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Update on PNNL's Oscillation and High-Speed Measurement Research

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U.S. DEPARTMENT OF ENERGY BATTELLE

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

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Topics

- Natural Oscillations
  - Transient-robust mode meter implementation in SEL's Synchrowave Operations
- Forced Oscillations
  - Eastern Interconnection Situational Awareness Monitoring System (ESAMS) co-developed with Electric Power Group (EPG)
- High-Speed Measurements
  - Plans for a distributed IBR monitoring platform built by GPA

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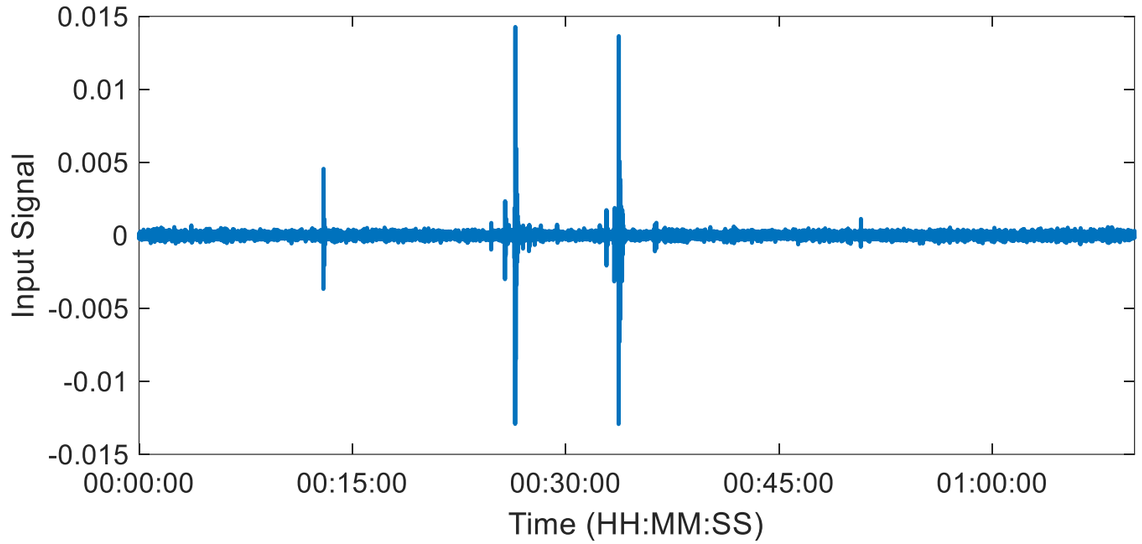
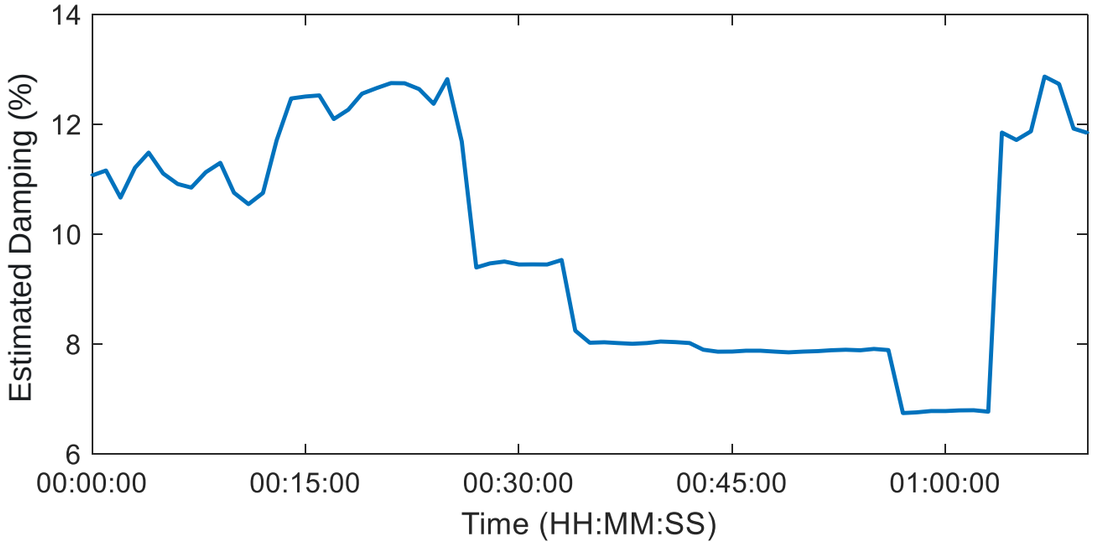
Transient-Robust Mode Meter

