Using Synchrophasor Technology to Identify Control System Malfunctions and Monitor Oscillations - Analysis of Select Past WECC System Oscillation Events

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SynchroPhasor Technology for Monitoring Power System Oscillations and Control System Performance

- Control system malfunctions or highly stressed system conditions can result in low damped or growing system oscillations
- These conditions can be monitored and detected by SynchroPhasor Technology in real-time, and later analysis of the data to identify and correct root causes
- The Phasor Grid Dynamics Analyzer (PGDA) was used for detailed off-line analysis of the events using archived data
- In real-time, this can be monitored using Real Time Dynamics Monitoring System (RTDMS®), which is in use at CAISO
- For mode meter analysis, Prof. Trudnowski's code has been incorporated in PGDA and RTDMS (Note – code is being updated)
- Four examples of WECC events that exhibited unusual oscillations caused by control systems of high stress are presented. Operators would have seen these events using real-time tools such as RTDMS. Here PGDA has been used for their analysis. The four events being presented are:
  - October 9, 2003 (caused by Colstrip lines/machines)
  - November 30, 2005 (caused by the governor at Nova Jaffre, Alberta)
  - January 26, 2008 (caused by DC controls)
  - August 4, 2000 (caused by high system stress)

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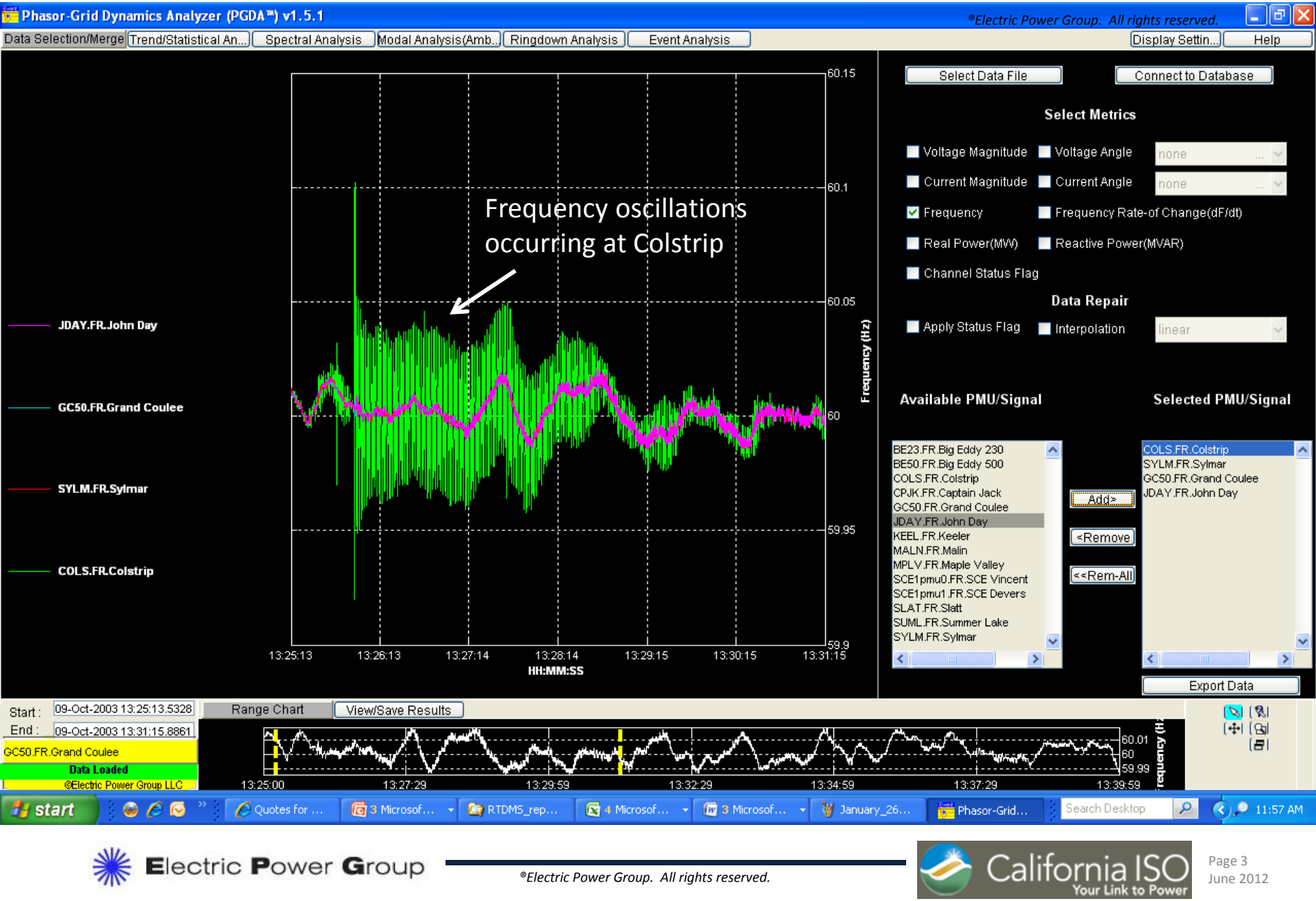
Colstrip Units Oscillations Caused by Generator Unit Controls on October 9, 2003 at 13:25 PDT

Event description:

- Oscillations were triggered by the malfunction of control system at Colstrip Power plant
- Oscillations occurred at 0.6 Hz (local mode)and were observed at Colstrip
- Oscillations (approximately +/- 0.05 Hz) clearly observable in frequency at Colstrip
- Damping during the incident was reduced to less than 2 percent
- Power swings of 50+ MW occurred on each generator
- Power swings observed on California-Oregon border (COI lines)
- Oscillations damped when corrective action taken by power plant operator

