

# Low Inertia and Abnormal ROCOF Detection Using Phasor Measurements

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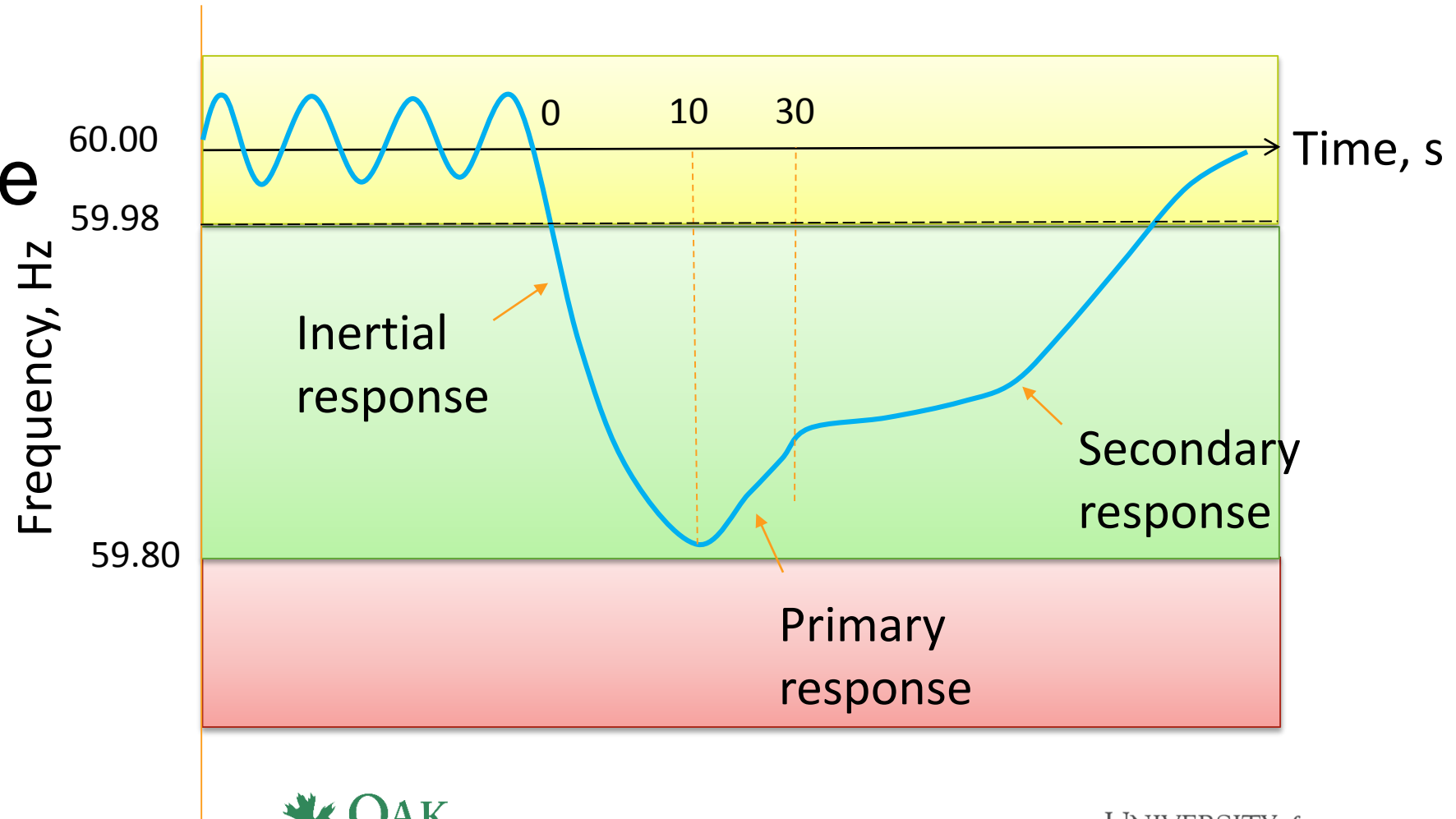
# Rate of Change of Frequency (ROCOF) Applications

