DOE Transmission Reliability Program Peer Review

WAMS Outreach Project: WECC Model Validation

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Project: WECC Model Validation

Objectives:

1. **Assist reliability councils, system planners and transmission operators with in the development and use of advanced tools for the validation and refinement of planning models.**

2. **Facilitate the development and use of planning procedures that identify and accommodate modeling uncertainties which have not or cannot be eliminated.**

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Project: WECC Model Validation

Deliverables: (established prior to August 14 Blackout)

1. **Direct assistance to WECC technical groups in developing methods, technology, and practices to compare and calibrate planning models against observed power system behavior.**

2. **Direct assistance to WECC technical groups resolving model validation issues that are major impediments to reliability management in the western interconnection.**

3. **A white paper, based upon experience in the western interconnection, that describes generic issues and solutions in model validation for reliability management in large power systems.**

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Project: WECC Model Validation

Progress in FY03: (Examples only)

1. **DSI Toolbox interfaces for advanced post-processing of data from General Electric and PTI stability programs.**
2. **Hybrid simulation tool for playback of measured data into planning model simulations [1] . This tool is being incorporated into the General Electric PSLF/PSDS commercial dynamic simulation package.**
3. **New PSLF codes for load modeling.**
4. **Use of all above tools in WECC effort to assess and adjust planning models for generation, load, and overall system performance.**
5. **Liaison with WECC measurements community to install and operate addition monitors at key WECC facilities (esp. generation & load).**

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Related Materials on Enhanced Modeling in the WECC

[1] **Interim Report on the Model Validation Tests of June 7, 2000 -- Part 1: Oscillatory Dynamics**, principal investigator J. F. Hauer. WSCC Performance Validation Task Force (PVTF) of the Modeling and Validation Work Group, October 26, 2000 . **Available from PNNL, or at web address http://www.transmission.bpa.gov/orgs/opi/Wide_Area/index.shtm.**

[2] **Effects of Governor Modeling Upon Oscillatory Dynamics in Simulation of the 750 Mw Grand Coulee Generation Trip on June 7, 2000**, J. F. Hauer and Les Pereira. Report of the WSCC Modeling & Validation Work Group, August 1, 2002 . **Available from PNNL, or as an appendix within [1].**

[3] **New Thermal Turbine Governor Modeling for the WECC,** principal investigator Les Pereira. Report by the WECC Modeling and Validation Work Group, October 11, 2002. **Available at web address http://www.wecc.biz/committees/PCC/TSS/MVWG/thermalgovernor.html**

[4] **"A new thermal governor modeling approach in the WECC," L. Pereira, J. Undrill, D. Kosterev, D. Davies, and S. Patterson, IEEE Trans. Power Systems, vol. 18, no. 2 , pp. 819-829, May 2003.**

[5] **"Large-Scale Hybrid Dynamic Simulation Employing Field Measurements," Zhenyu Huang, R. T. Guttromson, and J. F. Hauer. Accepted for the IEEE PES General Meeting, Denver, CO, June 6-12, 2004.**

[6] **(Other materials available at http://www.wecc.biz/committees/PCC/)**

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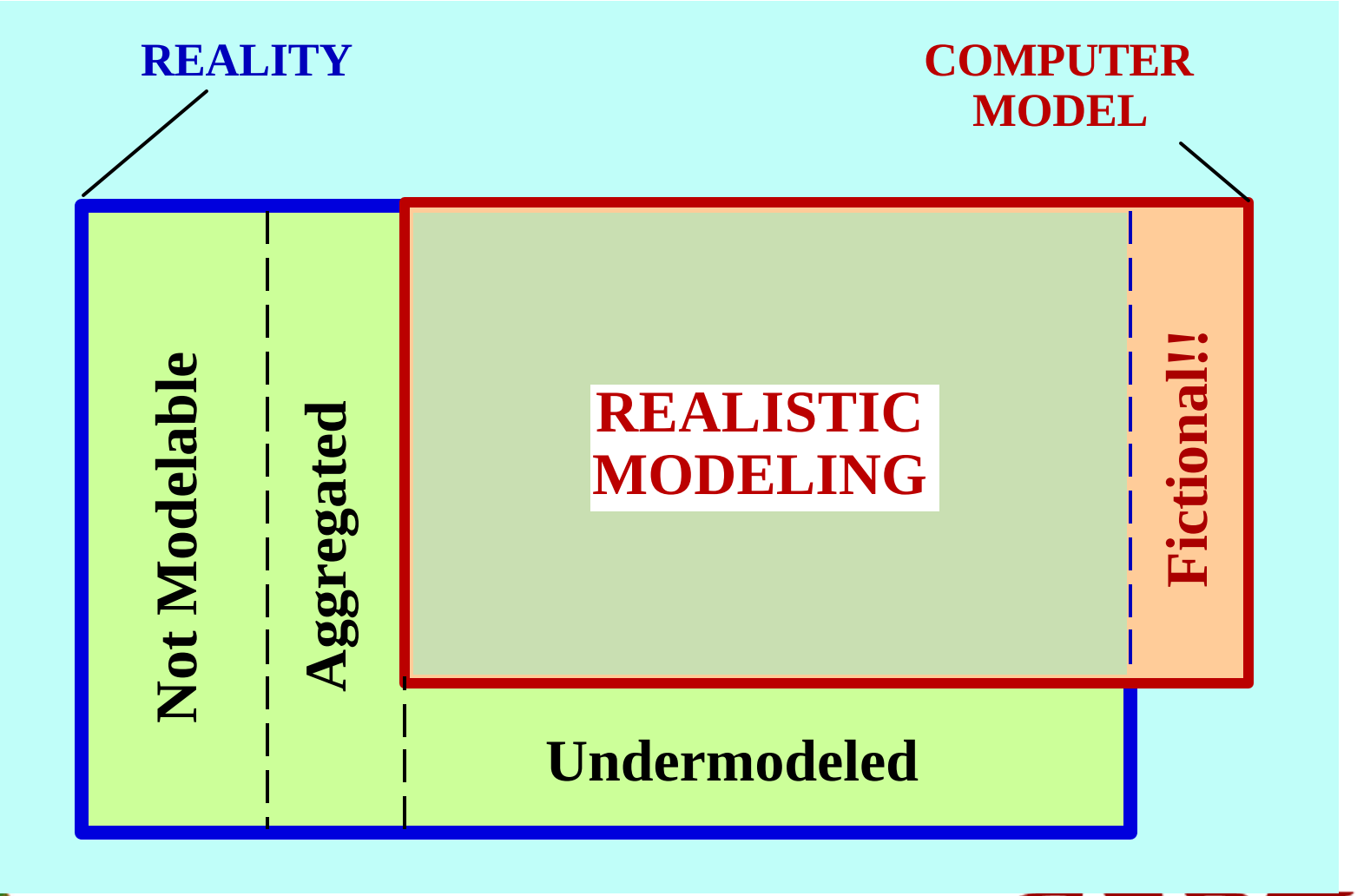
Model Validity Elements



Validation of System Performance & Modeling

Measurement process:

Determine actual system performance from tests or disturbances. *This is an ongoing effort.*

Calibration process:

Compare model against system. May require a wide range of time/frequency tools plus expertise in the mathematics of dynamic systems.

Adjust model to improve comparison. Presently an art that requires expert knowledge of planning practices. (Some automation may be feasible.)

Uncertainty Modeling:

Over time, determine & characterize errors in predictive modeling. *This too is an ongoing effort.*

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Model Validation: Caveat #1

Behavior we cannot model we probably don't understand!

