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Distributed Waveform Analytics in the WaveApps Platform

April 14, 2025

Jim Follum, PNNL

U.S. DEPARTMENT OF ENERGY BATTELLE

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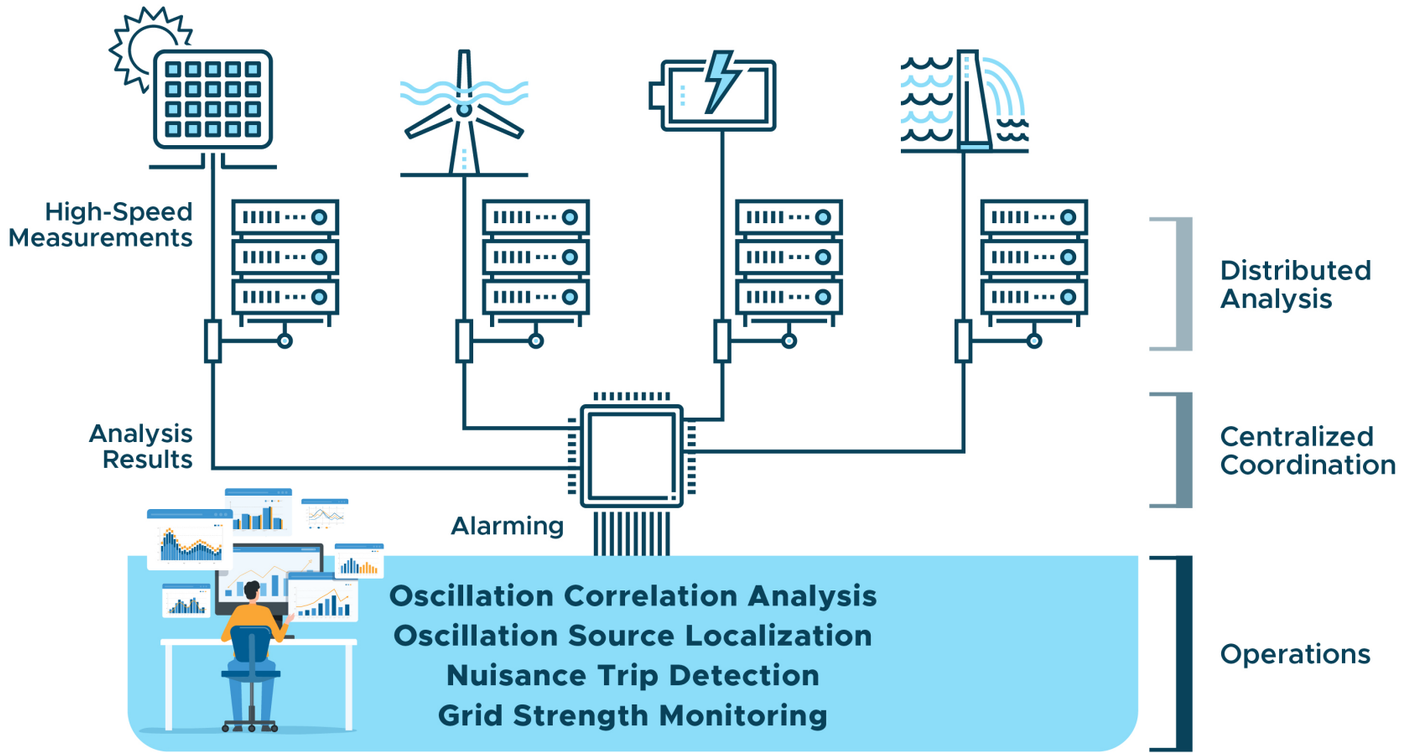
PNNL-SA-222012

Concept

- WaveApps is a distributed platform that enables wide-area monitoring based on point on wave (POW) data
- POW measurements are analyzed within substations by distributed instances
- Analysis results are then 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
- Extensible to allow additional applications