Large Sustained Frequency Oscillations at Colstrip



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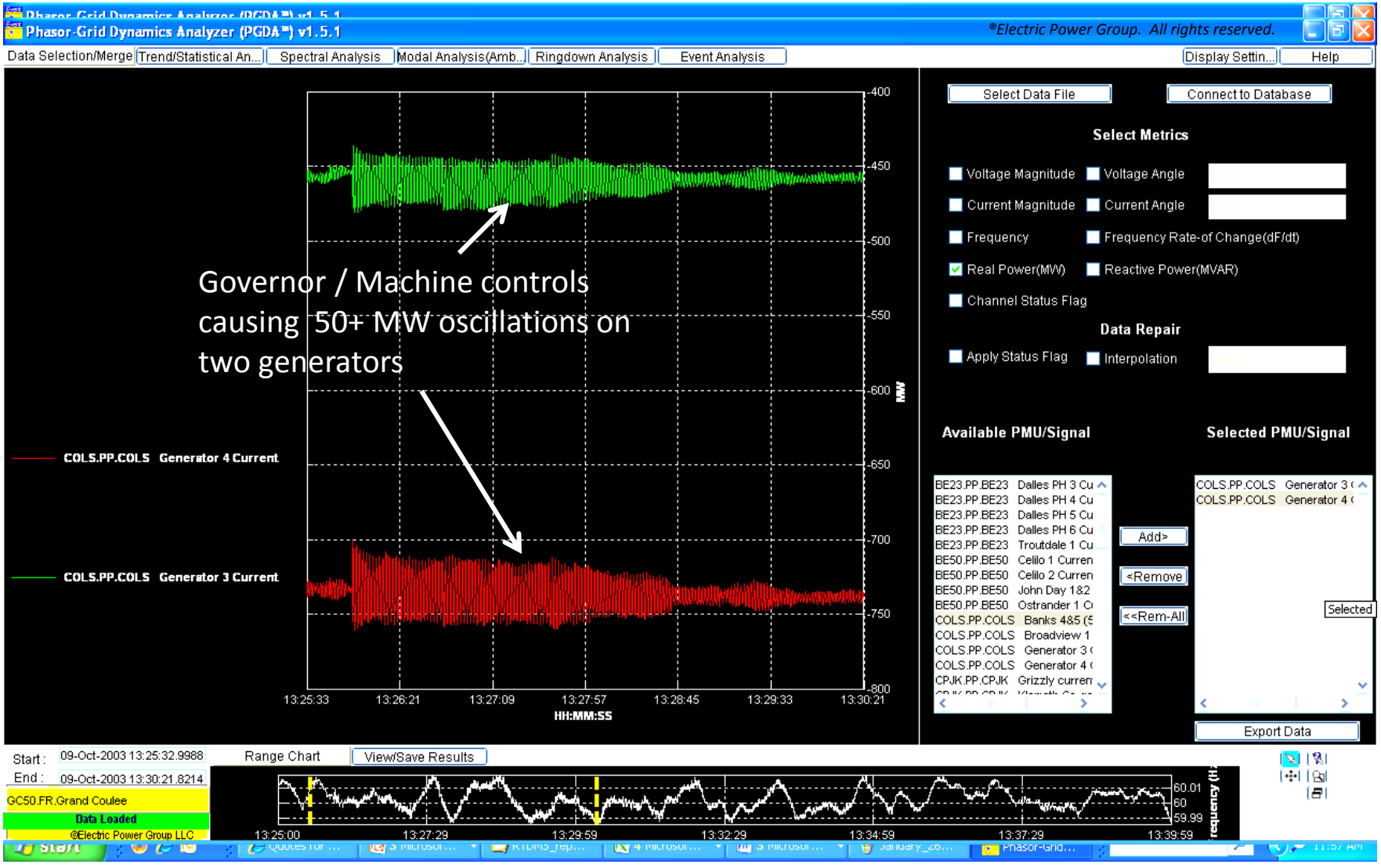
Power Flow Oscillations on Colstrip Generators



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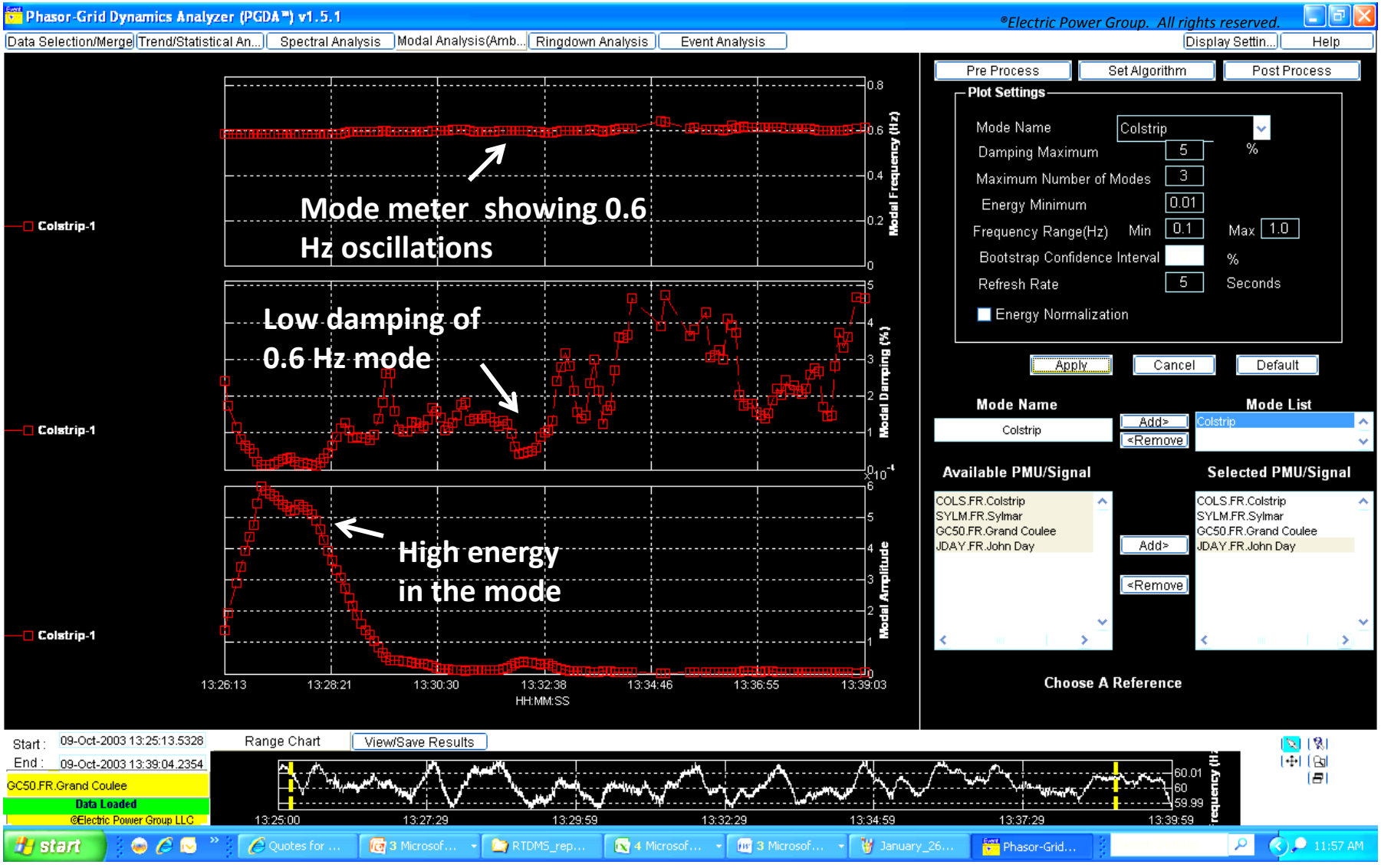
Modal Analysis of Colstrip Oscillations



