The Grid Event Signature Library:
An Open-Access Repository of Power System Waveform Signatures

NASPI Fall Meeting

Charlotte, NC, October 15, 2024

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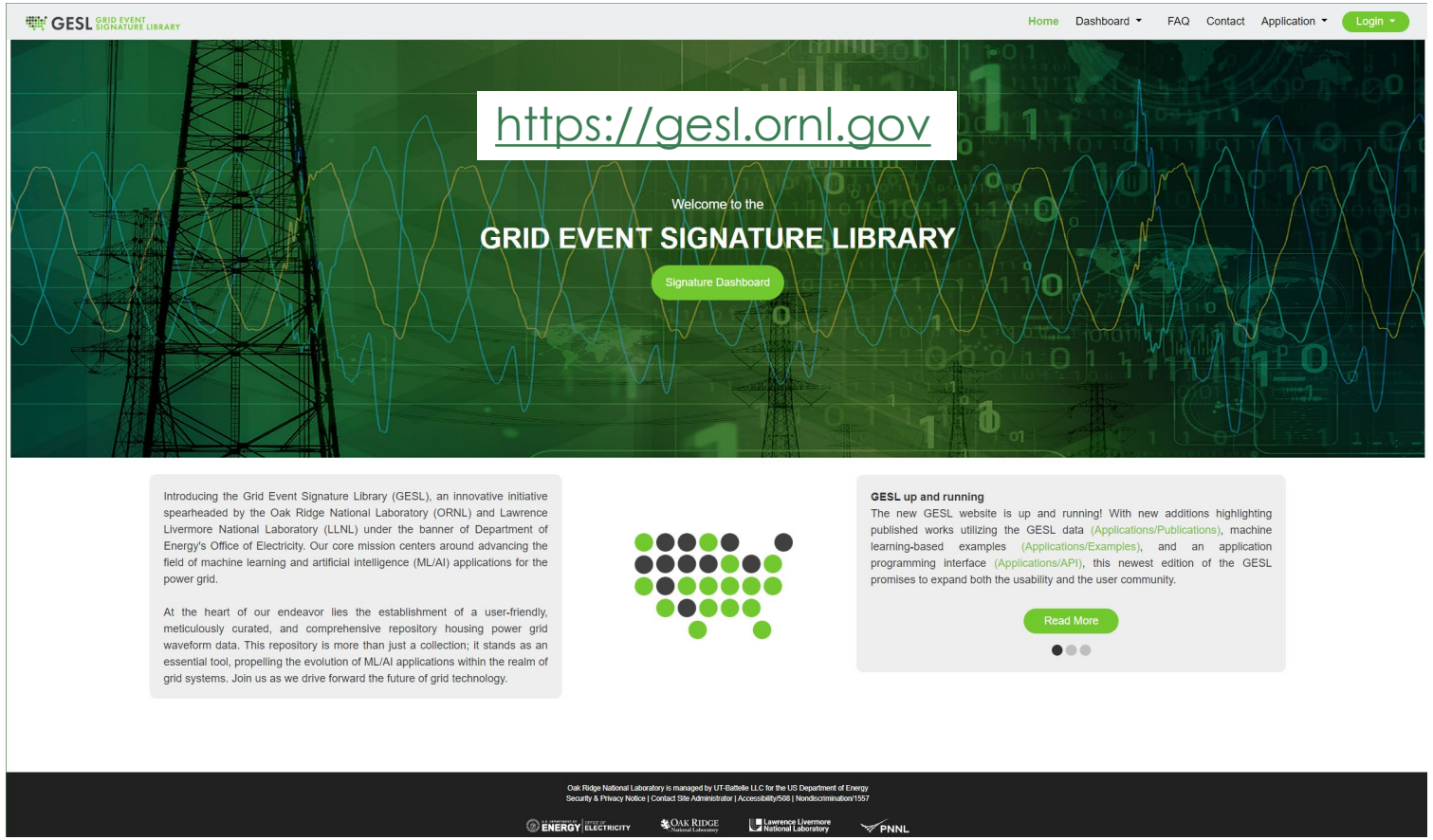
Grid Event Signature Library (GESL)

ORNL, LLNL, and PNNL, funded by DOE Office of Electricity, partnered to develop an open- access **Grid Event Signature Library (GESL)**

- Measurement data: raw data with signatures yet to be extracted
- Signature data: labeled events with data provided in specific formats

