# Update on PNNL's Oscillation Research

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PNNL-SA-200913

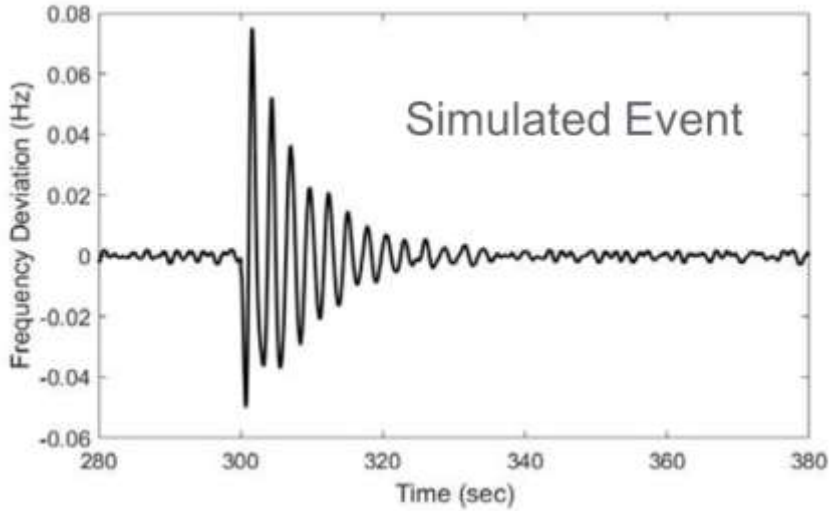
# Topics

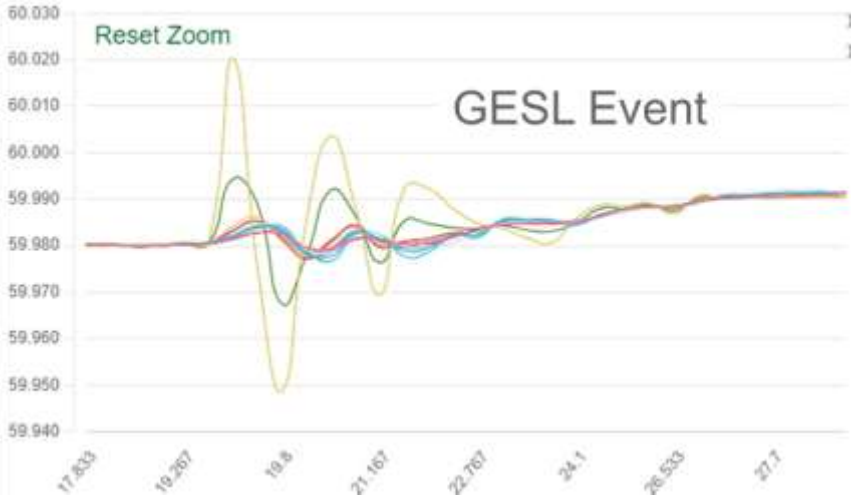
- Grid Event Signature Library
- Eastern Interconnection Situational Awareness and Monitoring System (ESAMS)
- Wave Apps

# Grid Event Signature Library

# Motivation

- DOE's Big Data Synchrophasor Analysis program highlighted the value of providing researchers with field-measured data
- DOE asked PNNL to make portions of the data publicly available in the Grid Event Signature Library (GESL) maintained by ORNL and LLNL [1]
- Common datasets improve the reproducibility of research and comparison of methods
- Simulated data cannot capture the diversity and complexity of real measurements

