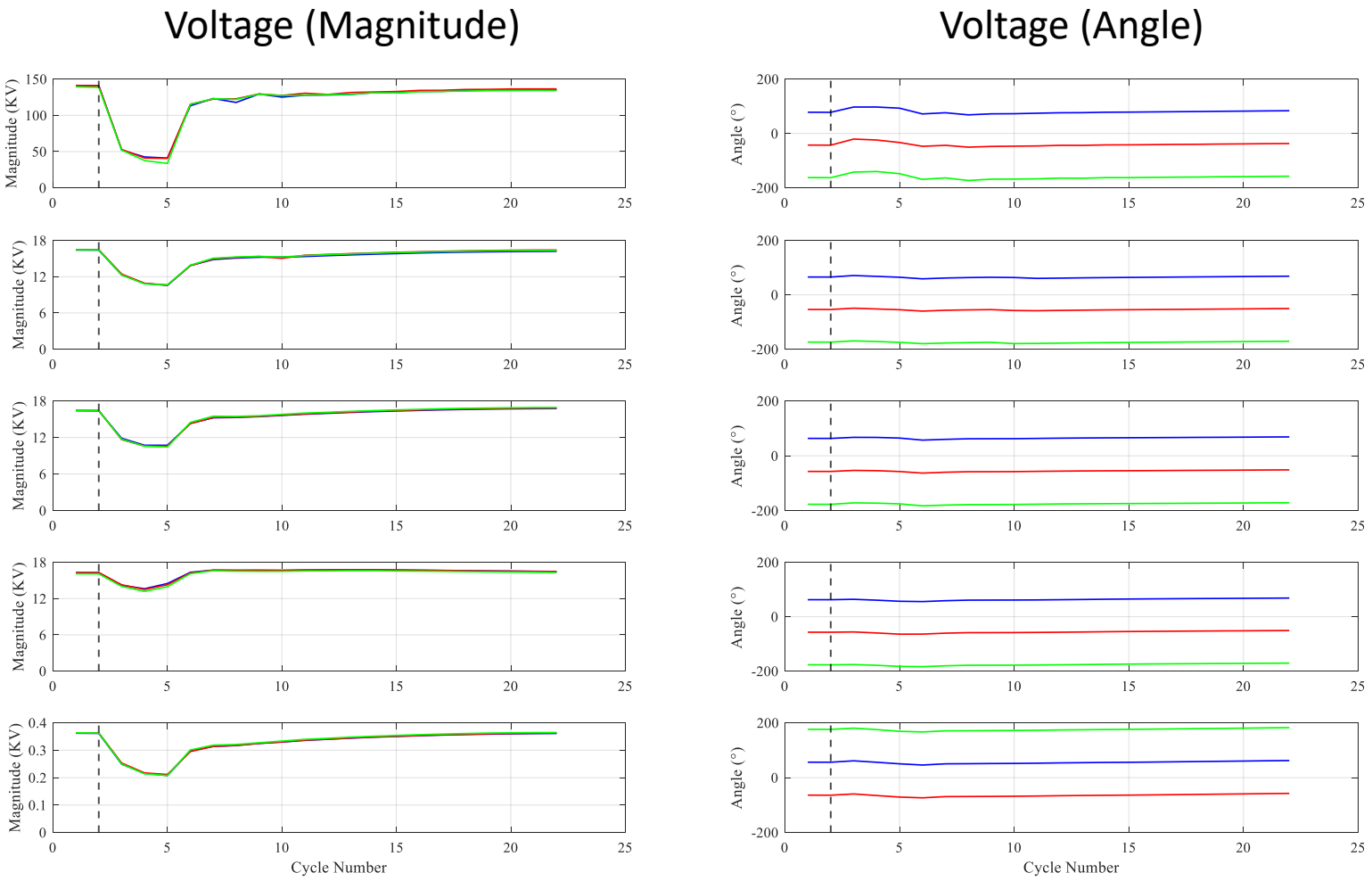
[1] H. M. Yazdi, C. Li, H. Mohsenian-Rad, "IBR Responses During a Real-World System-Wide Disturbance: Synchro-Waveform Data Analysis, Pattern Classification, and Engineering Implications", *under review*.

