



# Advancing Grid Research Through Shared PMU Data

The National PMU Dataset Story

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PNNL is operated by Battelle for the U.S. Department of Energy



# Speakers



**Jim Follum**  
Electrical Engineer



**Shuchismita Biswas**  
Electrical Engineer

# Talk Outline

1. FOA 1861 and the National PMU Dataset
2. What came after FOA 1861?
3. Success Stories
4. What Next?



# What is a Phasor Measurement Unit?

- Devices that provide **high-speed**, **precise**, **time-synchronized** measurements of electrical quantities.
- High-speed  $\Rightarrow$  30/60/120 frames per second
- Time-synchronization helps provide a wide-area view of the grid.

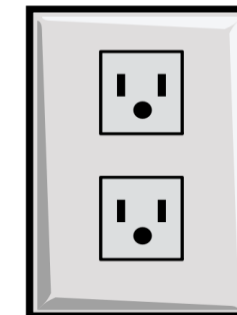
Image:NIST



*Transmission-connected PMUs*



*Distribution-connected PMUs*



Frequency  
Disturbance  
Recorder

*FDRs that plug into wall outlets*

# What is the National PMU Dataset?

**Two years of PMU data recorded by >500 transmission-system connected PMUs from all three interconnections in the United States.**

- First-of-its-kind. Unique in geographic and temporal diversity.
- What's included?
  - Timestamped Voltage, Current,
  - Frequency, ROCOF measurements
  - Substation Names
  - Limited utility event logs
- What's not?
  - Topology information
  - PMU specifications

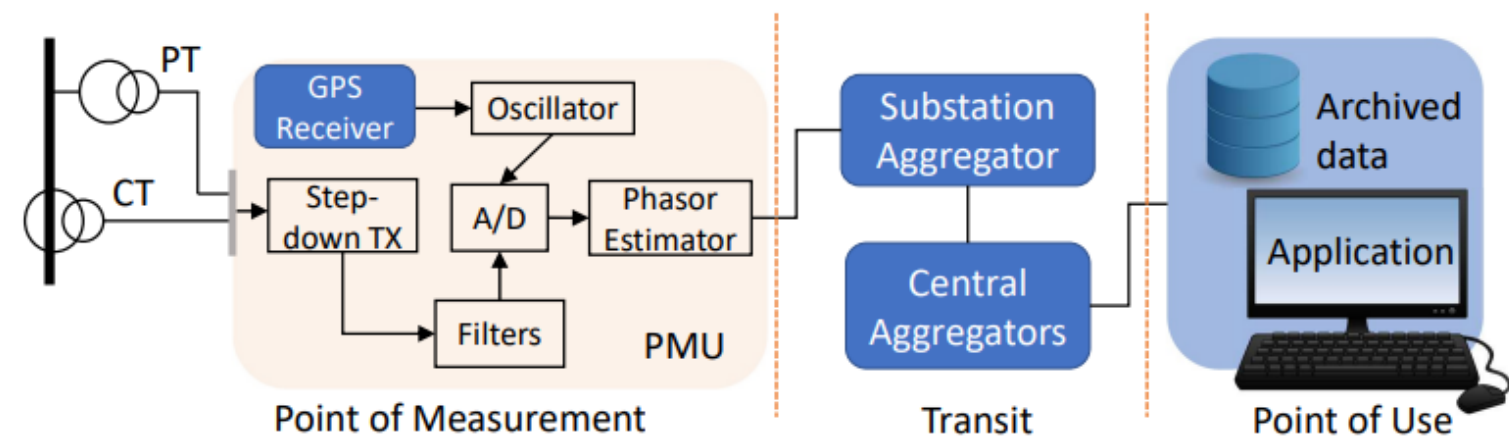


Fig. 1: PMU data flow from point-of-measurement to point-of-use



Pacific Northwest  
NATIONAL LABORATORY



# A Little History

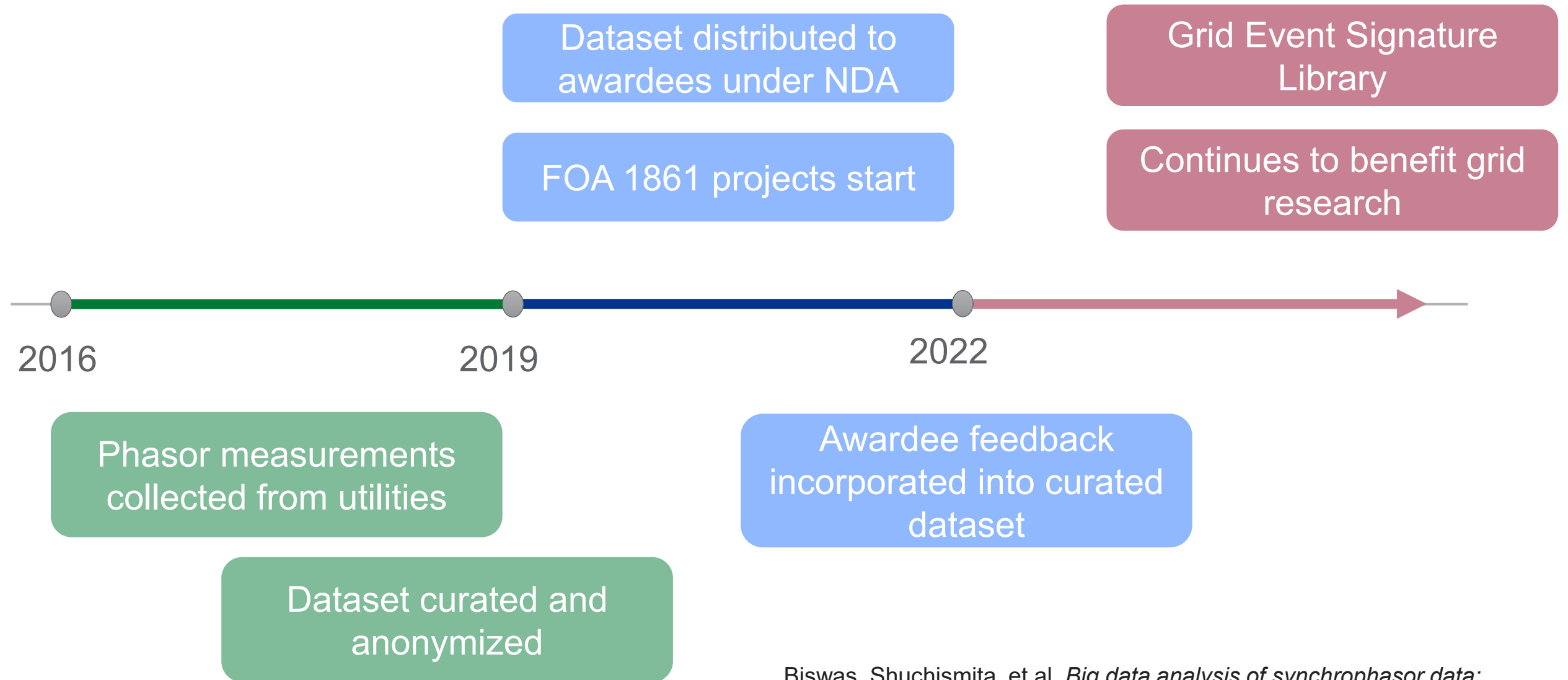
The NPDS was originally curated to support DOE FOA 1861 “**Big Data Synchronphasor Analysis.**”

## *Before the Genesis Mission, there was FOA 1861*

Phasor measurement units (PMUs) have been deployed at over 2,500 locations across the nation’s bulk power systems. Due to these PMU measurements, grid owners and operators now possess unprecedented quantities of data detailing the condition of the grid. Robust tools are needed for the analysis and discovery of the information hiding within the growing archives of PMU data, so future PMUs can contribute even more to the efficient, safe, and reliable operation and design of the nation’s electric system.

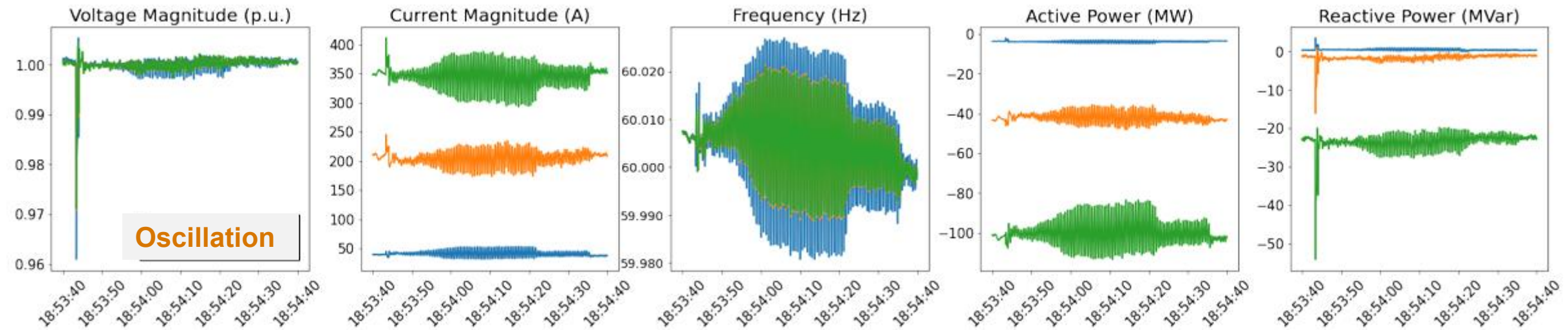
In 2019, the Department of Energy (DOE) selected eight projects to explore the use of big data, artificial intelligence (AI), and machine-learning technology and tools on PMU data to identify and improve existing knowledge, and to discover new insights and tools for better grid operation and management.