BUT

We cannot validate models for behavior we do not measure.

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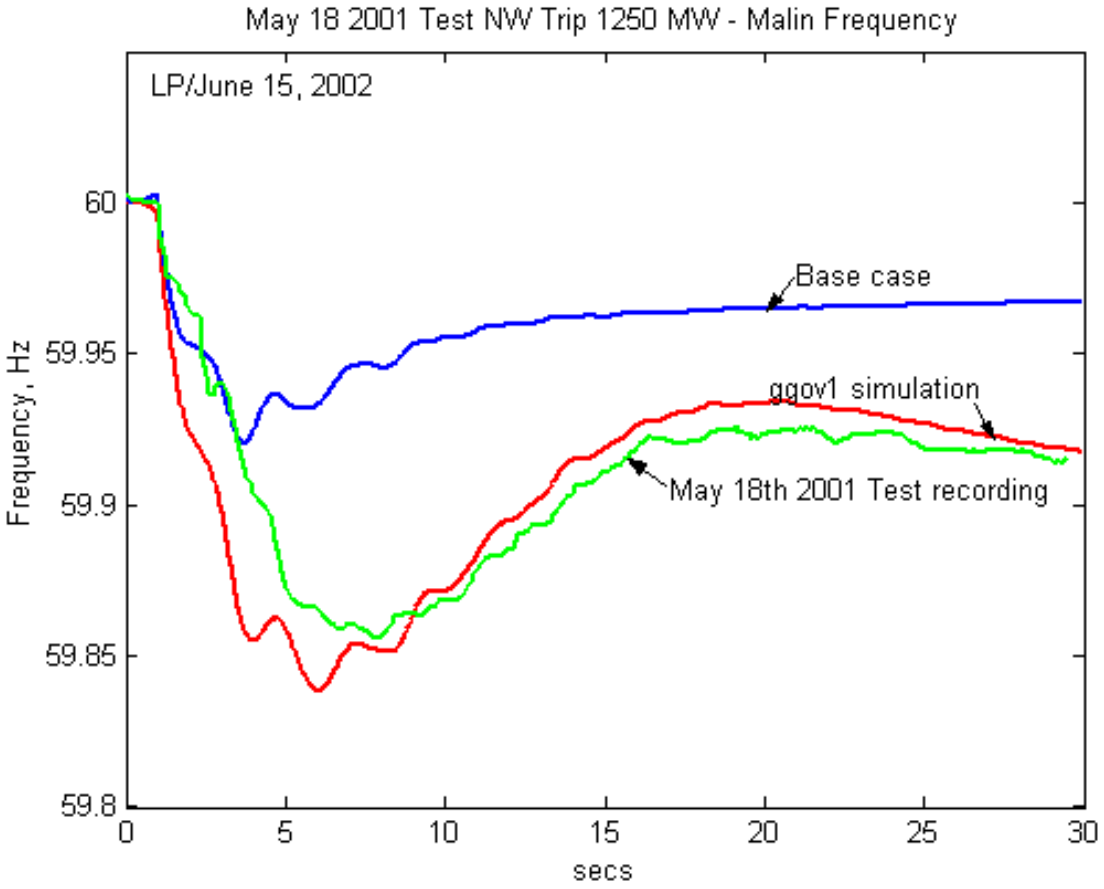
Model Validation: Caveat #2

Model refinement, based upon direct analysis of power system behavior, should be an ongoing process within power system planning.

Model Comparison:
Staged 1250 MW NorthWest generatation trip on May 18, 2001



[1] **"A new thermal governor modeling approach in the WECC**," L. Pereira, J. Undrill, D. Kosterev, D. Davies, and S. Patterson, IEEE Trans. Power Systems, vol. 18, no. 2 , pp. 819-829, May 2003. [extensive use of the WECC WAMS]

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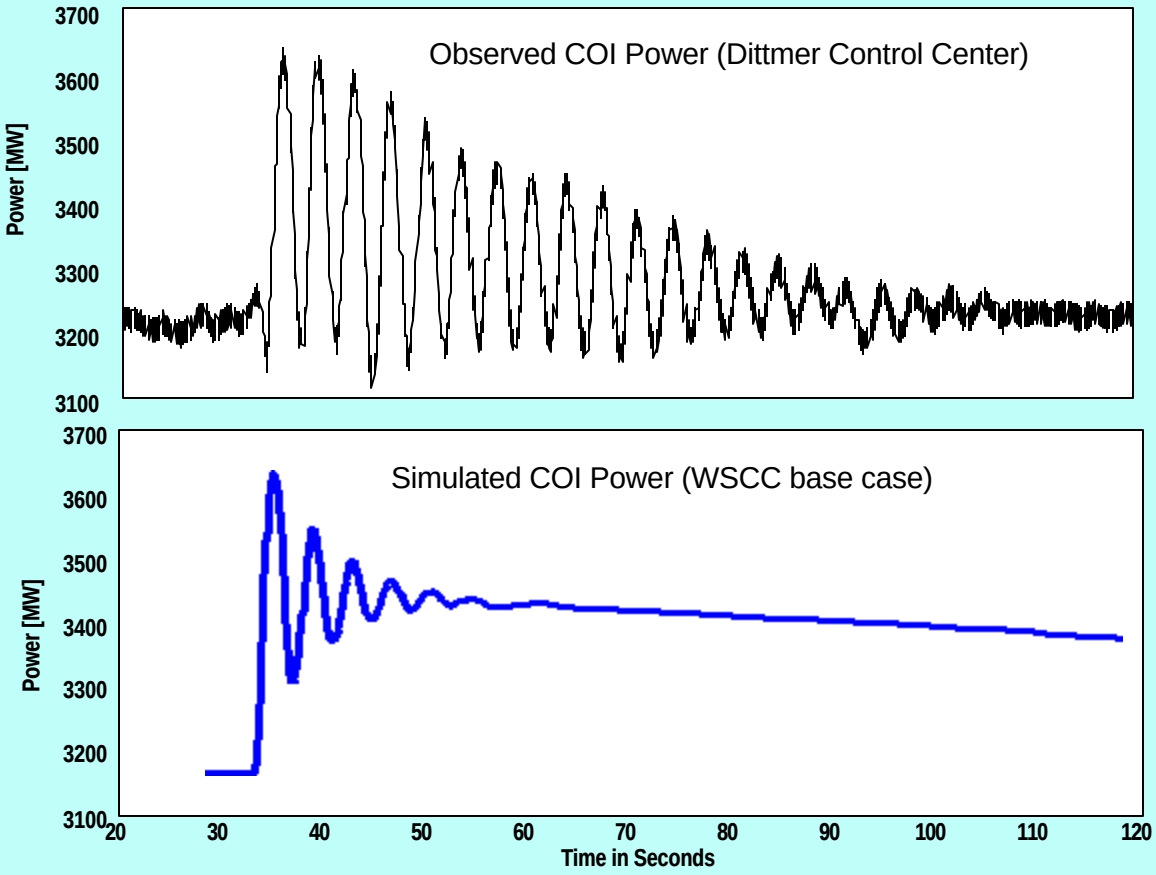
Modeling Problems in the WSCC: Oscillations of August 4, 2000 (controller interaction?)



