Data Analysis of the 2/26/08 Florida Blackout

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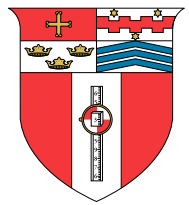
Power System Research Consortium (PSRC)



Rensselaer Polytechnic Institute
ECSE Department

NASPI Work Group Meeting, Sacramento, CA
June 4, 2009

Outline

- Description of the Event
- Event Propagation Movie
- Disturbance Data Analysis
  - Modal Analysis from Power Signals
  - Modal Analysis of Voltage Angle Oscillations
- Ambient Data - Spectral Analysis of Power and Frequency Signals
- Conclusions

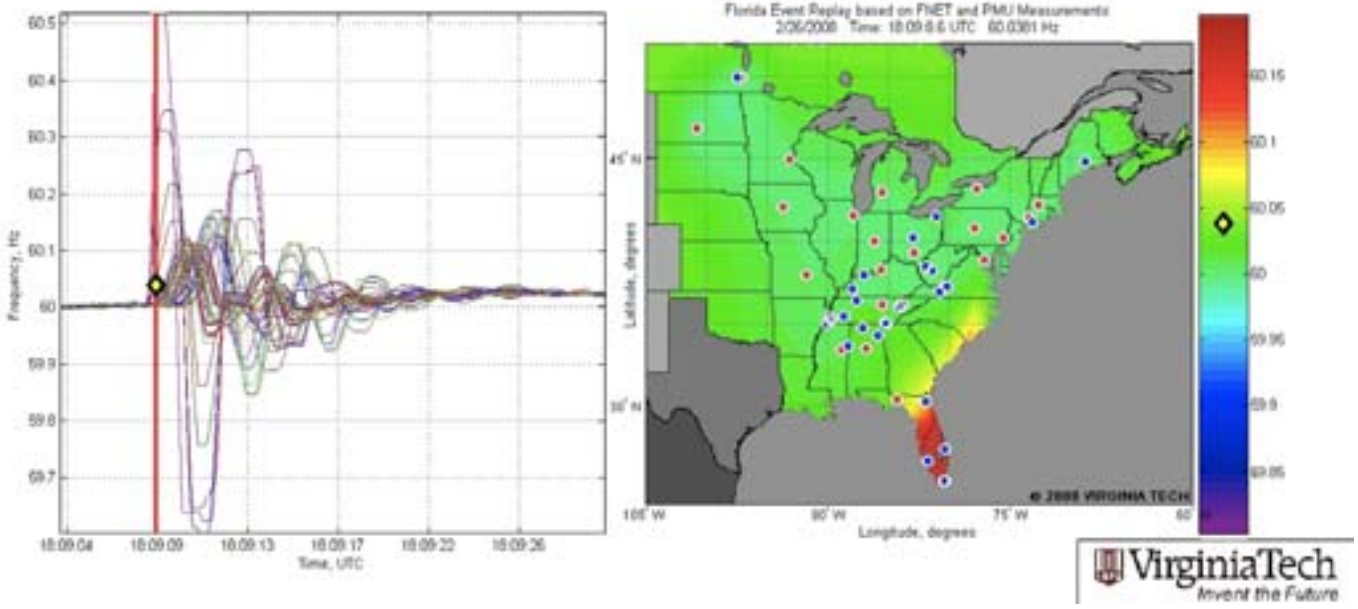
Event Description

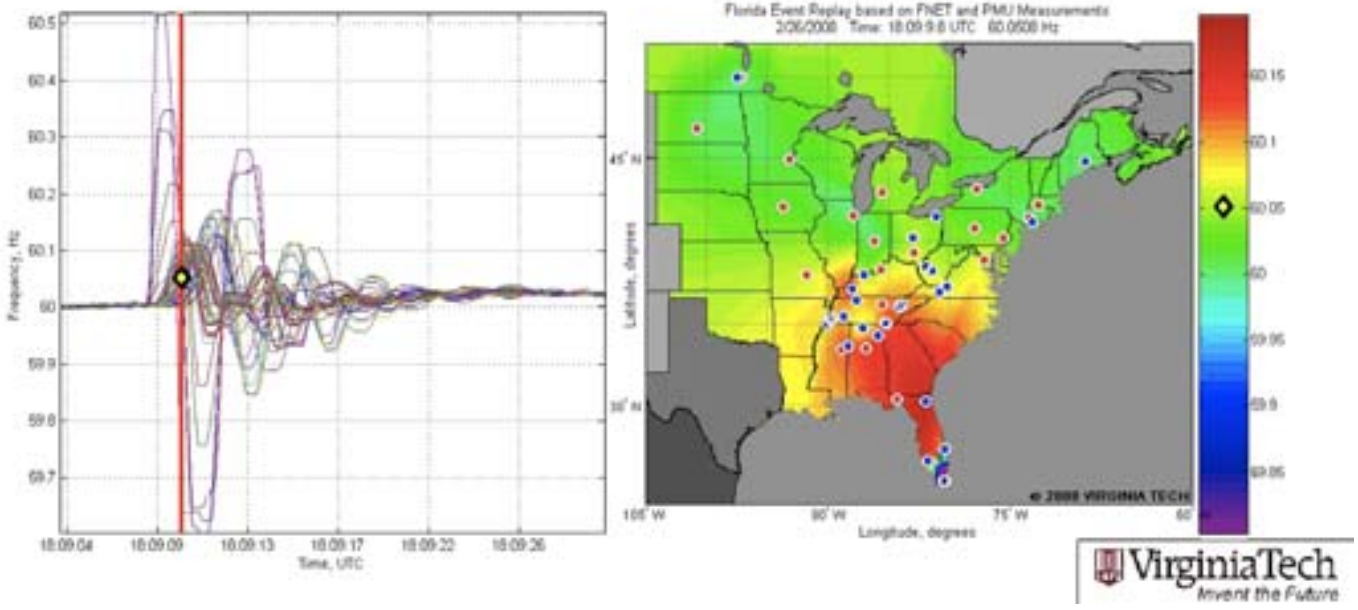
- Disturbance was initiated by a failure on a 138 kV switch.
- Local primary protection and local back-up breaker failure protection was disabled for troubleshooting
- Remote backup protection relays performed delayed clearing of the 138 kV fault (1ϕ fault evolved into 3ϕ fault)
- Disturbance outcome (FRCC Report):
  - 25 transmission lines tripped - involved in remote clearing
  - Generation loss: $\approx$ 2,500 MW near fault + 1,800 MW across FRCC
  - Load shedding: 2,300 MW for initial fault clearing
  - Under-Frequency Load Sedding: 2,200 MW between UFLS zones in FL (other regions did not participate in UFLS)
  - Other: delayed clearing produced low voltages; two nuclear units tripped as designed
- Noticable interarea oscillations in the EI $\Rightarrow$ for our analysis

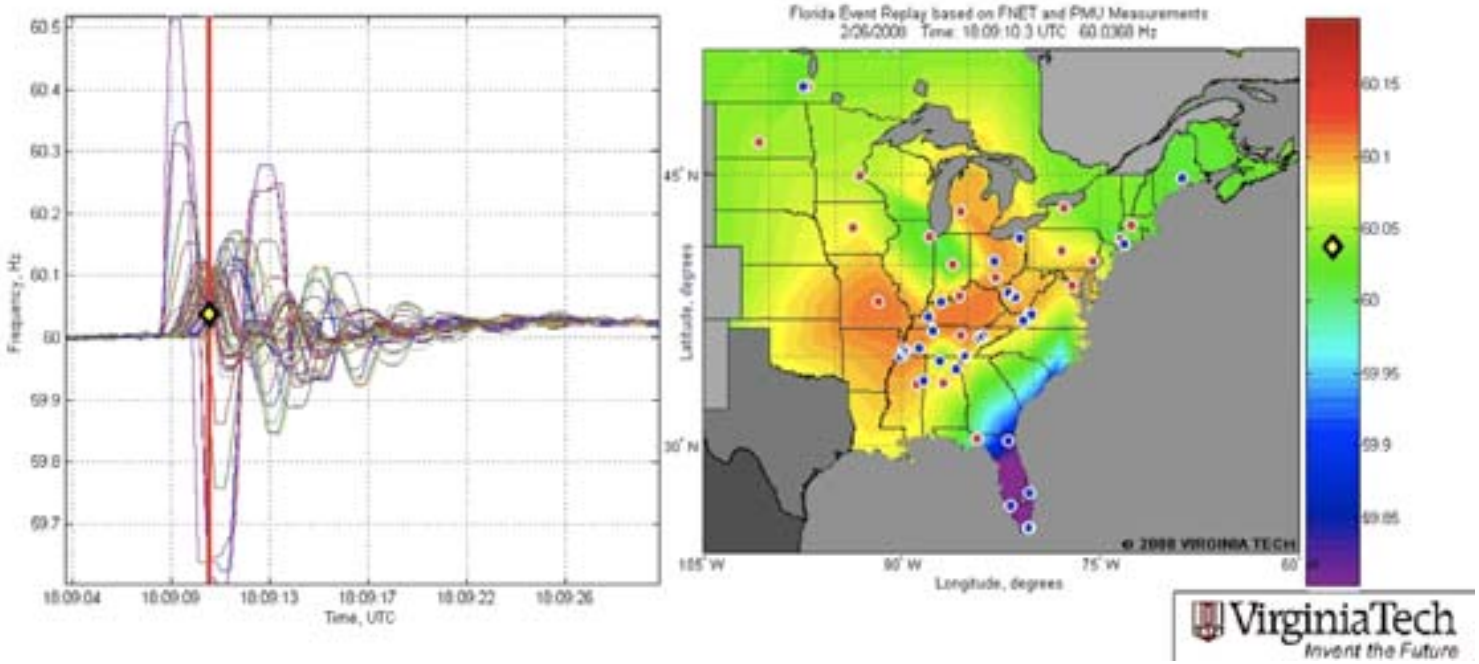
Available PMU Data

- Unavailable data from NY due to communication upgrades, some data loss from several other regions.