Synchro-Waveforms vs Synchro-Phasors



Synchro-Waveforms

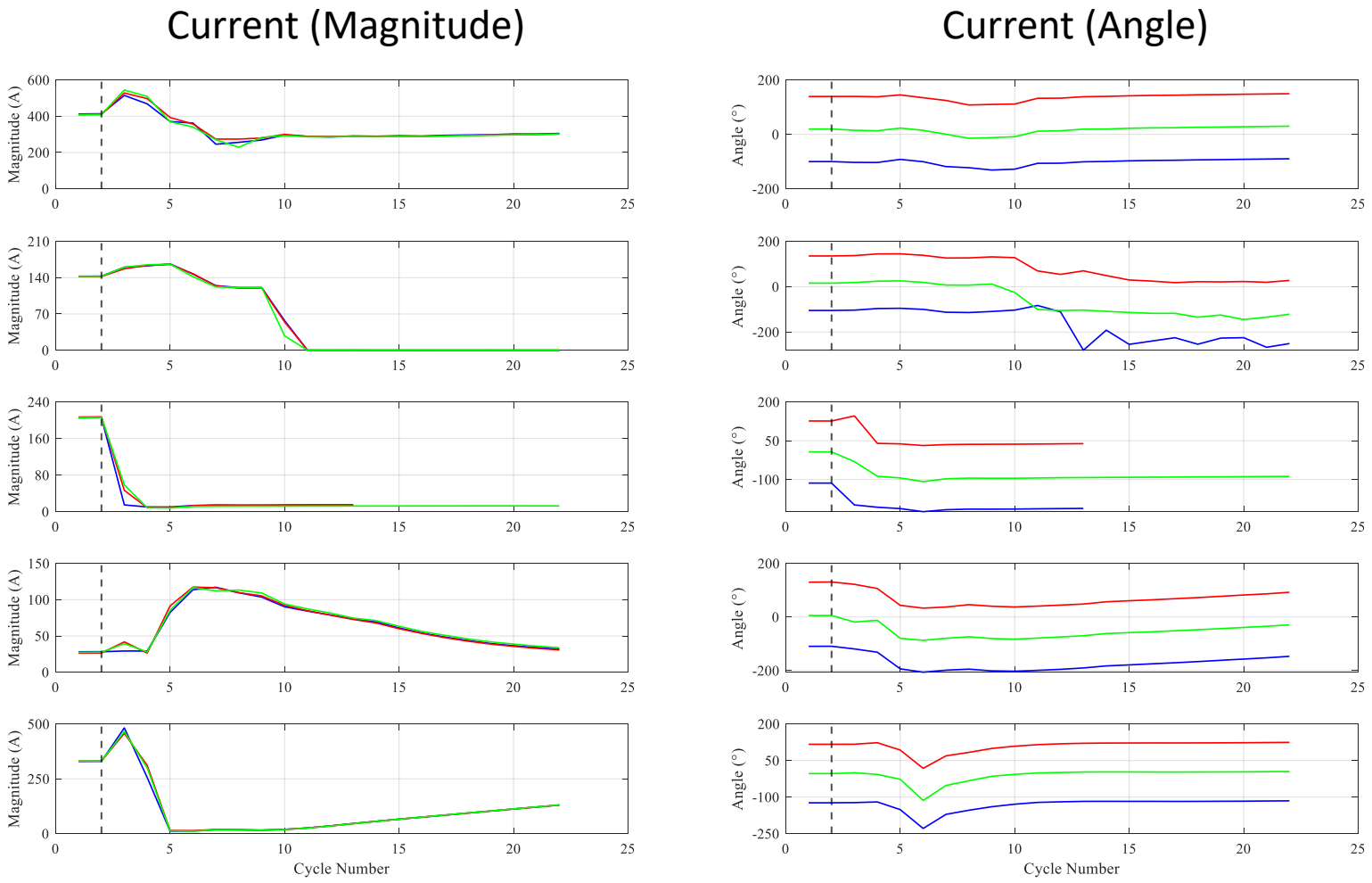
Synchro-Waveforms vs Synchro-Phasors



Synchro-Phasors

(Per-Cycle)

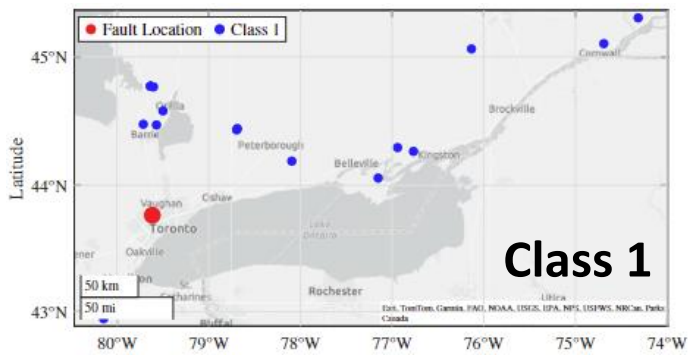
Synchro-Waveforms vs Synchro-Phasors

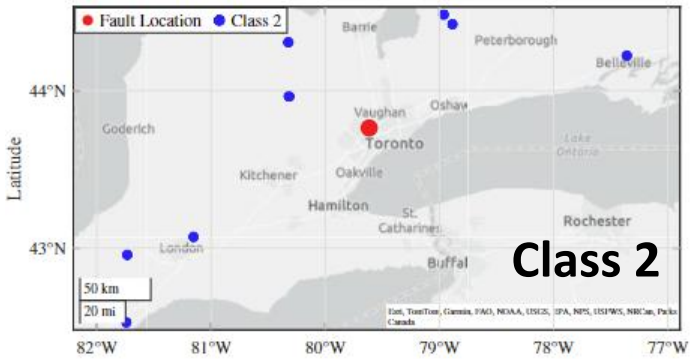


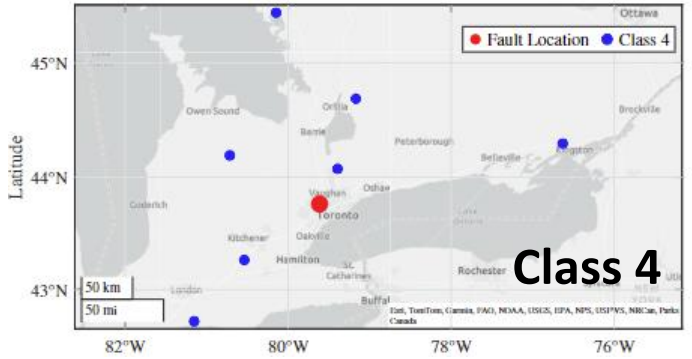
Synchro-Phasors

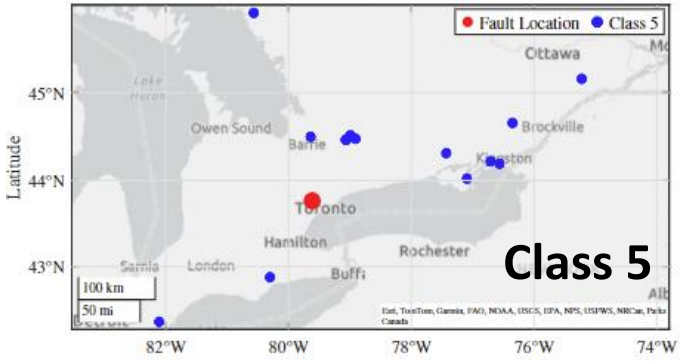
(Per-Cycle)