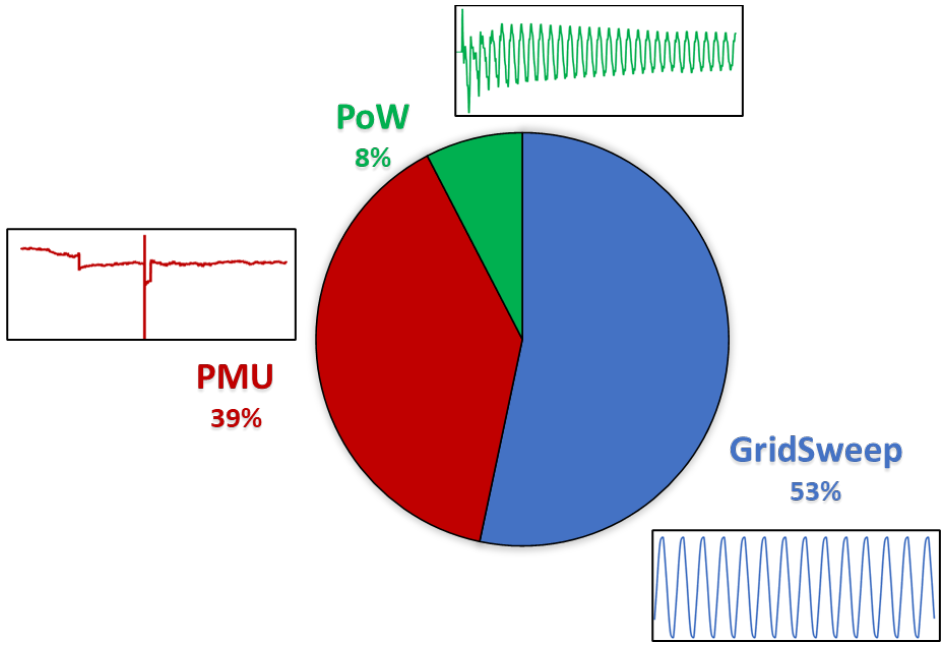
Goal

- **Assign labels** to event data sets from multiple sources
- Implement a **modular architecture** for expandable design
- **Anonymize event sources** to enable open data sharing



To date…

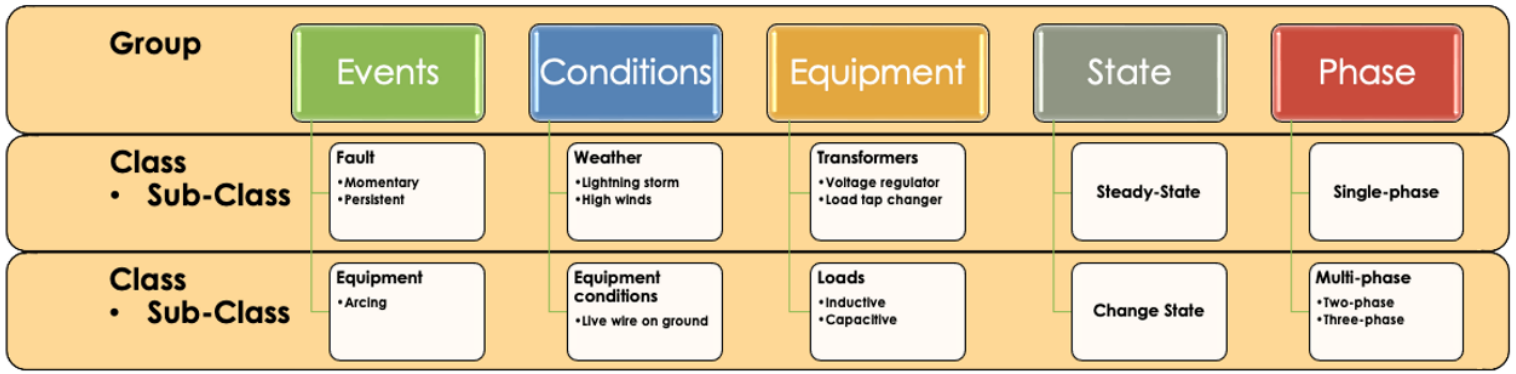
- 550+ registered users worldwide, encompassing industry, small businesses, academia, universities, and more
- More than 5500 signatures housed in the GESL, across 12 unique, anonymized, providers.
  - Types: Point-on-Wave (PoW), Phasor Measurement Unit (PMU), and GridSweep[1]
- Waveform visualization:
  - Time series, spectrum, RMS, and spectrogram
- Examples of data usage
- Journal publication (IEEE Access, 2024)



[1] *A. McEachern and A. von Meier, ''GridSweep: An early report on active measurements of electric distribution grids,'' in Proc. IEEE Power Energy Soc. Gen. Meeting (PESGM), Jul. 2022, pp. 1–5*