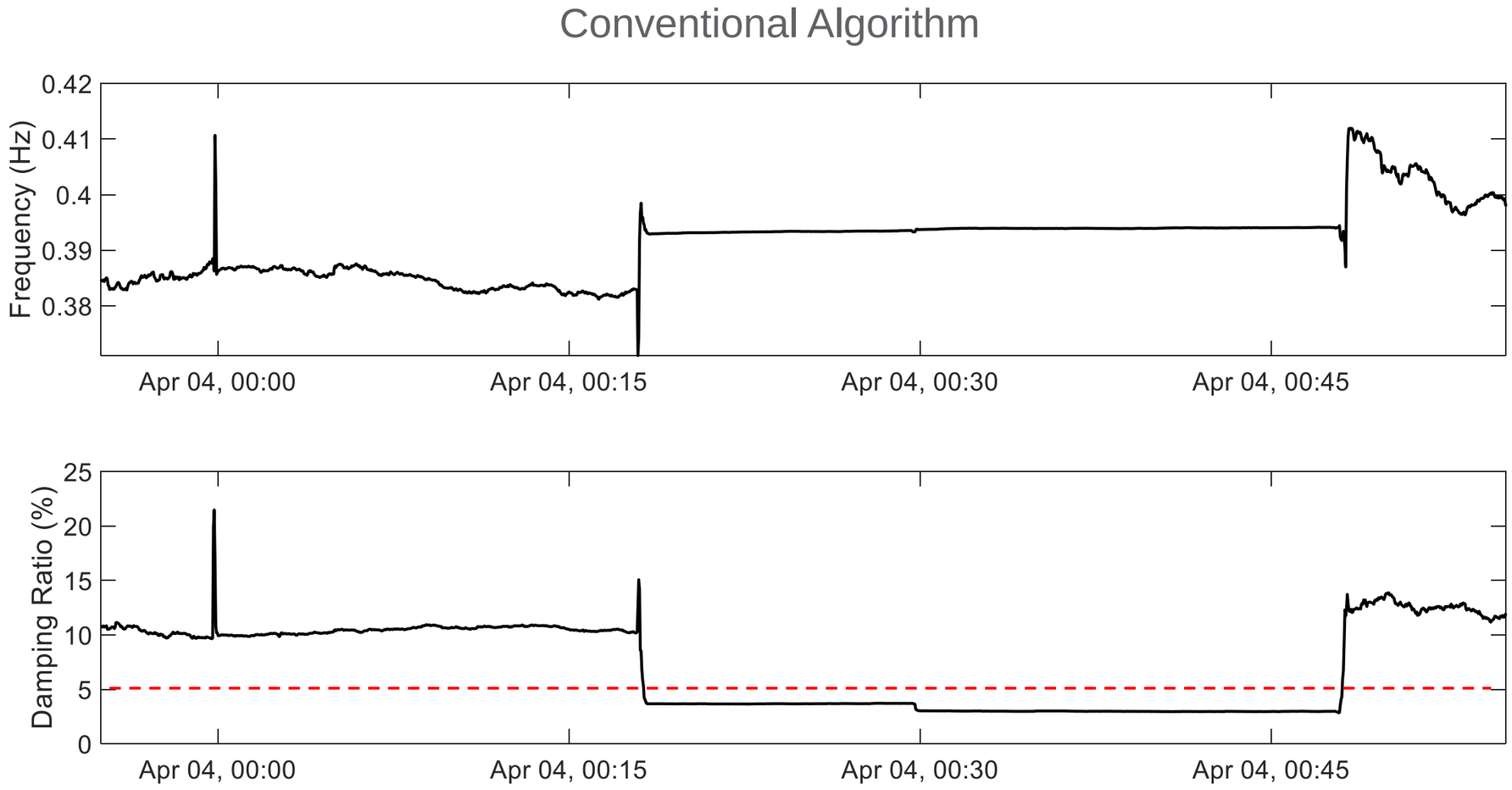
Transient-Robust Mode Meter

- Mode meters continuously track the power system's small-signal stability margin
- BPA identified bias in mode meter estimates following system disturbances
- PNNL developed a modification to address the problem
- SEL implemented the modification in Synchrowave Operations