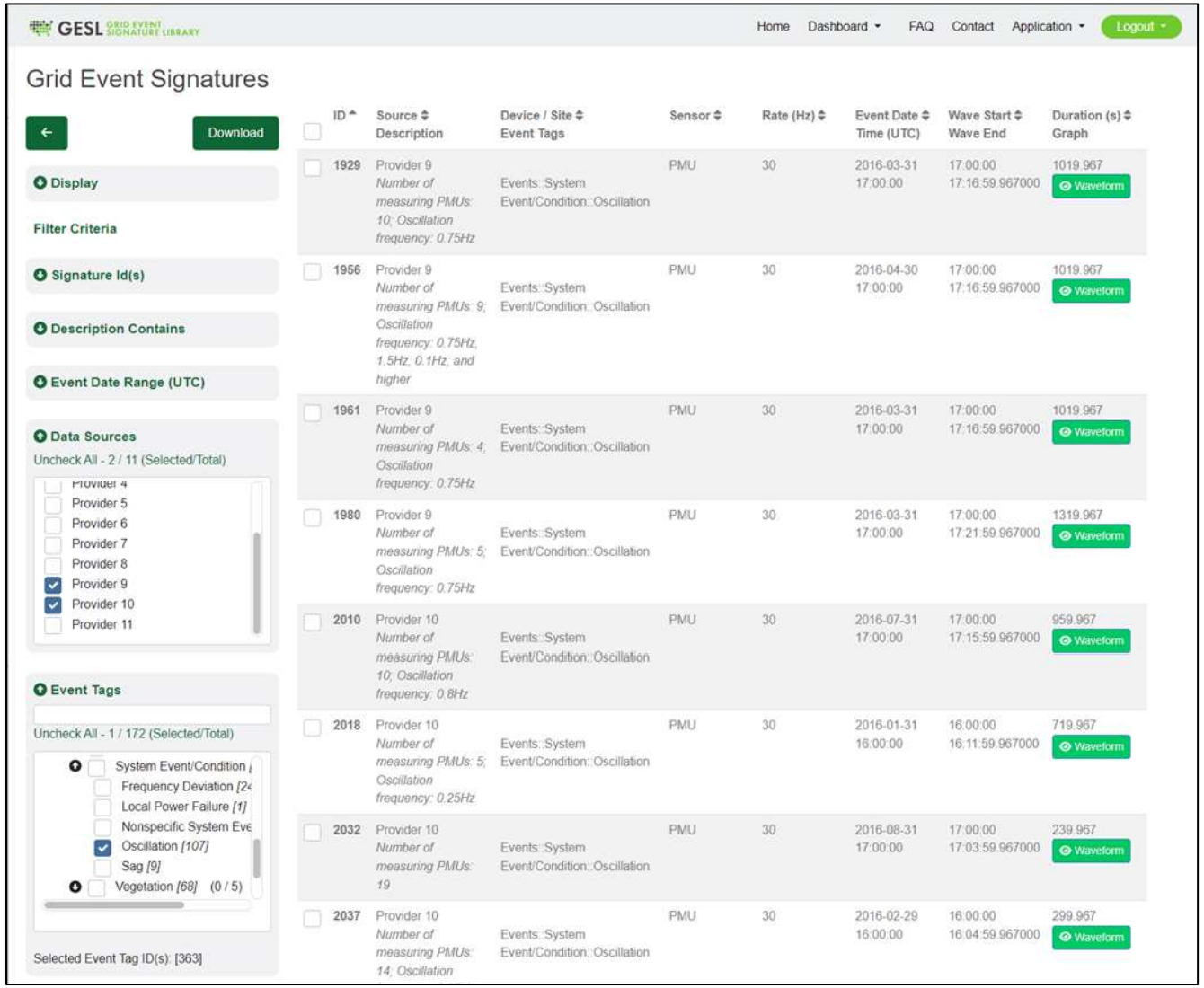



[1] A. J. Wilson et al., "The Grid Event Signature Library: An Open-Access Repository of Power System Measurement Signatures," in IEEE Access, vol. 12, pp. 76207-76218, 2024, doi: 10.1109/ACCESS.2024.3404886.

# Accessing Oscillation Events

- Transmission PMU data stored in Provider 9 (Eastern Interconnection) and Provider 10 (Western Interconnection) [2]
  - Total: 1694 events
  - Oscillations: 107
- Oscillations tagged as Events::System Event/Condition::Oscillation

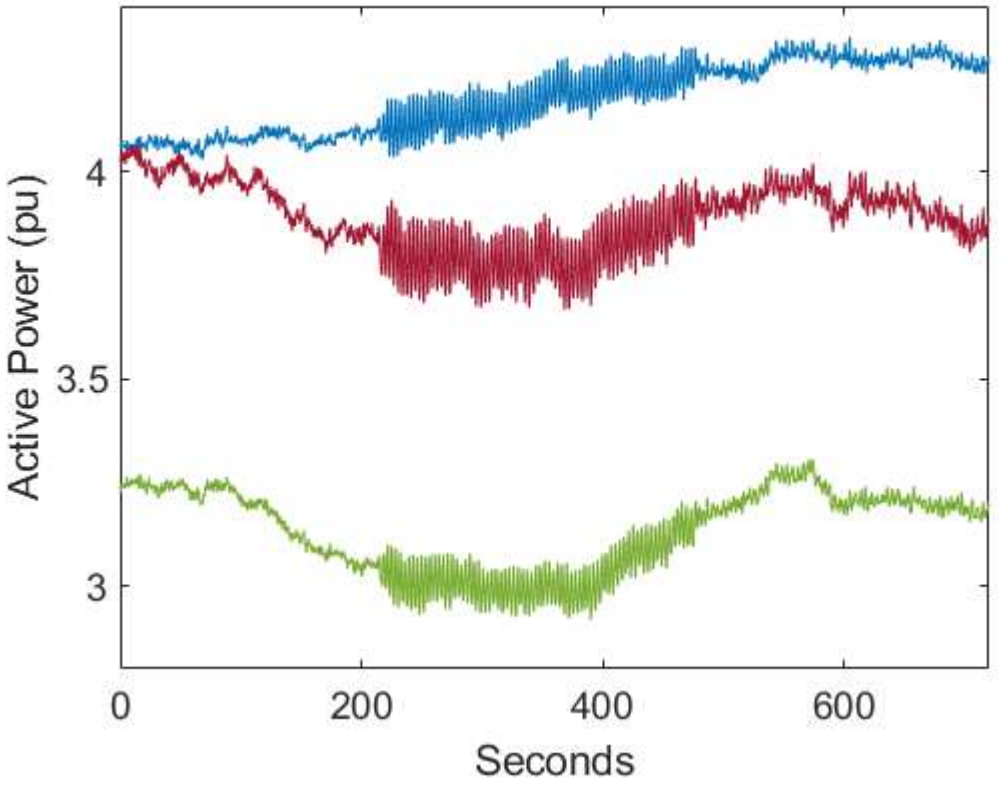



[2] S. Biswas, J. Follum, P. Etingov, X. Fan and T. Yin, "An Open-Source Library of Phasor Measurement Unit Data Capturing Real Bulk Power Systems Behavior," in IEEE Access, vol. 11, pp. 108852-108863, 2023, doi: 10.1109/ACCESS.2023.3321317.