Taxonomy

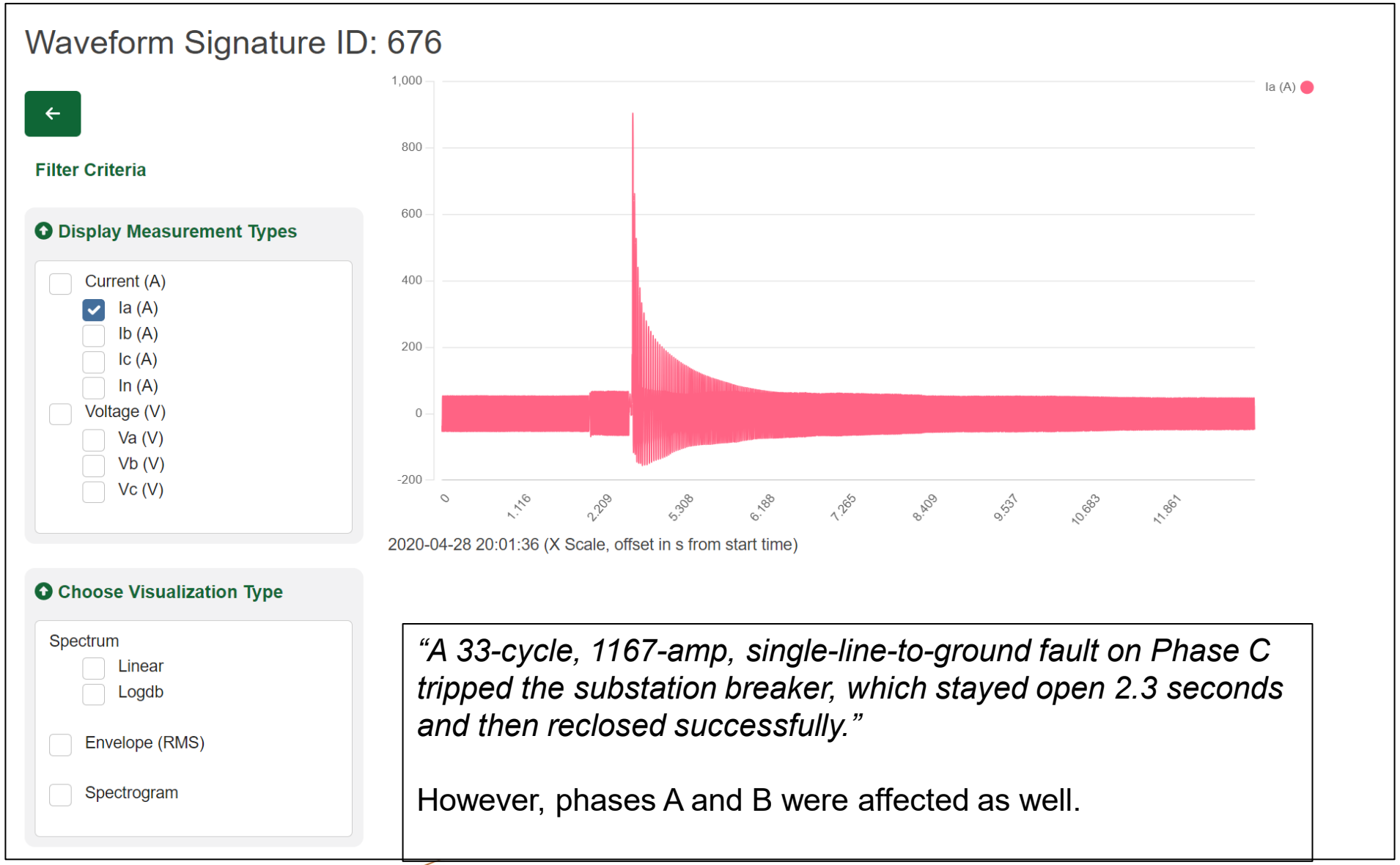
- Every provider gave textual descriptions with data, using their own terminology.
- The solution: create an all-encompassing taxonomy schema
- Useful for grouping similar types of disturbances
  - Avoids long list of unique disturbance types/conditions
- Flexible & expandable
  - creating entirely new entry when adding new disturbances



- 5 Groups
- 38 Total classes
- 129 Total subclasses

- Full event label takes form of `Group::Class::SubClass`

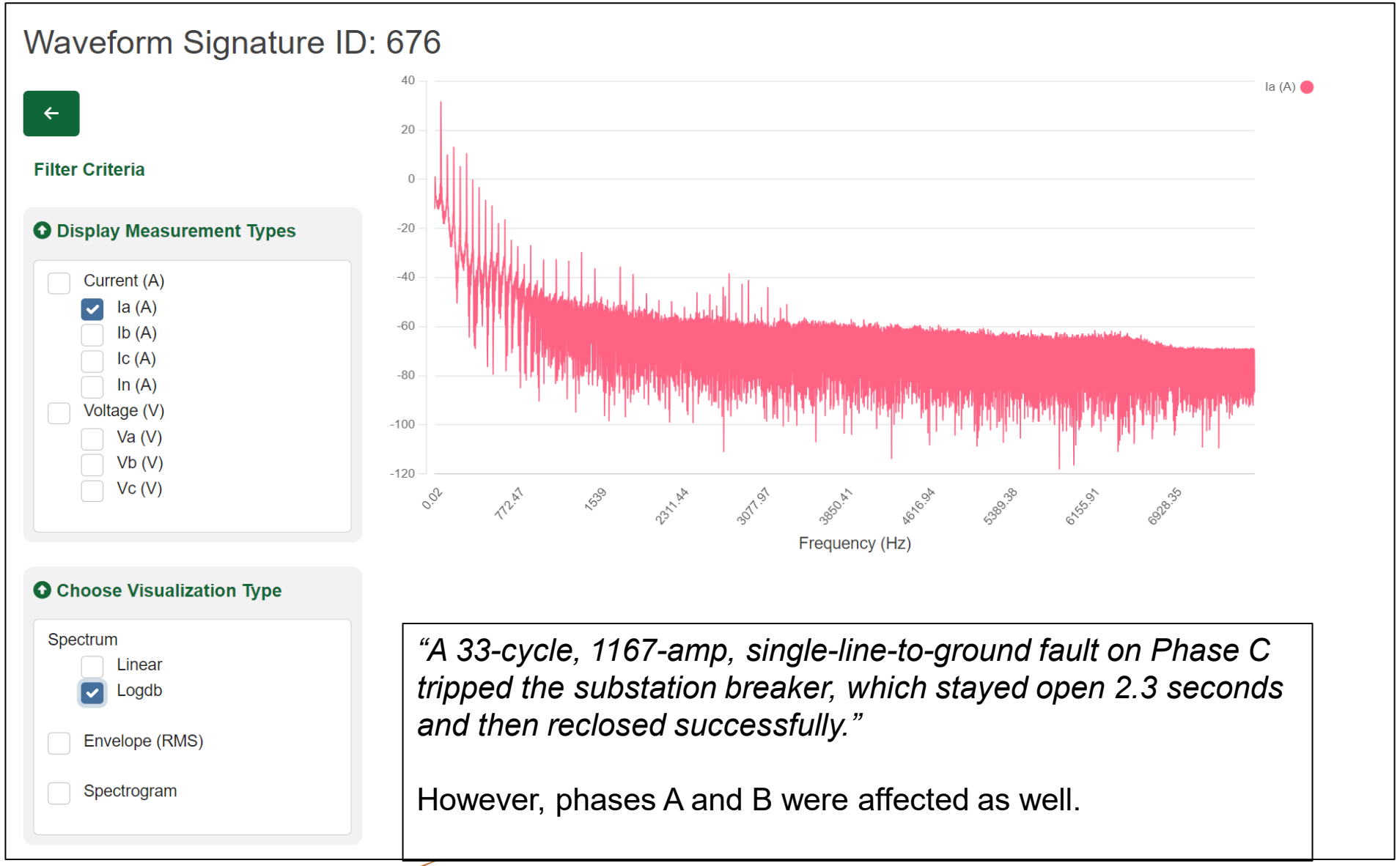
Visualization Example: Point-On-Wave (Time Series)



