Analysis of Eastern Interconnection Forced Oscillation Events

NERC Special Reliability Assessment

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NASPI
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November 27, 2016 Oscillation Event

We thank all the reliability coordinators for providing PMU data.

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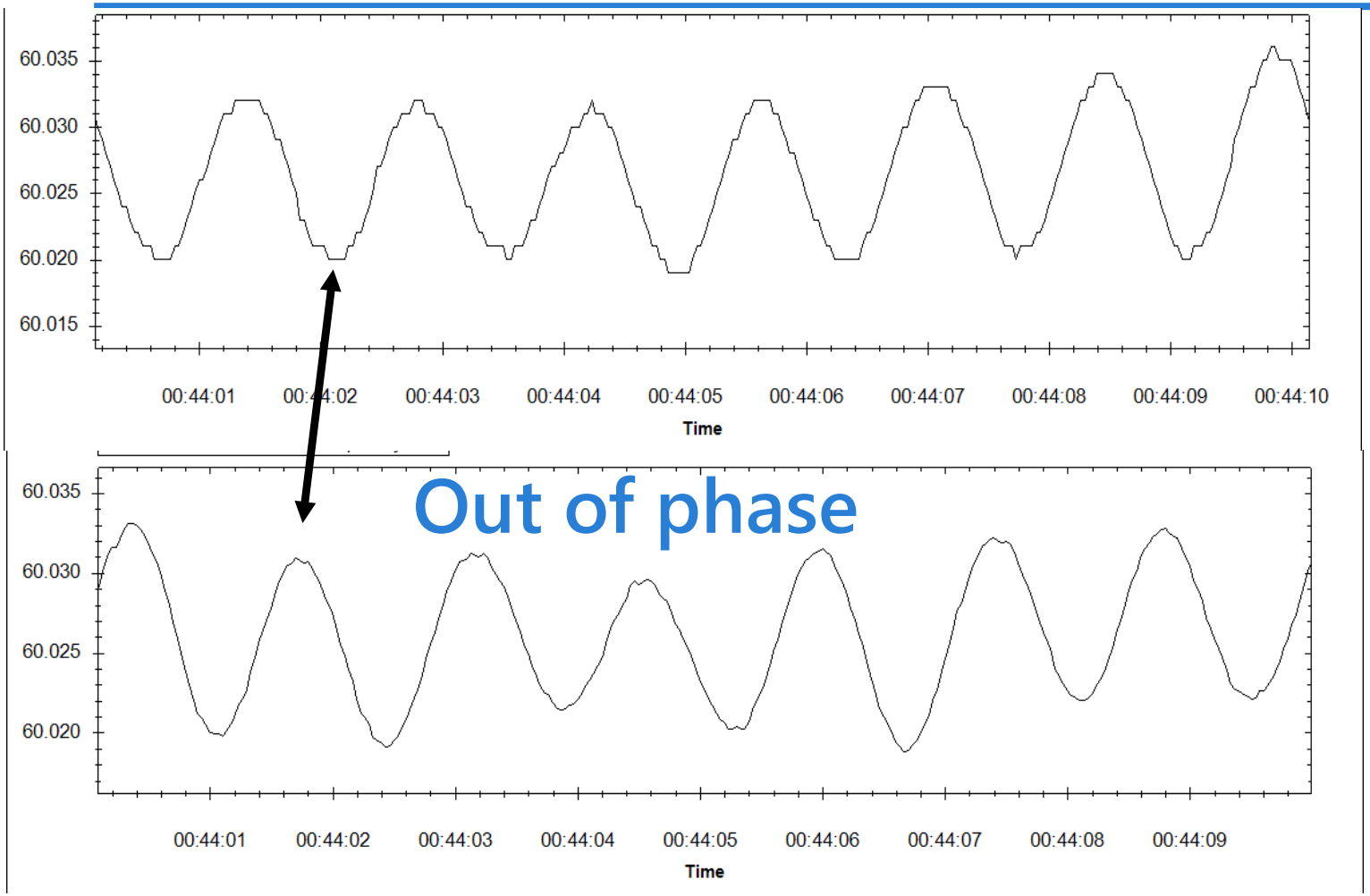
November 27 2016 Event

Bus Frequency Time Plots



Alabama

New Jersey

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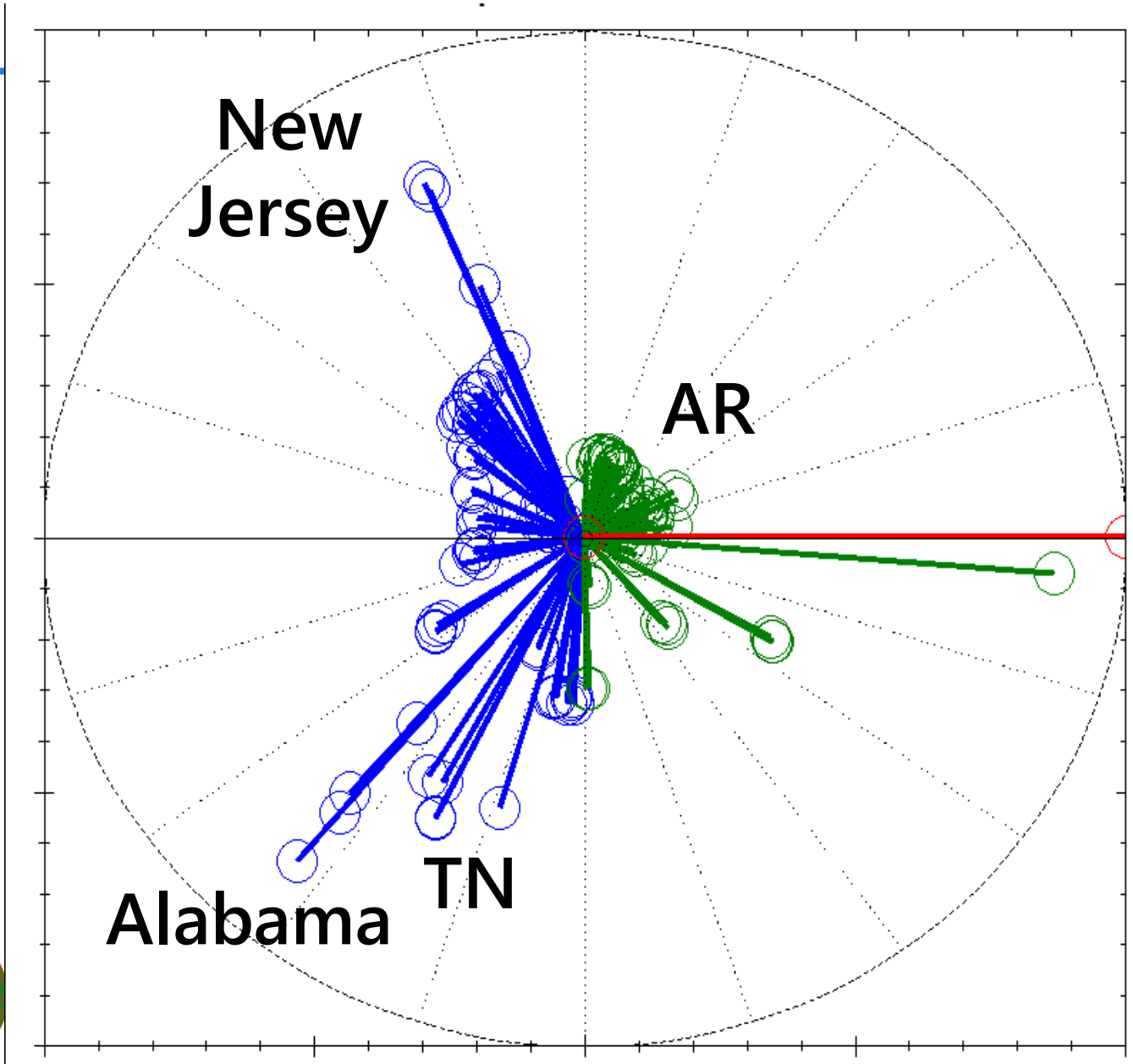
0.7 Hz Oscillation Mode Shape