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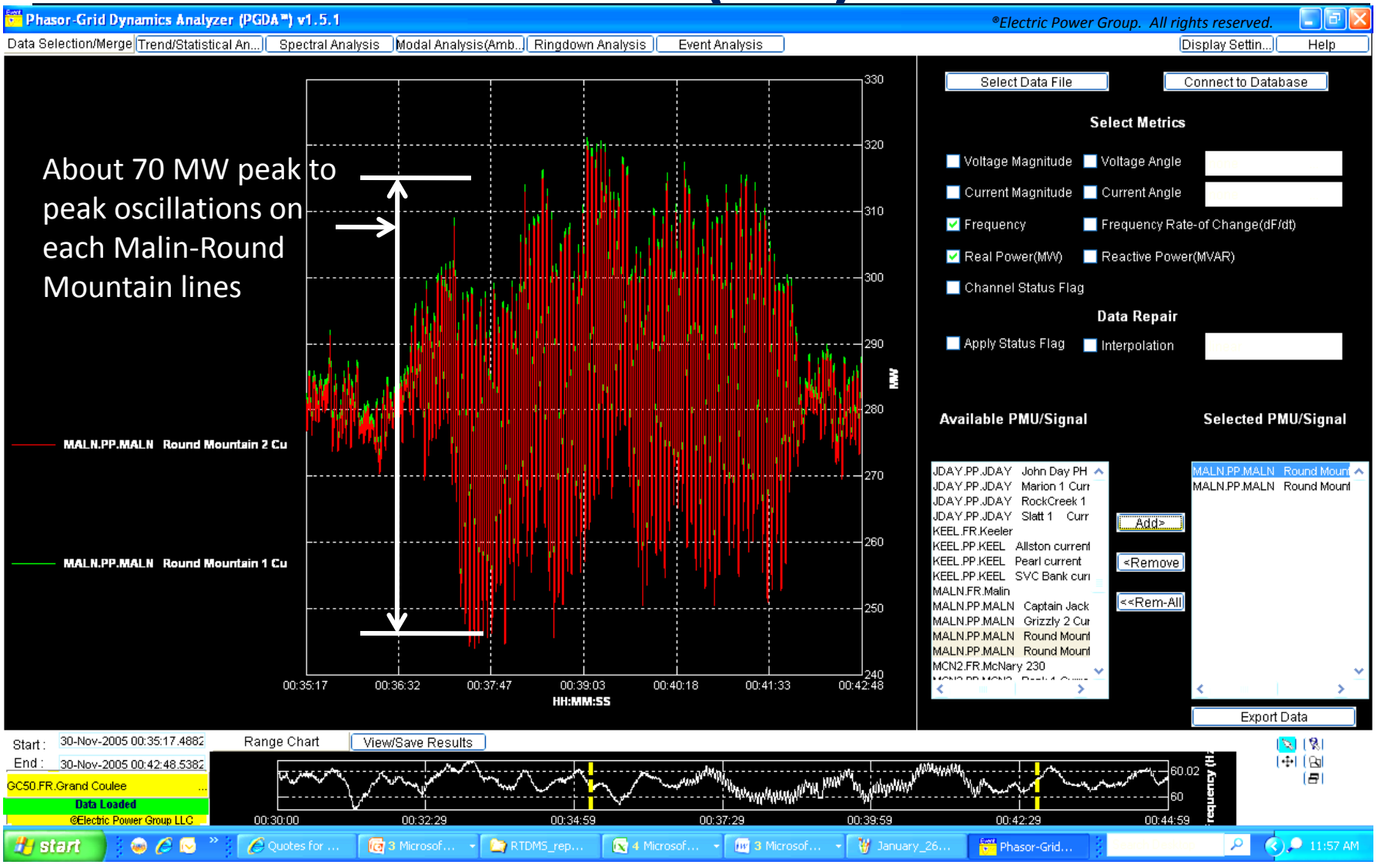
Oscillations Caused by Malfunction of Governor Control on a 20 MW Generator in Alberta on November 29, 2005

Event description:

- Oscillations believed to be caused by malfunction of the governor on a 20 MW generator (Nova Jaffre) in Alberta, Canada
- Oscillations caused by the generating unit at 0.28 Hz North-South mode
- Large power oscillations (approximately 70 MW on each Malin-Round Mountain line) observed on California-Oregon lines
- Damping reduced to 1-2 percent
- Oscillations were detected and finally stopped when the units were taken off-line
- This is a classical example of tail wagging the dog
  - excitation at a resonant mode

Power Flow Oscillations on Malin-Round Mountain (COI) Lines



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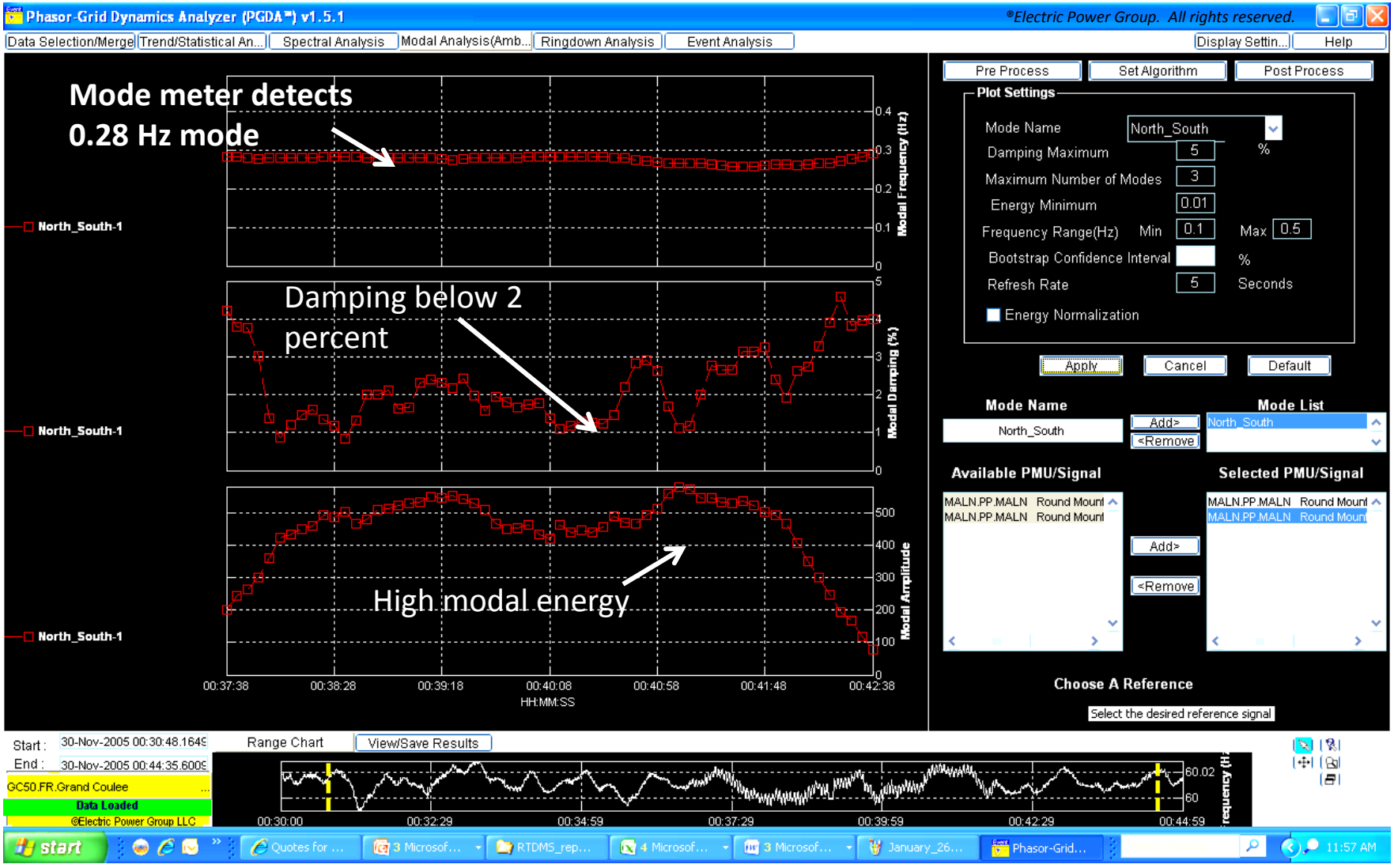
Modal Analysis (Mode Meter) of Power Flows on Malin-Round Mountain Lines