"A 33-cycle, 1167-amp, single-line-to-ground fault on Phase C tripped the substation breaker, which stayed open 2.3 seconds and then reclosed successfully."

However, phases A and B were affected as well.

Visualization Example: Point-On-Wave (Spectrum)



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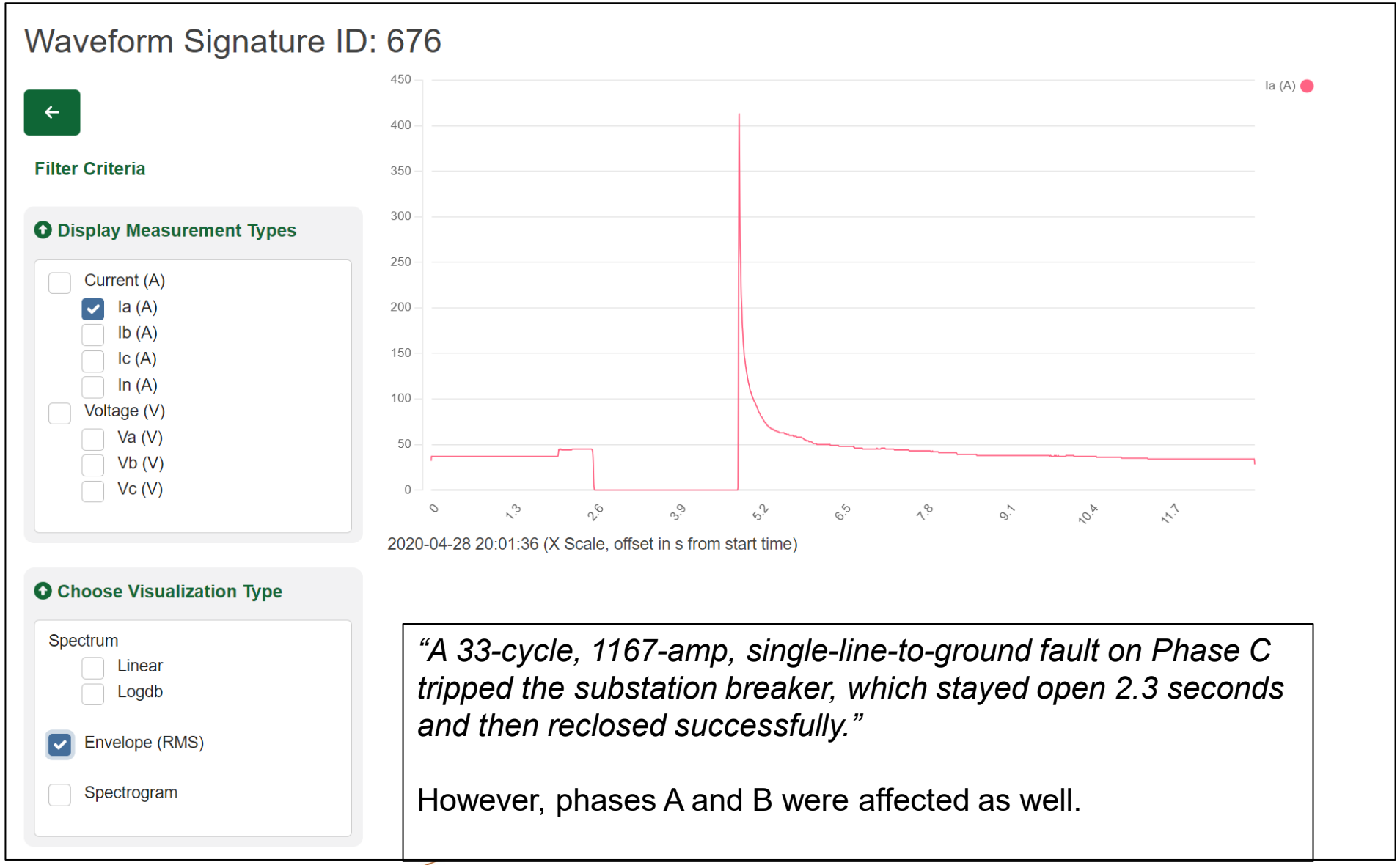
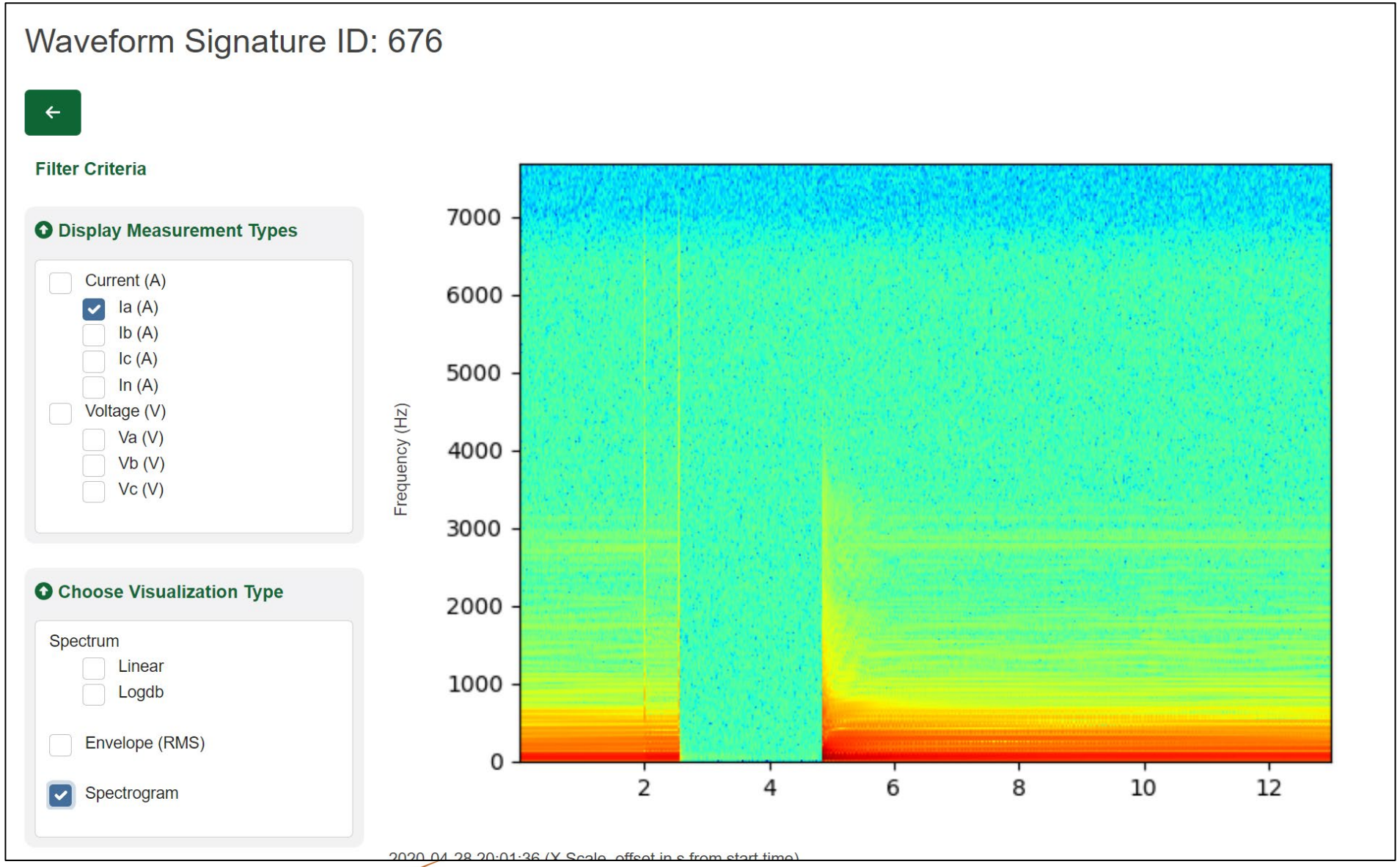
Visualization Example: Point-On-Wave (RMS Envelope)