Example



Note: data was replayed; timestamps do not correspond to actual events

Historical Data
15 16 17 18 19 20 21 22 23 00 01
4/4
1x

Historical Data
1h
Hour Chart Range

User + | Frequency | Angle | Power
General | Oscillation | Voltage | All

Dashboards
MMresults2 MMresults
+ Panel + Dashboard

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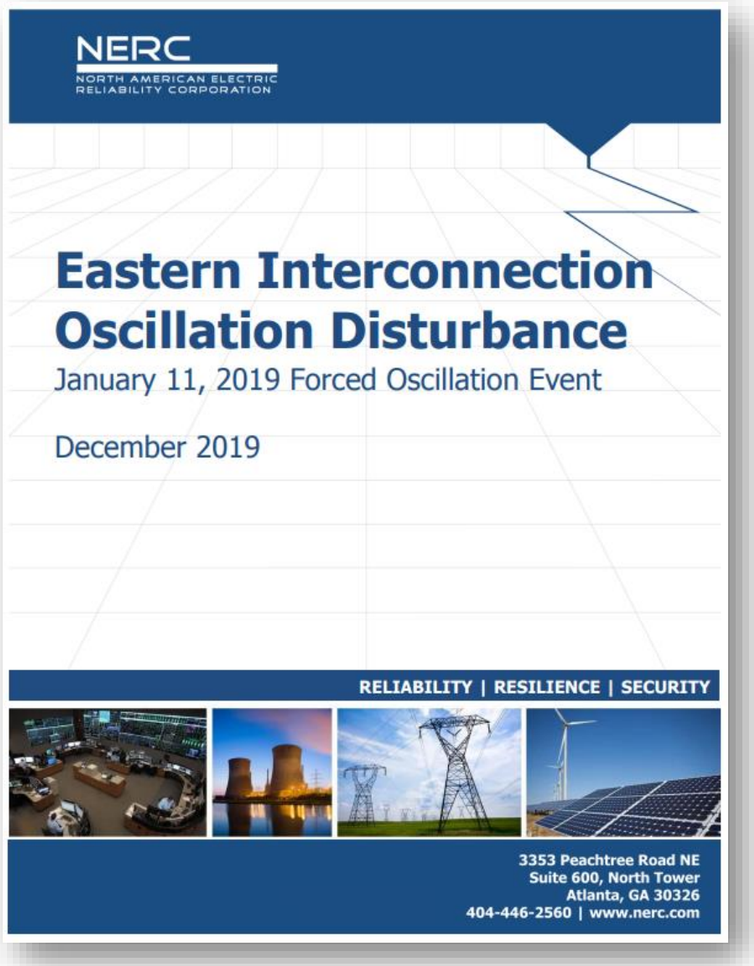
Eastern Interconnection Situational Awareness Monitoring System (ESAMS)

Eastern Interconnection Situational Awareness Monitoring System (ESAMS)

- Developed to:
  - Introduce a common, high-level interconnection-wide view based on synchrophasor information
  - Meet the need for improved coordination among Reliability Coordinators (RCs)
- Developed by Electric Power Group (EPG) and PNNL with leadership from Joe Eto at LBNL

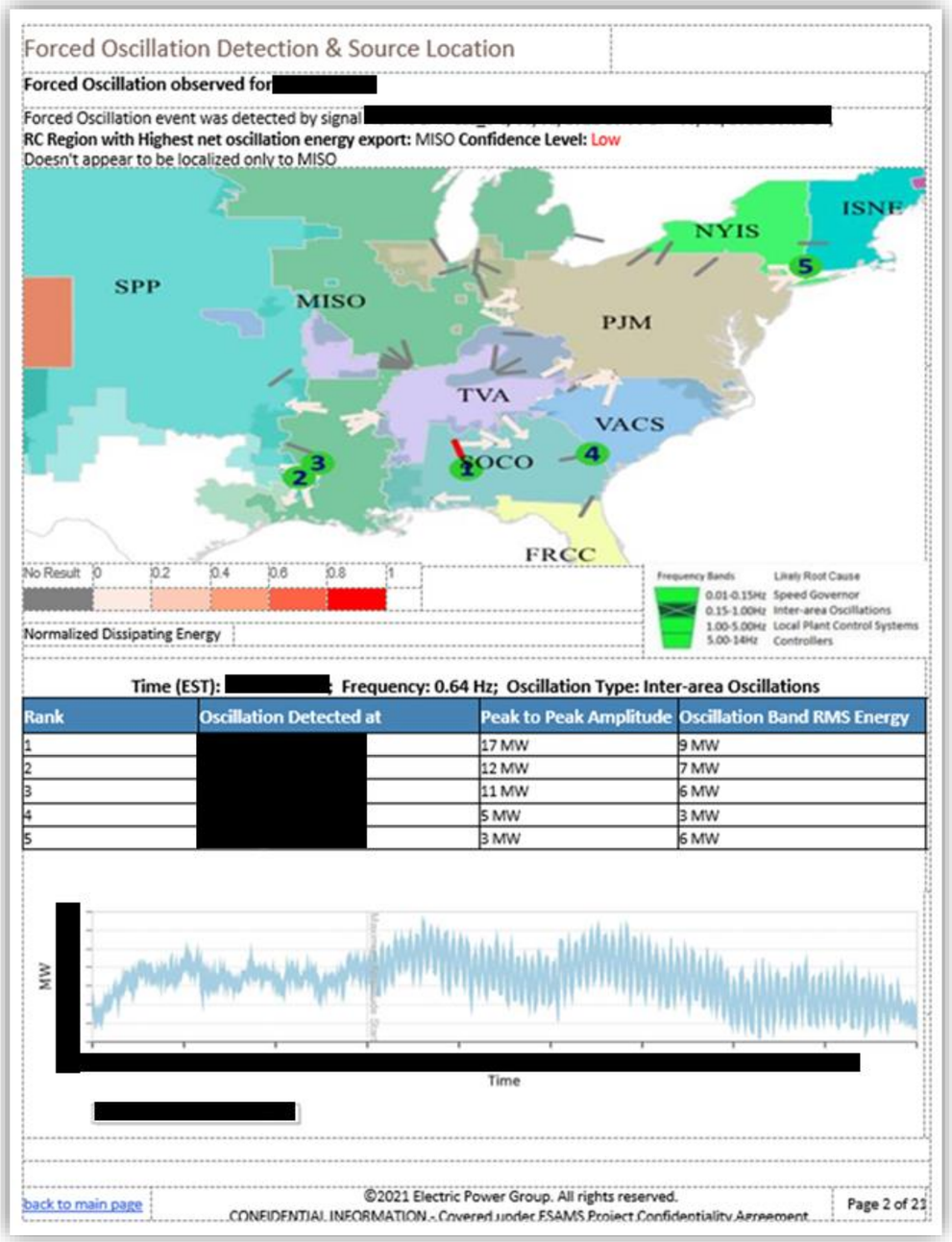
"RCs should consider jointly developing interconnection-wide oscillation detection and source location applications…"