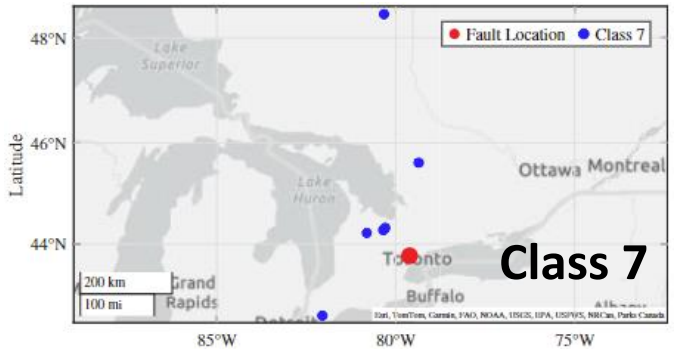
Geographical Patterns











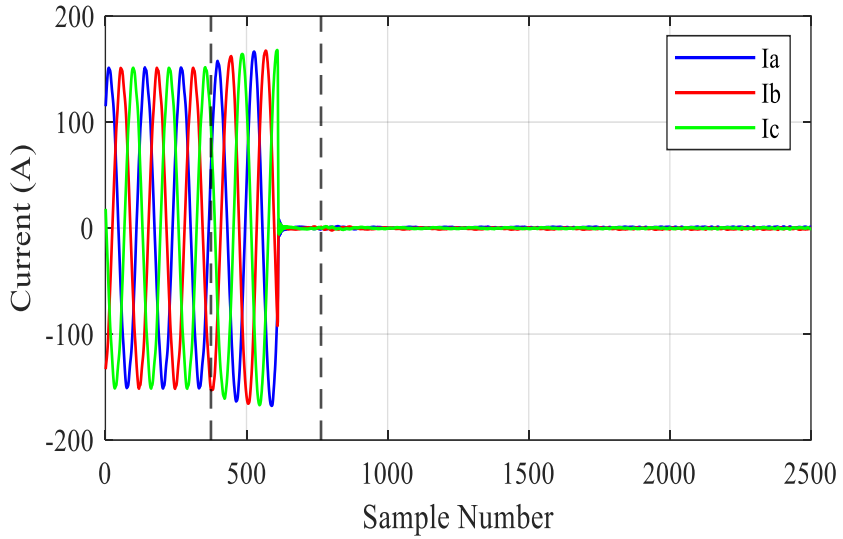
Most Classes are Scatted Across the Region

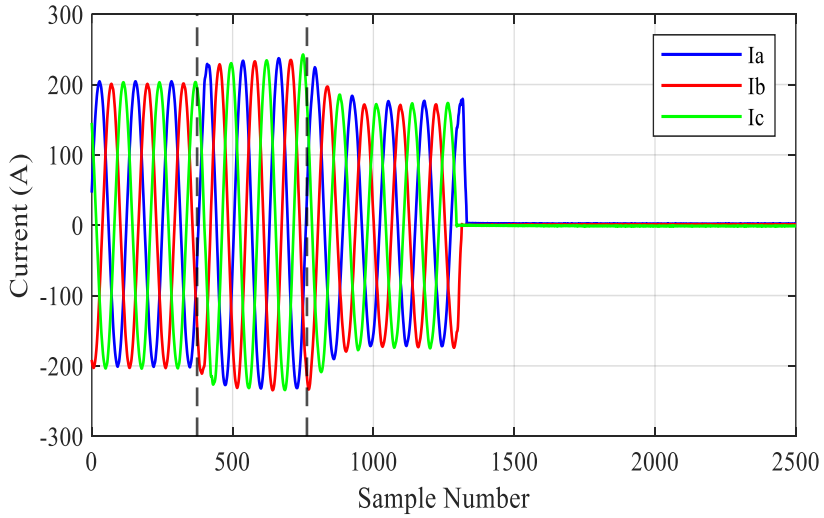
Some Classes have Geographical Patterns

Examples and Further Analysis

Trip *During* Fault vs

Trip After Fault





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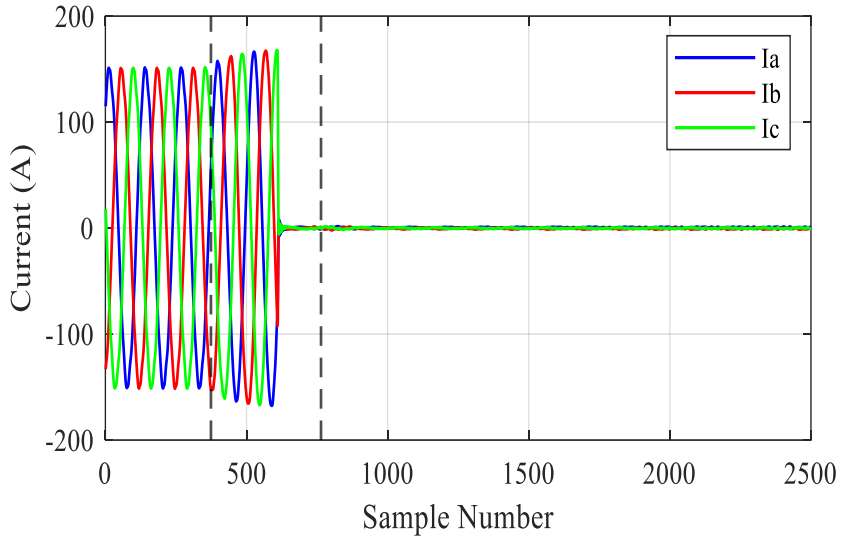
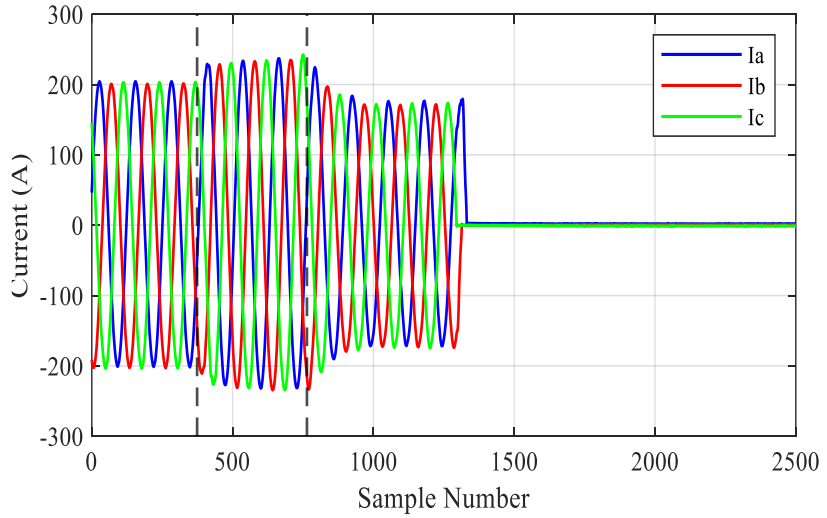
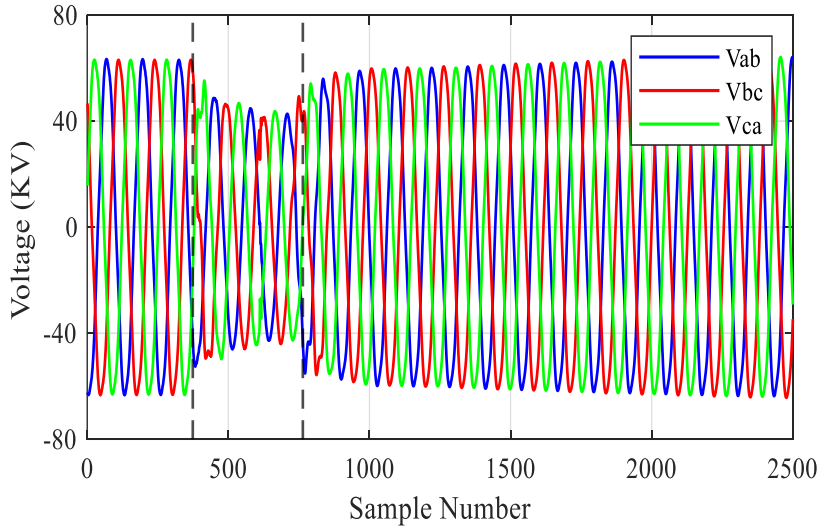
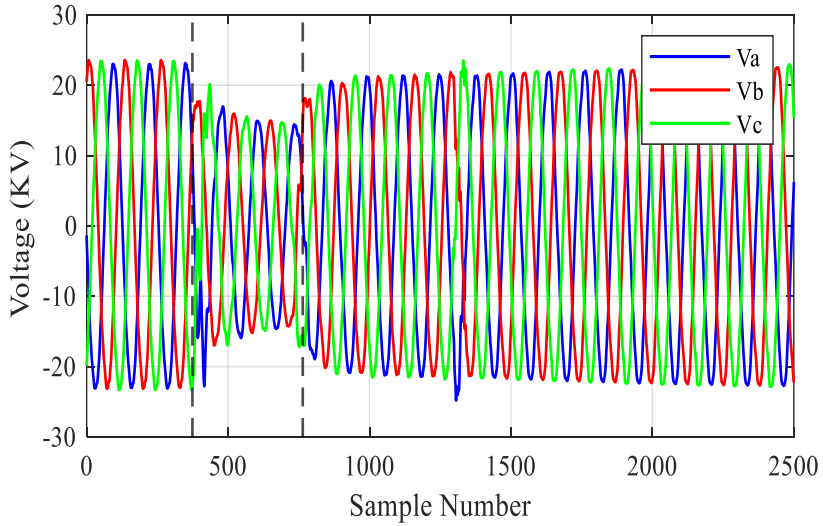