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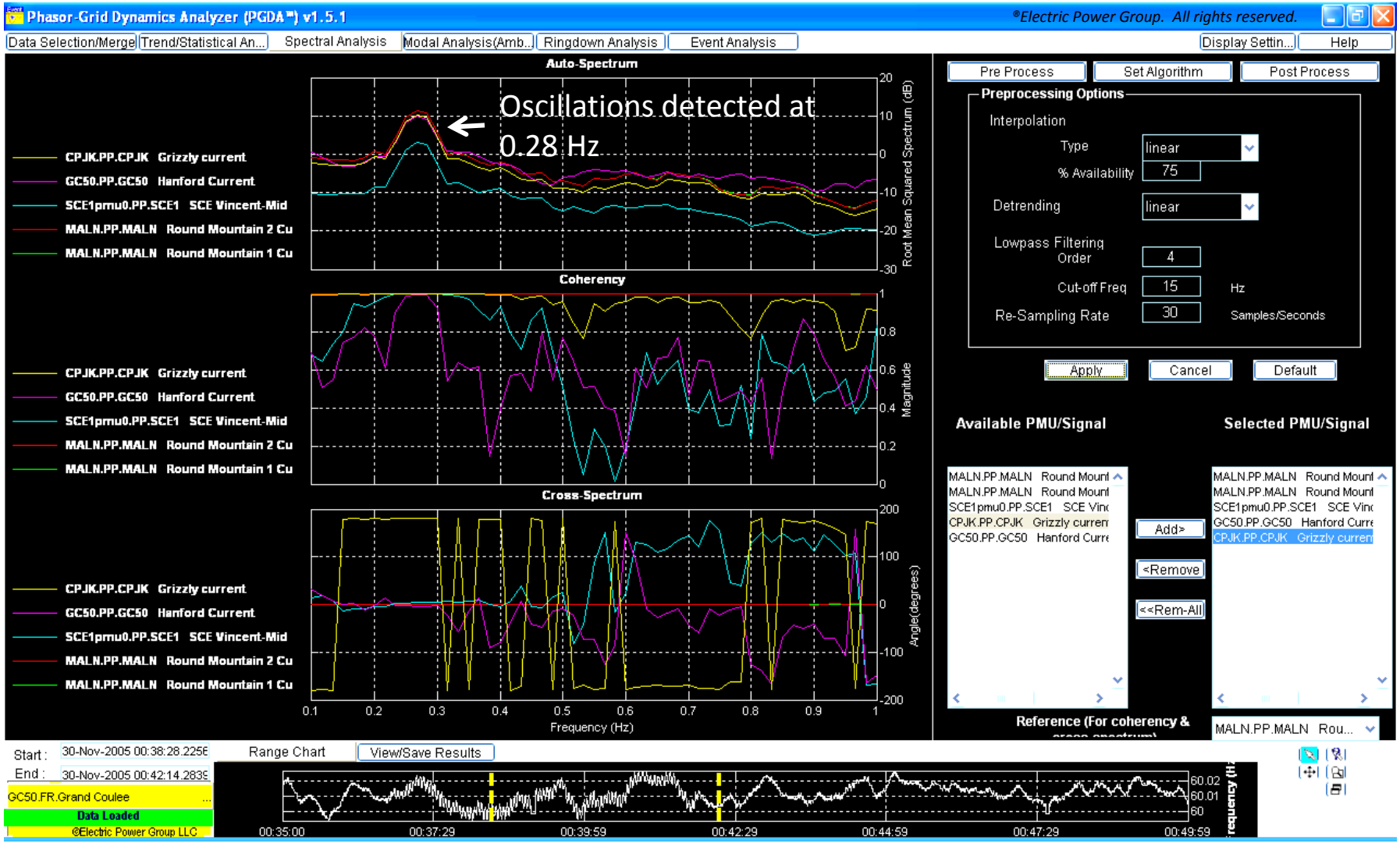
Spectral Analysis of November 29, 2005 WECC Event



