



# Distributed Waveform Analytics in the Wave Apps Platform

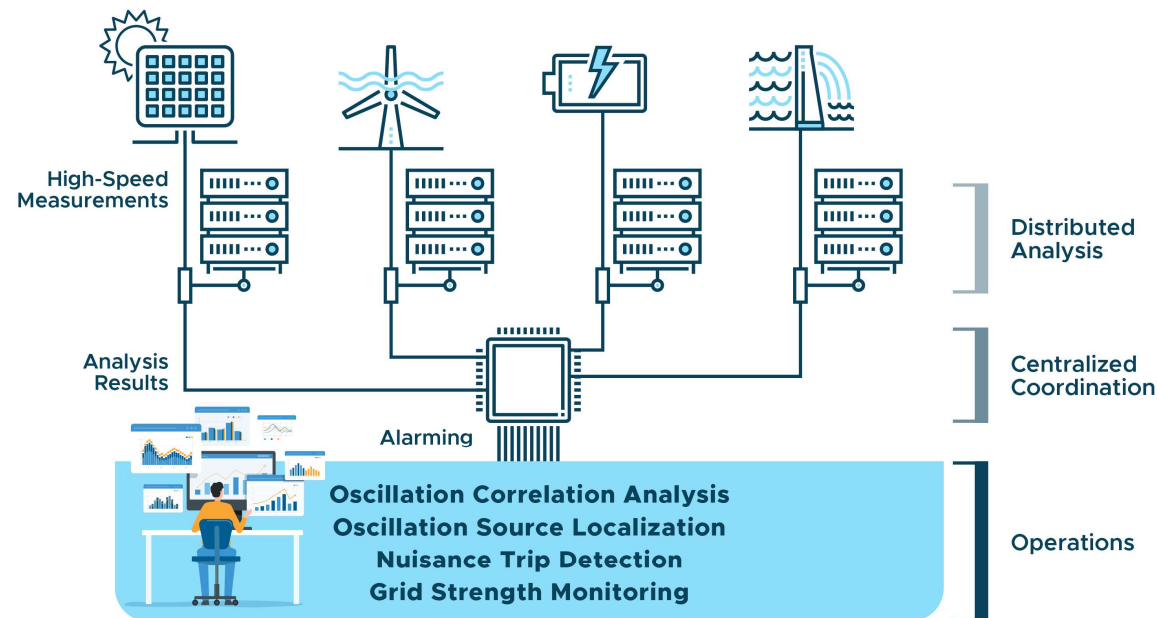
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# Concept

- Wave Apps is a distributed measurement-based platform that enables operators to monitor and mitigate inverter-based resource (IBR) performance issues
- 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

### Platform Development



### Testbed Evaluation



### Application Development



+ PROJECT LEAD

### Field Demonstration



### Advisors





## Timeline

2025

- Planning and early development of the platform and applications
- Hardware and demonstration site selection