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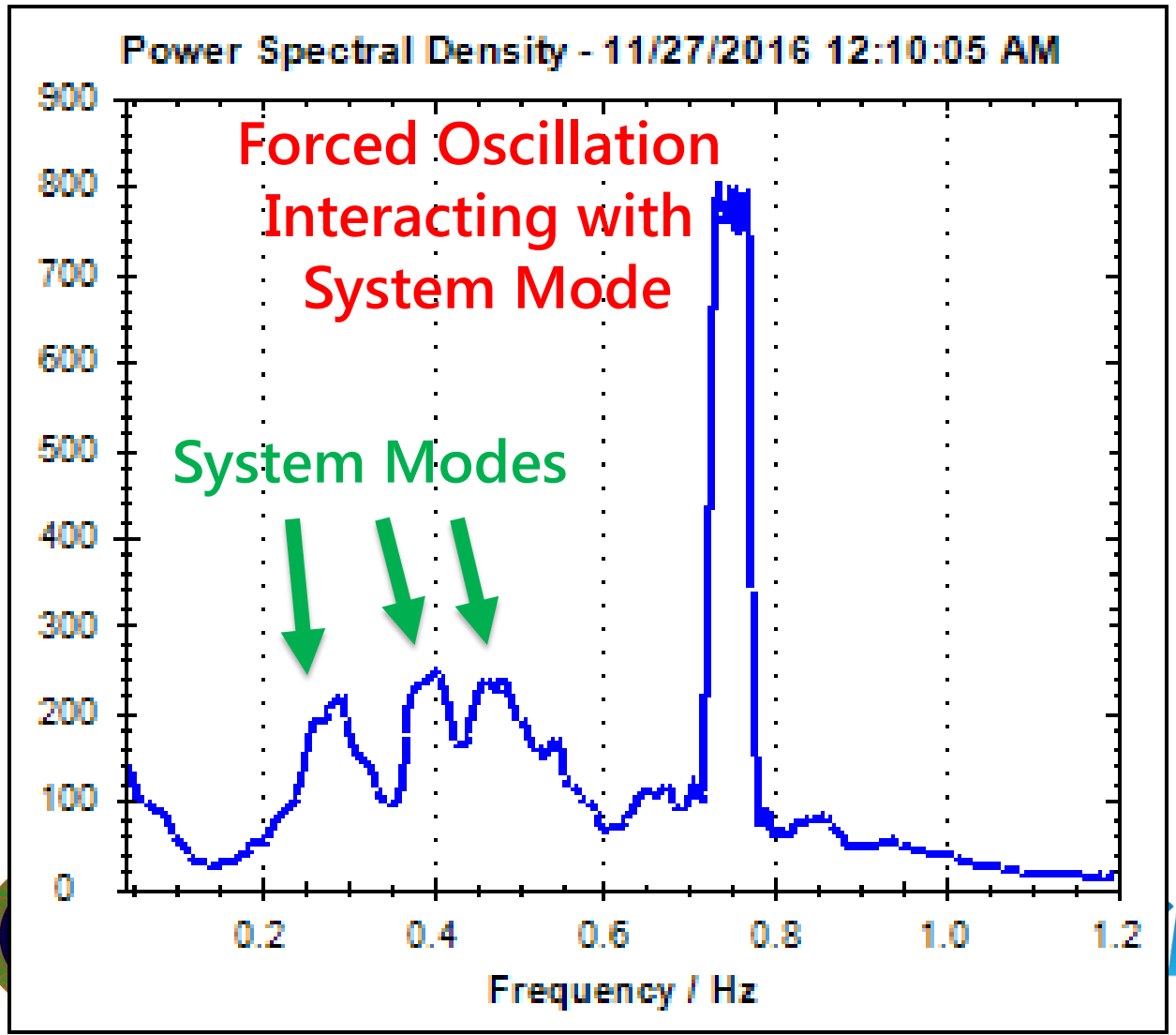
FFDD Power Spectrum@12:10AM (Before)