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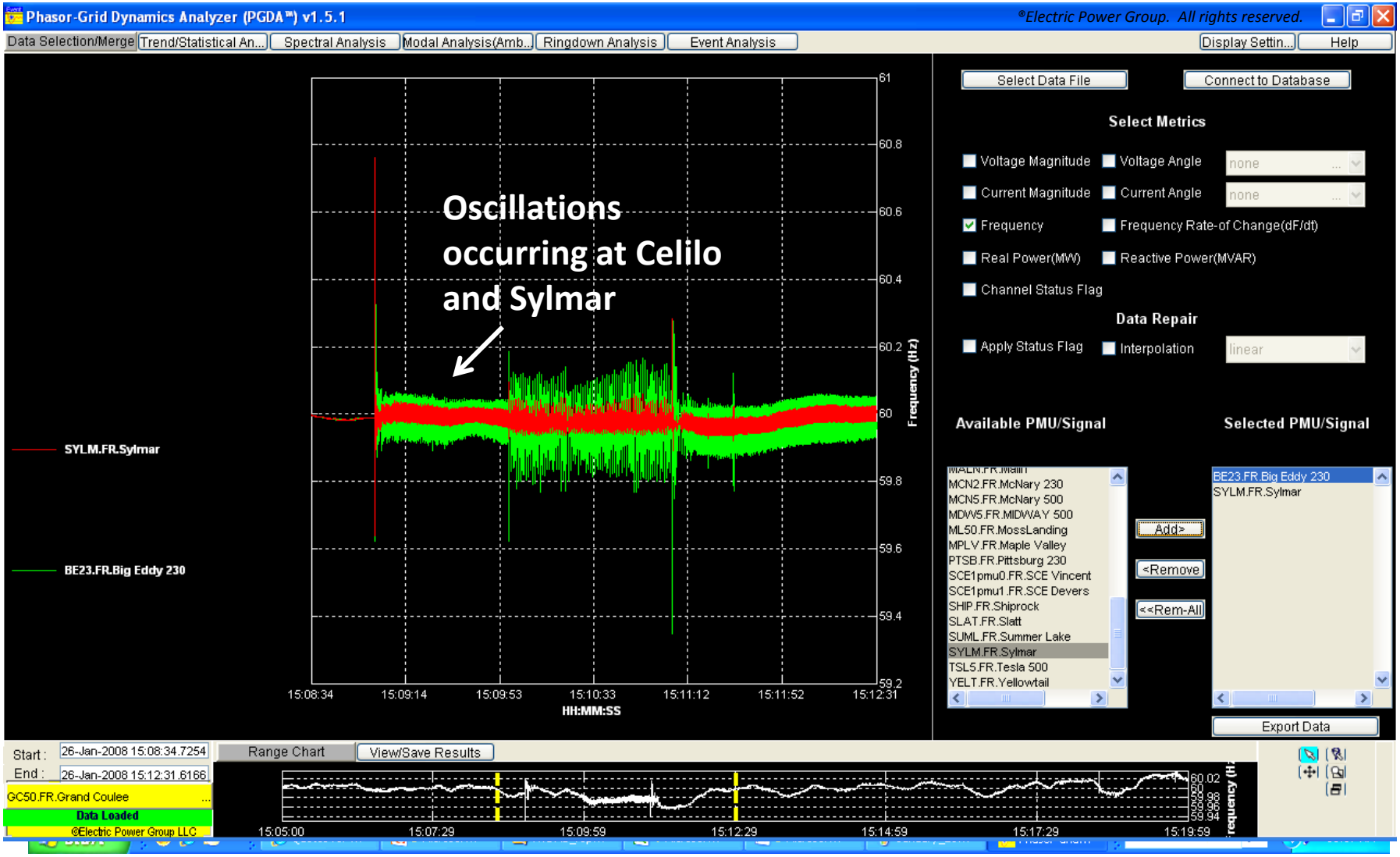
Oscillations Caused by PDCI Controls on January 26, 2008

Event description:

- Oscillations caused by the DC system control at Celilo substation when the three 525/230 kV transformers at Big Eddy – near Celilo tripped
- High frequency oscillations occurred at HVDC 230 kV busses at Celilo and Sylmar – the two ends of the PDCI line
- Oscillation frequency varied between 3.6 to 4.4 Hz.
- Damping dropped to 1-2 percent
- Oscillations were confirmed via analog frequency chart and stopped at 15.05 PM when the DC line was removed from service

Large Sustained Frequency Oscillations Occurring at Celilo and Sylmar



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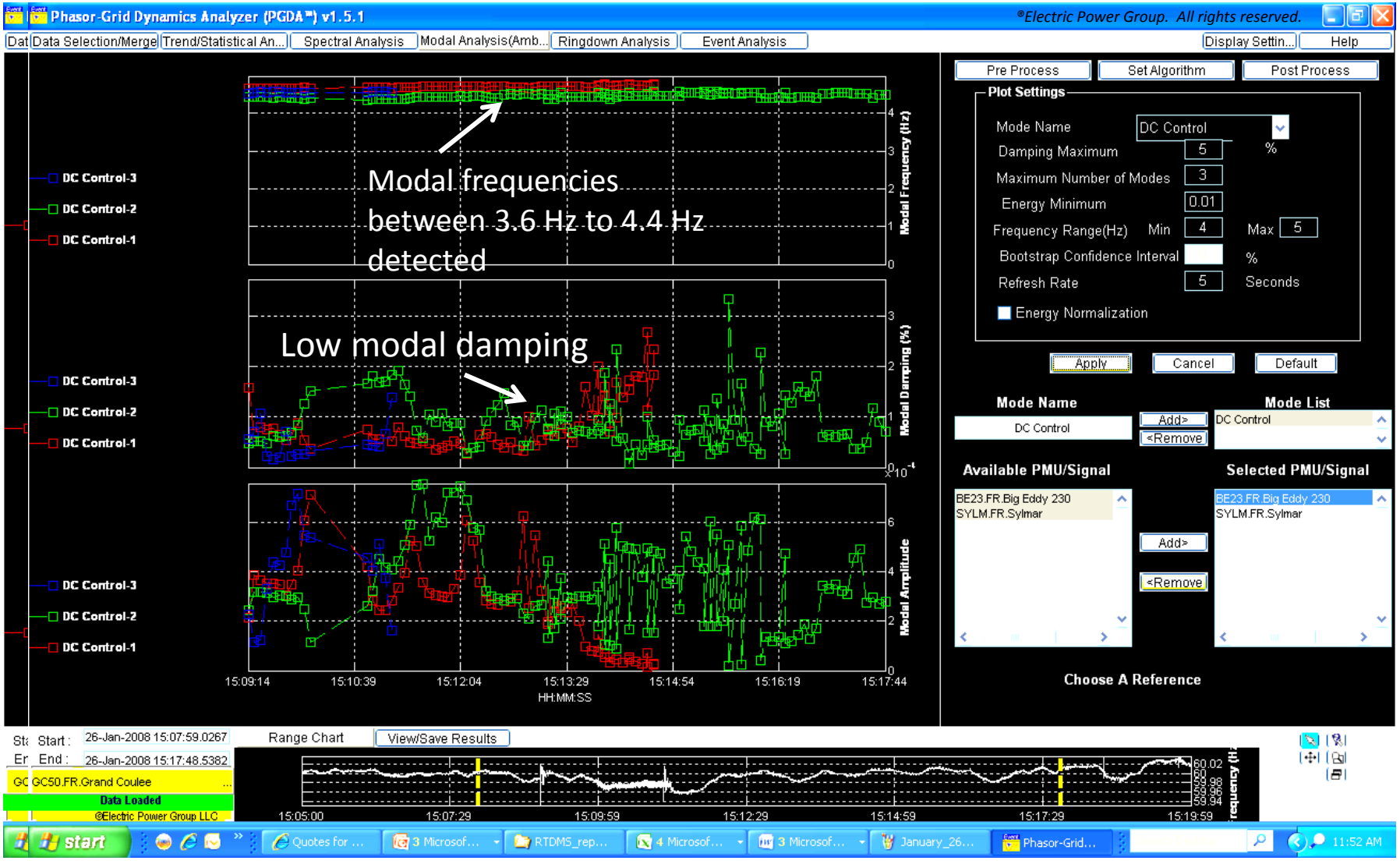
Large Sustained Frequency Oscillations Occurring in the System



