USE OF RTDMS® AND PGDA FOR REAL TIME POWER SYSTEM OSCILLATION MONITORING AND ADVANCED ANALYSIS

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Monitoring and Evaluating Modal Oscillations

Electric Power Group's Grid Dynamics Tools:

- Real-Time Dynamics Monitoring System (RTDMS)
- Phasor Grid Dynamics Analyzer (PGDA)

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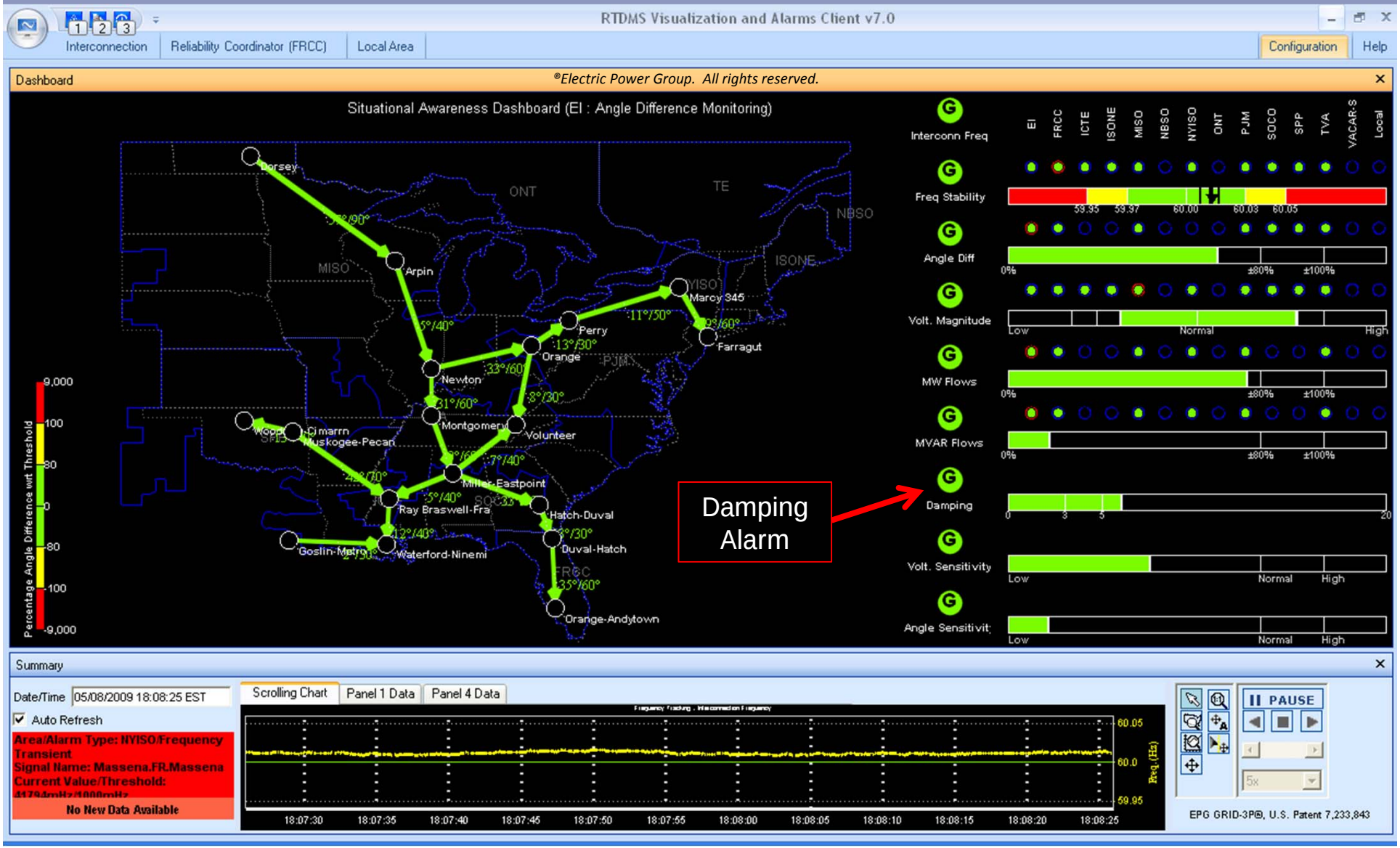
