Project Overview

ARPA-E Open Program DE-AR0001032

A PERSISTENCE METER FOR NIMBLE ALARMING USING AMBIENT SYNCHROPHASOR DATA

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Washington State University — **Sandip Roy**

Electric Power Group — **Neeraj Nayak**

Who are we?

Bernie Lesieutre: Professor of Electrical Engineering at the University of Wisconsin-Madison. Primarily work on power system monitoring, modeling, and analysis.

Sandip Roy: Professor of Electrical Engineering at Washington State University. Specializes in System Model, Analysis, and Control.

Neeraj Nayak: Senior Engineer at Electric Power Group (EPG). Primarily working on synchrophasor applications for power system monitoring and analysis.

Electric Power Group (EPG) - Introduction

- Established in 2000 by an experienced team of electric utility executives
- EPG’s team includes internationally acknowledged industry **experts in phasor technology with a highly qualified team**
- EPG has played a **pioneering role** in Synchrophasor and Wide Area Monitoring System (WAMS) technologies for analytics for real time and offline analytics and Wide Area Situational Awareness (WASA)
- EPG is **the leading provider of synchrophasor solutions** and services to Grid Operators and Transmission Utilities with over 32 Customers
- EPG Customers cover different geographies including North America, Latin America, Middle East and Asia

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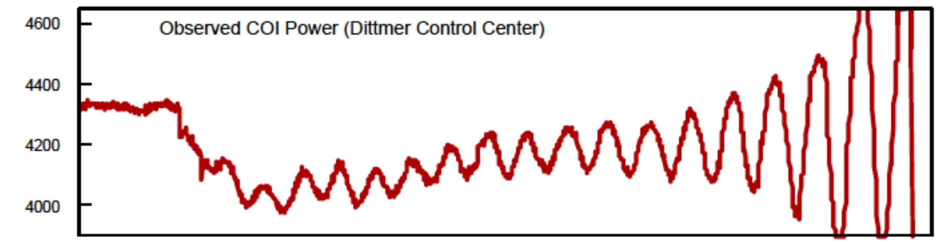
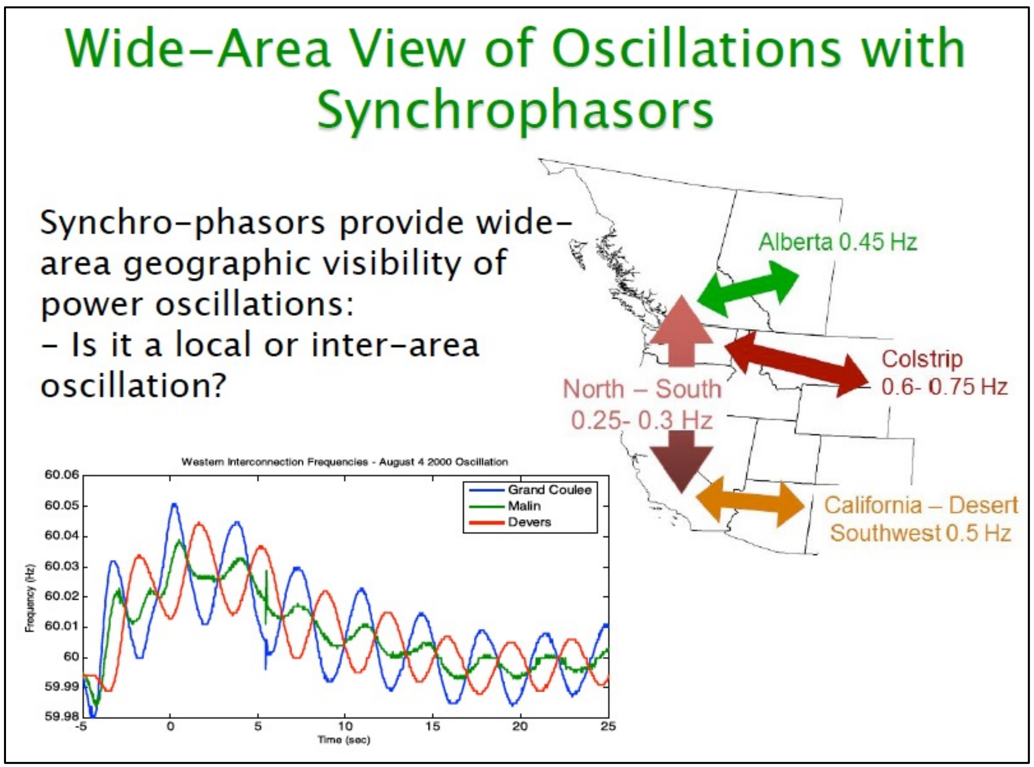
Background: Monitoring Damping

Sustained oscillations show lack of control in the grid, and can lead to blackouts.