- NERC Essential Reliability Services (ERS) effort to track grid inertial performance year over year
- NERC Reliability Issues Steering Committee (RISC) report
  - Profile # 6: Loss or lack of situational awareness
  - High raw ROCOF indicates either very large resource loss and/or lower Interconnection inertia
  - One cornerstone of an Interconnection-wide situational awareness toolset enabled through phasors
- High raw ROCOF events are NERC Standard MOD-027-1 generator modeling opportunities

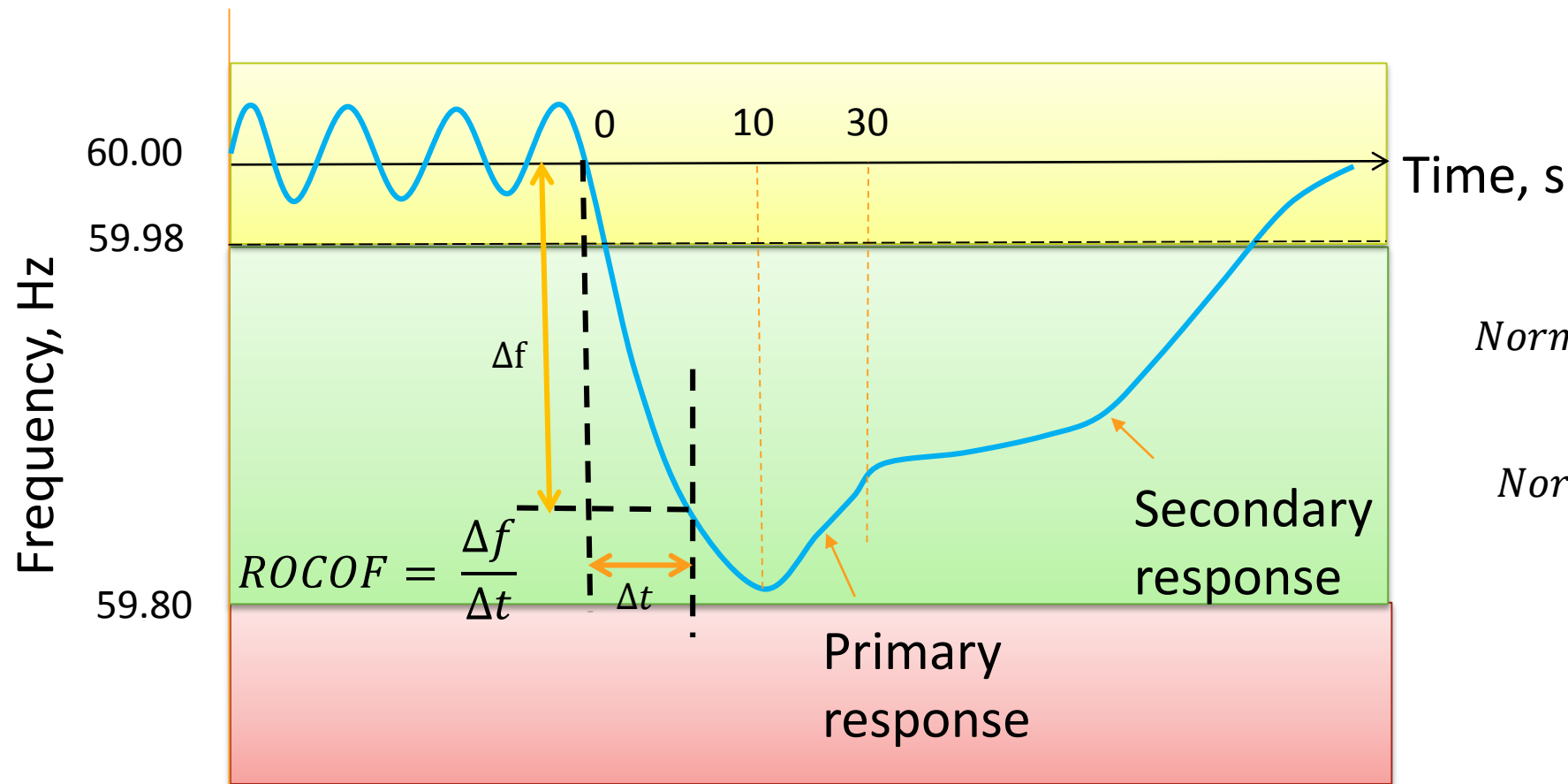
# Frequency Response Review

## Inertial response

$$\frac{df}{dt} = \frac{\Delta P}{2H} \times f_0$$



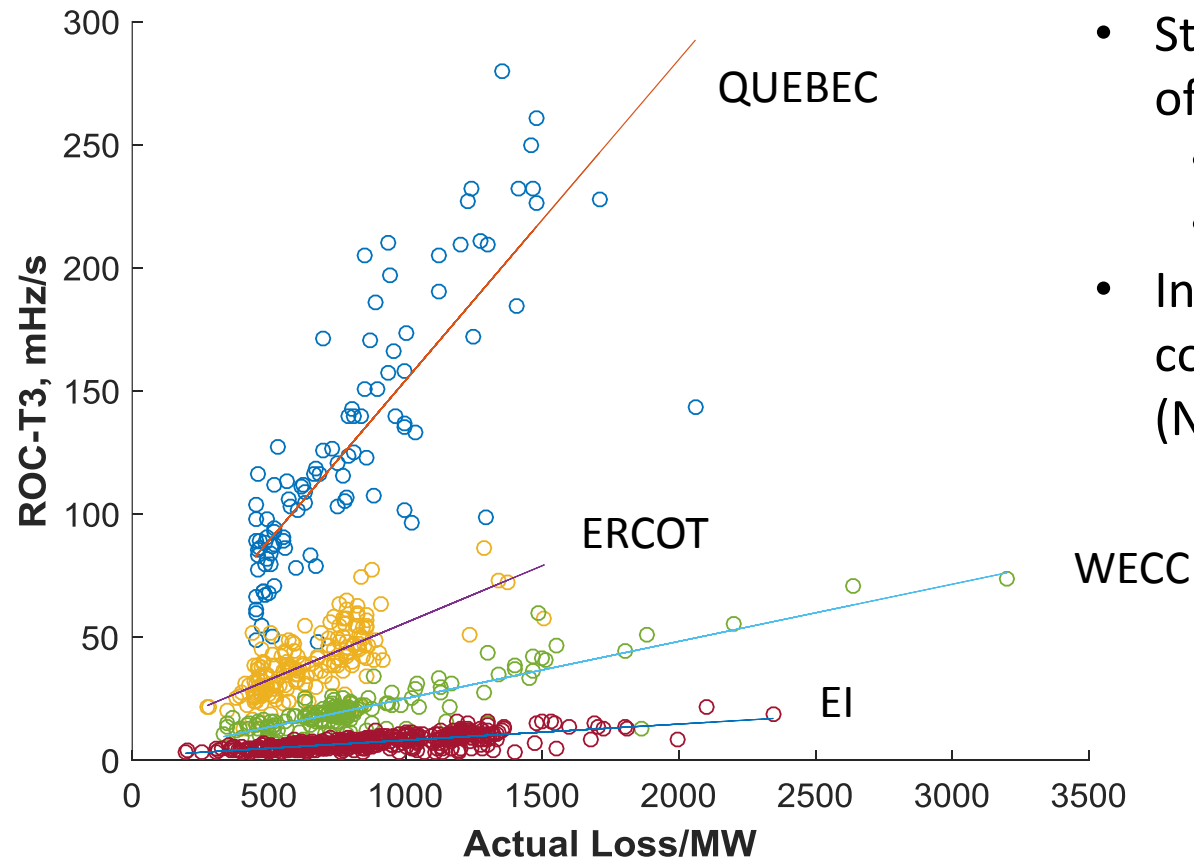
# ROCOF and Normalized ROCOF definitions