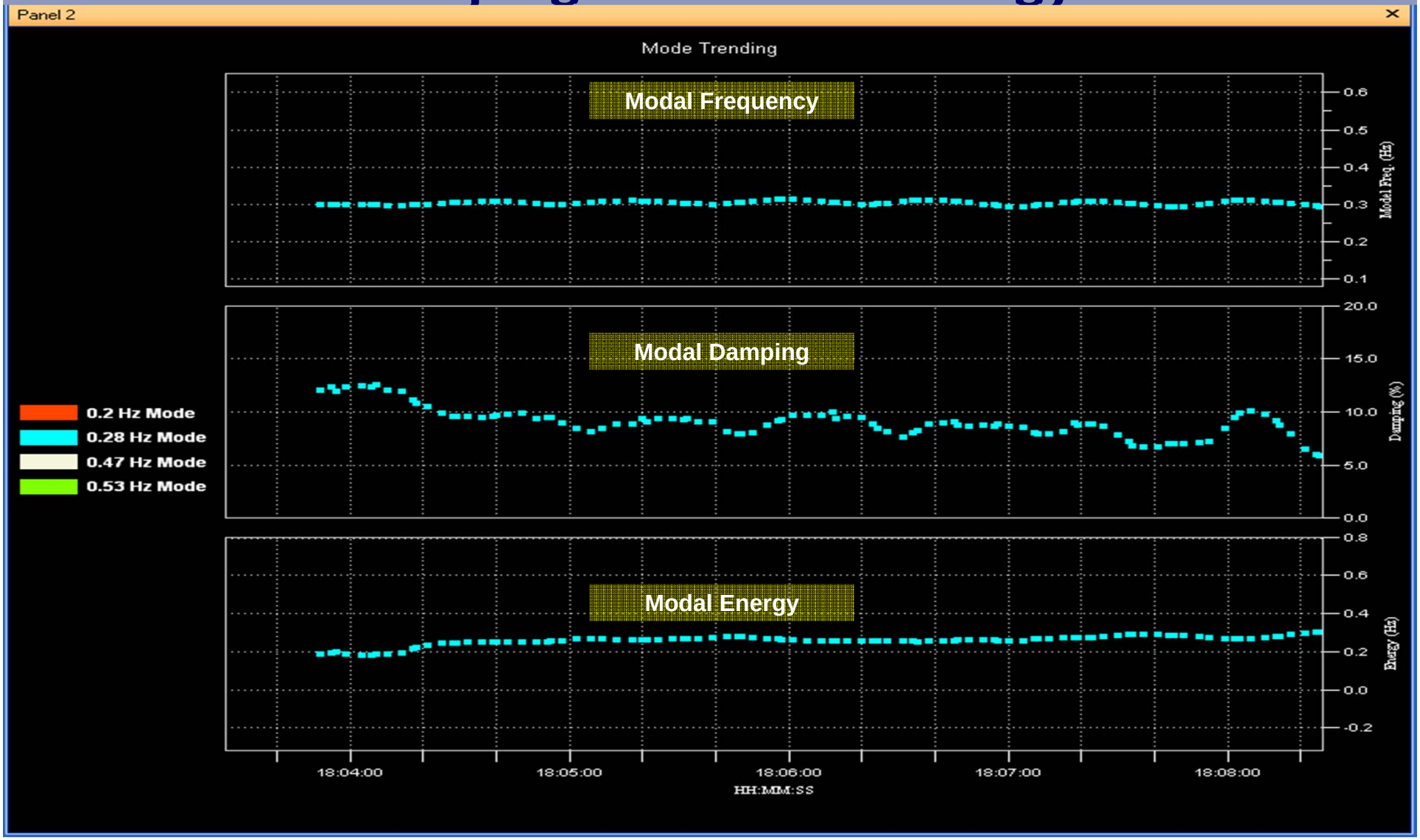
RTDMS – Monitoring of Damping & Oscillation Frequency

- RTDMS displays Oscillation Frequencies and Damping
- Algorithm used in RTDMS uses ambient data –10 minutes data desirable
- RTDMS Damping Display:
  - Identifies the presence of known modes
  - Oscillatory frequency and damping trend
  - Oscillation frequency energy trend
  - Mode and damping with respect to alert and alarm levels