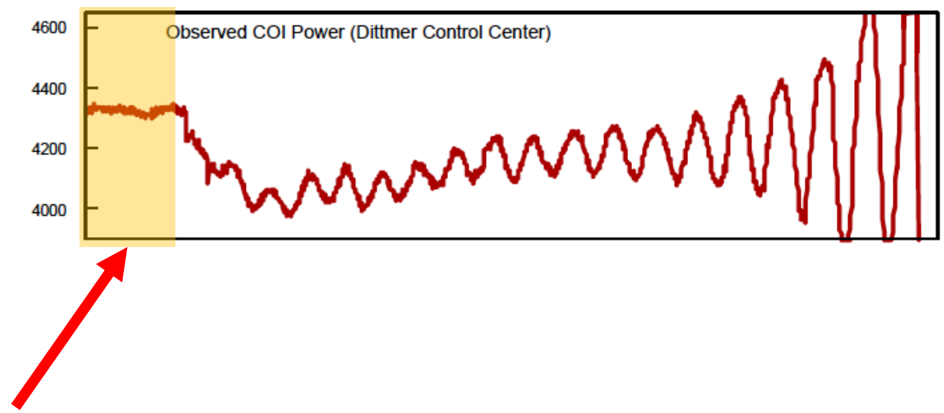




It would be useful to monitor system damping from ambient data, prior to a disturbance.

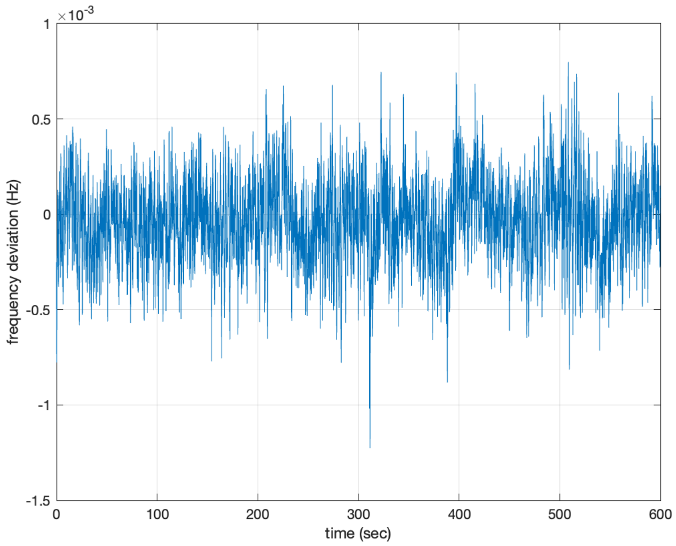
D. Kosterev, J. Undrill, "Oscillations in Power Systems," NASPI Jun. 3, 2011

Background: Monitoring Damping



Need to detect vulnerabilities prior to an event.

Challenge: Ambient data is noisy.

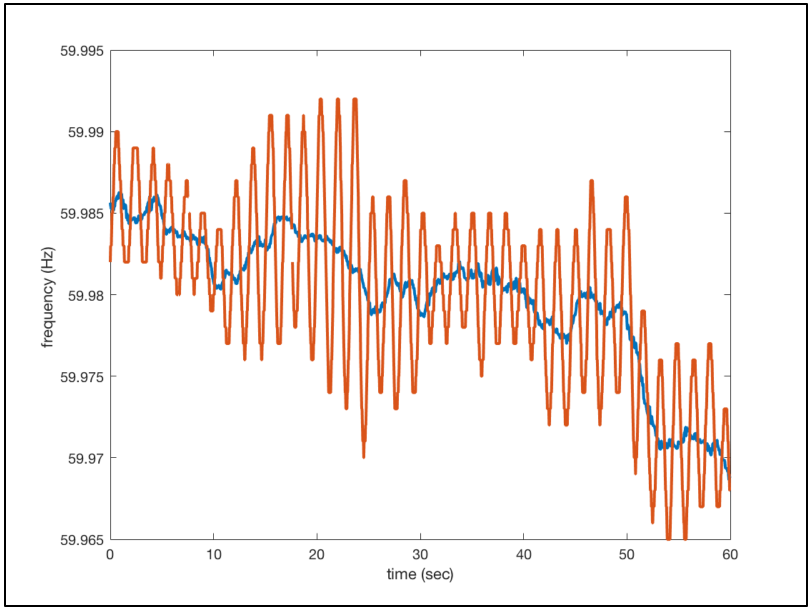


Background: Forced Oscillations

Forced Oscillations occur when something drives an oscillation that is observed in the grid.

Typically this phenomenon is related to a single component.

Risk: damage to the component.
Risk: exciting poorly damped system dynamics.



Challenge: Detecting Forced Oscillations

Determine the Location of the Forced Oscillation.