Graphics by D. N. Kosterev, for WSCC OCSG

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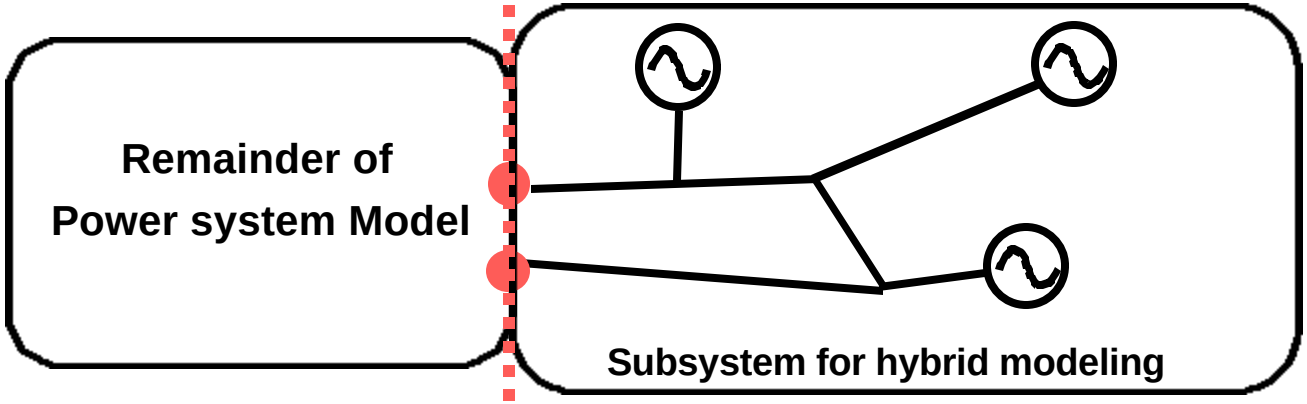
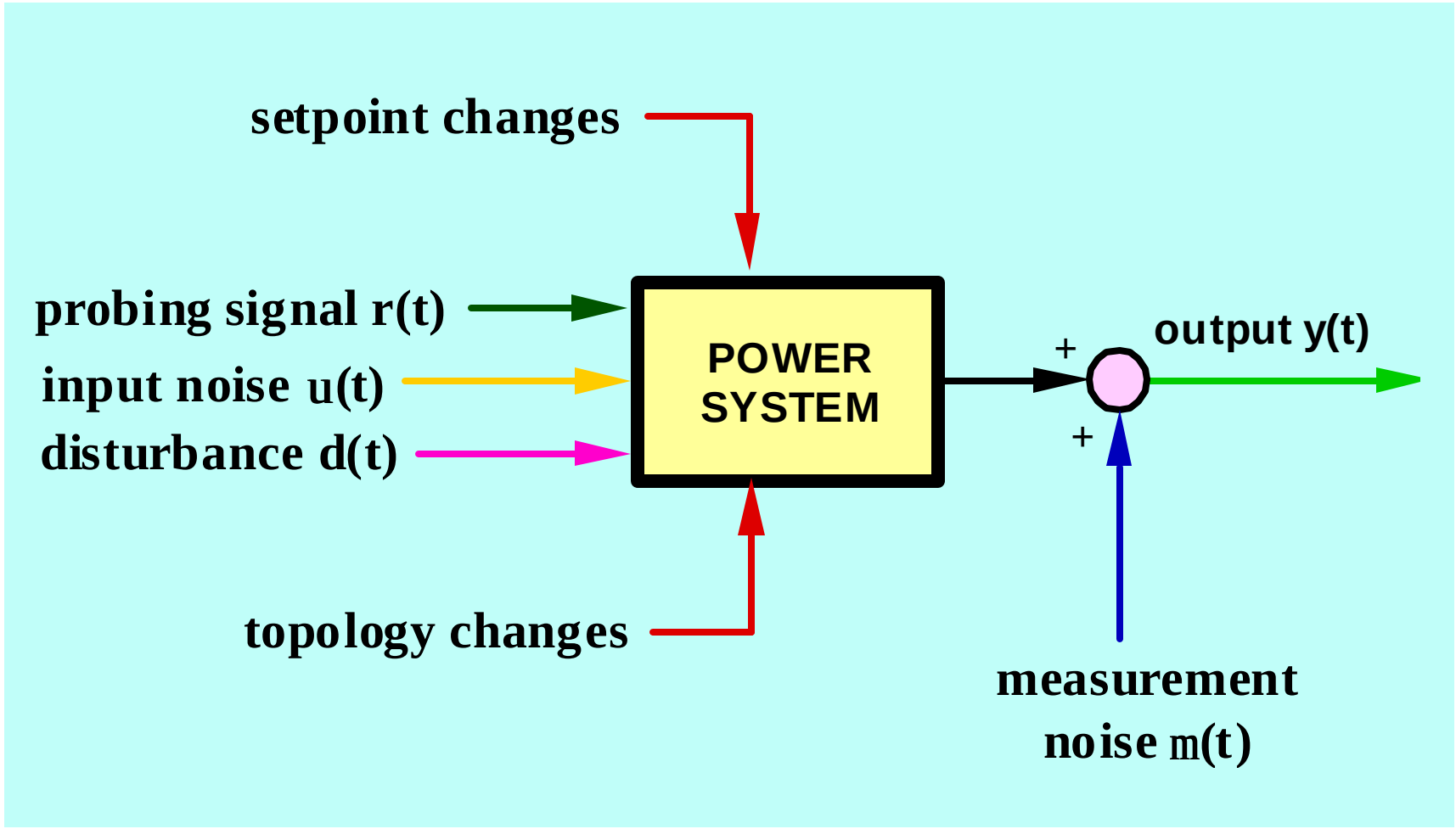
Hybrid Modeling for Validating Model Subsets Against Measured System Behavior [1]



1. Record bus & line quantities for system disturbance
2. Perform simulation studies with recorded bus quantities applied to radial subsystem
3. Adjust simulation models to replicate measured line quantities

[1] "Large-Scale Hybrid Dynamic Simulation Employing Field Measurements," Zhenyu Huang, R. T. Guttromson, and J. F. Hauer. Accepted for the IEEE PES General Meeting, Denver, CO, June 6-12, 2004.