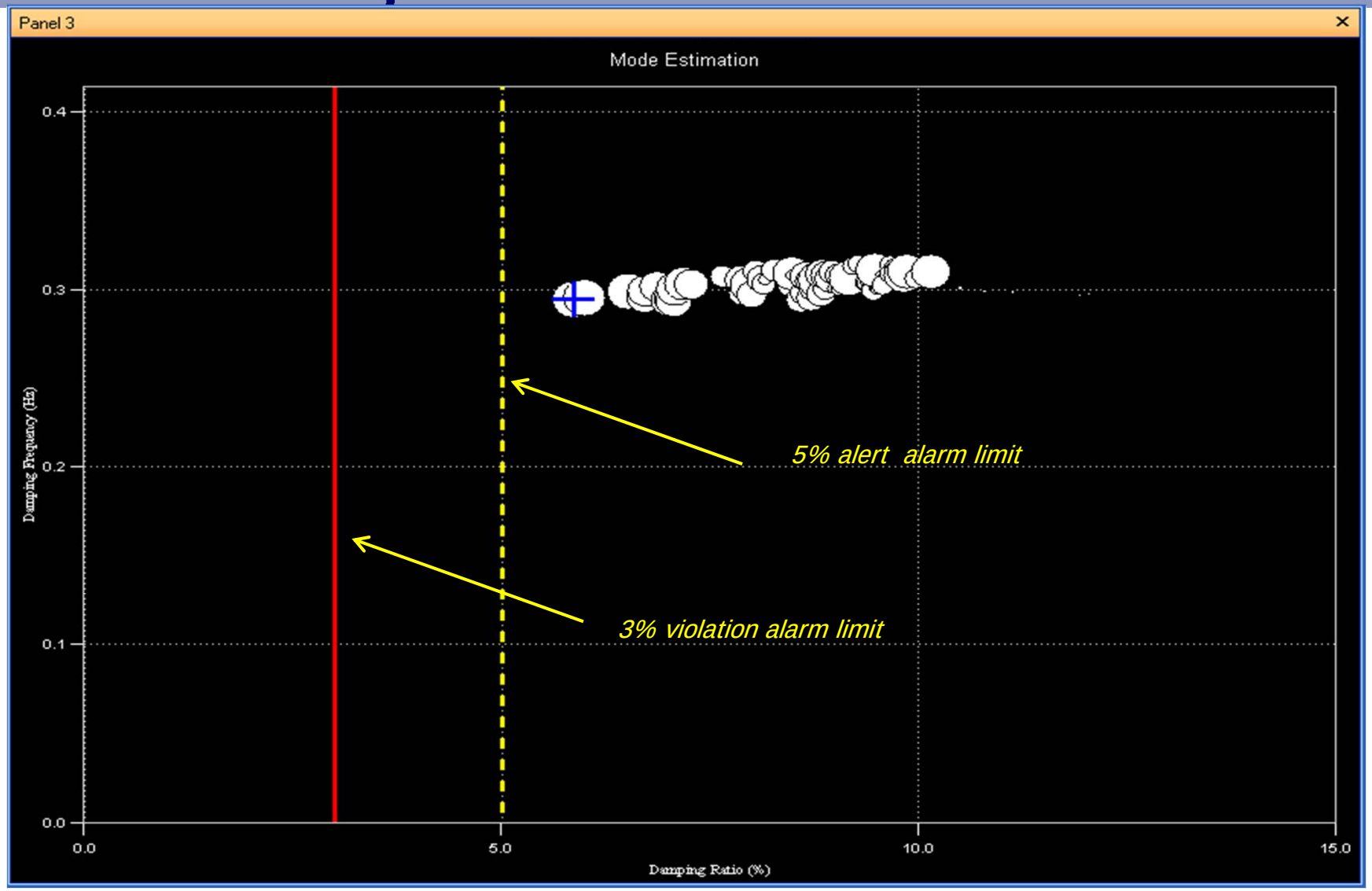
RTDMS – Damping Metric Selection From Dashboard