Main modes

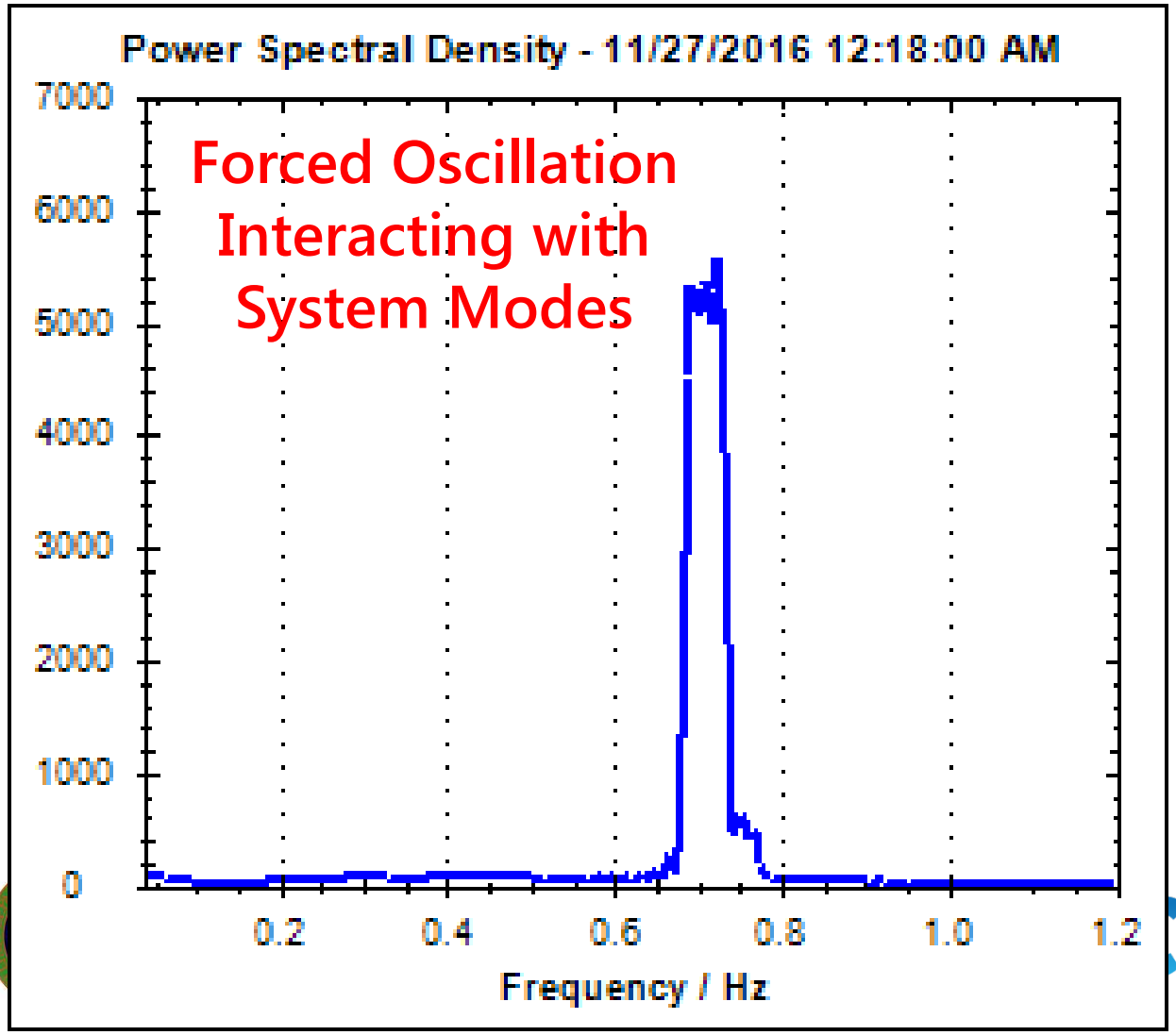
0.25 Hz

0.4 Hz

0.5 Hz

0.75 Hz

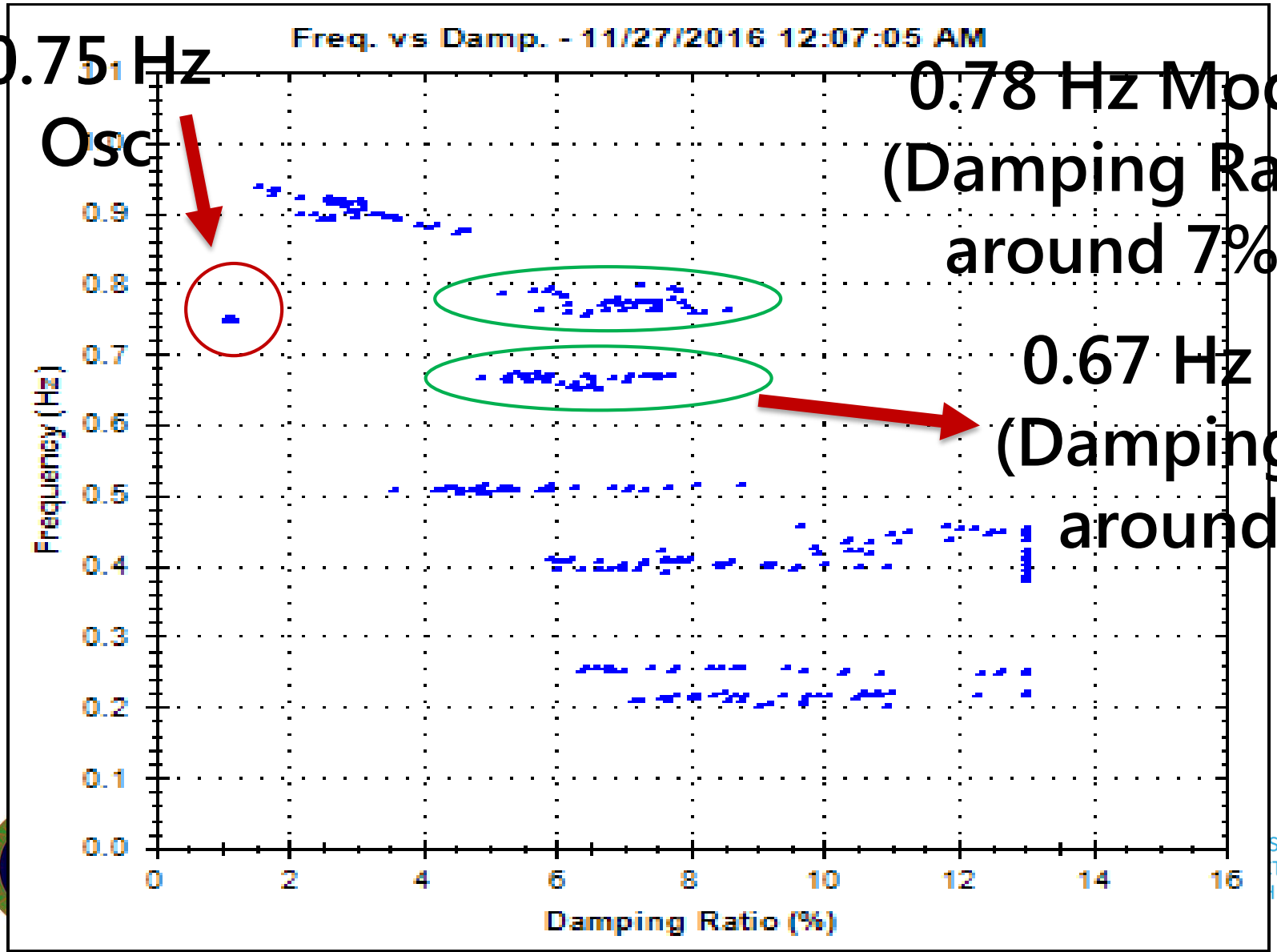
Power Spectrum @ 3:15 AM (During)



