Event-Type Identification in Distribution Grids Using Synchro-waveform Measurements from Adjacent Infrastructure

Presented to NASPI DisTT

NASPI Spring Work Group Meeting

April 16, 2026

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Grid Event Signature Library (GESL)

- ORNL, LLNL, and PNNL have developed the *Grid Event Signature Library (GESL)*, funded by the Department of Energy's Office of Electricity.
- The GESL contains over 5,500 waveform recordings, with measurement modalities encompassing PMU and PoW (point-on-wave).
- 13 distinct, anonymized providers from all over the United States

- **To Date:**
- 1150+ registered users worldwide, encompassing industry, small businesses, academia, universities, and more
- Waveform visualization:
  - Time series, spectrum, RMS, and spectrogram
  - Beta version for GridPULSE
- Examples of data usage
- PMU Signature Matching Tool
- Journal publication (IEEE Access, 2024)*

***Goal**: To create an open-access repository of grid events and applications that enhances research in data-driven grid applications and facilitates swift engineering analysis*

*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.

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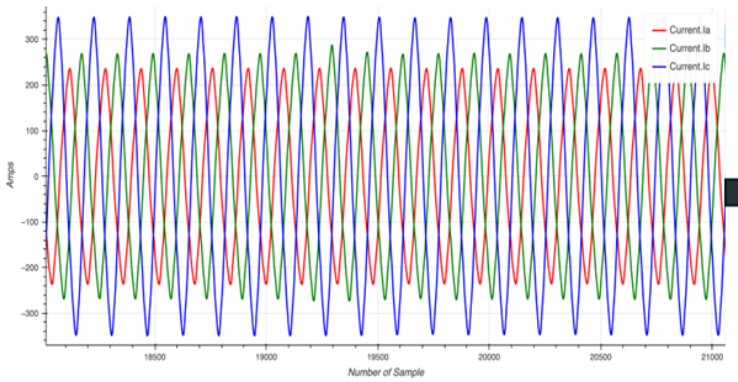
Multi Event Detection and Classification

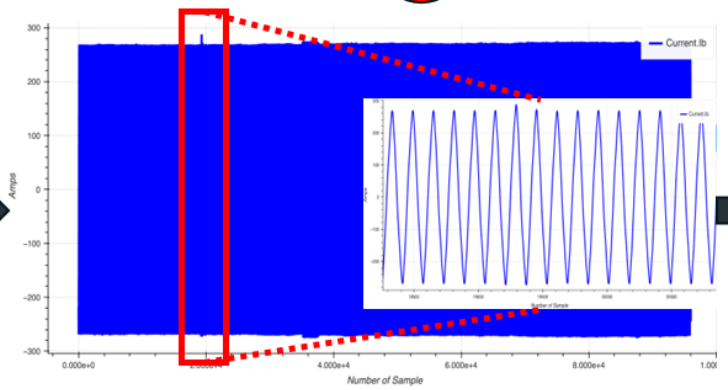
1



Three Phases: A, B, and C

1. Identify the faulty phase using waveform data (A, B, C).

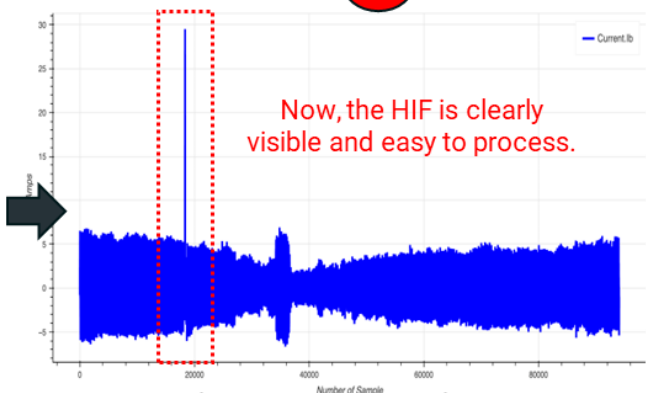
2



Fault Detected in Phase B with Zoomed Version

2. Apply MUSIC algorithm to isolate noise vectors and highlight abnormal patterns.

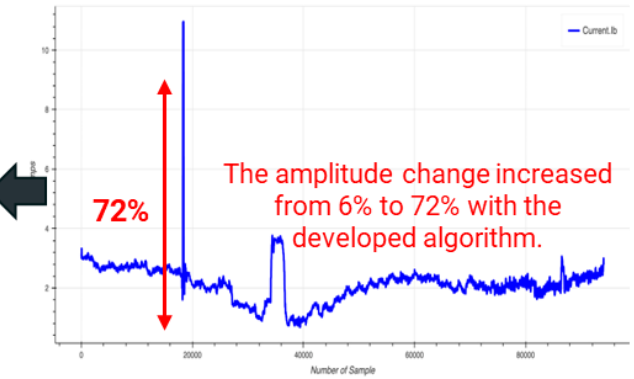
3



Noise Vector Extraction

3. Extract amplitude change to quantify fault intensity.

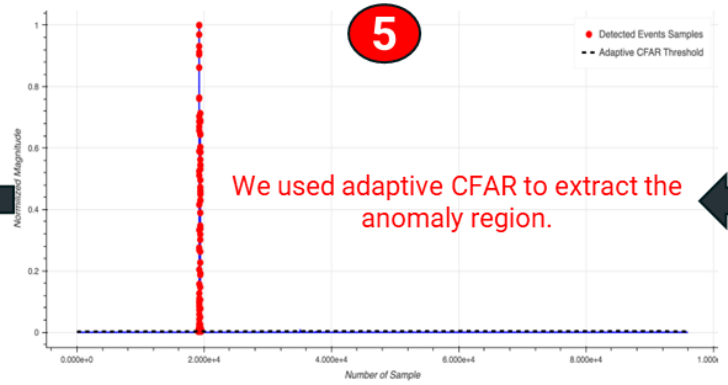
4



Amplitude Variation of Noise Vector

3. Detect anomaly region using adaptive CFAR for weak-signal faults.

5



Adaptive Threshold CFAR Applied to Detect Anomaly Region

4. Apply SCF features aided AI for classification of arcing events.

6

The developed **AI-aided** method amplifies weak fault signatures (6% → 72%), improving early fault visibility for wildfire prevention.