Information Sources for Validating Power System Performance & Modeling



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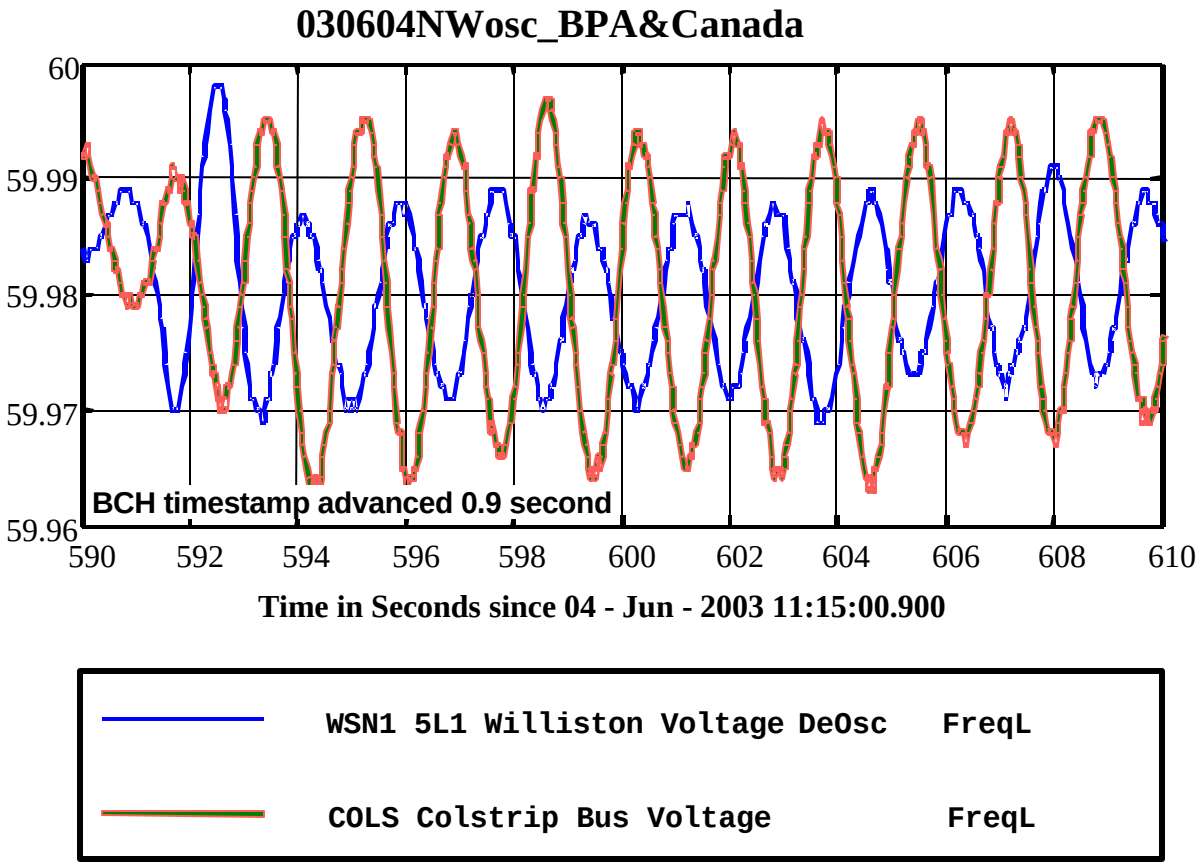
Frequency swings: Colstrip vs. BCH (detail)
WECC system event on June 4, 2003



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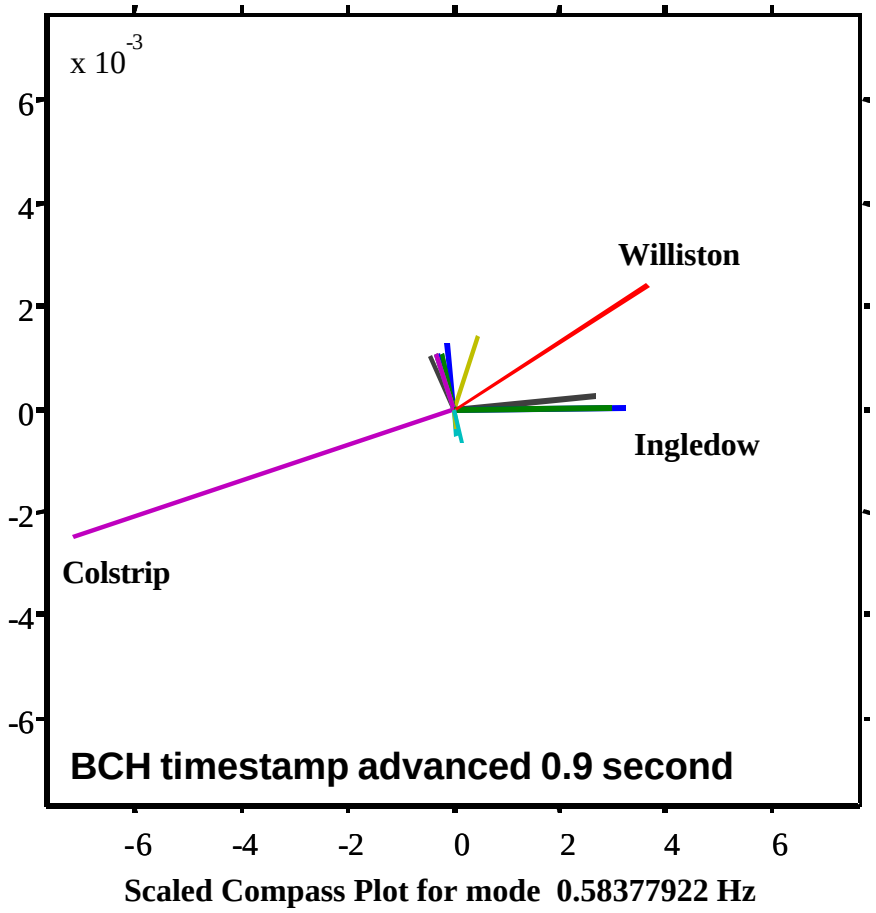
Modeshape Analysis to Determine Key Generators for Modeling & Control



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NERC Standards for Disturbance Monitoring, 1997

S1. Requirements for the installation of disturbance monitoring equipment (e.g., sequence-of-event, fault recording, and dynamic disturbance recording equipment) that is necessary to ensure data is available to *determine system performance and the causes of system disturbances* shall be established on a Regional basis.

S2. Requirements for providing disturbance monitoring data for the purpose of *developing, maintaining, and updating transmission system models* shall be established on a Regional basis.

Approved by Engineering Committee: July 8, 1997
Approved by Board of Trustees: September 16, 1997

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WSCC Validation of Performance & Modeling -- Summary of Activities

- Extensive performance validation tests
  - June 7, 2000 (oscillatory dynamics)
  - May 18, 2001 (frequency responsive reserves)
  - Summer 2003 (Extensive mid-level probing with Pacific HVDC Intertie)
- Rigorous examination of benchmark disturbances & oscillation incidents
  - Breakups of summer 1996
  - Alberta separations of summer 2000
  - Colstrip loss 090601 (2085 MW)
  - NW generation trip 100802 (2900 MW +1400 MW brake)
  - Oscillation incidents during summer of 2003
  - Other disturbances & anomalous behavior
- Special monitoring for generators & loads
- Model calibration logic integrated into GE stability program

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DOE/CERTS WAMS Outreach -- Accomplishments Since Project Start in FY2000

- **Information Systems Support for**
  - policy & planning for comprehensive monitoring of the western power system (WSCC WAMS)
  - technology development and direct support for operation of WSCC WAMS (DSI Toolbox, related products)
  - requirements & certification of phasor instruments
- **Performance Validation Support for**
  - planning and performing major tests of main grid dynamics
  - analysis & evaluation of system performance during tests, disturbances, and general conditions
  - comparative analysis of model response vs. recorded system behavior
  - major enhancements to WECC planning models
  - integration of related systems analysis technology, methods, and practices into the WSCC planning process

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Background on WAMS Outreach:
The Wide Area Measurements (WAMS) Effort

- **WAMS was initiated as a Federal project by the US Department of Energy (DOE) to reinforce power system reliability during the transition to a deregulated electricity market.**
- **Builds upon DOE information technology & infrastructure pioneered by the Federal utilities with support by DOE laboratories and others.**
- **Very strong ties to assets management visions such as the Intelligent Energy System (IES) and the EPRI Flexible AC Transmission System (FACTS) program.**
- **Now receives critical DOE support via CERTS. Selected aspects of the WAMS effort are supported by stakeholders.**