"A 33-cycle, 1167-amp, single-line-to-ground fault on Phase C tripped the substation breaker, which stayed open 2.3 seconds and then reclosed successfully."

However, phases A and B were affected as well.

Visualization Example: Point-On-Wave (Spectrogram)



Signature Matching Tool

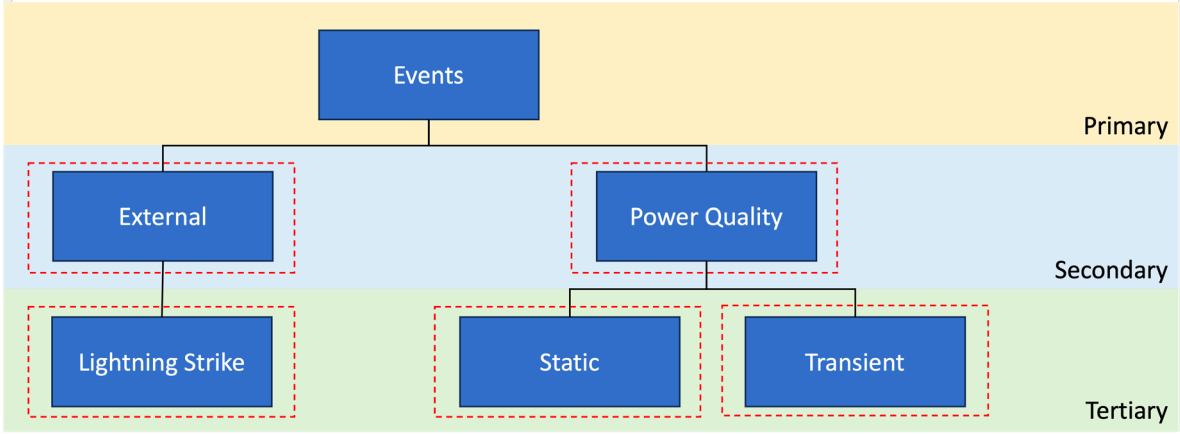
Tell me what this signature might represent