$$Normalized\ ROCOF = \frac{ROCOF}{GW\ loss}$$

$$Normalized\ ROCOF \propto \frac{1}{H}$$

# ROCOF Observations



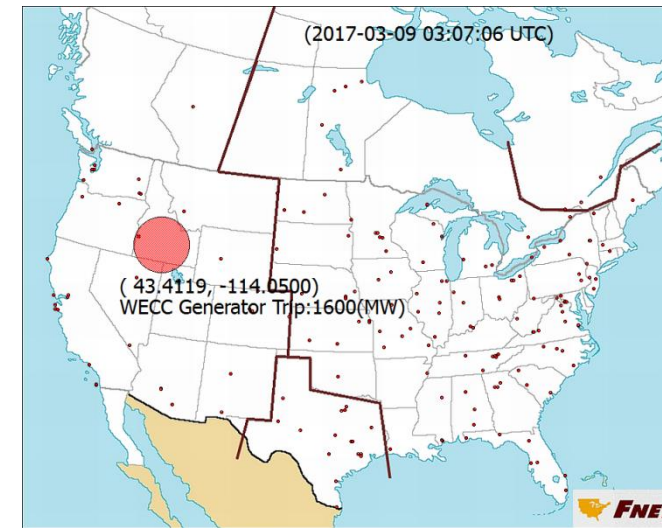
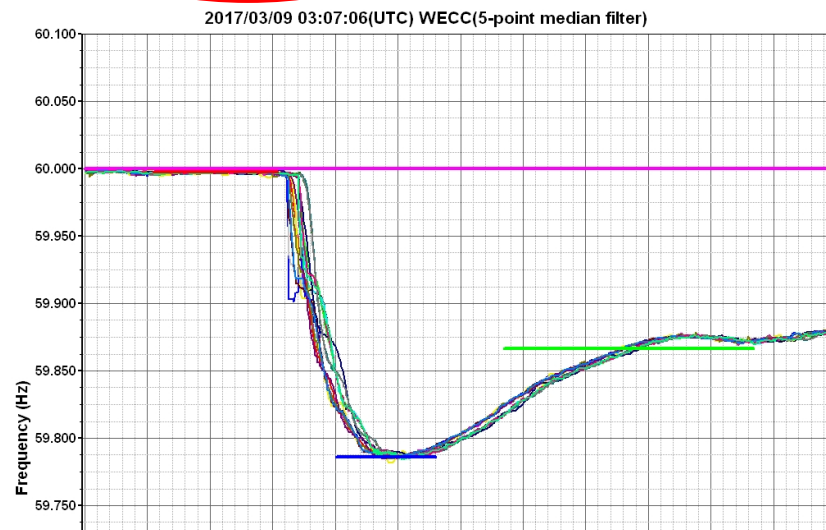
- Directly related to Interconnection size
- Strong positive correlation between ROCOF and size of resource loss
  - Can be used to improve loss estimation
  - Interconnection situational awareness
- Interconnection regression lines would rotate counter-clockwise over time with decreasing inertia (NERC Essential Reliability Services)

# Abnormal ROCOF Detection at FNET/GridEye

- High raw ROCOFs are generally associated with very large resources losses
- High normalized ROCOF reflects lower inertia
- Real-time detection and notifications of abnormally high normalized ROCOFs at FNET/GridEye provide situational awareness

# FNET/GridEye Notification

Basic Event Information							
Event Date	2017-03-09	Event Time	03:07:06 UTC	Event Type	Generation Trip	Estimated Amount	1600 MW
Point A	59.9973 Hz	Point B	59.8665 Hz	Point C	59.7858 Hz	Point C Prime	<u>59.8642 Hz</u>
MOD-027-1 Event	YES	InterConnection	WECC	Estimated Reliability Coordinator	WECC	ROCOF	49.72 mHz/s



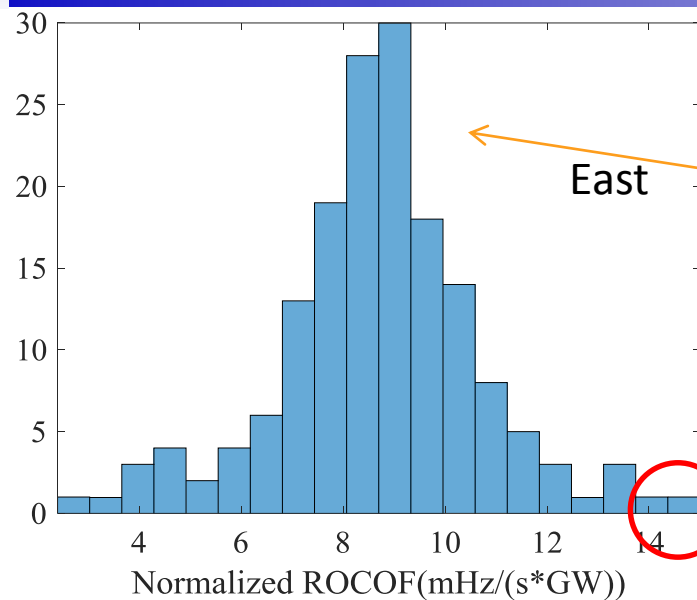
# High Normalized ROCOF Factors

- Predominantly off-peak hours
- Trace accompanied by large oscillations
- “Edges” of the Interconnection