# Use Case 1

## Impact of Frequency Error on Two OSL Algorithms

- GESL entry 1003 contains a 0.274 Hz oscillation
- The dissipating energy flow can be calculated multiple ways [1]:
  - Cross-power spectral density (CPSD)
  - Least squares (LS)
- Which is more robust to errors in the oscillation's frequency?

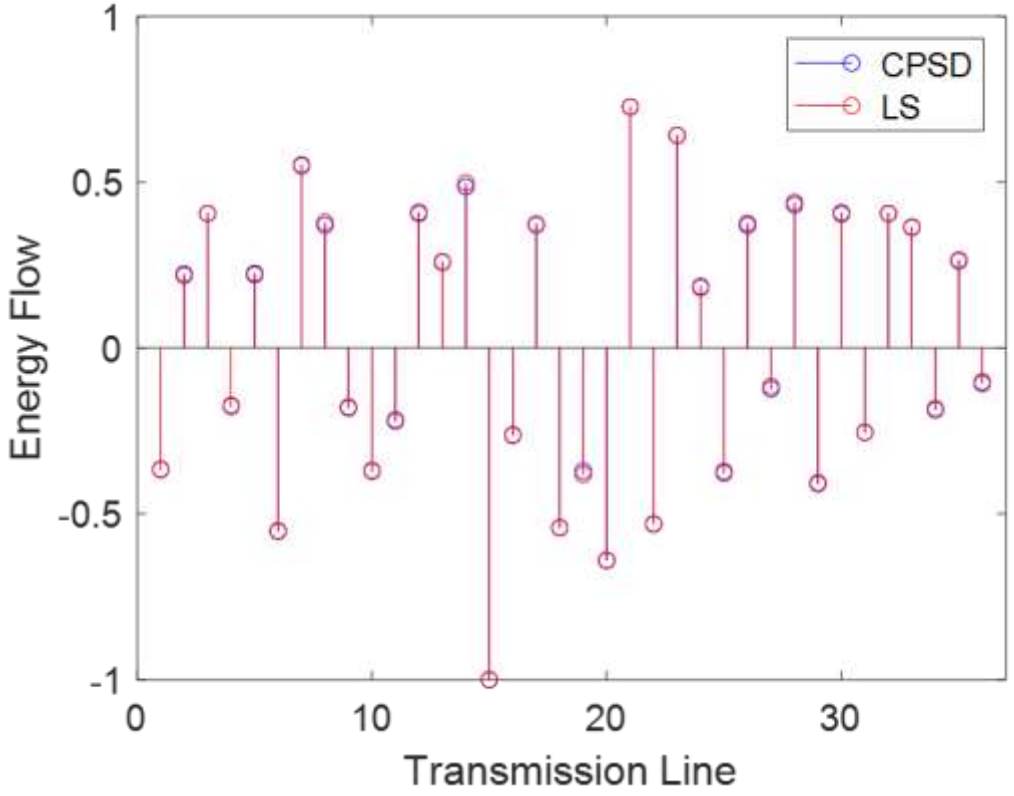