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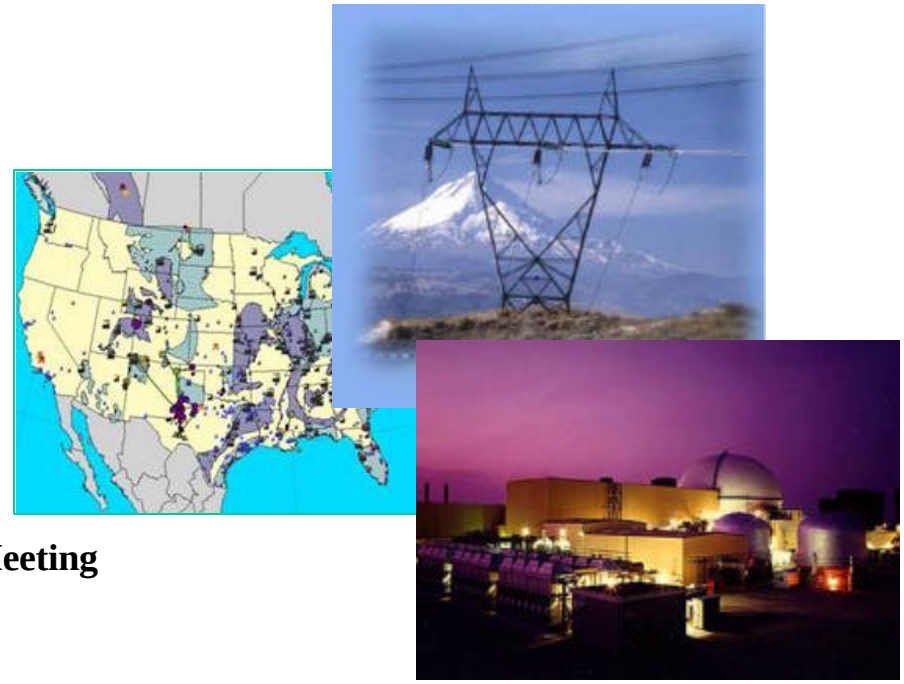
Model Validation with Event Playback – Application to Colstrip Plant



Henry Huang, Ph.D
Pacific Northwest National Laboratory

WECC Modeling and Validation Work Group Meeting
San Francisco, January 13-14, 2004

Some Details of WECC Model Validation

(RESERVE SLIDES FOR TECHNICAL QUESTIONS)

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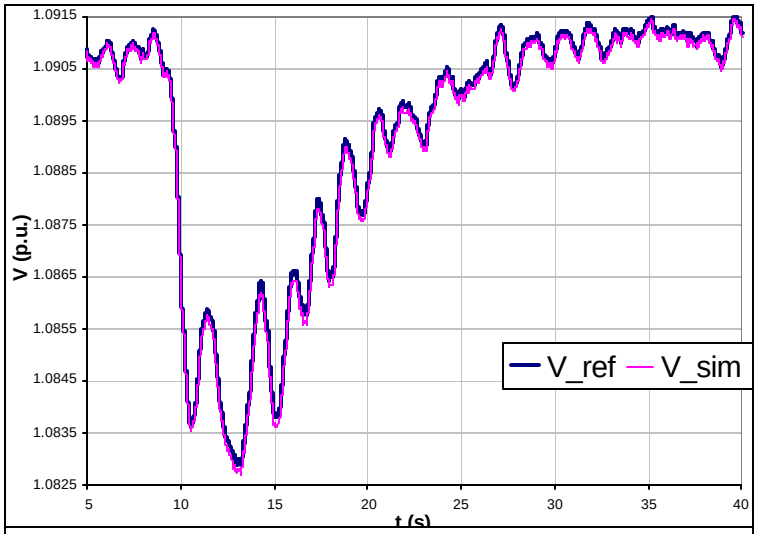
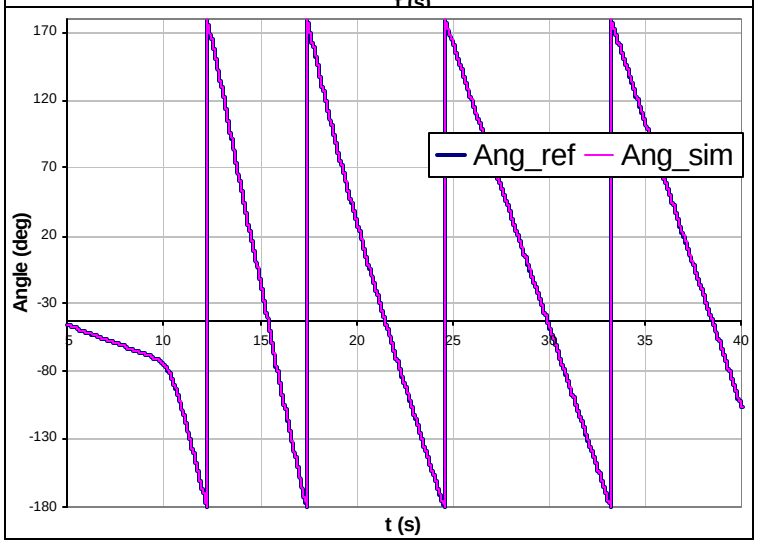
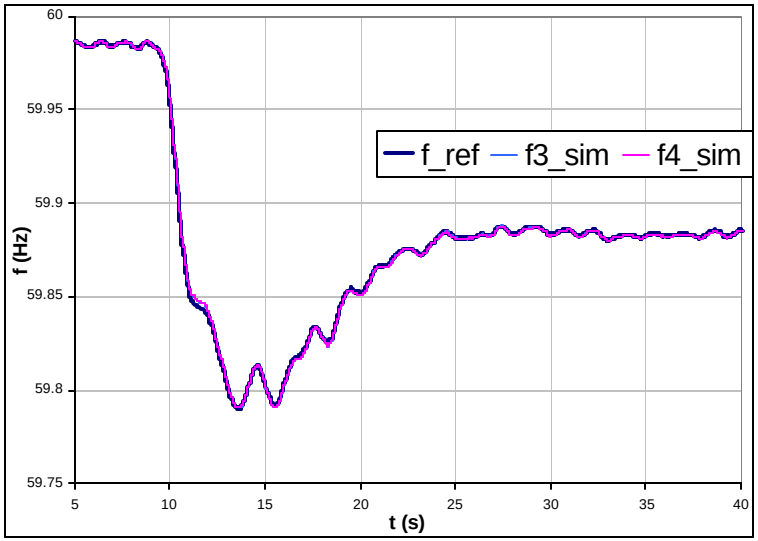
020818 - Drop of Navajo units #2 & #3 (1500 MW)







Plots of *V, q*: measured records are successfully repeated at the boundary bus.

Plot of *f*: Generators' speeds well match the recorded bus frequency.