Team Roles

Project Lead

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Platform Development

GRID PROTECTION ALLIANCE

Application Development

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GE VERNOVA

UTSA The University of Texas at San Antonio™

Field Demonstration

SRP®

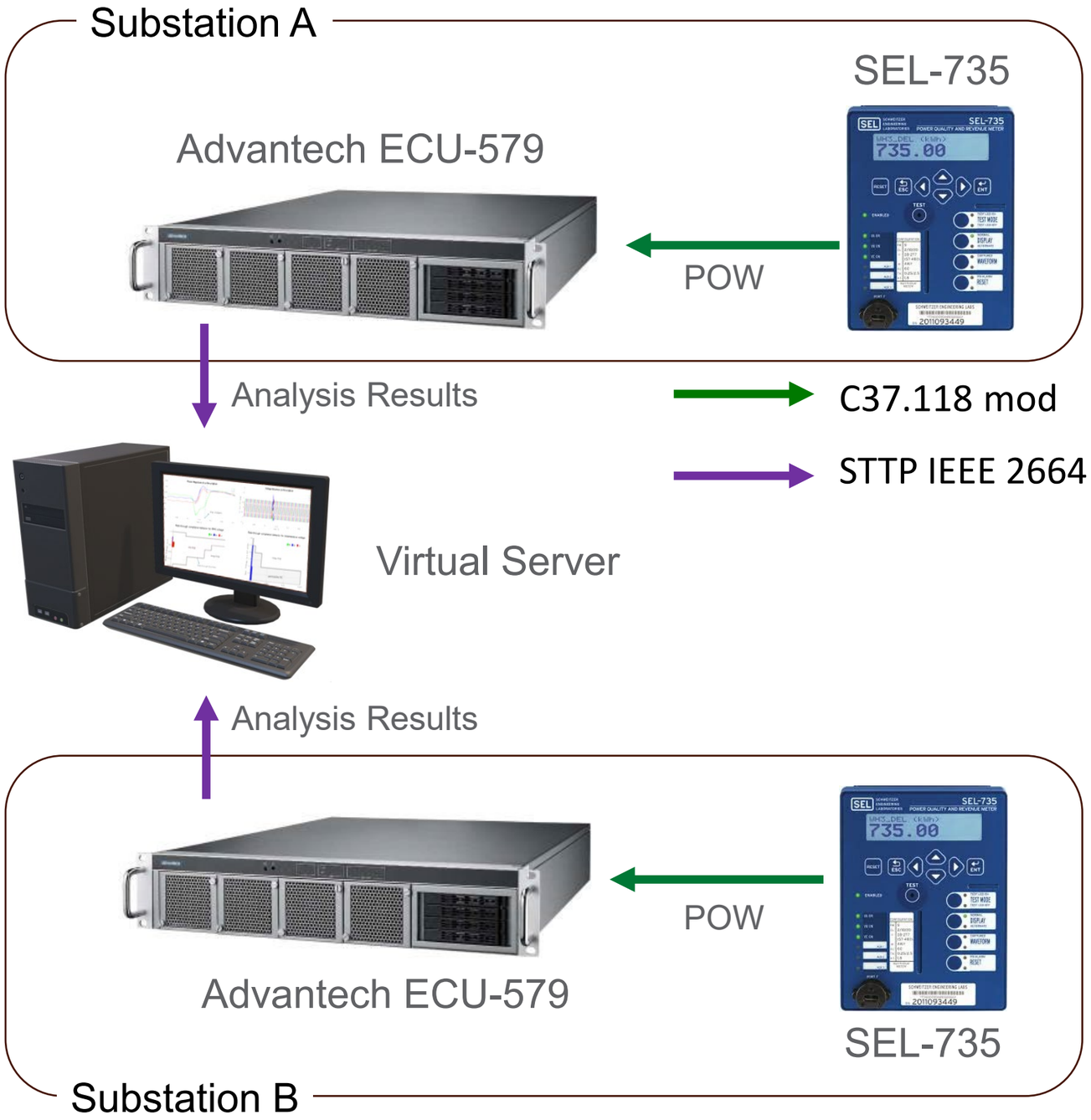
Advisors

ISO new england

NEW YORK STATE | NY Power Authority

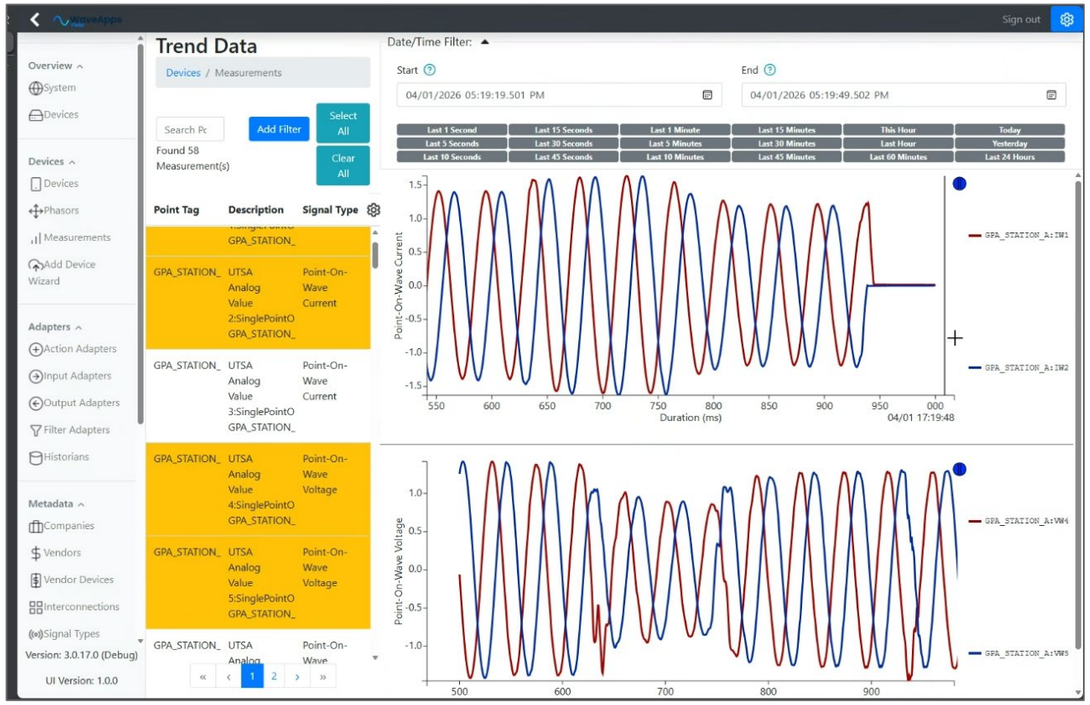
Hardware & Network

- SEL-735 streams 3 ksps POW over manufacturer-modified C37.118 protocol
- Advantech ECU-579 substation computer runs WaveApps Field
- Results transmitted via the Streaming Telemetry Transport Protocol (STTP) to virtual server hosting WaveApps Central

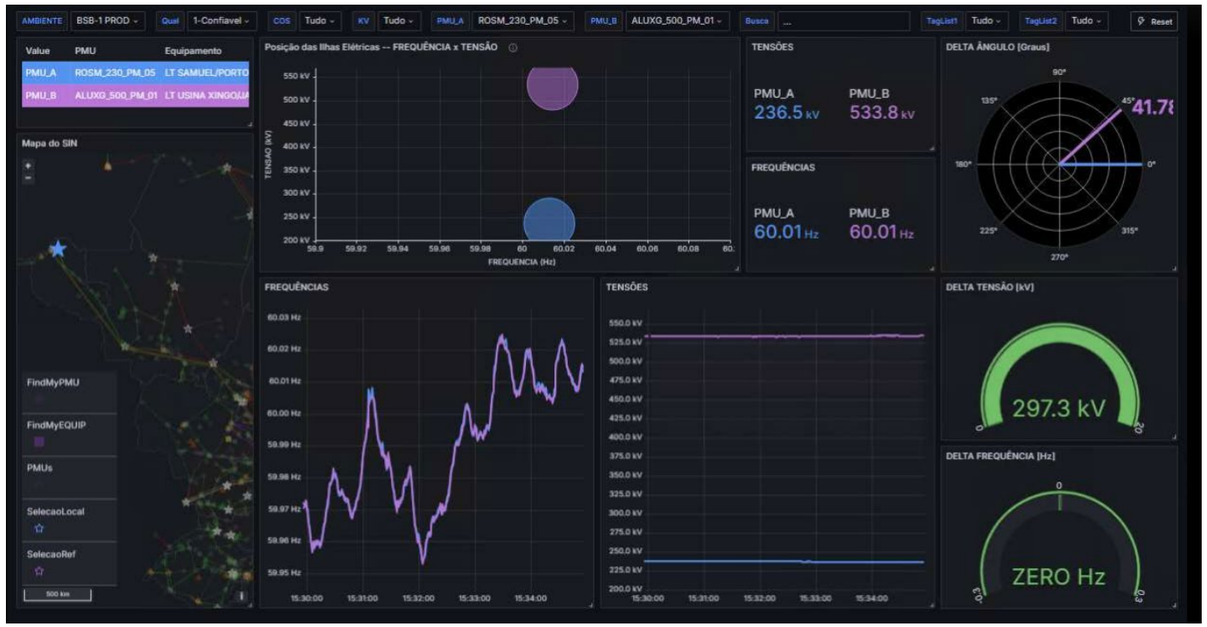


Platform Design

- Modular- adapter based
  - Deploy applications separately
  - Manage applications independently



Early-stage web-based management interface



Concept for Grafana-based result visualization

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Applications

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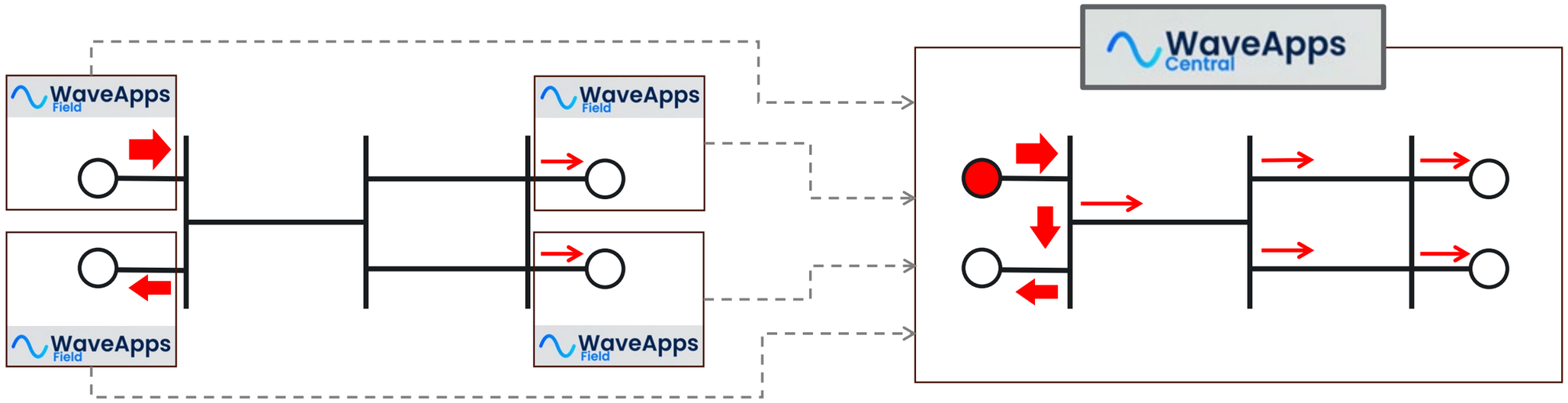
Oscillation Source Localization

- Dissipating Energy Flow (DEF)
  - Well-established PMU-based method developed and used by ISO-NE
  - Traces the **flow of dissipating energy** back to the source
- A POW-based version has been developed to address oscillations at frequencies too high for PMU-DEF, enabling timely and actionable mitigation