# NPDS Timeline

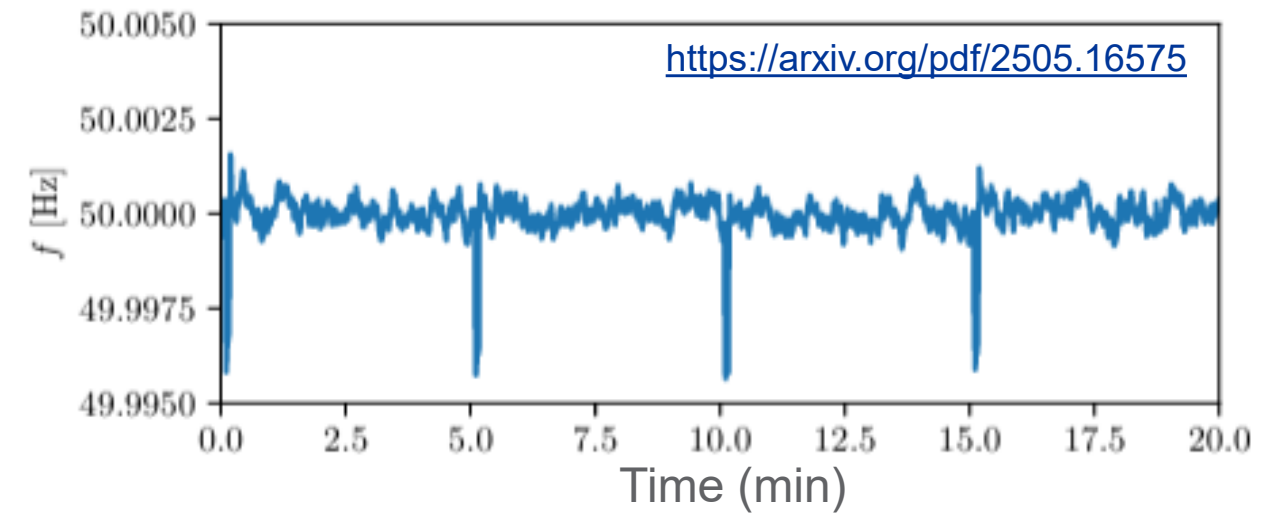


Biswas, Shuchismita, et al. *Big data analysis of synchrophasor data: Outcomes of research activities supported by DOE FOA 1861*. No. PNNL-33548. Pacific Northwest National Laboratory (PNNL), Richland, WA (United States), 2022.

# Some Cool Nuggets in the Dataset



Periodic frequency spikes due to clock drift correction



Effect on the Irish system of an increase of 10 MW of demand every 5 minutes in a data center

# Life After FOA 1861

## How can the NPDS continue to benefit grid research?

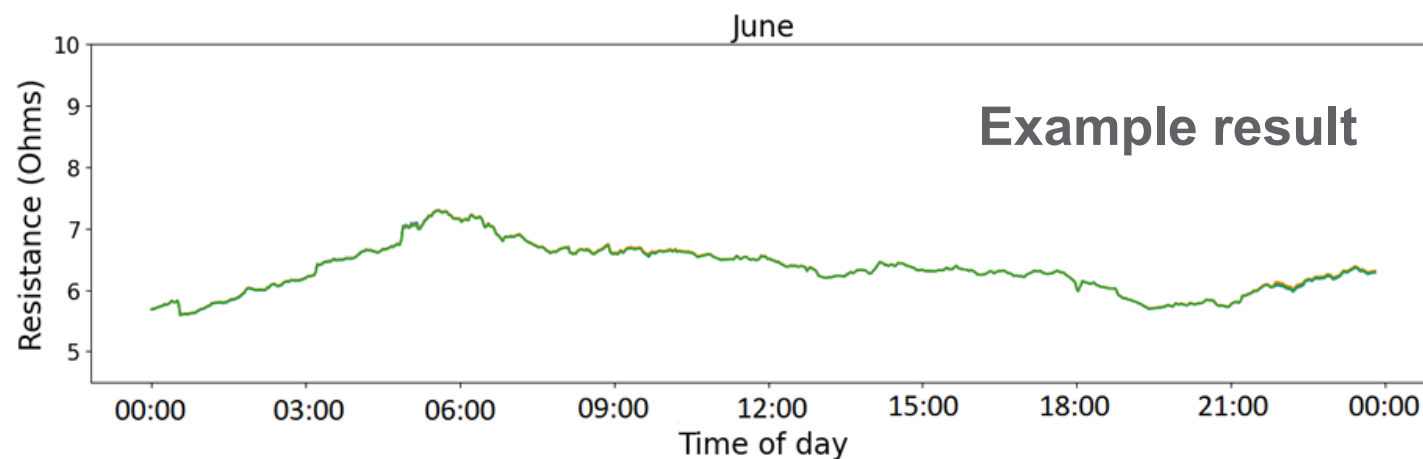
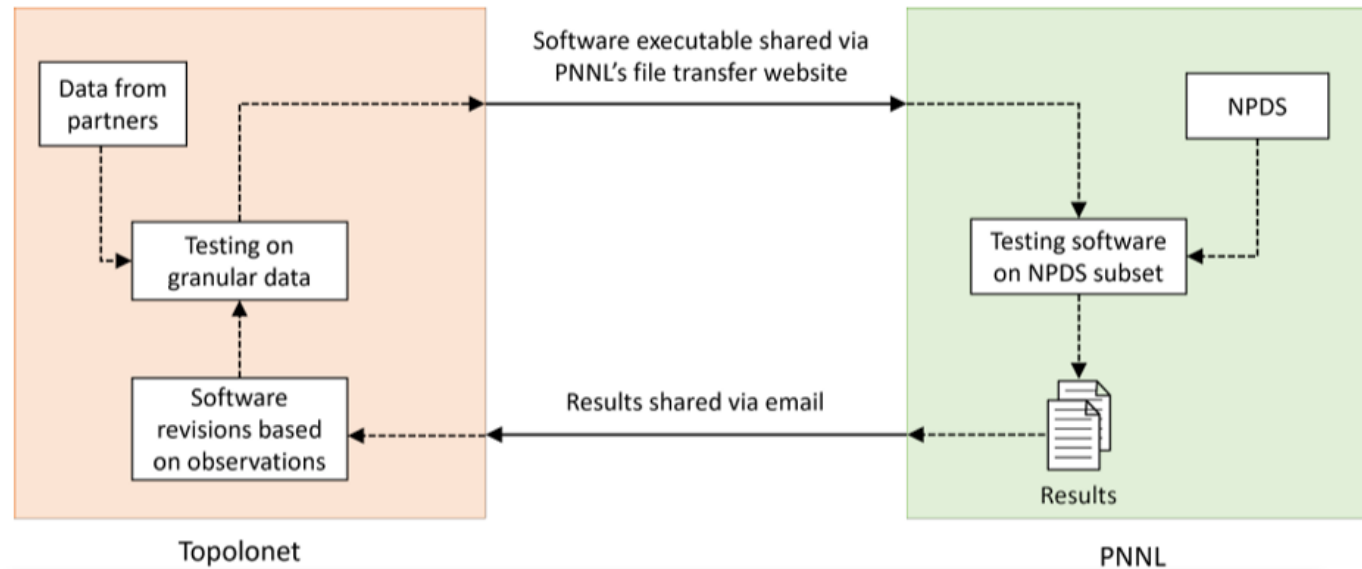
- Data snippets further anonymized and made publicly available through the [Grid Event Signature Library](#)
- Ad-hoc support to PNNL research projects. Enhanced documentation and data governance policies being crafted.
- Ad-hoc support to external research collaborations.

## Suggested Uses

- Is obfuscated data useful for evaluating the grid?  
**Not really.**
- Is it useful for education, development, testing, and demonstration?  
**Absolutely.**

- **Educators**
  - Familiarize students with real grid disturbances
  - Support students and professors without utility connections
- **Researchers**
  - Foster comparison as a reference dataset
  - Drastically reduce startup time for projects
  - Address risk that measurements will not be available
- **Utilities**
  - Reduce the burden of responding to frequent requests
  - Test capabilities developed in-house
- **Vendors**
  - Thoroughly validate tools
  - Demonstrate value with realistic test cases

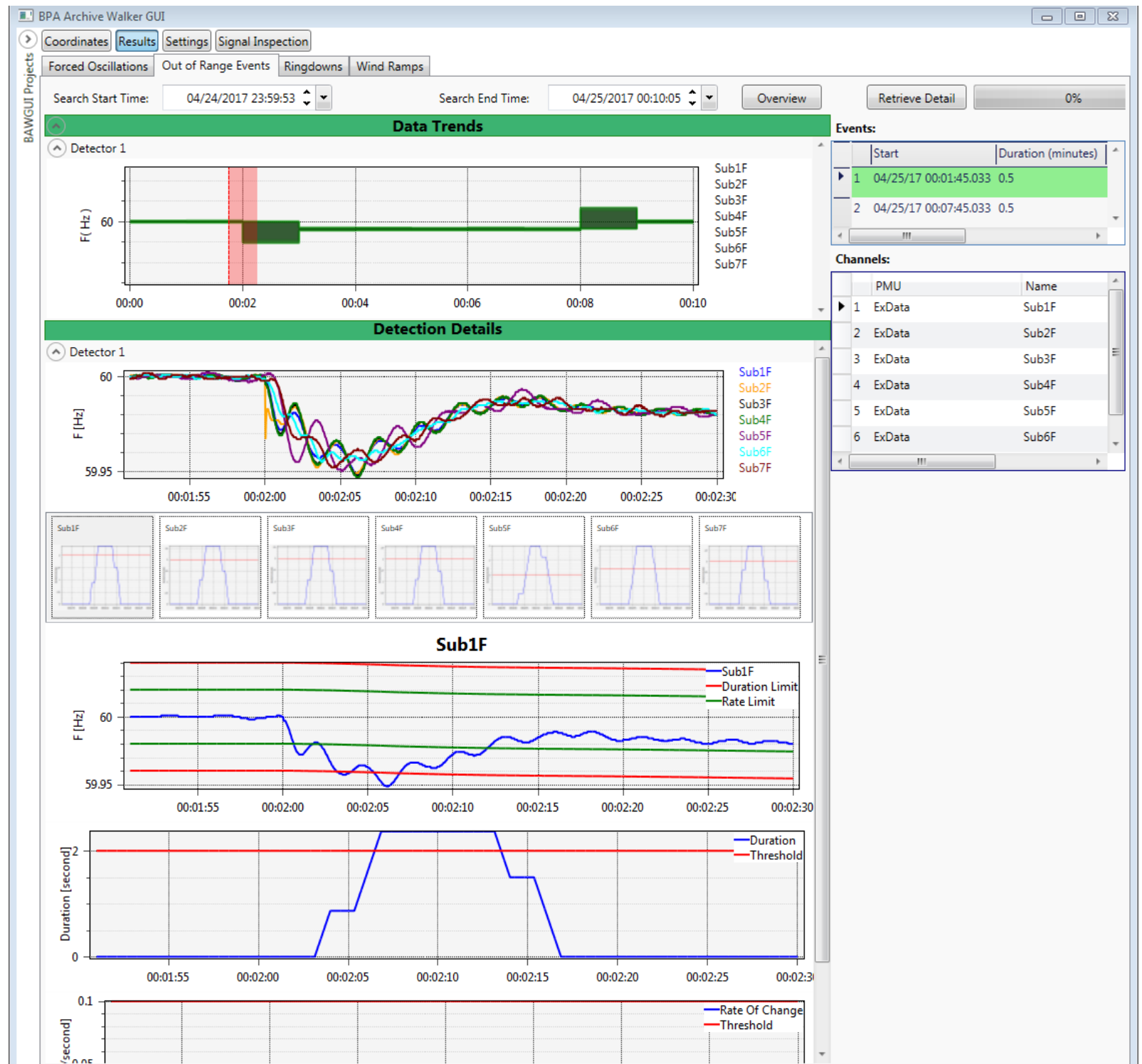
# Success Story: How PNNL partnered with Topolonet Corporation to evaluate their dynamic line rating software