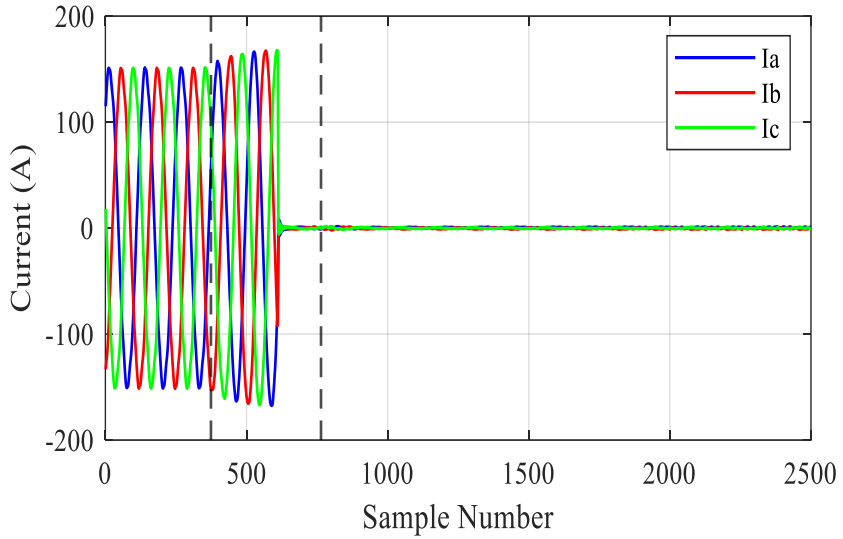


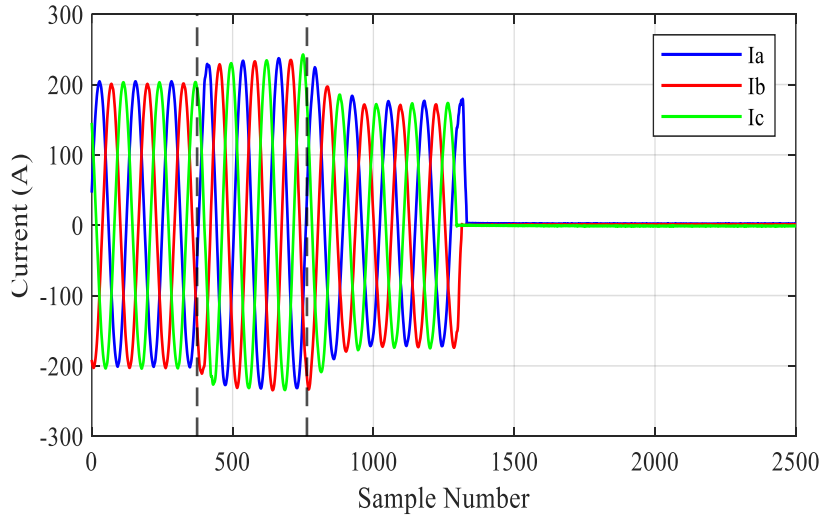


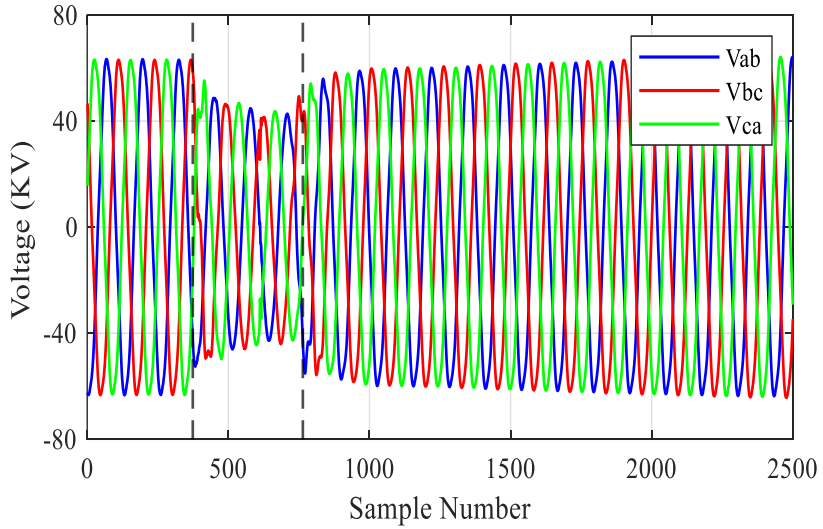
Examples and Further Analysis

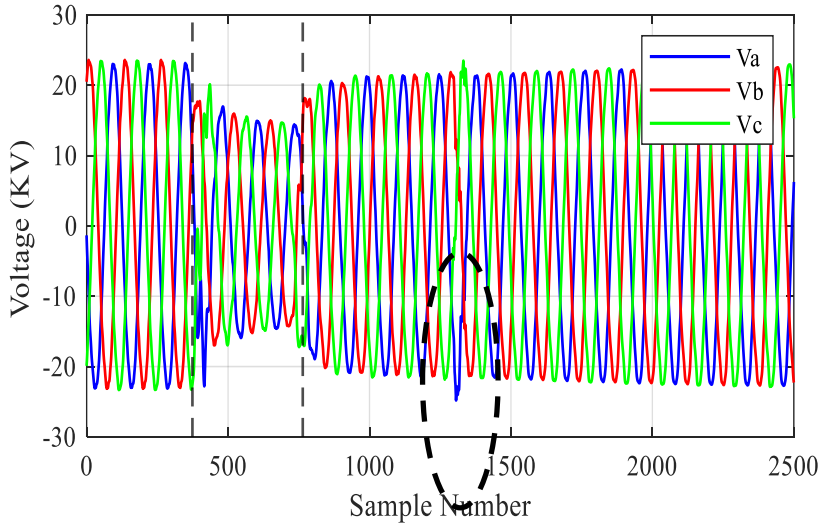
Trip *During* Fault vs

Trip After Fault



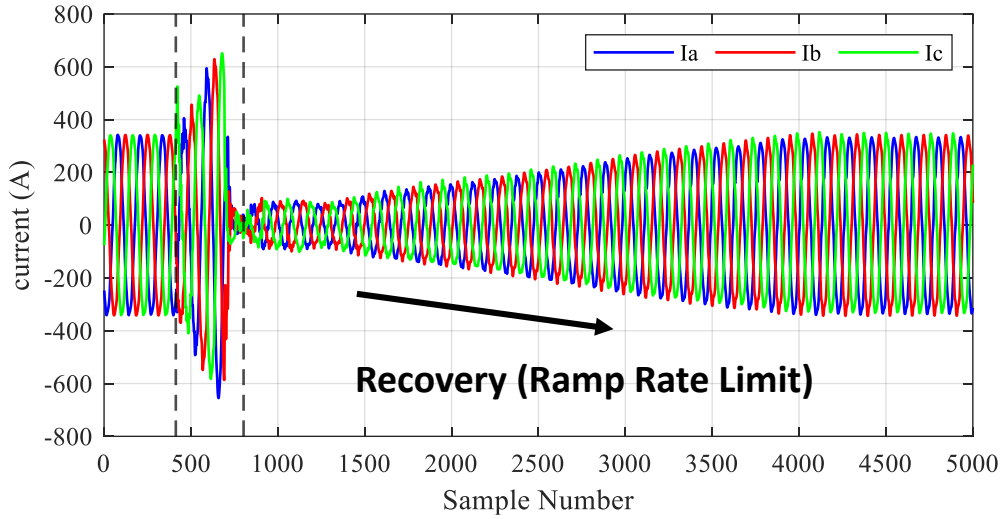


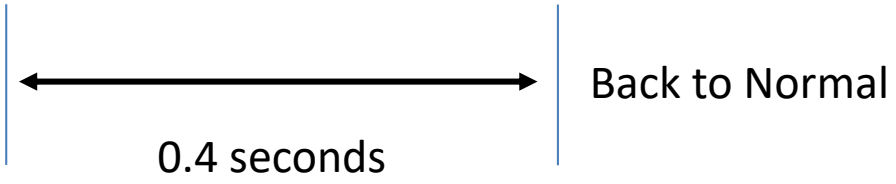




Examples and Further Analysis

Momentary Reduction

