WECC Dynamic Probing Tests: Purpose and Results

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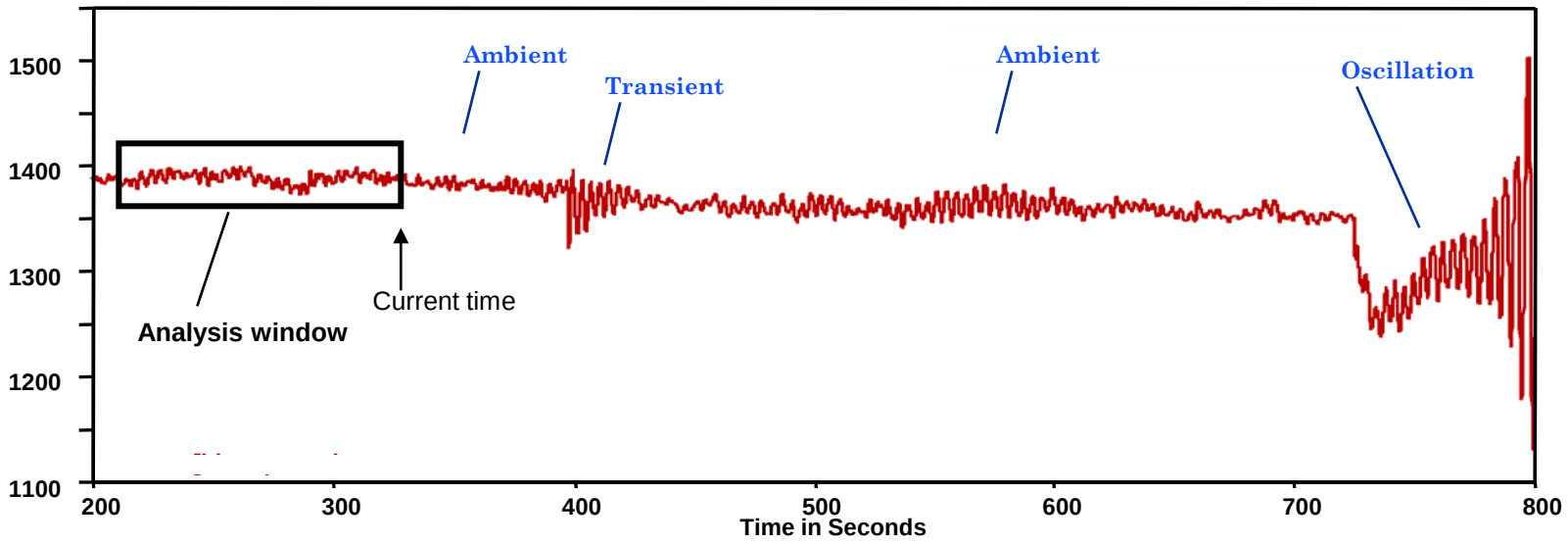
NASPI Meeting
Charlotte, NC
October 16-17, 2008