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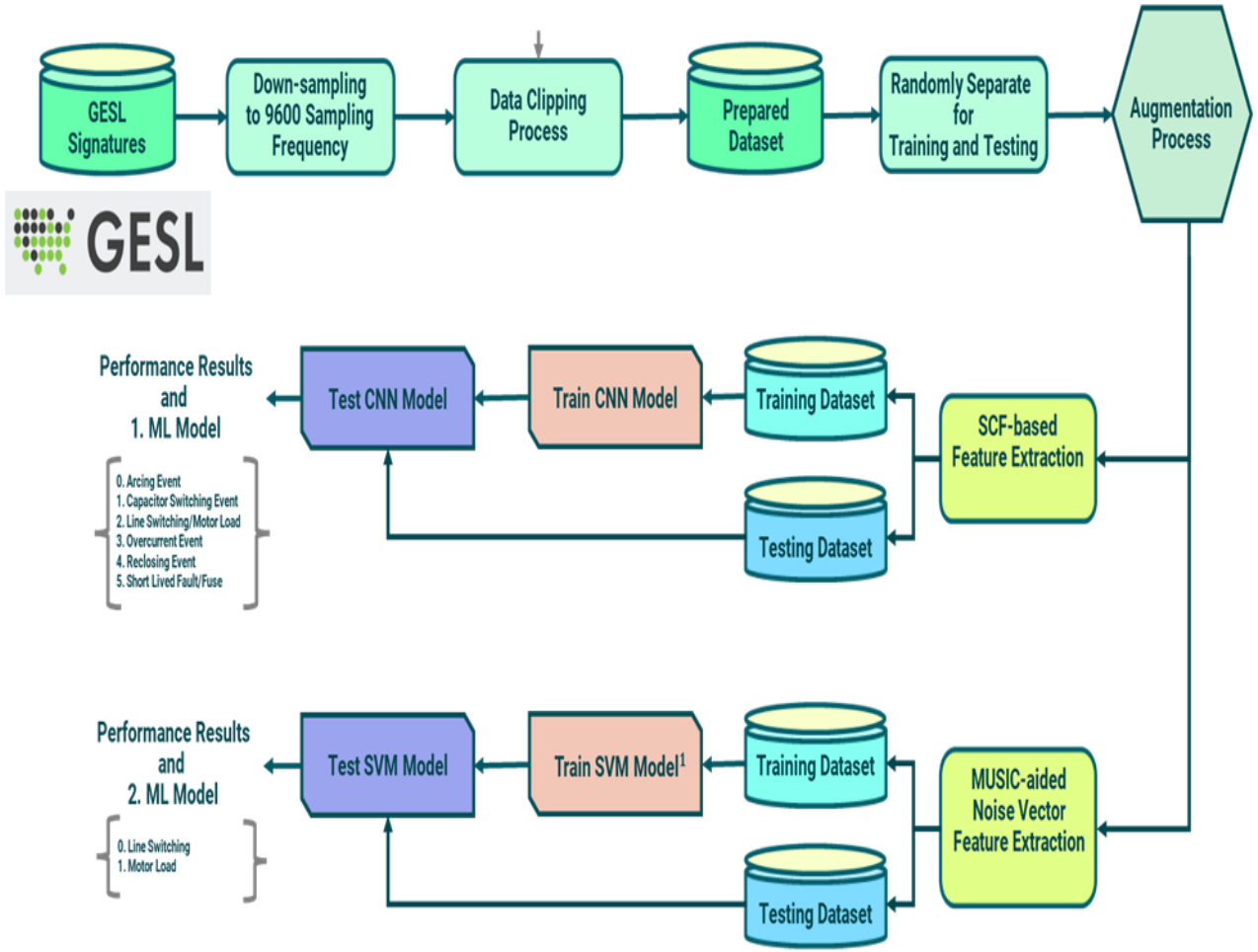
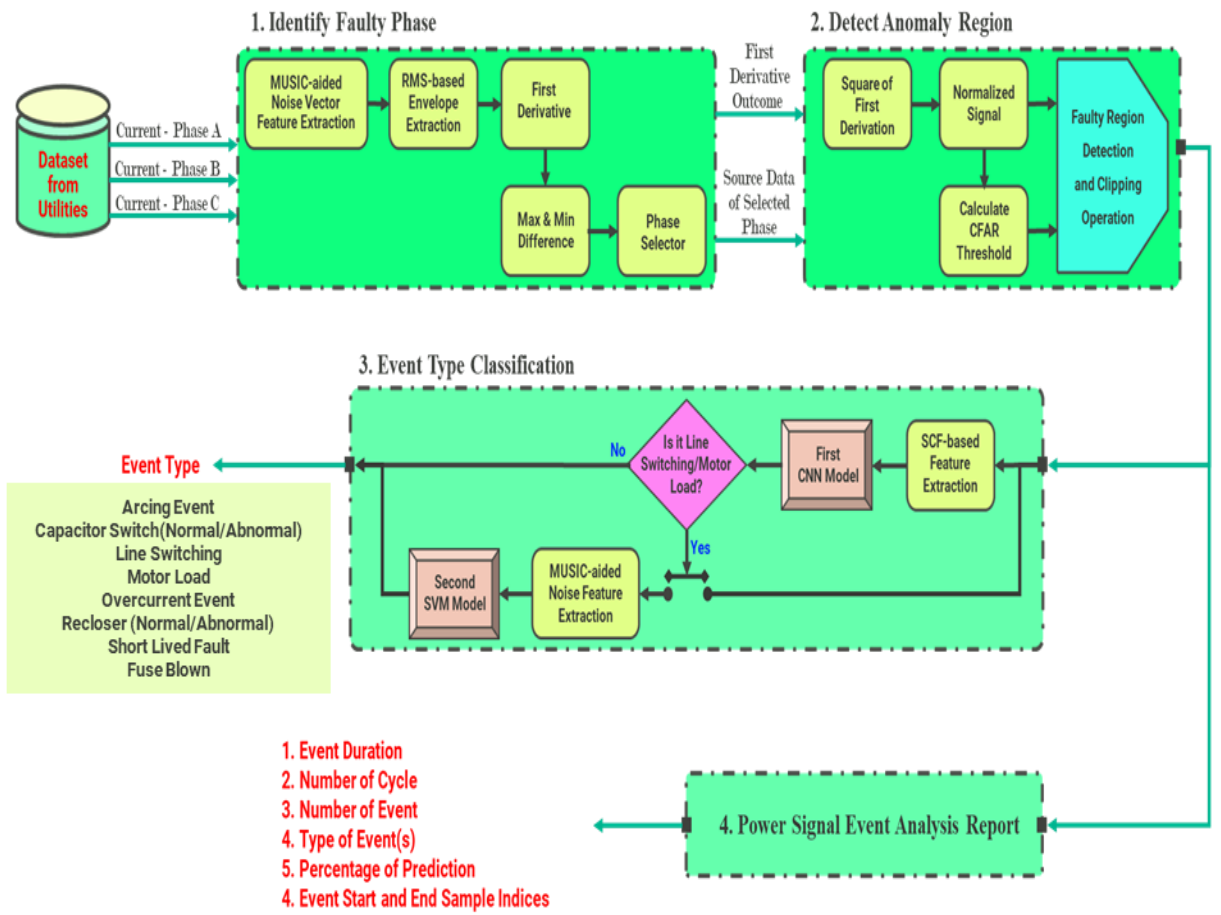
Multi-Event Detection Algorithm – Training phase