Event Propagation Snapshots






Florida Event Replay based on FNET and PMU Measurements
2/26/2008 Time: 18:09:10.3 UTC 60.0368 Hz
Frequency, Hz
Time, UTC
Latitude, degrees
Longitude, degrees
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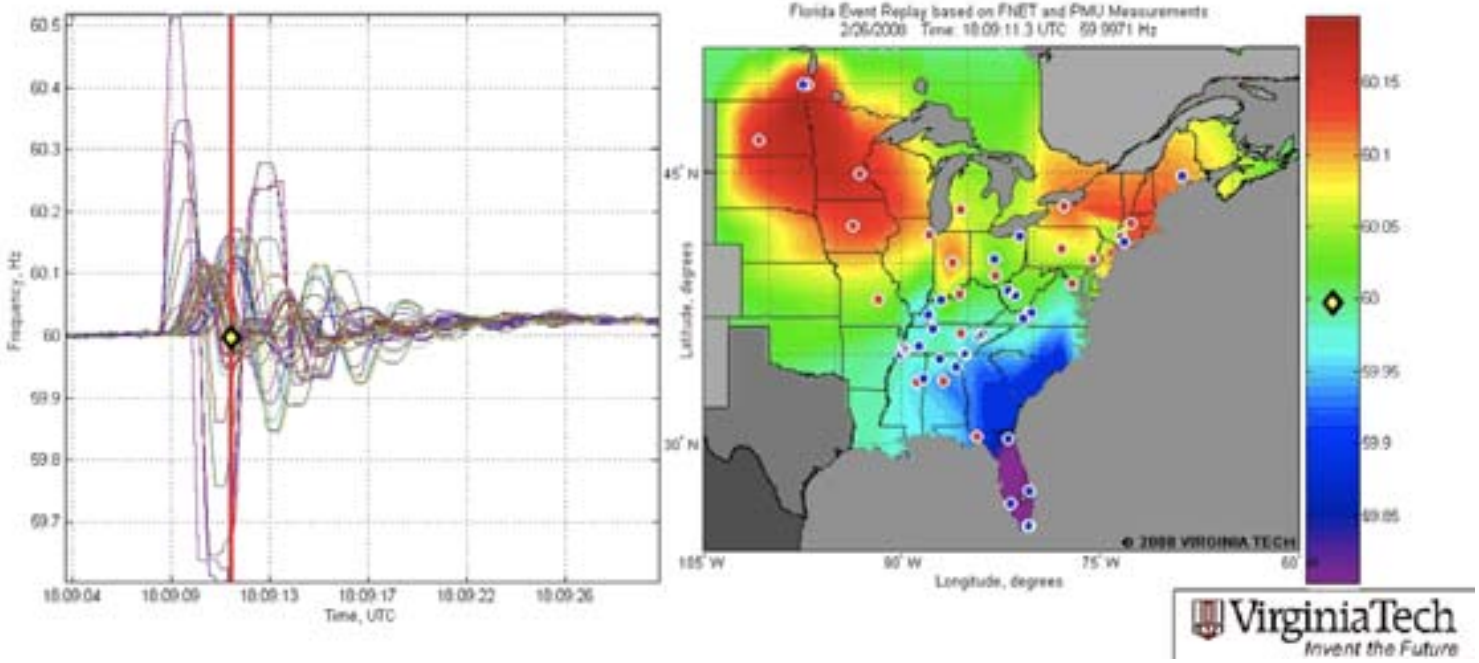
Florida Event Replay based on FNET and PMU Measurements
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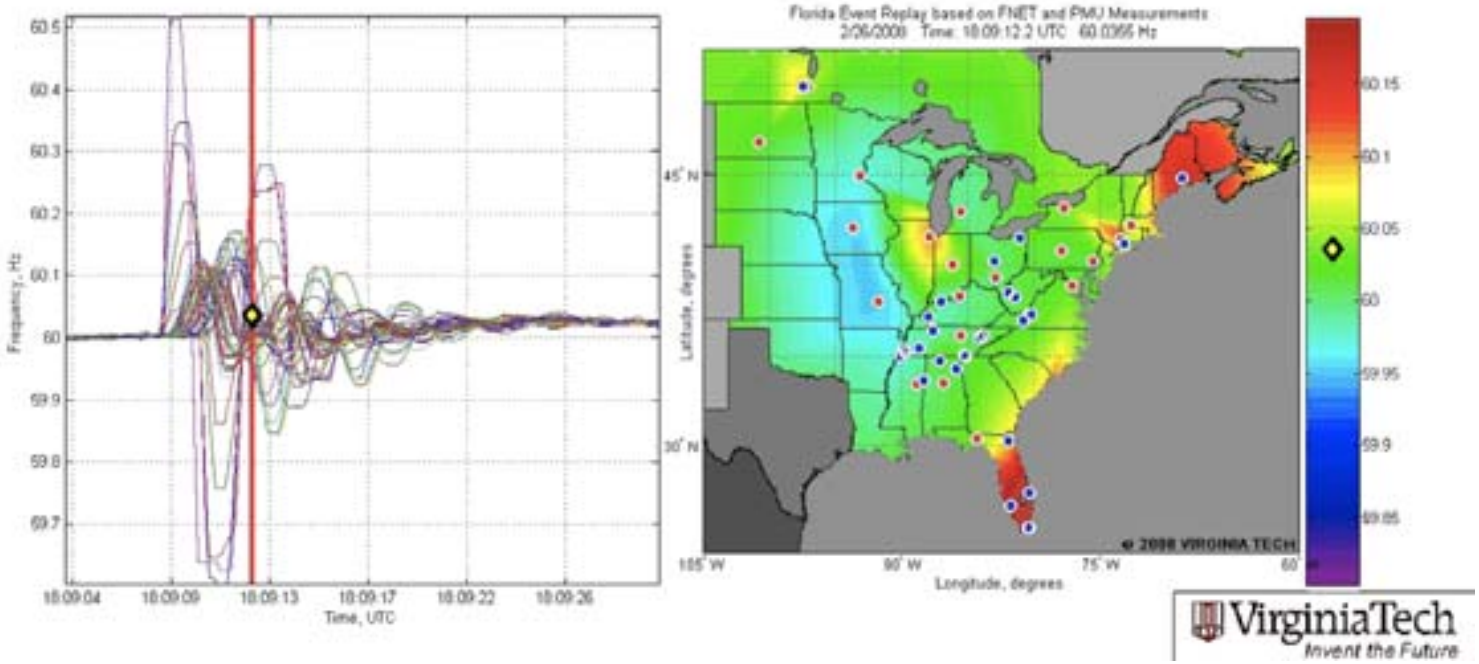
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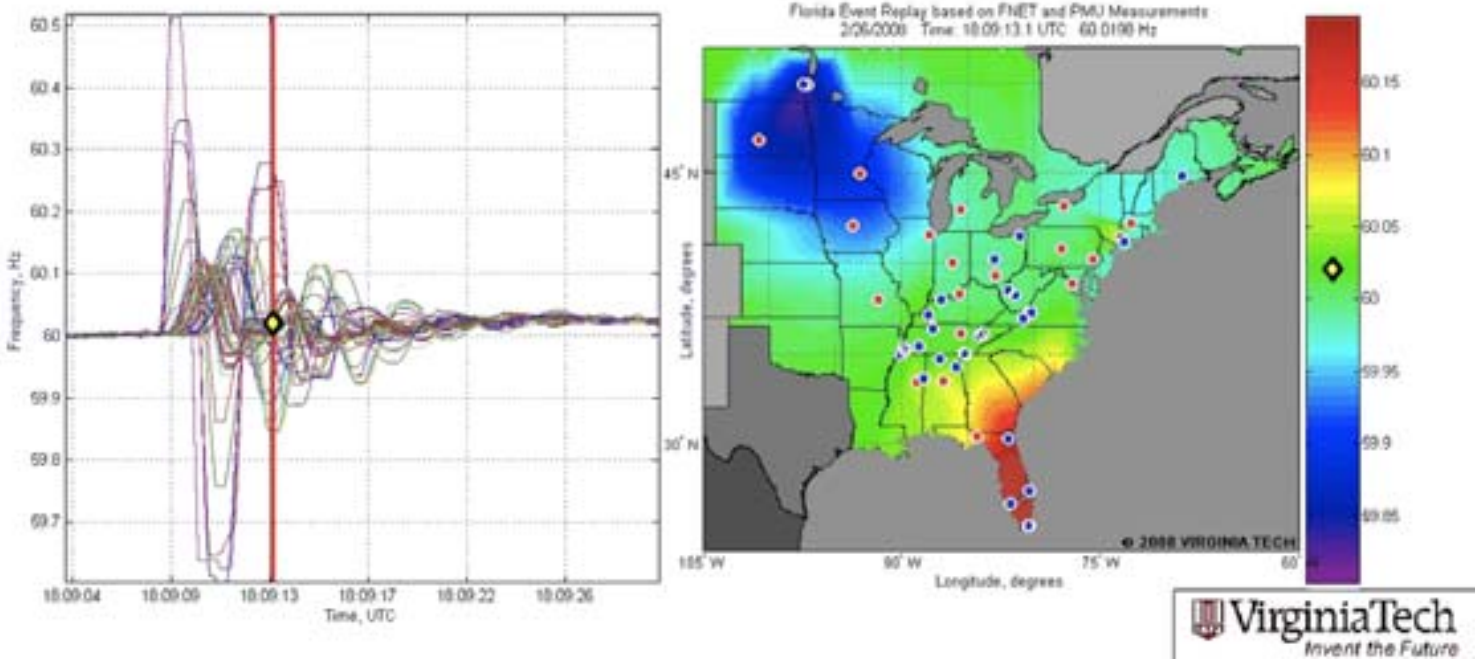
