Performance Monitoring and Model Validation of Power Plants Leveraging Synchrophasors

NERC Planning Committee

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NASPI Planning Implementation Task Team

NERC Standards

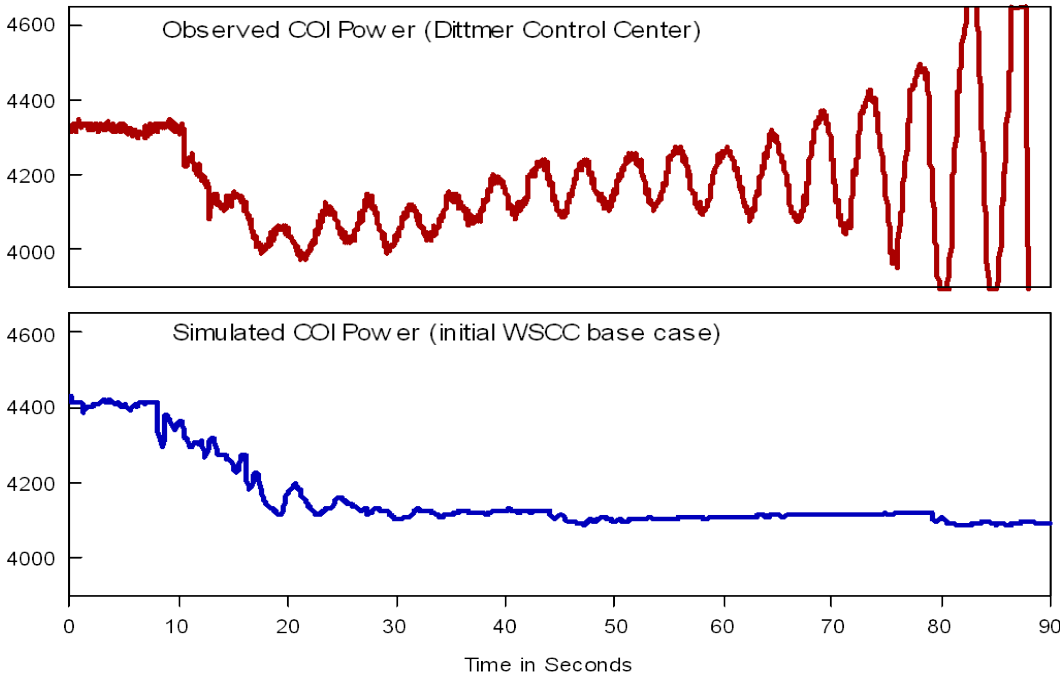
Power System Models are used in system studies to make decisions on the capital investment and to set system operating limits. Model verification is essential in ensuring that power system models are accurate and up to date

- MOD-012 requires power plant owners to provide power plant data for dynamic simulations
- MOD-026 will require power plant owners to **verify** that the provided dynamic models of excitation controls are accurate and up to date
- MOD-027 will require power plant owners to **verify** that the provided dynamic models of governors and turbine controls are accurate and up to date

WECC Experience

- Failure of models to predict or reproduce the 1996 disturbances
- Loss of confidence in model's ability to set transfer capability limits
- Operational de-rating of California-Oregon Intertie and Pacific HVDC Interie

August 10, 1996



WECC BOT required that all generators larger than 10 MVA be tested for the purpose of model verification

WECC Experience

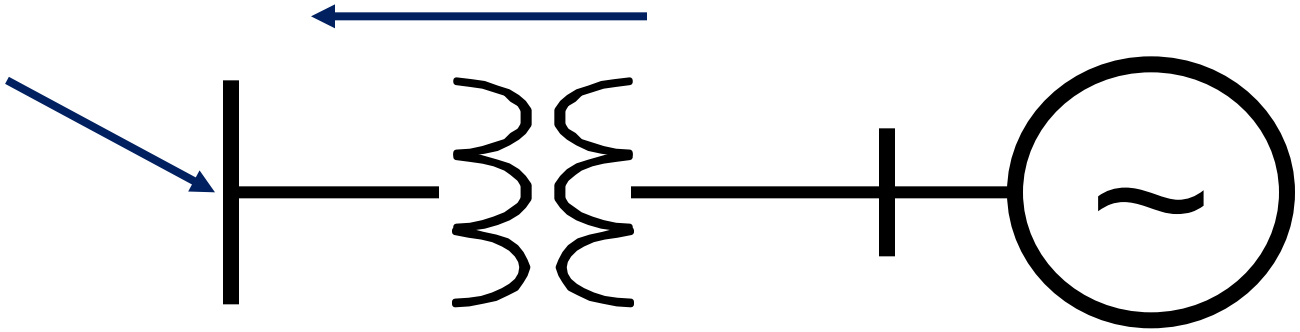
- 1996 - WECC BOT required generators be tested for model validation
- Baseline tests and model validation were performed for majority of generating units
  - Next issue – how to ensure that the models stay accurate
- 2006 – WECC Generating Unit Model Validation Criterion
  - Baseline testing
  - Periodic model verification (5 year)
- Using disturbance recordings was accepted as a method of model verification
  - Phasor Measurement Units are now installed at POI of many large power plants in the West
  - A cost-effective alternative to generator re-testing