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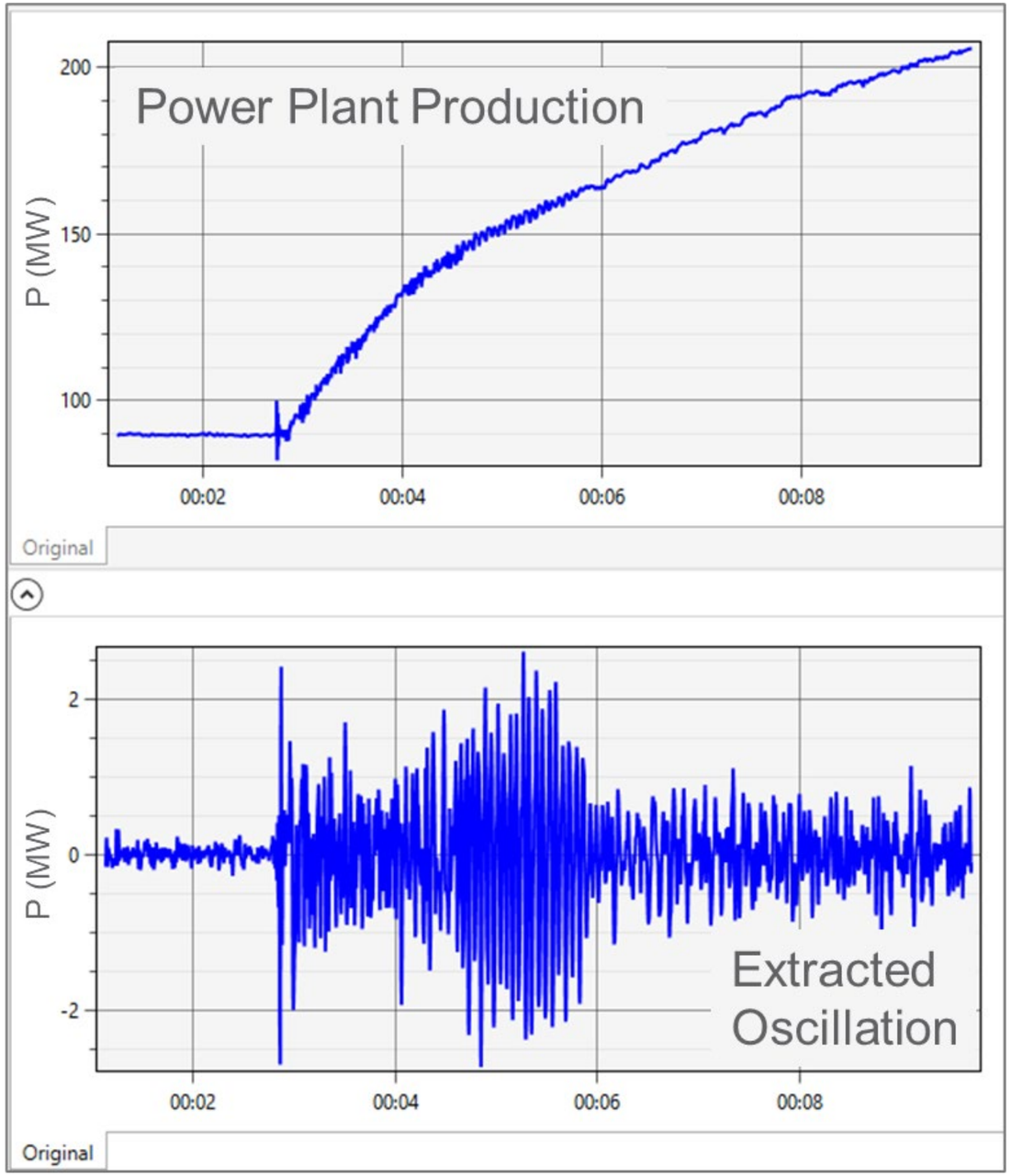
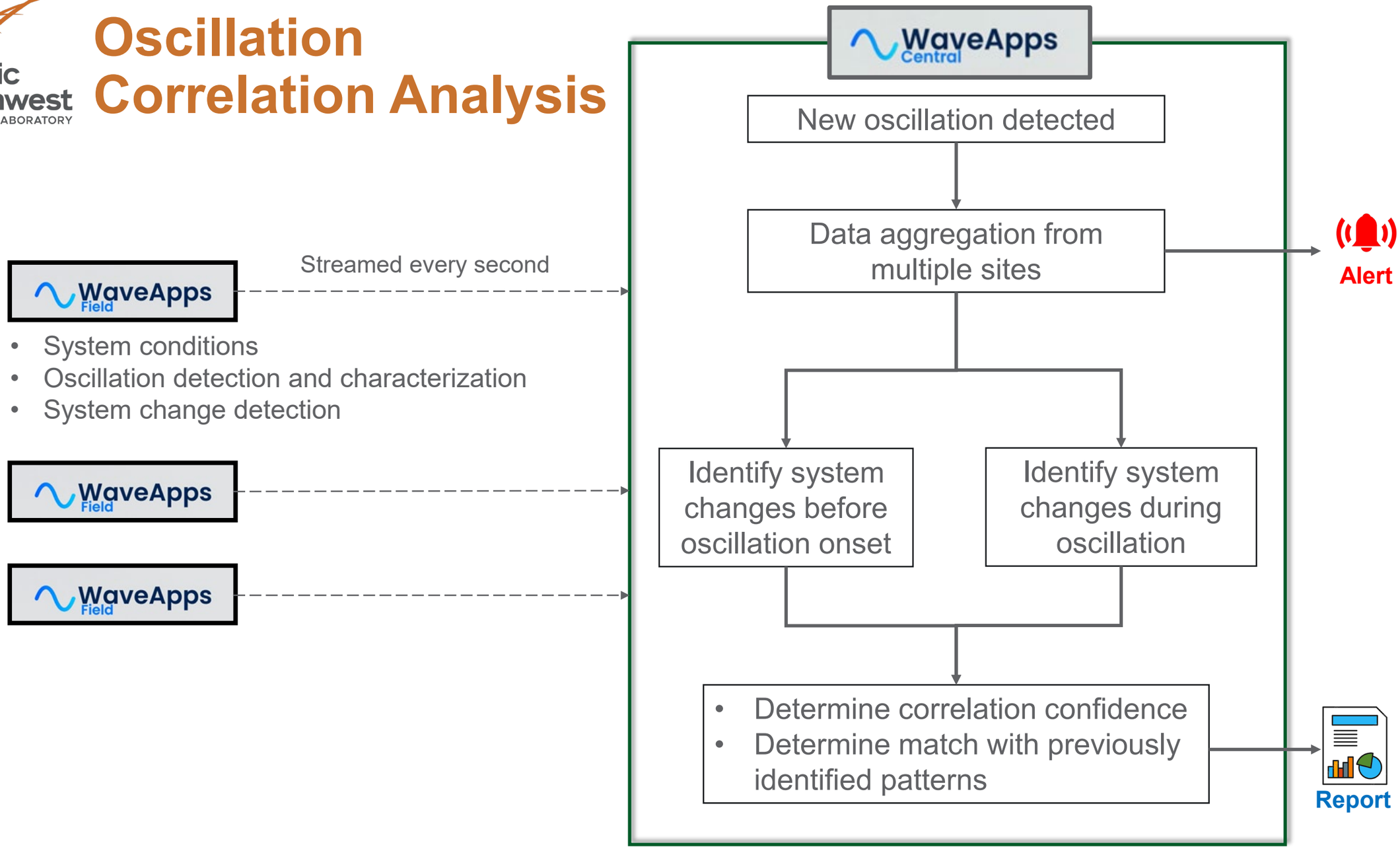
Oscillation Correlation Analysis

Supports root cause analysis of IBR-induced oscillations and early identification of latent configuration issues