[1] http://hdl.handle.net/10125/64111

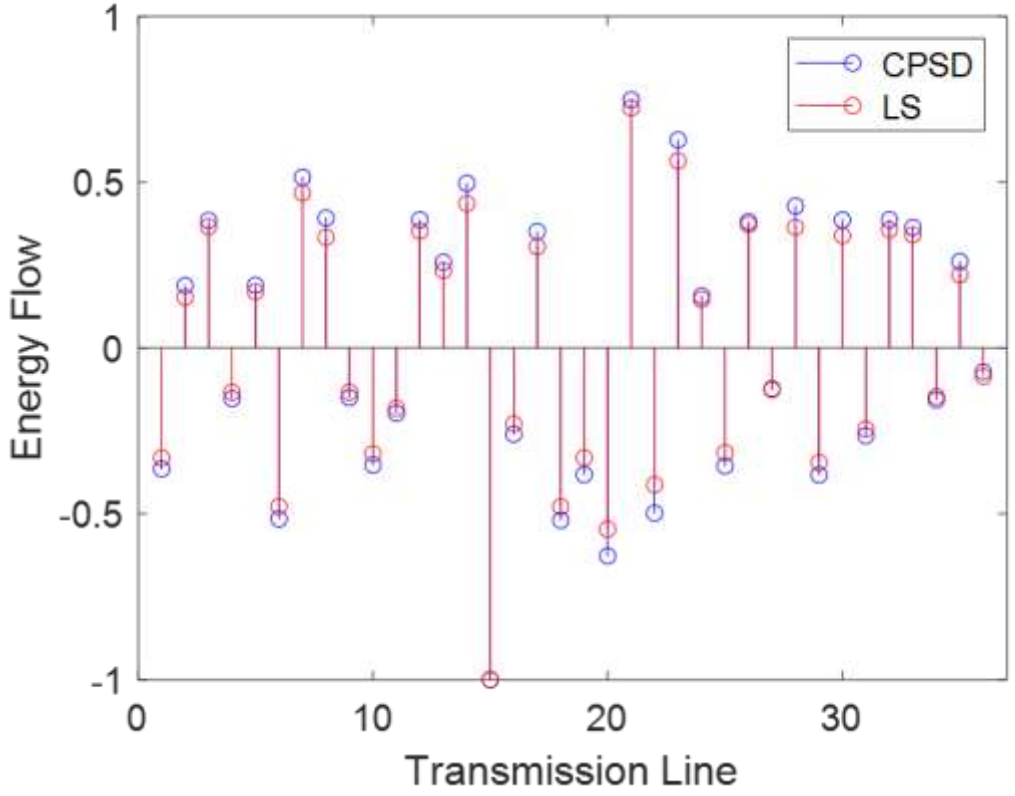
# Use Case 1

## Impact of Frequency Error on Two OSL Algorithms

**Frequency Estimate: 0.274 Hz**



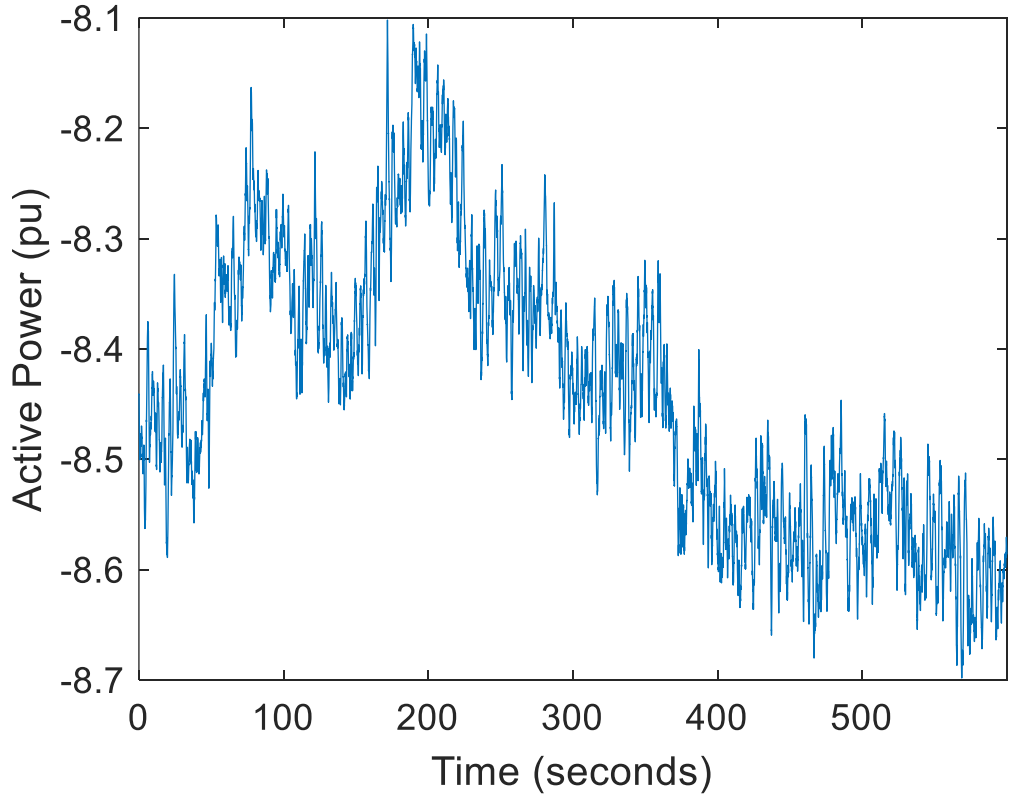

**Frequency Estimate: 0.28 Hz**



# Use Case 2

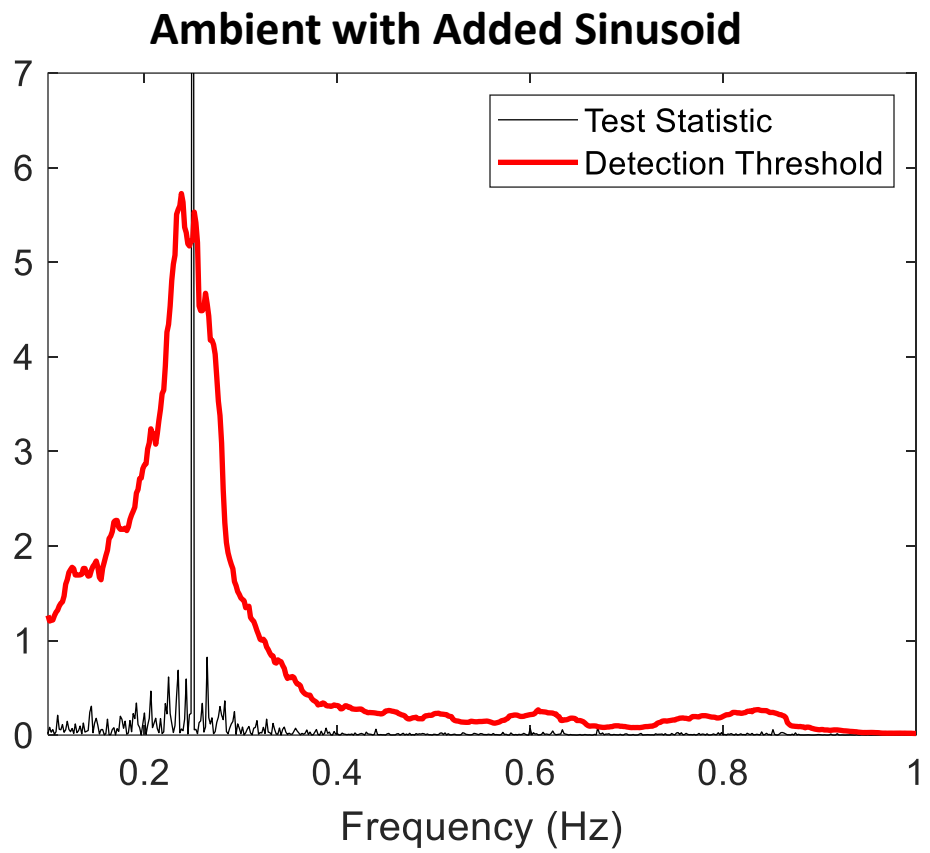
## Impact of Varying Frequency on Detection