Model Validation Overview

GE PSLF Simulations

Inject Recorded Voltage and Frequency

Compare Recorded and Simulated Power: MW and MVAR

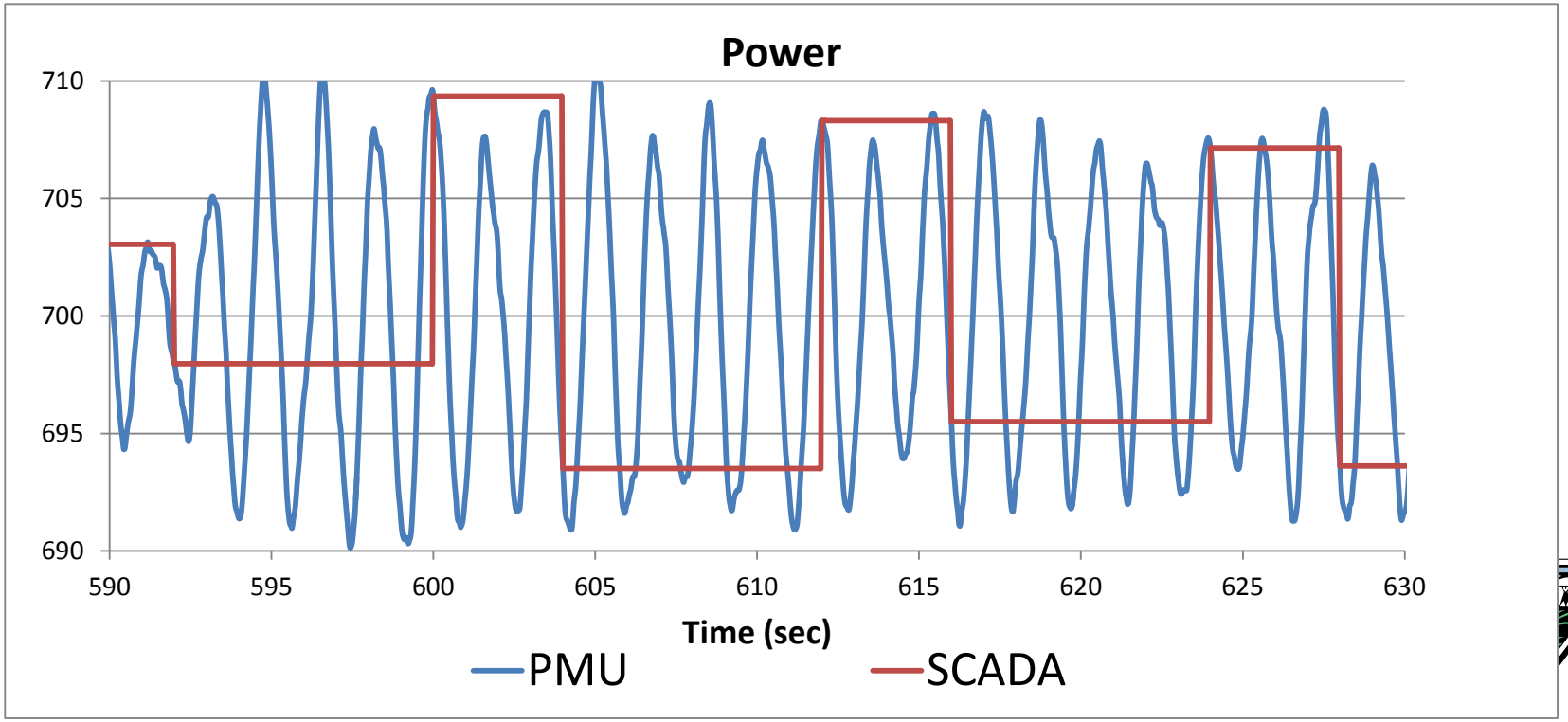


Disturbance “playback” is a standard feature in PSLF

Tools developed under a Technology Innovation project at BPA starting in 2000

Phasor Measurements

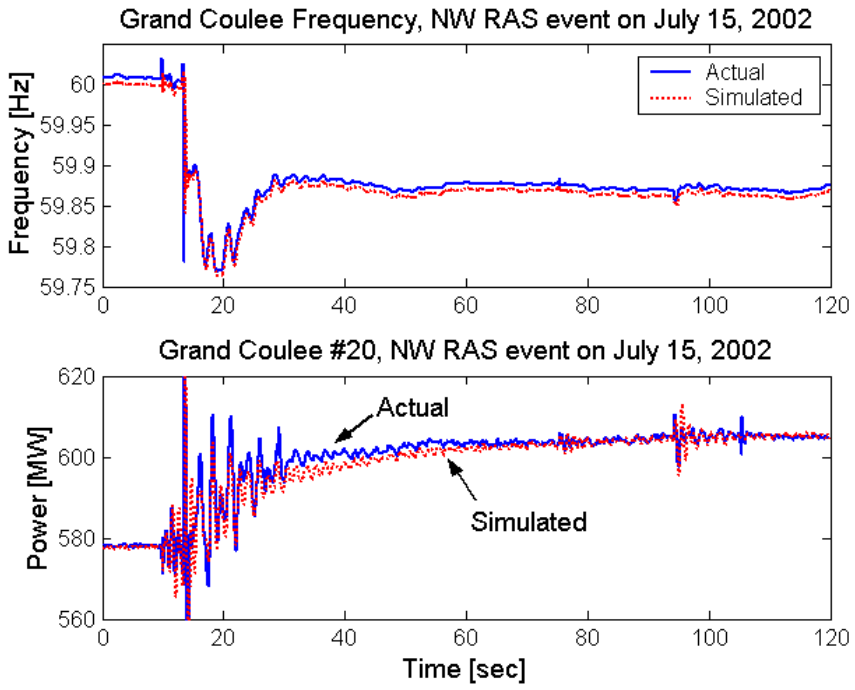
- Advantages of synchro-phasor data over SCADA for model validation:
  - High-resolution and accuracy
  - High sampling rate (30-60 per second) that is needed to observe and understand generator dynamics