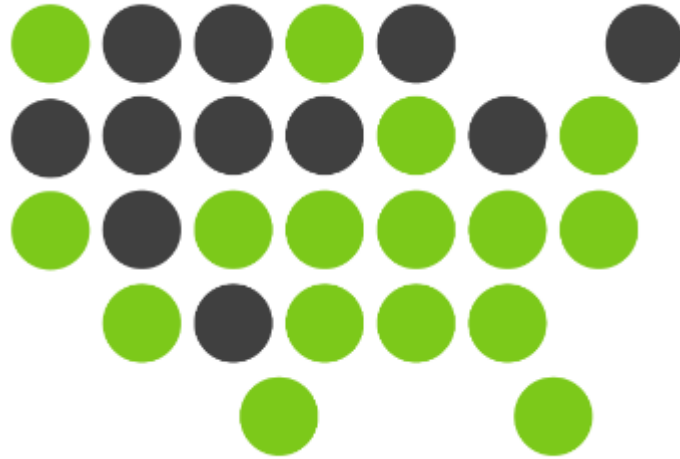
- Testing with NPDS data helped identify improvements needed for field deployment
- Sharing findings with the utility data contributor helped establish further collaboration
- Demonstrated the potential of a model where the NPDS accelerates early-stage commercial solutions.

## Success Story: Tool Interoperability

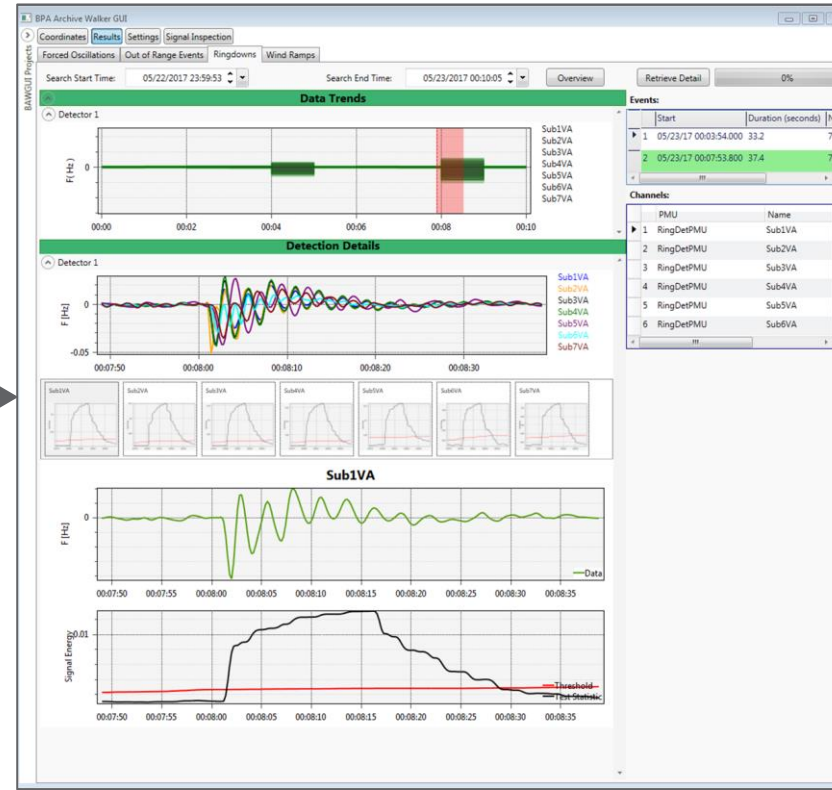
- PNNL has developed multiple tools to support analysis of synchrophasor measurements
- GESL data was used to validate a workflow involving three tools



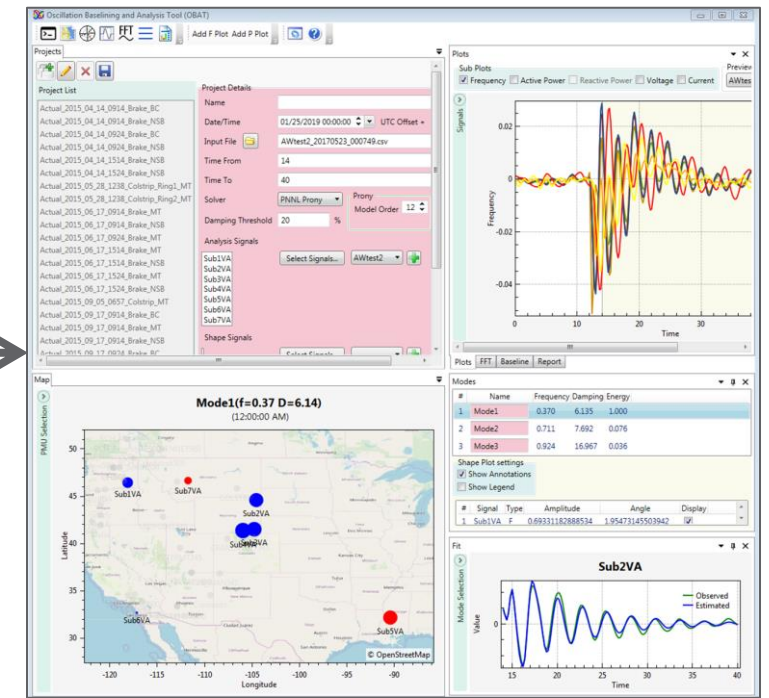
# Success Story: Tool Interoperability



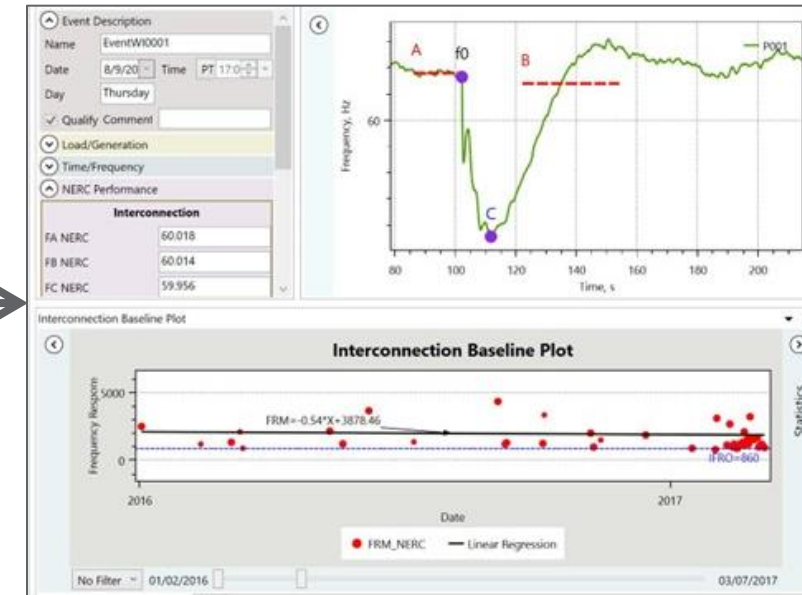
Grid Event  
Signature Library



Archive Walker  
(event detection)



Oscillation Baseline and  
Analysis Tool (OBAT)



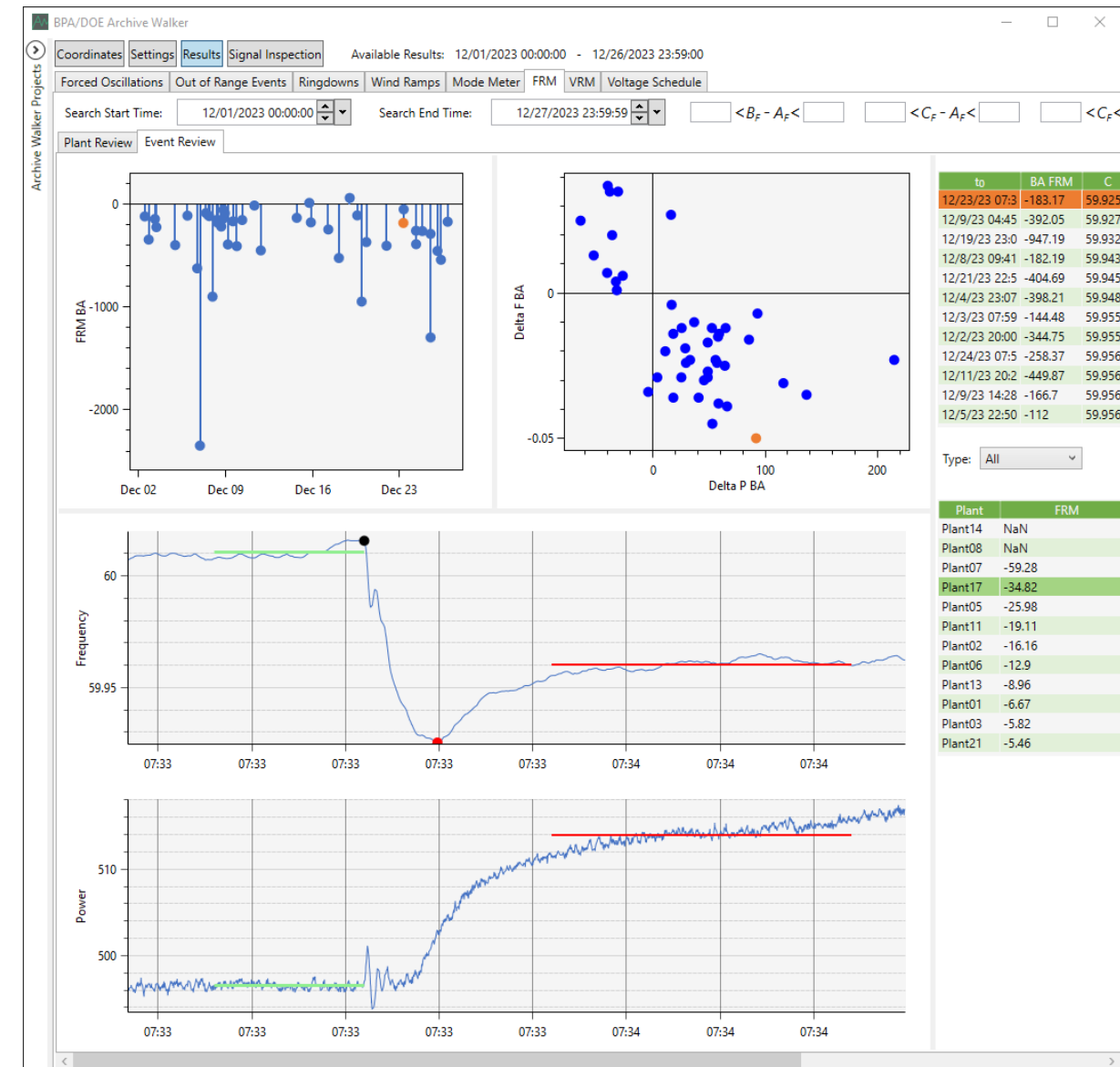
Frequency Response  
Analysis Tool (FRAT)

