Power Plant Model Validation and compliance with NERC MOD-026 & 027 Reliability Standards

i-PCGRID
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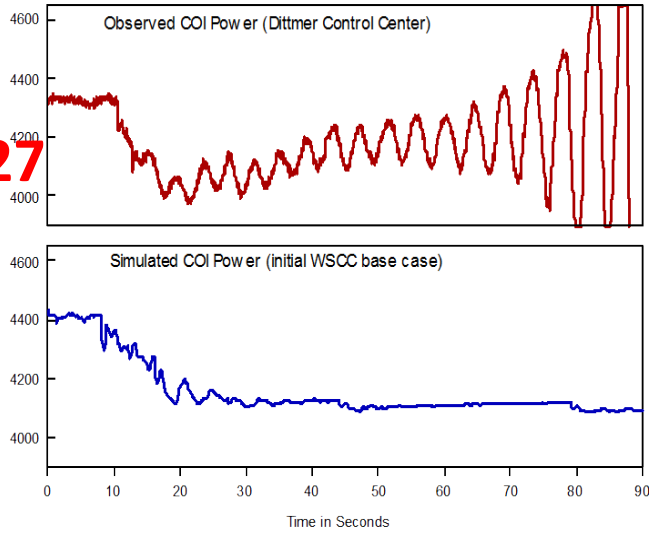
Steve Yang
Dmitry Kosterev
Bonneville Power Administration

Motivation and History

- Accurate and up-to-date models are needed for reliable and economic grid operations and planning
- WECC required generators to be tested for model validation after 1996 system outages
- WECC established a formal Generating Unit Model Validation Policy in 2006:
  - Baseline model development
  - Periodic model validation
- **NERC Reliability Standards MOD-026 & 027**
  - Developed from 2007 to 2013
  - In effect starting July 1, 2014