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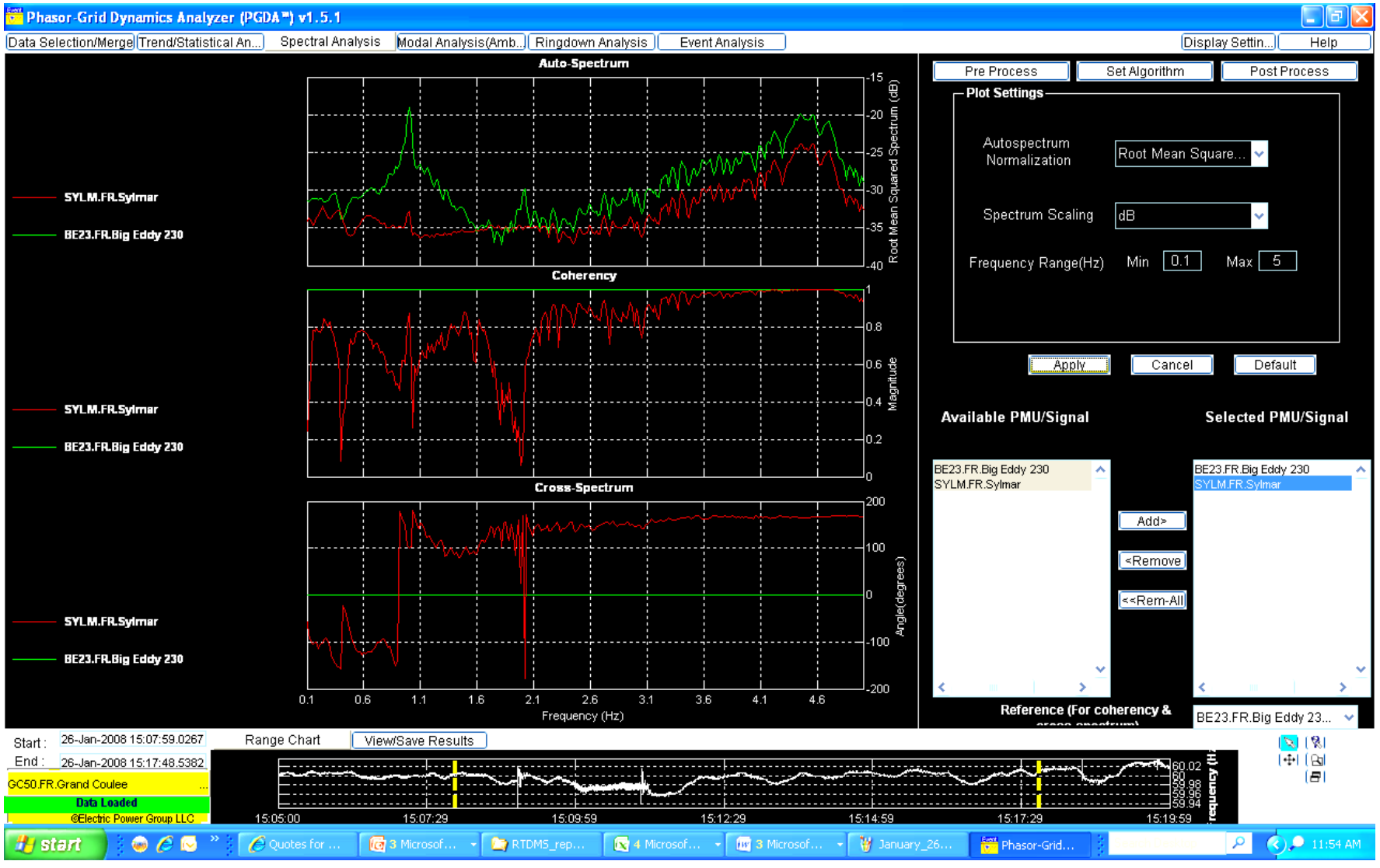
Spectral Analysis of January 26, 2008 Event



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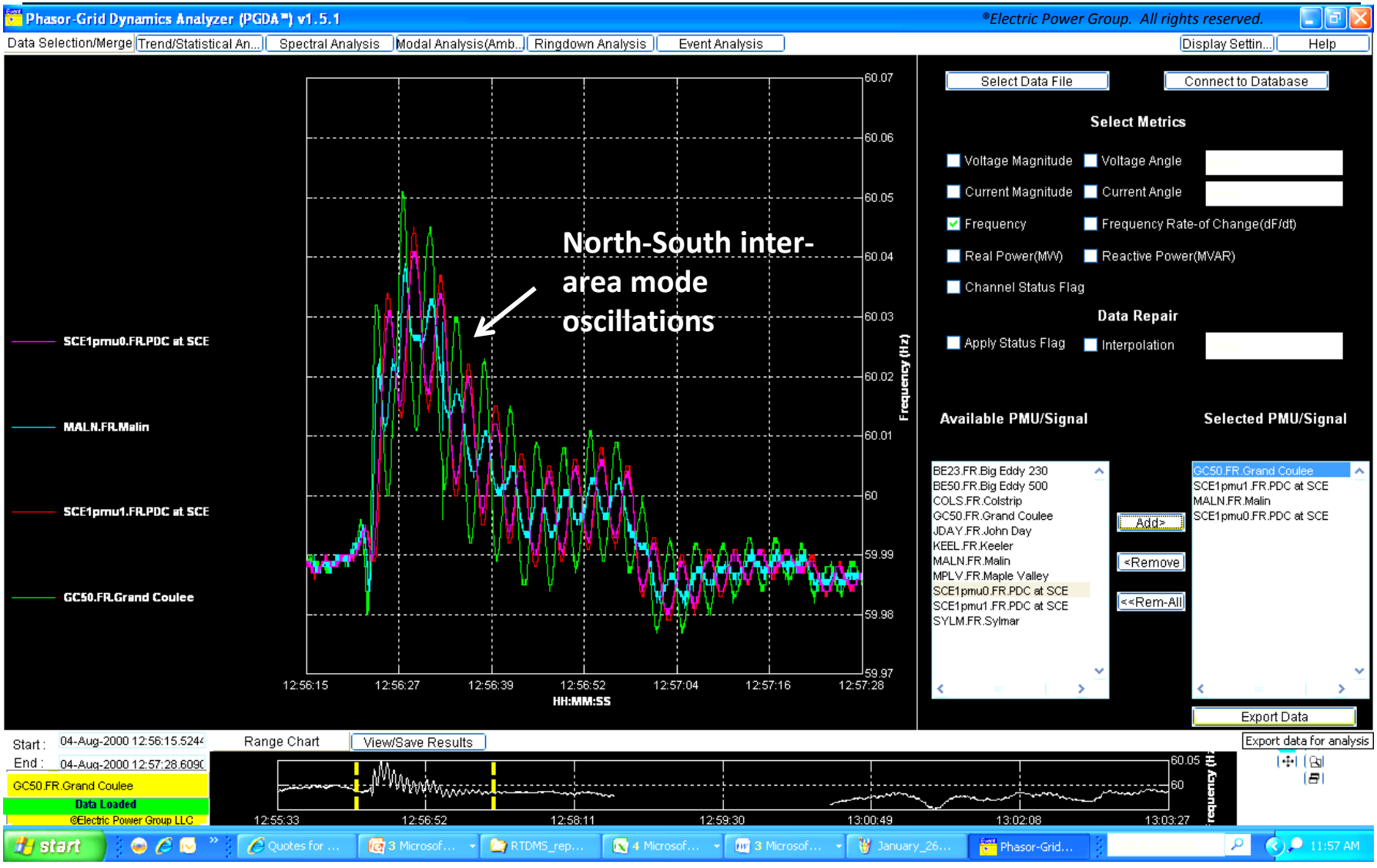
WECC Event on August 4, 2000 at 12:55 PDT