# Success Story: Automated Power Plant Performance Evaluation

*PNNL developed the Generator Scorecard tool to automatically detect frequency excursions and evaluate each generator's response*

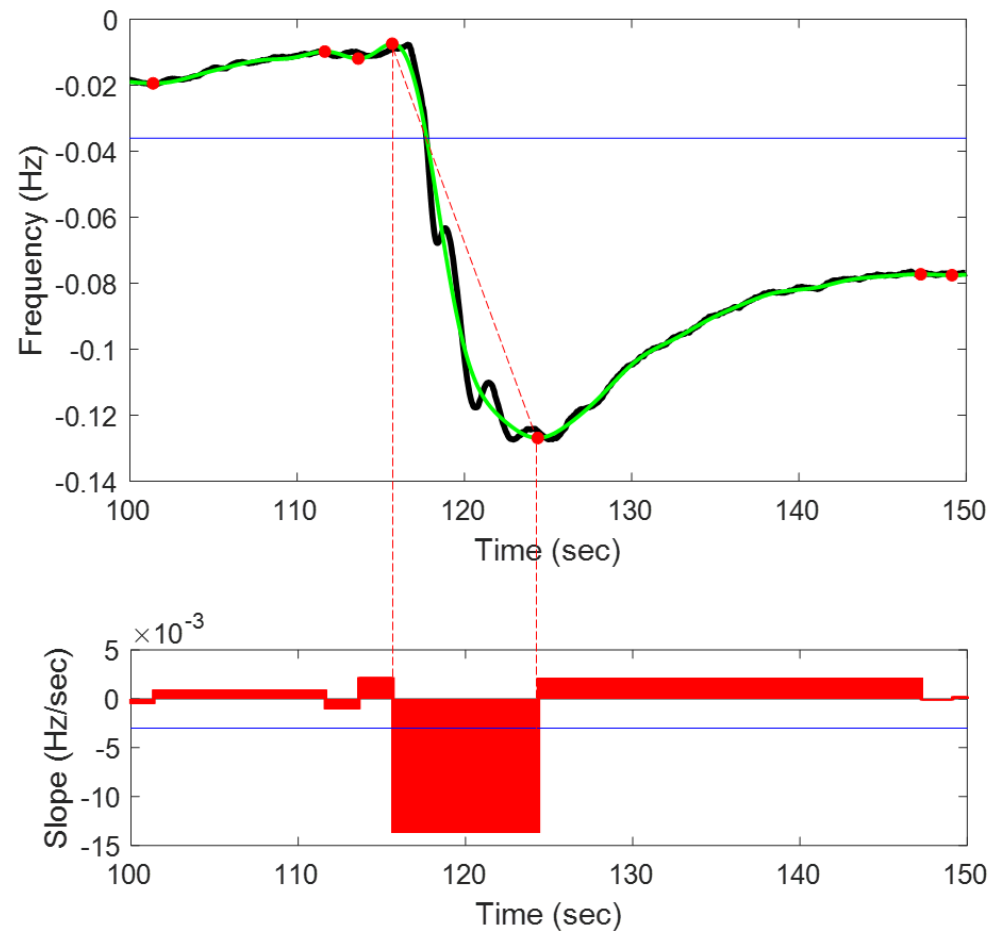
When a generator or large load trips offline, the system's frequency deviates from 60 Hz

- Generators must adjust their active power output to return the frequency to its nominal value
- Utilities review generator performance by comparing simulated and measured responses one-by-one, which is time consuming

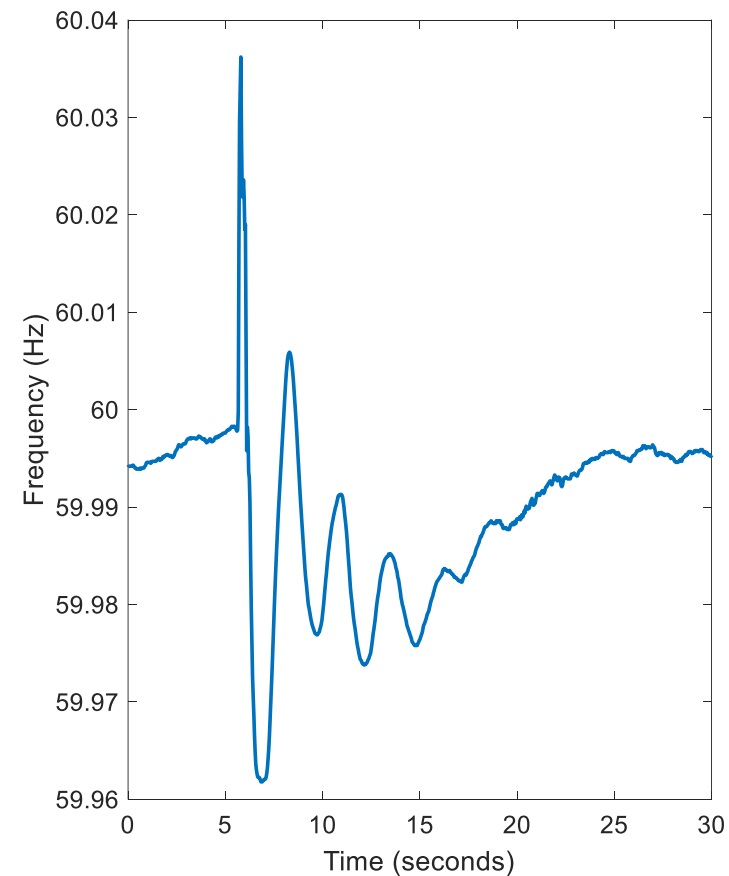


# Success Story: Automated Power Plant Performance Evaluation

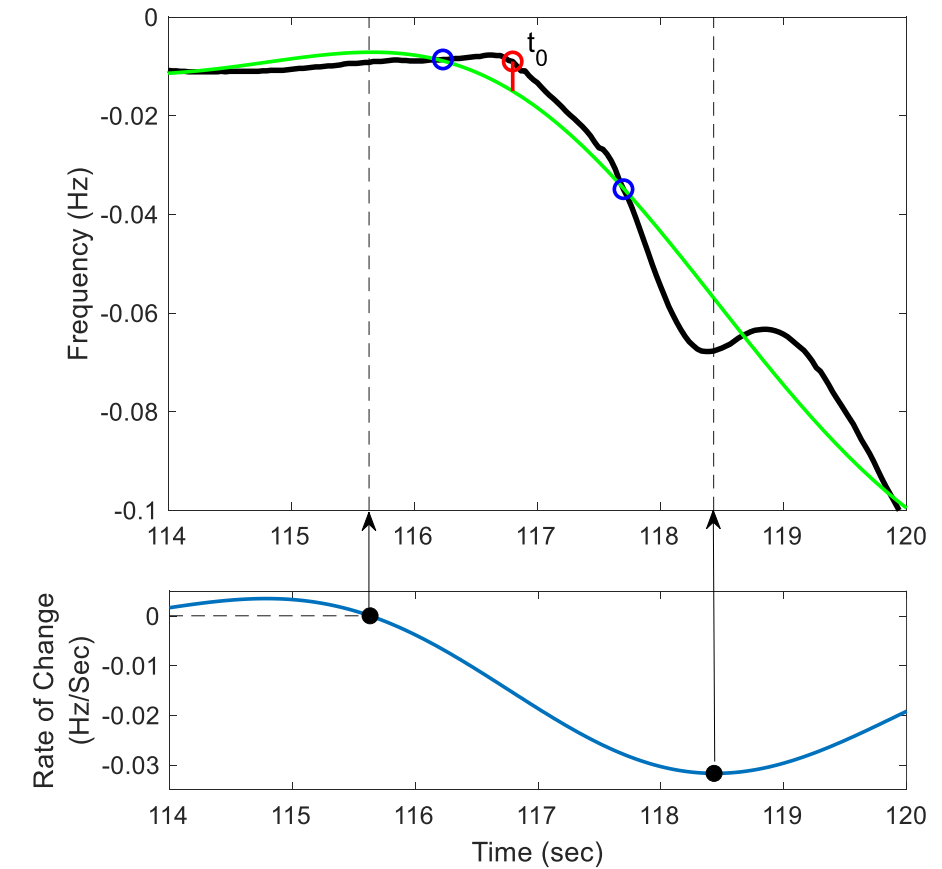
*The GESL was used to evaluate the Generator Scorecard's performance*