https://www.nerc.com/pa/rrm/ea/Documents/January_11_Oscillation_Event_Report.pdf

Initial Demonstration

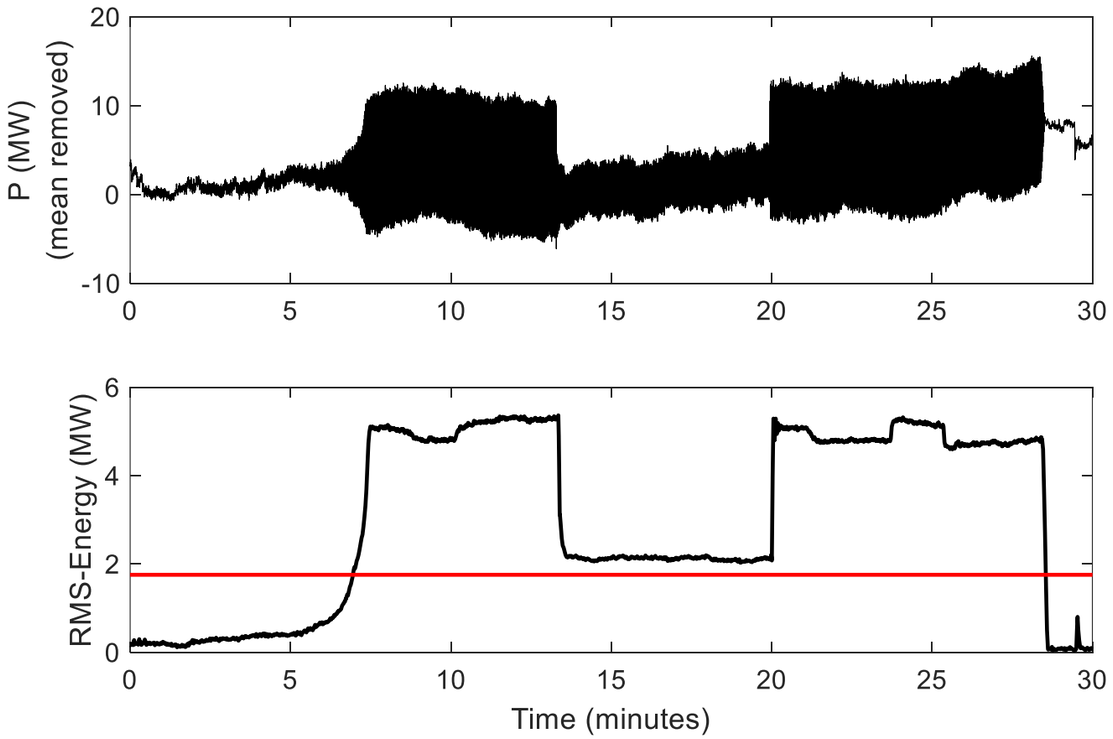
- Hosted by PJM between June 2021 and March 2022
- Daily event reports distributed to seven reliability coordinator participants
- Real-time notifications for oscillations with amplitudes greater than 10 MW
- Identified research topics
  - Reducing configuration burden for many measurement locations
  - Ensuring real-time notifications are actionable
  - Value within a system operator's territory
  - Hosting options for long-term interconnection-scale deployment