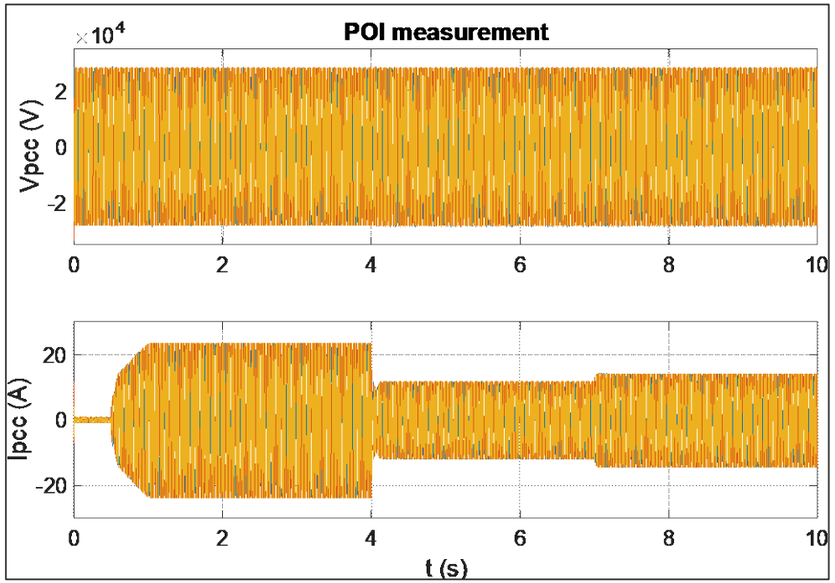
Oscillation Correlation Analysis

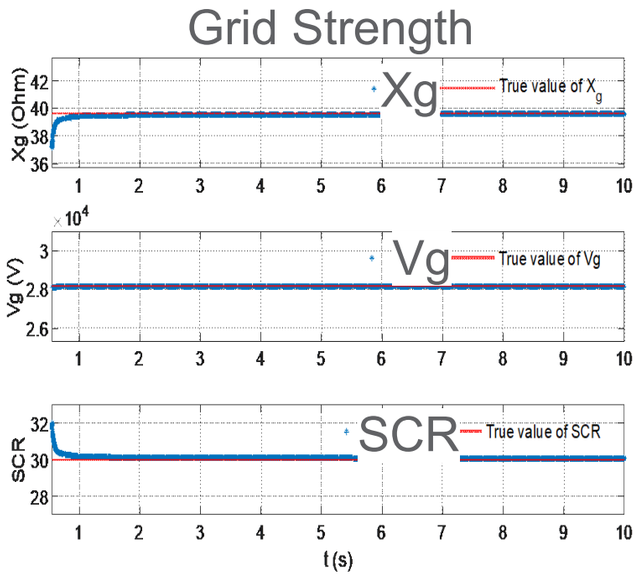


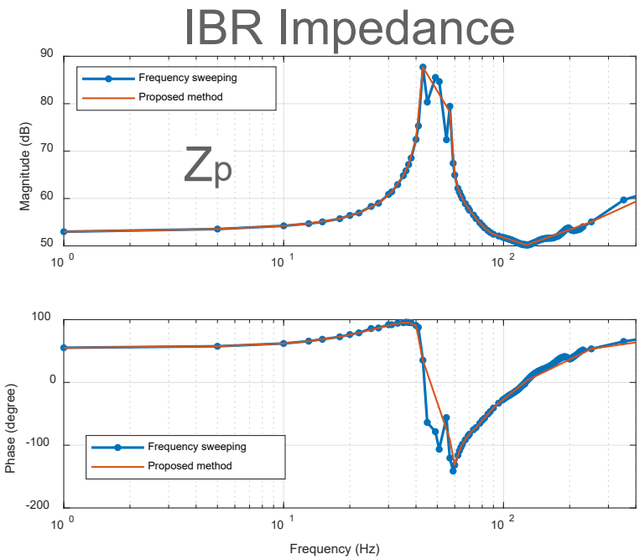
Example: Oscillation following Generation Change

Grid Strength Monitoring

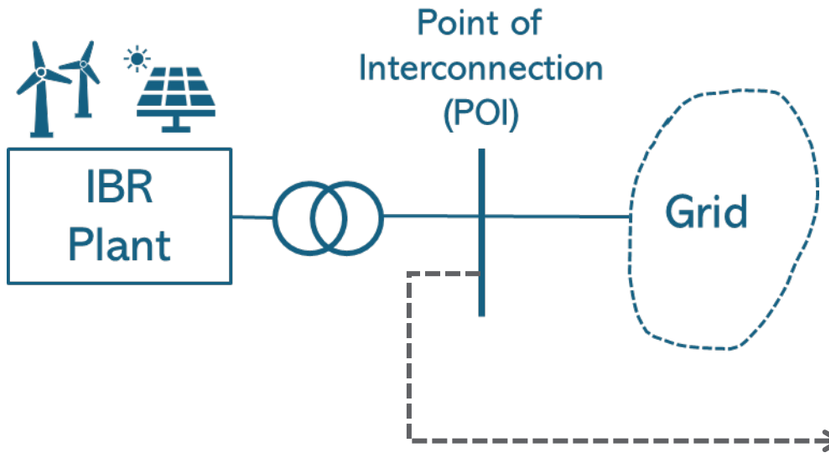
- Wide spectrum grid and IBR impedance monitoring
  - Grid impedance monitoring at fundamental frequency
  - Small signal impedance estimation at POI – Both of grid impedance and IBR impedance
- Provides system operator with:
  - Grid strength monitoring capability – P and Q transfer limits, voltage stability, etc.
  - Sub-synchronous oscillation prediction and stability margin estimation