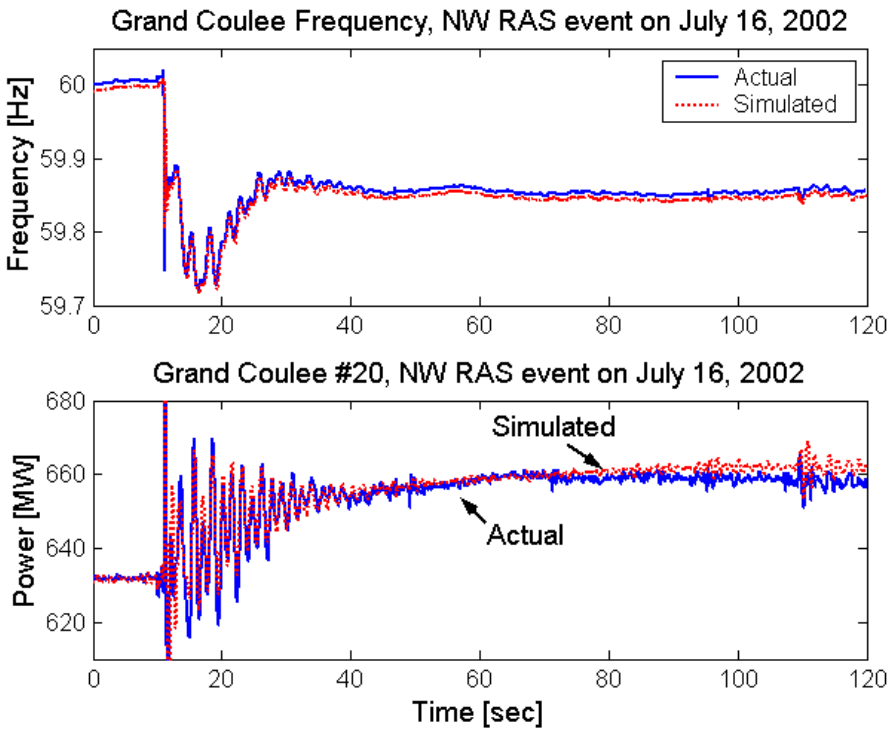


Proven Benefits: Power Plant Model Validation in lieu of re-testing

Power Plant Model Validation

- Power plant model verification by using disturbance data is an acceptable technical approach
- More frequent verification, early detection of abnormalities, much less expensive or risky than staged generator tests