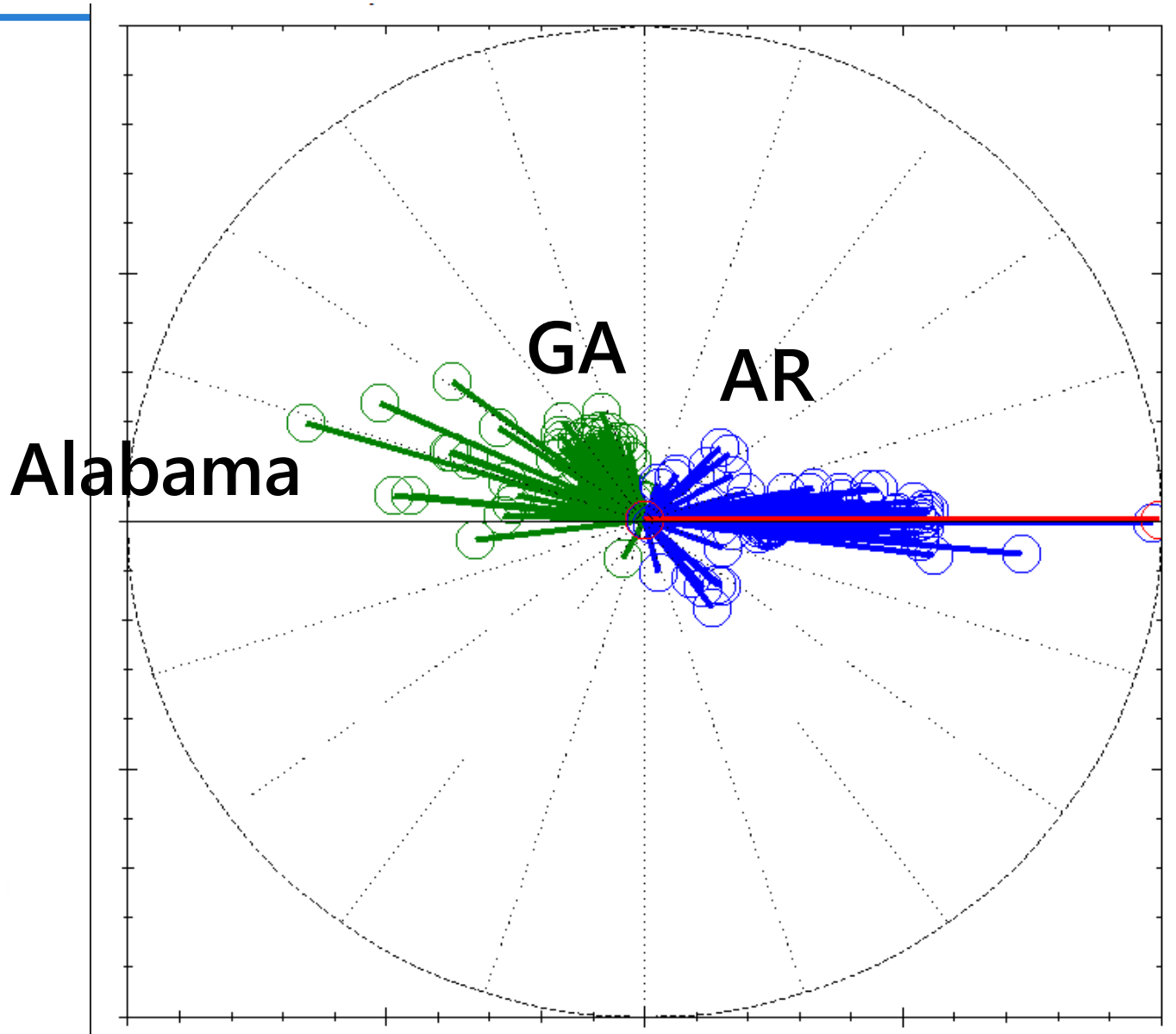
Main mode

0.7 Hz

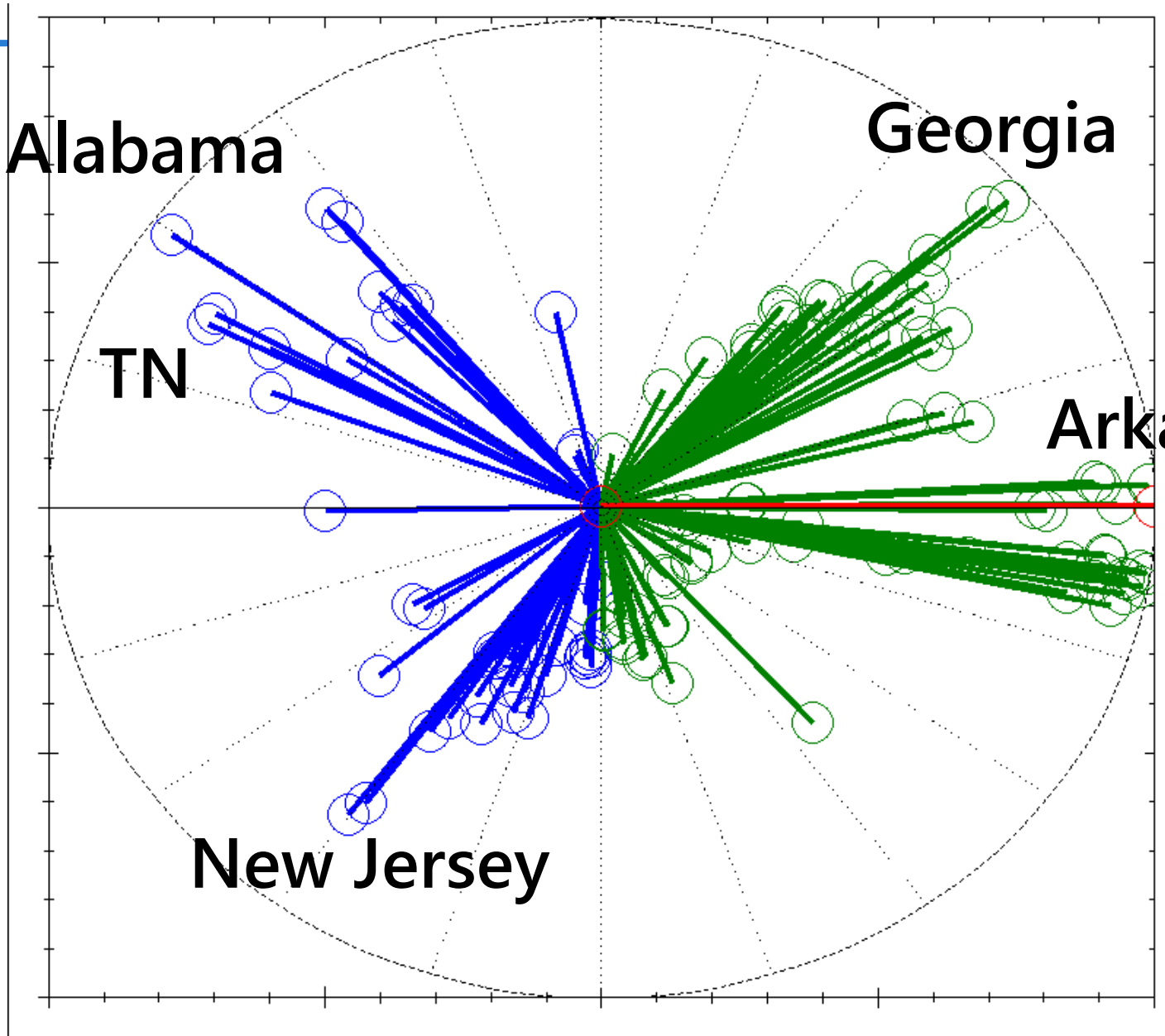
FSSI Estimates Before GA Osc Event



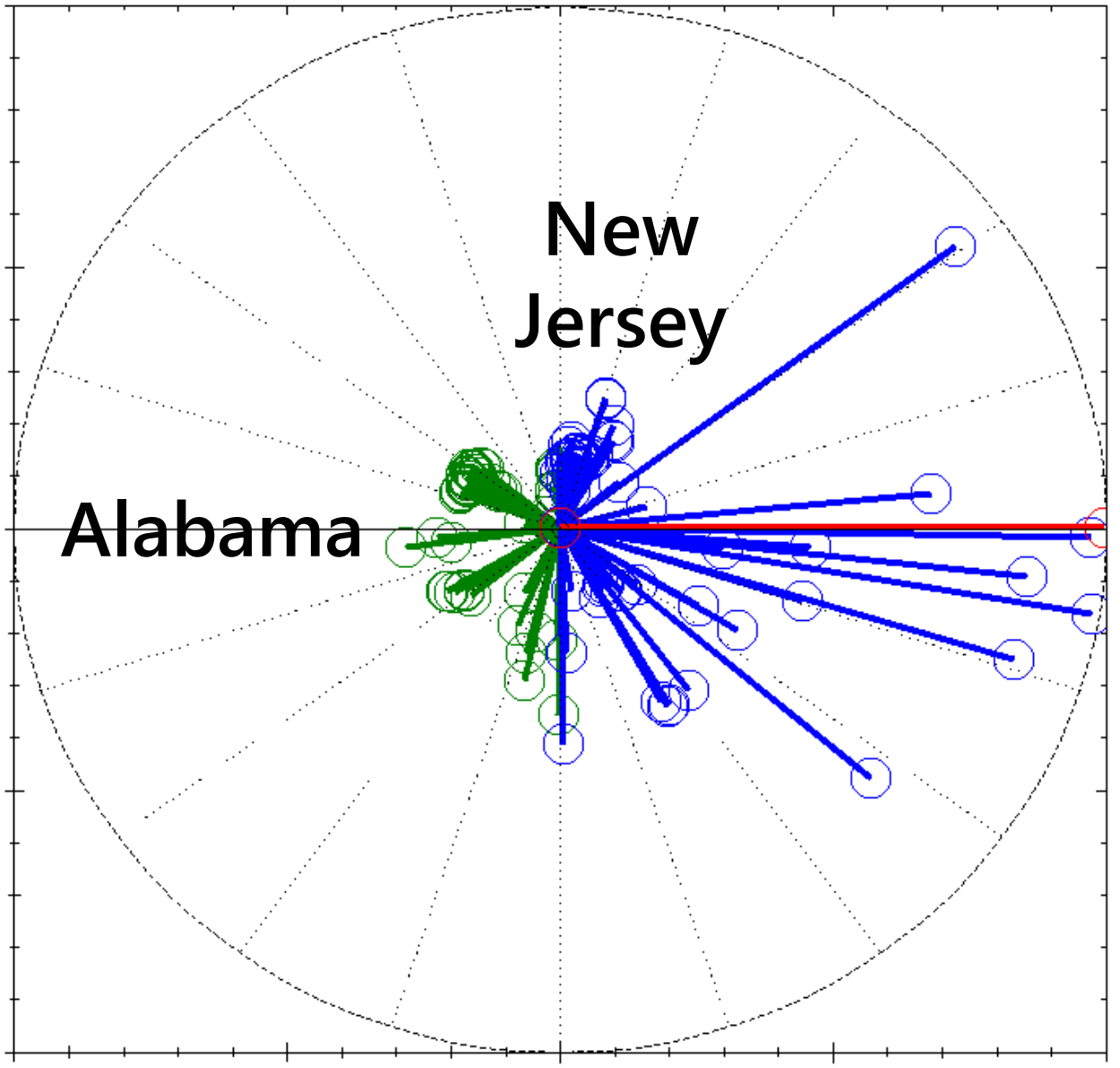