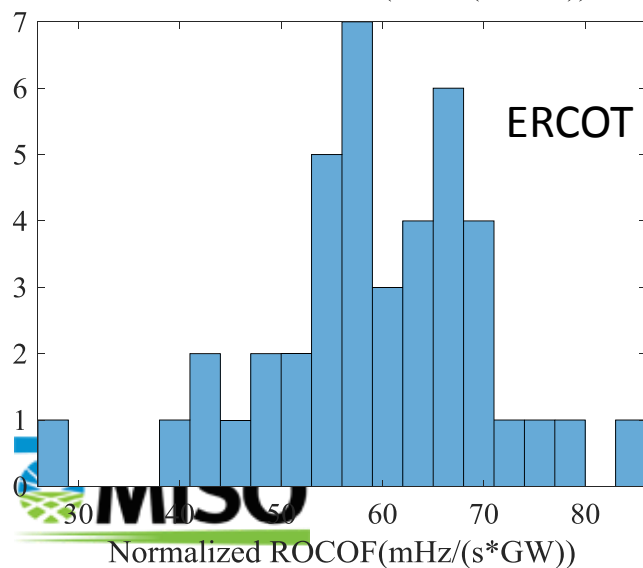


# Normalized ROCOF 2015 (All Interconnections)

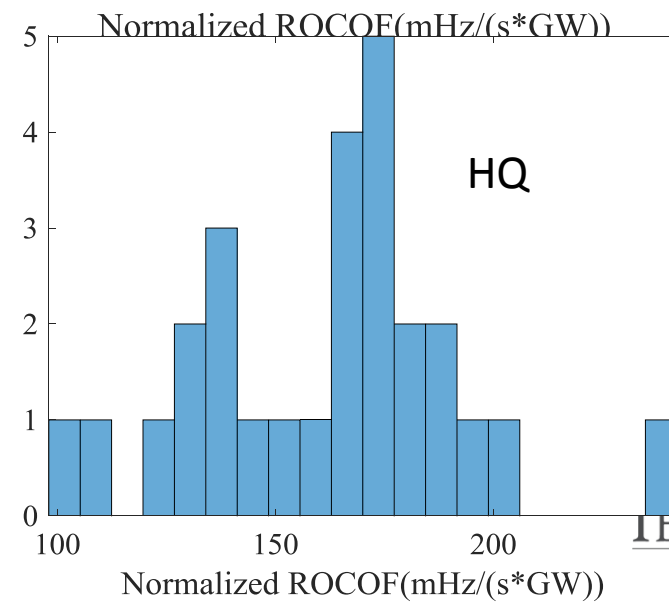
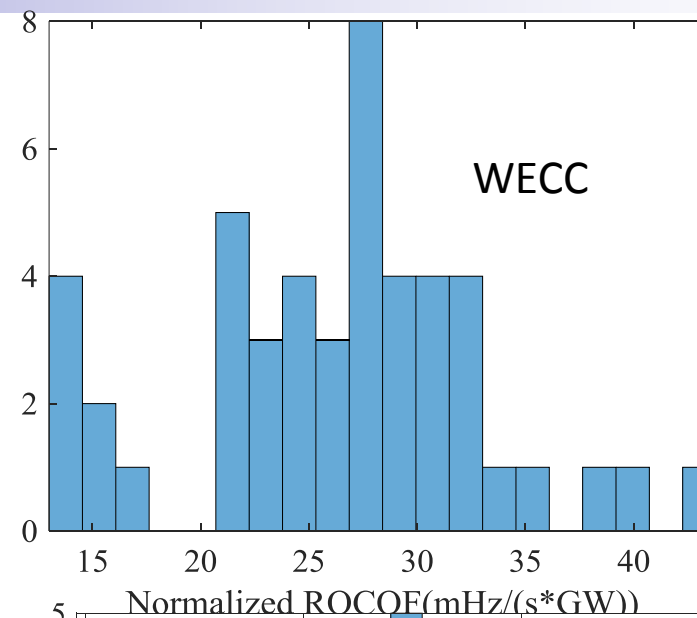