Funding: DOE-OE, BPA

BPA Probing Tests

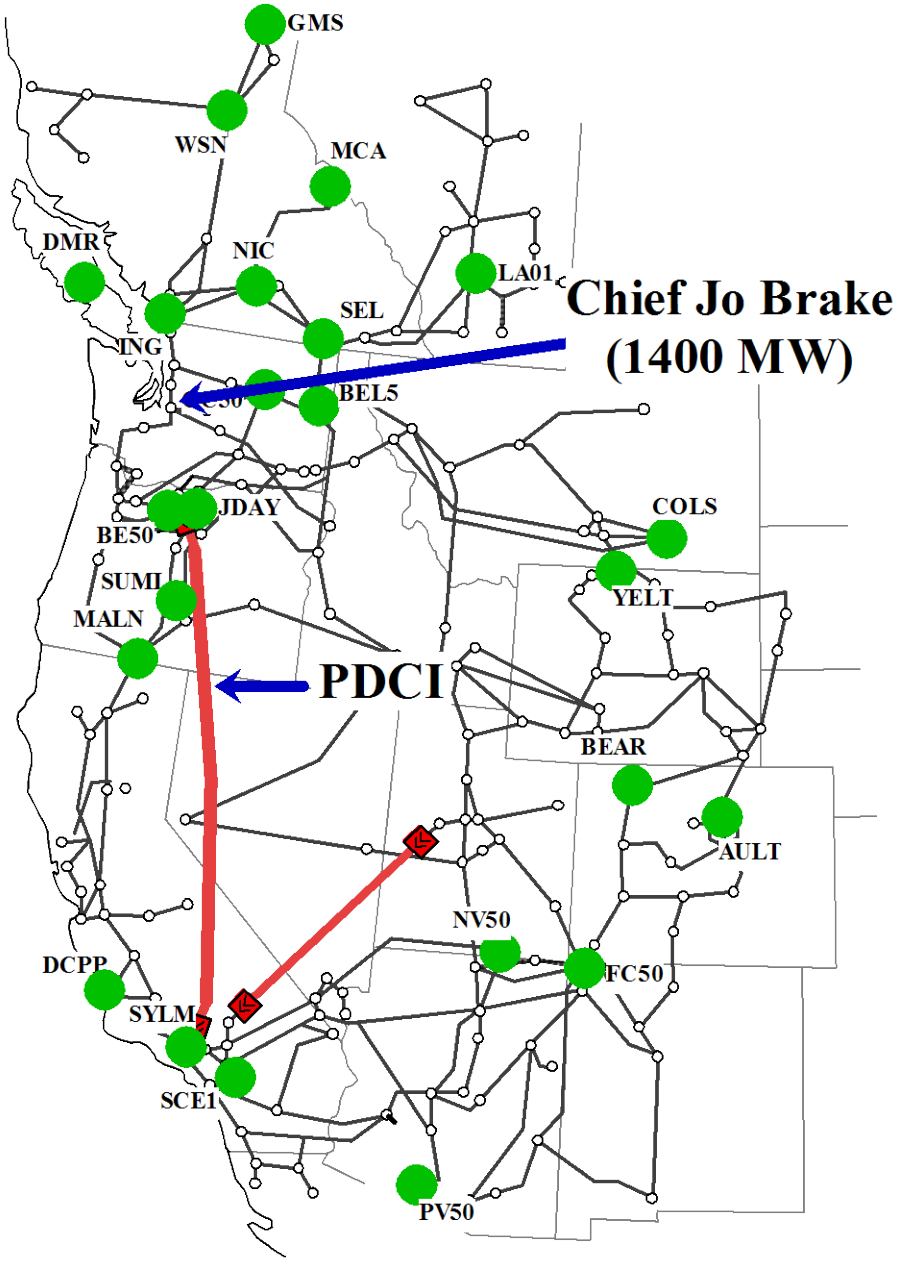
- BPA routinely conducts dynamic field tests
  - September 2005, June 2006, August 2006, August 2008
- Test objectives
  - Obtain historical dynamic benchmarks
  - Realism of WECC simulation models
  - **Benchmark mode-meter performance**

Mode Meters



- All mode meters require historical data to estimate mode
- Stochasitc problem – No mode meter provides a perfect estimate
- Many algorithms have been proposed – None are perfect
- **Math can only do so much**
- **Ambient based algorithms likely not accurate enough for real-time applications**
- **What is their performance?**
- **Can we do better by probing (exciting) this system?**