Blue line = actual recording

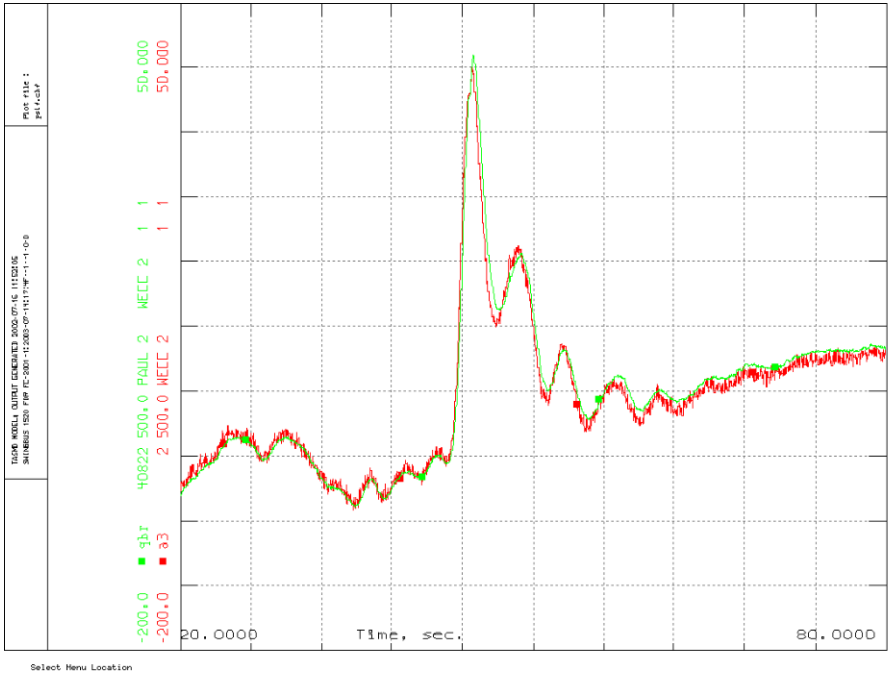
Red line = model

Power Plant Model Validation

- Successful model validation for a 750-MW coal-power plant

- active power

- reactive power

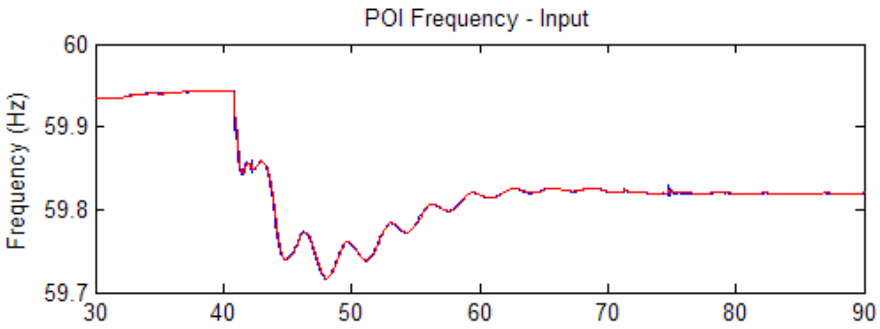


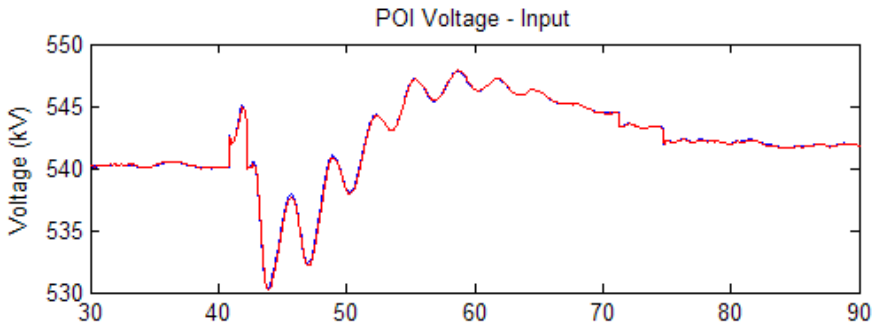
Green = actual, red = model

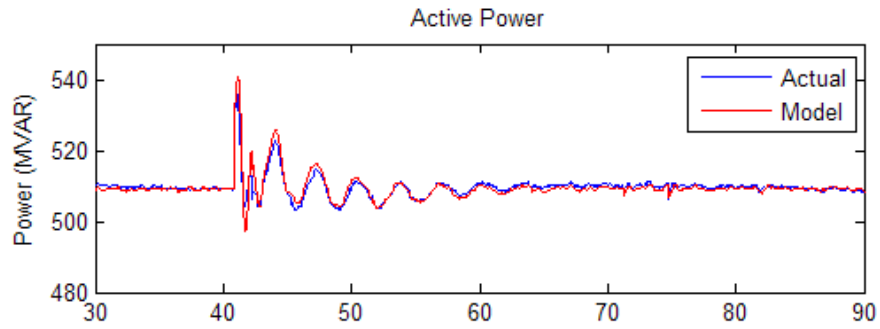
C.Huitt, D.Kosterev, J.Undrill, "Dynamic Monitoring is Cost Effective for TransAlta, BPA," Electric Light and Power vol.82-07, p.52, November/December 2004.