Example of a daily report showing a large forced oscillation

Current Southern Company Deployment

- ESAMS deployed using two complementary oscillation detection systems:
  - PNNL's oscillation analysis engine
  - EPG's Real Time Dynamics Monitoring System (RTDMS)
    - ➢ Utilizes the RMS-energy detector
- Research topic: Configuring RMS-energy thresholds with minimal baselining and predictable performance
- New process has significantly reduced nuisance alarms



Thresholding Process

- Applied to two days of PMU data
- Bootstrapping
  - Build AutoRegressive (AR) models of each signal
  - Resample: generate many trials of synthetic ambient data for each model
  - Evaluate probability of detection at various oscillation amplitudes
- Choose threshold to avoid nuisance alarms
  - 3 MW oscillation → 0.1% probability of detection
- Summarize performance with additional probabilities of detection for each signal:
  - 9 MW → 50%
  - 11 MW → 90%
  - 15 MW → 99.9%

Next Deployment: Cloud ESAMS

- Potential advantages of the cloud
  - Avoids a single reliability coordinator having to host
  - Avoids multiple deployments with data exchanges among all participants
  - Readily expandable
- Plan
  - ESAMS will be deployed in ISO-NE's Amazon Web Services cloud environment
  - PMU data streamed from ISO-NE and PJM
  - Considered regions: ISO-NE, NYISO, PJM
  - 6-month demonstration to begin in coming months
  - If successful, additional participants will be invited to join
- Progress
  - Networking and application architecture designed
  - Successful coordination between ISO-NE and PJM for data sharing and cloud hosting
  - Input signals selected
  - ISO-NE has provisioned AWS accounts

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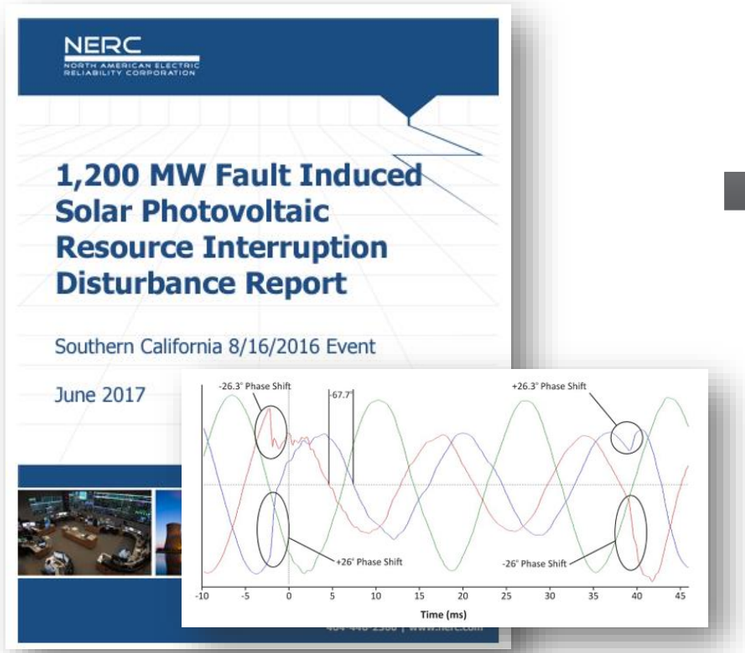
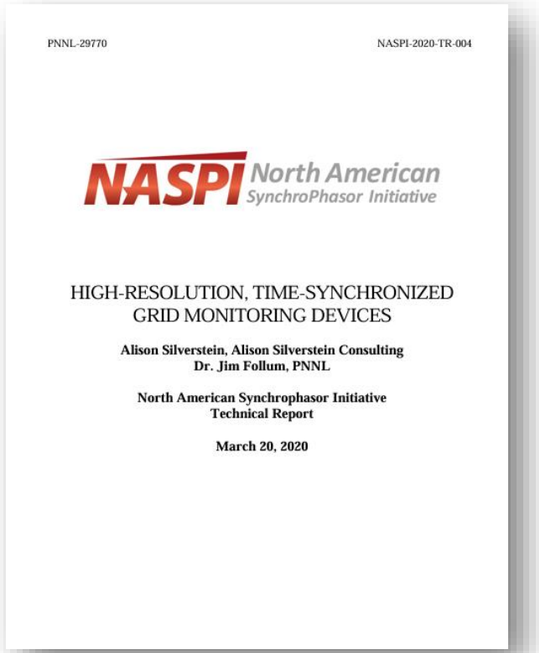
Distributed High-Speed Measurement Platform for IBR Monitoring