1



2

Multi-Event Detection Algorithm – Testing Phase at Utility Framework



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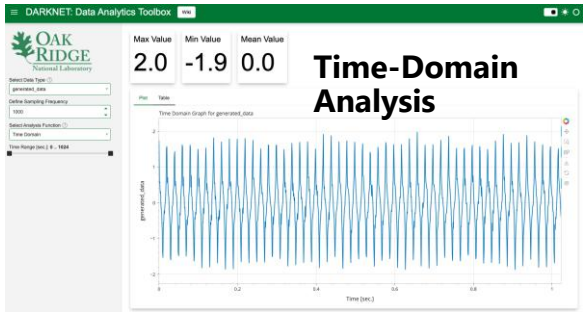
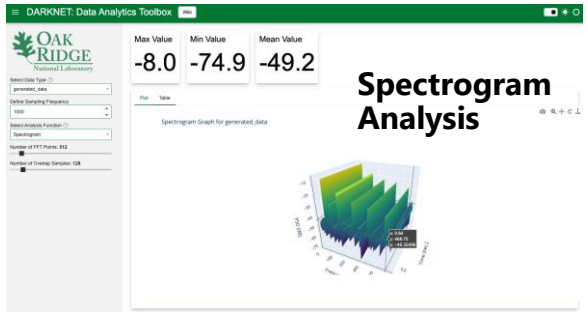
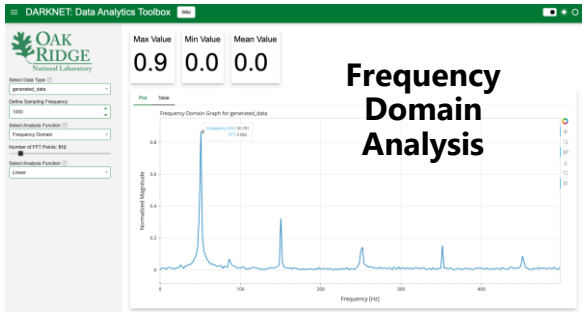
GridPULSE

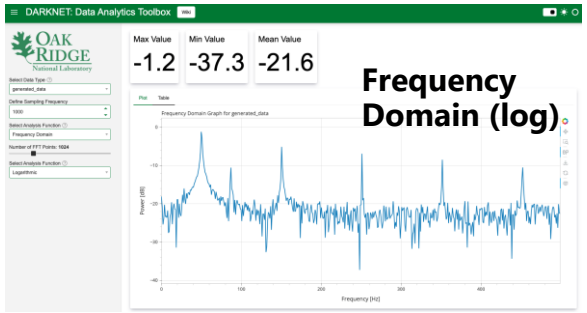
A web-based or Stand-Alone Grid Data Analytics Toolbox (GridPULSE) is currently under development. The recent analysis functions of the toolbox include the following but not limited to:

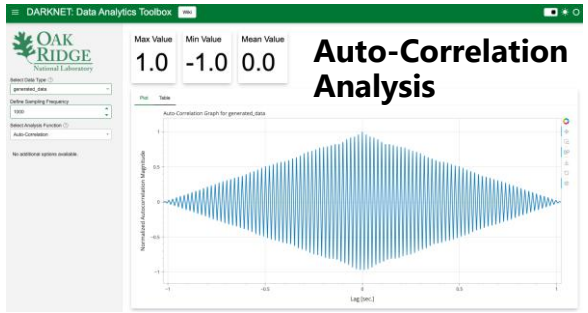
- **Python based algorithms are integrated into toolbox.**
  - **Time-domain analysis**
  - **Frequency-domain analysis using FFT**
  - **Power spectral density analysis with STFT**
  - **Auto-correlation analysis**
  - **Spectral correlation function analysis**
  - **Harmonic analysis with Multiple Signal Classification (MUSIC) and Root-MUSIC algorithms**
  - **Pseudo-spectrum estimation**
  - **RMS value computation**
  - **Total Harmonic Distortion (THD) calculation**
  - **Signal-to-noise ratio (SNR) estimation**
  - **Each analysis function includes configurable options.**
  - **To provide theoretical and technical details about the toolbox's features, a dedicated Wiki page has also been created.**
  - **User can upload custom .csv file.**

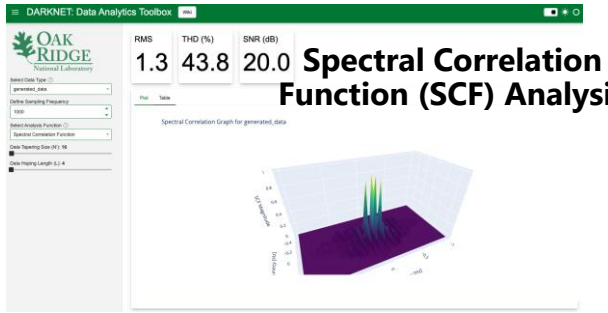


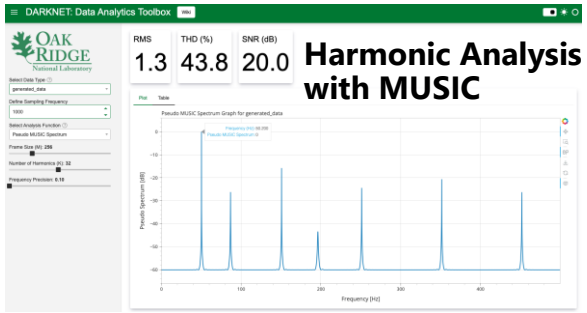












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This material is based upon work supported by the U.S. Department of Energy, Office of Electricity (OE).

Welcome to the **ORNL-GridPULSE Data Analytics Toolbox** (Power Grid Waveform Understanding through Learning & Signal Exploration Toolbox)

1. Upload a CSV with power-grid signals
2. We'll auto-map headers to **Time, IA, IB, IC, VA, VB, VC** if possible
3. Review the preview, set **Data Settings**, then **Start Analysis**