Event description:

- Event was triggered by the loss of BC Hydro-Alberta 500 kV line
- The line was exporting approximately 450 MW to Alberta
- System was operating at high stress level 90+ angle between Grand Coulee(BPA) and Devers(SCE)
- Loss of this line resulted in additional stress on the North-South system, which was already operating at a high stress level
- Increased flow resulted in North-South system oscillations at approx. 0.28 Hz (North-South Inter-area mode) at low damping
- Oscillations continued for over 60 seconds (less than 3 percent damping)
- Peak to peak oscillations of approximately 300 MW observed on the California-Oregon border
- Oscillations damped when a shunt capacitor closed and provided voltage support in Pearl/Keeler station

Large Sustained Frequency Oscillations Occurring in the WECC System on August 4, 2000



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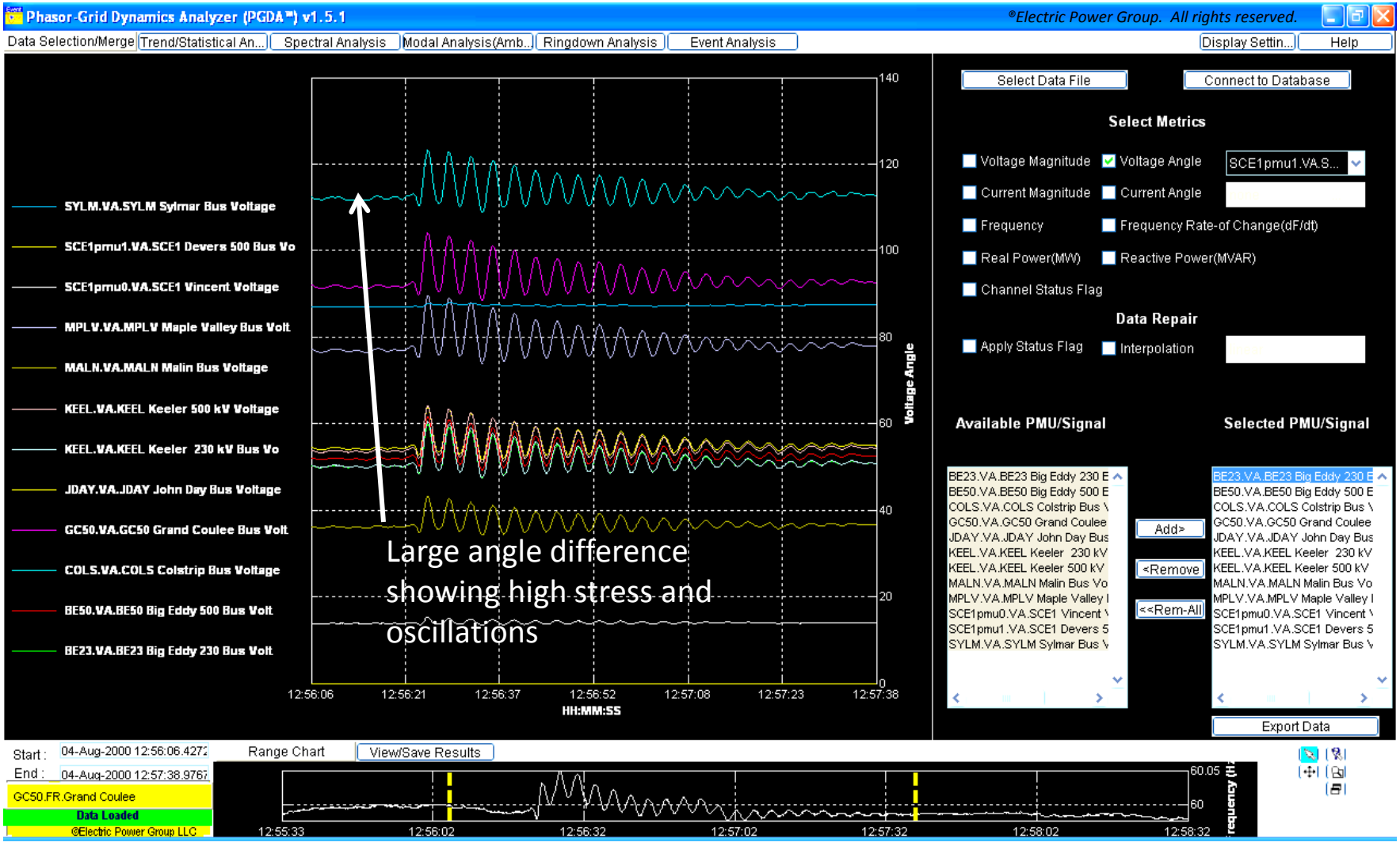
Voltage Angle Plot for August 4, 2000 WECC Event