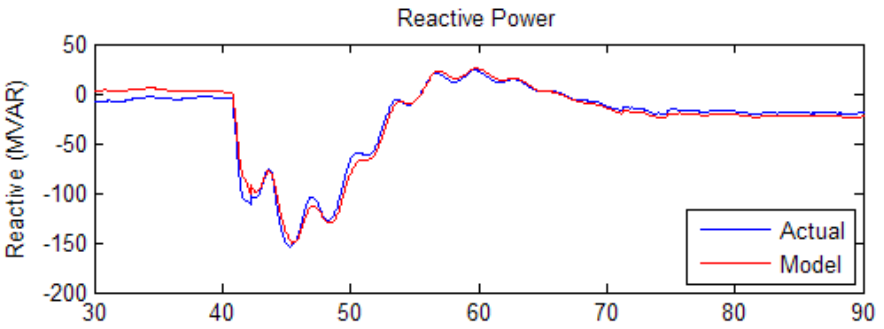
Power Plant Model Validation

- Successful model validation for 550 MW combined cycle plant







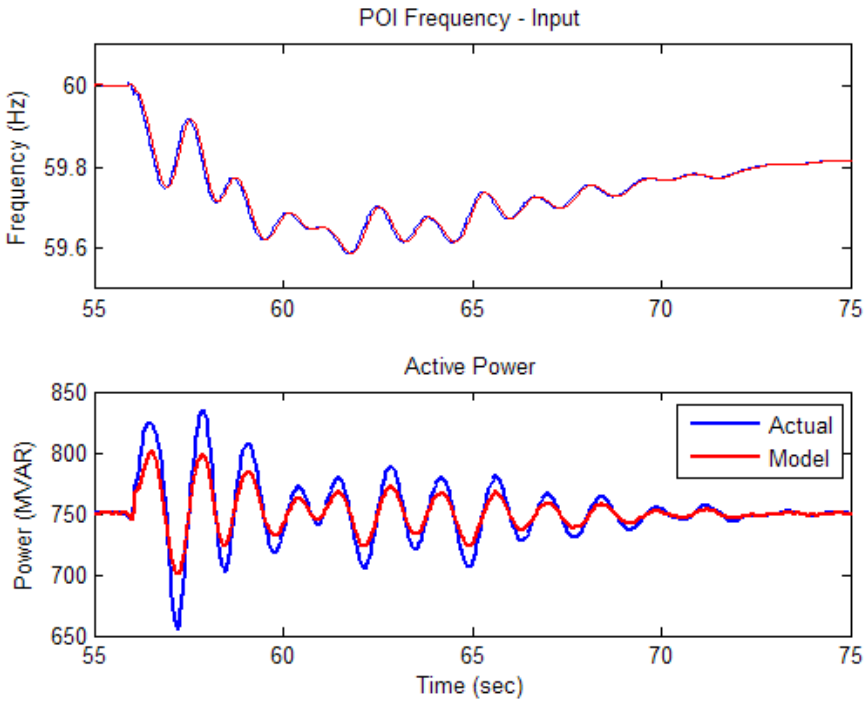


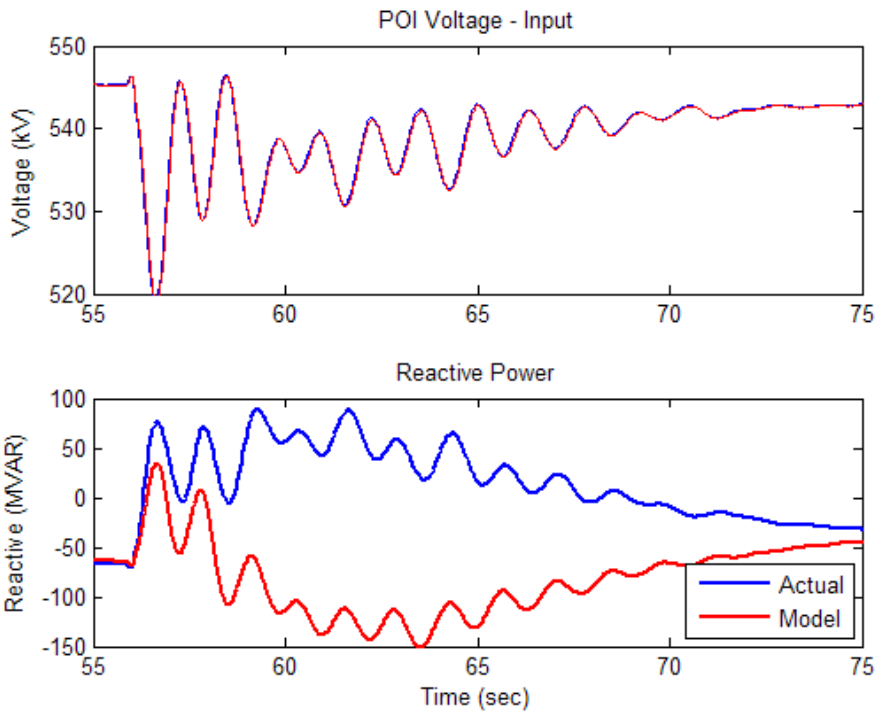
Voltage and frequency are inputs
Active and reactive power are “measures of success”

Blue line = actual recording
Red line = model

Power Plant Model Validation

- What a bad model looks like (800 MW steam-turbine unit)





Voltage and frequency are inputs

Active and reactive power are “measures of success”

Blue line = actual recording

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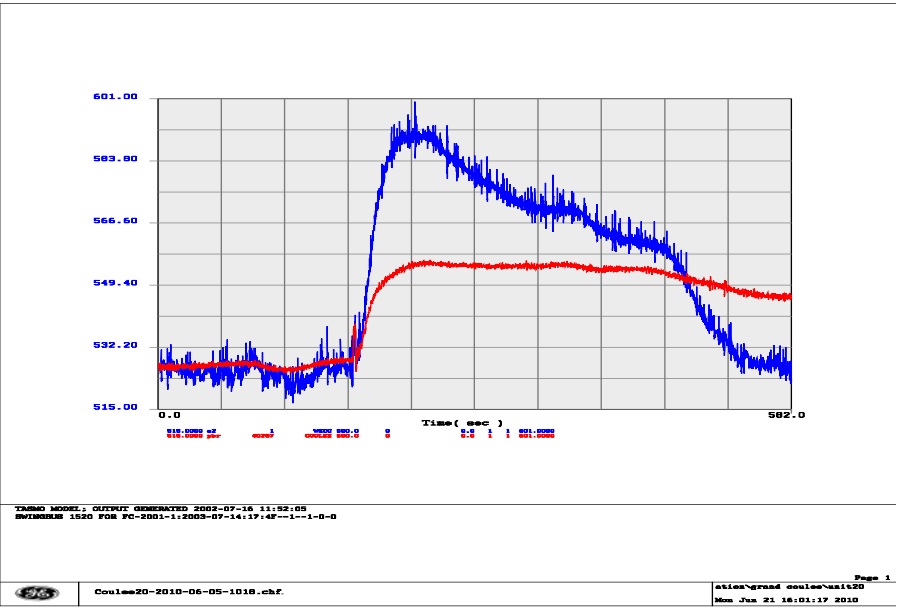
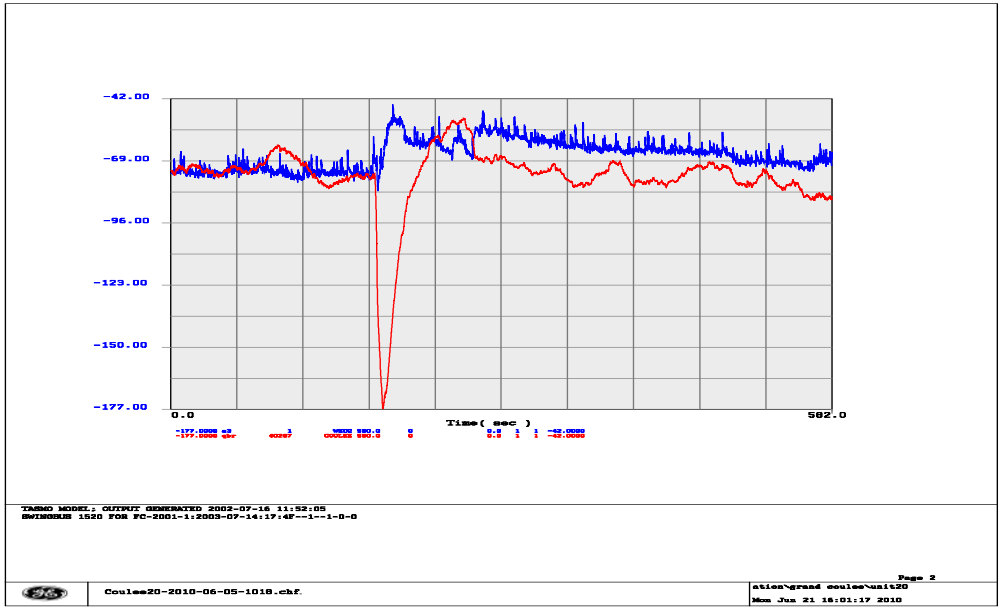
Power Plant Model Validation

