DOE/OE Transmission Reliability Program

PNNL-SA-110672

Improved Oscillation Detection for Alarming and Daily Summary Reports

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June 10-11, 2015
Washington, DC

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Project Objective

Objective

Extend the existing spectral coherence algorithm to improve the detection of persistent oscillations and provide tractable information to the end user

Motivation

Provide detection of oscillatory behaviors to aid in diagnosing grid issues and events, as well as increased understanding of power system dynamic behavior

Forced oscillations

- Result of rogue inputs driving the system
  - Steam turbine regulator malfunction
  - Power system stabilizer failures or disconnects
  - Stable limit cycles due to upper limits on generator field-voltage
- Detection algorithms are needed to determine when forced oscillations are present

Approach

- Improve oscillation detection through refinements of the spectral coherence method
  - Extend to multiple channels to aid in detection and possible localization
  - Refine methods for setting appropriate detection threshold
- Extend simple spectral coherence to multiple channels

Approach

- Improve performance by expanding existing single-channel methods to operate on data from multiple PMUs
- Periodogram-based method
  - Based on the multi-channel generalized likelihood ratio test (GLRT) for sinusoids in Gaussian noise
  - Compares a **sum** of scaled periodograms to a threshold
  - Statistics-based threshold provides expressions for the probabilities of detection and false alarm

$$\hat{P}_n(f) = periodogram(x_n(t)) = \frac{1}{K}|fft(x_n(t))|^2$$

$$\hat{P}(f) = \sum_{n=1}^{N} \frac{2\hat{P}_n(f)}{P_n(f)} \qquad \hat{f}_{FO} = \{f : \hat{P}(f) > \gamma(f)\}$$

Approach

- Self-coherence algorithm
  - Compares the **average** of self-coherence spectrums to a threshold
  - No statistical basis, but simple to implement
  - Correlation of data already addressed in single-channel algorithm

$$\hat{S}_n(f) = mscohere(x_n(t), x_n(t-\tau))$$

$$\hat{S}(f) = \frac{1}{N}\sum_{n=1}^{N} \hat{S}_n(f) \qquad \hat{f}_{FO} = \{f : \hat{S}(f) > \gamma\}$$