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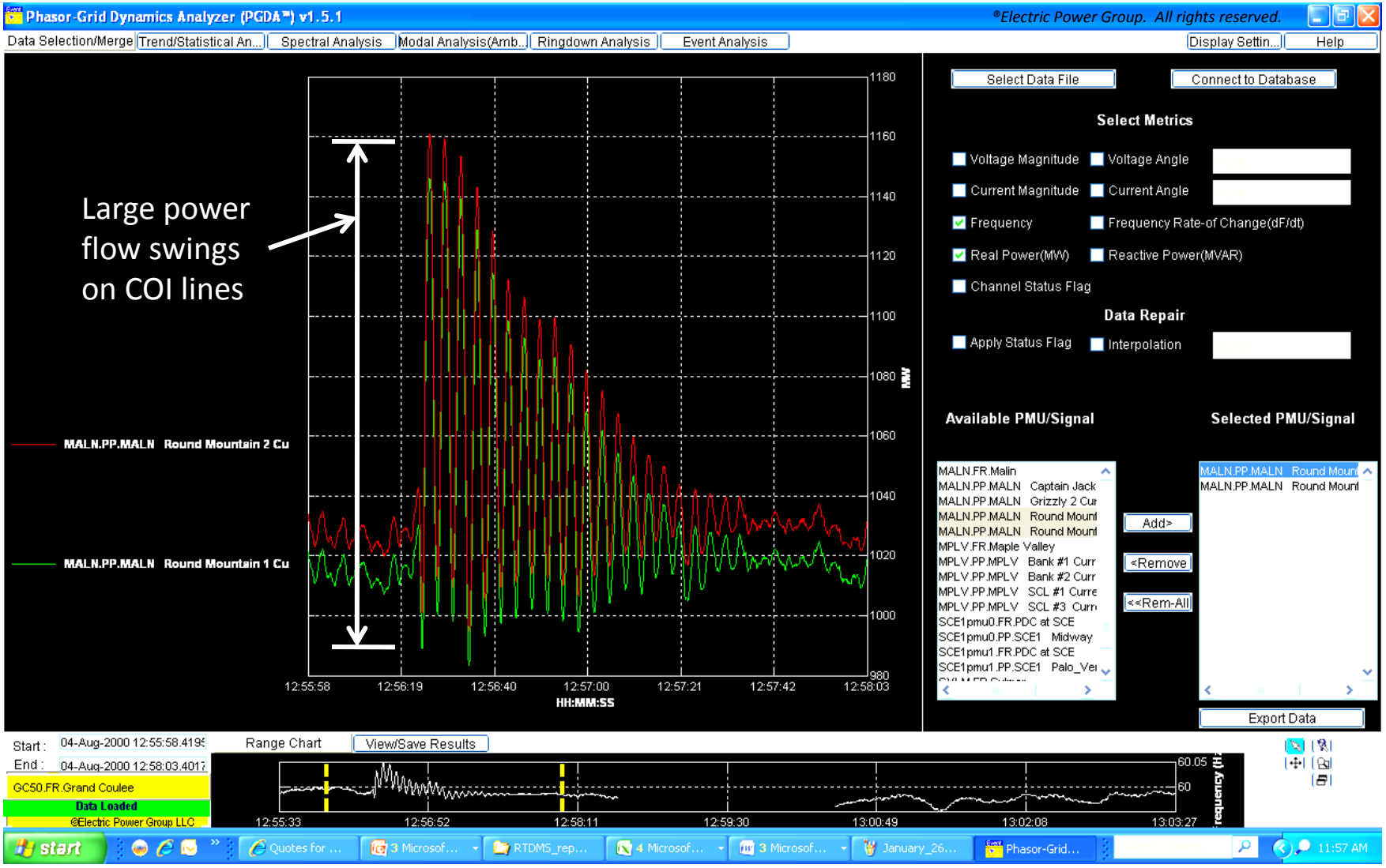
Power Flow Oscillations on California – Oregon Border



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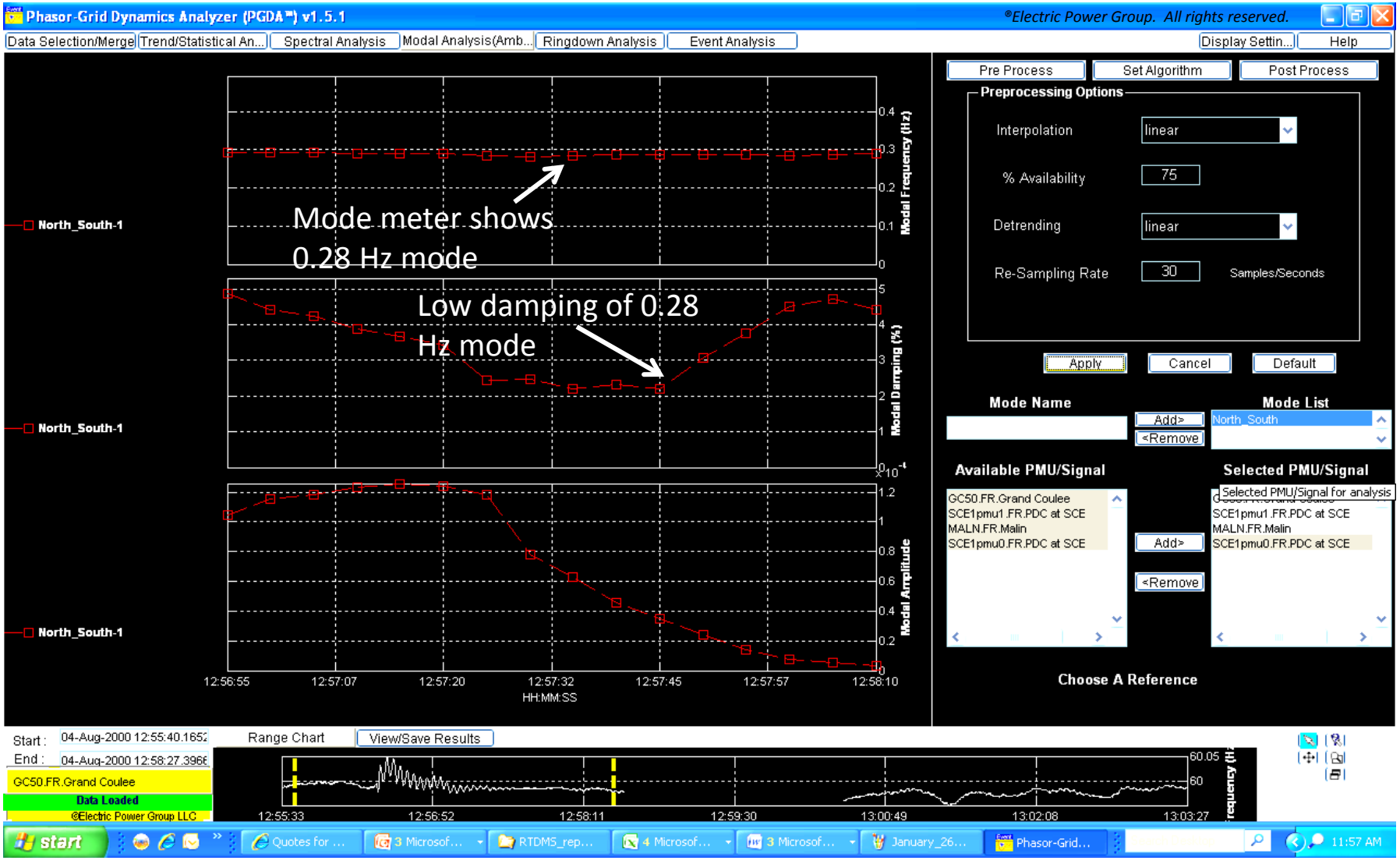
Modal Analysis of August 4, 2000 Event



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Conclusions / Summary

- **Control system malfunctions and high system stress conditions can cause low damped or un-damped system oscillations**
- **It is important to monitor the critical modes of oscillations and their damping to ensure the system is operating reliably**
- **The following low damped oscillations caused by controls or high system stresses were observed and have been presented:**
  - Colstrip (0.6 to 0.7 Hz) - October 9, 2003
  - Alberta generator (0.28-0.29 HZ) – November 29, 2005
  - DC Control (3.6 Hz to 4.5 Hz) – January 26, 2008
  - North – South (0.28 Hz) August 4, 2000
- **The abnormal system oscillations were detected using SynchroPhasor system data at appropriate locations**
- **Real-time monitoring with RTDMS and off-line analysis with PGDA can be used to identify root causes of oscillations and events and help operators take corrective action**

Thank You.

Any questions ?

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