Background and Motivation

- The Blue Cut Fire event highlighted the potential for reliability issues related to high-speed IBR behavior
- The North American SynchroPhasor Initiative (NASPI) working group identified high-speed point-on-wave (POW) measurements as a key technology for addressing these challenges



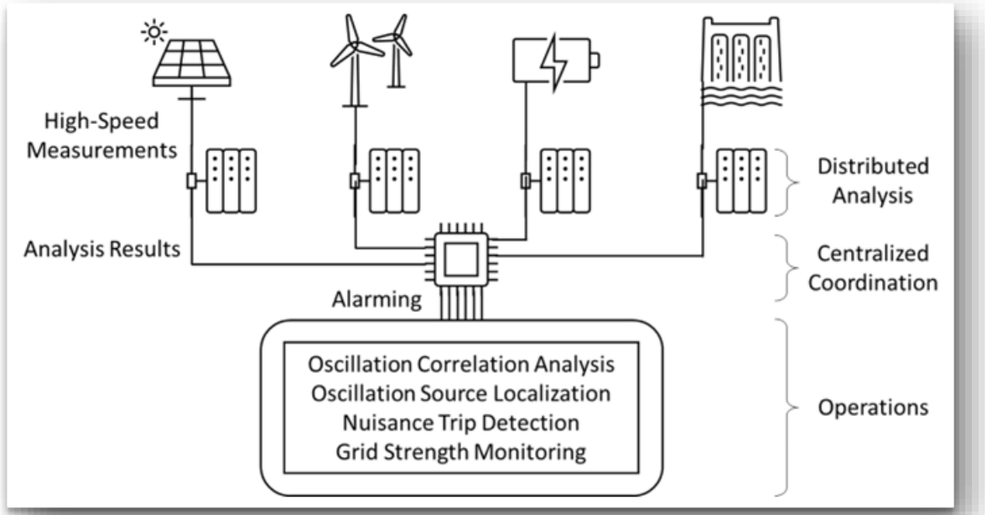


Background and Motivation

- A 2023 gap analysis found that seven years after the Blue Cut Fire event, utilities still have limited ability to use POW measurements for IBR integration
  - POW measurements typically only collected after specific triggering conditions, such as a fault
  - Continuous streaming prevented by expensive communication upgrades
  - Deploying specialized equipment in multiple substations for distributed applications is impractical
- These findings motivated the Wave Apps project

Wave Apps

- Objective: Develop and demonstrate a distributed measurement-based platform that enables operators to monitor and mitigate inverter-based resource (IBR) performance issues.
- Approach
  - Wave Apps consists of a central platform and distributed instances
  - POW measurements are analyzed within substations by distributed instances
  - Analysis results are streamed to the central platform for coordination, alarming, and visualization
  - Streaming will be comparable to a PMU, so existing networks can be used
  - Four high-value applications will be developed and demonstrated
  - The platform will be extensible to allow additional applications



Field Demonstration

- A three-month capstone demonstration will be performed at Salt River Project (SRP) in 2027
- Measurement hardware and substation computers to host distributed instances will be deployed at two substations
  - Only commercially available hardware will be deployed
- The central instance will be deployed on a server at an SRP facility

Team

- Platform development
  - Dr. Christoph Lackner, GPA
- Application development
  - Dr. Shuchismita Biswas & Dr. Kaustav Chatterjee, PNNL
  - Dr. Bin Wang, University of Texas at San Antonio and ISO-NE
  - Dr. Hanchao Liu, GE Vernova
- Utility partners
  - Field demo: Salt River Project – Matthew Rhodes
  - Testbed demo: Southern California Edison – Anthony Johnson
- Advisors
  - Dr. Slava Maslennikov, ISO-NE
  - Dr. Denis Osipov, New York Power Authority