- What a bad model looks like (700 MW hydro-turbine unit)

- active power



- reactive power



Active and reactive power are “measures of success”

Blue line = actual recording

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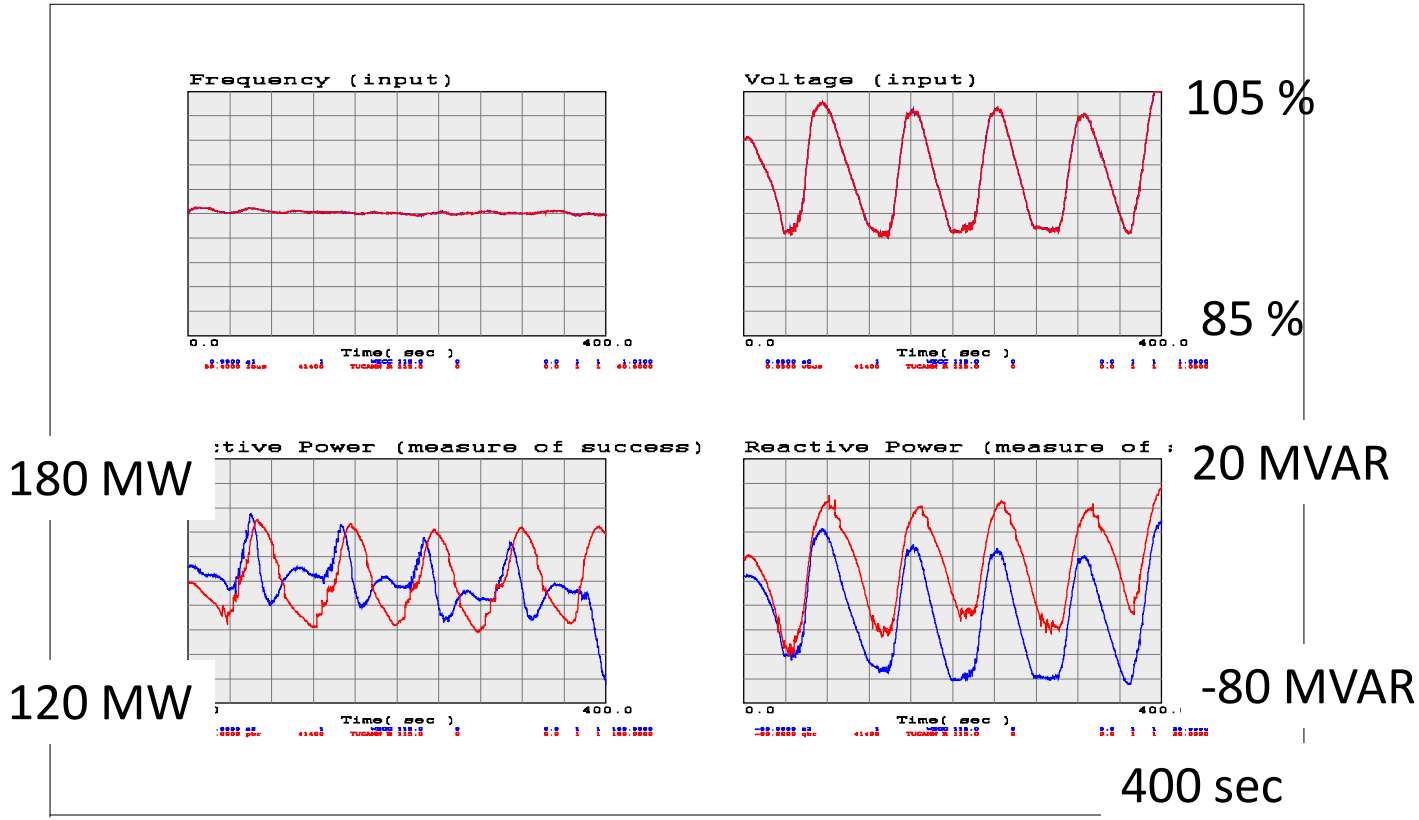
Power Plant Model Validation

- TO contacts GO when discrepancy between model and actual response is observed persistently
- Does the mismatch indicate a possible controller failure in a plant ?
  - Fix the controller first
- Is the mismatch due to an incorrect model ? Most likely causes include:
  - Bad turbine-governor data
    - Unit is baseloaded, model is on governor control
  - Bad Power System Stabilizer data
  - Wrong generator inertia
  - Inappropriate model (static exciter is modeled as rotating dc exciter)

Wind Power Plants

- Disturbance recordings may be the best technical approach for wind power plant model validation



- 150-MW wind power plant with type 2 machines
- Several random "instability" events observed, power output was curtailed