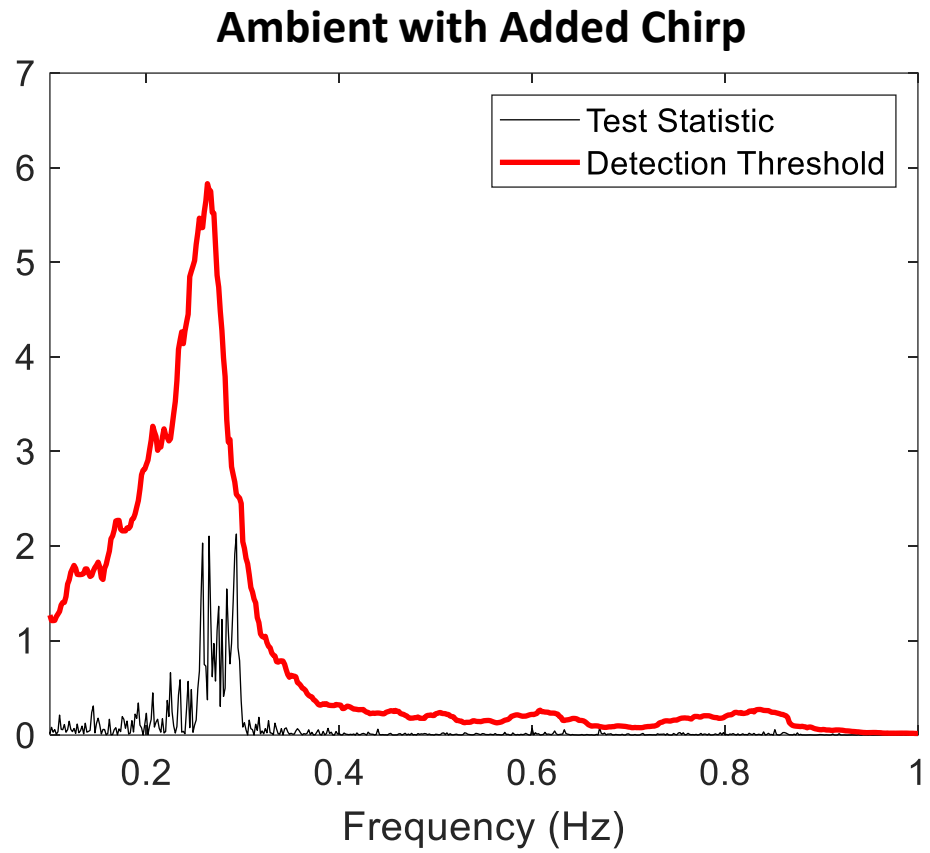
- The GESL also contains ambient data
  - State::Steady State::Nonspecific Steady State
- For oscillation studies, realistic noise can be helpful in comparing algorithms
- Signals can be added to explore performance