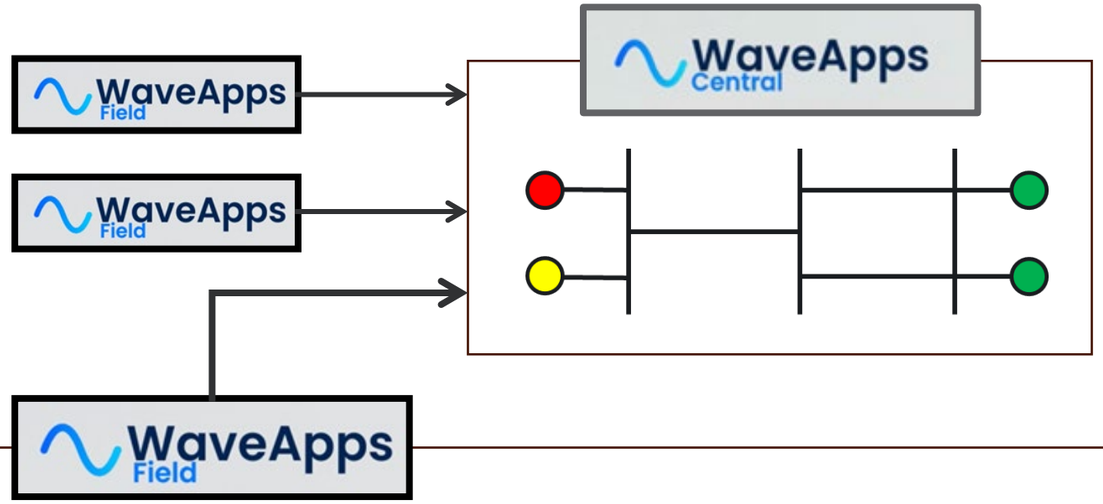


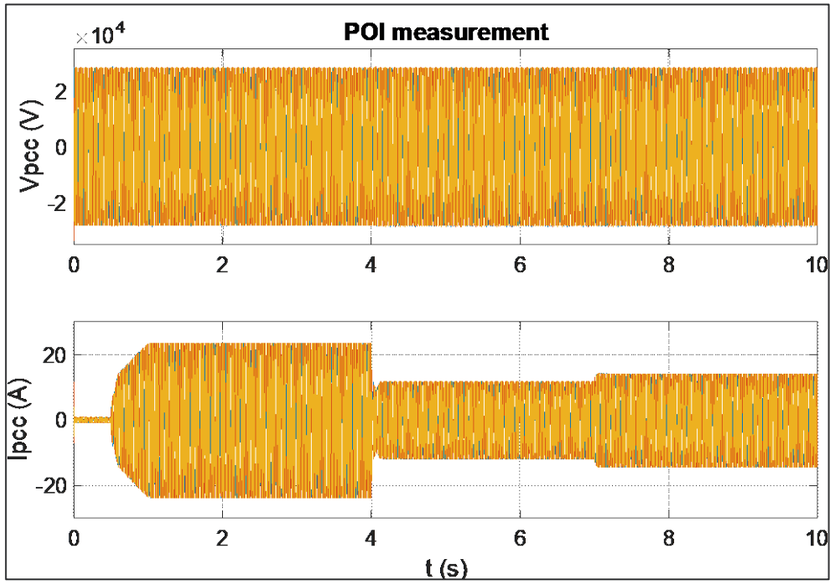


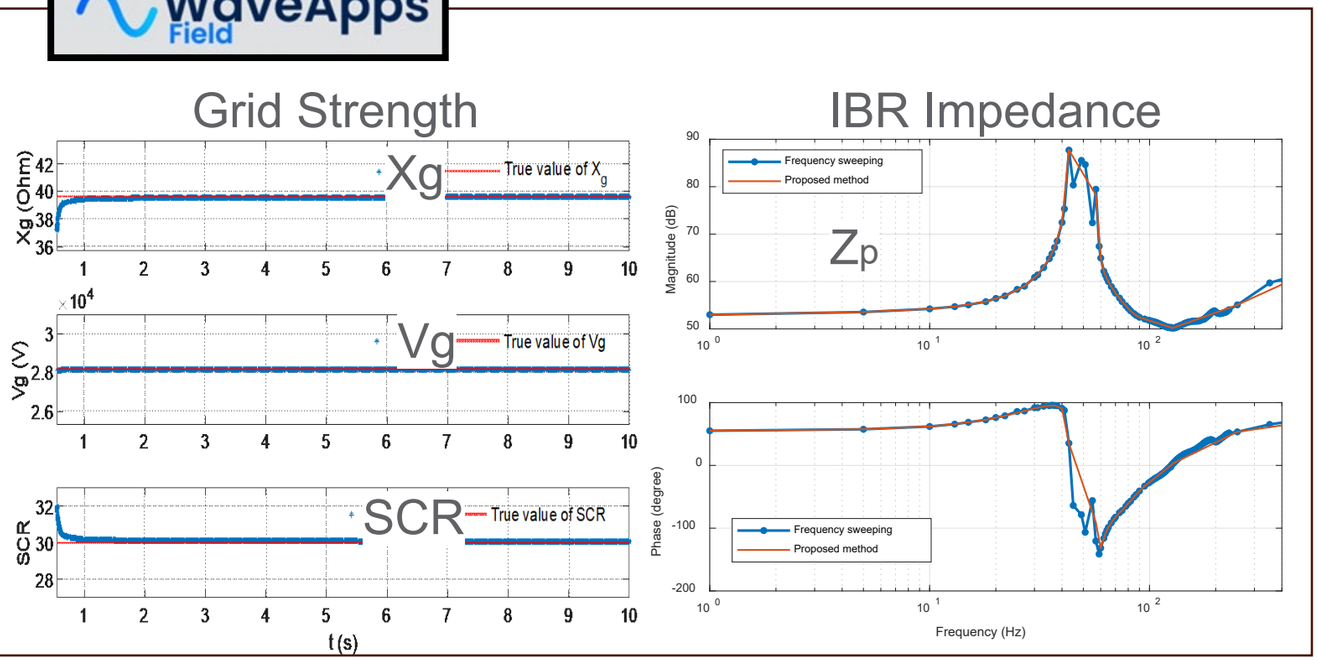


Grid Strength Monitoring

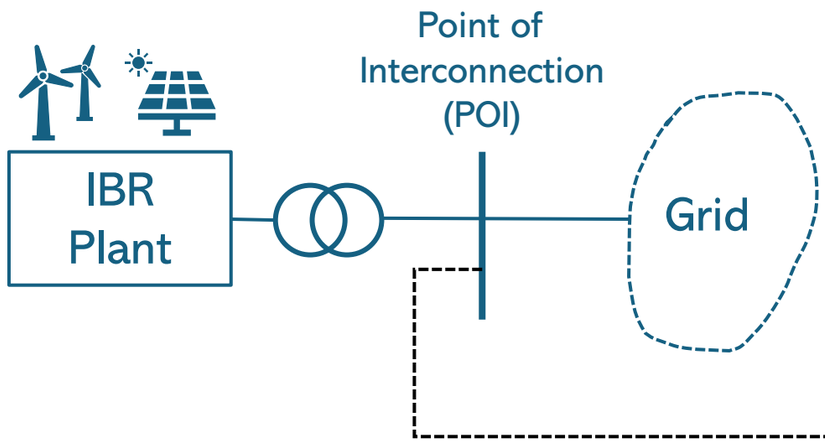




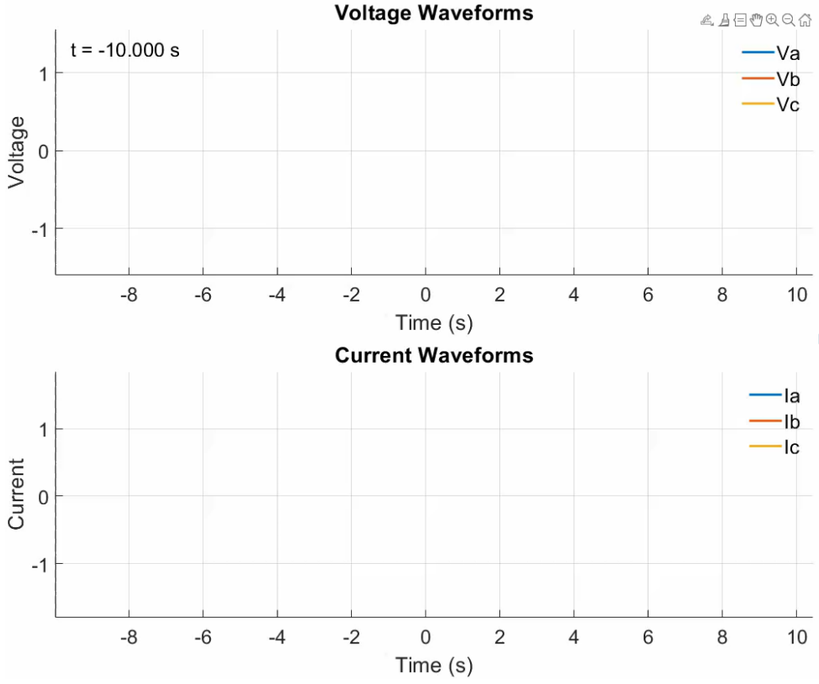




Nuisance Trip Detection

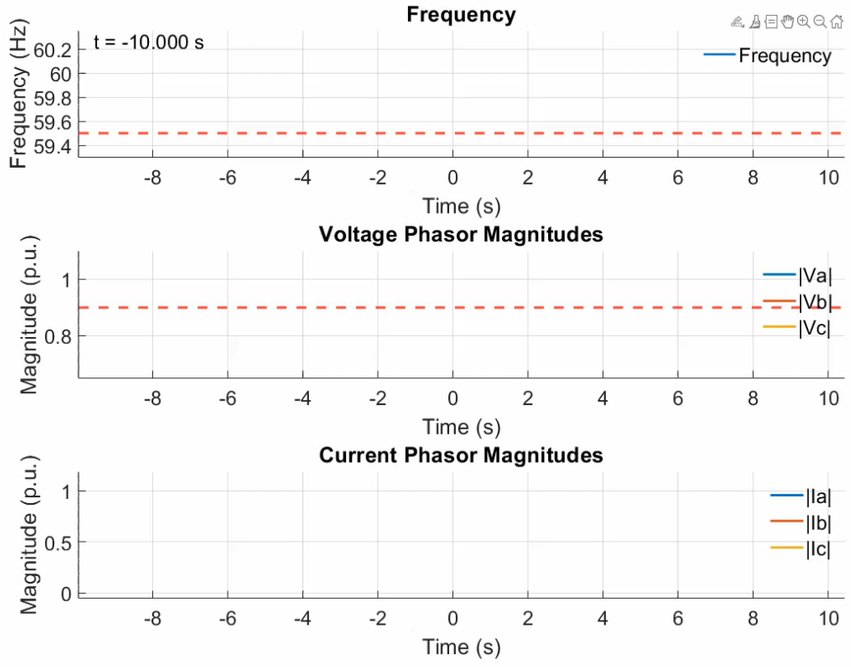


Waveform Measurements: v_{abc}, i_{abc}

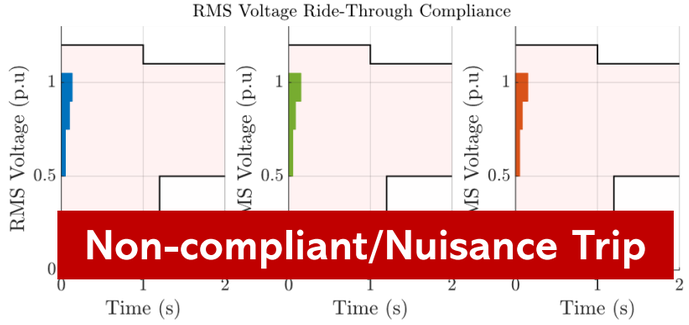


WaveApps Field

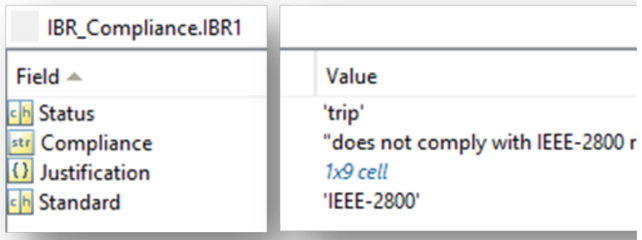
Phasor Estimation, Event Detection, and IBR Status Identification



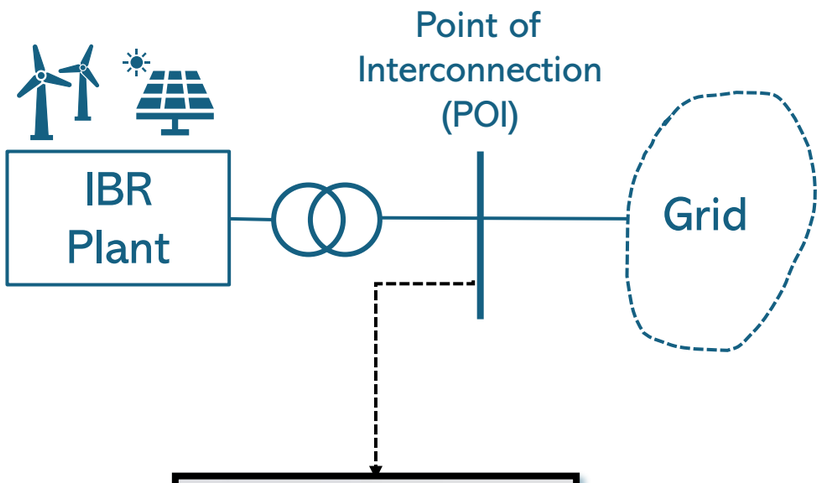
IEEE-2800 Compliance Determination (using phasors and waveforms)