2026

- Finalize and test platform and applications
- Begin hardware deployment

2027

- Field demonstration
- Laboratory evaluation

2028

- Report and wrap up



**Hardware**

**Networking**

**Platform**

**Applications**

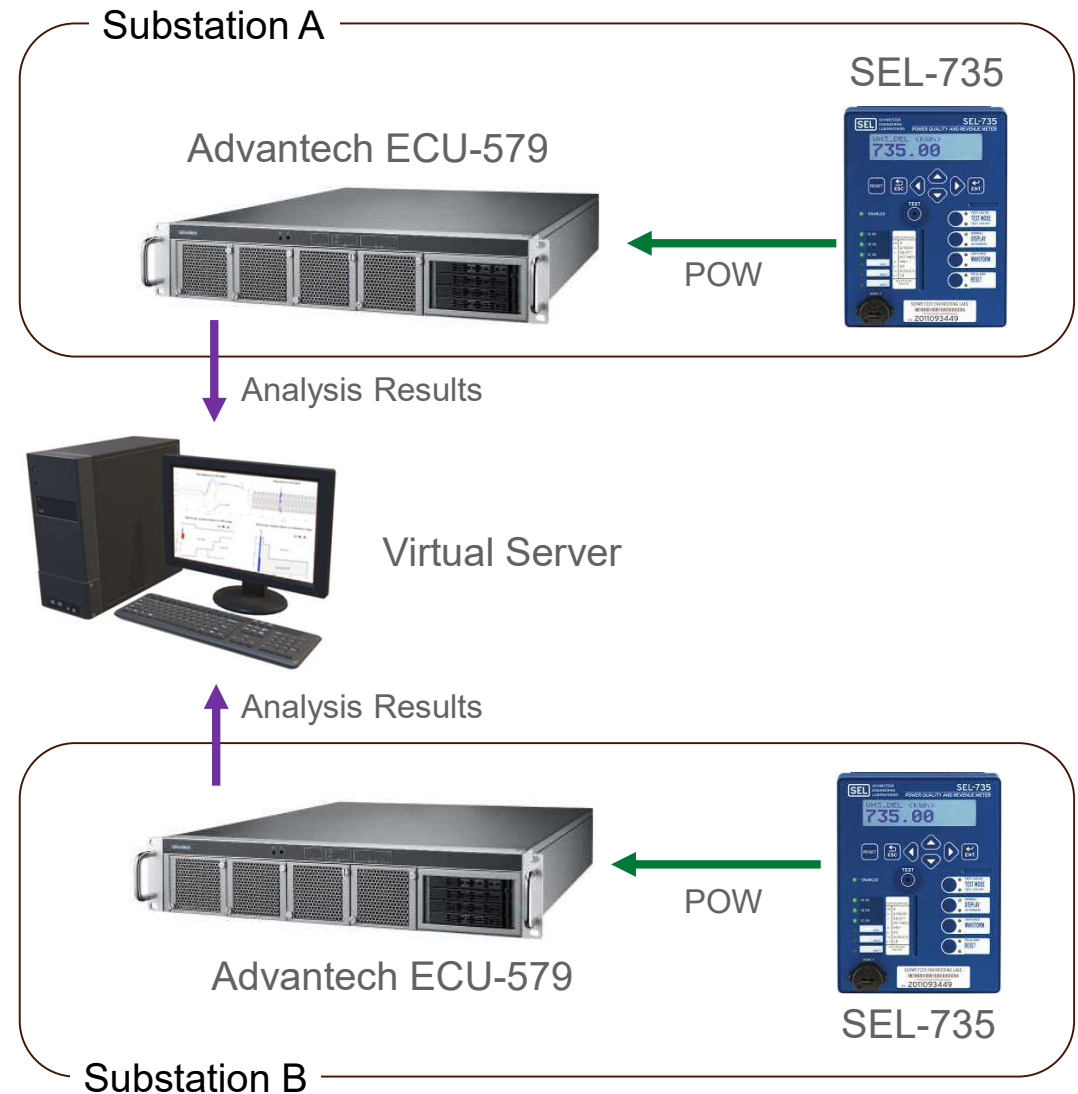


# Hardware



## Measurement Instrument

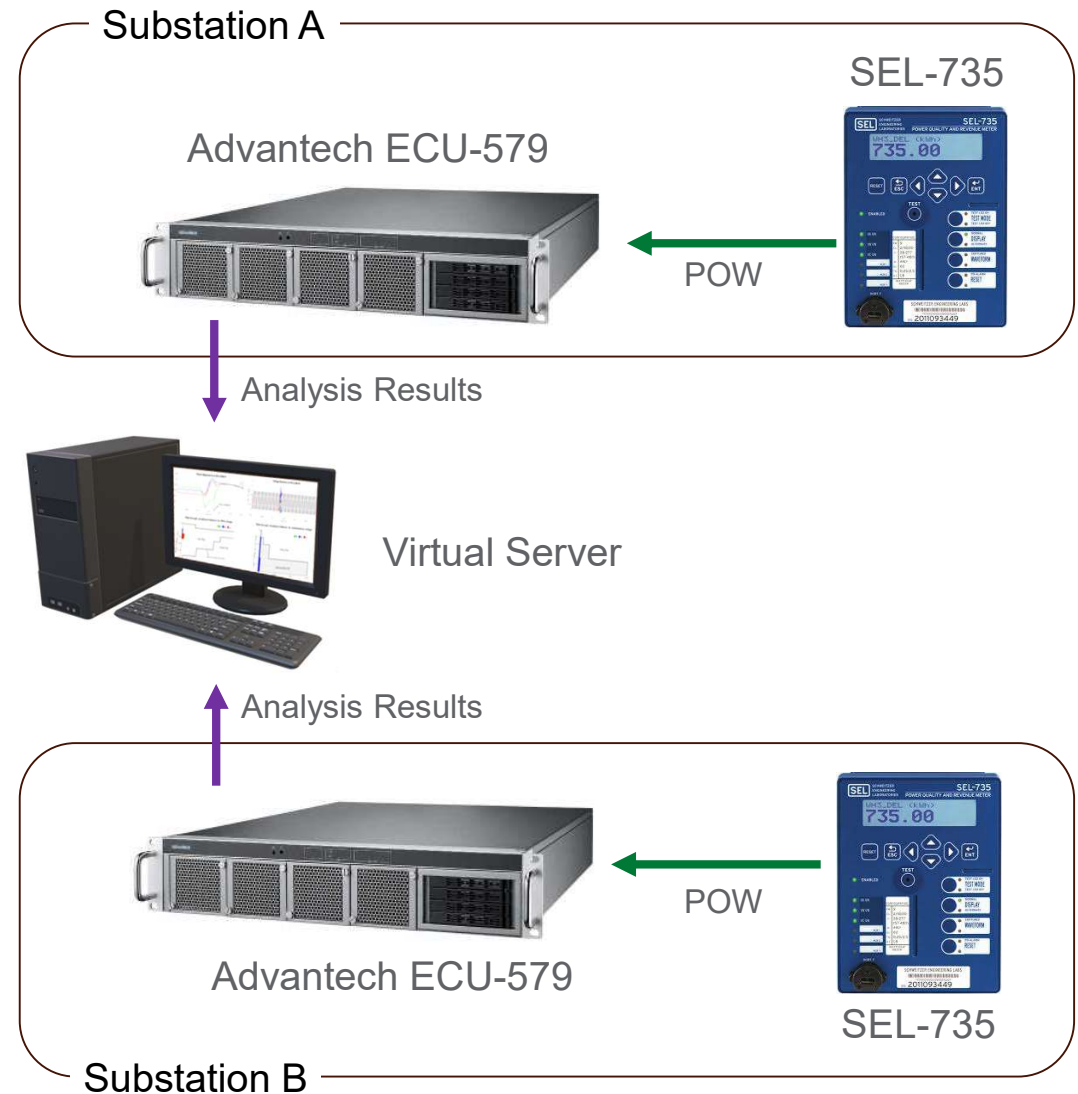
- SEL-735 power quality and revenue meter
- Capable of continuous waveform streaming at 3 ksp/s