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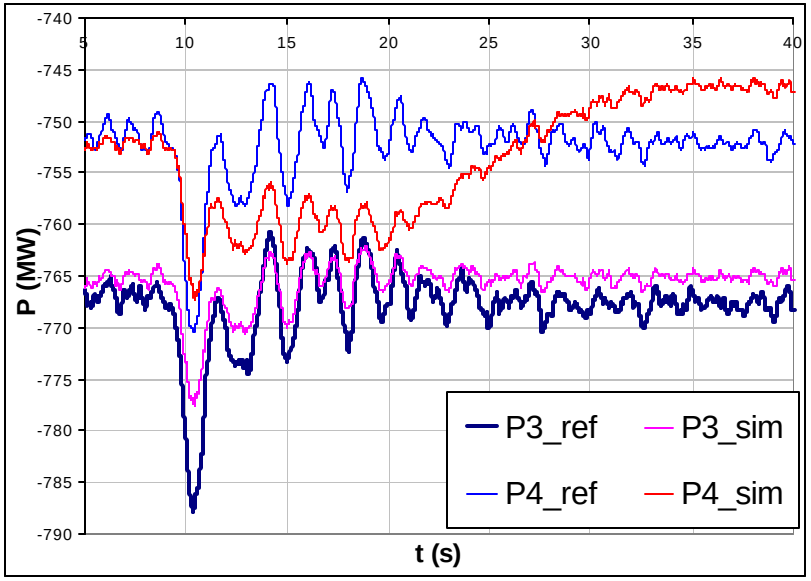
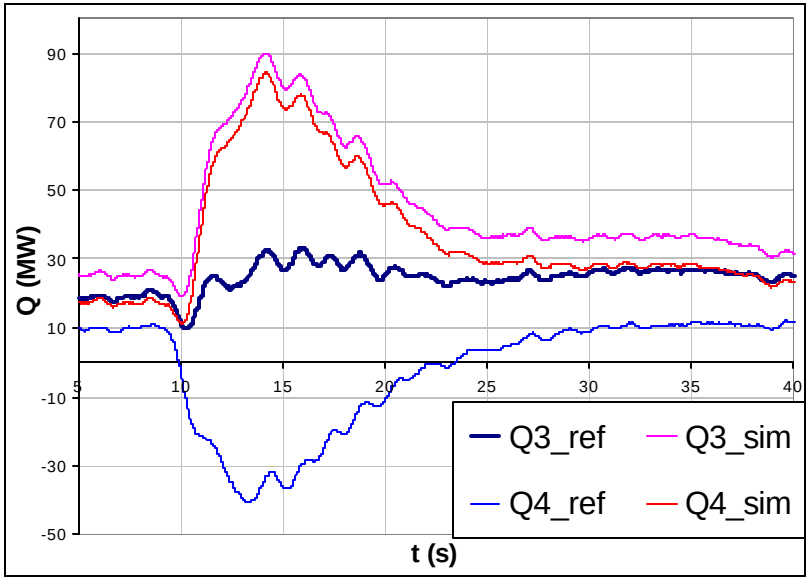
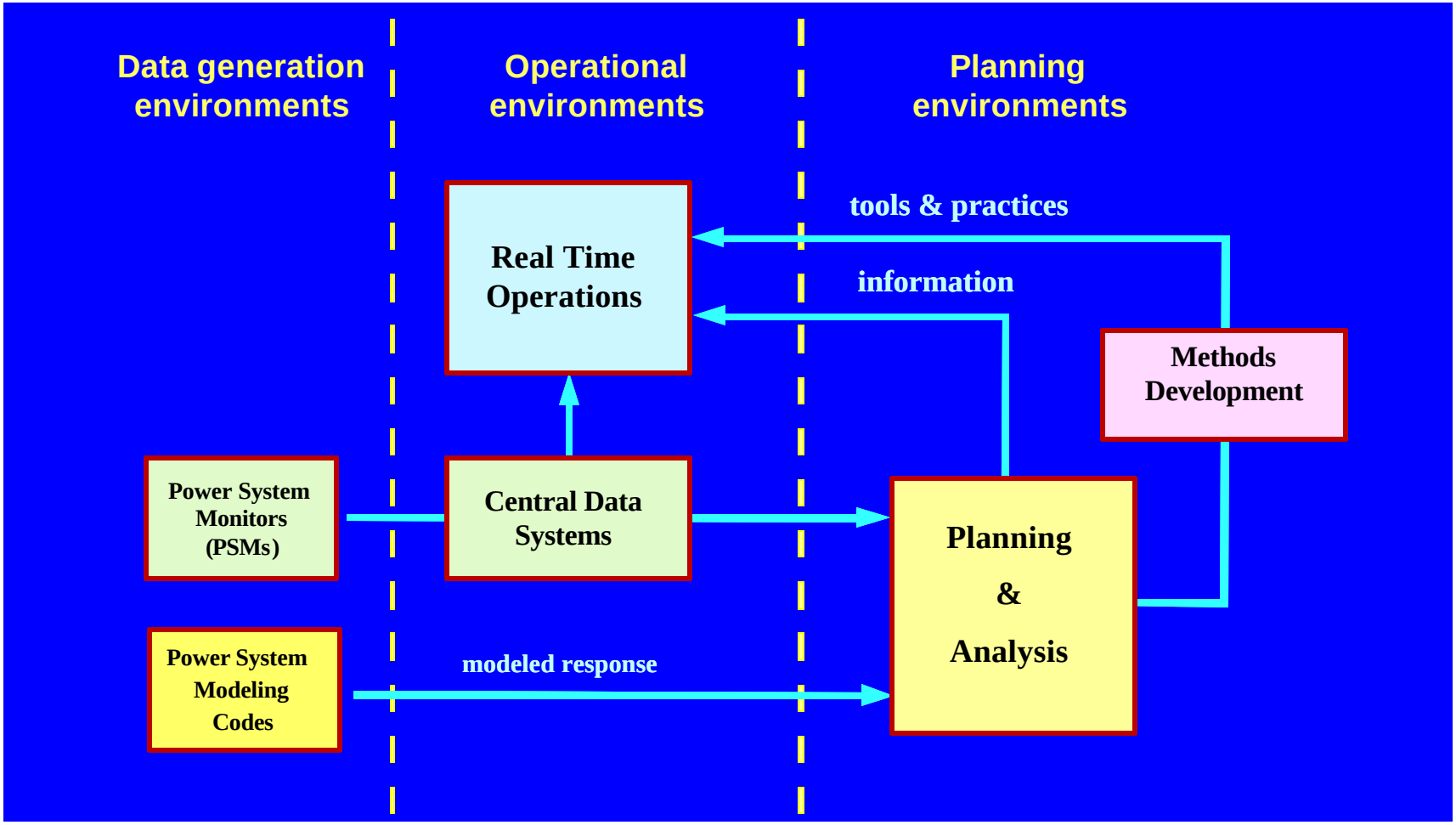




Note 1. Measured P are similar for both G3 and G4, and P3_sim matches the measured record fairly well. However, the simulated P are different, even though the models and parameters are the same.

Note 2. Measured Q are very different for G3 and G4. This indicates their excitation models and/or parameters should NOT be same. The simulated Q match each other but not the measurements.