# Use Case 2

## Impact of Varying Frequency on Detection – Algorithm 1

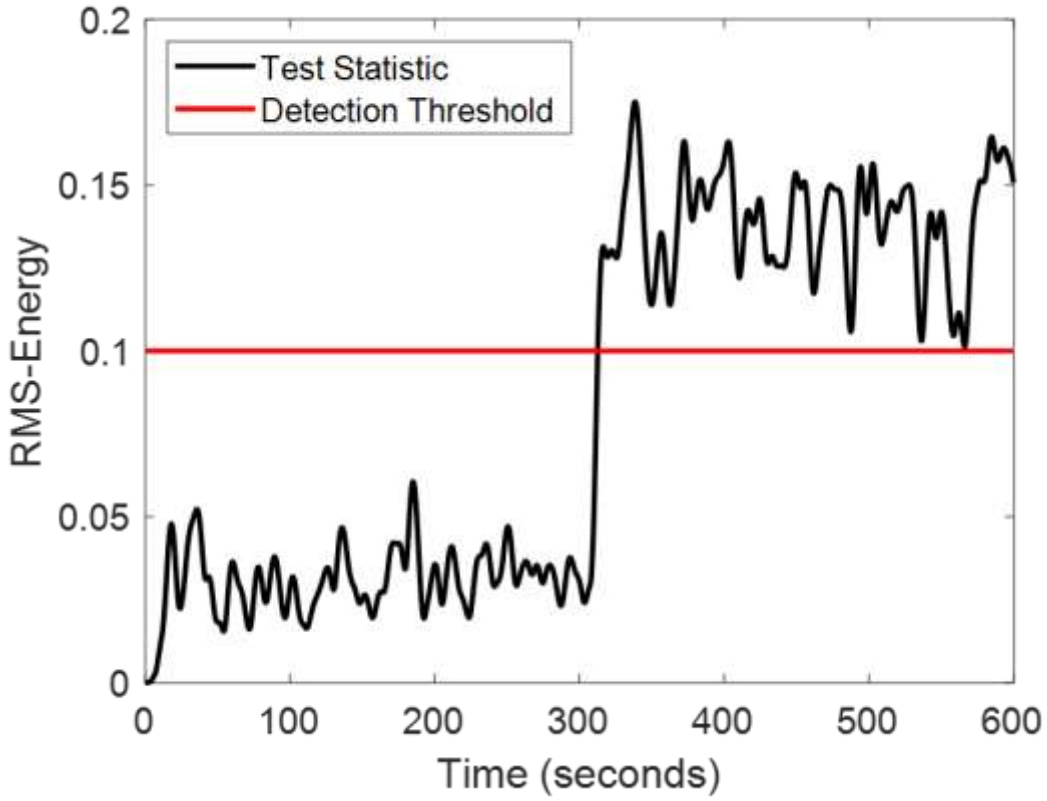


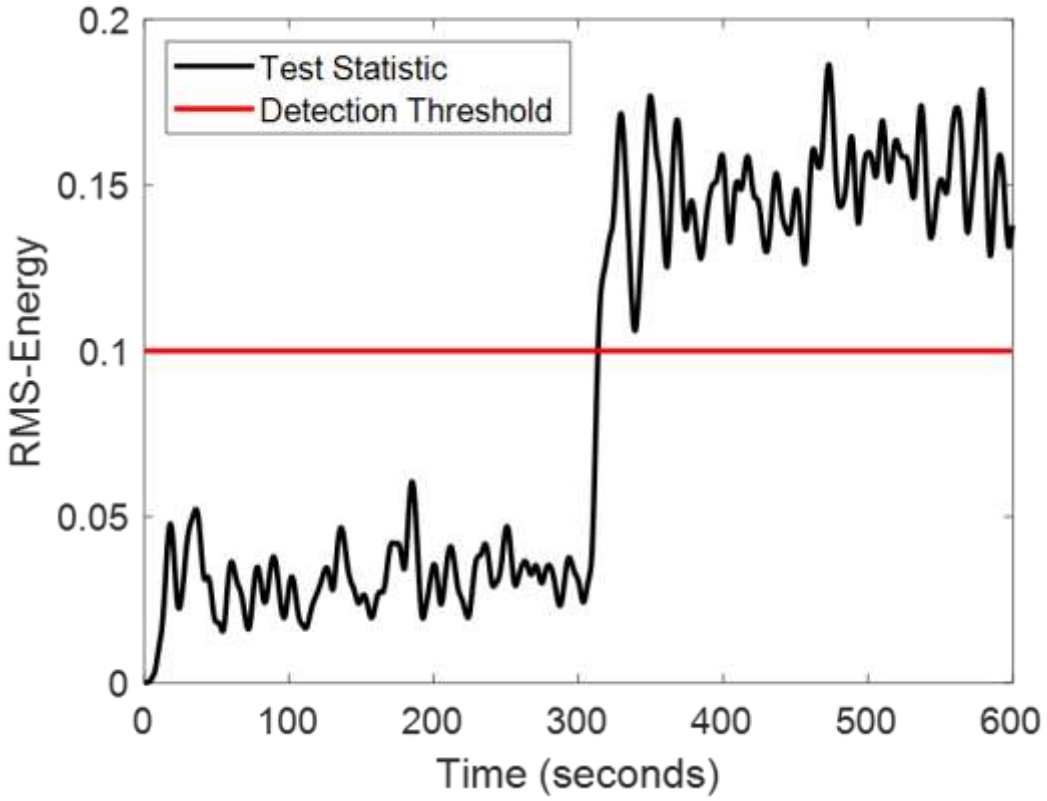
# Use Case 2

## Impact of Varying Frequency on Detection – Algorithm 2

**Ambient with Added Sinusoid**




**Ambient with Added Chirp**



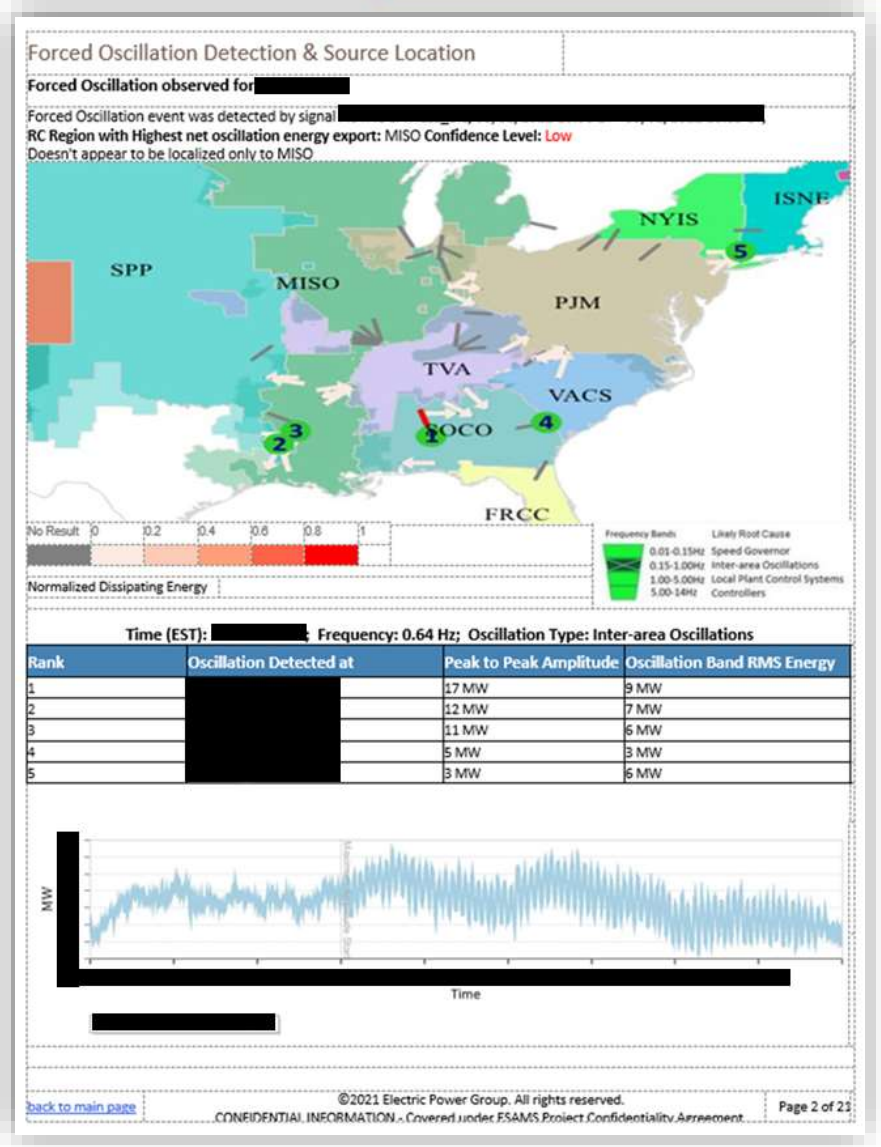
# Eastern Interconnection Situational Awareness and Monitoring System (ESAMS)

# ESAMS Concept

- Software tool developed by Electric Power Group (EPG) and PNNL with leadership from LBNL
- Purpose
  - Introduce a common, high-level interconnection-wide view based on synchrophasor information
  - Improve coordination among reliability coordinators

# Initial Demonstration

- Live demonstration ran from June 2021 through March 2022
- Hosted by PJM
- Seven Reliability Coordinators participated
- Daily reports summarized previous day's events
  - 65 oscillation events reported
- Real-time notifications for oscillations larger than 10 MW


Forced Oscillation Detection & Source Location

Forced Oscillation observed for [redacted]

Forced Oscillation event was detected by signal [redacted]

RC Region with Highest net oscillation energy export: MISO Confidence Level: Low

Doesn't appear to be localized only to MISO

SPP MISO PJM NYIS ISNE TVA VACS SOCO FRCC

Normalized Dissipating Energy

Time (EST): [redacted] Frequency: 0.64 Hz; Oscillation Type: Inter-area Oscillations

| Rank | Oscillation Detected at | Peak to Peak Amplitude | Oscillation Band RMS Energy |
|---|---|---|---|
| 1 | [redacted] | 17 MW | 9 MW |
| 2 | | 12 MW | 7 MW |
| 3 | | 11 MW | 6 MW |
| 4 | | 5 MW | 3 MW |
| 5 | | 3 MW | 6 MW |

MW

Time

[redacted]