0.67 Hz System Mode Shape from FSSI



0.78 Hz System Mode Shape from FSSI



0.75 Hz Oscillation Mode Shape from FSSI



MISO signals

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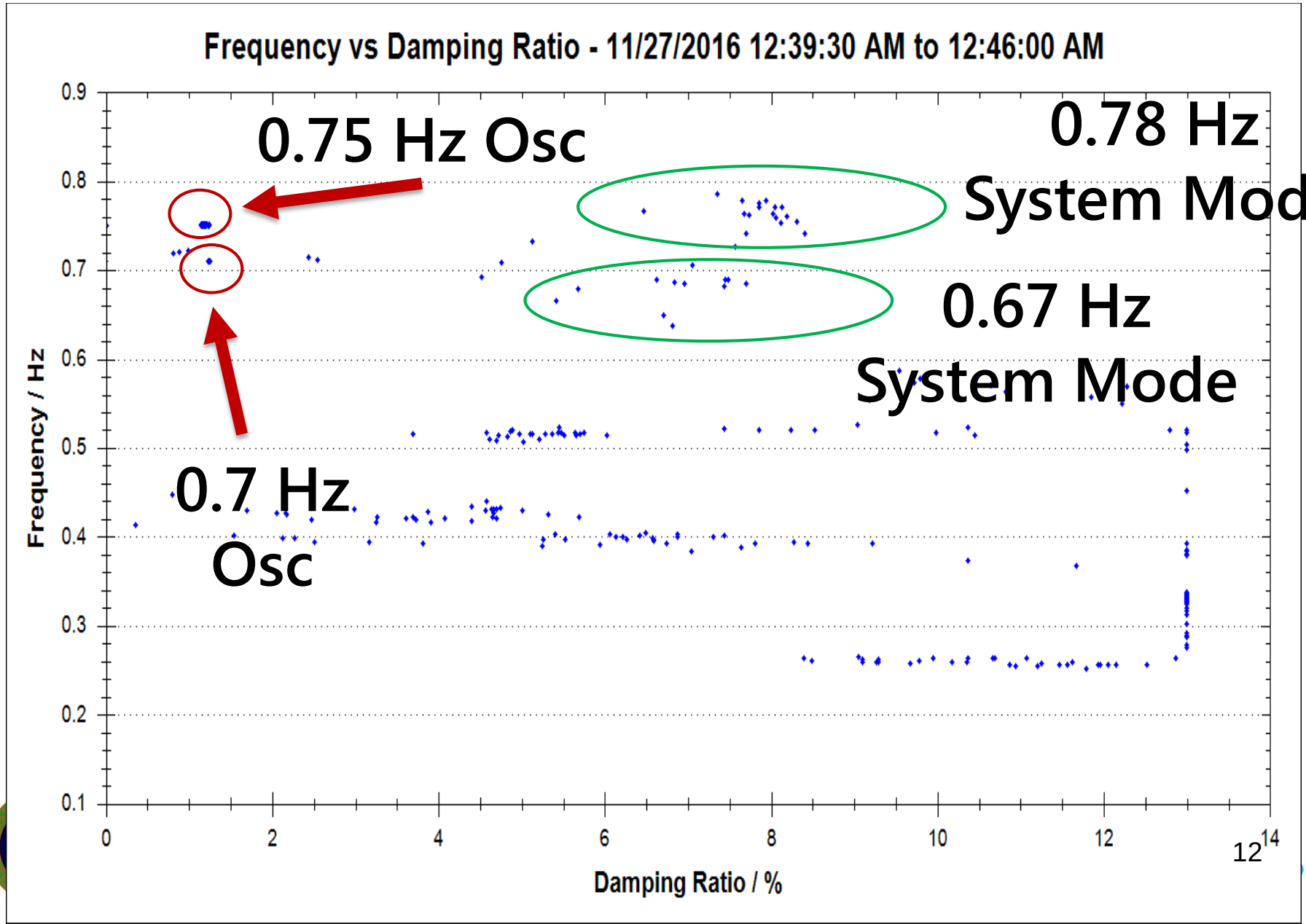
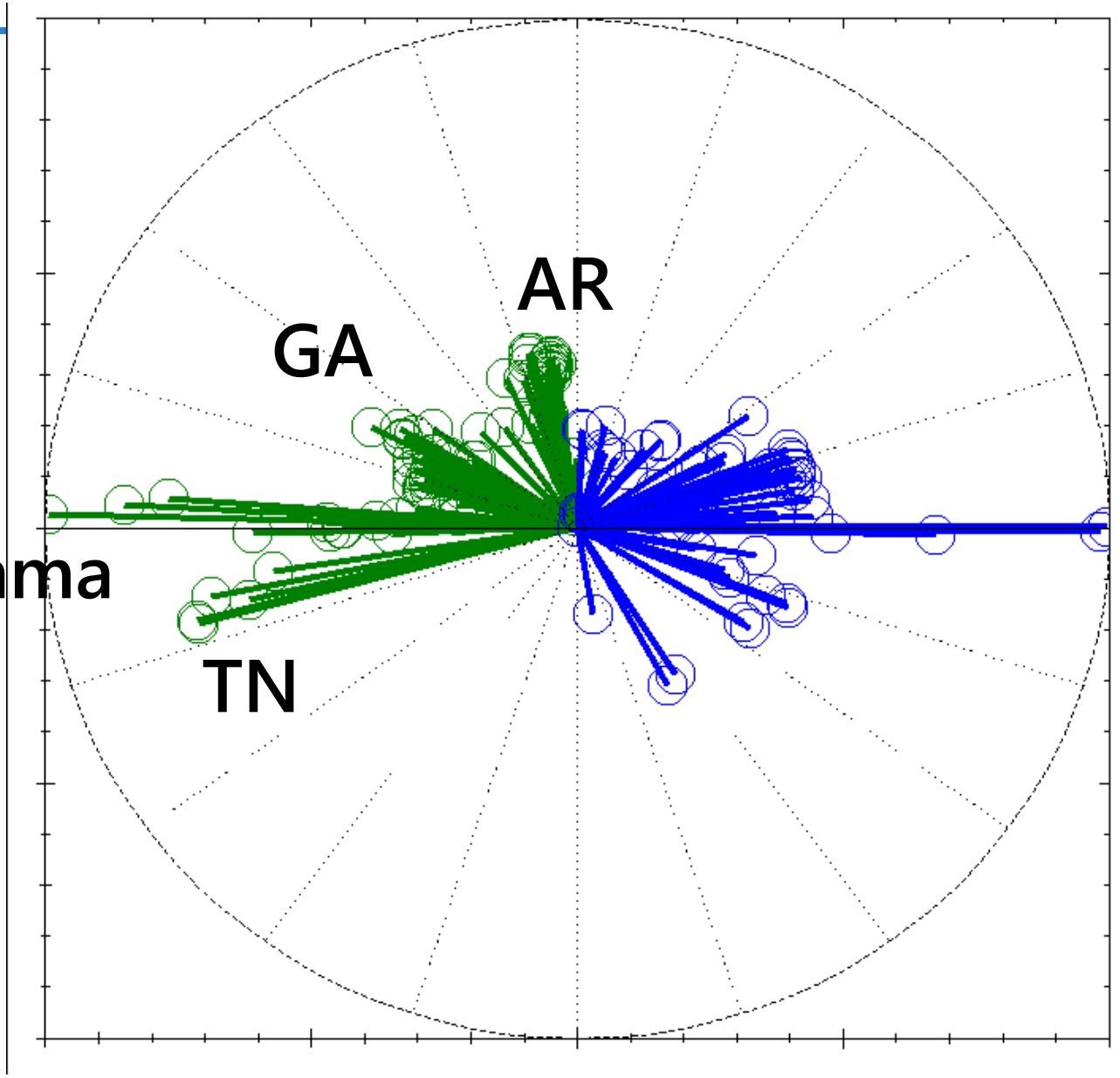
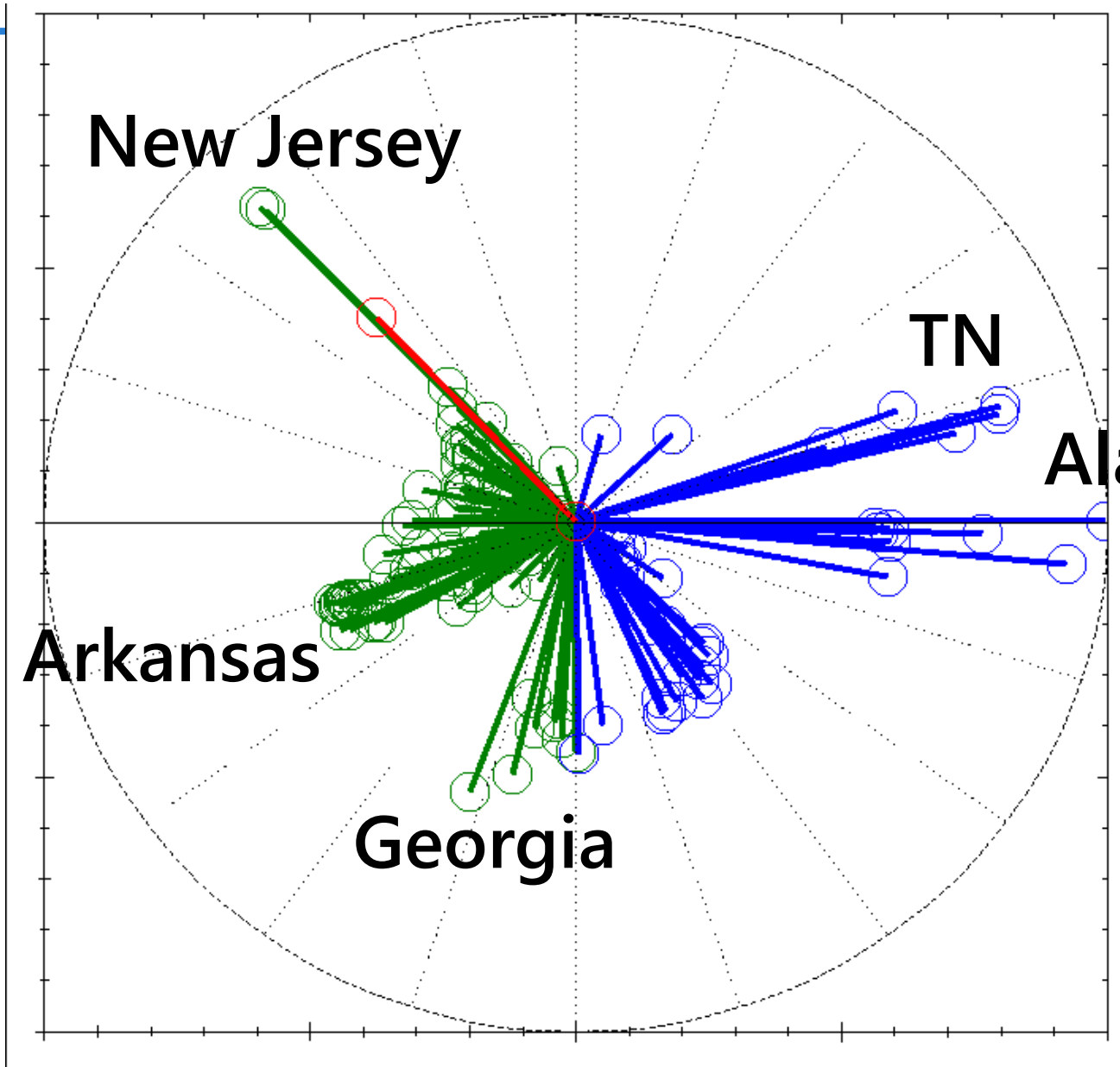
FSSI Estimates During GA Osc Event