Upload CSV File

Choose File | No file chosen

Data Settings

Estimated Sampling Frequency

15360

Data Type

Voltage | Current

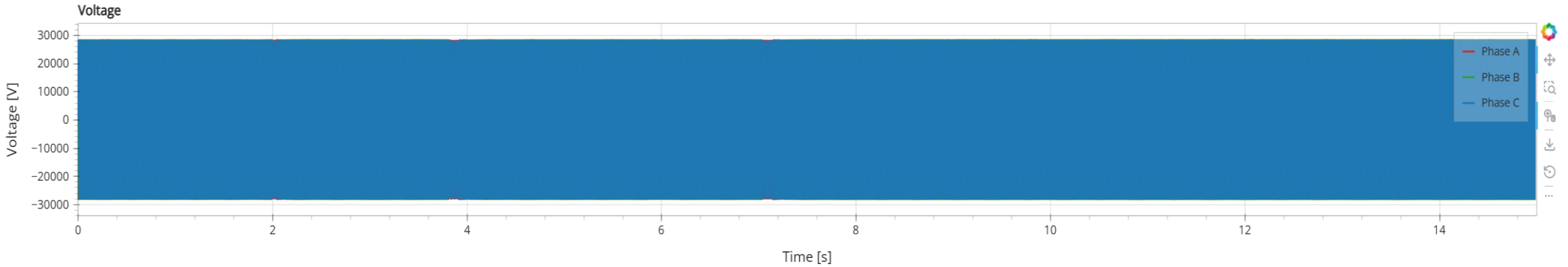
Phase

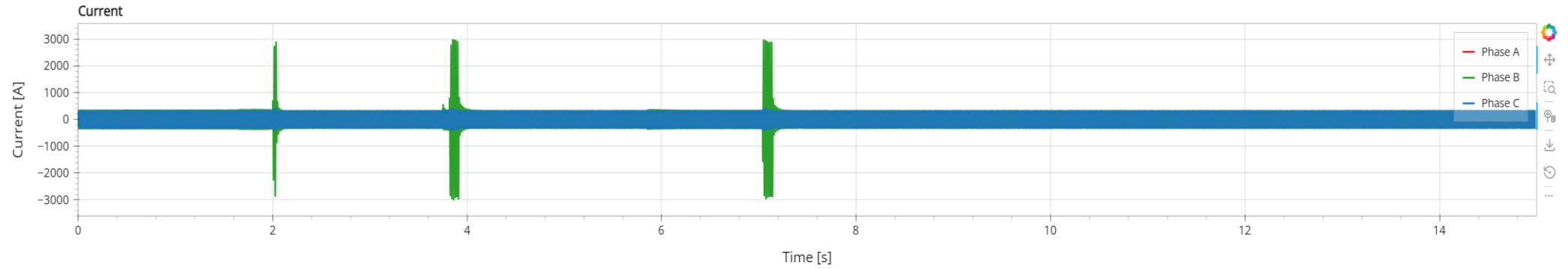
A | B | C

Start Analysis

Plot | Table

Analysed File





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Select New Data

Analysis

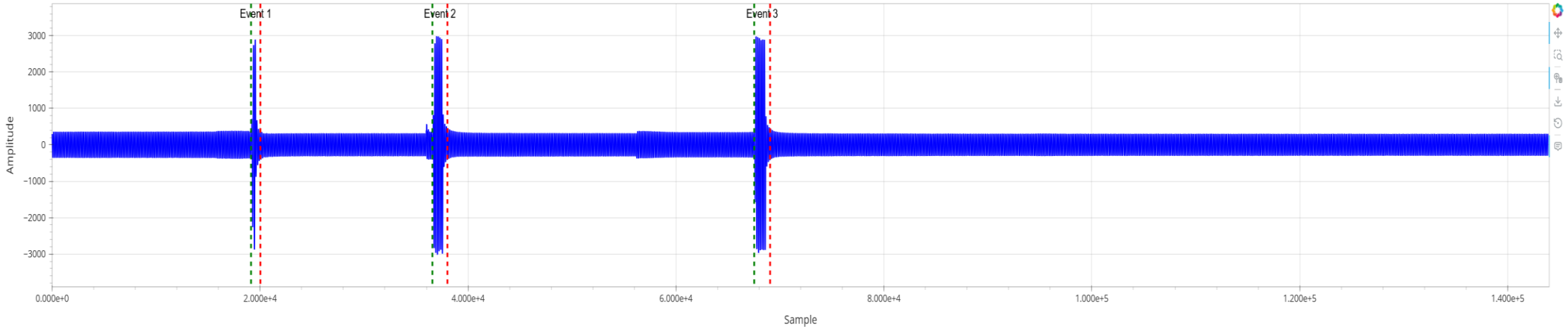
Select Type of Analysis
Anomaly Detection Analysis

Select statistical analysis type.
MUSIC-based Detector

Configuration

Identify Event(s)

MUSIC-based Anomaly Detection



Number of Events: 3

1. Event: Overcurrent Event: Tripped but Not Reclosing Successfully

Prediction Percentage: 100.00%,
Other Probabilities: Arcing Event (0.0%), Capacitor Switching (0.0%), Line Switching/Motor Event (0.0%), Reclosing Event (0.0%), Short Lived Fault/Fuse (0.0%),
Event Start and End Sample Indices: 19130 - 20027,
Event Duration: 0.0934 seconds,
Number of Cycles: 5.606

2. Event: Overcurrent Event: Tripped but Not Reclosing Successfully

Prediction Percentage: 99.93%,
Other Probabilities: Arcing Event (0.0%), Capacitor Switching (0.0%), Line Switching/Motor Event (0.0%), Reclosing Event (0.1%), Short Lived Fault/Fuse (0.0%),
Event Start and End Sample Indices: 36572 - 38017,
Event Duration: 0.1505 seconds,
Number of Cycles: 9.031

3. Event: Overcurrent Event: Tripped but Not Reclosing Successfully

Prediction Percentage: 99.86%,
Other Probabilities: Arcing Event (0.0%), Capacitor Switching (0.0%), Line Switching/Motor Event (0.0%), Reclosing Event (0.1%), Short Lived Fault/Fuse (0.0%),
Event Start and End Sample Indices: 67526 - 69057,
Event Duration: 0.1595 seconds,
Number of Cycles: 9.569

There are repetitive events.

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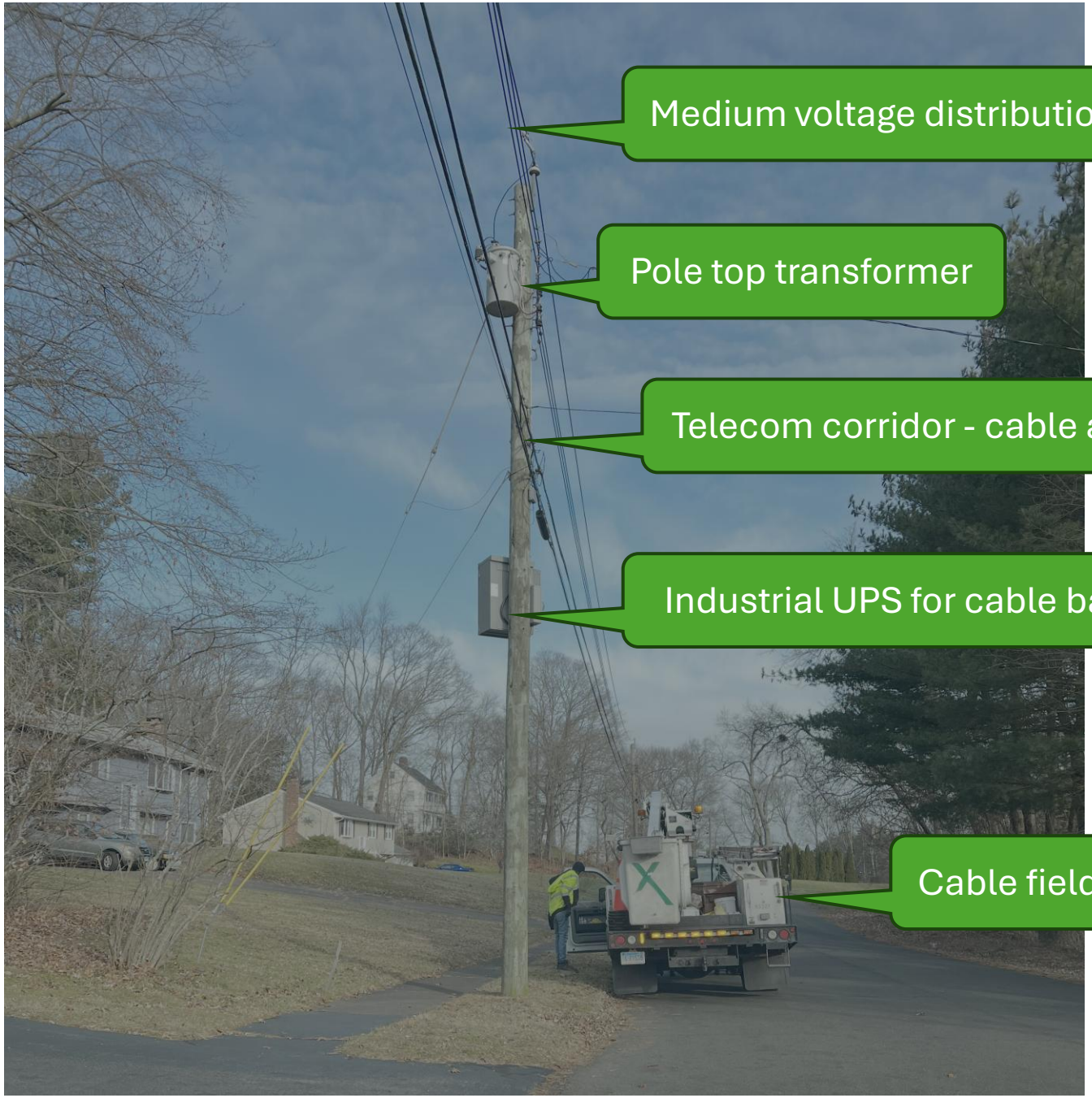