With sufficient samples,  
reflects normal  
distribution

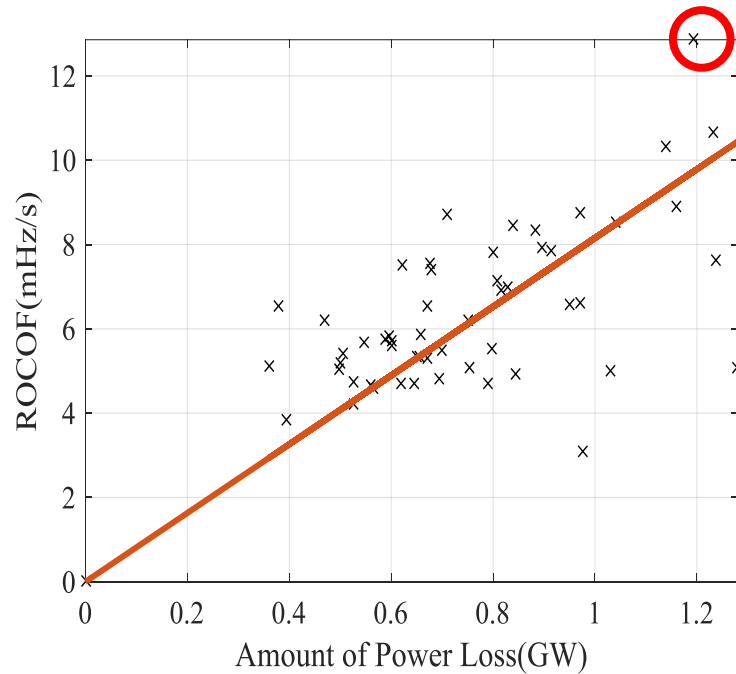
Lower inertia events



Events from NERC  
Frequency Response  
(M-4) dataset; more  
samples needed in WECC,  
ERCOT, HQ