Project Goals

- Detection:
  - Identify Low Damping Conditions
  - Identify "Forced Oscillations"
  - Determine Location of Forced Oscillations
- Mitigation:
  - Recommend Recourse Actions to Improve Damping
  - Recommend Actions to Eliminate Forced Oscillations
- Create On-Line Monitoring System to Assist in Control Room Applications

Technology Advances

- New “Persistence” measure, to assess damping
- Quick Detection of Forced Oscillations
  - Allows detection of oscillations in a few cycles
  - High frequency oscillation detection is faster
- Locating Forced Oscillations
  - Analysis of Harmonics
  - Dissipative Energy
  - Model-Based Enhancements

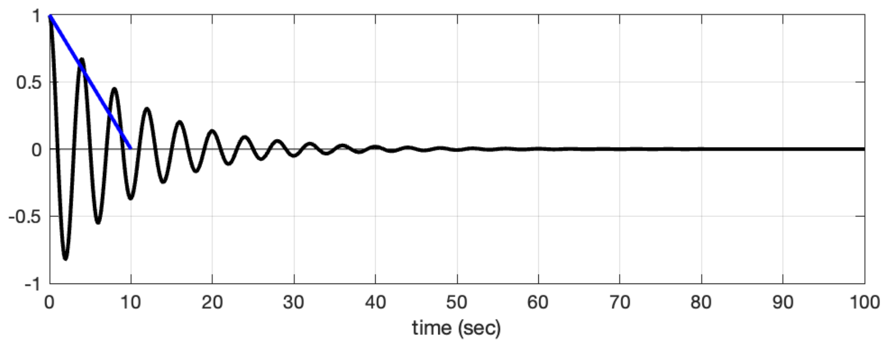
Technology Development and Transfer

Create Monitoring System Tools

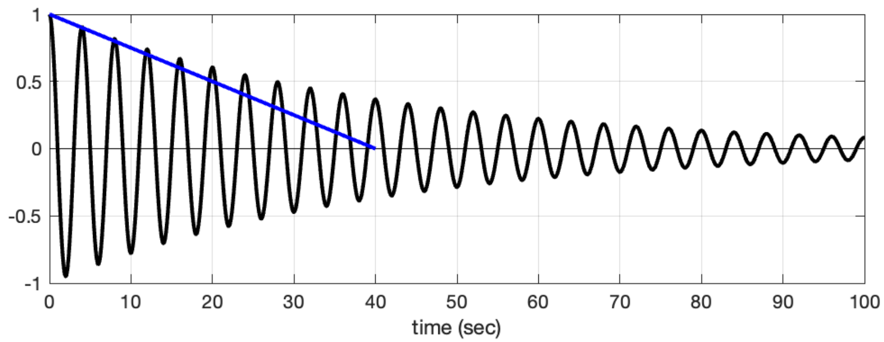
- Working with BPA Engineers, developed a real-time monitoring system prototype.
- Partner EPG makes control room applications.

Persistence

- A measure of the duration of a system impulse response, similar to a time-constant.