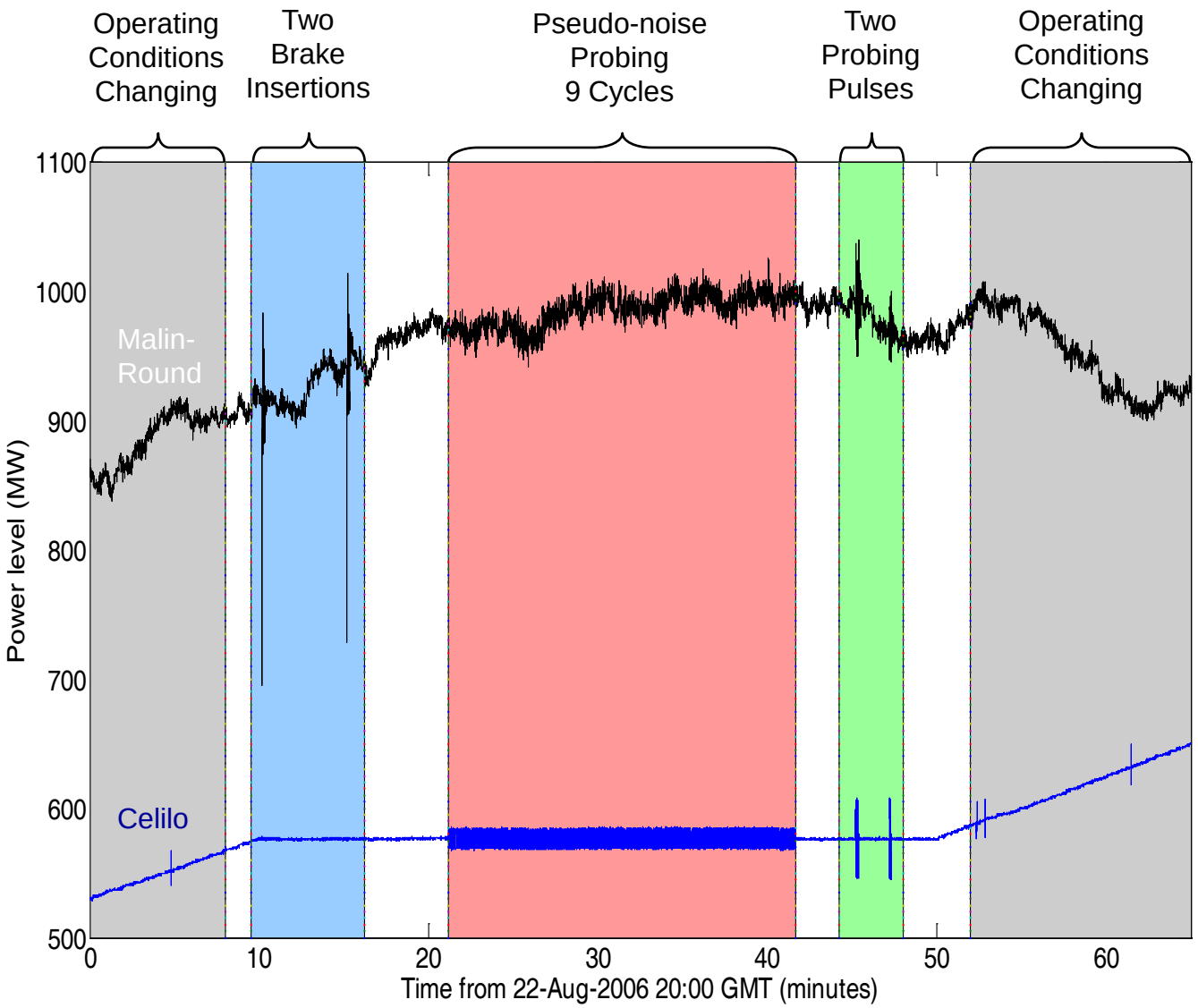
WECC System and PMUs



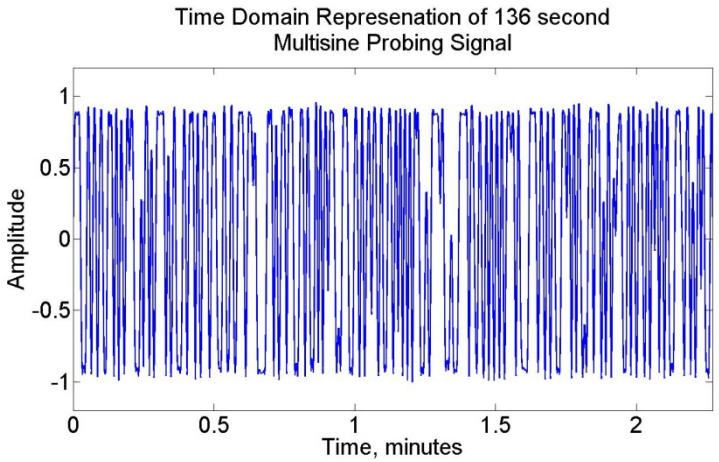
Typical Test

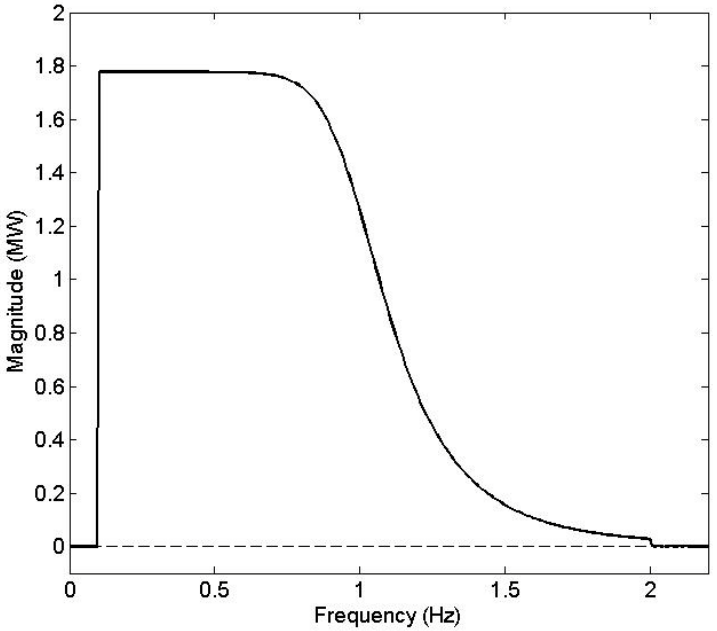
- Each test consist of several hours
- Each hour consists of a combination of
  - Chief Joe dynamic brake insertions
    - 1400 MW, 0.5 sec.
  - Several minutes of low-level pseudo-random Pacific DC Intertie (PDCI) modulation
    - ±10 to ±20 MW
    - 20 to 40 minutes
  - Short bursts of mid-level PDCI probing
    - ±125 MW
    - Sine wave, Square wave, and Chirp signals