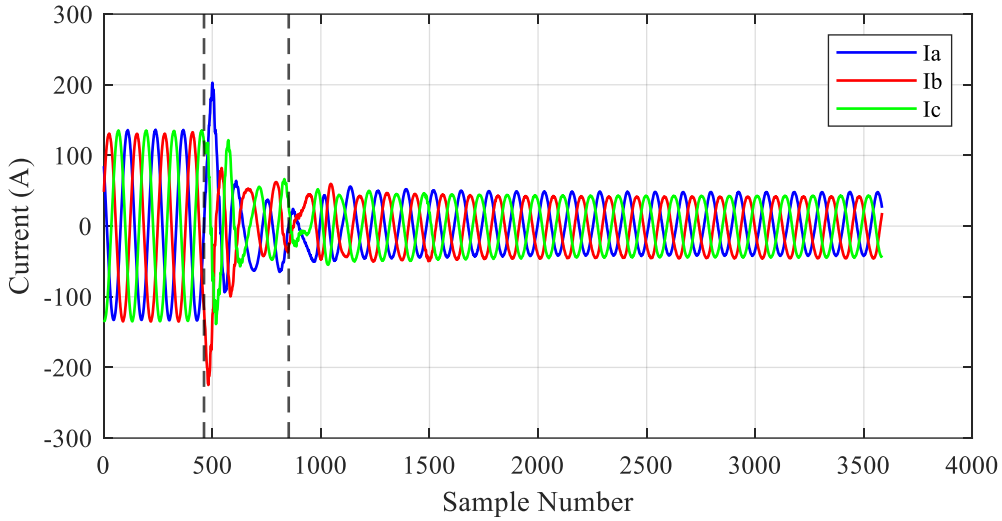




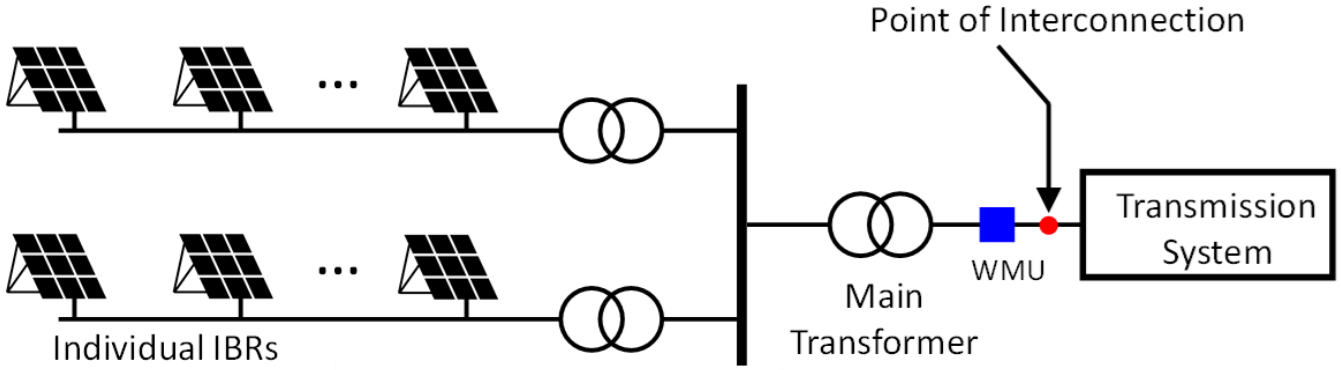
Momentary Cessation + Immediate Recovery + Ramp Rate Limit

Examples and Further Analysis

Sustained Reduction

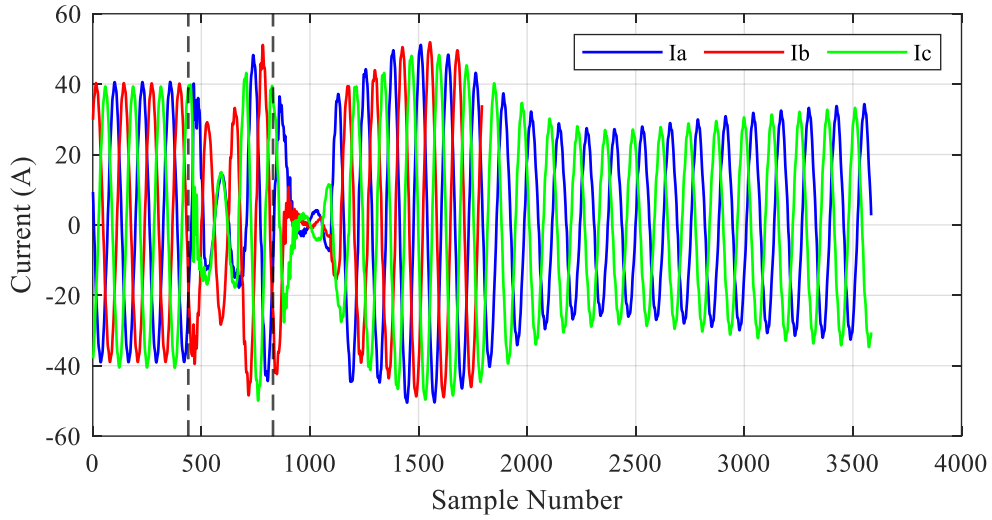


Partial Tripping

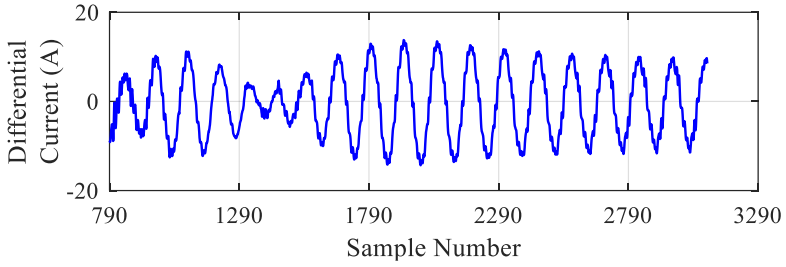


Examples and Further Analysis

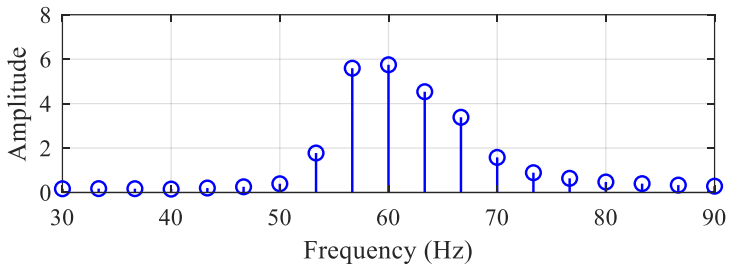
Side Band Oscillations
(Sub-synchronous)