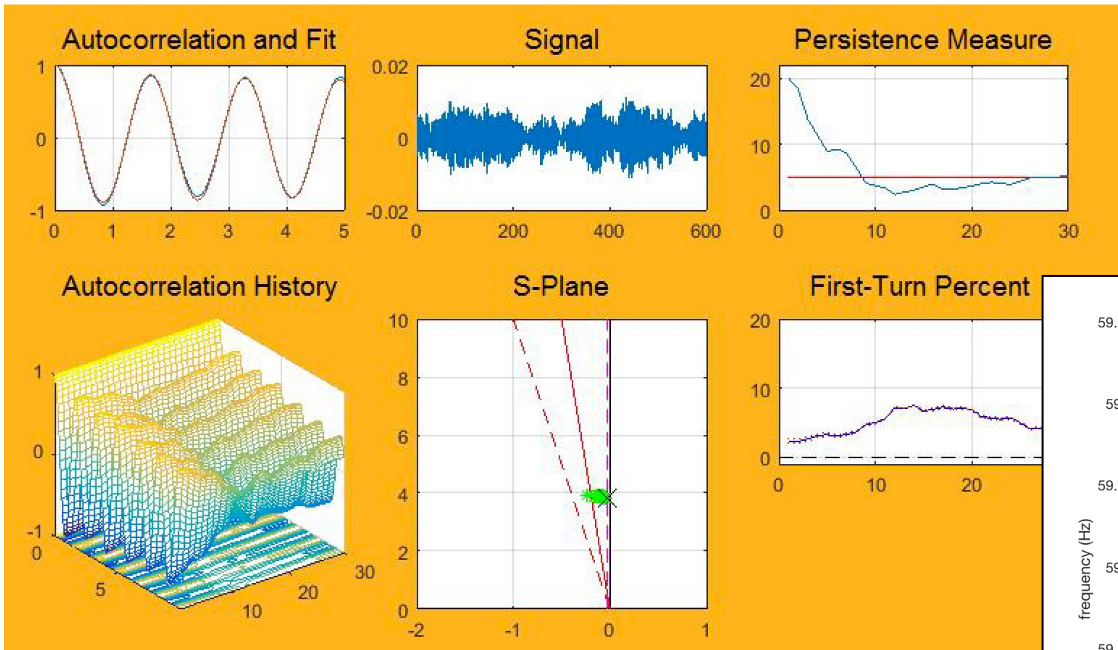


Shorter duration, smaller persistence measure



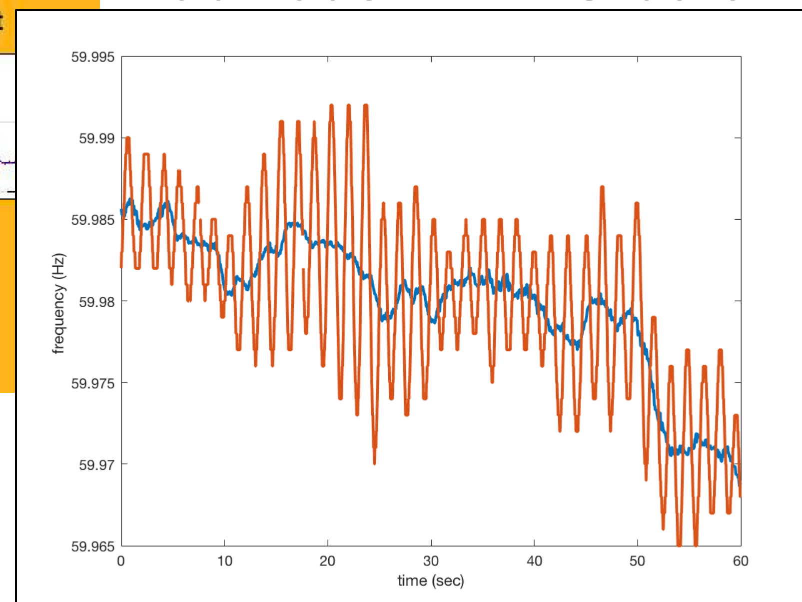
Longer duration, larger persistence measure

Forced Oscillations



Monitoring System

Oscillations are obvious in PMU data.



Locating Forced Oscillations

Forced oscillations differ from traditional grid oscillations associated with system stability.

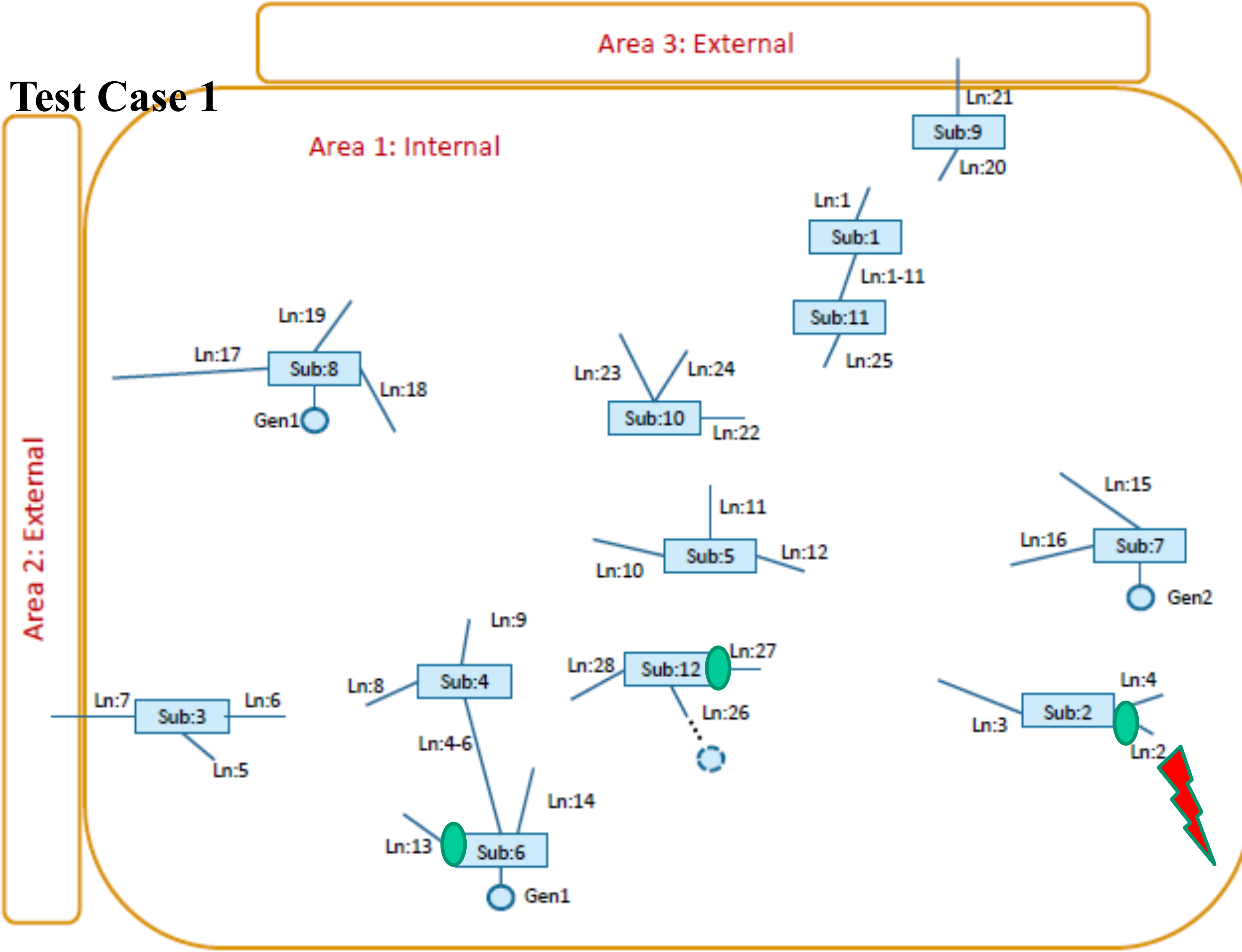
- Observed as persistent oscillations.
- Typically they represent oscillatory behavior driven at a single location.
- Challenges in detecting: Generally these are easy to detect eventually. The challenge is to do so as quickly as possible.
- Challenges in locating: the largest observed response is not necessarily at the location of the driving oscillation.