# Substation Computer

## Advantech ECU-579

Operating System	Windows 11 Professional
Processor	Intel Xeon Gold 5218T
Processor Frequency (Base)	2.1 GHz
Processor Cores	16
Processor Threads	32
RAM	32 GB DDR4 3200 MHz
Storage	2 TB SSD
Network Ports	Four RJ-45 10/100/1000 ports
Required Rack Space	2U
Cooling	Active (Fan cooling)

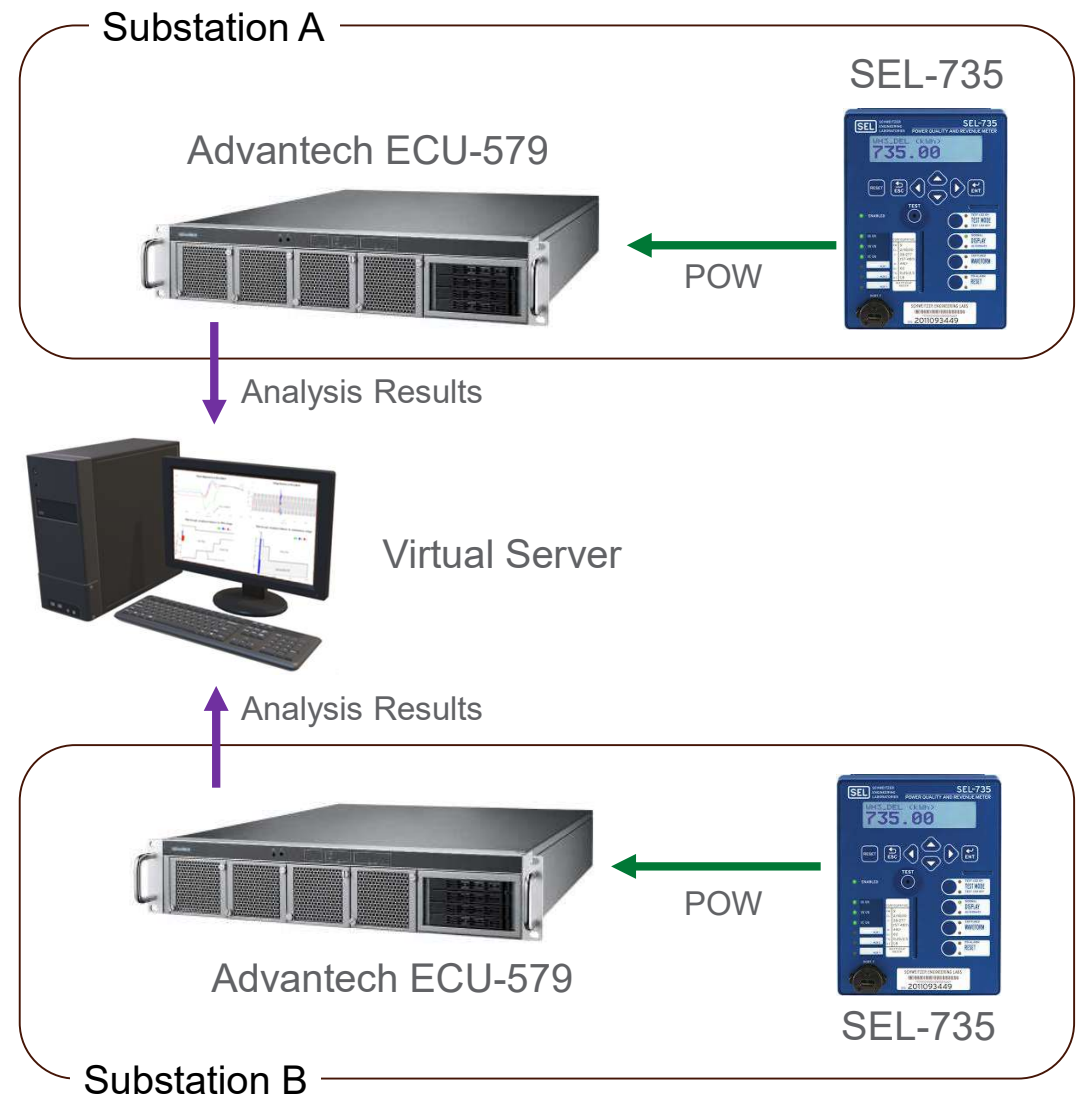




## Central Computer

Virtual server hosted by SRP

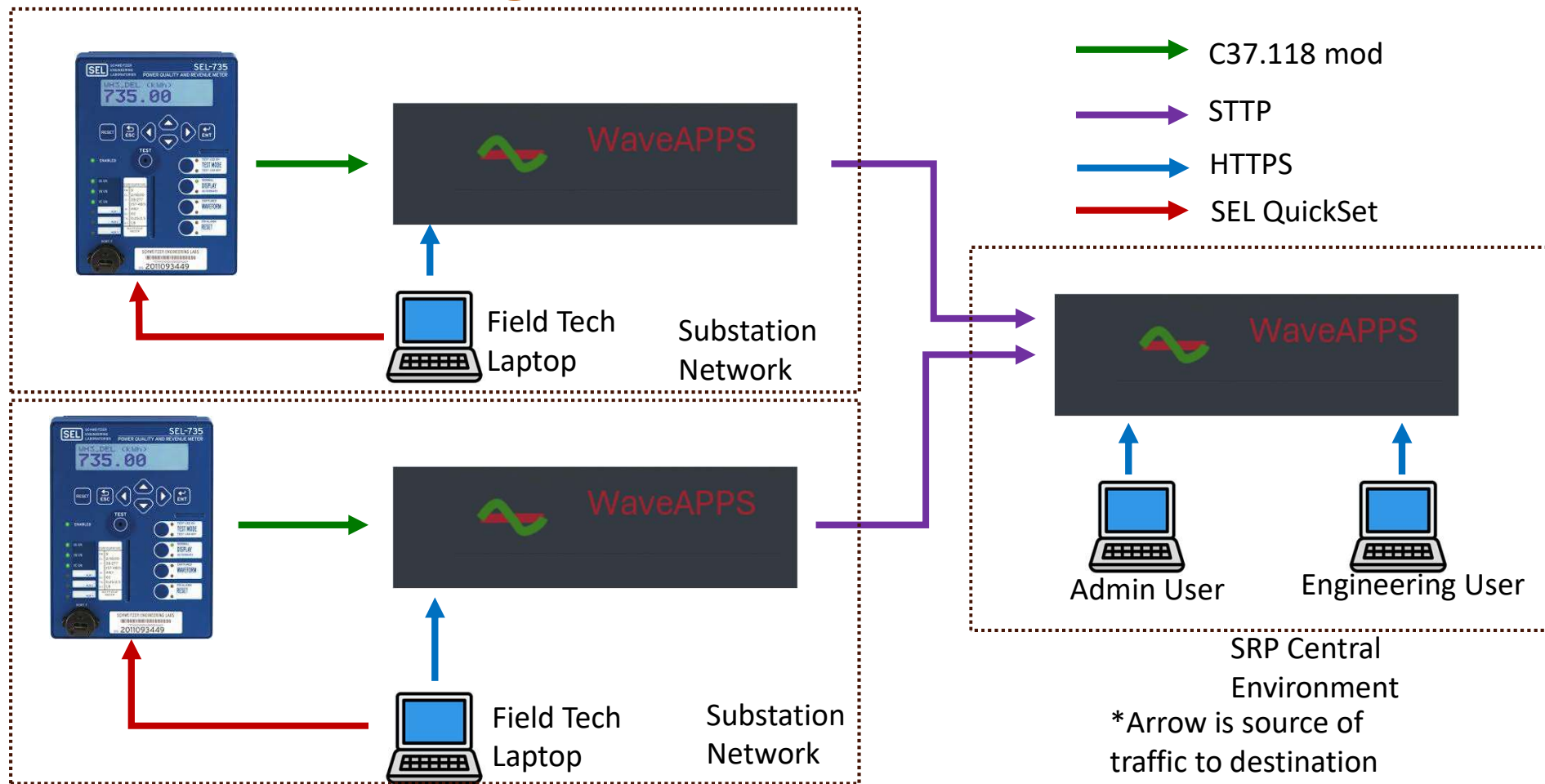
Operating System	Windows 11 Professional
Processor Cores	16-24
RAM	32-64 GB
Storage	4 TB SSD
Virtual Network Interface Cards	Substation Computer Remote User Access



# Networking



# Networking Overview



## Networking Instrument to Substation

- Sending Point on Wave Data
  - 3 Currents and Voltages
  - 3ksps resolution
  - Continuous data
- Use of IEEE C37.118\*
  - Manufacturer modified version
  - Designed for specific device
  - Proven to work for PoW data



# Networking Substation to Central

- Sending Analysis Results
  - Low resolution data
  - Large Variation in data volumes
  - Large packets
- Use of IEEE 2664
  - Proven to work for Synchrophasor data
  - Proven to work for PoW data
  - Supports Data Gap Recovery
  - Supports varying time resolution