- What it is
  - Tool to help a user identify an unlabeled signature by comparing it with the signatures in GESL
- Approach
  - GESL event tag (label) taxonomy is hierarchical
  - Local binary classifier per node (LCN)
    - Binary classification at each root node
    - Three methods for binary classifiers tested (random forest, support vector machine, naïve Bayesian)
  - Providers 9 & 10 data (PMU) used as training datasets
    - Statistical moments as features

Event Tags

Total	Signatures Count	Event Tags Count
172 (5-Main Categories 38-Sub Categories 129-Class Tags)	5643	8513

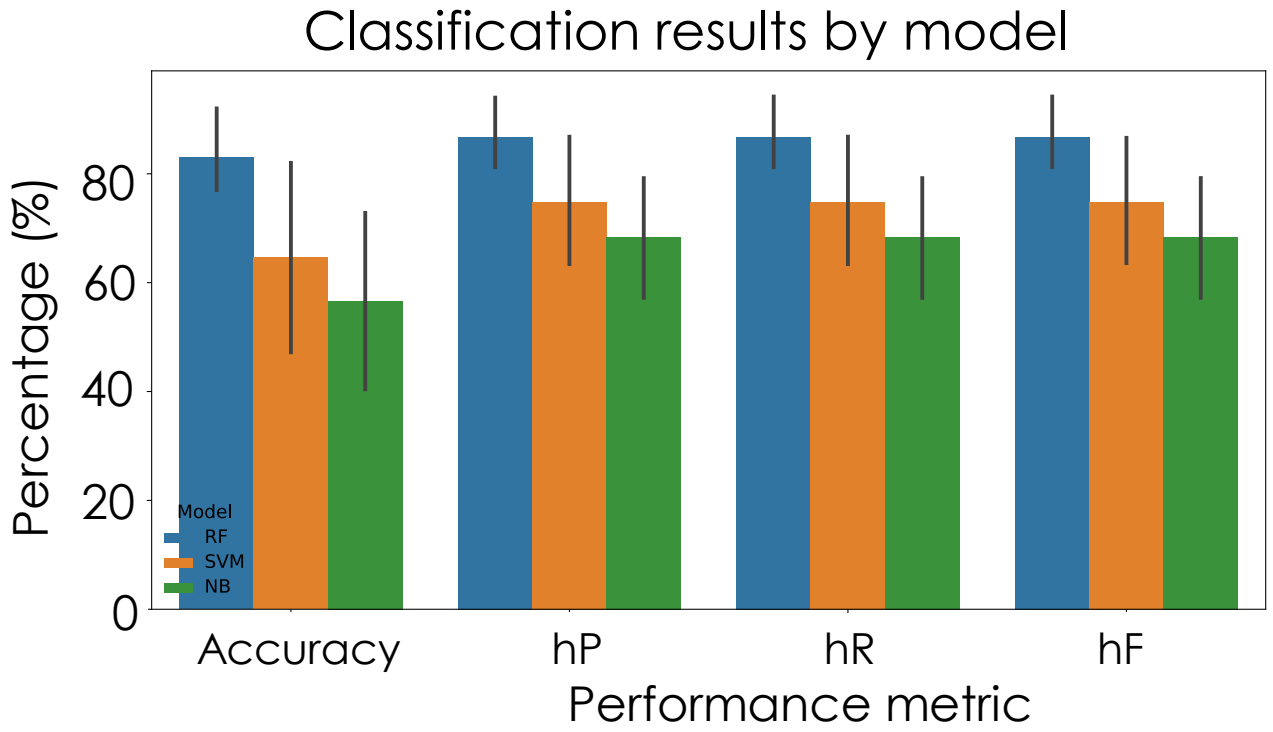
Conditions	463
Equipment	2049
Events	1485
Construction & Maintenance	107
Defect or Deterioration	5
Equipment Failure	256
Error	2
External	255
Fault	194
Cable Fault	11
Insulation Fault	1
Momentary	16
Nonspecific Fault	126
Partial Discharge Fault	1
Permanent	1
Unknown Fault	38
Other	78