Locating Forced Oscillations

We have taken two fundamental approaches using synchrophasor data:

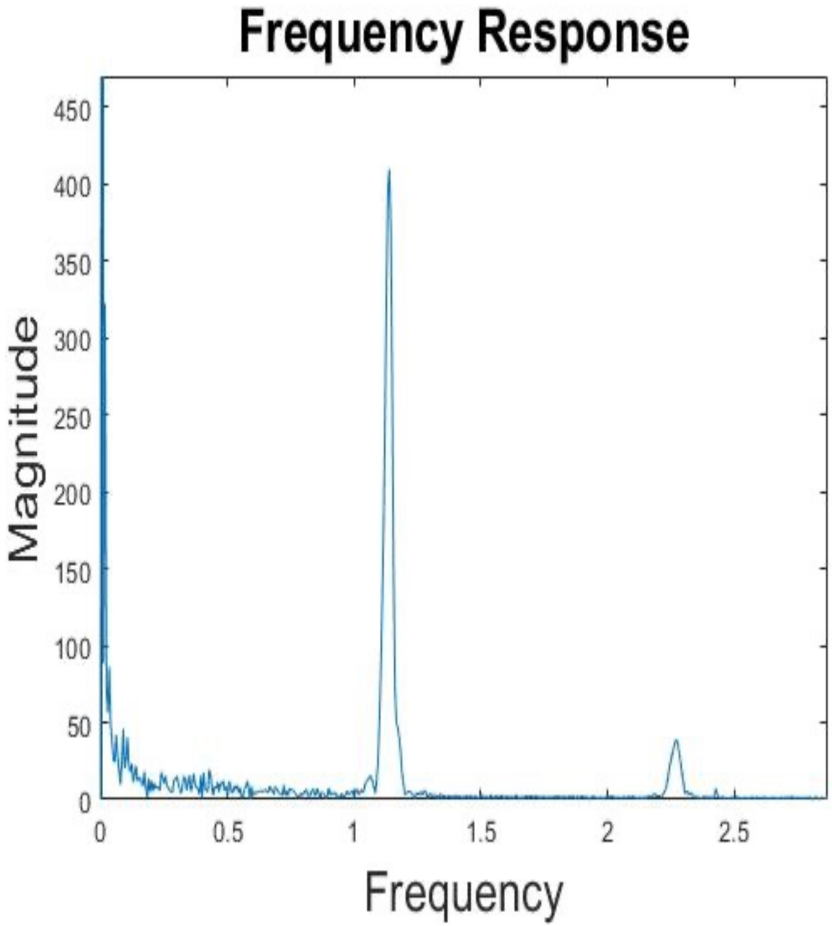
1. Measurement only approaches:
   – Harmonics in oscillations will decay more quickly with distance from the source of oscillation.
   – Dissipative energy approach
2. Model-enhanced triangulation: with an accurate system model, the source may be determined that is consistent with observed measurements.