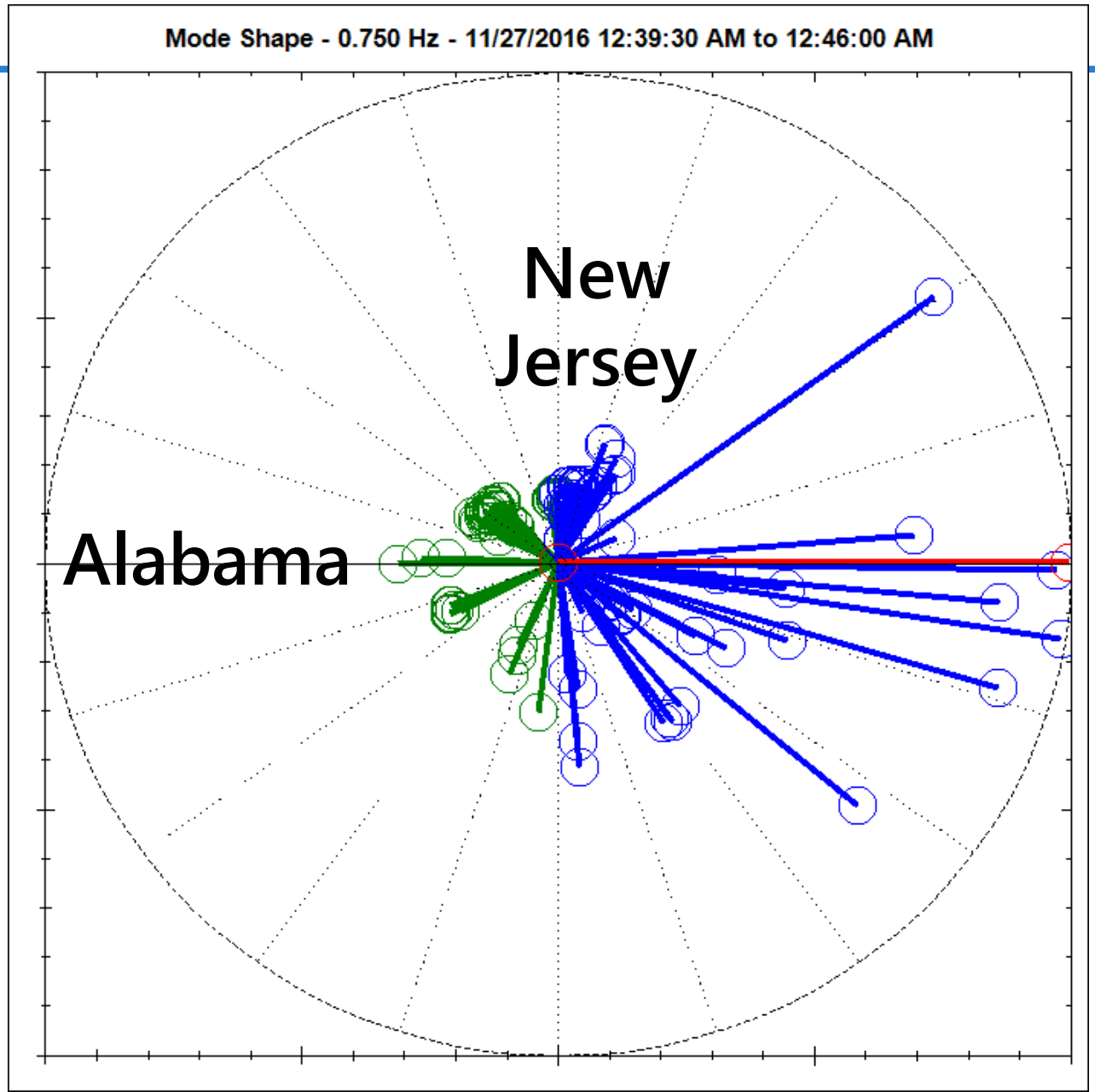
0.69 Hz System Mode Shape from FSSI



0.76 Hz System Mode Shape from FSSI



0.75 Hz Oscillation Mode Shape from FSSI



MISO signals

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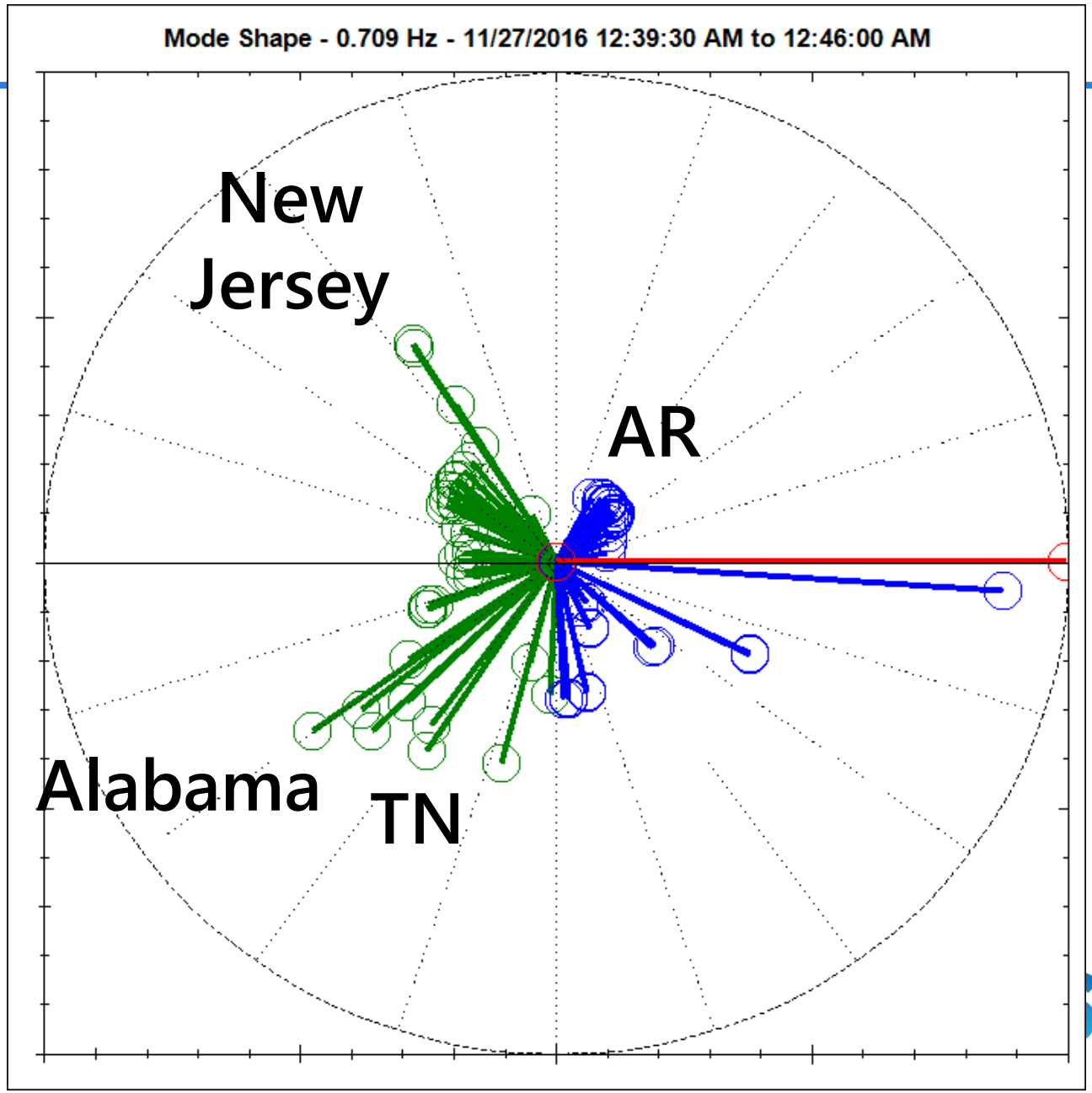
0.7 Hz Oscillation Mode Shape from FSSI



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Resonance with Inter-area Mode

Resonance effect high when:

(R1) Forced Oscillation freq near System Mode freq

(R2) System Mode poorly damped

(R3) Forced Oscillation location near the two distant ends (strong participation) of the System Mode

Resonance effect medium when:

- Some conditions hold

Resonance effect small when:

- None of the conditions holds

(Source: Our recent papers in IEEE Trans. Power Systems)

Resonance Conditions for the Ever Present 0.75 Hz Forced Oscillation

(R1) Forced Osc freq near System Mode freq **(close)**

- **0.75 Hz Oscillation versus 0.78 Hz Mode**

(R2) System Mode poorly damped **(invalid)**

- **0.78 Hz Well-damped (7% Damping Ratio)**

(R3) Forced Osc location near the two distant ends (strong participation) of the System Mode **(not true)**

- **MISO Location 33% Relative Energy for the Mode**

Only ~1 condition valid: Resonance effect very small.

Resonance Conditions for 0.7 Hz Georgia Oscillation

(R1) Forced Osc freq near System Mode freq **(close)**