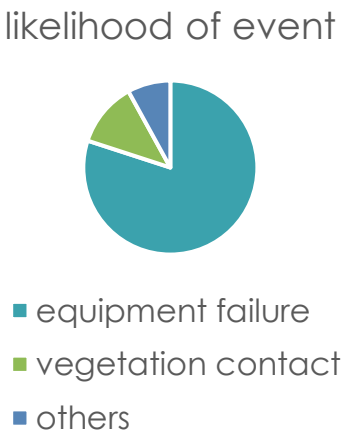


Signature Matching Tool
Overall ~80% accuracy

- Random forest showed the best performance for all primary labels

- Work in progress
  - Taxonomy revamp
  - User interface being planned





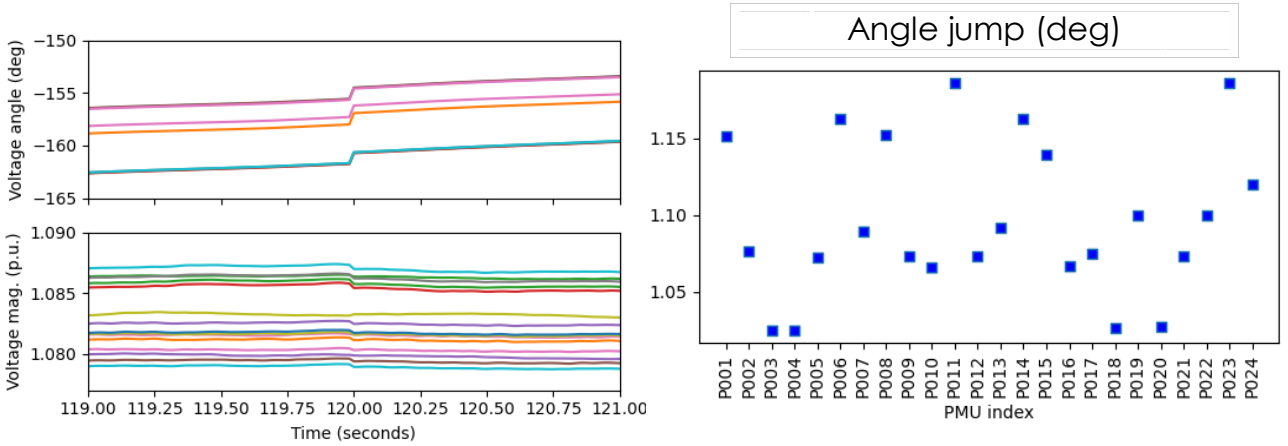
C. Annalicia and J. Joo, "Hierarchical Classification of Grid Event Signatures Using a Public Data Repository," 2024 IEEE Power and Energy Society General Meeting, Jul 2024

Recent Additions

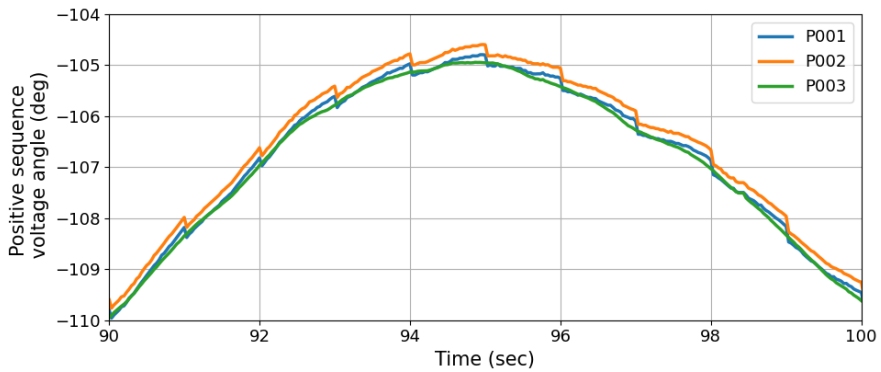
- Data Quality Library
- Data from an island grid
- Data from a solar+storage facility

Recent Additions

- Data Quality Library
  - 123 records of data anomalies in PMU measurements
  - Includes examples of clock errors, quantization noise, data dropouts, etc.
- Data from an island grid
- Data from a solar+storage facility