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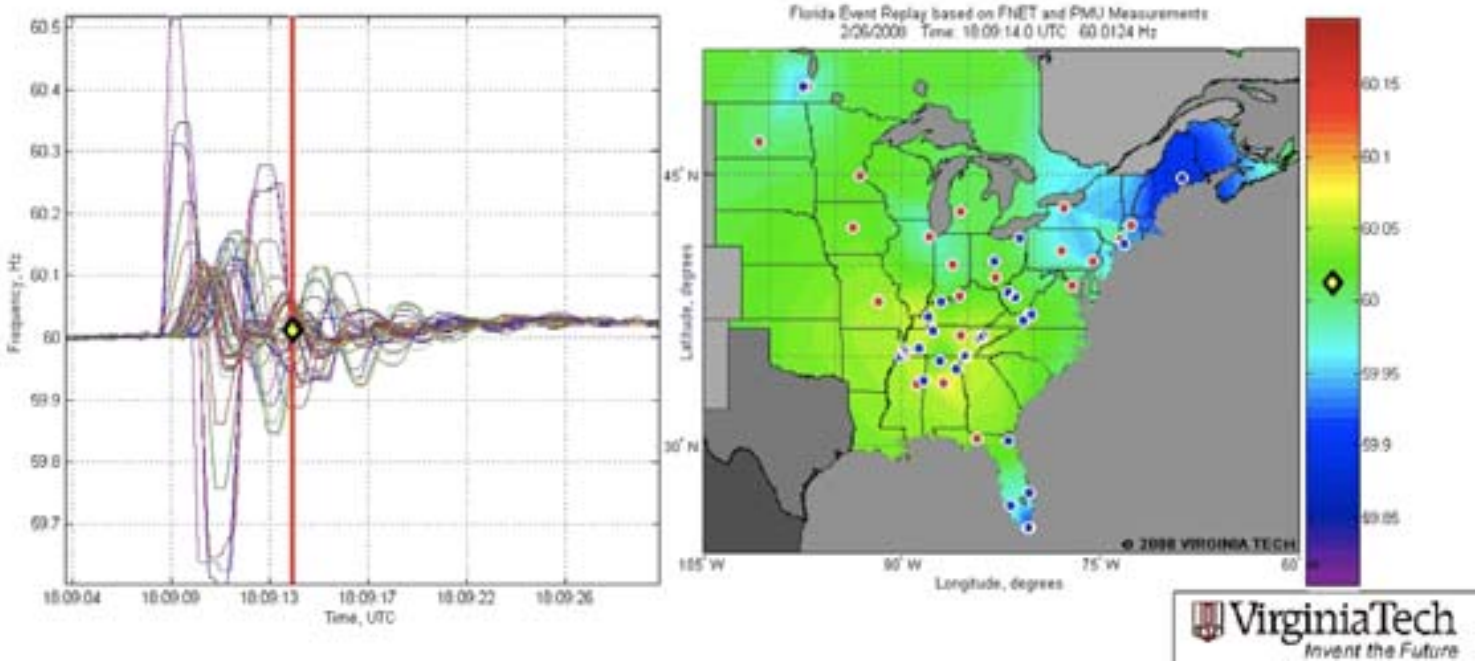
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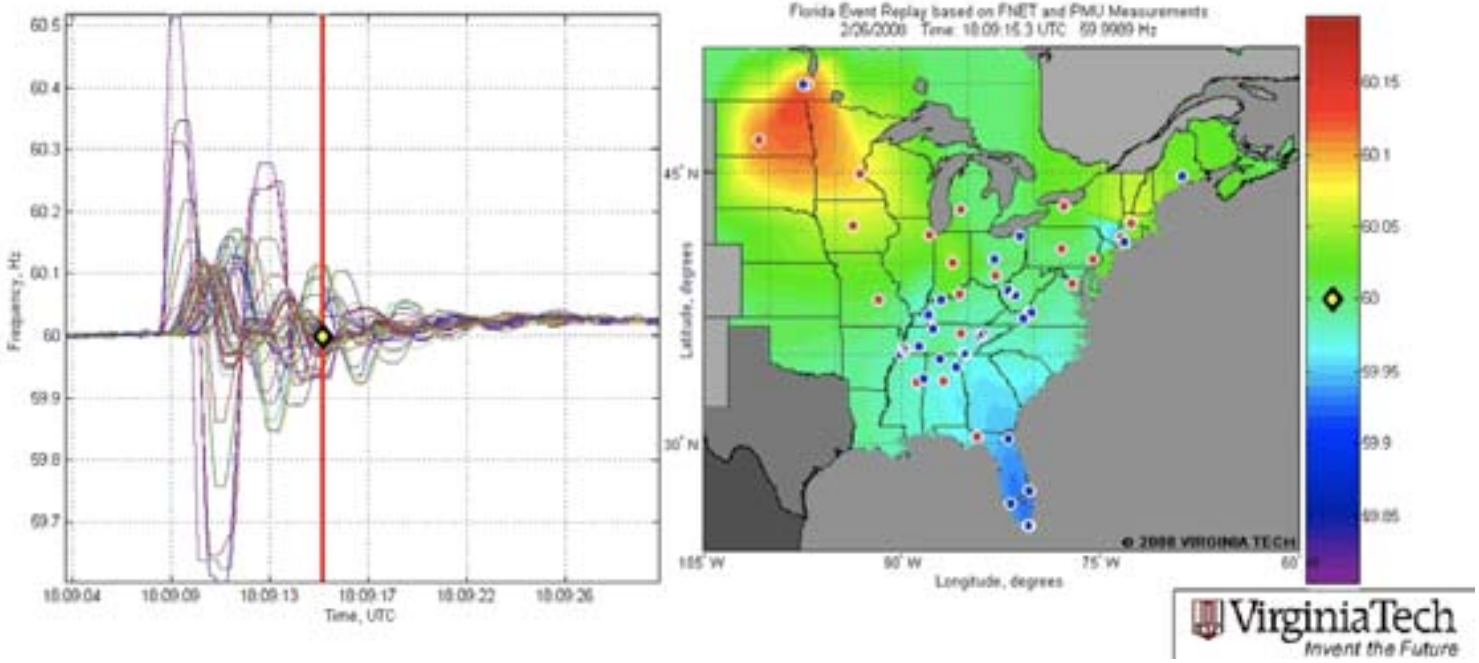
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Frequency, Hz
Time, UTC
Latitude, degrees
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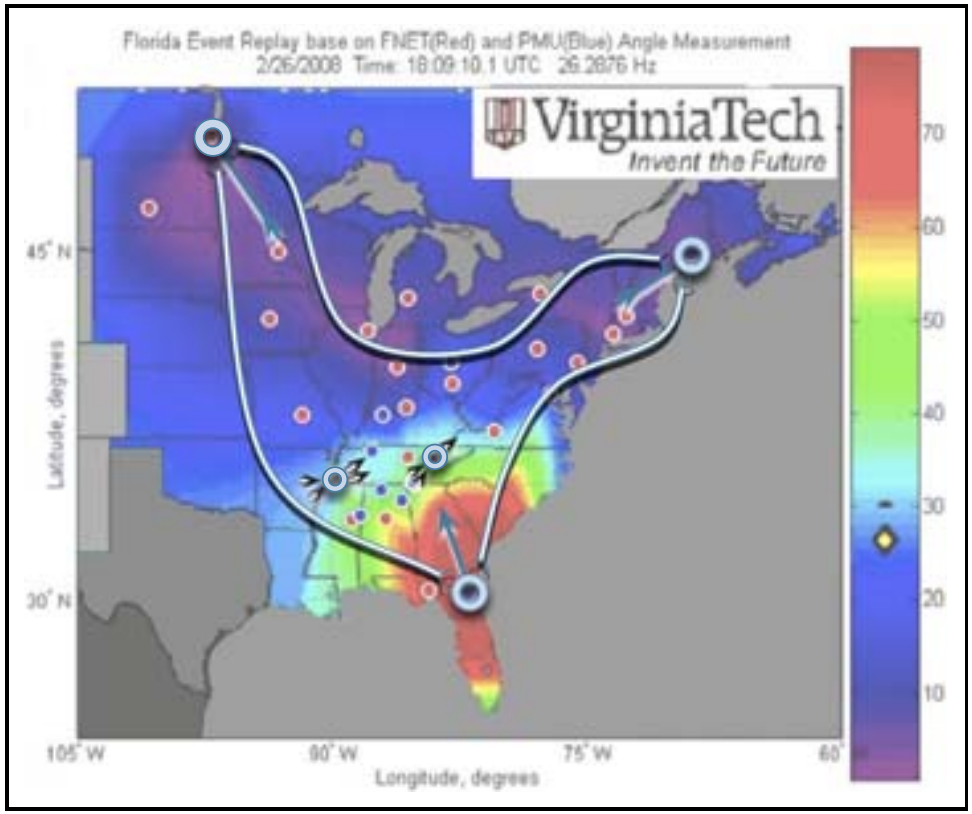
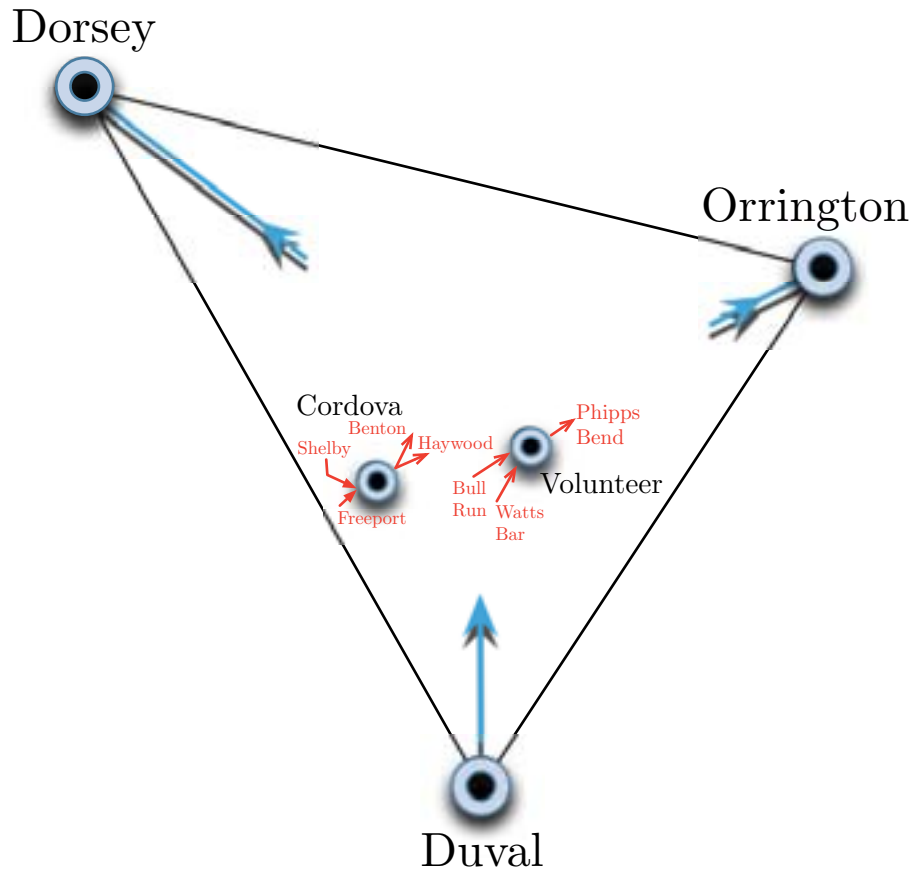
Modal Analysis from Active Power Signals