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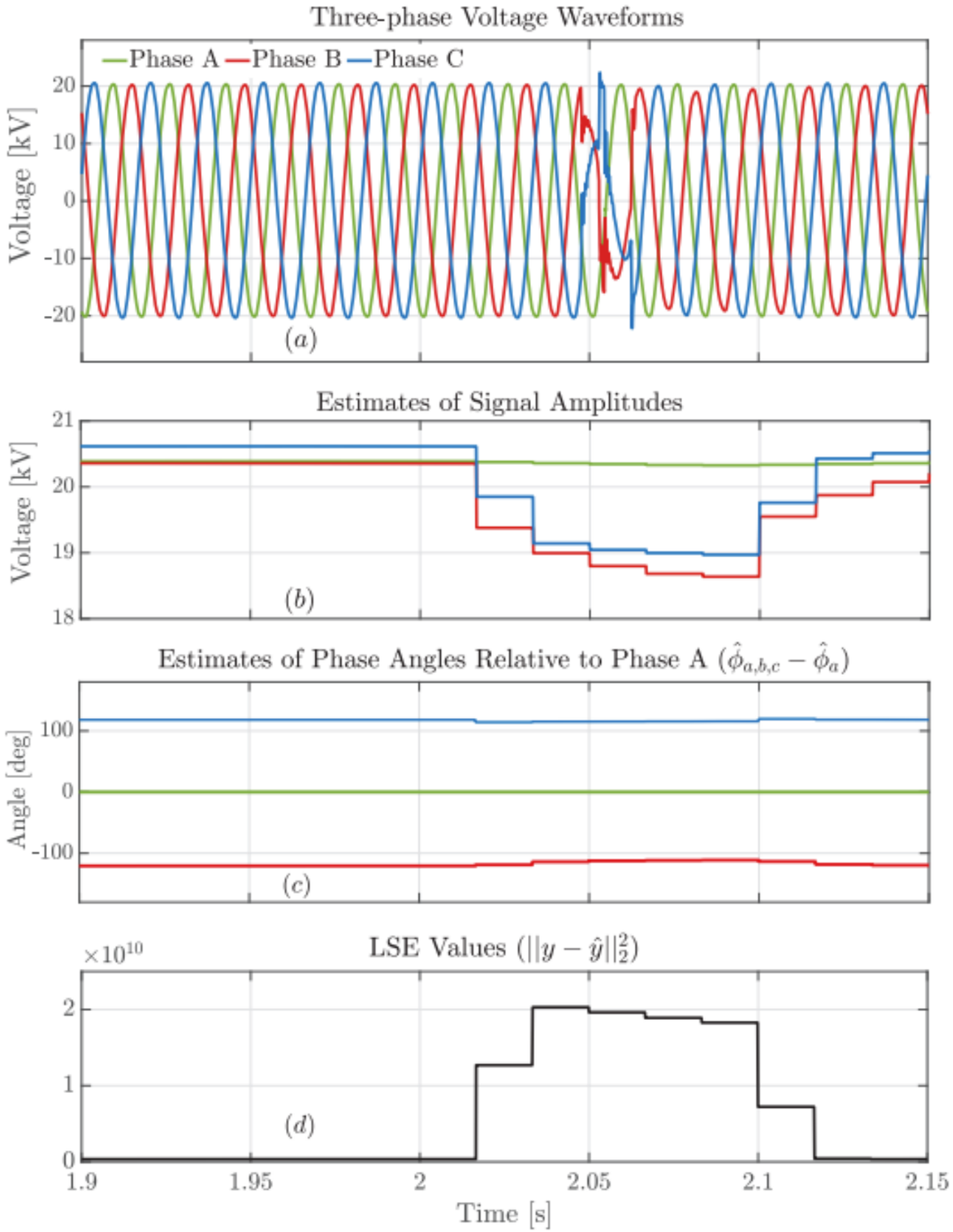
Prototype Application: PMU with Trust Metric

- For curve-fitting PMU algorithms, error between measured and modeled waveforms can serve as a trust metric
- The STTP protocol that will be used for Wave Apps offers flexibility to stream the metric along with measurements