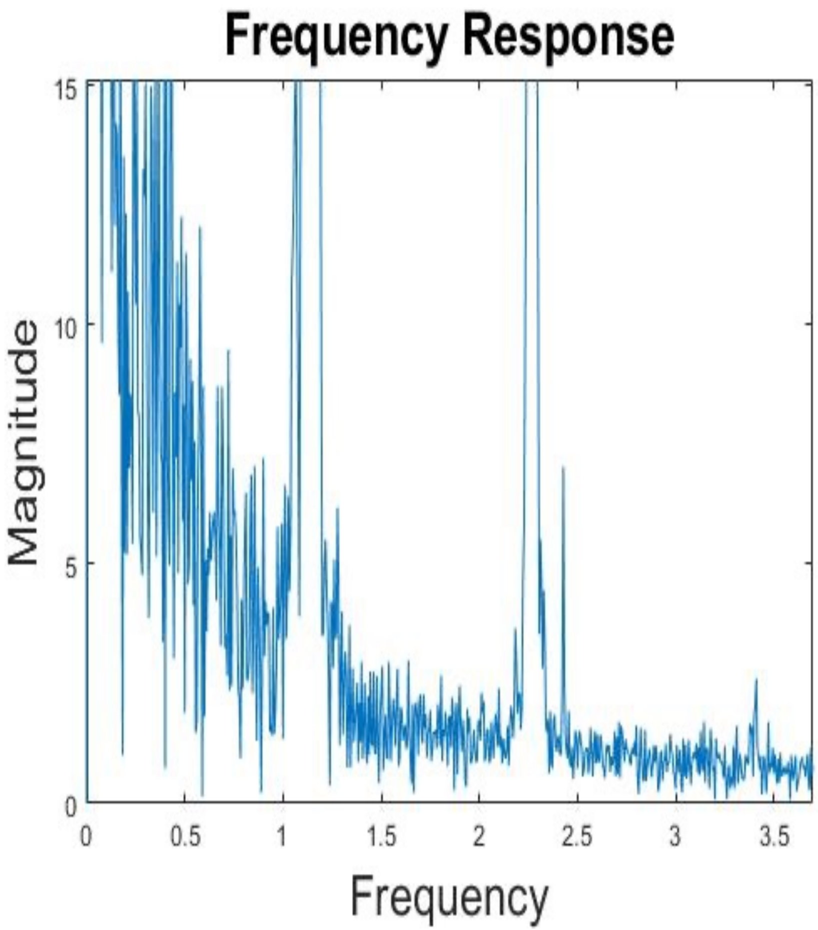
Test Case 1



http://web.eecs.utk.edu/~kaisun/Oscillation/

Harmonics Analysis Real Data: Line2





Harmonics Analysis Using Real Data

Line 2
- Fundamental: 409.20
- Second harmonic: 38.51 **(9.4%)**
- Third harmonic: 2.6

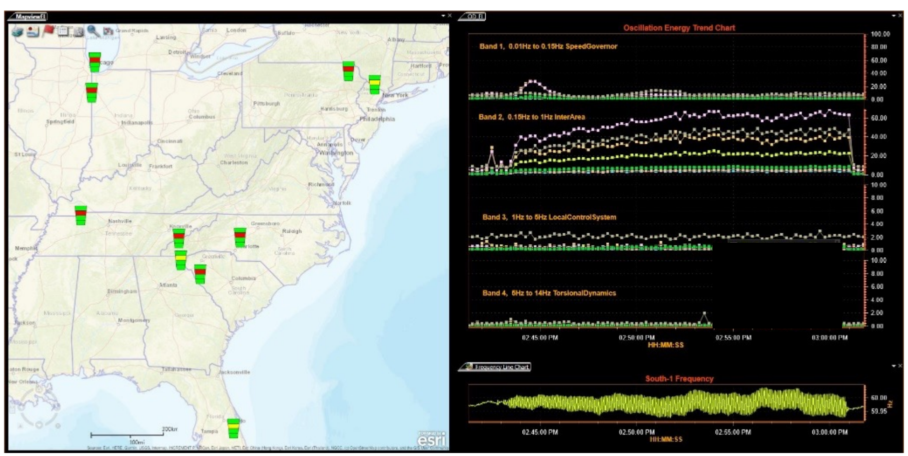
Line 27
- Fundamental: 161.76
- Second Harmonic: 11.28 **(6.9%)**
- Third harmonic: noise floor

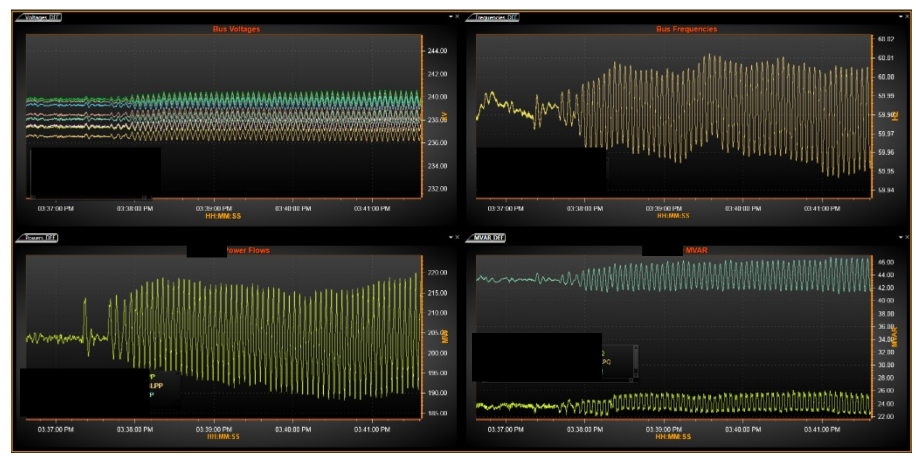
Line 13
- Fundamental: 102.20
- Second Harmonic: 3.8 **(3.7%)**
- Third Harmonic: noise floor

Key observation: the amplitude of the harmonics fall off faster with distance from the source, as compared to the fundamental frequency component.