Typical Hour

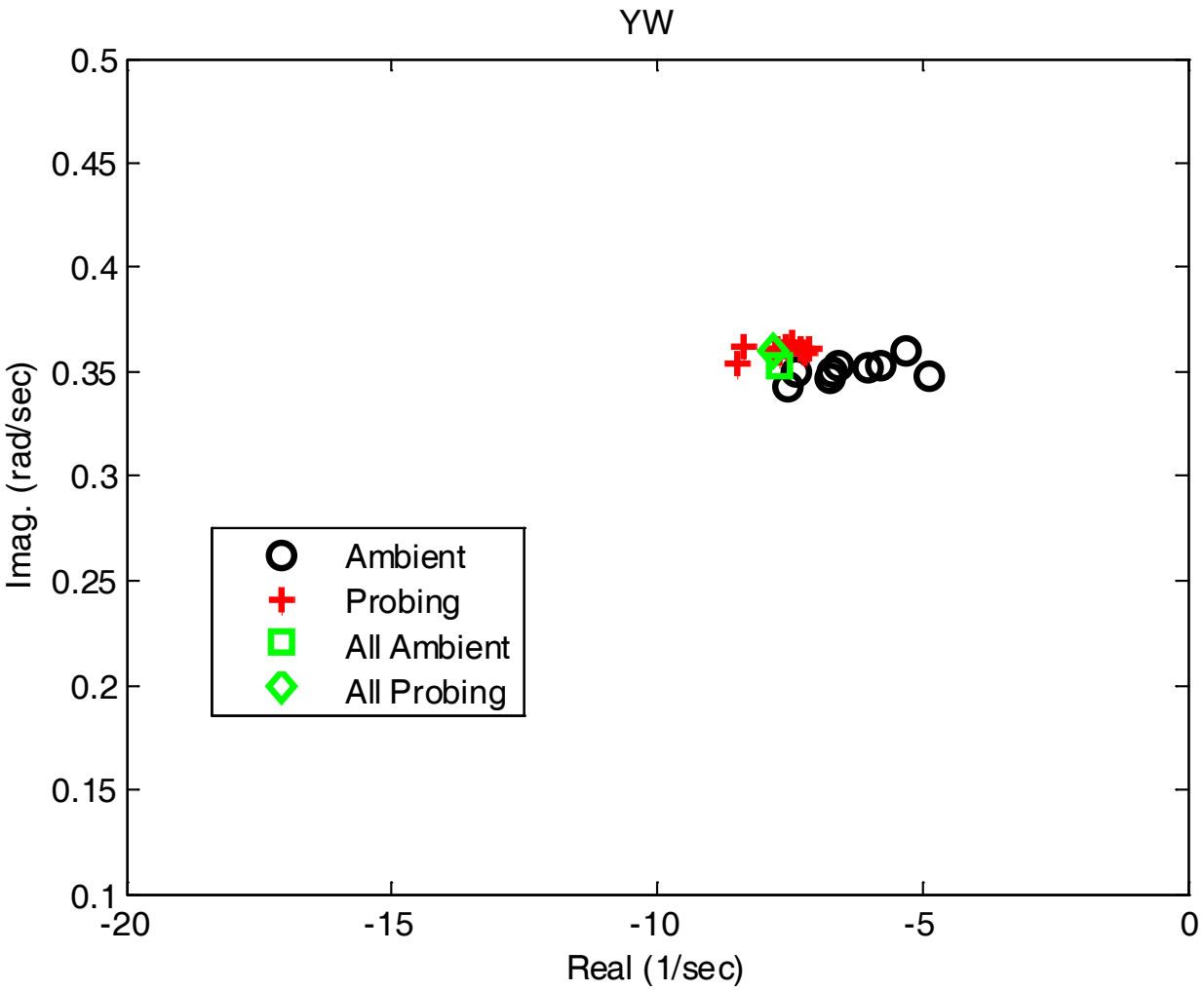


Low-level Multi-Sine Probing Signal