1. Detecting frequency excursions



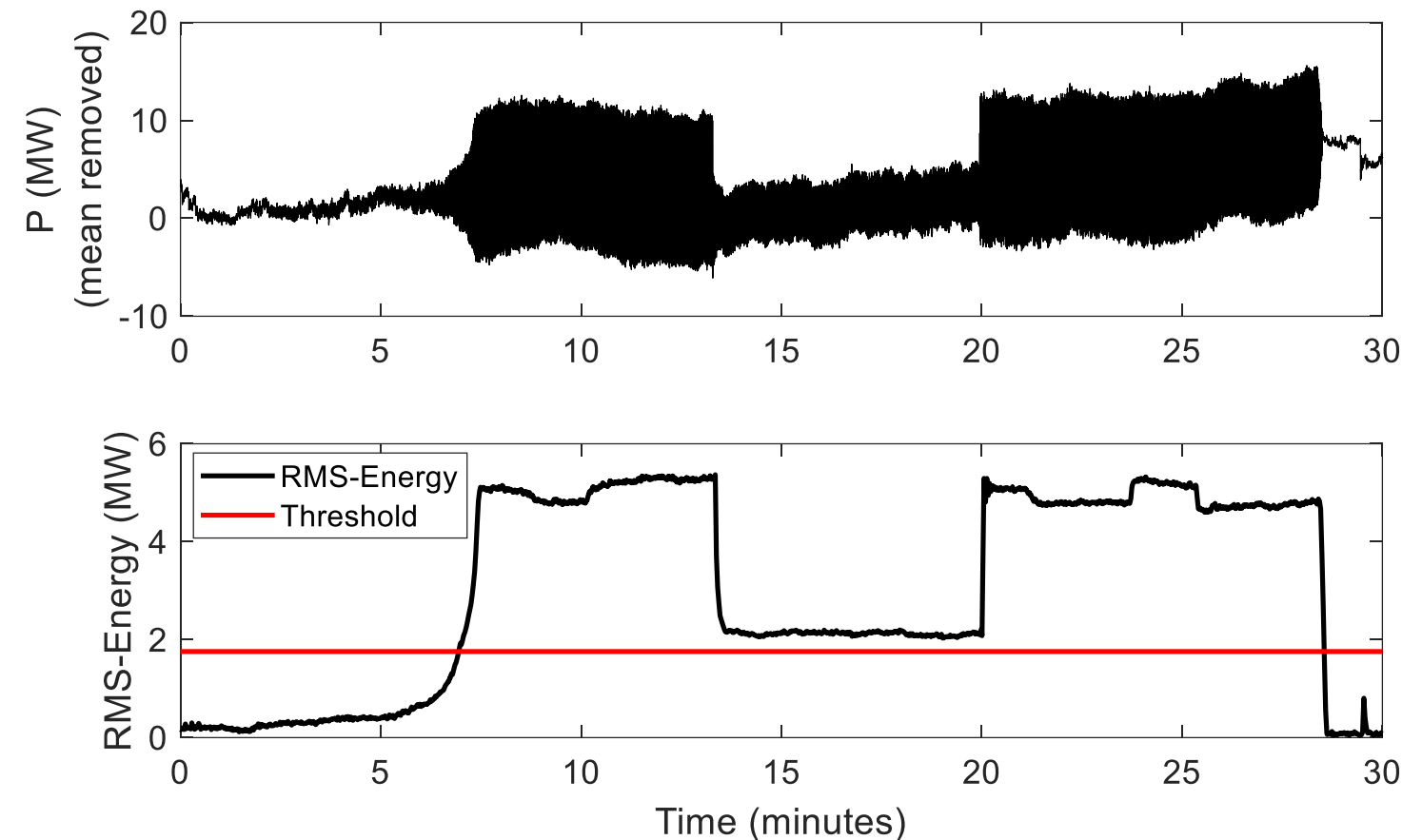
2. Excluding events unsuitable for analysis, e.g., transients



3. Estimating the event's start time

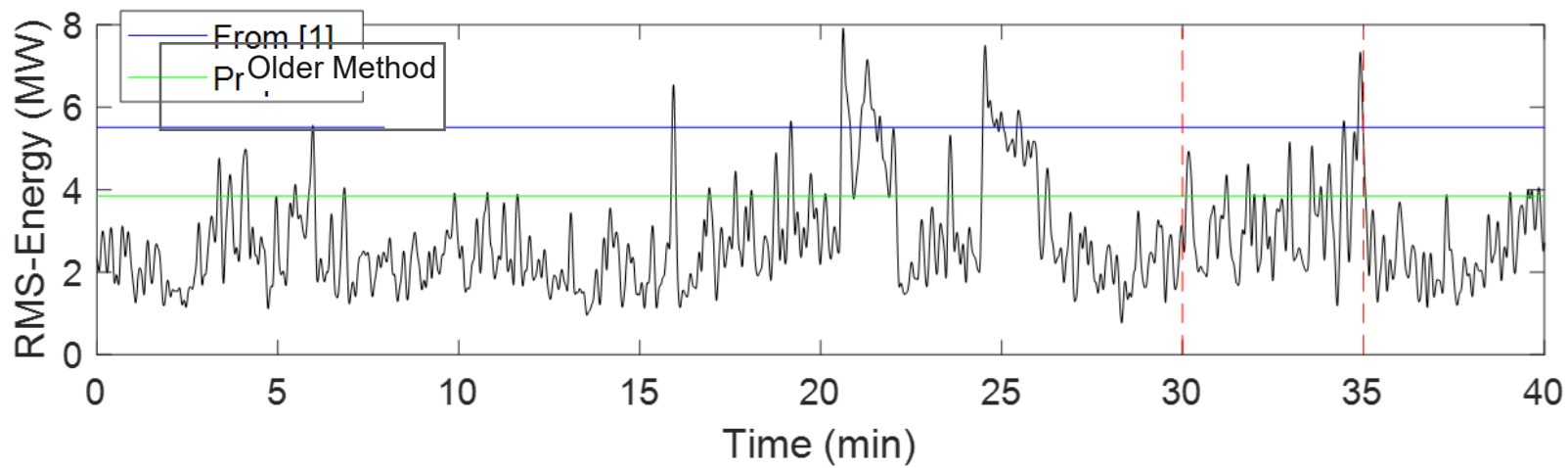
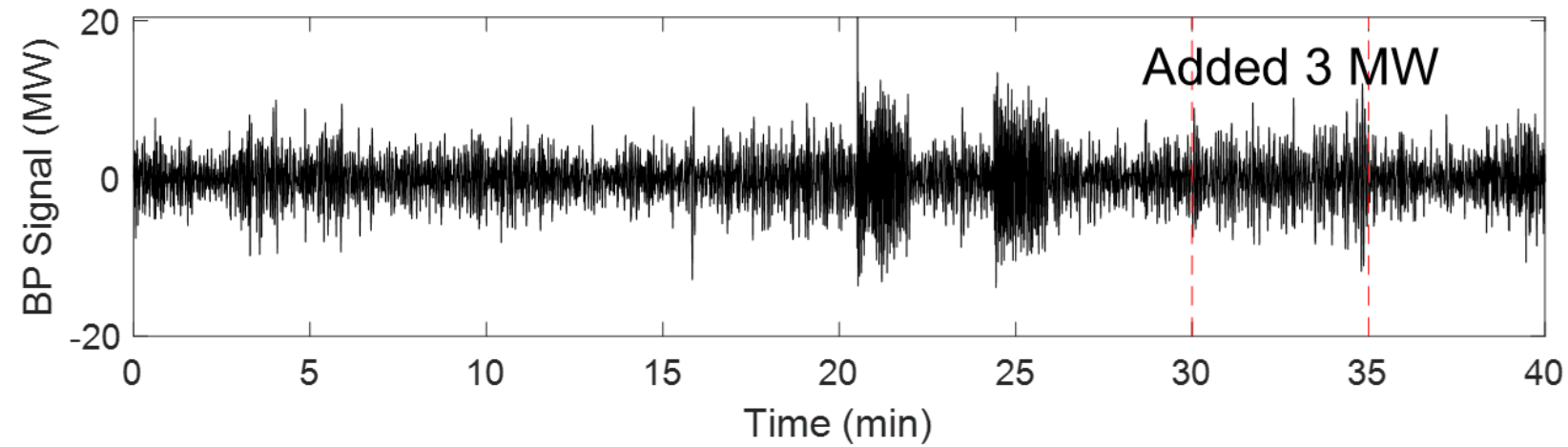
# Success Story: Oscillation Detection

- Utilities have commercial tools to detect sustained oscillations that can threaten system reliability
  - PMU data is used to calculate the RMS-energy in the input signal
  - An increase in energy indicates the presence of an oscillation
- PNNL developed threshold design methods to balance:
  - Avoiding nuisance alarms from small oscillations
  - Ensuring that large oscillations are detected reliably
- Oscillation events in GESL were used to test the methods



- J. Follum, S. Biswas, P. Etingov, and T. Yin, "A Novel Method for Setting Meaningful Thresholds for RMS-Energy Oscillation Detectors," Hawaii International Conference on System Sciences (HICSS), 2024.
- J. Follum, S. Biswas, T. Ahmad, C. Black, and M. Breuhl, "A Bootstrapping Approach to Setting Thresholds for RMS-Energy Oscillation Detectors," 2025 IEEE Power & Energy Society General Meeting (PESGM), Austin, TX, USA, 2025.
- J. Follum, S. Biswas, C. Black, and M. Breuhl, "An Amplitude-Based Threshold Design Process for Reliable RMS-Energy Oscillation Detectors," Hawaii International Conference on System Sciences (HICSS), 2026.