Good Information: The key to managing complexity



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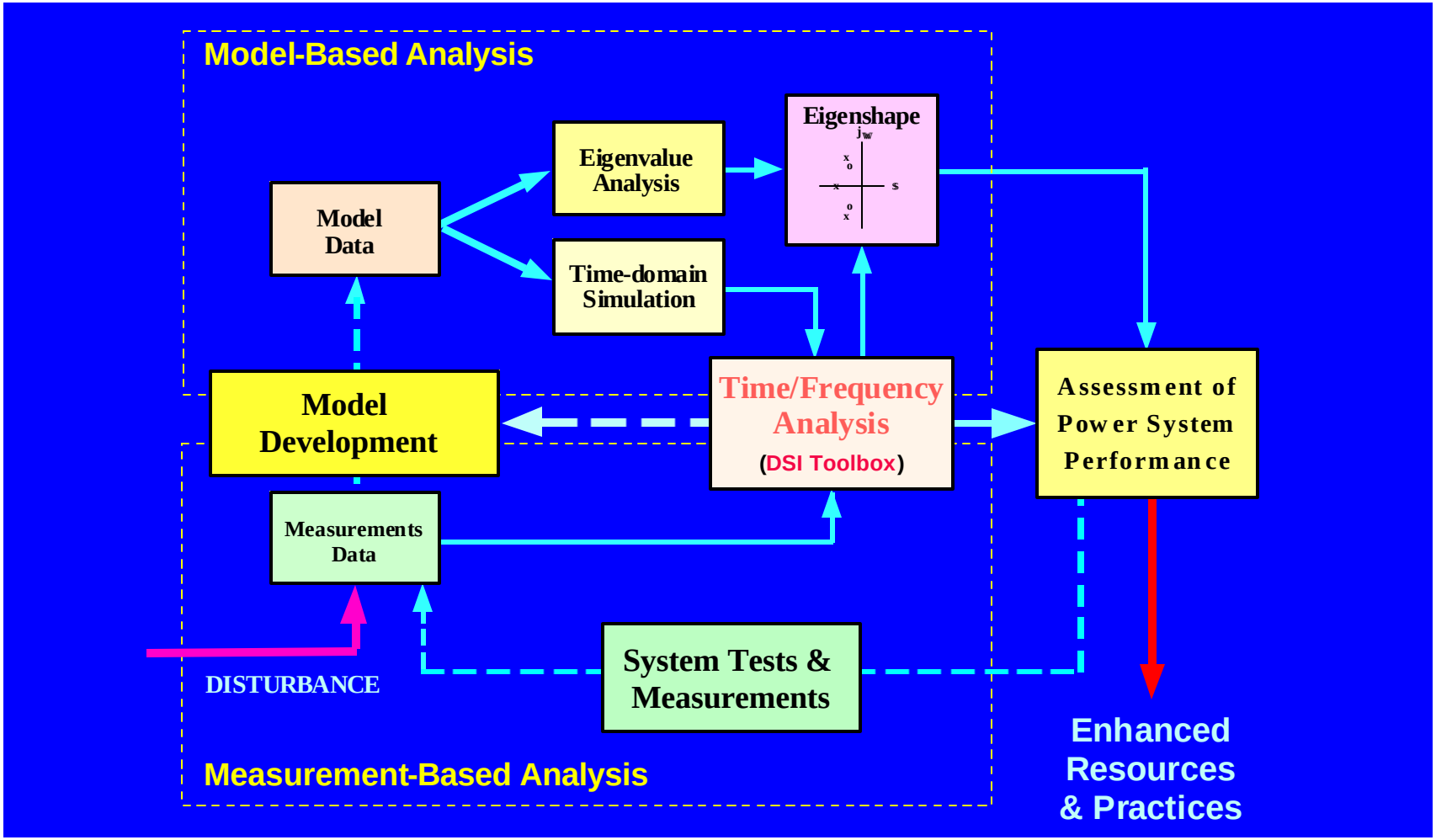
Validation of System Performance & Modeling



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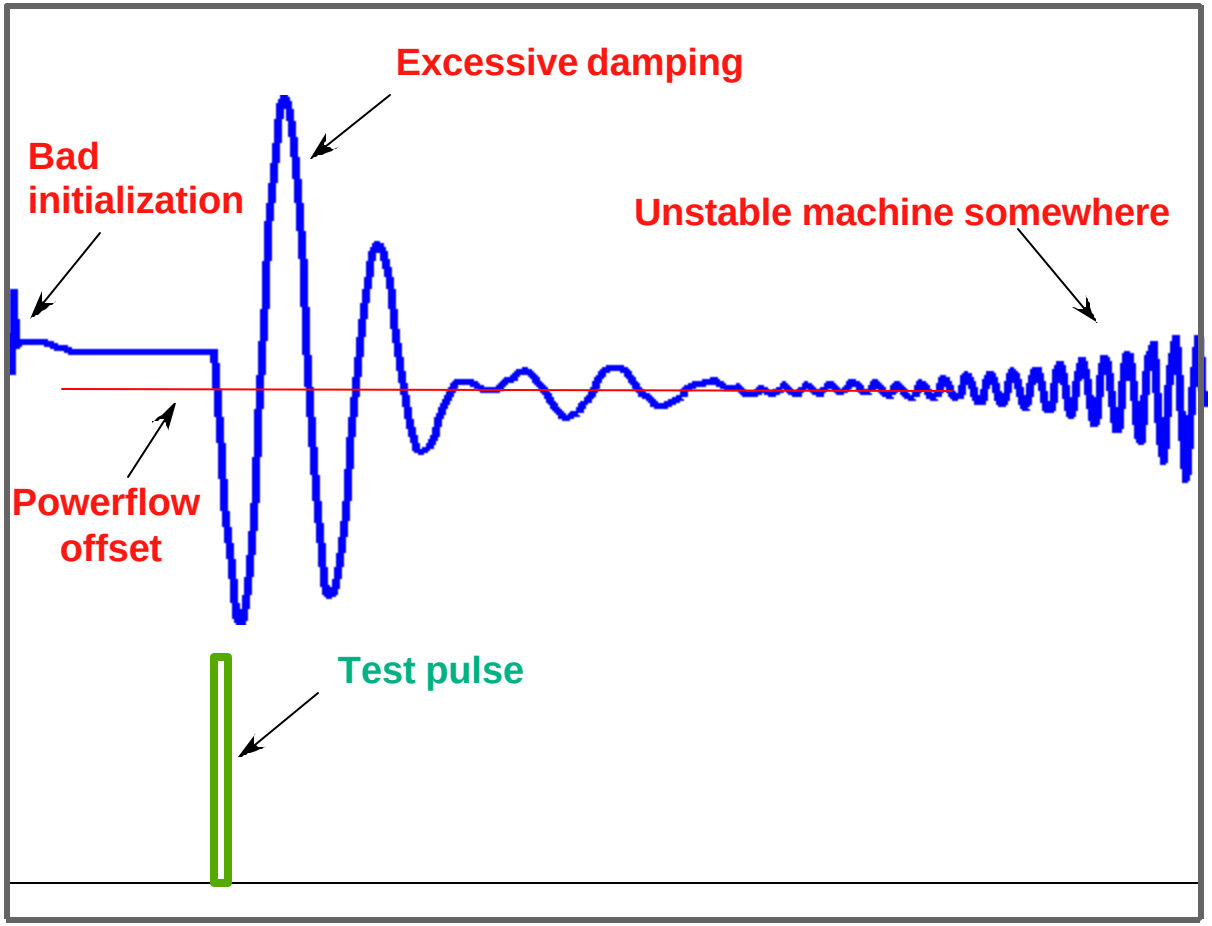
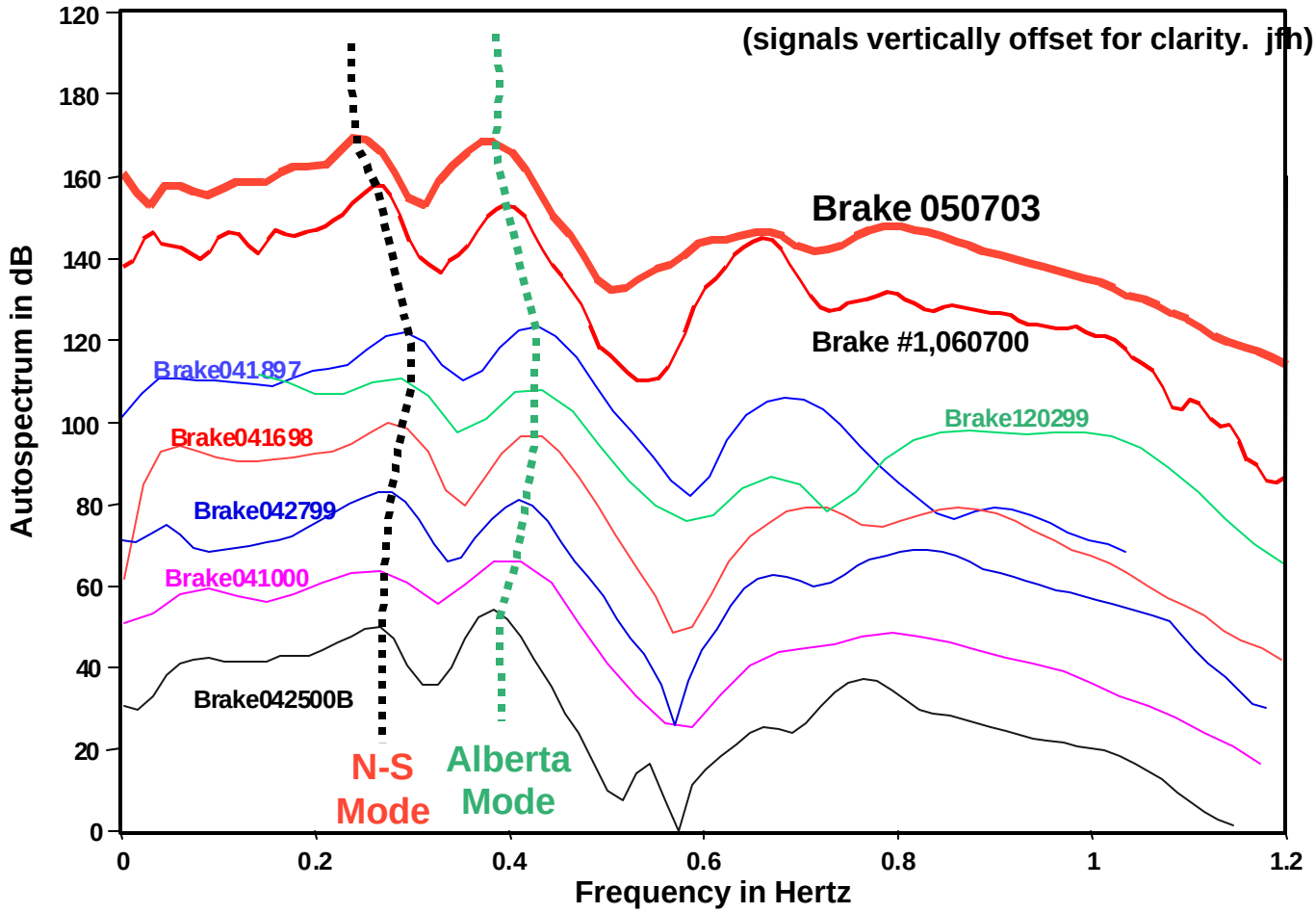
Ringdown check on model quality



