



Enhanced Grid Stability Monitoring with Synchronized Waveform Measurements

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Proudly Operated by Battelle since 1992

Synchronized Waveforms Contain Valuable Information!

But we are essentially looking for needles in a haystack.

Challenge: Find the valuable needles without being buried.



A Variety of Sensors Can Report Waveform Measurements

They may use different sampling methods

Powerline synchronous sampling

- Equal number of samples per **cycle**
- Samples NOT equidistant in time

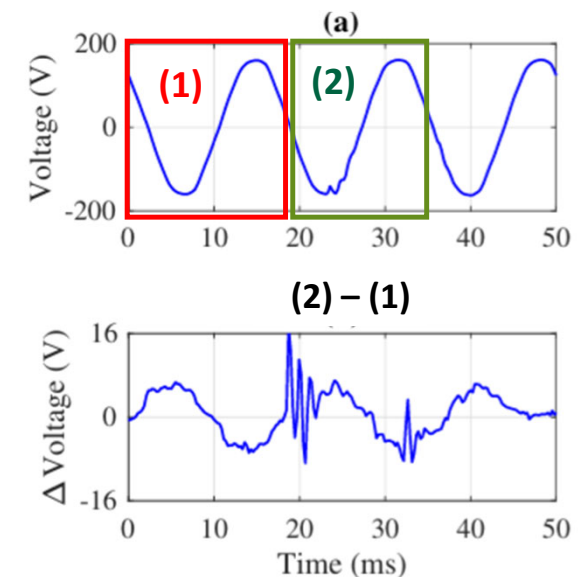
GPS-Disciplined sampling

- Equal number of samples per **second**
- Samples equidistant in time

Sub-cycle Event Detection

Application: Equipment health monitoring, incipient fault detection, etc.

- Several proposed approaches look at the difference between consecutive cycles. (Absolute difference, THD, etc.)
- Computationally fast, easy to implement, but...
 - Could be susceptible to outliers
 - Intelligent threshold-tuning required
 - Cycle alignment
 - How to flag slow changes?

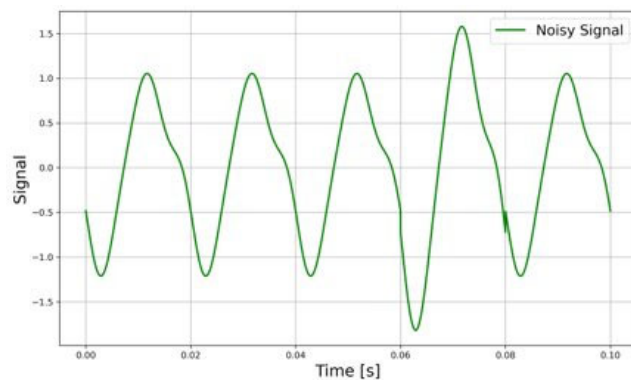


Source: N Ehsani et al, "Sub-cycle Event Detection and Characterization in Continuous Streaming of Synchro-waveforms: An Experiment Based on GridSweep Measurements", NAPS 2023.
<https://ieeexplore.ieee.org/abstract/document/10318763>

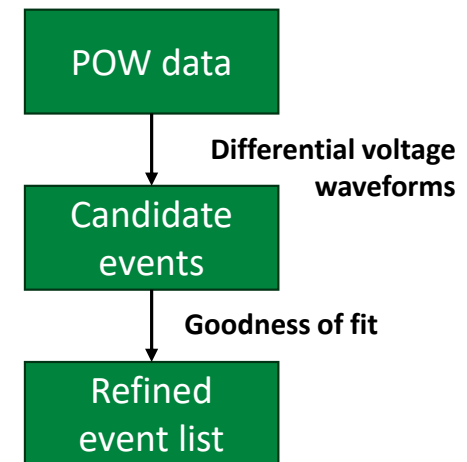
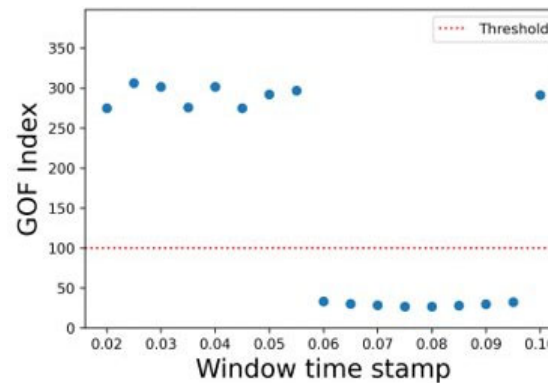
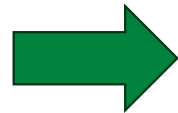
Event Detection Based on Phasor Estimation Residual

Fit POW data window to a sinusoidal model. An event is detected if residual higher than a threshold.