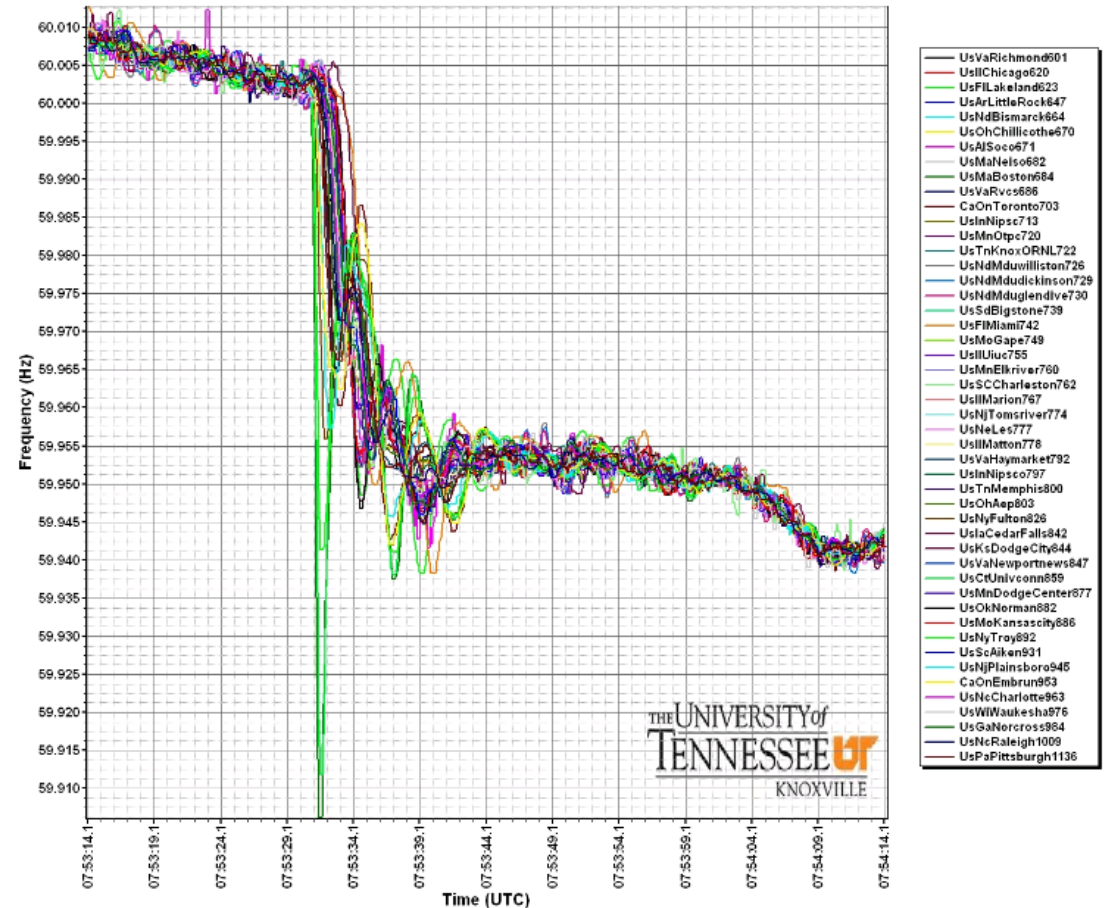
# High EI ROCOF Example



**Event time:**

**2016/03/02 07:53:29 UTC**

**Amount: 1194MW in NH**



# Next Steps and Future Work

- NERC to select “base year” for normalized ROCOF for ERS tracking, clean and build dataset
- Use ROCOF to improve estimated resource loss size notification
- Explore other situational awareness capabilities (2016 NERC RISC Report, profile # 6)
- Post high ROCOF events as modeling opportunities as well as to study possible local low inertia issues

Questions?

# Appendix

# Risks of Inadequate Situational Awareness\*

- *Risks:*
  - Inadequate situational awareness can be a precursor or contributor to BPS events
  - Insufficient communication and data regarding neighboring entity's operation is a risk as operators may act on incomplete information
- *Mitigating the risks:*
  - Develop new measures of reliability beyond reserve margins
  - Develop real-time notification of interconnection anomalies and outliers (e.g., large load or resource losses, large oscillations, large angle changes, low inertia)