**sttp IEEE 2664**  
Streaming Telemetry Transport Protocol



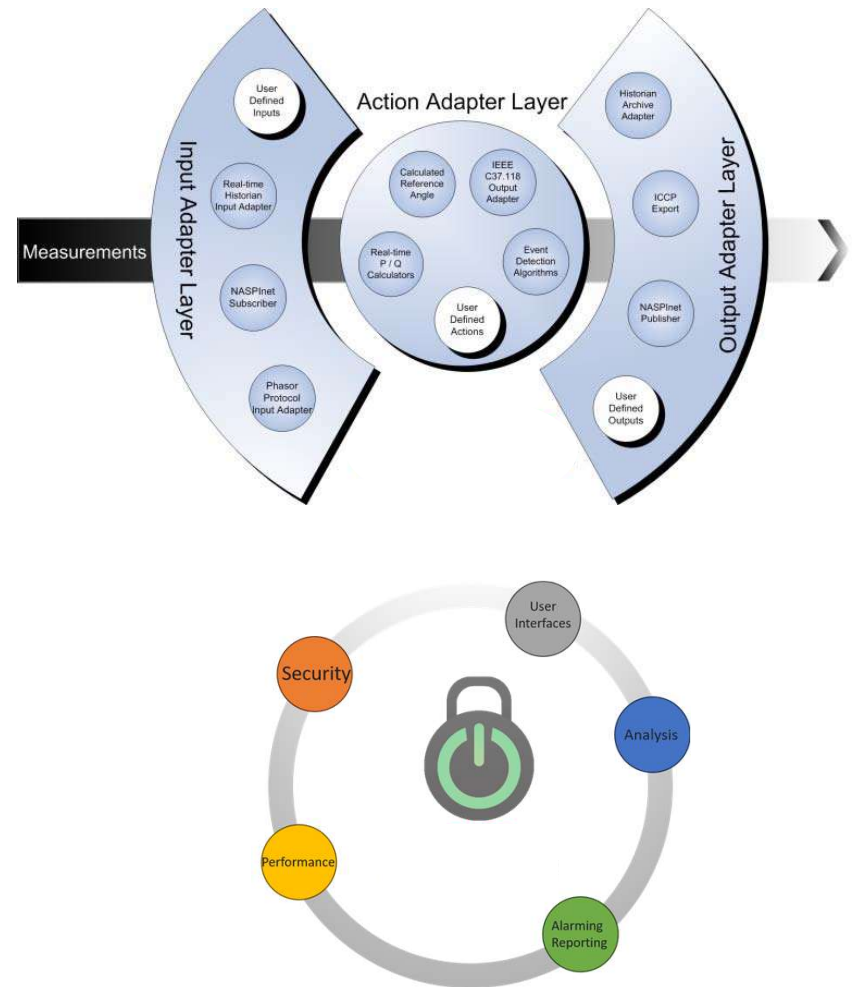


# Platform



# Platform Design

- Modular- adapter based
  - Deploy applications separately
  - Manage applications independently
- Visualizations and user interfaces
  - Web based management interfaces
  - Grafana based visualization



# Configuration GUI Concept

The screenshot displays a web-based configuration interface. On the left is a sidebar with navigation links: Devices, Phasors, Measurements, Add Device Wizard, Adapters (Action, Input, Output, Filter), Metadata (Companies, Vendors, Vendor Devices, Interconnections, Signal Types), Data (Export, Trend, Event), and Configuration (Themes, Device States, Alarms). The main area is split into two panels. The left panel, titled 'Devices', contains a search bar, a table with 4 devices, and an 'Add New Record' button. The table has columns for Name, Acronym, Load Order, Time Zone, and Parent Acronym. The right panel, titled 'Settings', contains a form for configuring a device with fields for Name, Acronym, Time Zone, Access ID, Longitude, Latitude, a map, Historian, Interconnection, Vendor Device, Company, Contact List, Time Adjustment Ticks, Load Order, and Description. At the bottom of the settings panel are checkboxes for 'Enabled' and 'Is Concentrator'.

Name	Acronym	Load Order	Time Zone	Parent Acronym
GPATEST1	GPATEST1	0	UTC	CHRISTOPH-DESK-DEV-ACRONYM
GPATEST2	GPATEST2	0	UTC	CHRISTOPH-DESK-DEV-ACRONYM
Christoph-Desk-Dev	CHRISTOPH-DESK-DEV-ACRONYM	1	UTC	
File Device	FILE_DEVICE	2	UTC	

**Settings**

**General**

Name: GPATEST1, Acronym: GPATEST1

Time Zone: (UTC) Coordinated Universal Time, Access ID: 2

Longitude: -85, Latitude: 35

Map: Shows a location in the Southeastern United States (Georgia/South Carolina area).

Historian: Primary Phasor Archive, Interconnection: Eastern Interconnection

Vendor Device: Arbitrator-1133A, Company: [Empty]

Contact List: [Empty]