Can increase model order to account for harmonics.



Model fitting



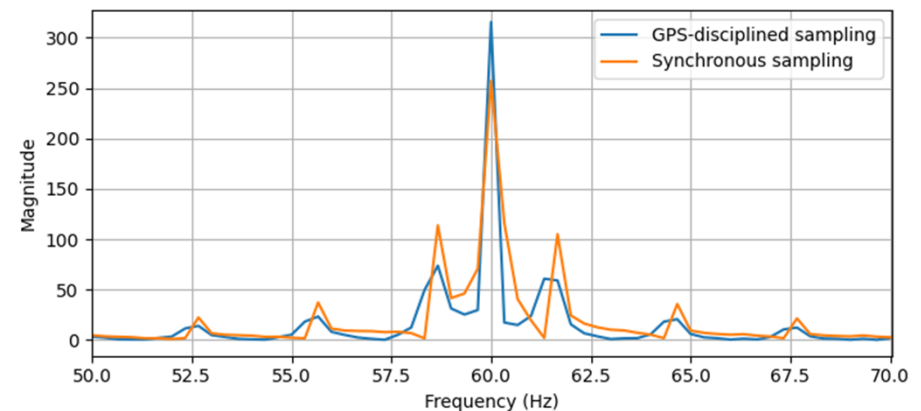
- Computationally more expensive.
- Two-stage process might be the way to go.

Acknowledgement: Antos Varghese,
Kaustav Chatterjee

Oscillation Analysis

What artifacts can powerline frequency synchronous sampling introduce?

- FFT not defined for samples not equidistant in time.
- Potential for estimation error in practice due to time warping effects.
- When is this problematic?
 - Oscillation amplitude-based alarming?
 - Comparison across multiple sites if the sites are monitored by different sensors employing different sampling strategies?



Frequency spectrum of a signal with drifting fundamental frequency modulated by a 2 Hz square wave

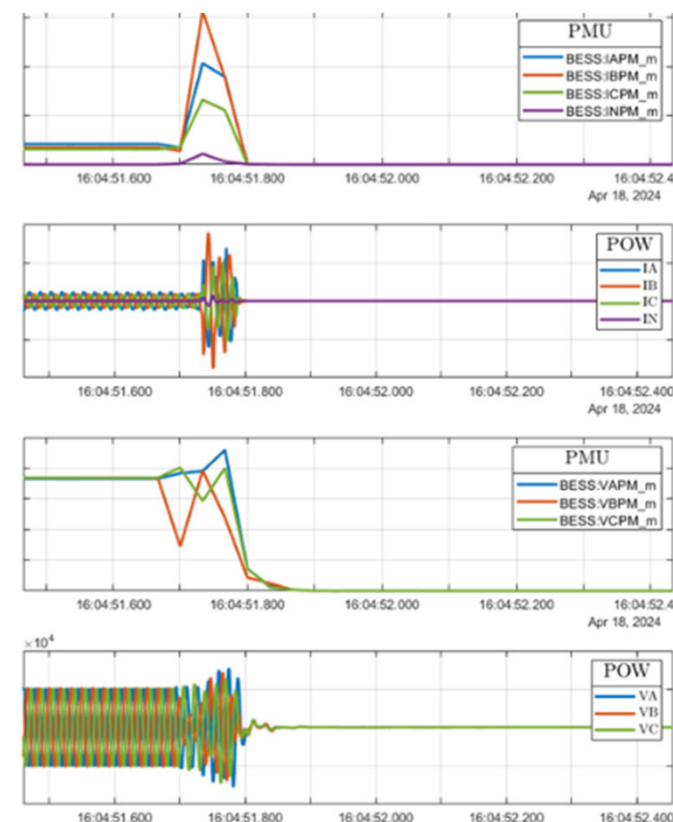
Grid Event Signature Library

Enhanced with a multi-time resolution datasets

GESL at a glance:

- Open-access repository of power-system measurements
- 5,500+ event recordings
- 13 data providers
- 550+ registered users worldwide, from utilities, vendors, small businesses, academia, and more.

gesl.ornl.gov



Example fault recording: Phasor and waveform measurements from the same location (Provider 12)

Questions?

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