August 10, 1996

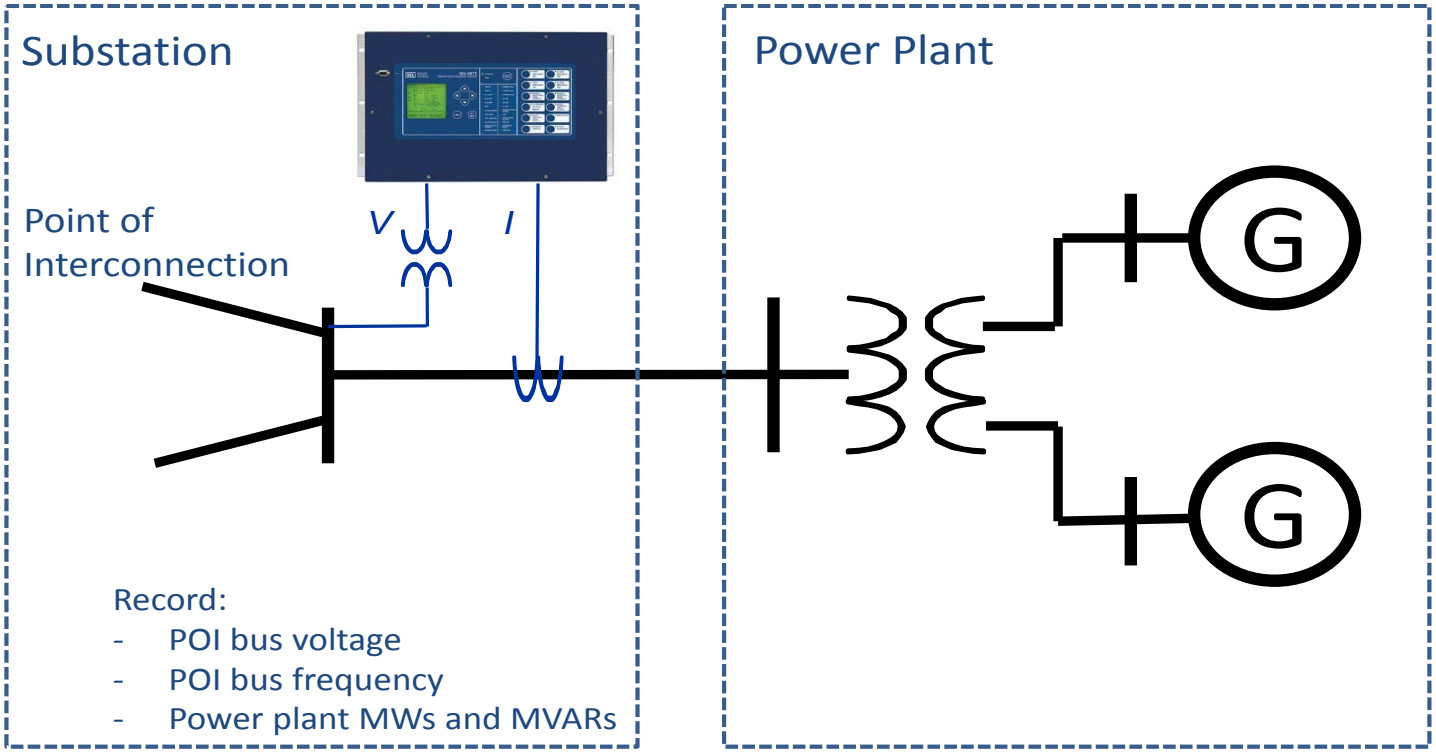


Highlights of MOD-026 & 027

- Applies to Generator Owners(GOs) and Transmission Planners(TPs)
  - GOs to periodically validate generator excitation (MOD-026) and governor (MOD-027) models
  - TPs to verify model usability
- Every 10 years (every 5 years in WECC)
- Eastern Connection
  - Great than 100 MVA individually or aggregate
- Western Connection
  - Great than 75 MVA individually or aggregate
- ERCOT
  - Great than 50 MVA individually or aggregate greater than 75 MVA
- Requirements
  - Documentation demonstrating the applicable unit's model response matches the recorded response for voltage and frequency excursion from either a staged test or a measured system disturbance

Power Plant Model Validation

- BPA has installed PMUs at power plant POIs
- BPA developed Power Plant Model Validation (PPMV) application using PMU data and GE PSLF play-in function
- BPA requires PMU installation for all new generation including the wind



PMU needs to be placed at Power Plant POI

BPA's PPMV PMU Coverage

- BPA's PMU disturbance monitoring:
  - Conventional –
    - 12 plants,
    - 130 generators,
    - 21,145 MW of generation
  - Wind –
    - 11 plants
    - 1,200 MW of generation
- Review model performance periodically (system events)