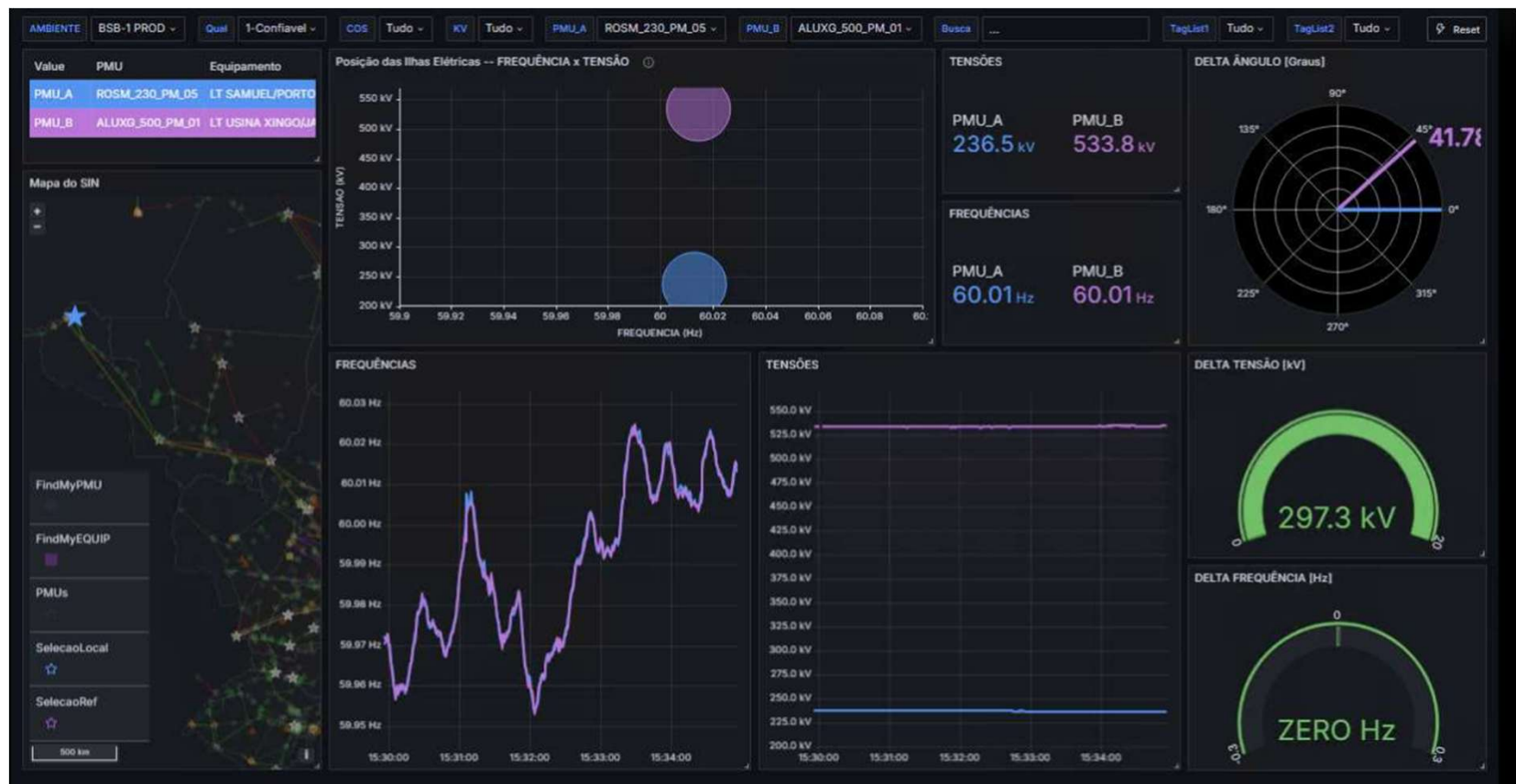
Time Adjustment Ticks: 0

Load Order: 0

Description: [Empty]

☒ Enabled, ☐ Is Concentrator

# Event Review GUI Concept





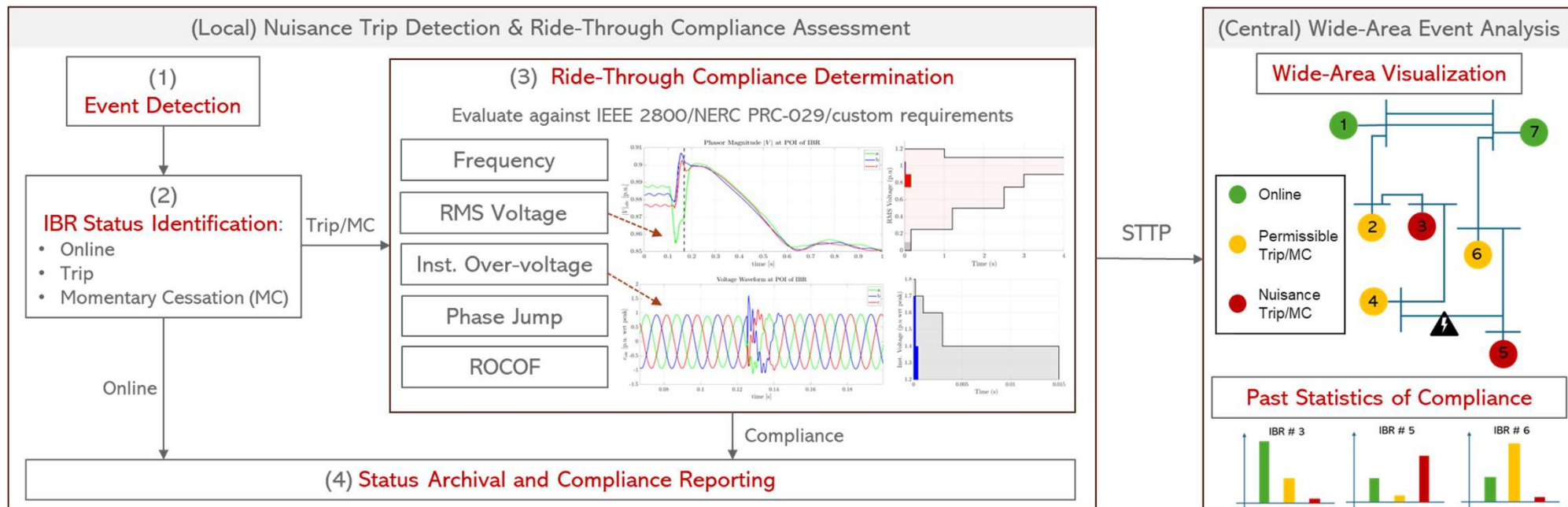
# Applications





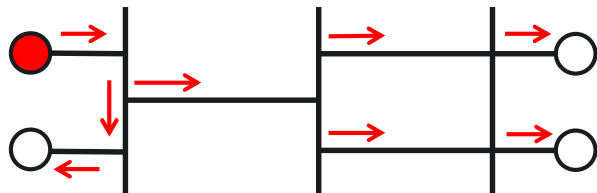
# Nuisance Trip Detection

Automates detection and analysis of IBR tripping to prevent future multi-plant events