- How are the modes propagated across the network?
- Analyze the power oscillations in different points of the EI.
  - Power oscillations from each mode indicate how the disturbance is being propagated.
- Shelby and Freeport are very close to Cordova.

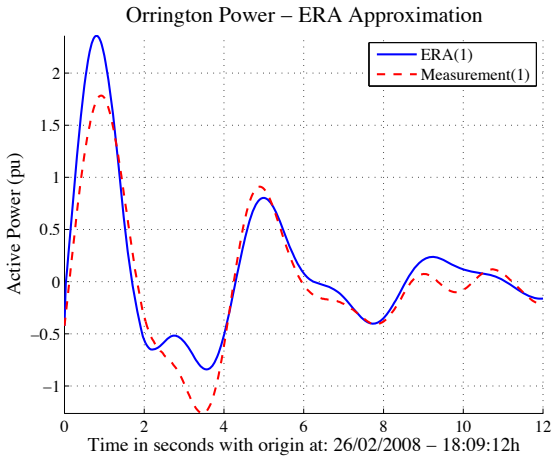


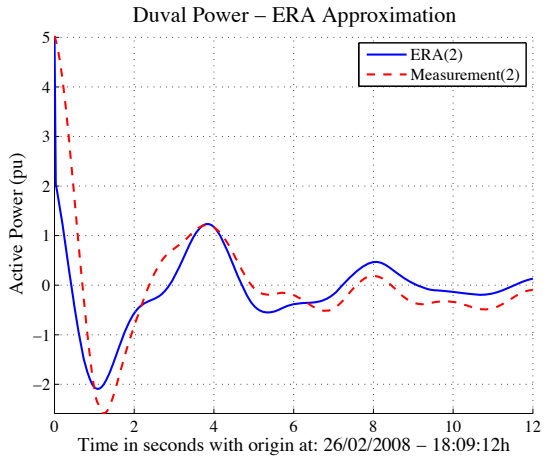


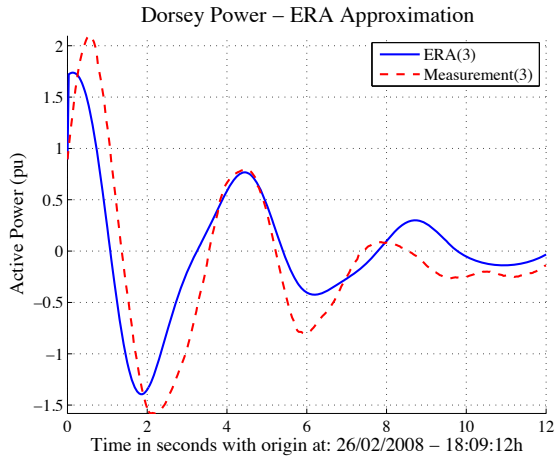
Identified Modes from Power Oscillations

- Two oscillatory frequencies: $f_1 = 0.22$ Hz with $\zeta_1 = 15.97$ %, and $f_2 = 0.49$ Hz with $\zeta_2 = 8.6$ %

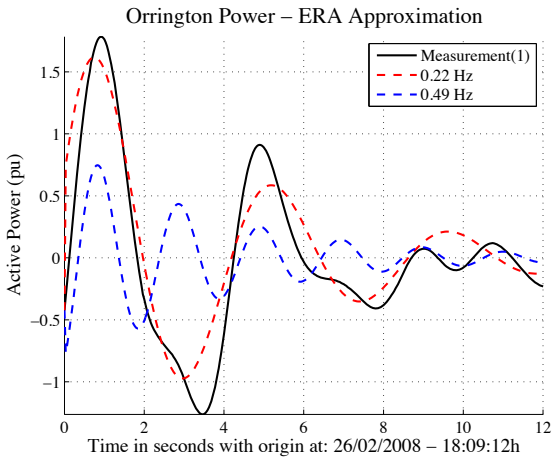
ERA Approximation of Active Powers at Orrington, Duval, and Dorsey

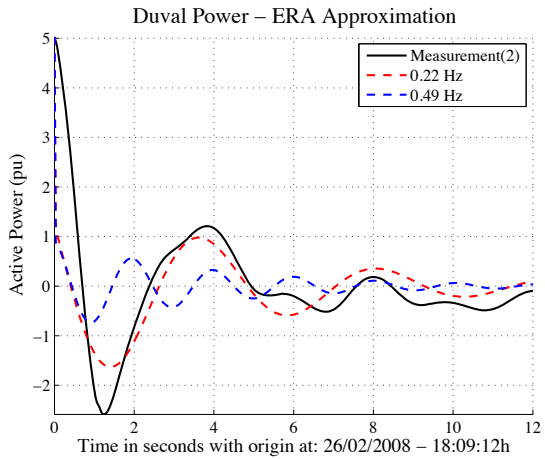


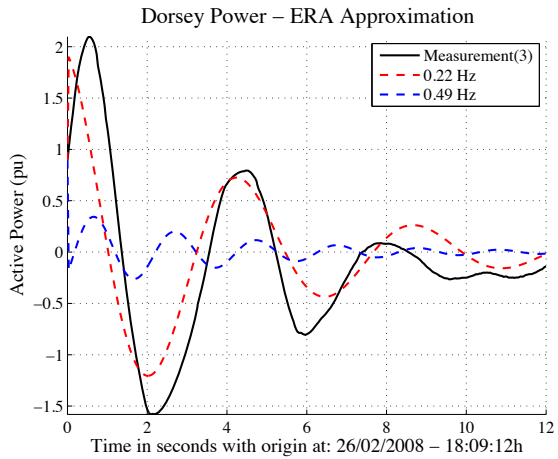




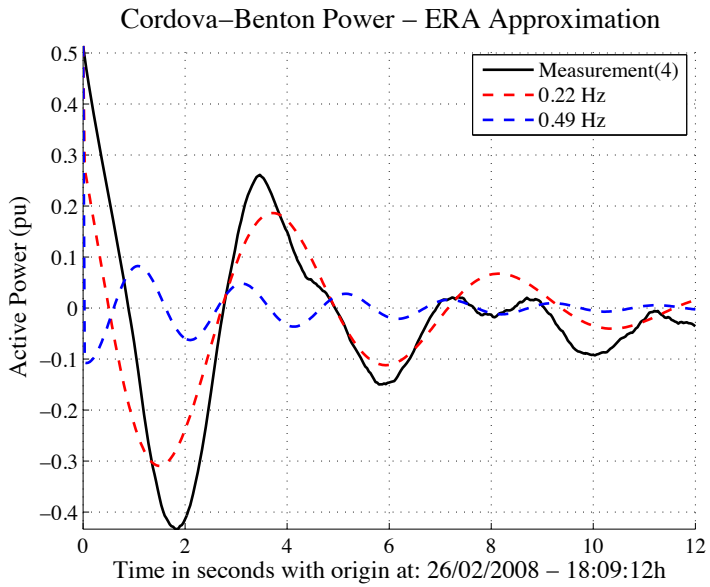
PMU Measurements and Frequency Components from ERA Approximation