RTDMS Trending – Monitor Dominant Frequency, Damping And Modal Energy



RTDMS –Modal Frequency and Damping Trend With Respect to Alerts and Alarms

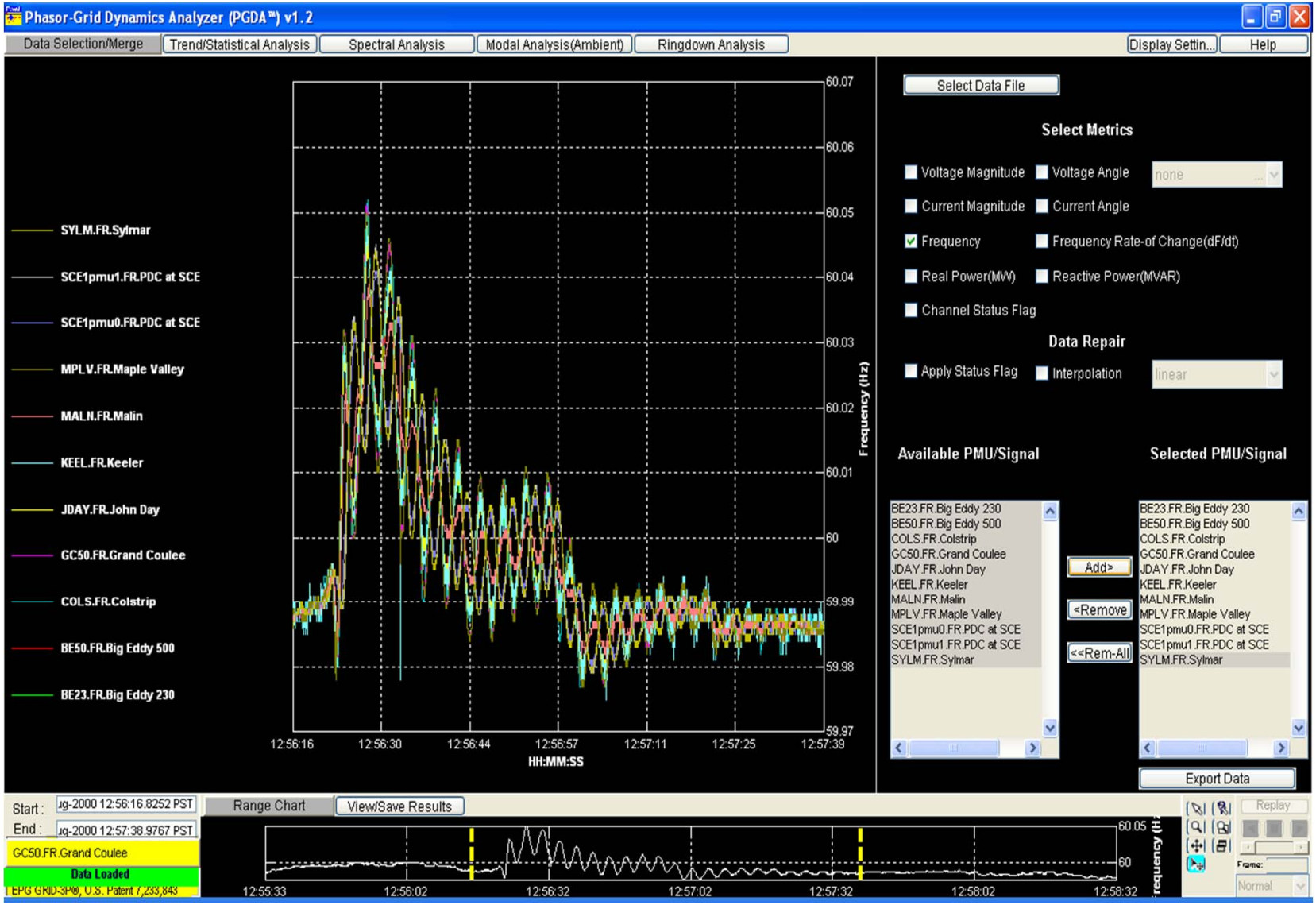


Phasor Grid Dynamics Analyzer (PGDA)

Phasor Grid Dynamics Analyzer is used to perform advanced analysis and evaluation of grid oscillations:

- Spectral Analysis
  - Auto spectrum plot
  - Coherency plot
  - Cross – Spectrum
- Ring Down Analysis
  - Reconstructed signal comparison
  - Modal frequencies & Damping
  - Mode shapes