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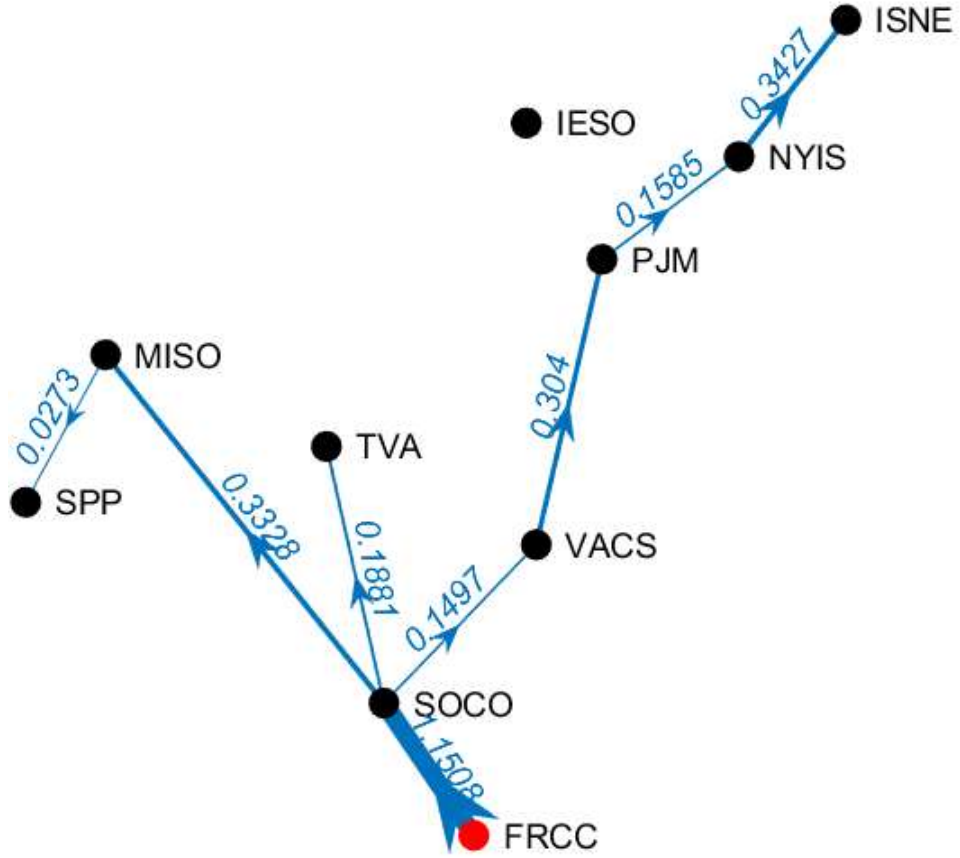
# Regional Source Localization

- Identifying exact source impractical at interconnection scale
- PMUs used to calculate Dissipating Energy Flow (DEF) on tie-lines
- The region with the highest net export is identified as the source



# Southern Company Deployment

- Currently monitoring Southern Company's northern and southern borders
- Nine significant (typically > 10 MW) events detected since May
- Study topics
  - Comparing ESAMS with the RMS-energy detector in EPG's RTDMS
  - Using ESAMS to monitor regions within a reliability coordinator
  - Updating ESAMS notifications to make them more useful to system operators

# Planned Cloud Deployment

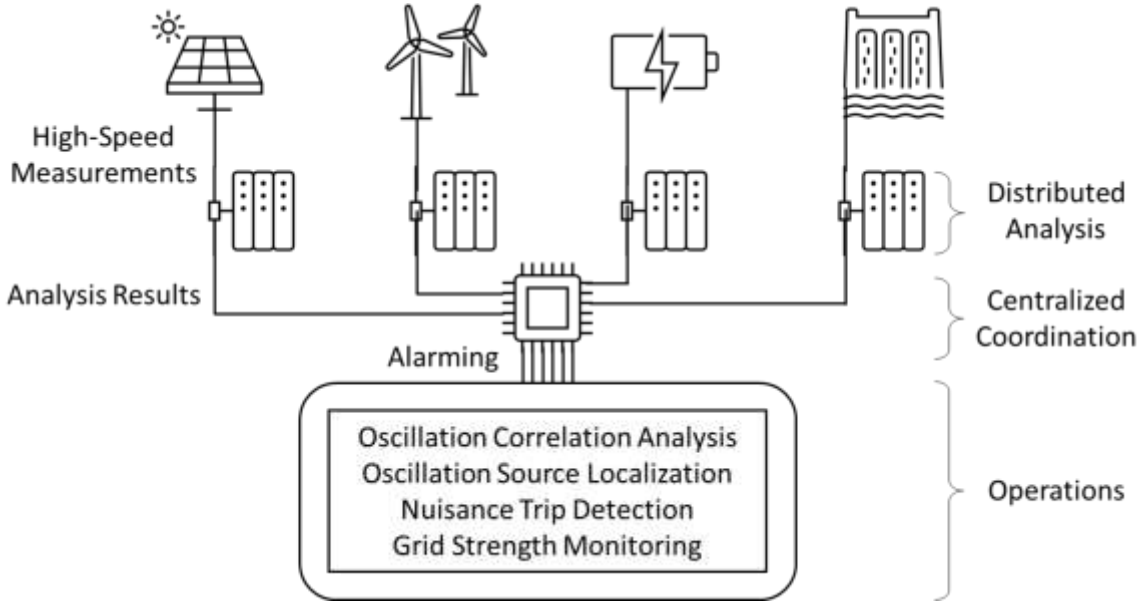
- A cloud deployment has potential advantages
  - Does not require a single entity to accept hosting responsibilities
  - Avoid bi-lateral data exchange
  - Flexible for future expansion
- Plan:
  - ESAMS will be deployed in an Amazon Web Services cloud environment
  - PMU data streamed from ISO-NE and PJM
  - Considered regions: ISO-NE, NYISO, PJM
  - 6-month demonstration scheduled to begin fall 2024
  - If successful, additional participants will be invited to join

# Wave Apps

# Wave Apps

## Upcoming project funded under SETO's OPTIMA

- Scheduled to begin October 1
- Motivation
  - IBR integration would benefit from wide-area high-speed waveform measurements
  - Continuous streaming is impractical for many utilities
- Key outcome: distributed platform to host an extensible set of applications




**Team**

PNNL – Management, Application development
Grid Protection Alliance – Software development
University of Texas at San Antonio – Application development, Testbed
GE Vernova – Application development
Salt River Project – Field demonstration
Southern California Edison – Testbed evaluation

# Thank You!