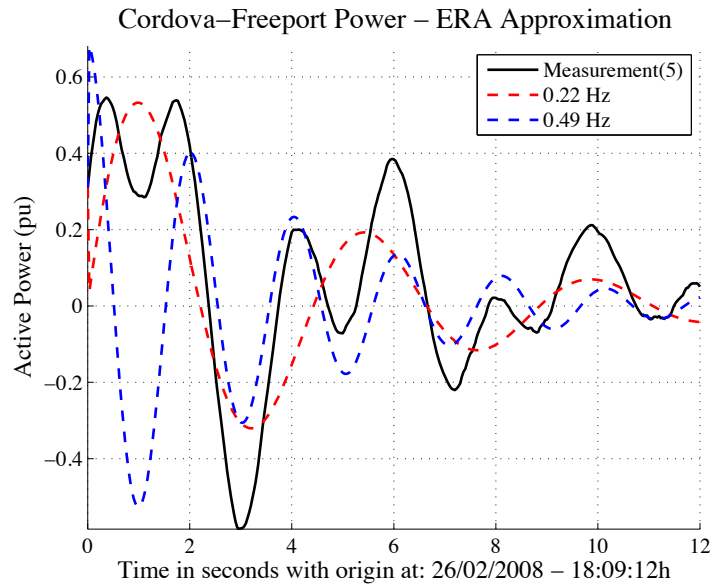


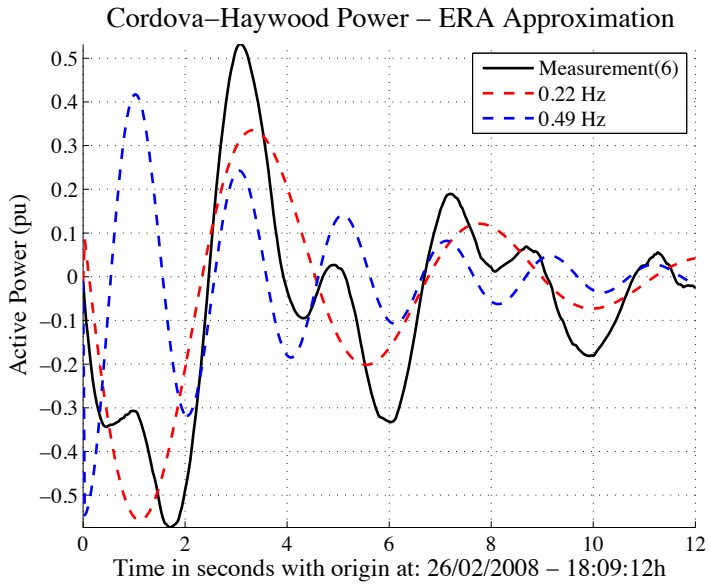


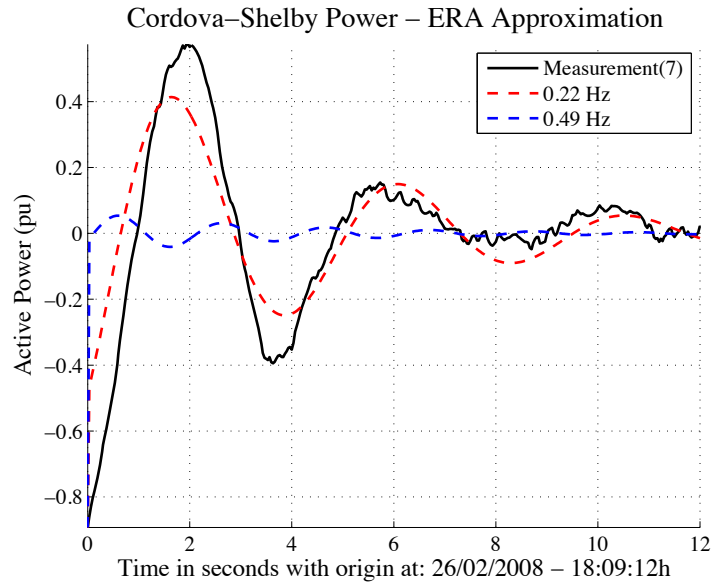


Cordova PMU Measurements and Frequency Components from ERA Approximation

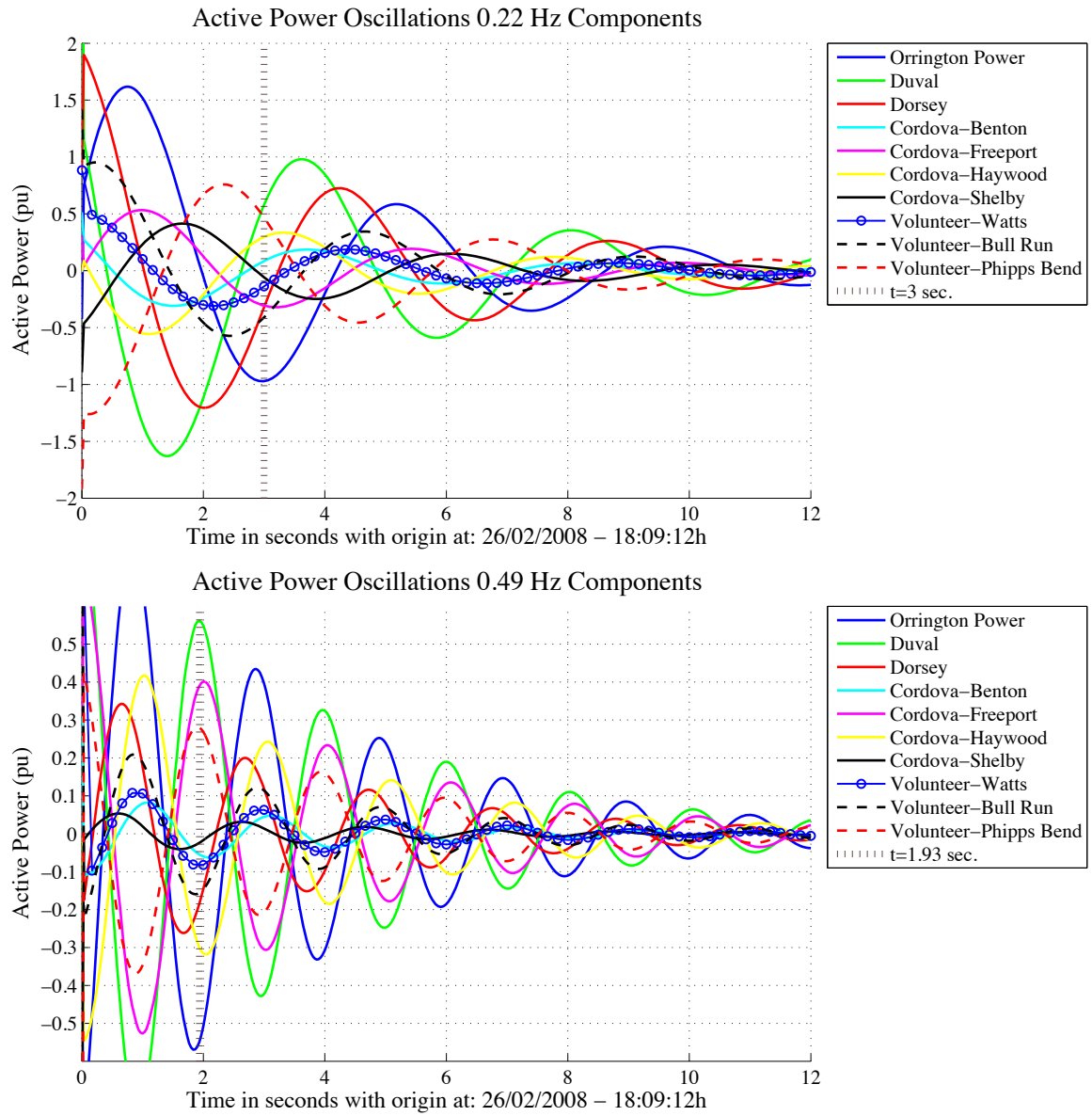






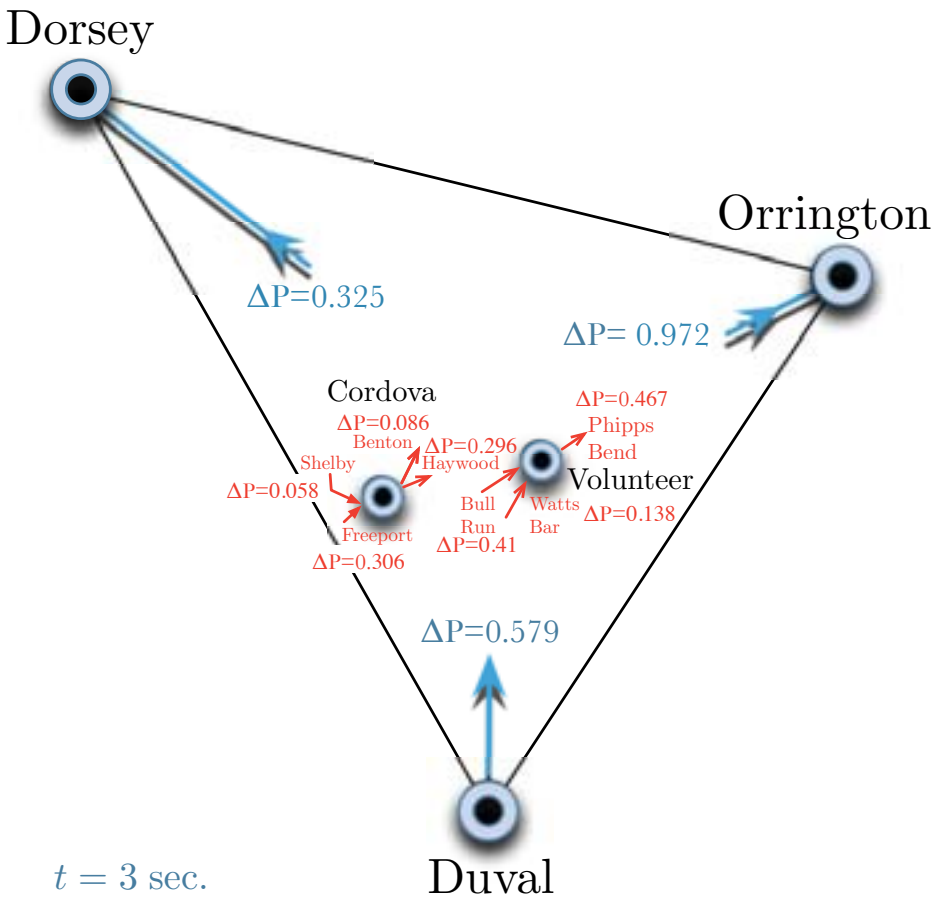


Active Power Oscillations of 0.22 Hz and 0.49 Hz



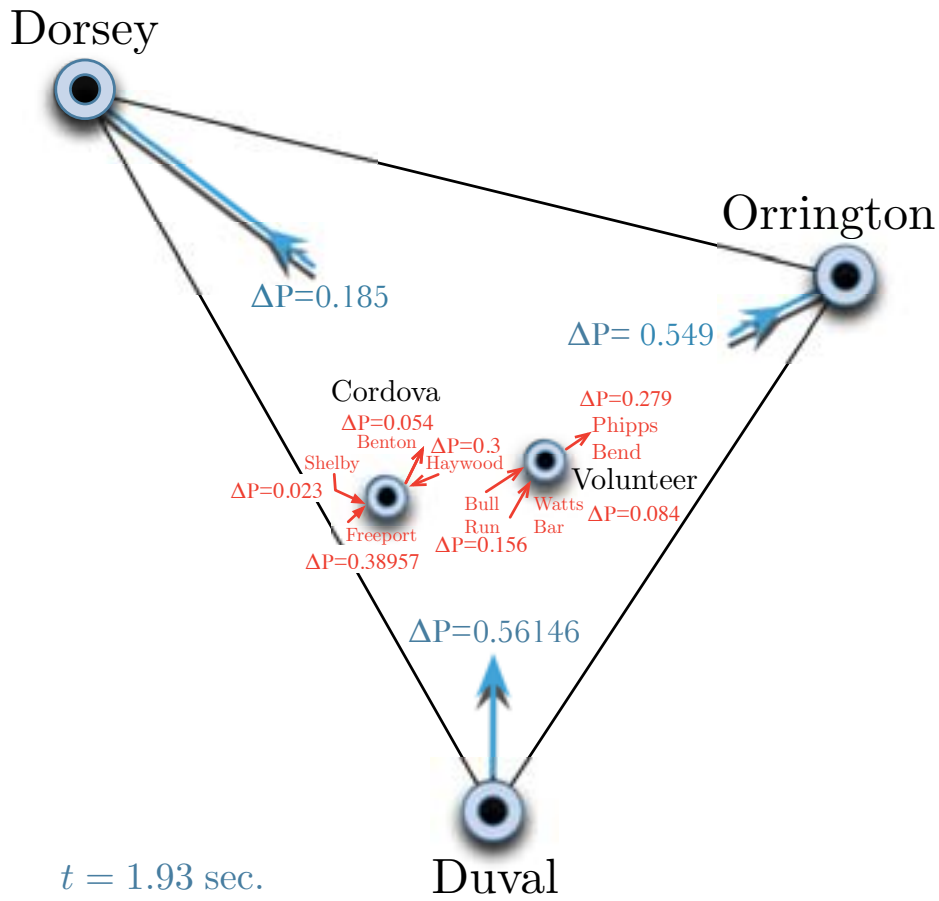