High Fidelity GridVisibility

- High fidelity
  (12+ bit sampled 10,000/sec)
- GPS time synchronized
  (0.5 microseconds)
- 650,000 UPS potential hosts in US
- 15-minute broadband tech install
- Security-by-design
- 4+ hour ride through
- Continuous low latency data stream

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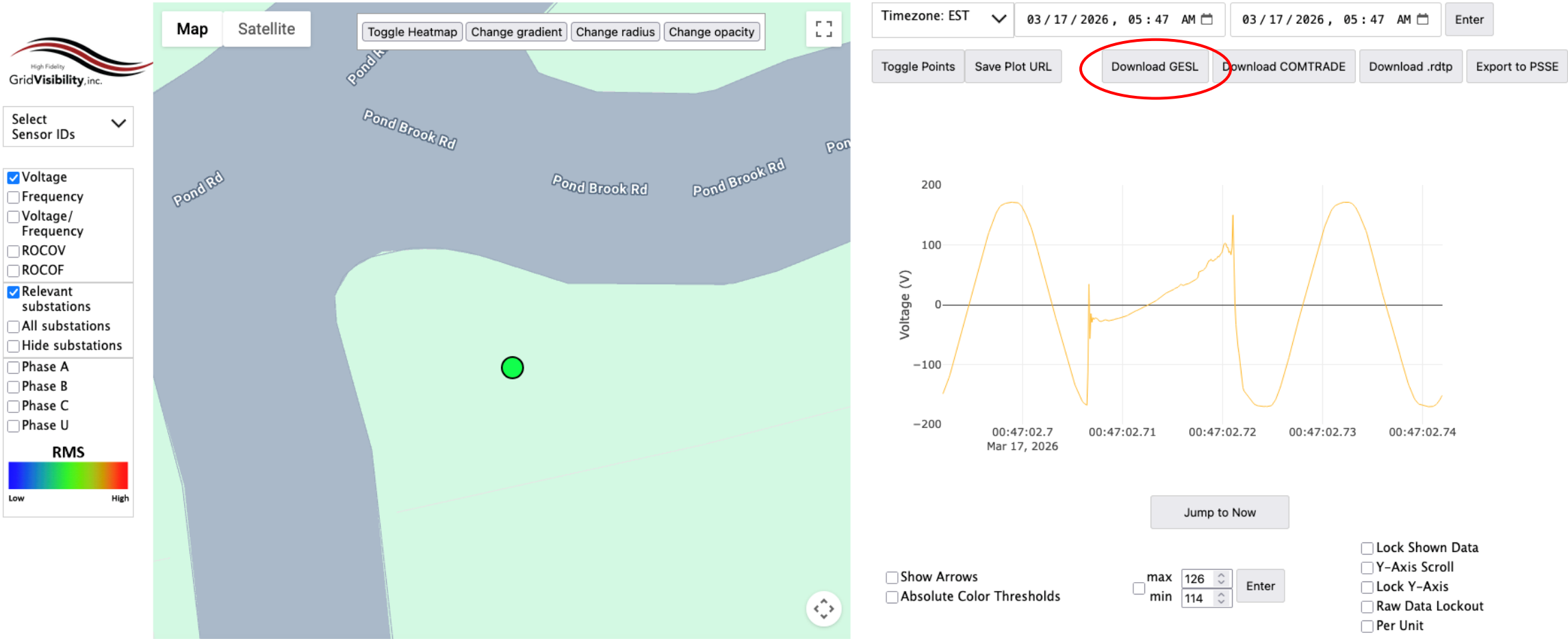
Event #1 – Arcing Event



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ORNL-GridPULSE Data Analytics Toolbox

Wiki

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Select New Data

Analysis

Select Type of Analysis

Anomaly Detection Analysis

Select statistical analysis type.