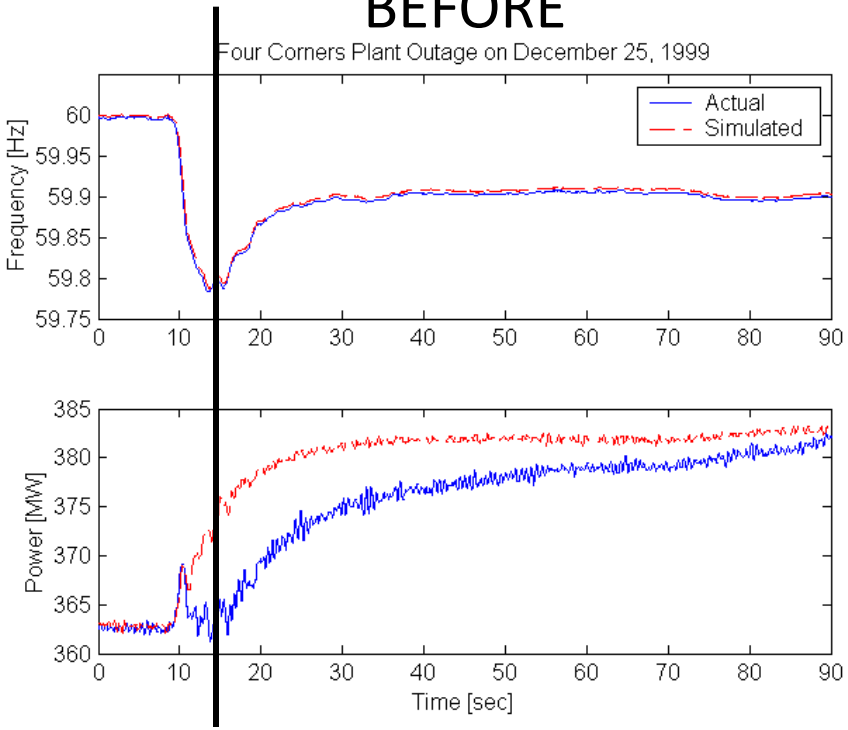
Blue = actual, Red = model

Proven Benefits: Monitoring and Modeling Governor Response

Modeling Governor Response

- PMU data was very instrumental in identifying which power plants are responsive, under load control or base-loaded
- Several model improvements were made – gas-turbine models, Kaplan hydro-turbine models

BEFORE



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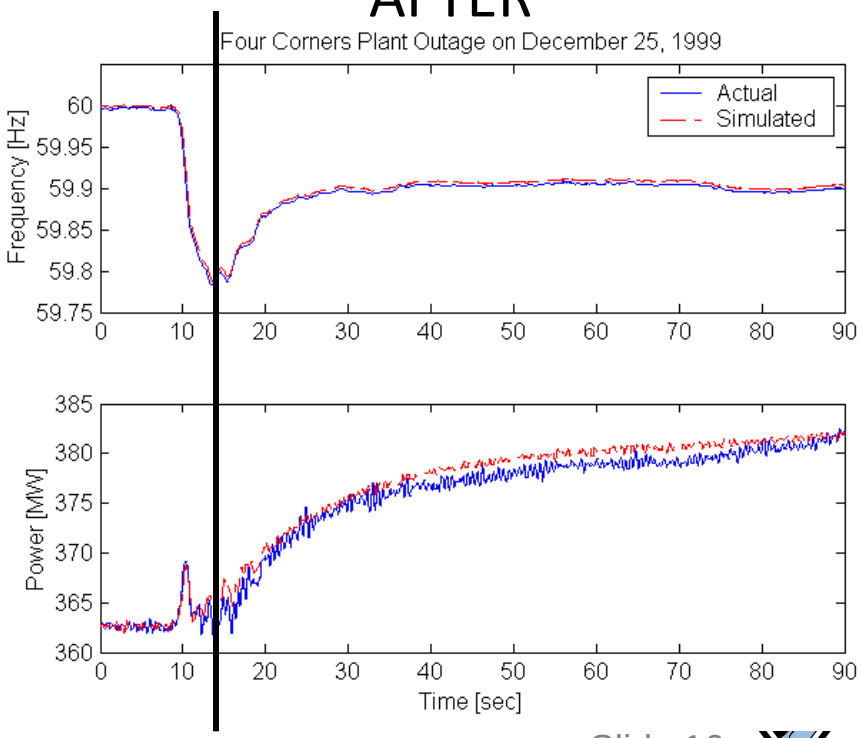


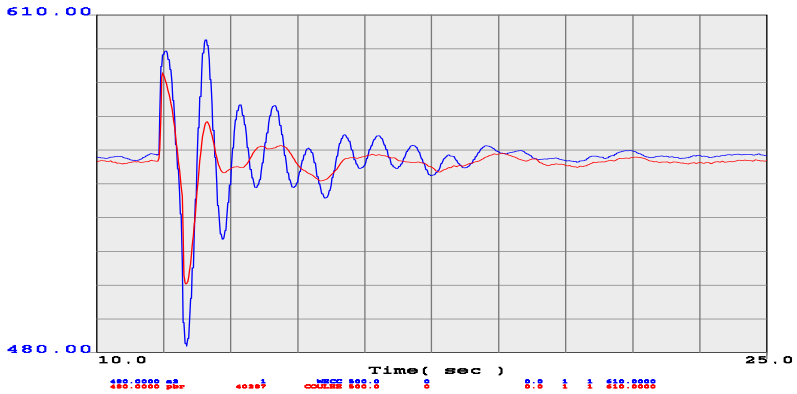
Blue = actual, Red = model

Proven Benefits: Early Detection of Generator Control Failures

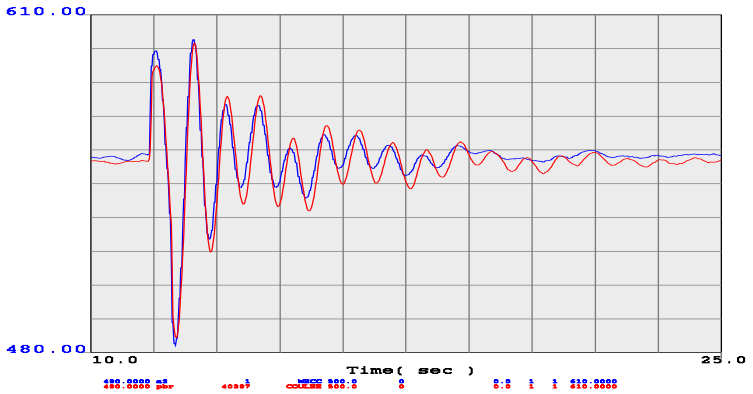
Early Detection of Control Failures

- Having phasor data available at a 700 MW hydro-power plant allowed to identify Power System Stabilizer failure