# Success Story: Oscillation Detection

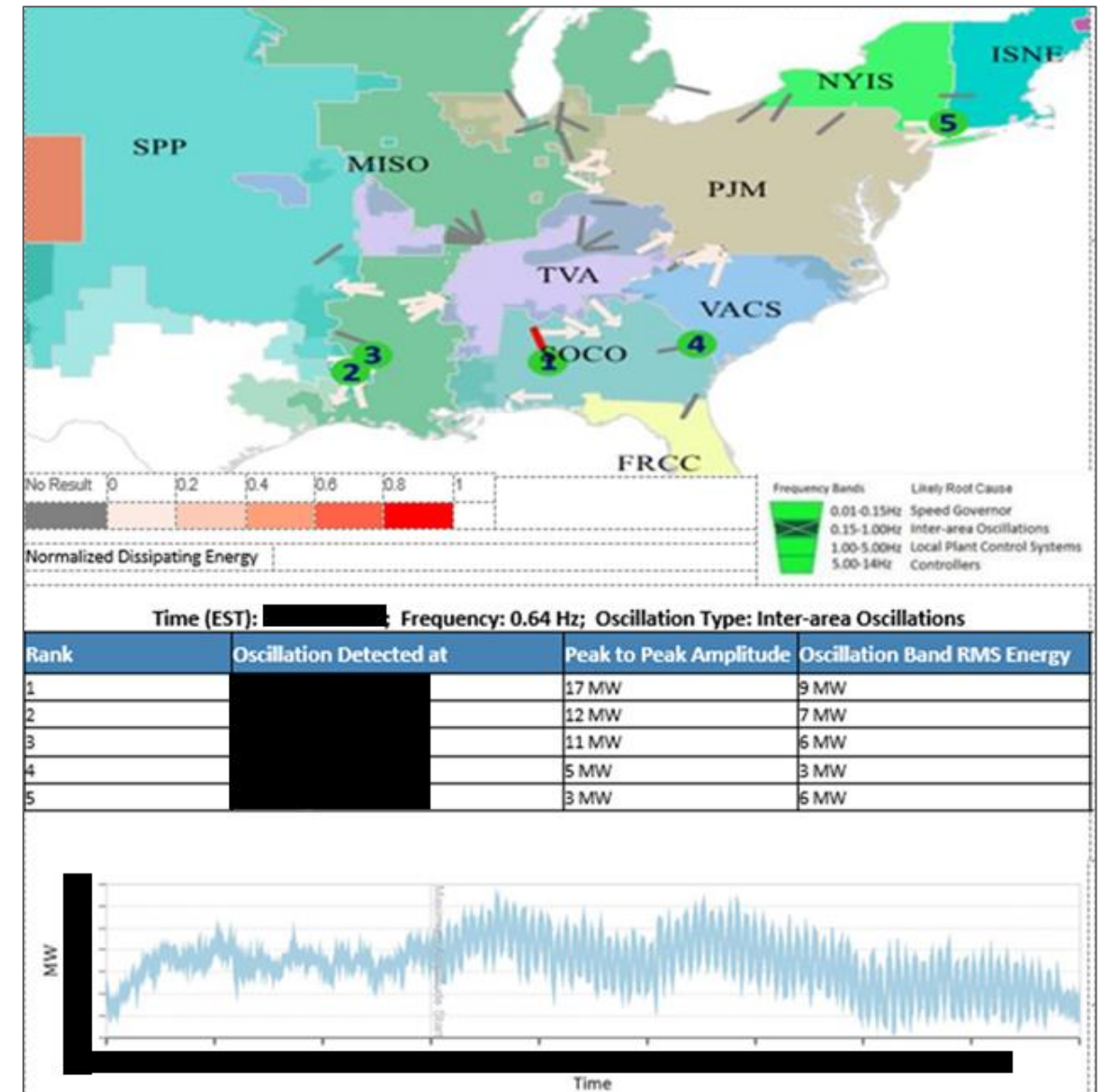


Expected Performance:

Amplitude (MW)	Detection (%)
3	< 0.1
7	≈ 50
9	≈ 90
12	≈ 99.9

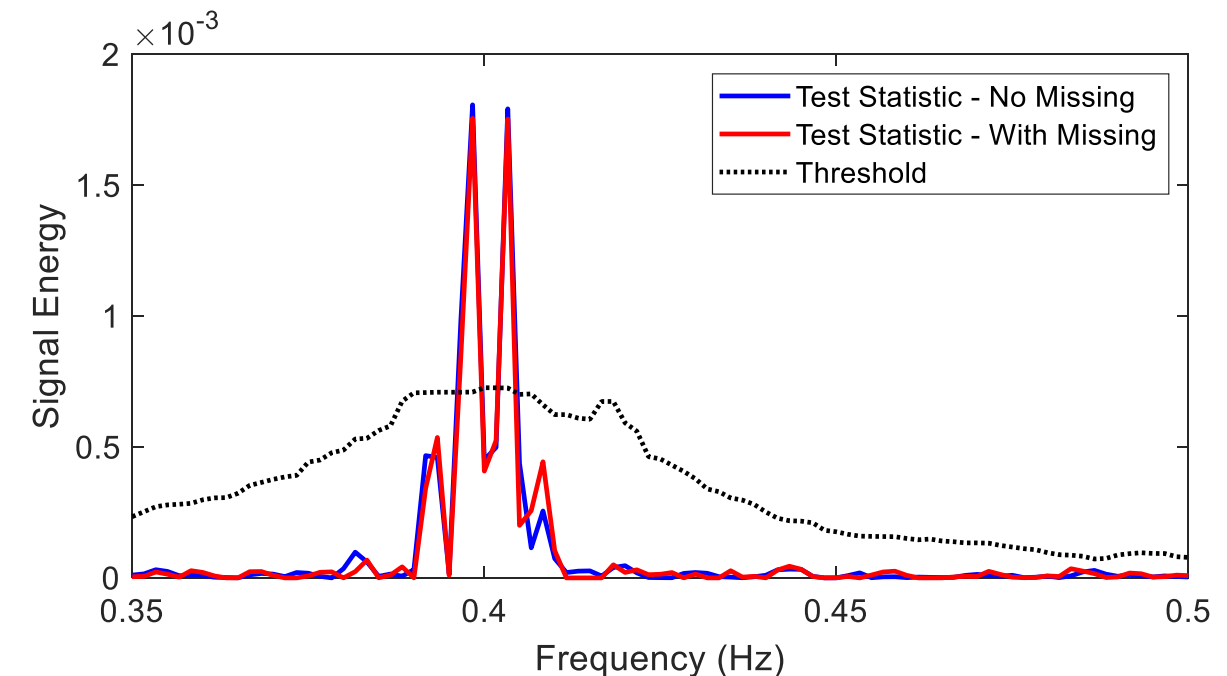
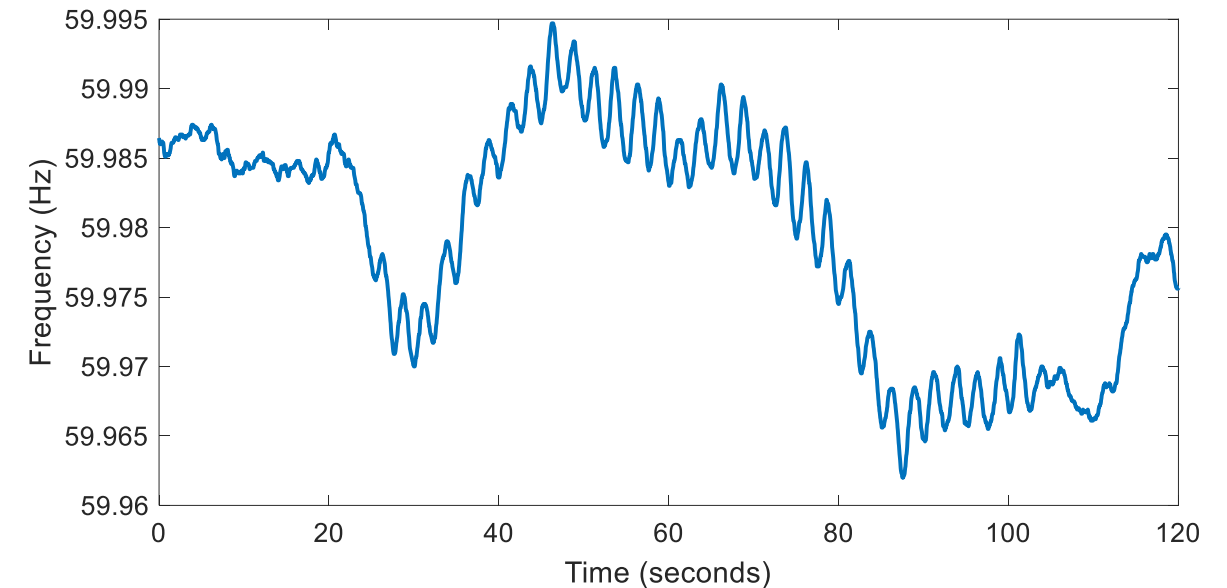
# Success Story: Impact of Missing Data

- The Eastern Interconnection Situational Awareness Monitoring System (ESAMS) provides grid operators with a common view of oscillations impacting a wide area
- The approach to addressing missing data in the 10-minute analysis window was conservative:
  - Linear interpolation
  - Signals with more than 10 seconds missing were discarded
- PNNL used GESL data to develop and test a more robust approach



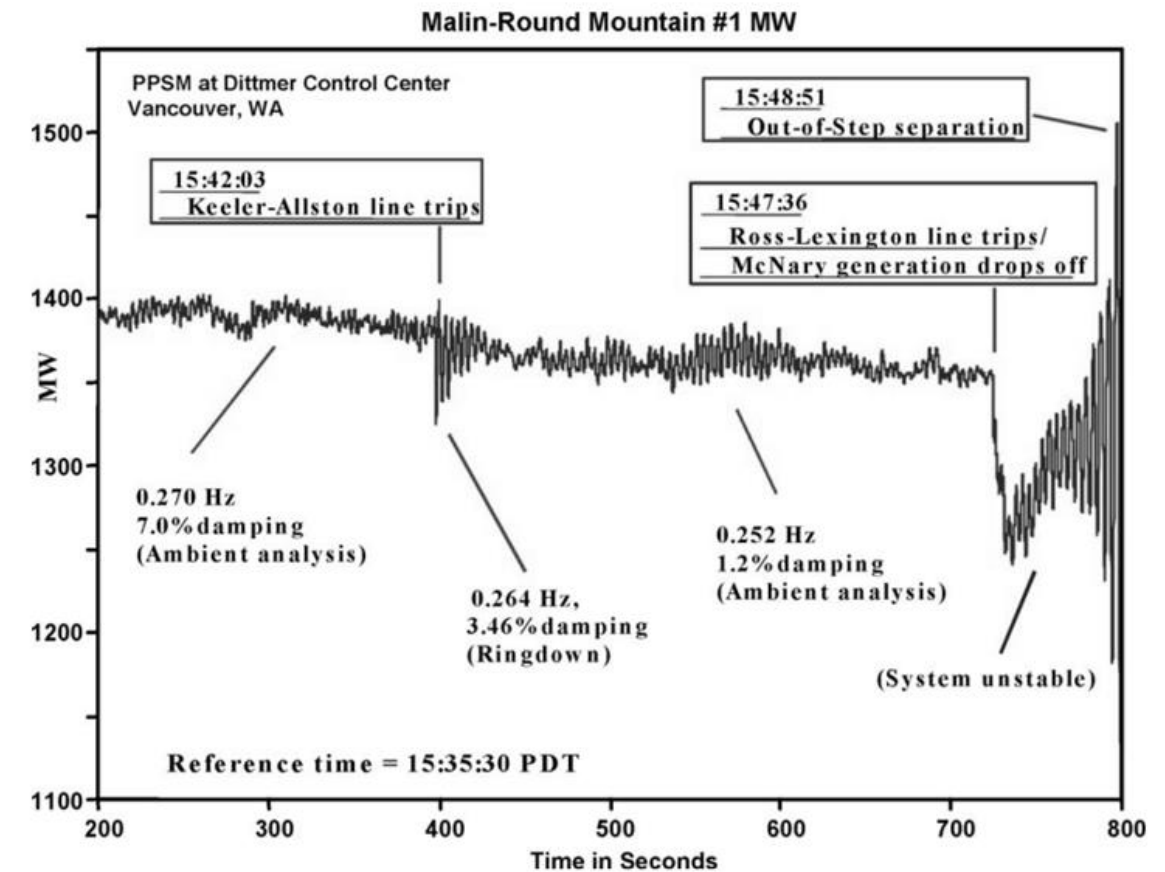
# Success Story: Impact of Missing Data

- The new method uses a combination of methods to handle missing data:
  - Linear interpolation faithfully recreates scattered missing samples
  - An approach based on the Modified Correlogram ignores blocks of missing data, rather than trying to recreate them
- GESL testing
  - 10-minute analysis window corrupted with 45 seconds of scattered missing data and an addition 45-second block of missing data
  - The performance of the oscillation detector is maintained