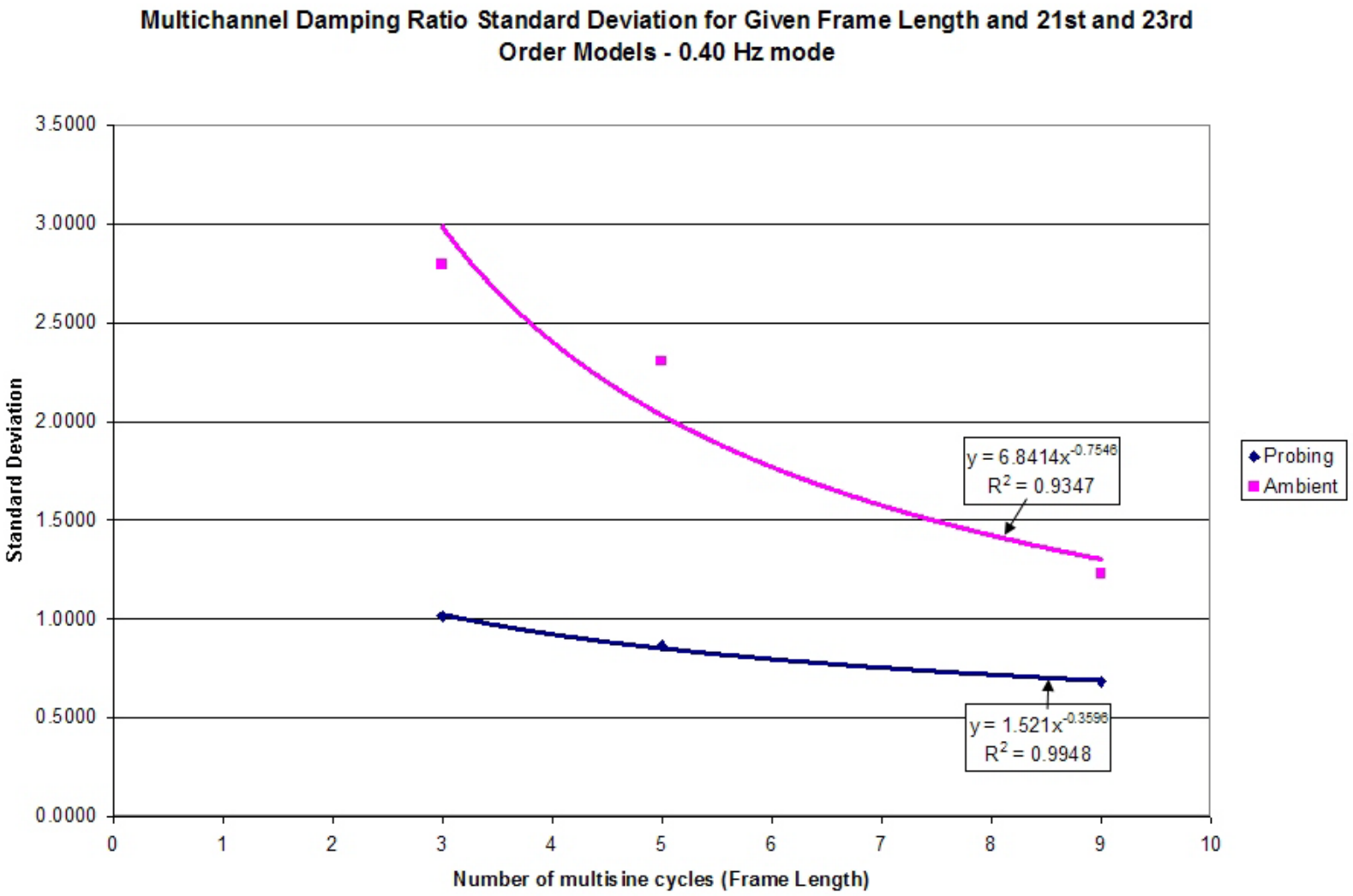




Probing vs. Ambient (8/22/2006 test)