Propagation of 0.22 Hz and 0.49 Hz Power Oscillations

0.22 Hz Power Oscillations



$t = 3$ sec.

0.49 Hz Power Oscillations

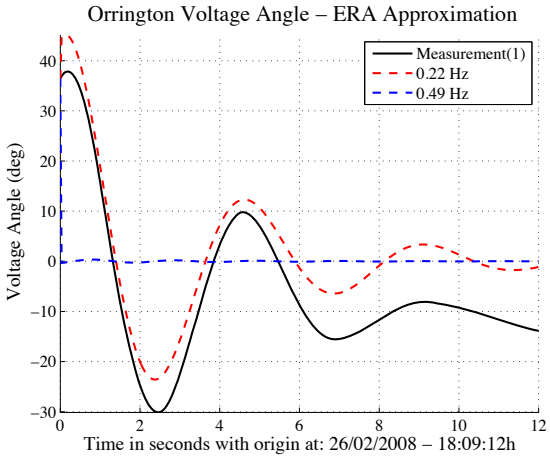


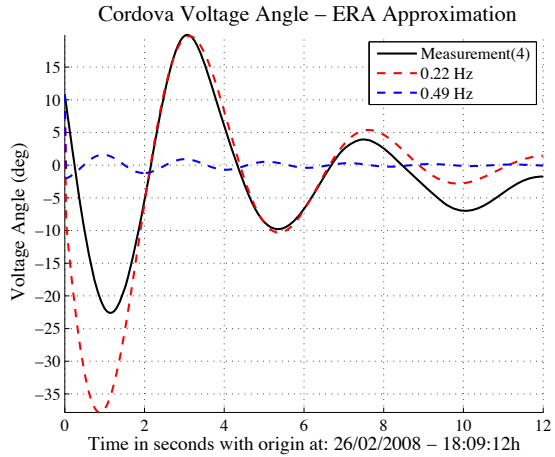
$t = 1.93$ sec.

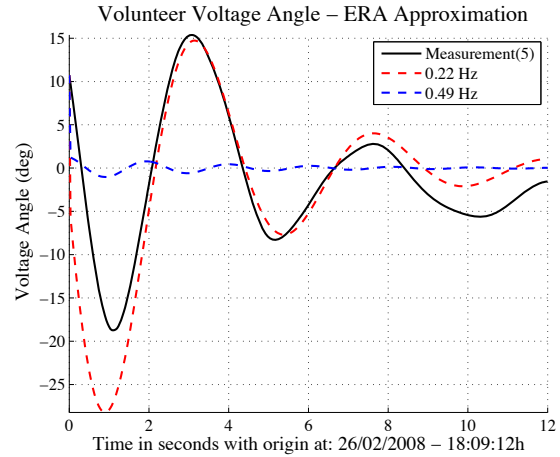
Simultaneous identification of Interarea Modes using Voltage Angle and Magnitude