\*Source NERC 2016 “ERO Reliability Risk Priorities” report

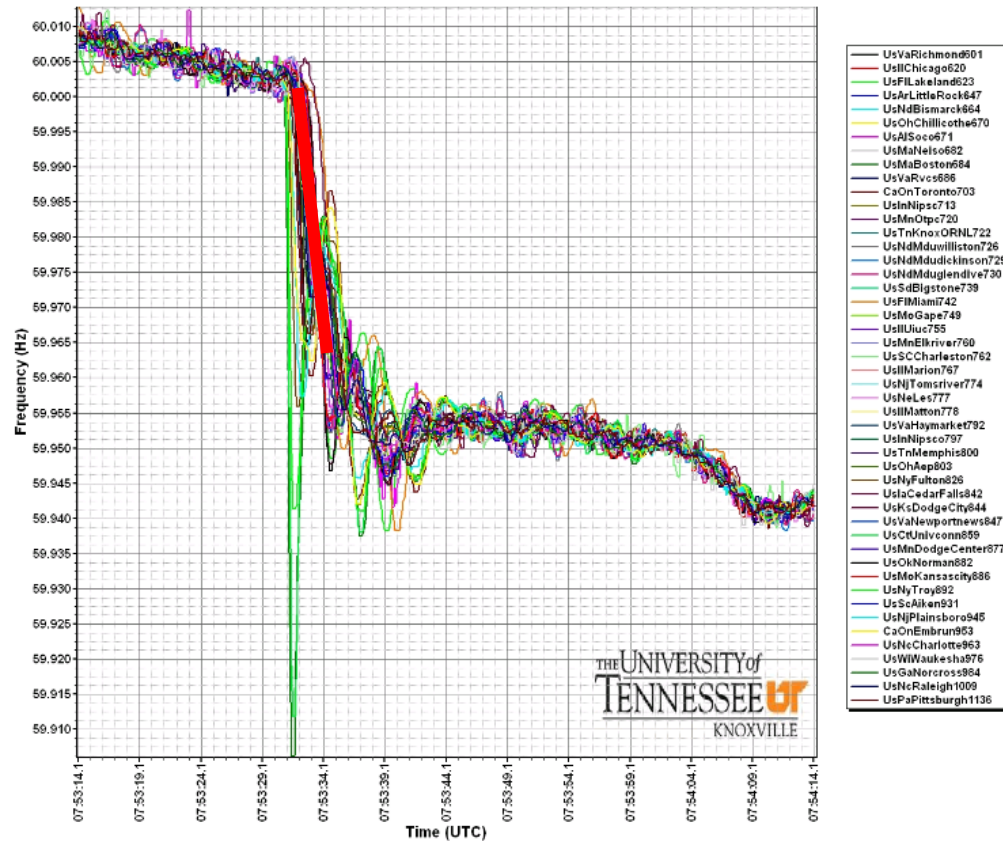
# Situational Awareness Opportunities

- The NERC 2016 “*ERO Reliability Risk Priorities*” report\* notes the need for enhanced situational awareness
- FNet toolset could be used to meet goals in the report, specifically real-time notification of
  - Very large load or resource losses
  - Large or persistent oscillations
  - Large interconnection angle changes
  - Low inertia
- Recommend NERC and NASPI work on this goal

\*Report available at

[http://www.nerc.com/comm/RISC/Related%20Files%20DL/ERO\\_Reliability\\_Risk\\_Priorities\\_RISC\\_Recommendations\\_Board\\_Approved\\_Nov\\_2016.pdf](http://www.nerc.com/comm/RISC/Related%20Files%20DL/ERO_Reliability_Risk_Priorities_RISC_Recommendations_Board_Approved_Nov_2016.pdf)

# Power Loss and ROCOF Estimation



- Average =  $4 * 7866 \text{ MW/Hz}$
- In this case, frequency drop 0.025Hz,  
estimated amount of generation trip MW:  
Estimated drop =  $0.038 * 4 * 7866 = 1200 \text{ MW}$

• actual = 1194 MW

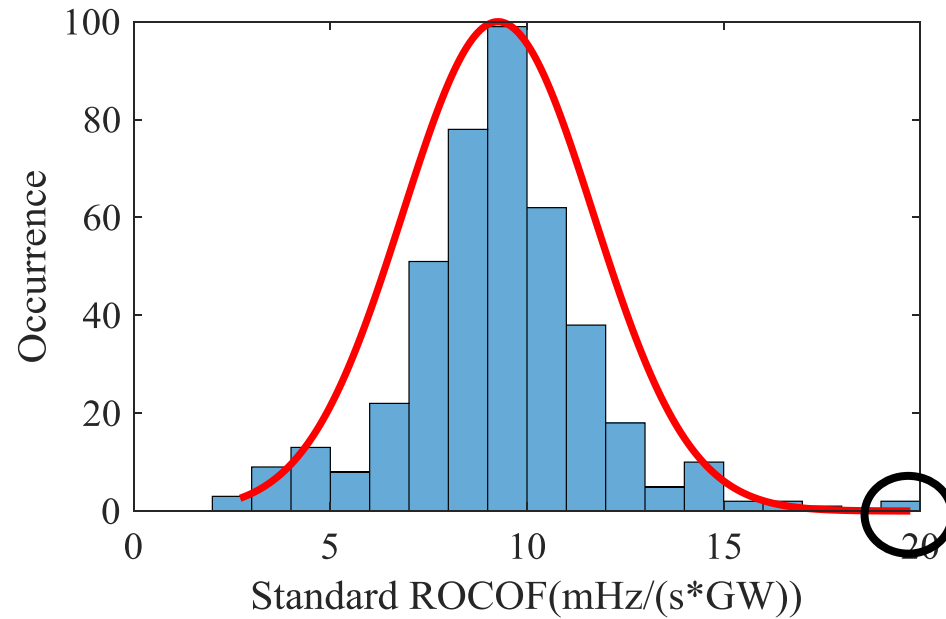
- The ROCOF =  $\frac{\Delta f}{\Delta t} = 8.62 \text{ mHz/s}$

- The normalized ROCOF  

$$= \frac{ROCOF}{\text{Estimated drop}} = 7.18 \text{ mHz/(s*GW)}$$



# High EI normalized ROCOF Example



**Event time:**

2015/02/02 14:33:27 UTC

**Amount:** 257 MW in ND