Too Short
Waveform Capture



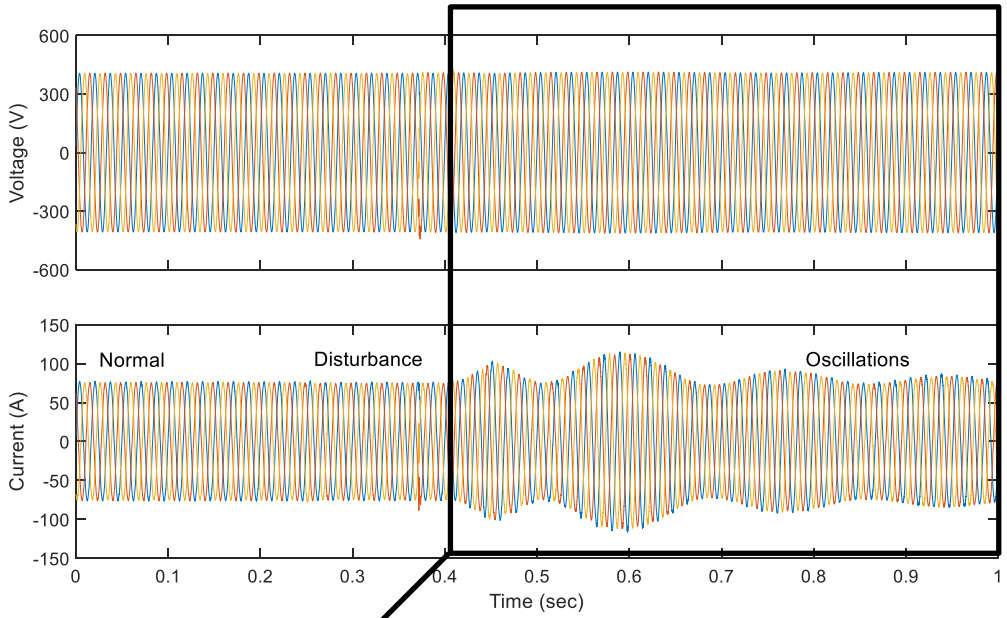
$\Delta i(t)$



$\mathrm{FFT}\{\Delta i(t)\}$

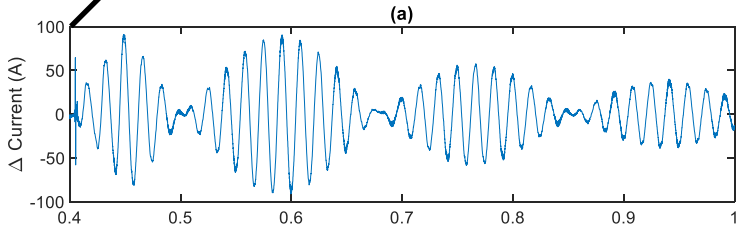
Examples and Further Analysis

Side Band Oscillations
(Sub-synchronous)