Jan 11, 2019 EI Oscillations - Background

- Jan 11 Eastern Interconnection Oscillation Event in USA
  - Oscillation Frequency 0.25 Hz
  - Cause: Local Generator Oscillation resonance with Inter Area Mode
  - Impact: > 150 MW Oscillations on Key Transmission Lines





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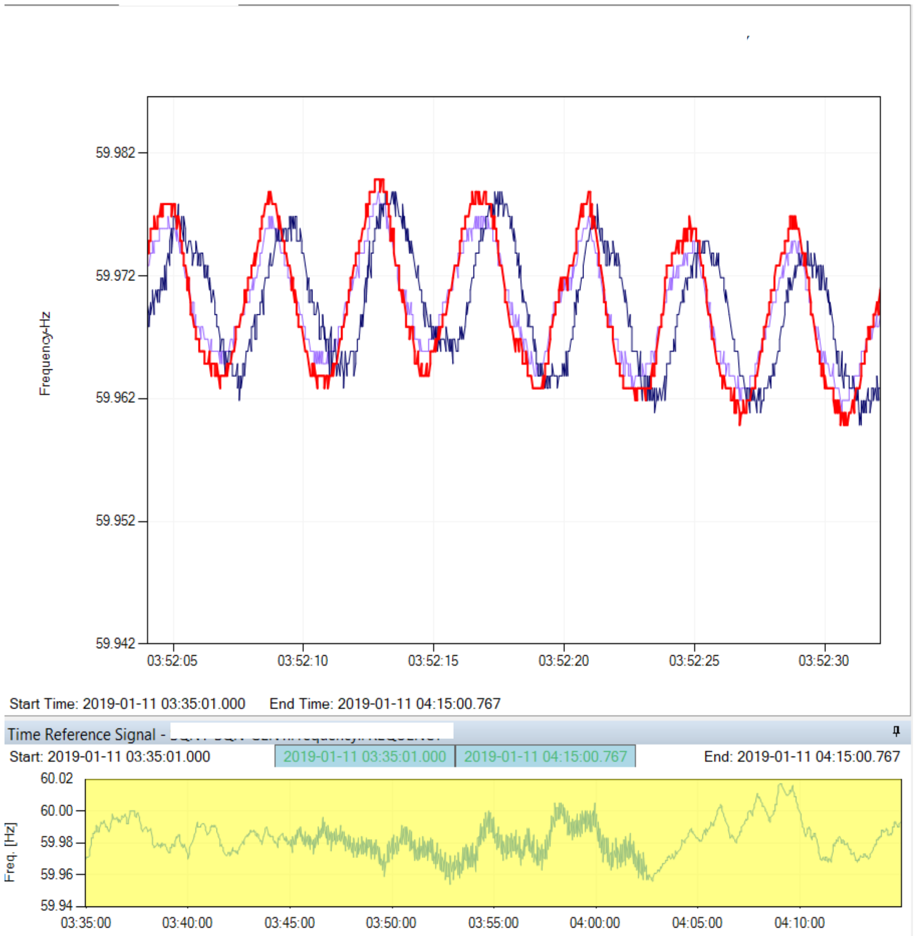
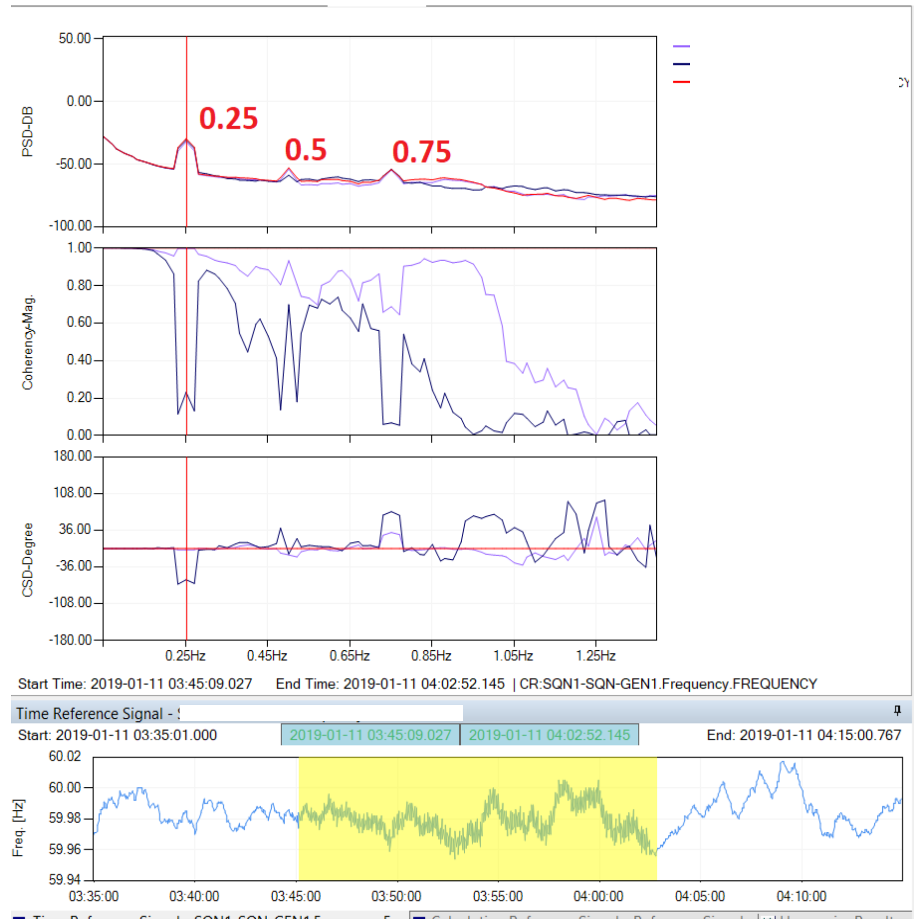
Oscillations in Frequency