Signature Id 5790: Leap second insertion in the Western Interconnection

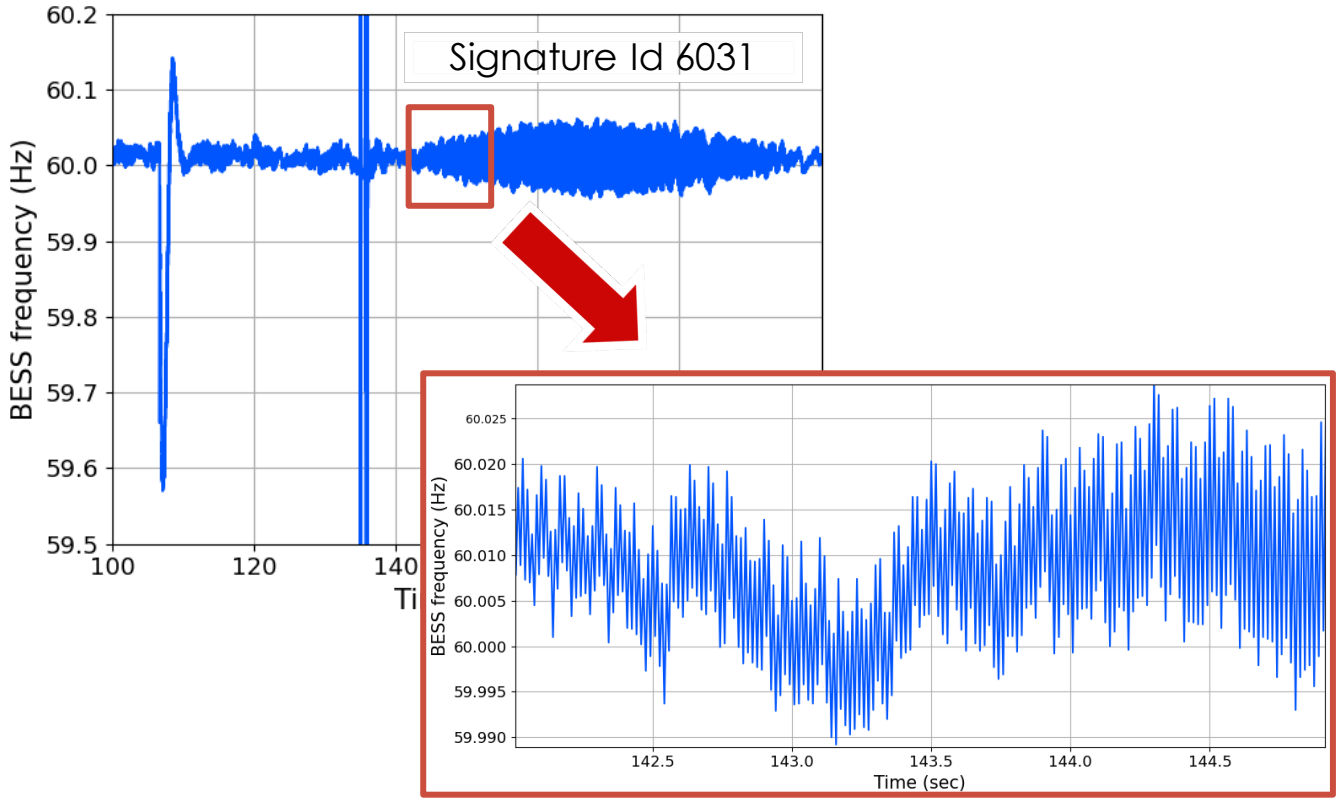


Signature Id 5737: Periodic correction of clock error

- Distinguish data artifacts from real events
- Benchmark the performance of data repair algorithms
- Evaluate bad data impact on synchrophasor applications

Recent Additions

- Data Quality Library
- Data from an island grid
  - Island grid has hydro-generators, diesel generator, and a BESS
  - MicroPMUs with 120 fps reporting rate
  - Provider 11
- Data from a solar+storage facility

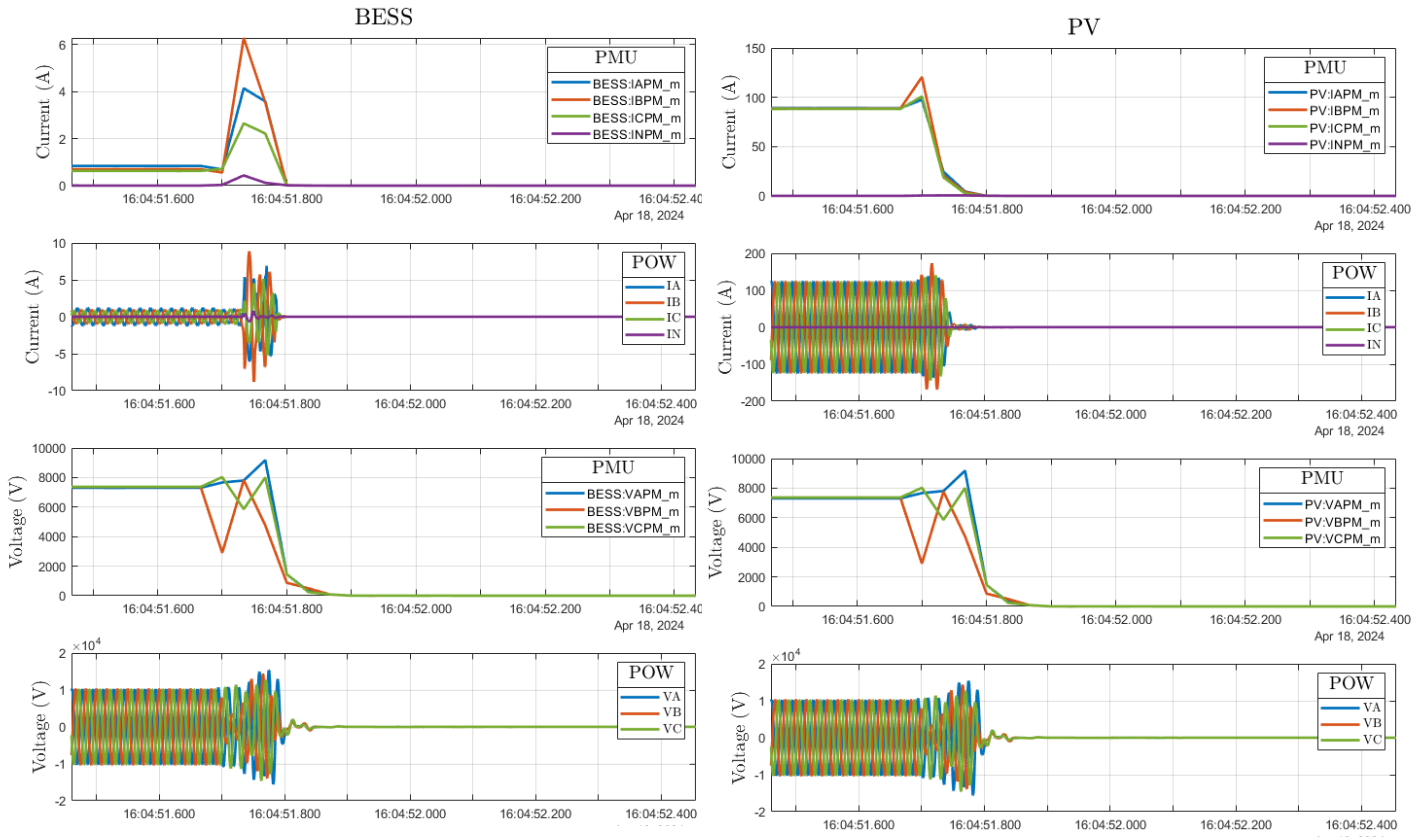


Oscillation frequency appears to be 60 Hz, perhaps the aliased version of a higher frequency oscillation

- Characterization of BESS-induced oscillations
- Study synchronous machine vs. IBR response to the same events

Recent Additions

- Data Quality Library
- Data from an island grid
- Data from a solar+storage facility
  - Includes PMU and POW measurements for the same disturbance
  - Data to be posted on GESL shortly



Example voltage disturbance captured in PMU and POW data

- Methods that analyze multi-time-resolution datasets
- Statistical analysis of fluctuations in solar power output using high-resolution data

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Thank you!

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