Series C - Noise Probing vs. Ambient



Conclusions and Future Plans

- Probing provides detailed view
  - Inter-area modal frequencies and damping
  - Inter-area modal shape
- Mode estimates often not accurate enough during ambient conditions
- Mode estimates are much more accurate during probing
- PDCI low-level probing
  - AC system response below noticeable levels
  - Operational PDCI low-level probing being proposed for real-time dynamic stability security assessment

Reports and Publications

J. F. Hauer, W. A. Mittelstadt, K. E. Martin, J. W. Burns, H. Lee, J. W. Pierre, and D. J. Trudnowski, in association with the WECC Disturbance Monitoring Working Group, "Use of the WECC WAMS in Wide Area Probing Tests for Validation of System Performance & Modeling," *IEEE Transactions on Power Systems*, (to be published).

J. Pierre, N. Zhou, F. Tuffner, J. Hauer, D. Trudnowski, W. Mittelstadt, "Probing Signal Design for Power System Identification," *IEEE Transactions on Power Systems*, (in preparation).

D. Trudnowski and J. Pierre, "Signal-Processing Methods for Estimating Small-Signal Dynamic Properties from Measured Responses," Chap. 1 of Analysis of nonlinear and non-stationary inter-area oscillations: A Time-frequency Perspective, Springer Science, (to be published).

J. Hauer, D. Trudnowski, and J. DeSteese, "A perspective on WAMS analysis tools for tracking of oscillatory dynamics," *IEEE Power Engineering Society General Meeting*, paper no. PESGM2007-001391, June 2007.

D. Trudnowski, J. Pierre, N. Zhou, J. Hauer, and M. Parashar, "Performance of three mode-meter block-processing algorithms for automated dynamic stability assessment," *IEEE Transactions on Power Systems*, vol. 23, no. 2, pp. 680-690, May 2008.

N. Zhou, D. Trudnowski, J. Pierre, W. Mittelstadt, "Electromechanical mode on-line estimation using regularized robust RLS methods," *IEEE Transactions on Power Systems*, (to be published).

J. F. Hauer, W. A. Mittelstadt, K. E. Martin, J. W. Burns, and Harry Lee in association with the Disturbance Monitoring Work Group of the Western Electricity Coordinating Council, "Integrated dynamic information for the western power system: WAMS analysis in 2005," Chapter 14 in the Power System Stability and Control volume of The Electric Power Engineering Handbook, edition 2, L. L. Grigsby ed., CRC Press, Boca Raton, FL, 2007.

N. Zhou, J. W. Pierre, and J. F. Hauer, "Initial results in power system identification from injected probing signals using a subspace method," *IEEE Transactions on Power Systems*, vol. 21, no. 3, pp. 1296-1302, Aug. 2006.

F.K. Tuffner, "Computationally efficient weighted updating of statistical parameter estimates for time varying signals with application to power system identification," Ph.D. dissertation, Department of Electrical and Computer Engineering, University of Wyoming, Laramie, WY, USA, 2008.

D. Trudnowski, "Estimating electromechanical mode shape from synchrophasor measurements," *IEEE Transactions on Power Systems*, vol. 23, no. 3, pp. 1188-1195, Aug. 2008.

L. Dosiek, D. Trudnowski, J. Pierre, "New algorithms for mode shape estimation using measured data," *IEEE Power & Energy Society General Meeting*, paper no. PESGM2008-001014, July 2008.

D. Trudnowski, "Performance of Mode-Meter Algorithms applied to BPA August 2006 Probing Tests," Report no. ENGR 2007-1, Electrical Engineering Dept., Montana Tech of the University of Montana, Butte, MT 59701 USA, March 2007.

J. F. Hauer, W. A. Mittelstadt, J. W. Burns, H. Lee, D. Trudnowski, "Staged System Tests for Validation of WECC System Performance and Modeling: Summary Report for September 2005–August 2006, PNNL Working report, April 18, 2007.