Key Benchmark for WECC Validation: Malin Ringdown Signatures for Dynamic Brake Insertions



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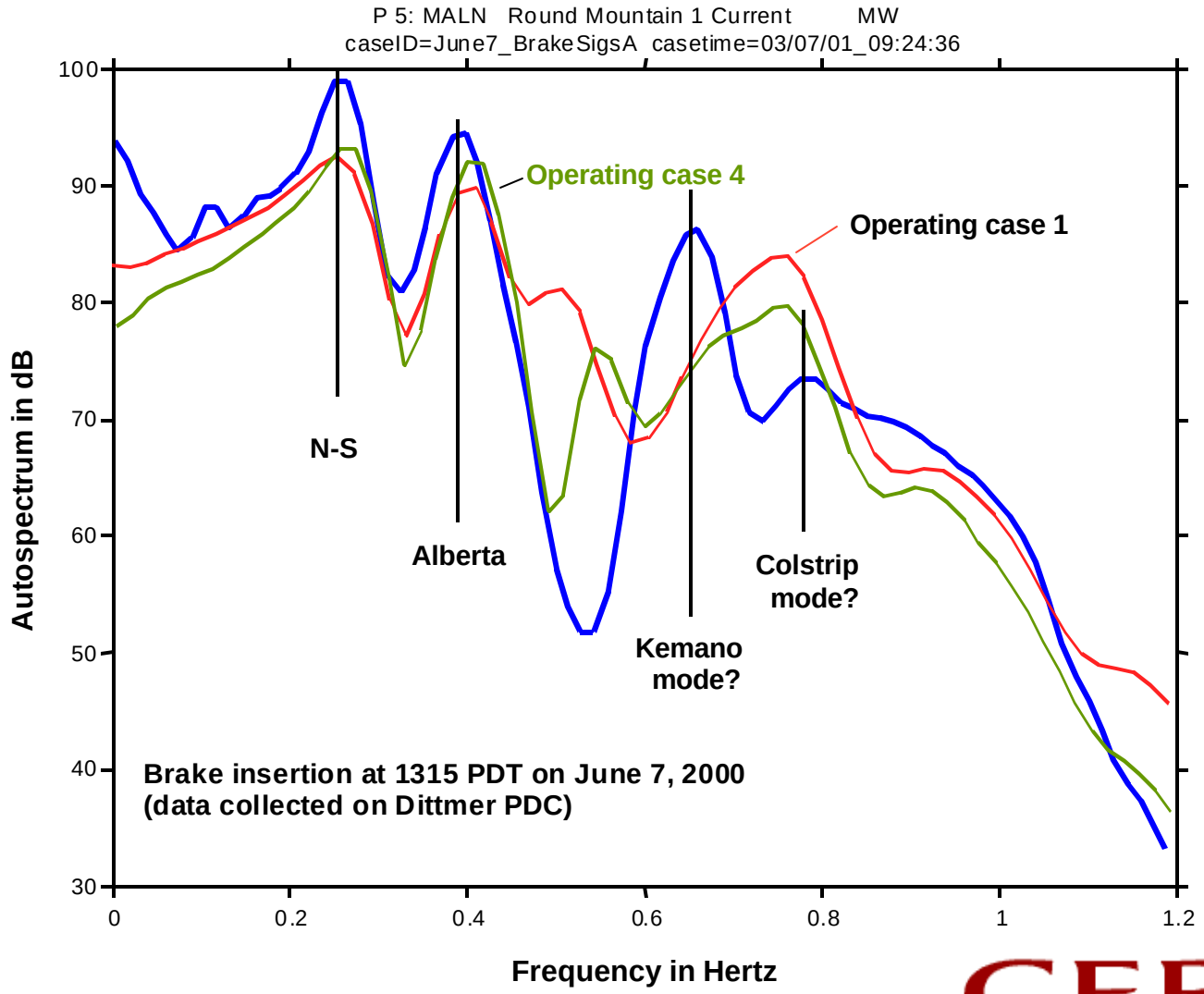
Comparing Models Against Historical Records for Malin Ringdown Signatures



Information Value of Major Control Systems

Major control systems require, and can provide, highly competent windows into power system dynamics .

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Modeling Criteria for Oscillatory Dynamics

A fully realistic model for wide area oscillation dynamics must, for all important modes, replicate and predict actual system behavior in the following respects:

a) **Mode parameters (eigenvalues). Usually characterized in terms of frequency and damping.**

b) **Mode shape (eigenvectors). Usually characterized by the relative phasing of generator swings, for each mode. As used here, mode shape also includes the relative strengths of generator swings.**

c) **Interaction paths. The lines, buses, and controllers through which generators exchange energy during oscillatory behavior.**

d) **Response to control. Modification of oscillatory behavior due to control action, including changes to network parameters and load characteristics.**

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