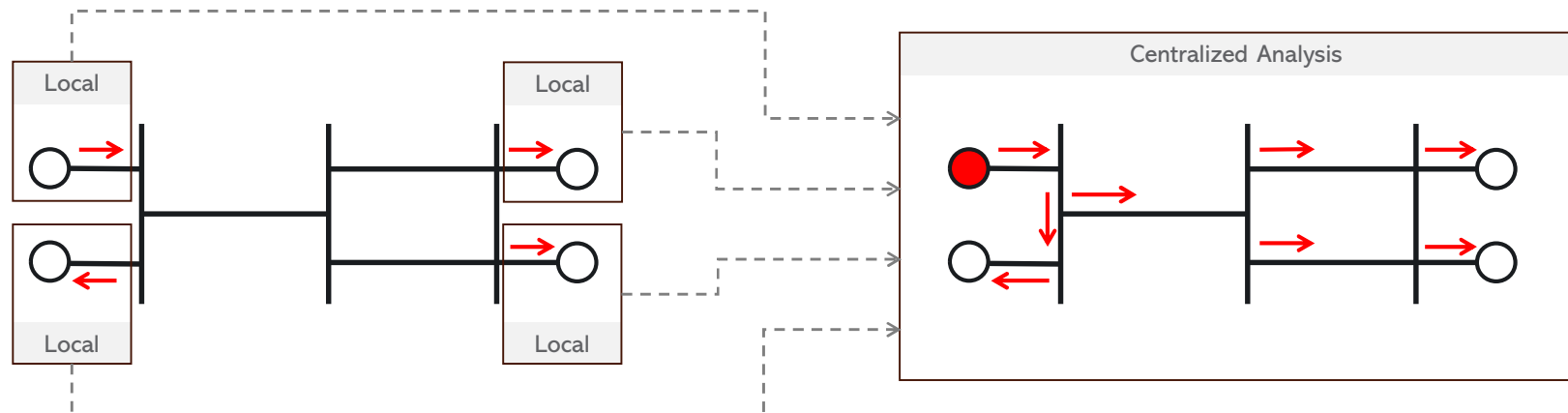
# Oscillation Source Localization

- Dissipating Energy Flow (DEF)
  - Well-established PMU-based method
  - Traces the flow of oscillation energy back to the source

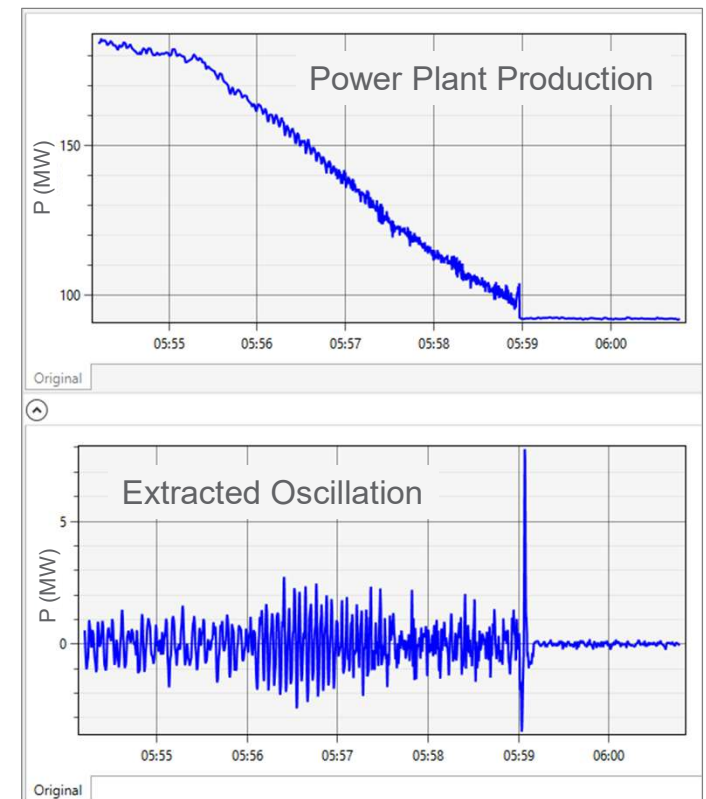
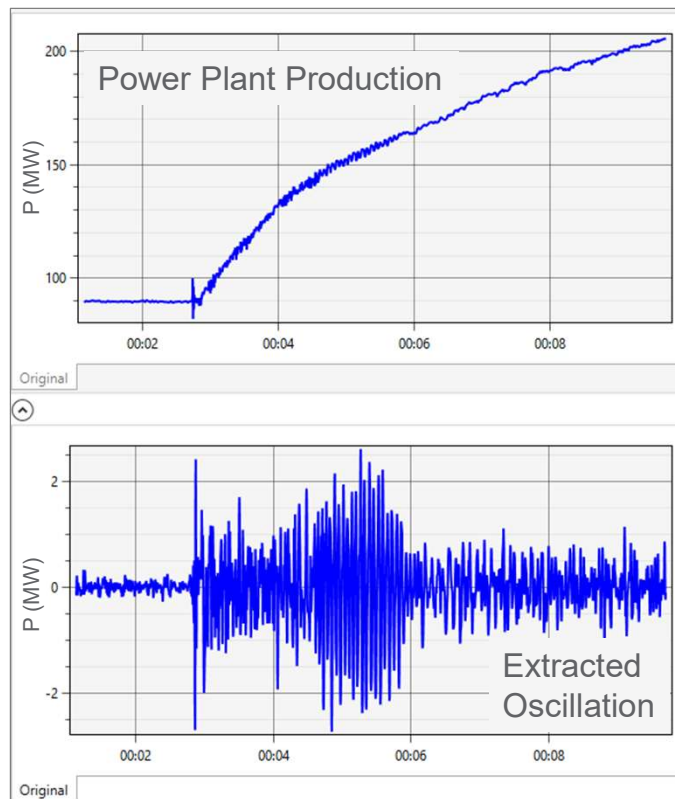