PSS is modeled ON



PSS is modeled OFF



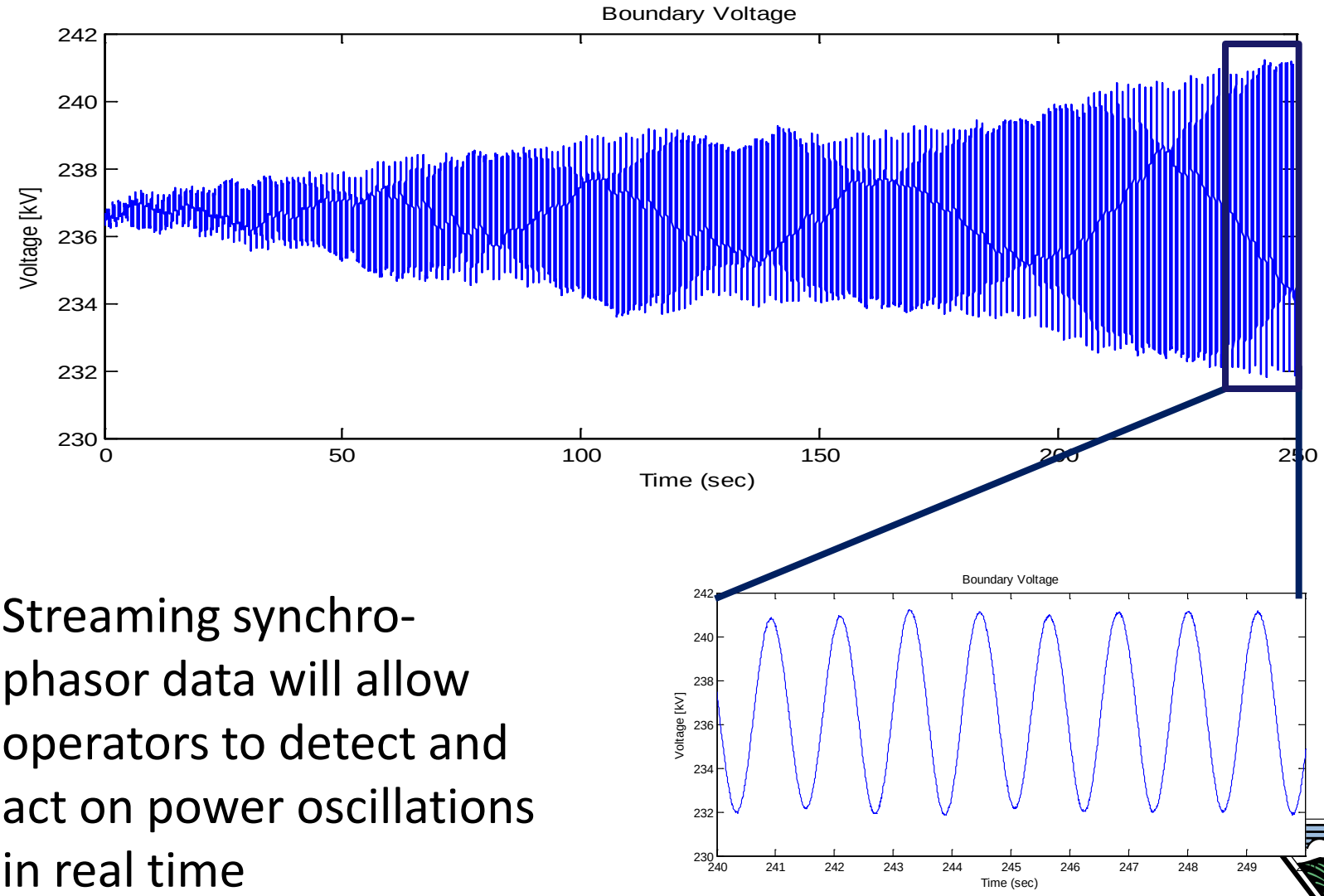
Active Power Oscillation

Blue = actual recording

Red = models

Operational Benefits: Detection of Generator Instabilities

Large Hydro Power Plant Oscillation



Streaming synchro-phasor data will allow operators to detect and act on power oscillations in real time

Moving Forward

- Vision:
  - Being able to evaluate dynamic performance of the entire generating fleet within an hour of a disturbance event
  - Being able to evaluate performance of a single unit over a wide range of disturbances, produce validation reports for NERC / WECC compliance
  - Continue using phasor data for improvement of power plant dynamic models
- Use NASPI to spread technical knowledge
- Power Plant Model Validation is one of the deliverables under Western Interconnection Synchrophasor Project (NASPI)

Conclusion – why BAs and TOs want PMUs at Power Plant POI

- Monitor performance of its generating fleet during power system disturbances and staged tests
- Validate models of power generators
  - Cost-effective compliance with emerging MOD standards
- Detect acute control failures in real time
  - Prevent equipment damage

- To realize these benefits, Phasor Measurement Units need to be deployed at POIs of major power plants, including wind generation
  - A good start is to put the requirement in your interconnection standards

If You are Interested in Synchrophasors

- NERC RAPIR
- www.naspi.org/resources/pitt/pittresources.stm:
  - Power Plant PMU Requirements
- Contacts:
  - Alison Silverstein, alison.silverstein@me.com
  - Planning: Dmitry Kosterev, dnkosterev@bpa.gov
  - Equipment: Antony Faris, ajfaris@bpa.gov