Plots from EPG's Phasor Grid Dynamics Analyzer (PGDA)



Spectral Analysis

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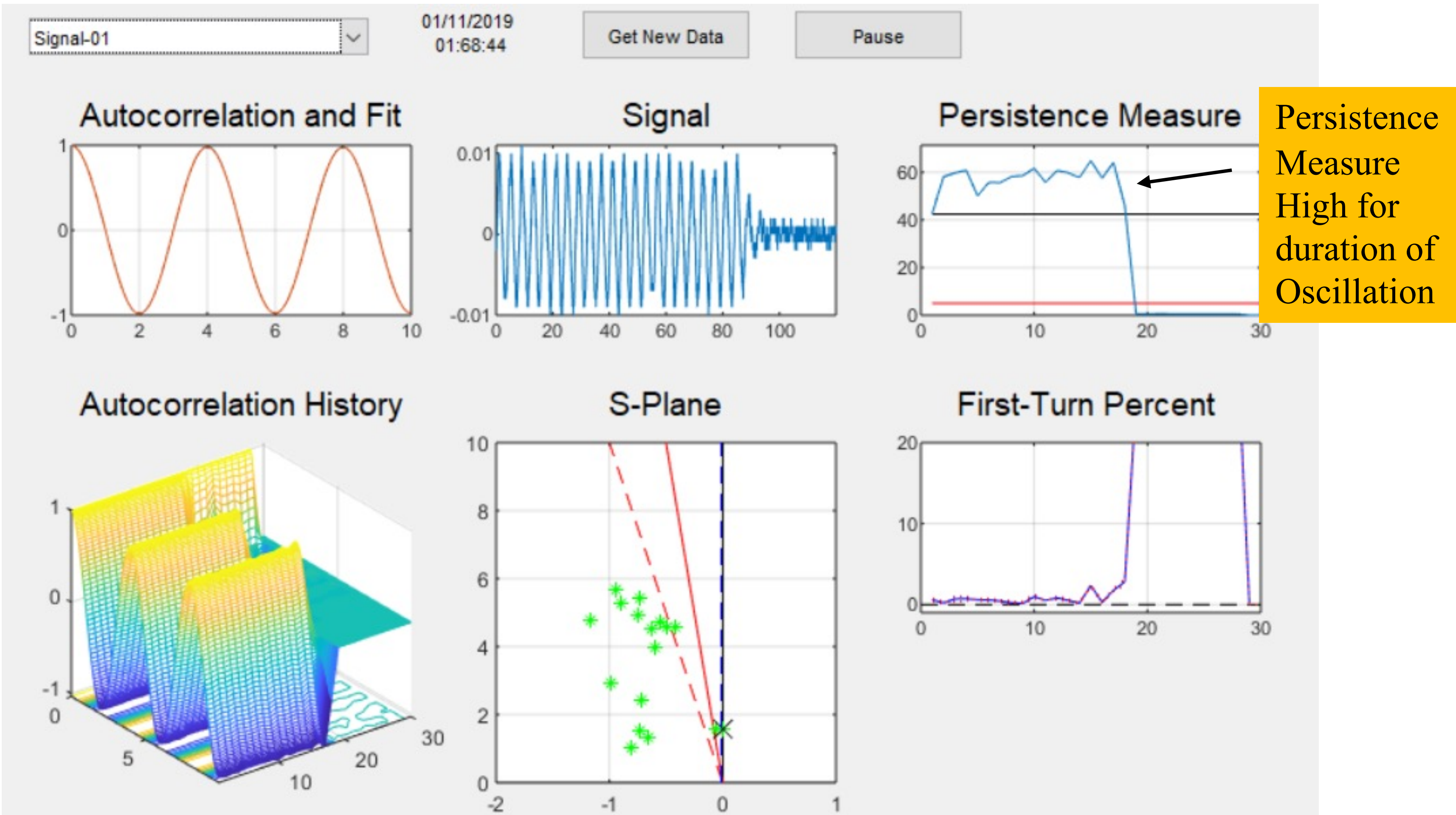
Sustained Oscillations



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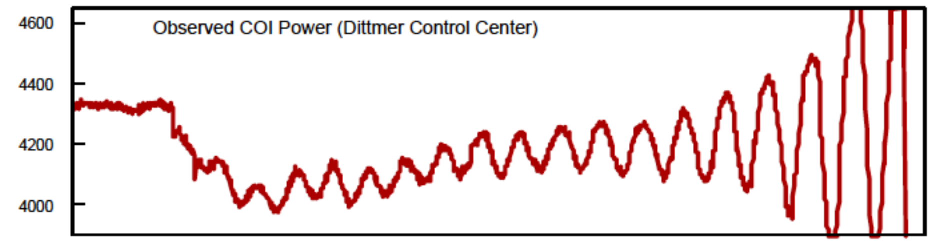
Project Goals



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