# Oscillation Source Localization

- Dissipating Energy Flow (DEF)
  - Well-established PMU-based method
  - Traces the flow of oscillation energy back to the source
- A POW-based version is being developed to address oscillations too high in frequency for conventional DEF

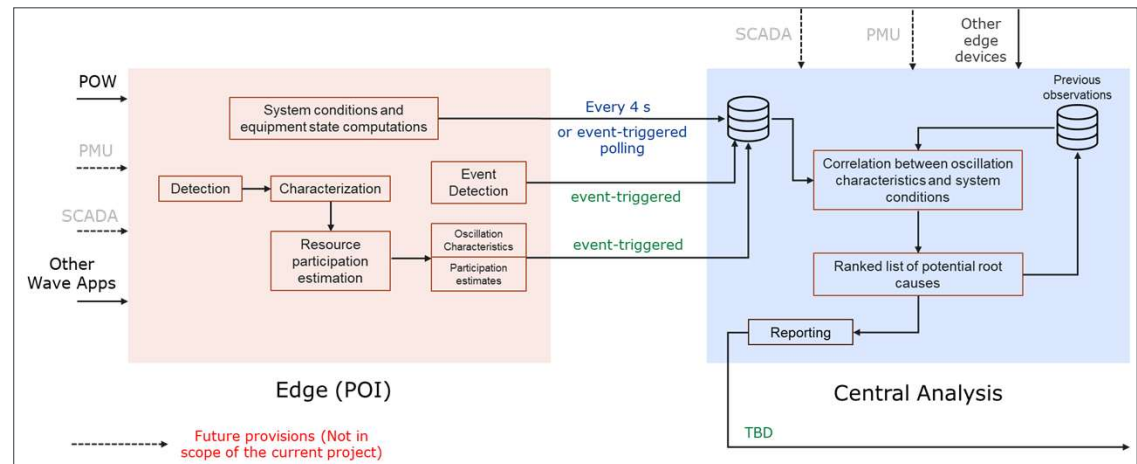
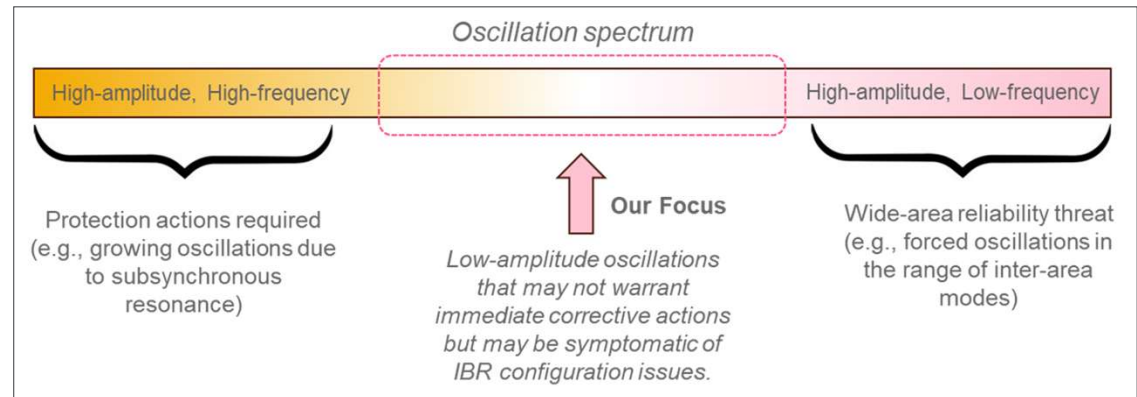


# Oscillation Correlation Analysis



# Oscillation Correlation Analysis

- Identifies root causes of IBR-induced oscillations
- Detects oscillations with the distributed instances
- Correlates the oscillation's appearance with grid conditions at the central instance







## Summary and Next Steps

- The Wave Apps platform will address a gap in utilities' ability to monitor IBRs
- 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

**Thank you**