Zero Crossing-based Detector

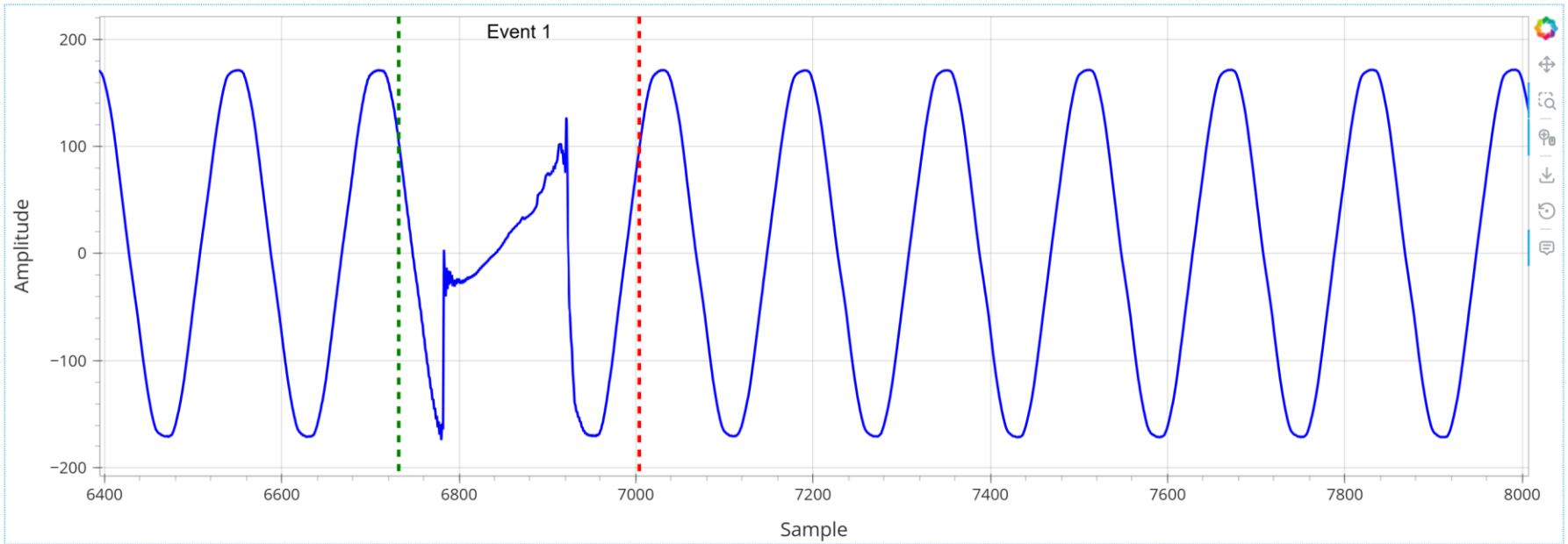
Configuration

Template Cycle: **1.70**

Overlap Percentage [%]: **25**

Identify Event(s)

Zero Crossing-based Anomaly Detection



Number of Events: 1

1. Event: Arcing Event

Prediction Percentage: 62.32%,
Other Probabilities: Capacitor Switching (36.2%), Line Switching/Motor Event (1.5%), Overcurrent Event (0.0%), Reclosing Event (0.0%), Short Lived Fault/Fuse (0.0%),
Event Start and End Sample Indices: 6732 - 7004,
Event Duration: 0.0283 seconds,
Number of Cycles: 1.700

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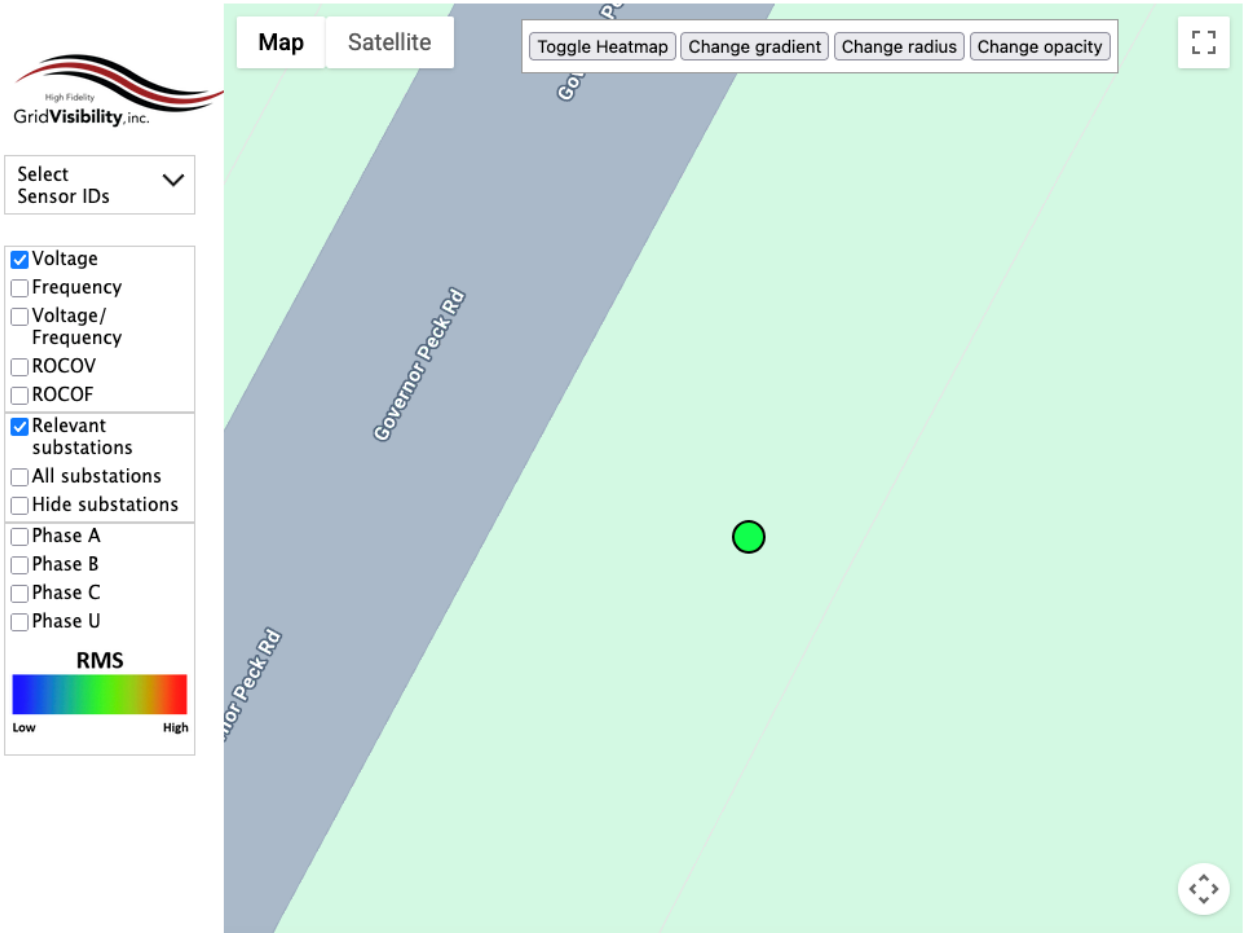
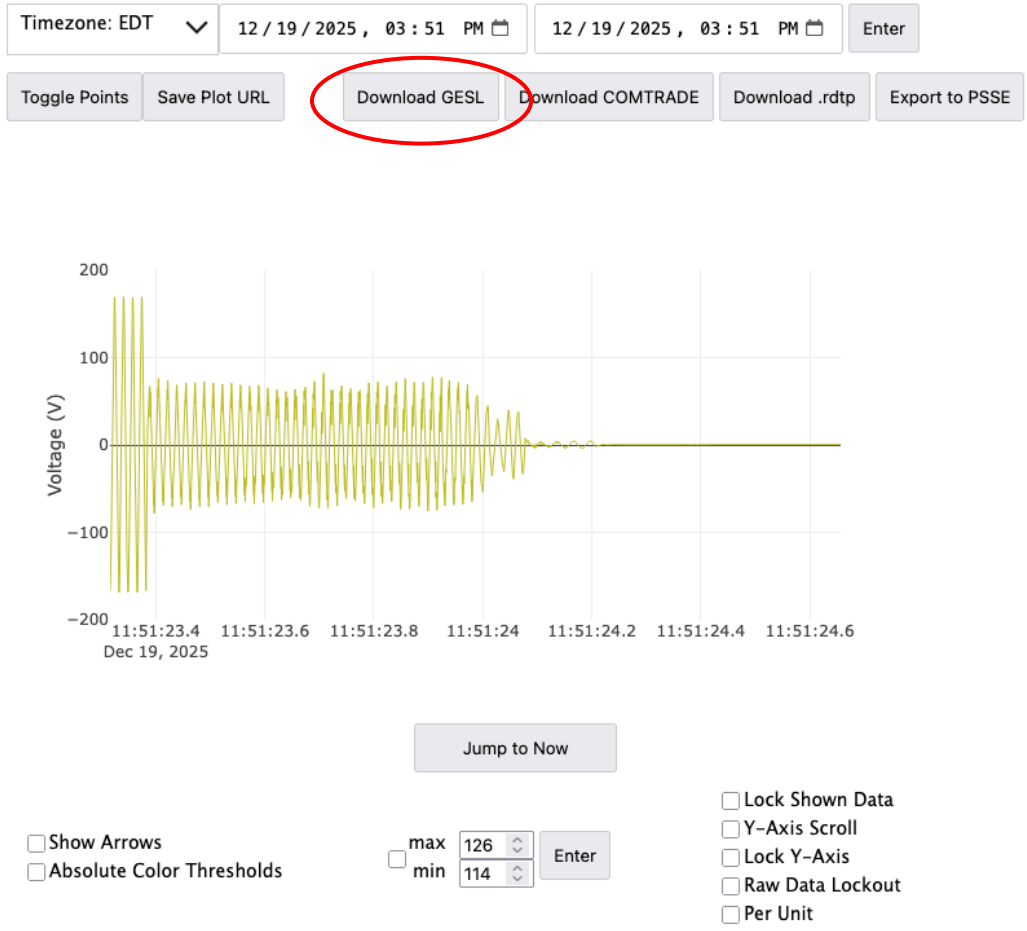
Event #2 – Reclosing Event