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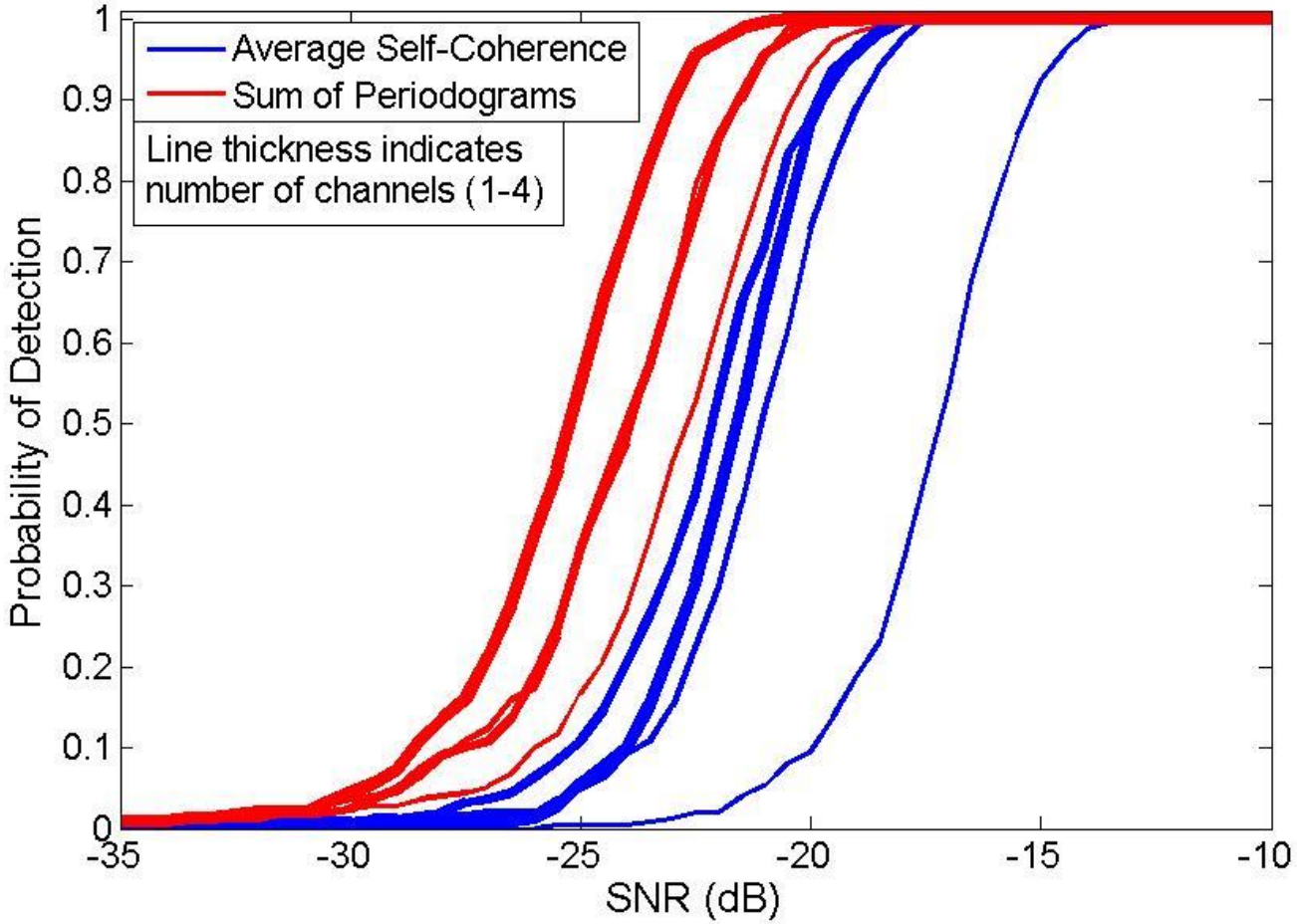
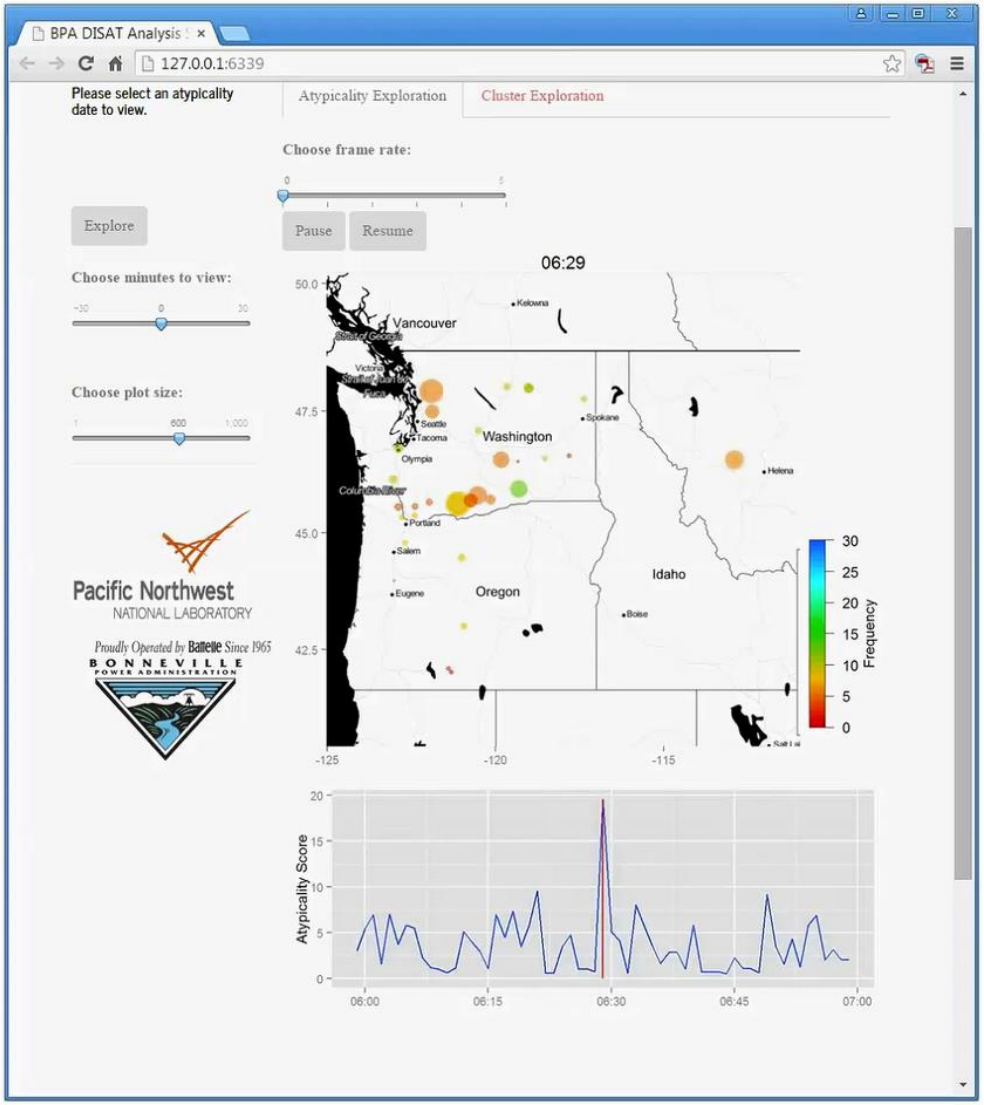
Results


Average Self-Coherence
Sum of Periodograms
Line thickness indicates number of channels (1-4)
Probability of Detection
SNR (dB)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-35
-30
-25
-20
-15
-10

DISAT Interface



Major Technical Accomplishments for FY15

- Implemented initial improved detection algorithm into DISAT
- Preliminary implementation and results presented at Western Electricity Coordinating Council (WECC) Joint Synchronized Information Subcommittee (JSIS) meeting
- Report on initial Data Integrity for Situational Awareness Tool (DISAT) implementation and results completed: *Integration of a Self-Coherence Algorithm into DISAT for Forced Oscillation Detection* – PNNL-24127

FY15 Deliverables and Milestones

#	Milestone/Deliverable	Target Date
1	Evaluation of expanded coherence and spectral methods	November 2015
2	Submission of journal or conference article on findings	December 2015
3	Implement refined algorithms into DISAT	January 2016
4	Final report with improved methodology and results	March 2016

Risk Factors

- Unforeseen complications with the proposed algorithm
  - Verify assumptions
  - Examine alternative algorithms or refinement
- User feedback may be too specific
  - Engage wide audience to get multiple perspectives

Follow-on Work for FY16+

- Localization of forced oscillations
  - Incorporate and leverage others' work
  - Investigate new algorithmic approaches
- Further "spectral baselining"
  - Consistent behaviors in higher frequencies
  - Understand root cause of observations

Questions?

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