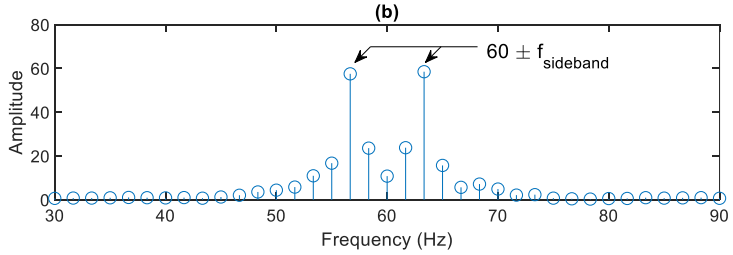
Different Case Study

$\Delta i(t)$



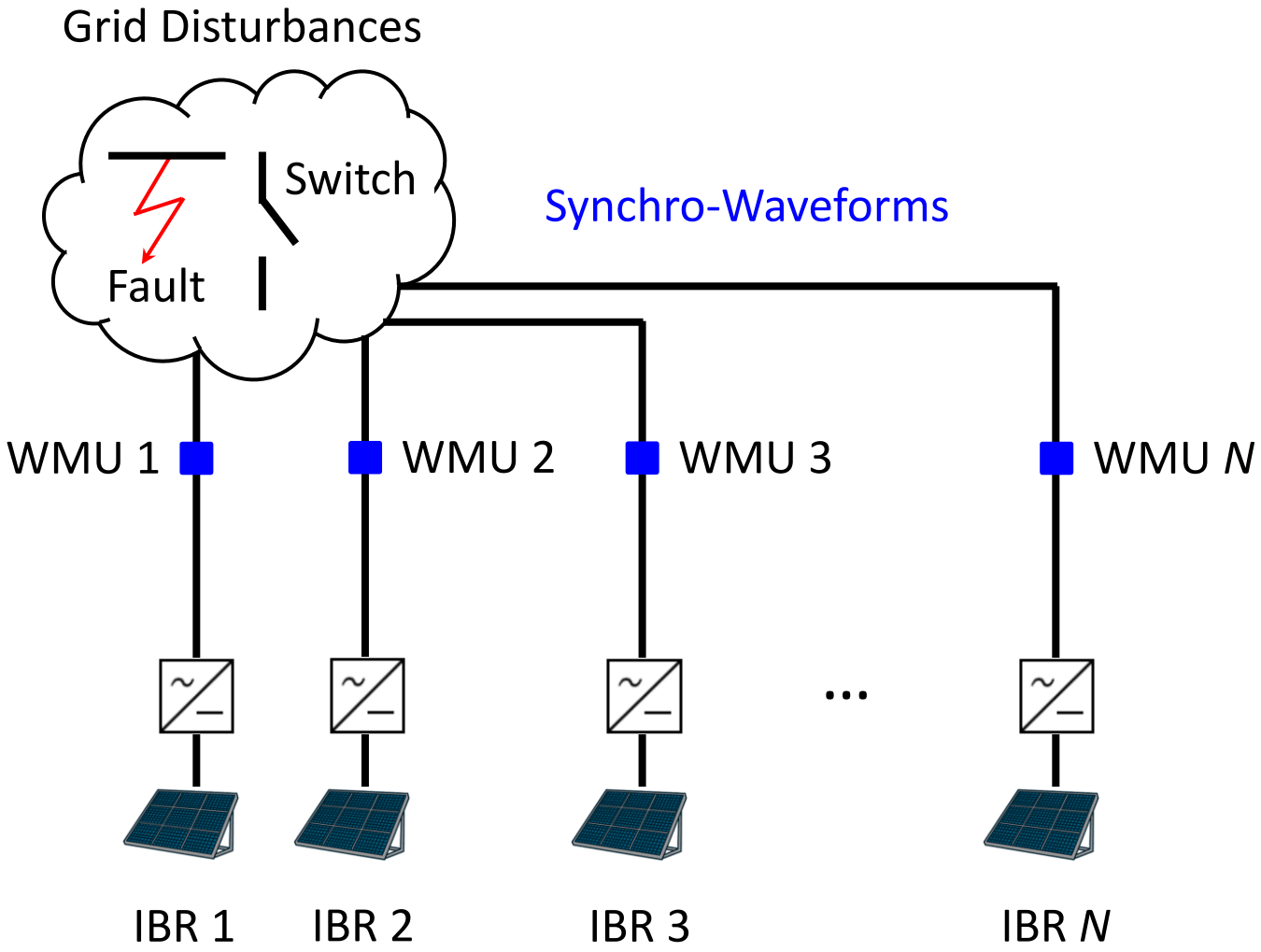
Amplitude Modulation

$\mathrm{FFT}\{\Delta i(t)\}$



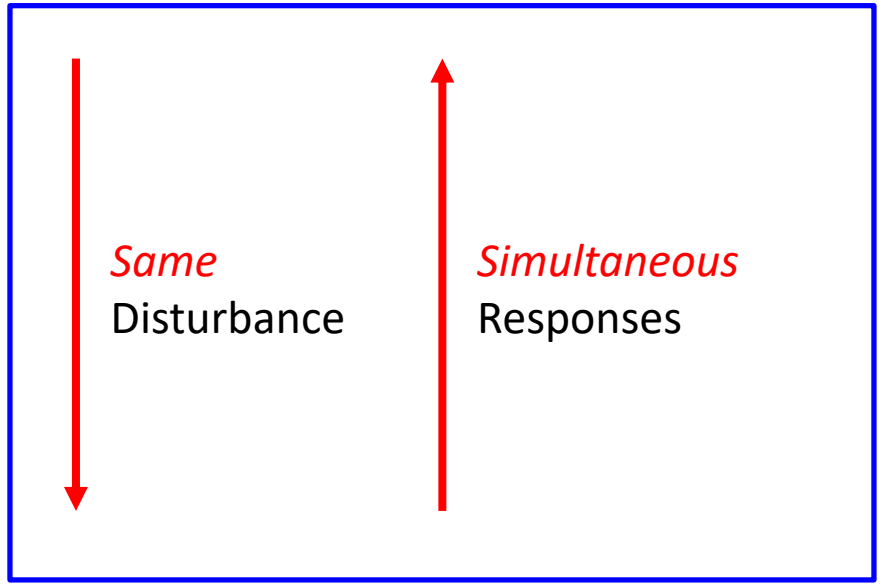
Side Band Oscillations

Synchro-waveform Measurements from IBR Rich Grids

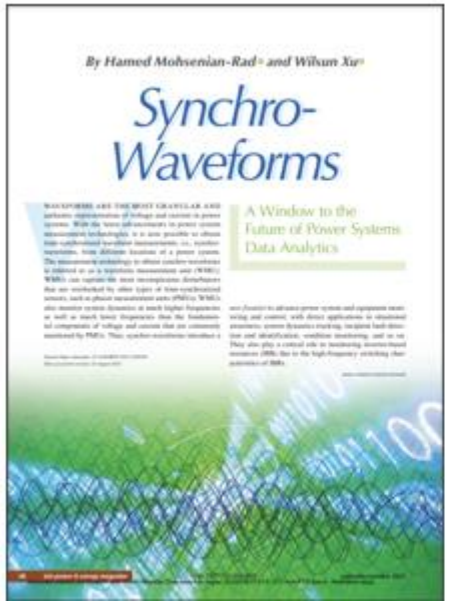


Impact on *System Dynamics and Control*

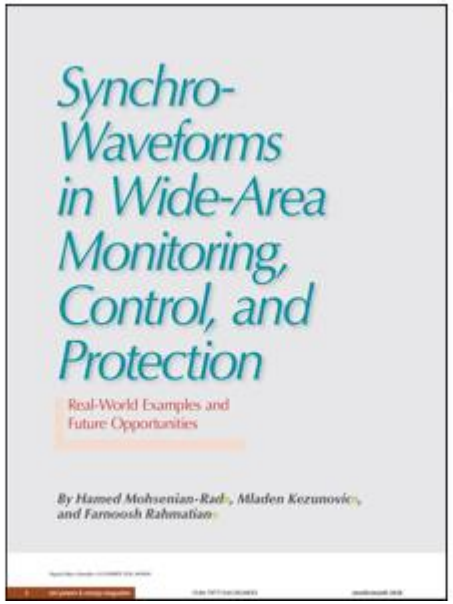