PMU Measurements and Frequency Components from ERA Approximation

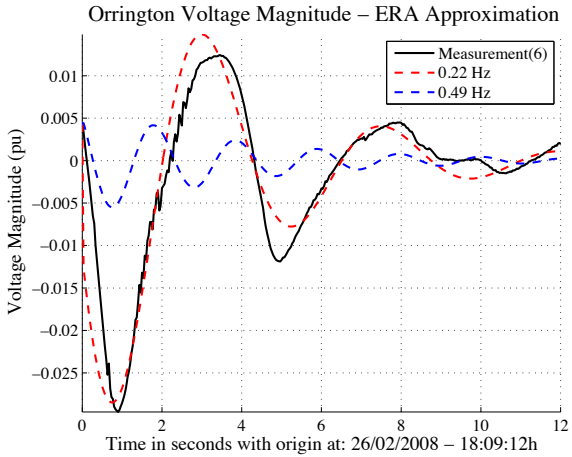
Voltage Angles

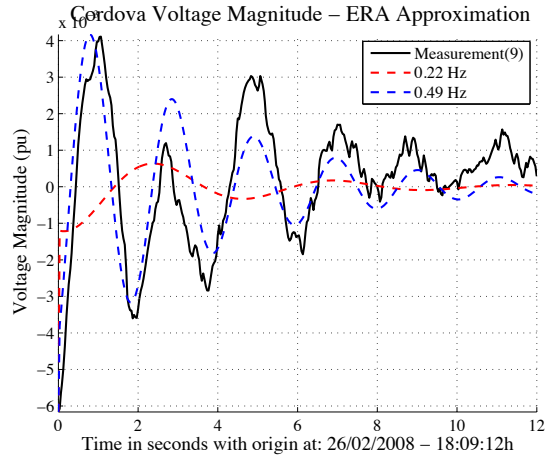


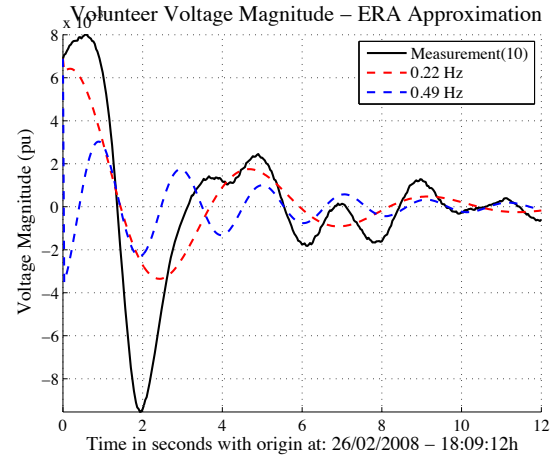




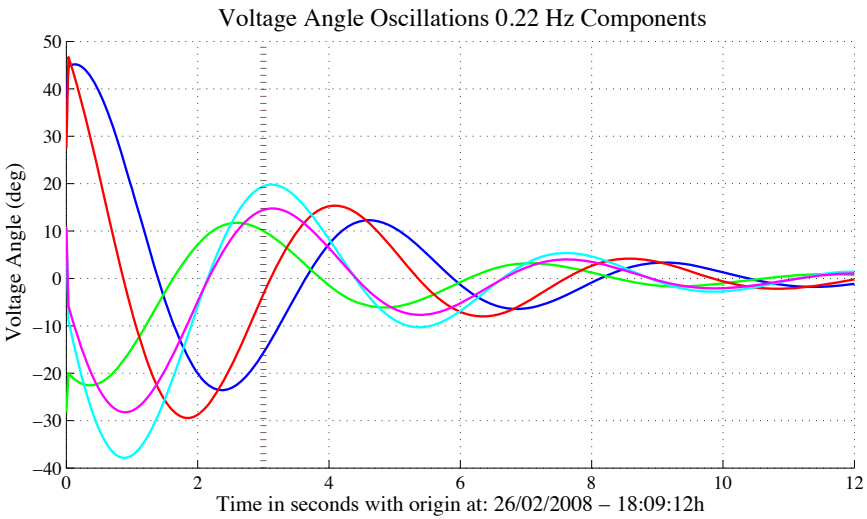
Voltage Magnitudes

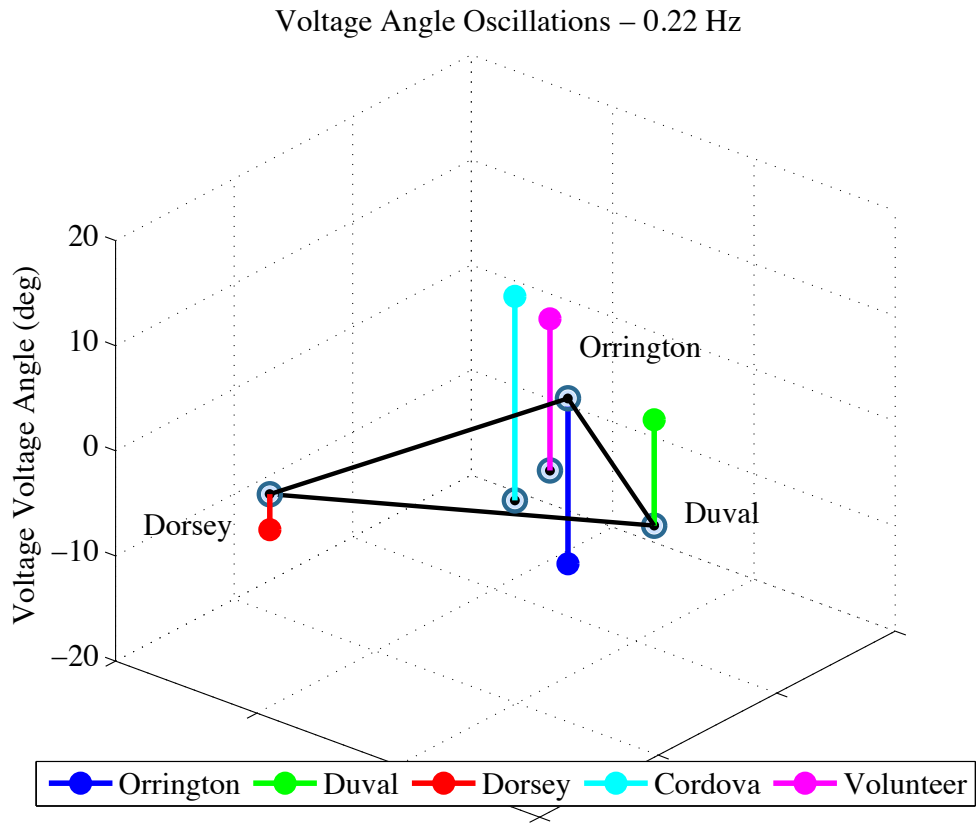






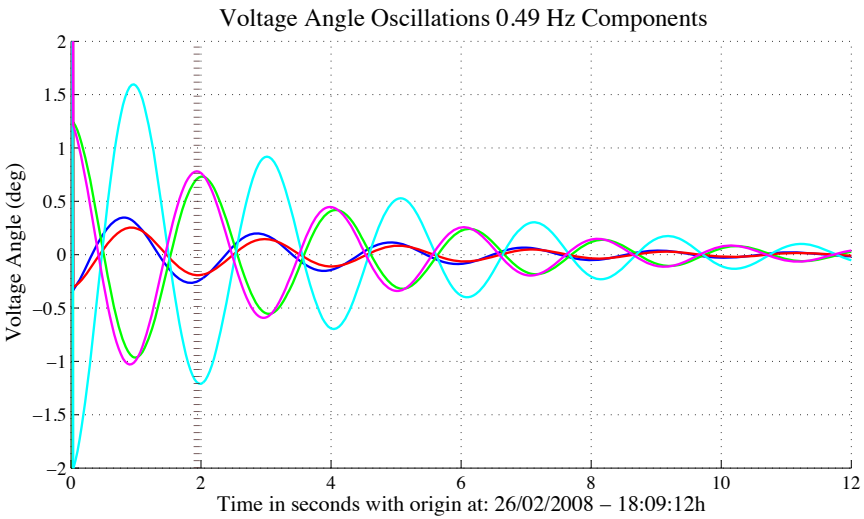
0.22 Hz Oscillations in the Voltage Angles - Modeshape

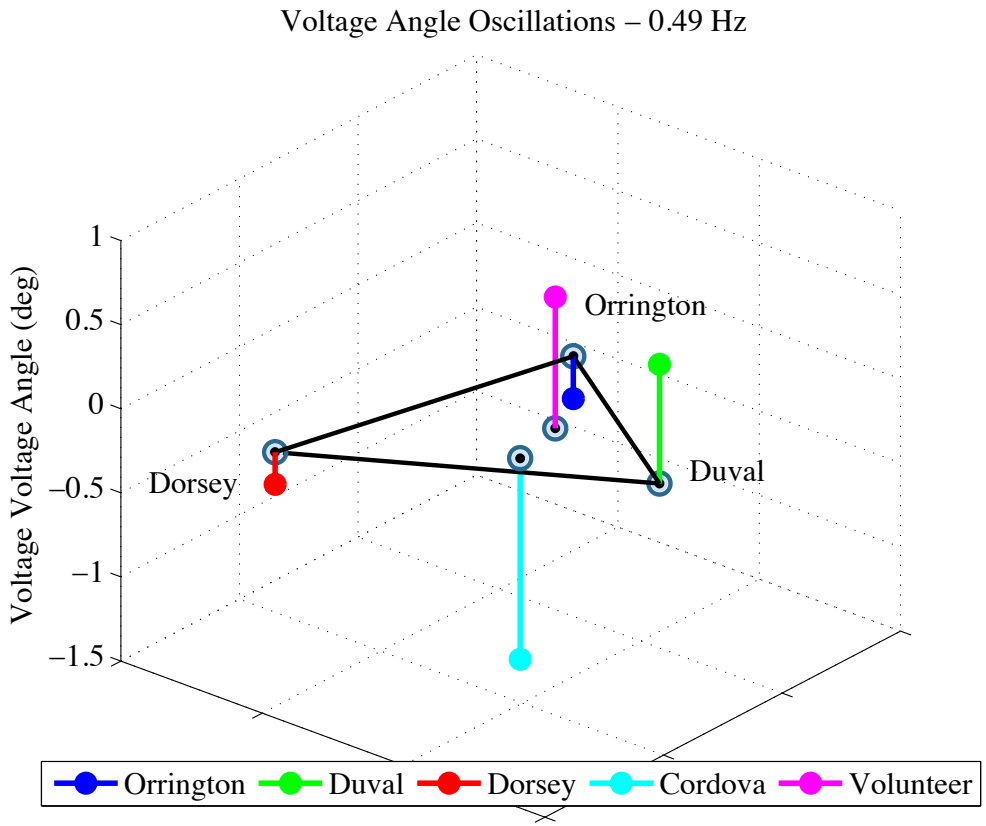




$t = 3$ sec.