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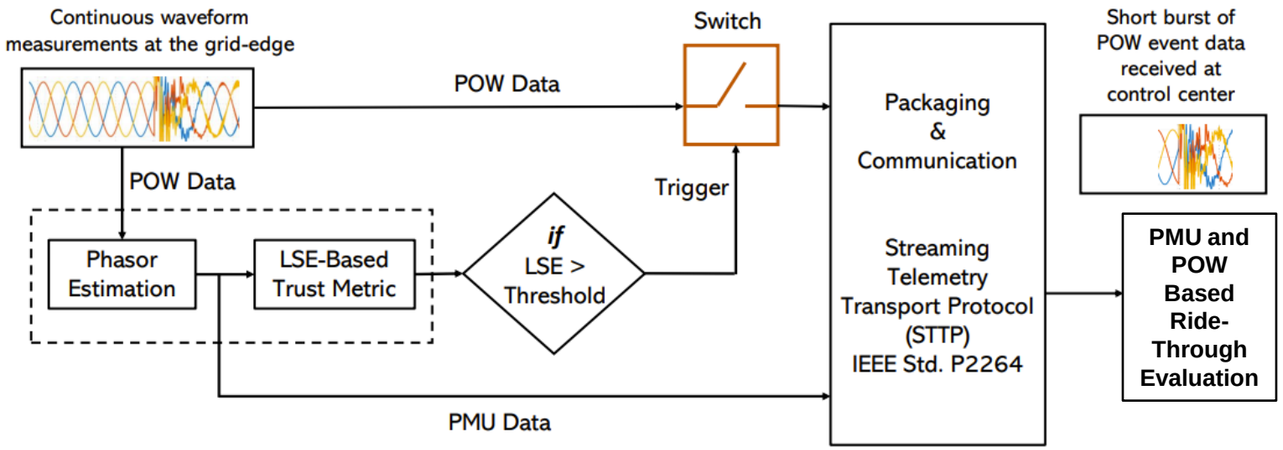
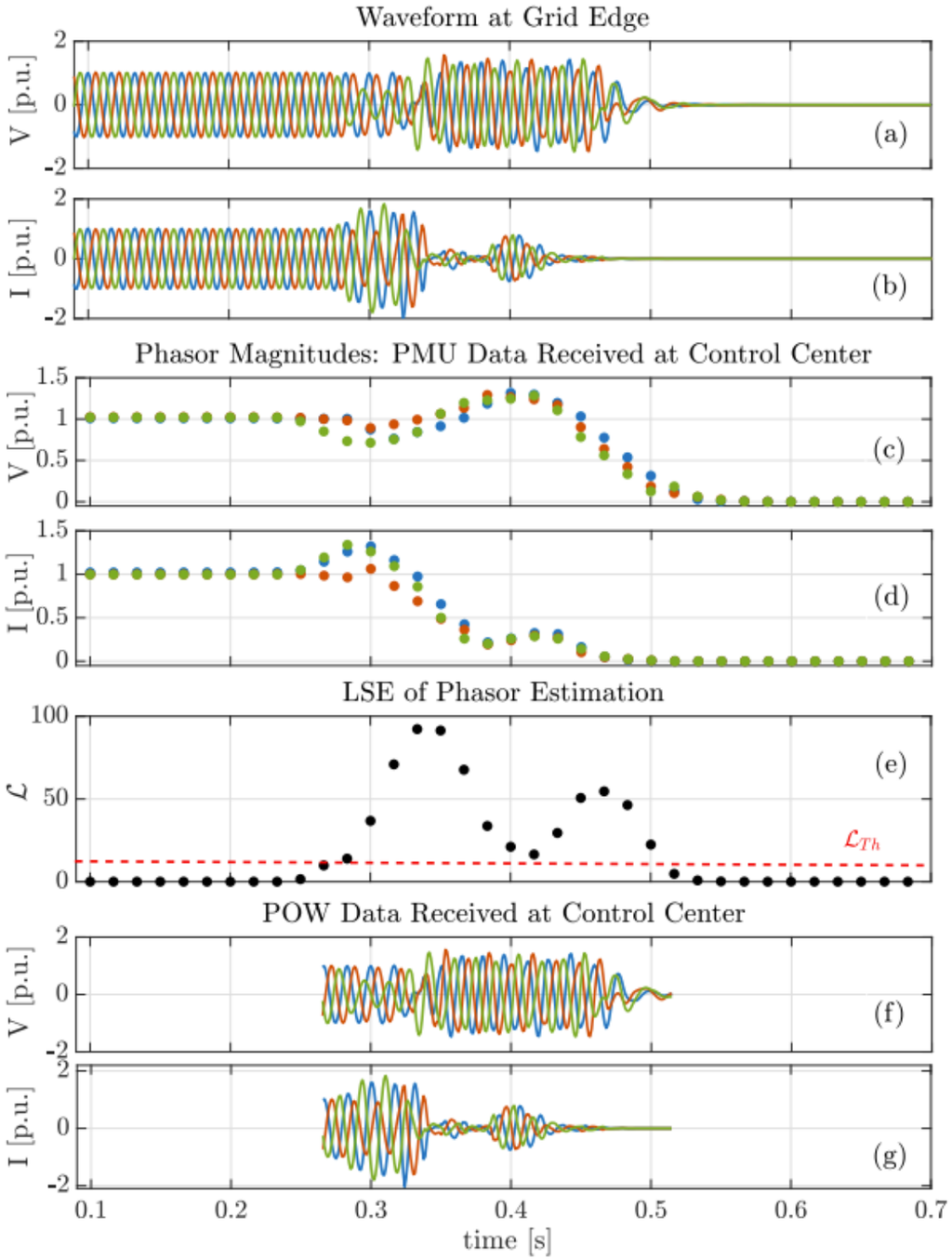
Prototype Application: Event-Triggered Streaming & Ride-Through Evaluation





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Thank you