Impact on *Protection System*



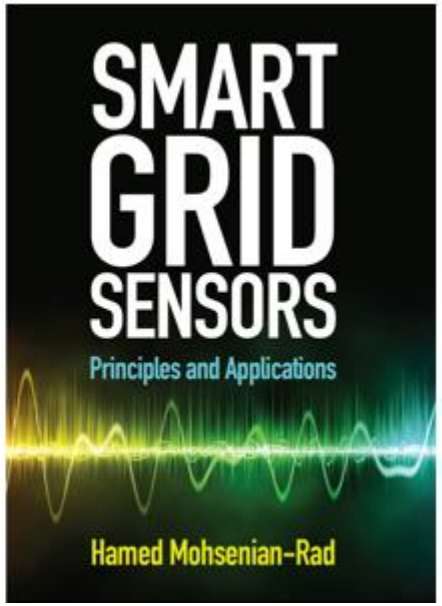
Further Reading: Synchro-Waveforms



IEEE PES Magazine
September 2023

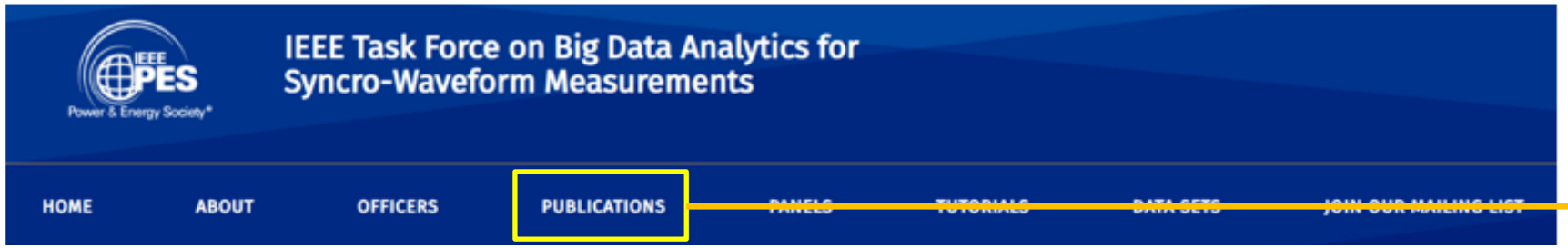


IEEE PES Magazine
November 2024



Cambridge University Press, 2022
(**Chapter 4: Waveform Measurements**)

https://ieee-synchrowaveform.engr.ucr.edu/



37 papers and industry reports

Thank You!

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