- **0.7 Hz Oscillation versus 0.67 Hz System Mode**

(R2) System Mode poorly damped **(invalid)**

- **0.67 Hz Well-damped (6% Damping Ratio)**

(R3) Forced Osc location near the two distant ends (strong participation) of the System Mode **(not true)**

- **GA Location 22% Relative Energy for the Mode**
- **Interaction with 0.78 Hz mode?**

Only 1+ conditions valid: Resonance effect small.

November 27 2016 Event Summary

- **0.7 Hz Eastern Interconnection Mode Shape: VACAR versus TVA. Many TVA units showed oscillations during the event.**
- **Oscillation source in Georgia was not a sensitive location for the 0.67 Hz Mode**
- **Oscillation frequency 0.7 Hz close**
- **0.67 Hz System mode well-damped (excellent)**
- **Resonance effect was mild**
- **0.75 Hz forced oscillation present throughout – weak resonance with 0.78 Hz system mode**

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Oscillation Modes Analysis Summary

- 7 Events each for East, West and Texas.
- Several simulation cases using NERC models by JP.
- Models reasonable for West and Texas. Less so for East.
- Results in a draft report submitted to NERC SMS.
- Modes well-damped mostly.
- Few forced oscillation events.
- Complex mode shapes in EI.
- Continuous monitoring of modes and mode shapes recommended.

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