Automated Event Report with Compliance Justification



Nuisance Trip Detection



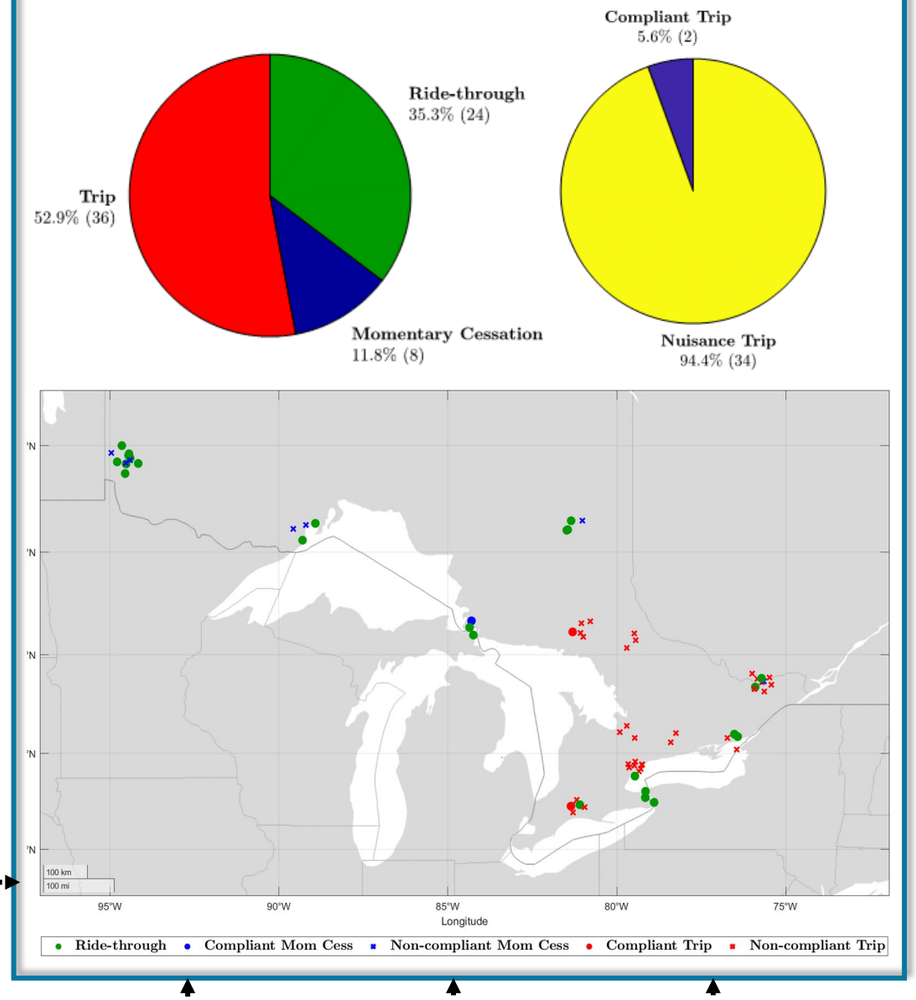
WaveApps Field

Automated Event Report with Compliance and Compliance Justification

IBR_Compliance.IBR1

Field	Value
Status	'trip'
Compliance	"does not comply with IEEE-2800 ride-through requirements"
Justification	*1x9 cell*
Standard	'IEEE-2800'

WaveApps Central



From Other WaveApps Field Instances

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Demonstrations

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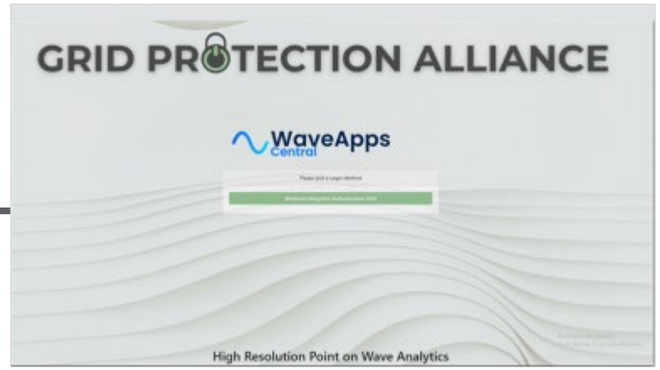
Lab Demonstration