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ORNL-GridPULSE Data Analytics Toolbox

Wiki

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Select New Data

Analysis

Select Type of Analysis

Anomaly Detection Analysis

Select statistical analysis type.

UFT-based Detector

Configuration

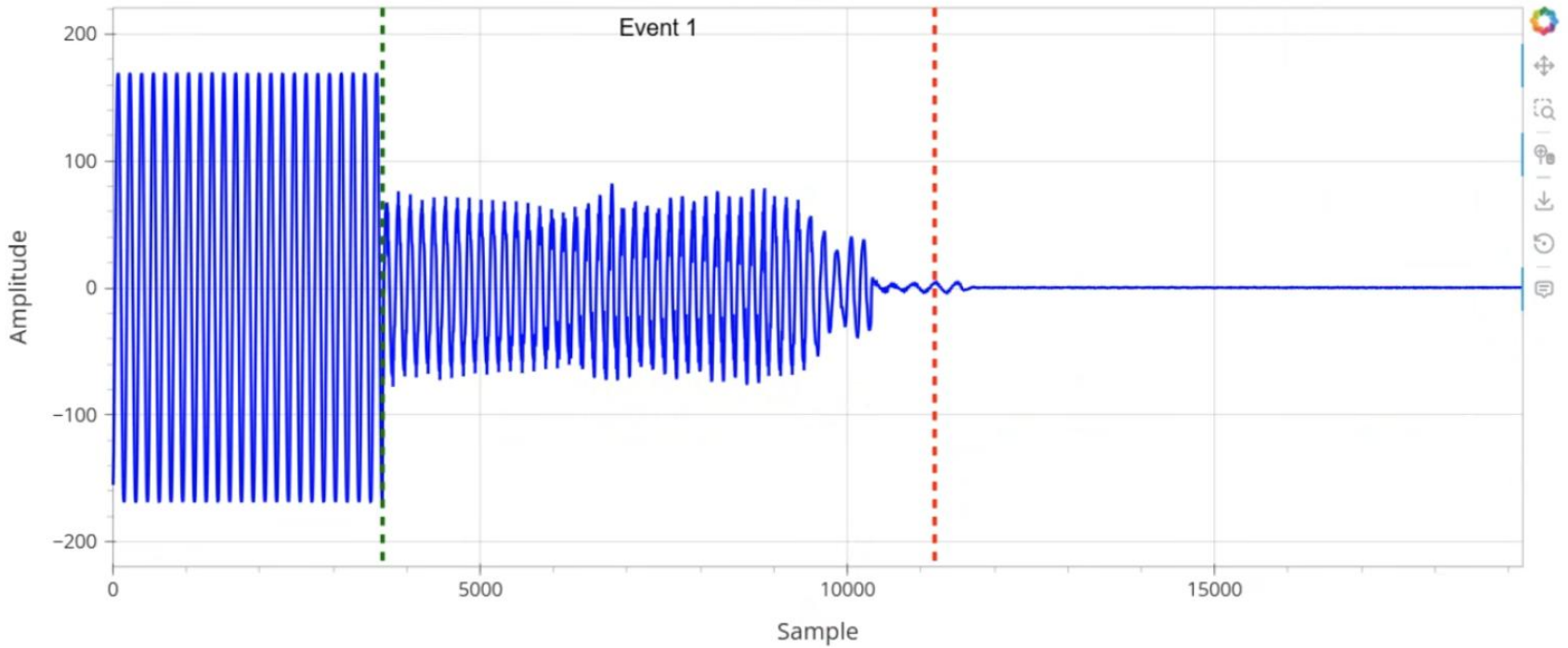
Lockout Number: **10**

Threshold Coefficient

2.5

Identify Event(s)

Ultra Fast Transient Detector-based Anomaly Detection



Number of Events: 1

1. Event: Reclosing Event

Prediction Percentage: 99.28%,
Other Probabilities: Arcing Event (0.0%), Capacitor Switching (0.0%), Line Switching/Motor Event (0.0%), Overcurrent Event (0.7%), Short Lived Fault/Fuse (0.0%),
Event Start and End Sample Indices: 3669 - 11188,
Event Duration: 0.7832 seconds,
Number of Cycles: 46.994