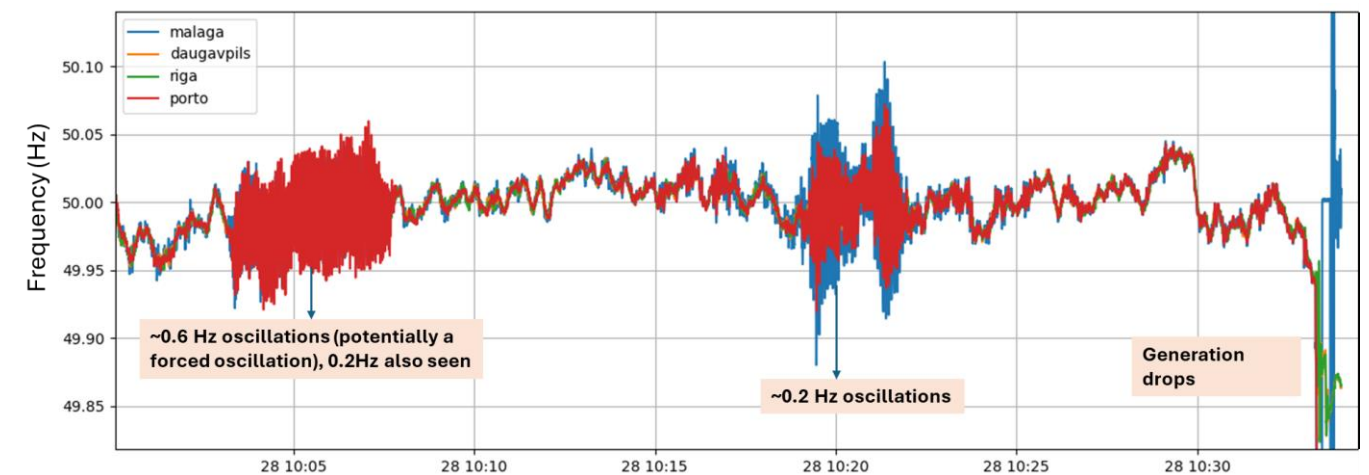


# Success Story: Stability Monitoring

- Generators in different parts of the system tend to oscillate against each other
- Contingencies can make the system unstable, leading to growing oscillations
- The modes of oscillation in the western power system have been studied for decades, but much less is known about the Eastern Interconnection
- The National PMU Dataset provides the necessary wide-area view

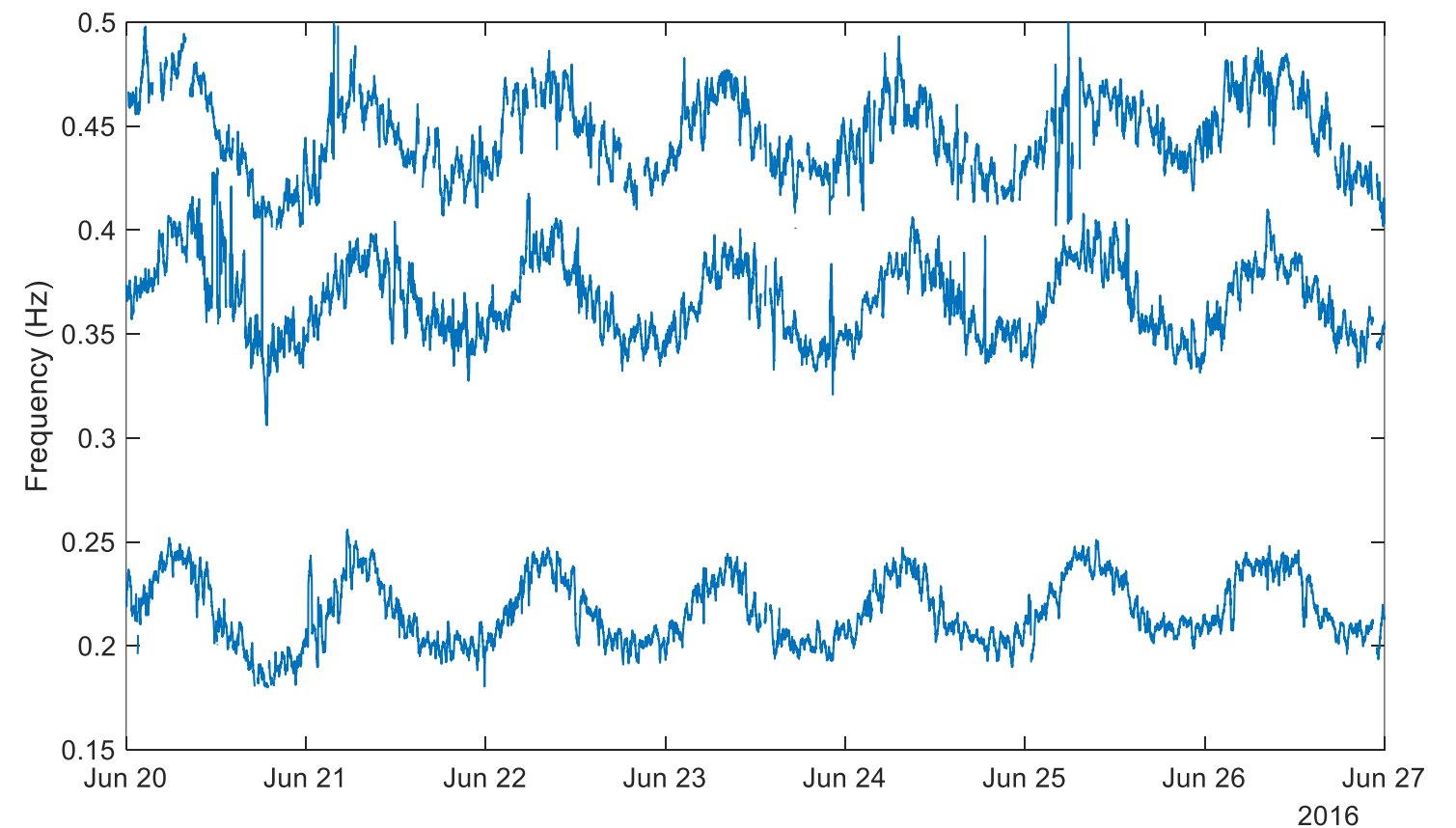
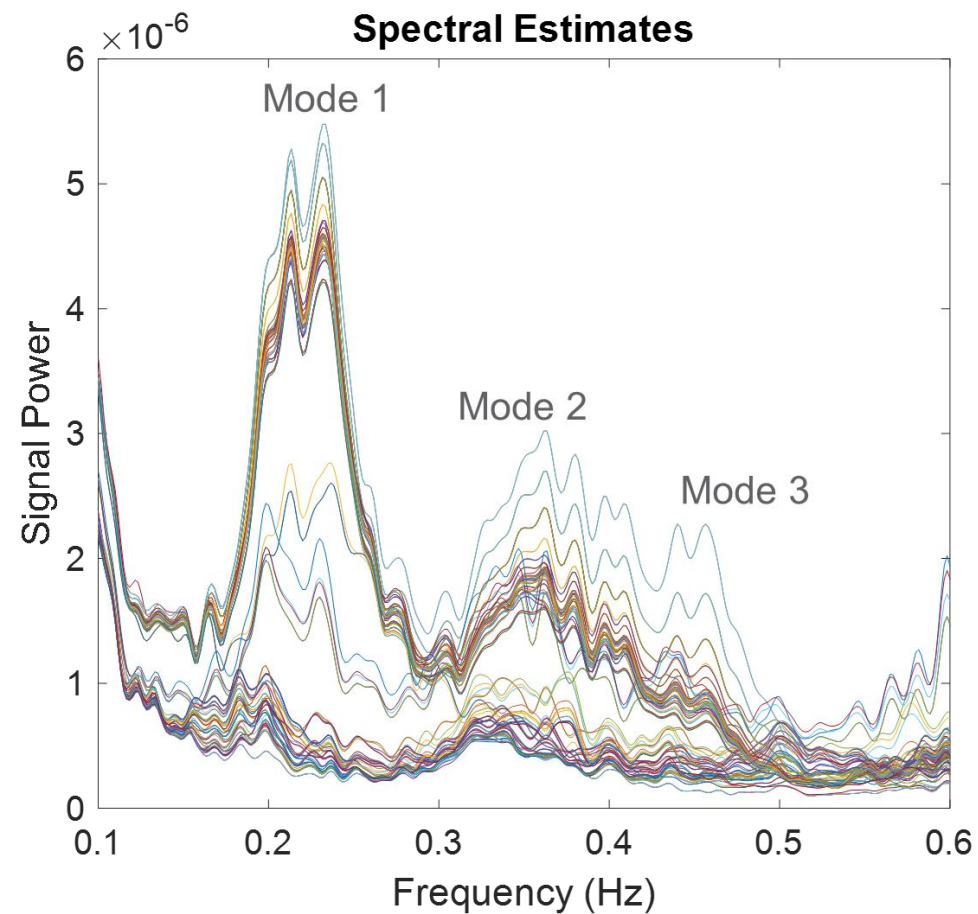


D. J. Trudnowski et al, "Performance of Three Mode-Meter Block-Processing Algorithms for Automated Dynamic Stability Assessment," in IEEE Transactions on Power Systems, vol. 23, no. 2, pp. 680-690, May 2008, doi: 10.1109/TPWRS.2008.919415.