WaveApps Field

Local Instance at Richland, WA

WaveApps Central

Central Instance at Chattanooga, TN



GRID PROTECTION ALLIANCE

CL

WaveApps Field

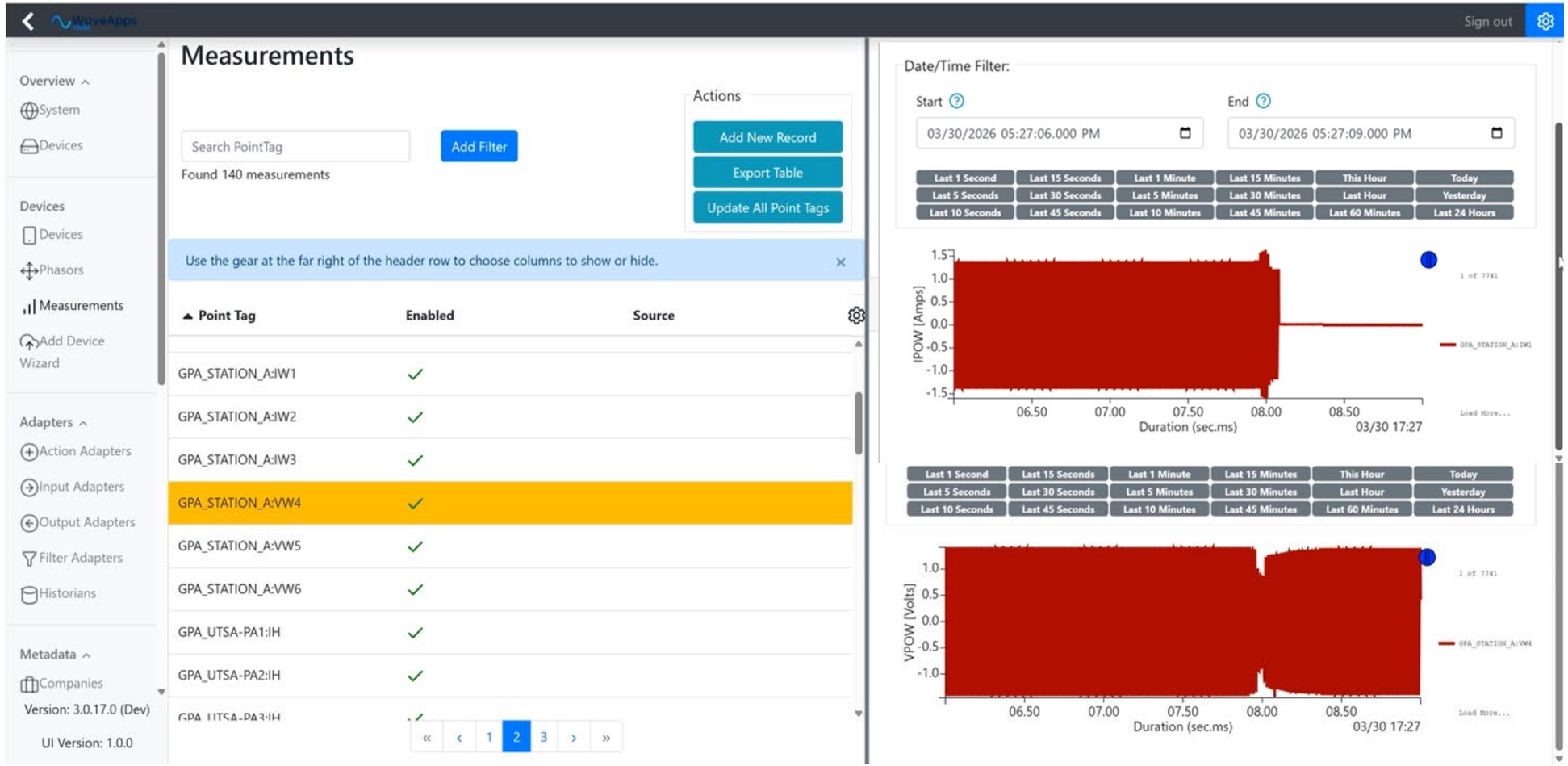
Please pick a Login Method

Windows Integrated Authentication (AD)

High Resolution Point on Wave Analytics

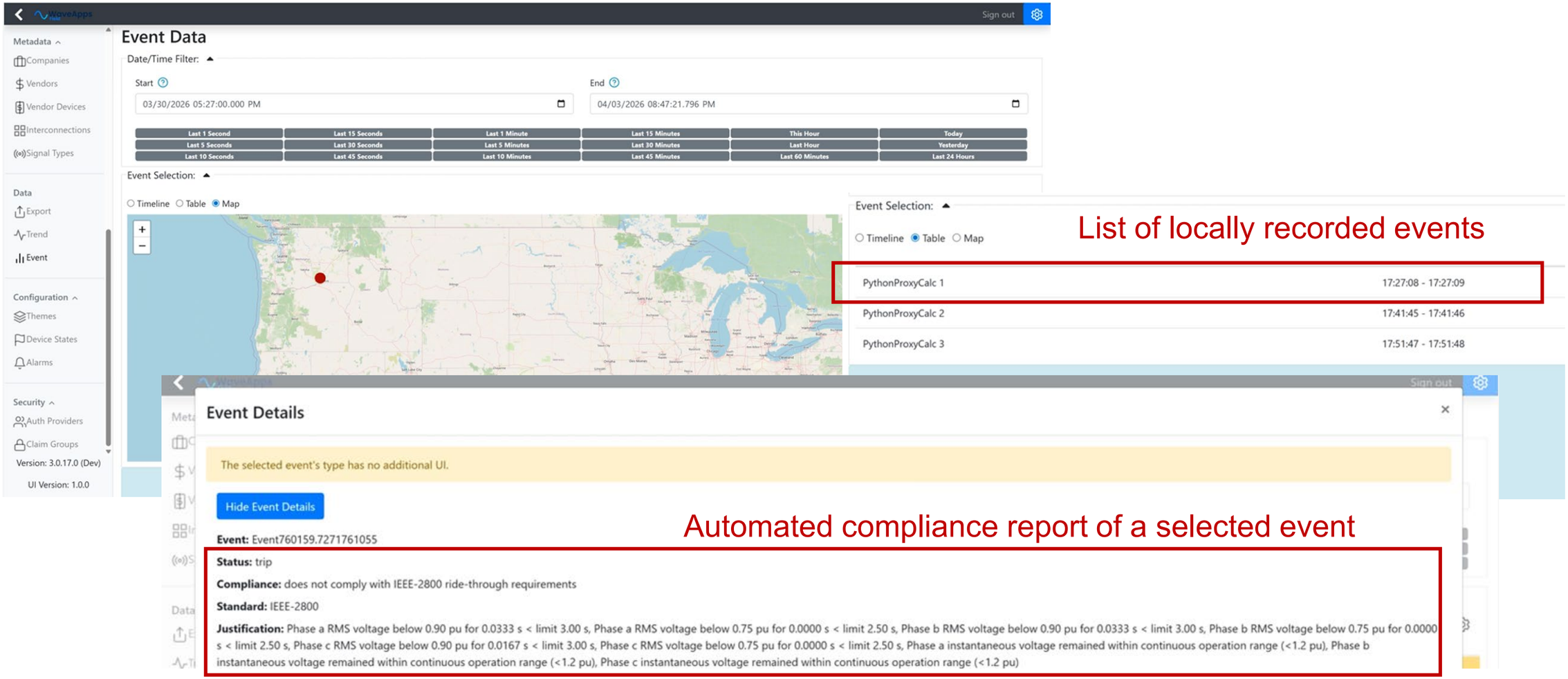
WaveApps Field Instance

Continuous voltage and current waveform measurements played into WaveApps Field from a local file



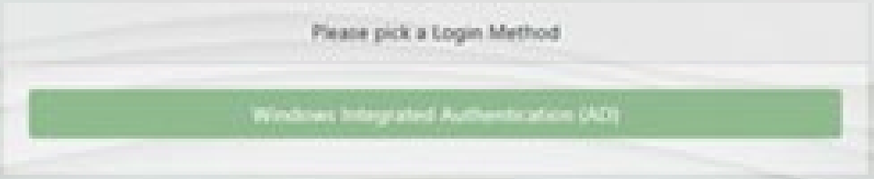
WaveApps Field Instance

- Detects trip and momentary cessation events
- Determines compliance to IEEE 2800 and/or NERC PRC-029-01 ride-through requirements