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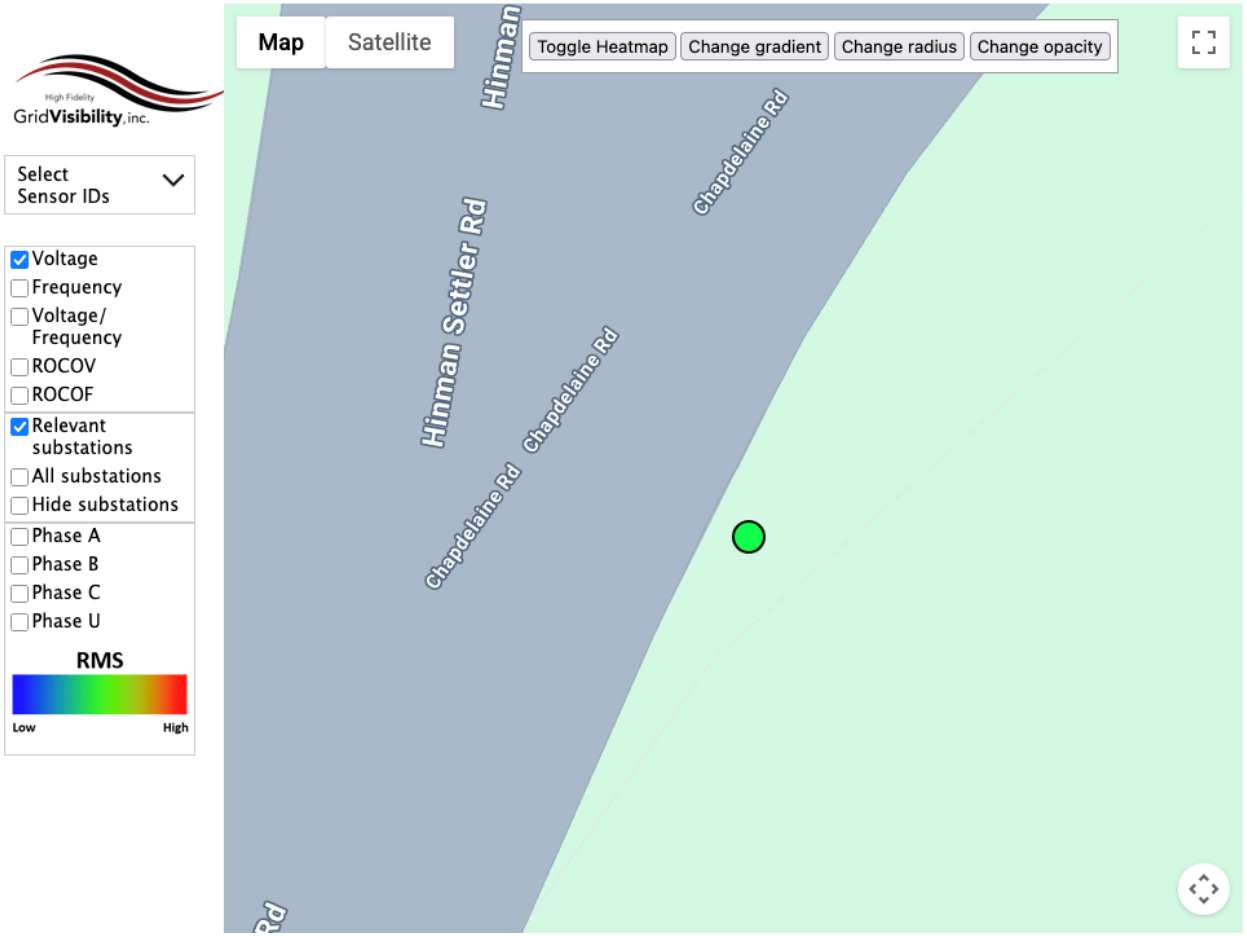
Event #3 – Over Current Event, Tripped but Not Reclosing Successfully



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Select New Data

Analysis

Select Type of Analysis

Anomaly Detection Analysis

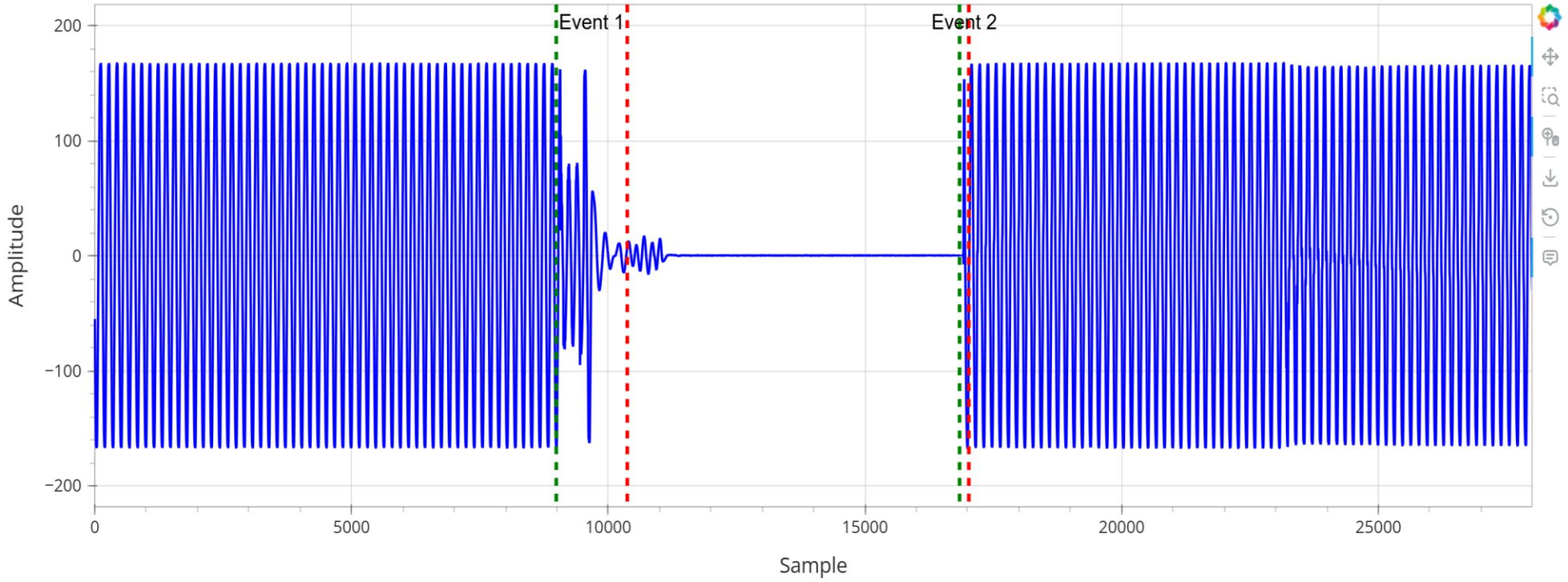
Select statistical analysis type.

MUSIC-based Detector

Configuration

Identify Event(s)

MUSIC-based Anomaly Detection



Number of Events: 2

1. Event: Overcurrent Event: Tripped but Not Reclosing Successfully

Prediction Percentage: 89.96%,
Other Probabilities: Arcing Event (0.0%), Capacitor Switching (0.0%), Line Switching/Motor Event (0.0%), Reclosing Event (10.0%), Short Lived Fault/Fuse (0.0%),
Event Start and End Sample Indices: 8988 - 10371,
Event Duration: 0.1441 seconds,

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Conclusions

- Demonstrated that high-fidelity, continuous point-on-wave measurements can be easily ingested into and detected and classified by the GridPULSE Data Analytics Toolbox
- This is just the first step, in the future:
  - Automate the ingest process and scale/improve classification process
  - Contribute events Grid Event Signature Library
  - Expand access to GESL by researchers and practitioners
  - Correlate events across sensors geographically
  - Ultimately, enable detection and notification of incipient faults for purposes of proactive grid maintenance

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  - Sandra Jenkins and Christopher Irwin and Anne Egger
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- **Team Members GridVisibility:** Ralph Brown, Steve Glennon, Scott Caruso, Dan Kopin
- **Utility Partner:** Southern California Edison (SCE)
- **Lab Partners:** PNNL, LLNL

*** Orders are random**

Thank You!

Any Questions

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