Displaying System Oscillations - Frequency Plot



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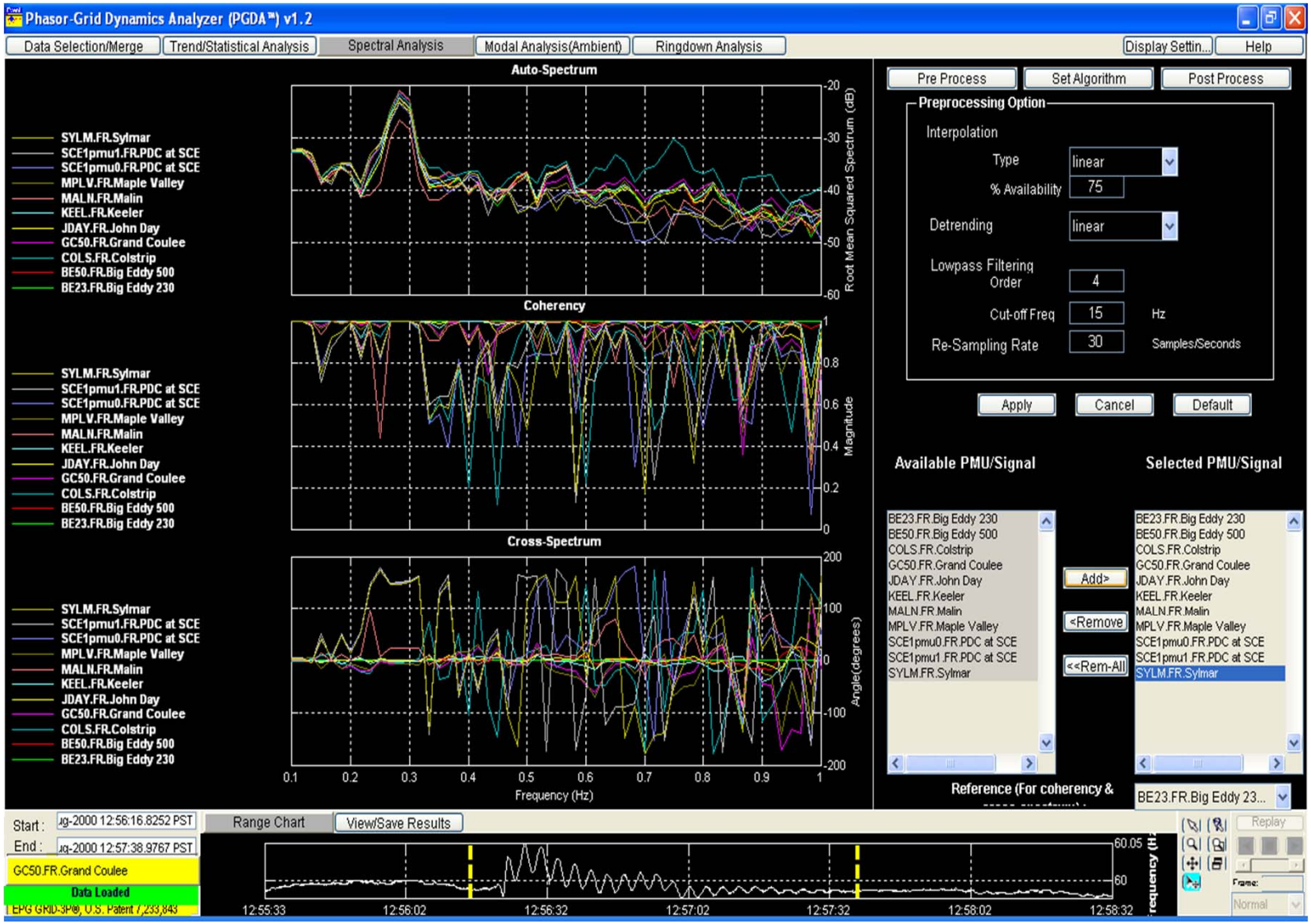
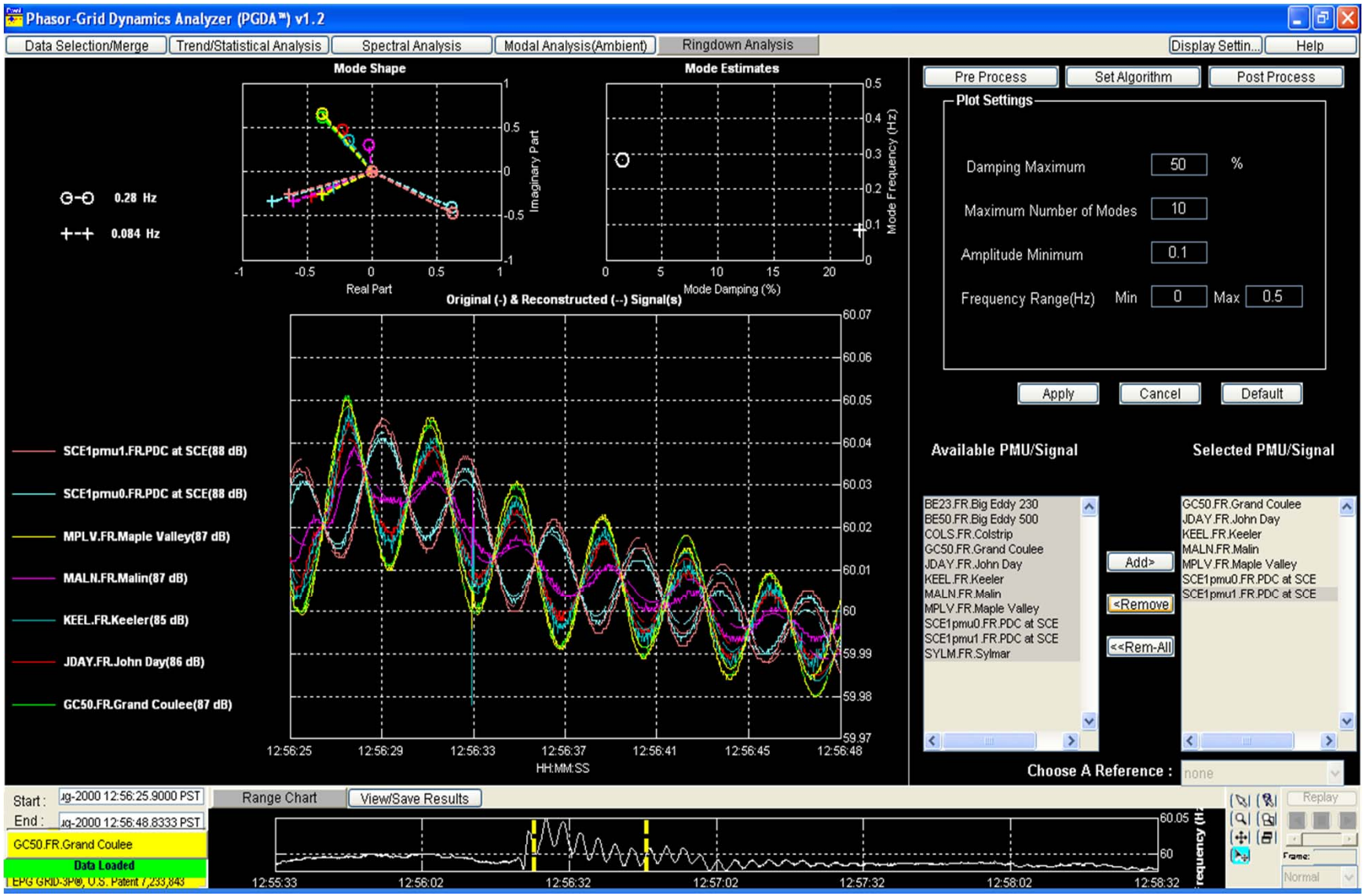
System Oscillations - Spectral Analysis