GRID PROTECTION ALLIANCE

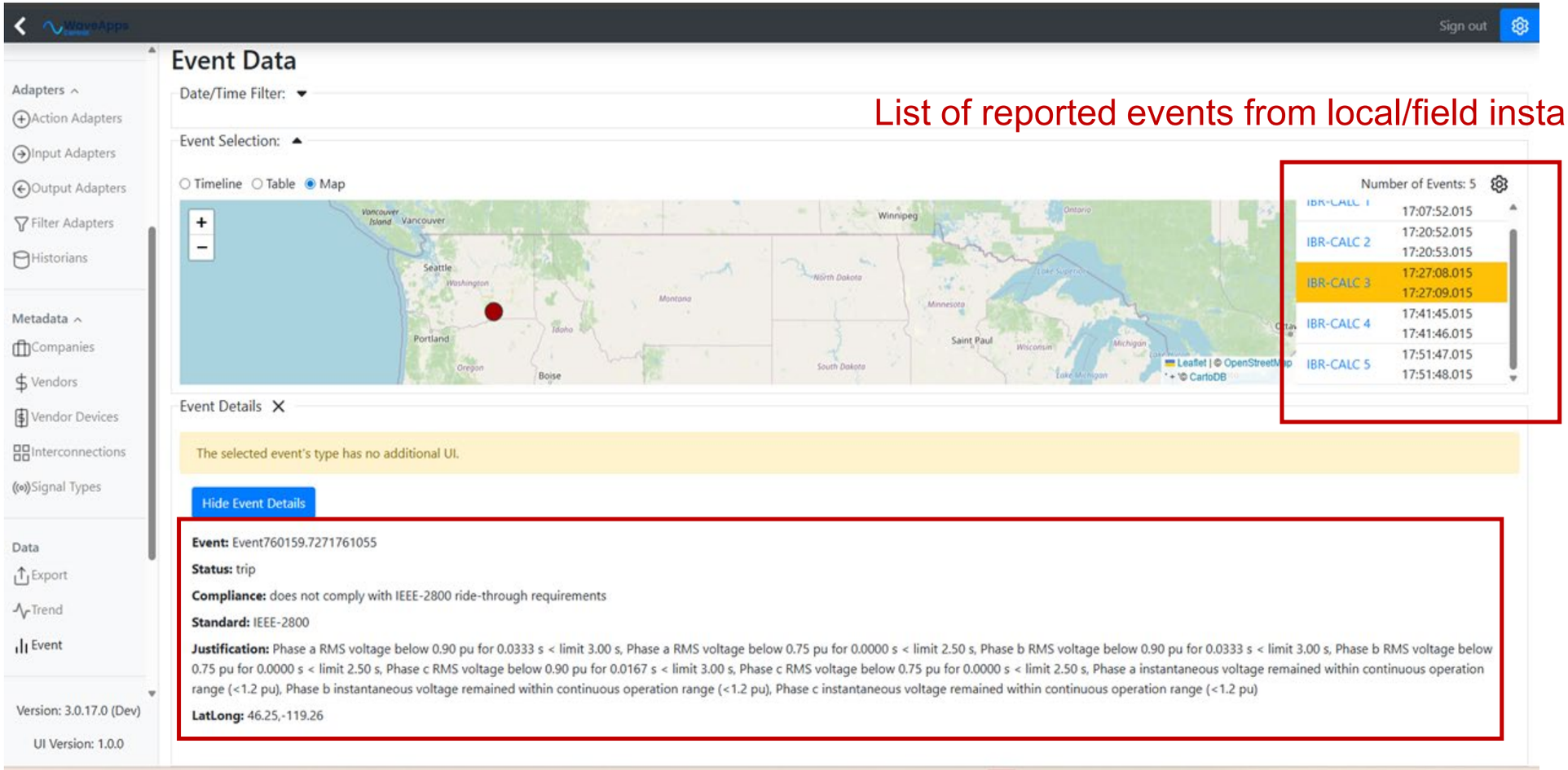
WaveApps Central



High Resolution Point on Wave Analytics

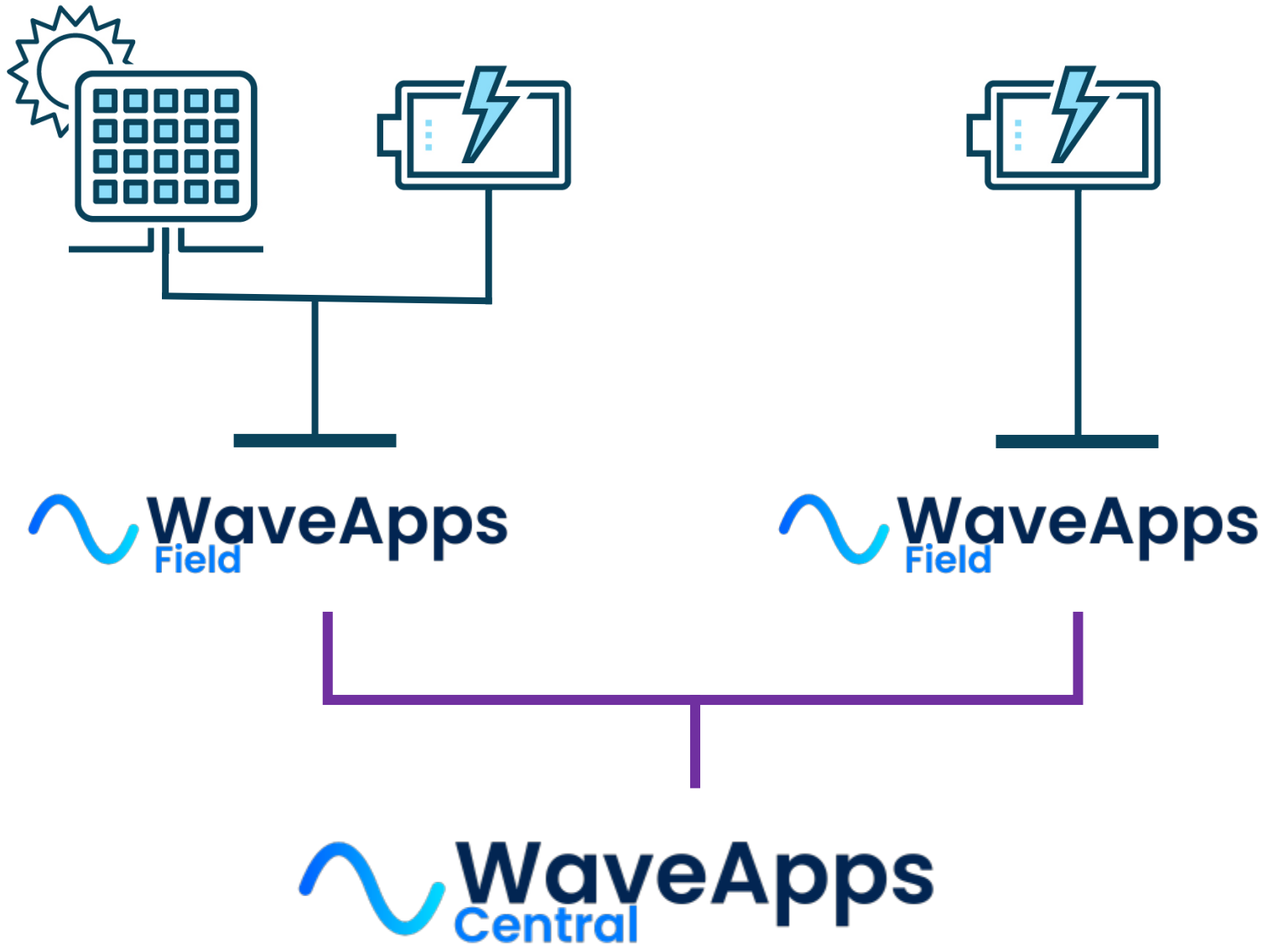
WaveApps Central Instance

- Events and compliance reports received from the local/field instance are logged
- Visualization modules being developed



Field Demonstration Plan

- 6-month demonstration is scheduled to begin by June 30, 2027
- Hosted by Salt River Project (SRP)
- WaveApps Field will be deployed at two substations
  - Co-located PV and BESS
  - BESS
- Results from the four example applications will stream to WaveApps Central



Summary and Next Steps

- The WaveApps platform will address a gap in utilities' ability to monitor high-frequency oscillations and other high-speed behaviors
- A distributed architecture enables POW-based analytics while limiting communication requirements
- The initial set of four applications will be extensible to meet emerging needs
- Looking forward:
  - Platform finalized
  - Algorithms translated to applications
  - Field demonstration at Salt River Project

Acknowledgment and Disclaimer

Thank you to our technology manager at DOE, Dexter Newton.

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Thank you