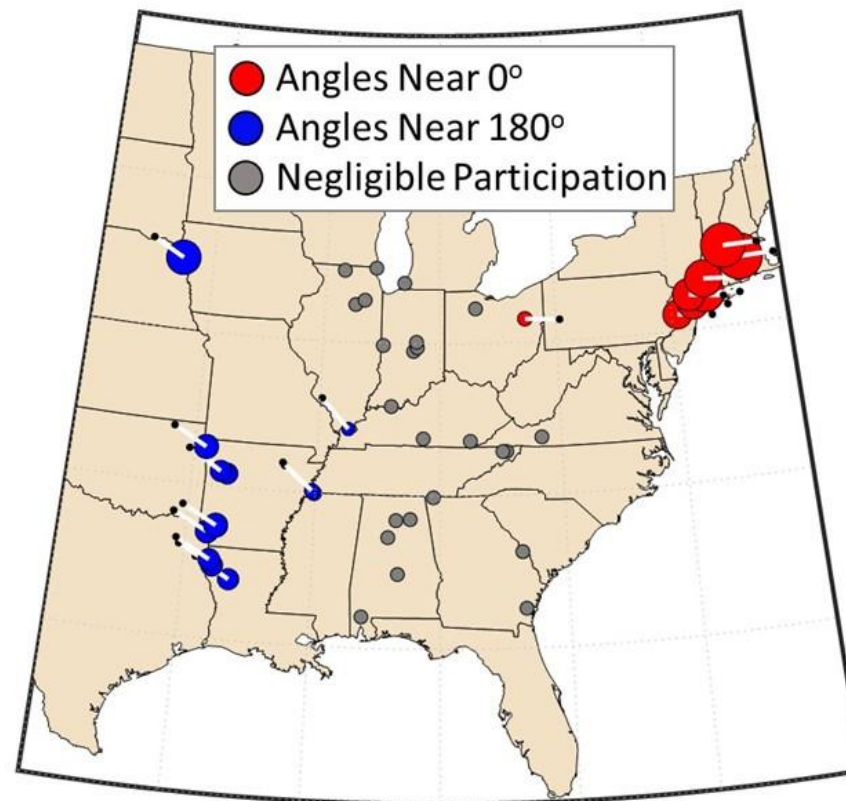
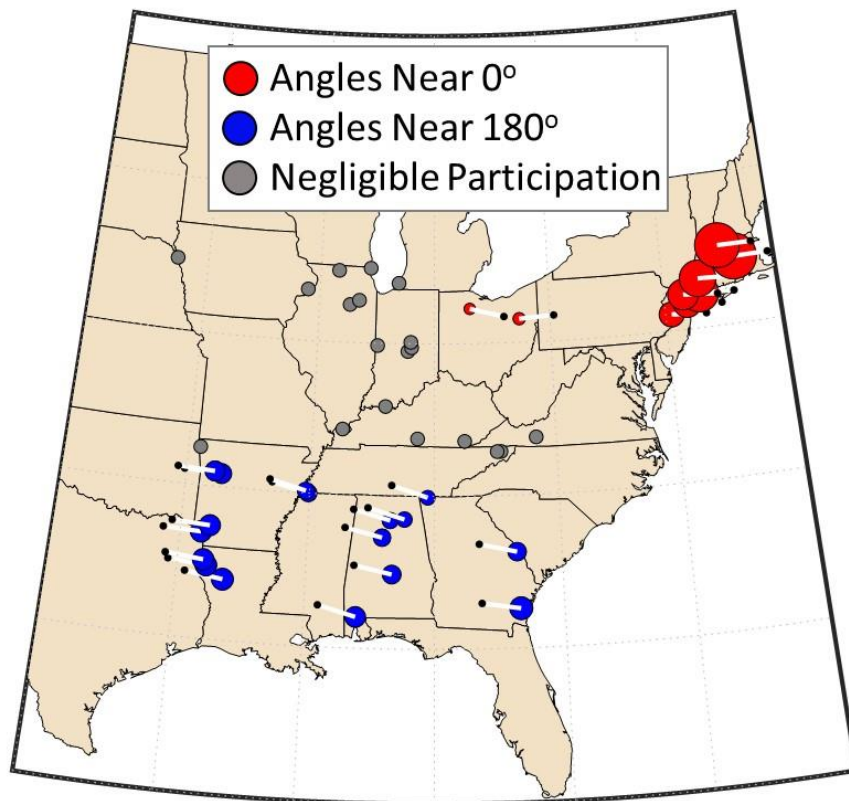
# Success Story: Stability Monitoring

The National PMU Dataset was used to identify modes of oscillation and configure monitoring algorithms



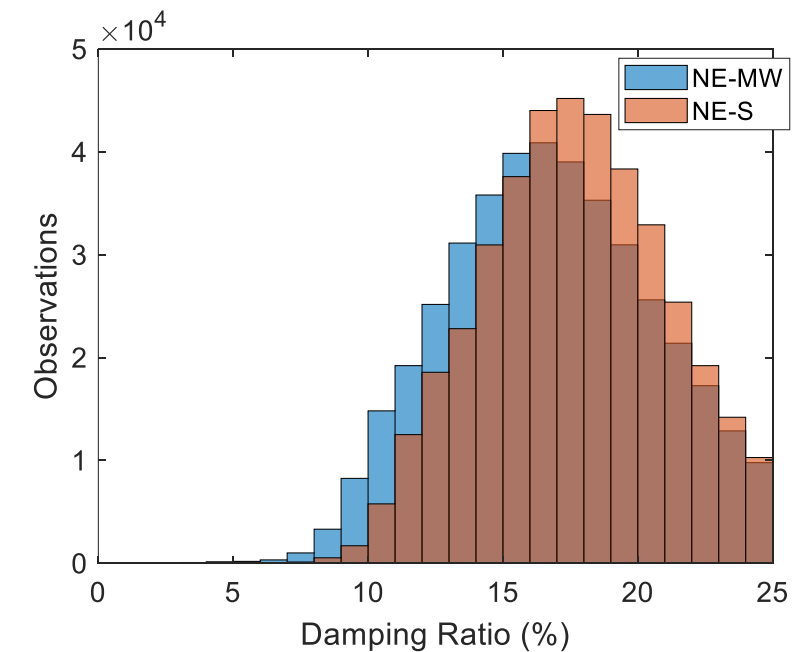
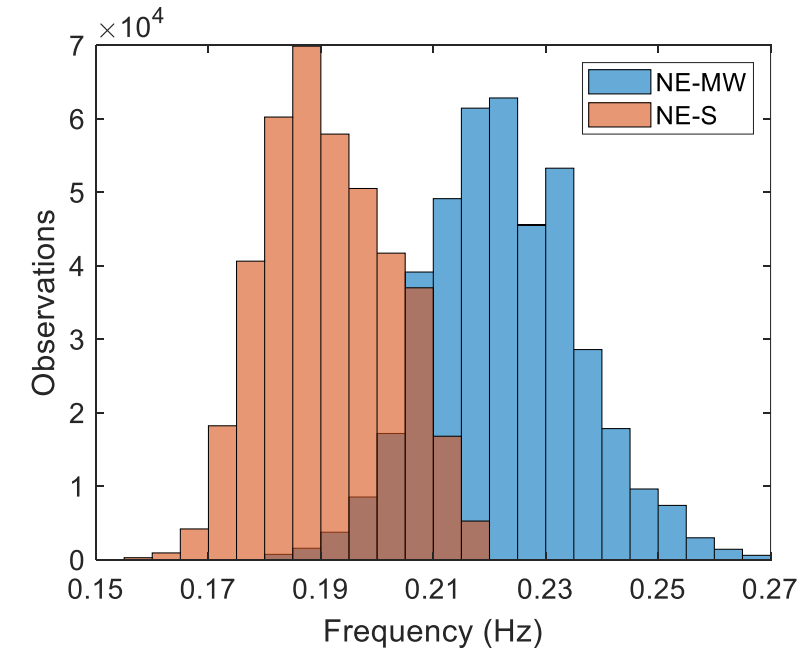
# Success Story: Stability Monitoring

The monitoring algorithms were later deployed in ESAMS, marking the first time eastern interconnection modes had been continuously tracked.



## Best Paper

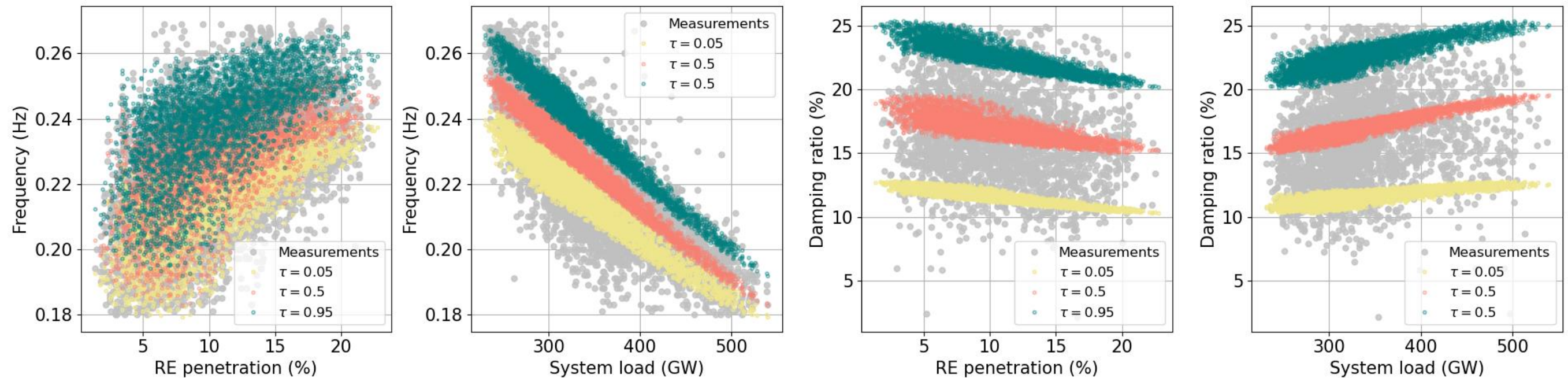
*Hawaii International Conference on System Sciences, 2023*



# Success Story: Stability Monitoring

**Best Paper**

*International Conference on Smart Grid Synchronized Measurements and Analytics, 2024*



We tracked how the mode properties varied with system operating conditions and found evidence that the frequency and damping ratio of one mode varied with instantaneous non-synchronous generation penetration.

Biswas, Shuchismita, and Jim Follum. "A data-driven exploration of the impact of renewable energy on inter-area oscillations in the US eastern interconnection." *2024 International Conference on Smart Grid Synchronized Measurements and Analytics (SGSMA)*. IEEE, 2024.

## Conclusion

- **EIOC as the backbone:** Enabled curation and operationalization of the National PMU Dataset
- **NPDS as a strategic asset:** A unique PNNL capability powering data-driven grid research and insights. The possibilities are endless.
- **What's next:** Strengthening accessibility through improved documentation and robust data governance



**Thank you**