Analysis of System Oscillations - Ring Down Analysis



Oscillation Analysis and Evaluation of Algorithms Continuing

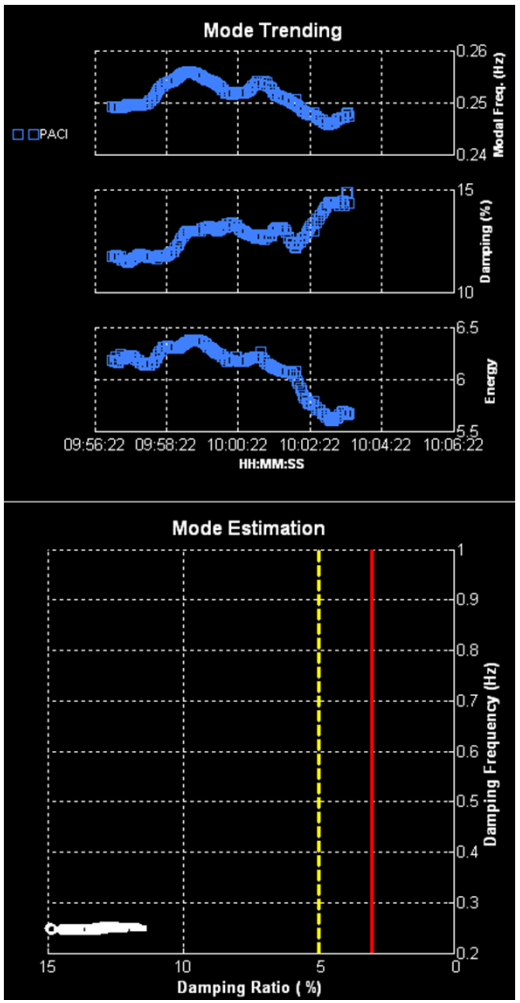
The following activities will continue in an effort to better understand the grid dynamics:

- Analysis of events to identify additional modes
- Addition of identified modes to RTDMS for monitoring
- Validation and refinement of algorithms
- Analysis of observed low and negative damping incidents

CAISO, BPA and WECC Plan to Operationalize North to South Oscillations in the Control Room

Background:

- Generators in Canada and Pacific Northwest oscillate against generators in Southwest
- Presents a risk to major transmission paths carrying power N-S (e.g. COI, P-26, PDCI)
- N-S oscillations can be observed in large power oscillations at the COI



Operationalizing PMU data at the CAISO:

- Development of operating procedures (ongoing)
  - Monitor damping ratio, BC-NW flow, GC-ML angle diff
- Provide operator training on RTDMS and procedures

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Additional Slides

Monitoring Modal Oscillations

- The components of a complex power system are always oscillating with respect to each other
- Under normal conditions, the system oscillations are damped and controlled
- Low damping can occur when the grid is weak (e.g., inadequate voltage support and high energy transfer conditions)
- Oscillations, if not damped, lead to instability and system collapse e.g., 1996 WECC break-up
- Damping – Good damping is when oscillations damp out in less than 20 seconds – approx 12% damping. 5% damping means oscillations damped in 60 seconds
- **RTDMS** has the capability to monitor oscillations and their damping, and can alert if damping falls below the threshold levels
- Advanced analysis can be conducted using tools like **Phasor Grid Dynamics Analyzer (PGDA)**

Power System Oscillation Frequencies

- Sub-harmonic oscillation frequencies range from 0.01 Hz to below 60 Hz
- Sub-harmonic system oscillations can be characterized based on frequencies as follows:

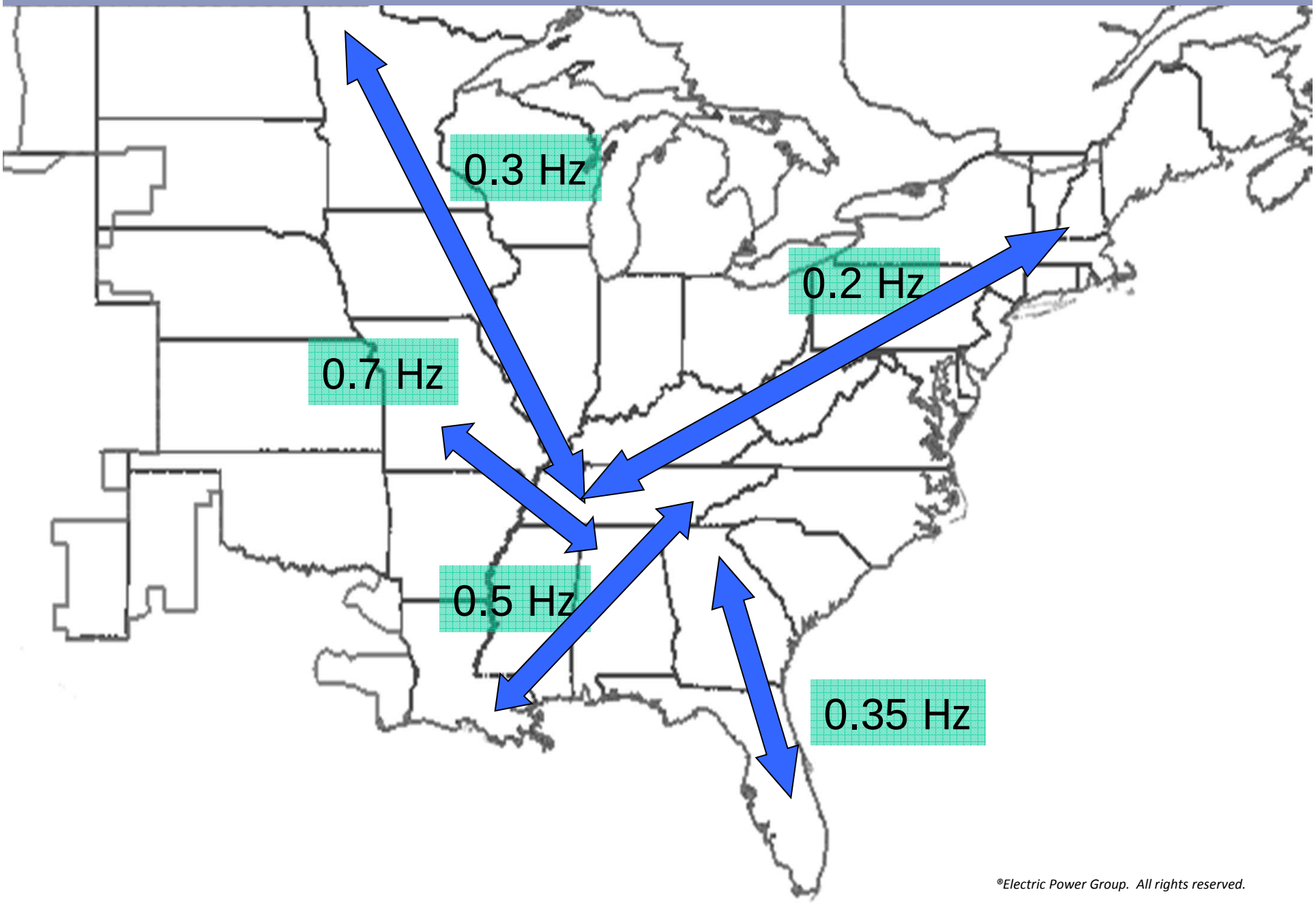
HZ	Sub-harmonic System Oscillations
0.01 to 0.5	Inter-area power system oscillations
0.5 to 0.8	Sub-regional area oscillations
0.8 to 2.0	Local mode power system oscillations
1.5 to 3.0	Generator control system oscillations
3.0 to 10	Fast acting control system oscillations (HVDC, and other FACTS devices)
5.0 to 55.0	Sub-synchronous system oscillations
60	System frequency

Results from Analysis of Past Events – Modes and Damping

Five Modes – Well Damped

EI Frequency Disturbance	MRO System Separation	South Florida Disturbance
–	0.25 Hz @ 16%	0.21 Hz @ 17%
0.32 Hz @ 16%	0.39 Hz @ 7%	0.31 Hz @ 12%
0.52 Hz @ 5%	0.57 Hz @ 6%	0.51 Hz @ 5%
0.71 Hz @ 18%	–	–

Identified EI Modes and Oscillating Areas



Summary of EI Inter-Area Oscillations Characteristics

- EI system has several inter-area oscillation frequencies
- Dominant oscillation modes identified from some past disturbances are:
  - Dorsey (Manitoba) against Center region – 0.3 Hz
  - New York against Center region – 0.2 Hz
  - Florida against Center region – 0.35 Hz
  - SE/SO against Center region – 0.5 Hz
- Analysis of additional system events required to understand EI dynamics

PGDA Analysis

PGDA Can Display Plots Such As:

- Voltage Magnitude plot
- Voltage Phase Angle plot
- Frequency plot
- Df/dt plot
- Power flow plot
- Reactive power flow plot
- Spectral Analysis
  - Auto spectrum plot
  - Coherency plot
  - Cross – Spectrum
- Ring Down Analysis
  - Reconstructed signal comparison
  - Modal frequencies & Damping
  - Mode shapes