0.49 Hz Oscillations in the Voltage Angles - Modeshape





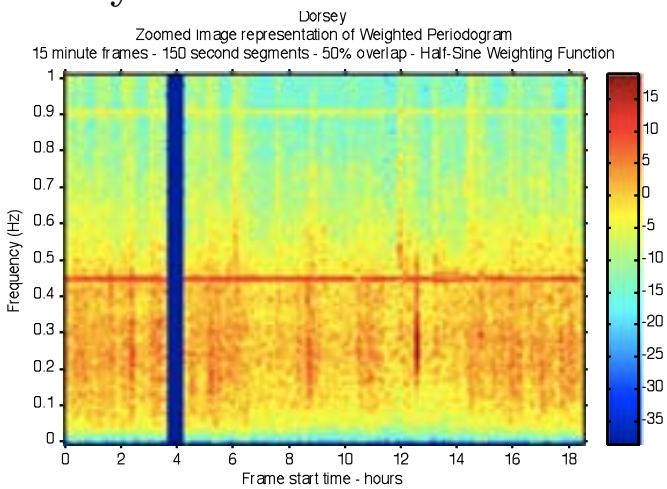
$t = 1.93$ sec.

Spectral Analysis of Power Signals

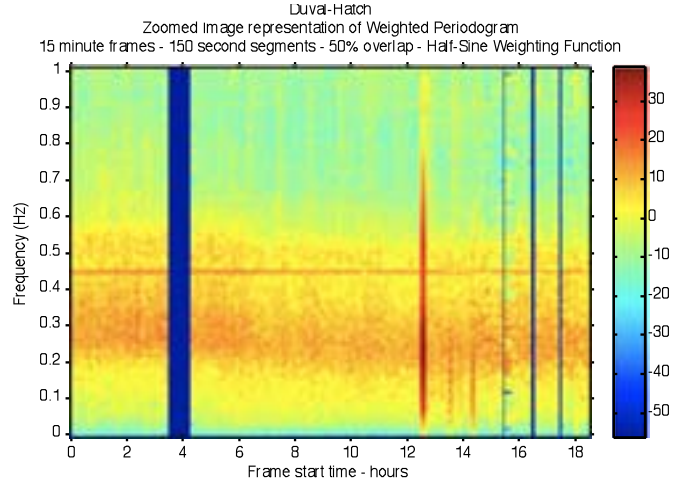
- Two oscillatory frequencies: $f_1 = 0.2 - 0.3$ Hz and $f_2 = 0.45$ Hz

Periodograms of Active Powers at Orrington, Duval, and Dorsey

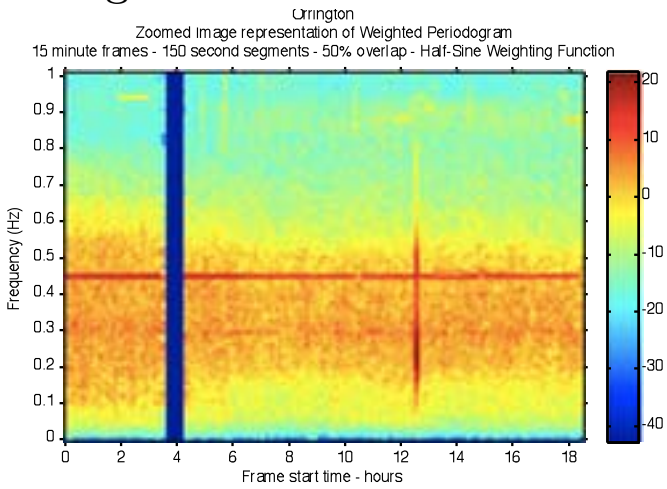
Dorsey



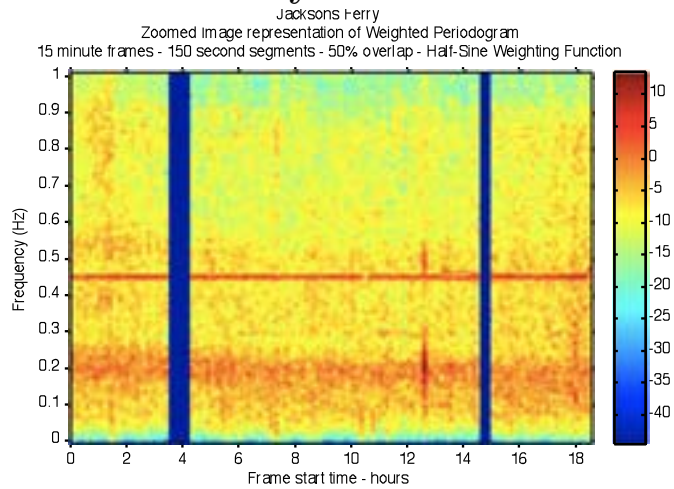
Duval



Orrington

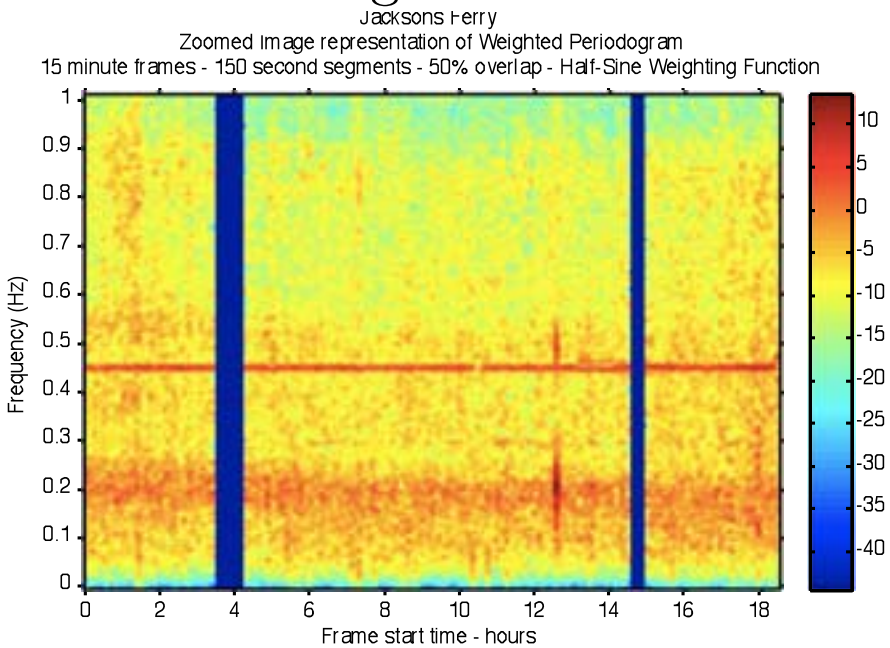


Jackson's Ferry

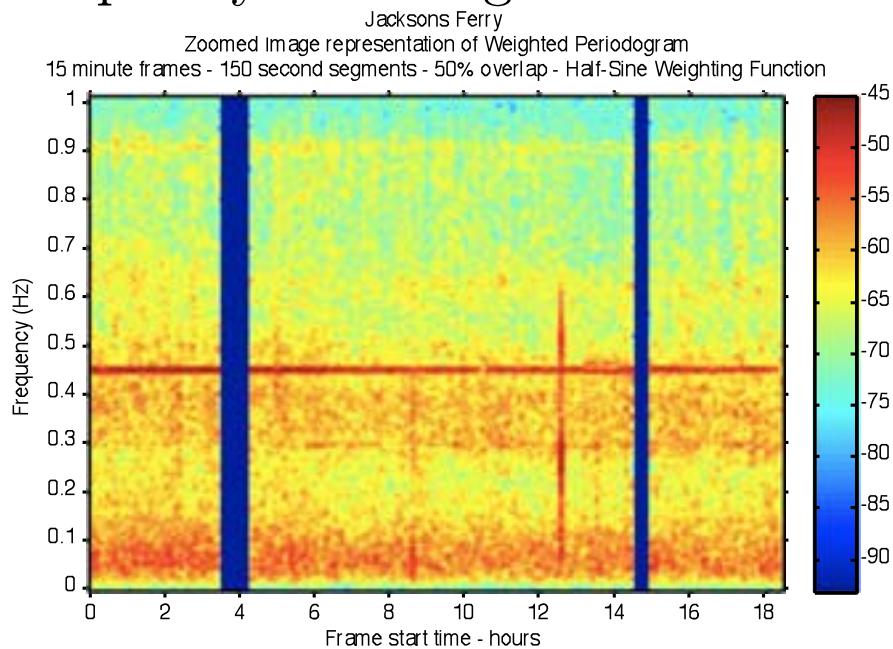


JF Power Periodgram vs Frequency Periodogram

Power Periodogram



Frequency Periodogram



Conclusions

- Oscillatory modes using bus angle and line active power can be used to trace propagation of interarea modes.
- Disturbance Data
  - 0.22 Hz mode - Duval vs Orrington & Dorsey (South vs North)
  - 0.49 Hz mode - More complex mode shape (caterpillar type)
- Ambient Data
  - 0.45 Hz mode - Persistent (light damping)
  - $\approx$ 0.2-0.3 Hz mode - not visible in JF and BRun Frequency (pivot of the system)

Acknowledgments

- Tony Weeks (Manitoba Hydro),
- Ritchie Carrol, and Paul Trachian (TVA)

Thank you!

Questions?