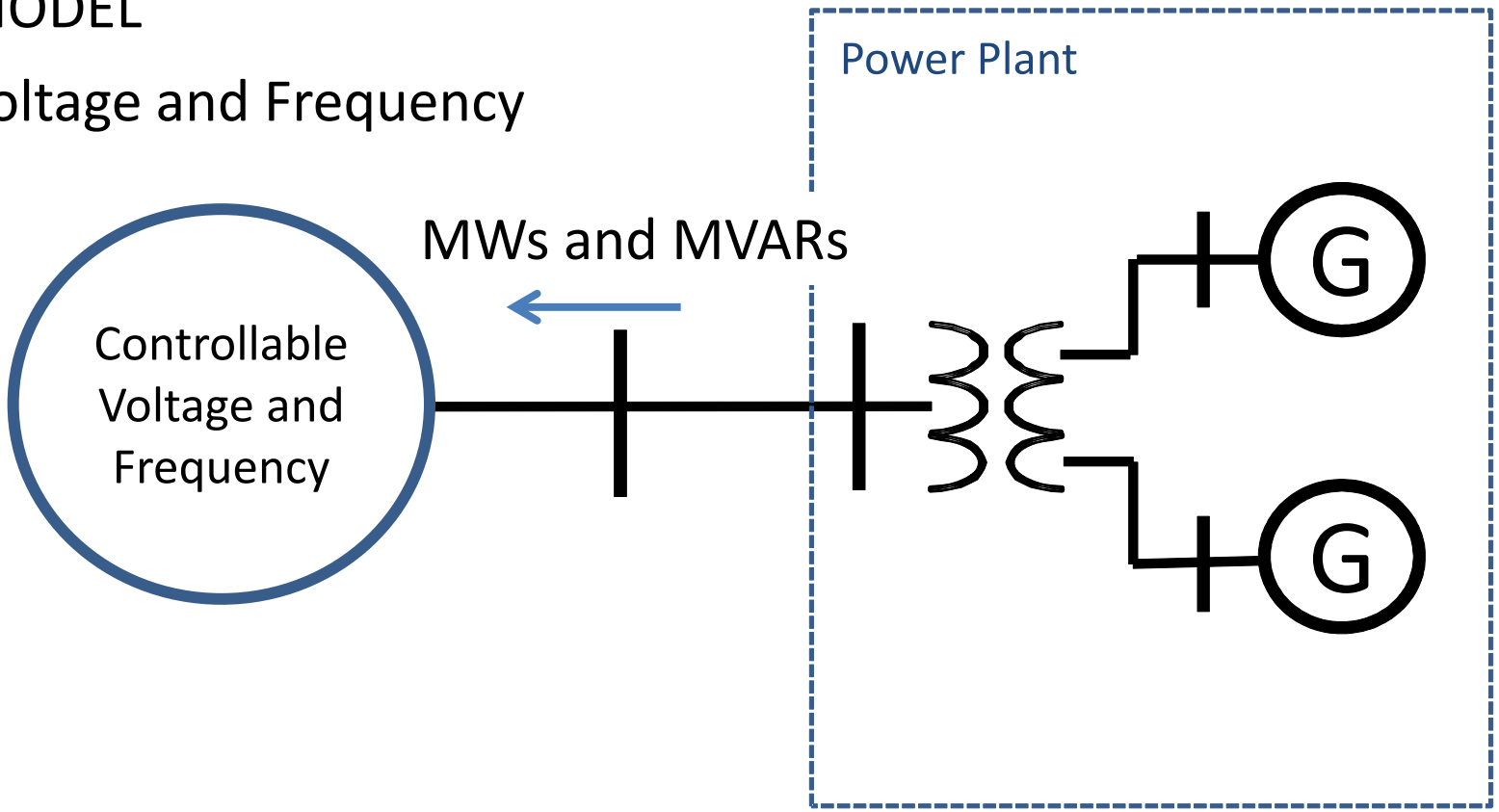
PPMV Tools

- BPA PPMV
  - Sequence of GE PSF EPCLs and MATLAB programs
- **BPA-PNNL PPMV**
  - Stand-alone data management program and automated PSLF interfaces
- Idaho Power
  - Excel macro with PI data link and PSLF interfaces
- EPRI PPPD
  - Stand-alone MATLAB based software

Mechanics of PPMV

MODEL

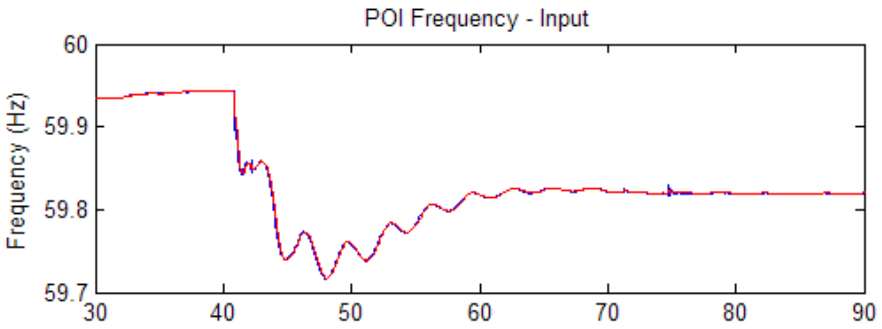
Voltage and Frequency

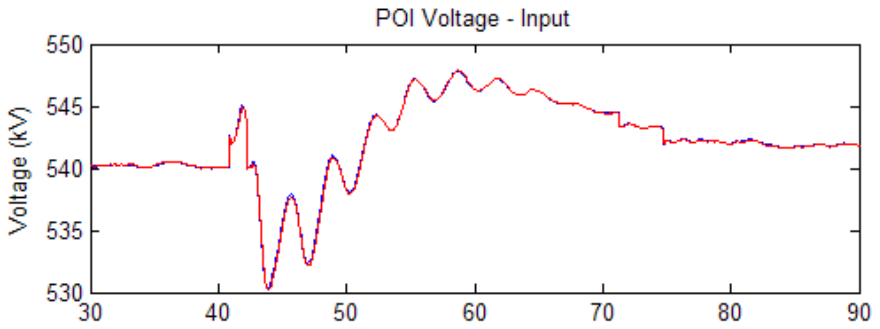


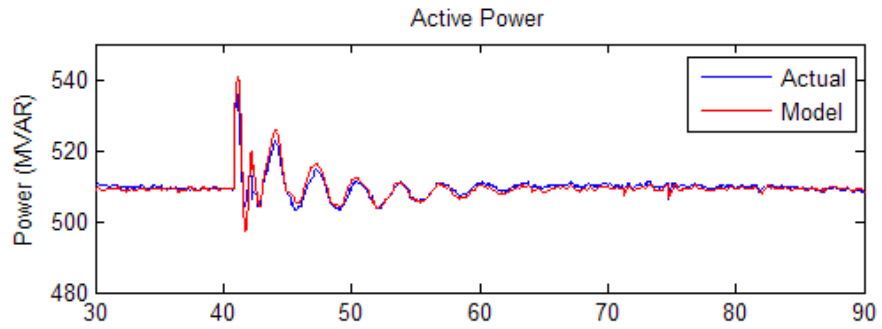
- **Measured and responded MWs and MVARs are compared for measures of success**

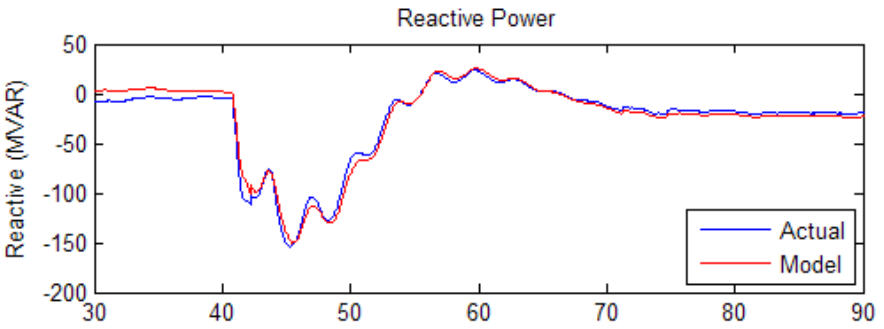
PPMV Results – Good Models

- What a good models looks like:







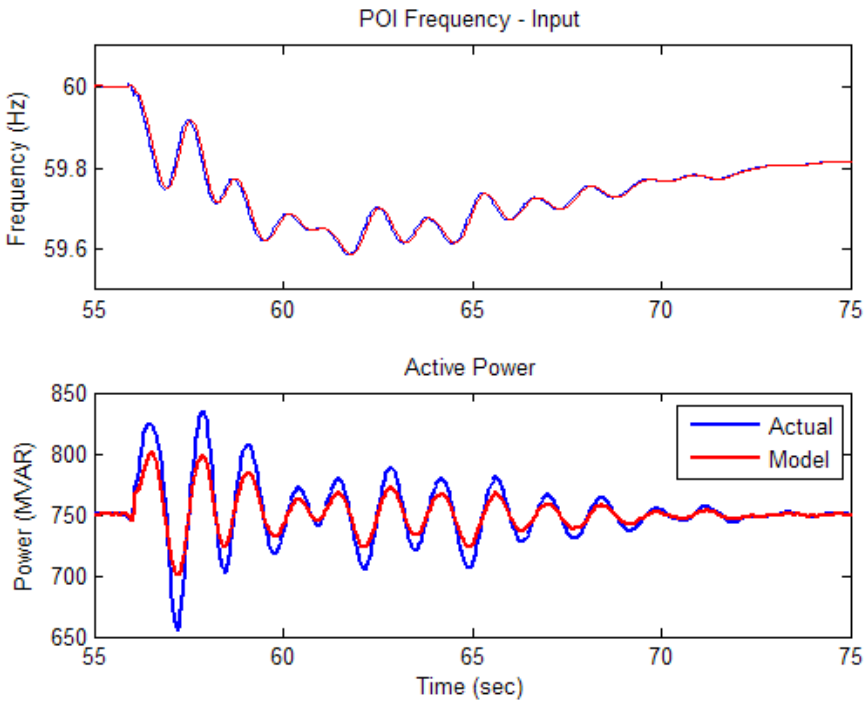


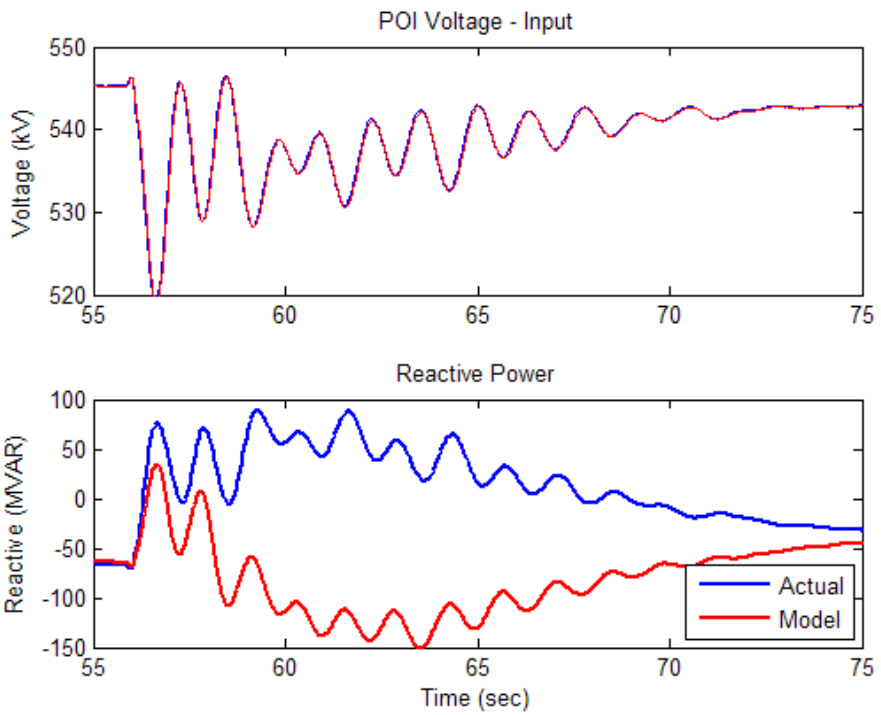
Voltage and frequency are inputs
Active and reactive power are “measures of success”

Blue line = actual recording
Red line = model

PPMV Results – Bad Results

- What a bad model looks like:





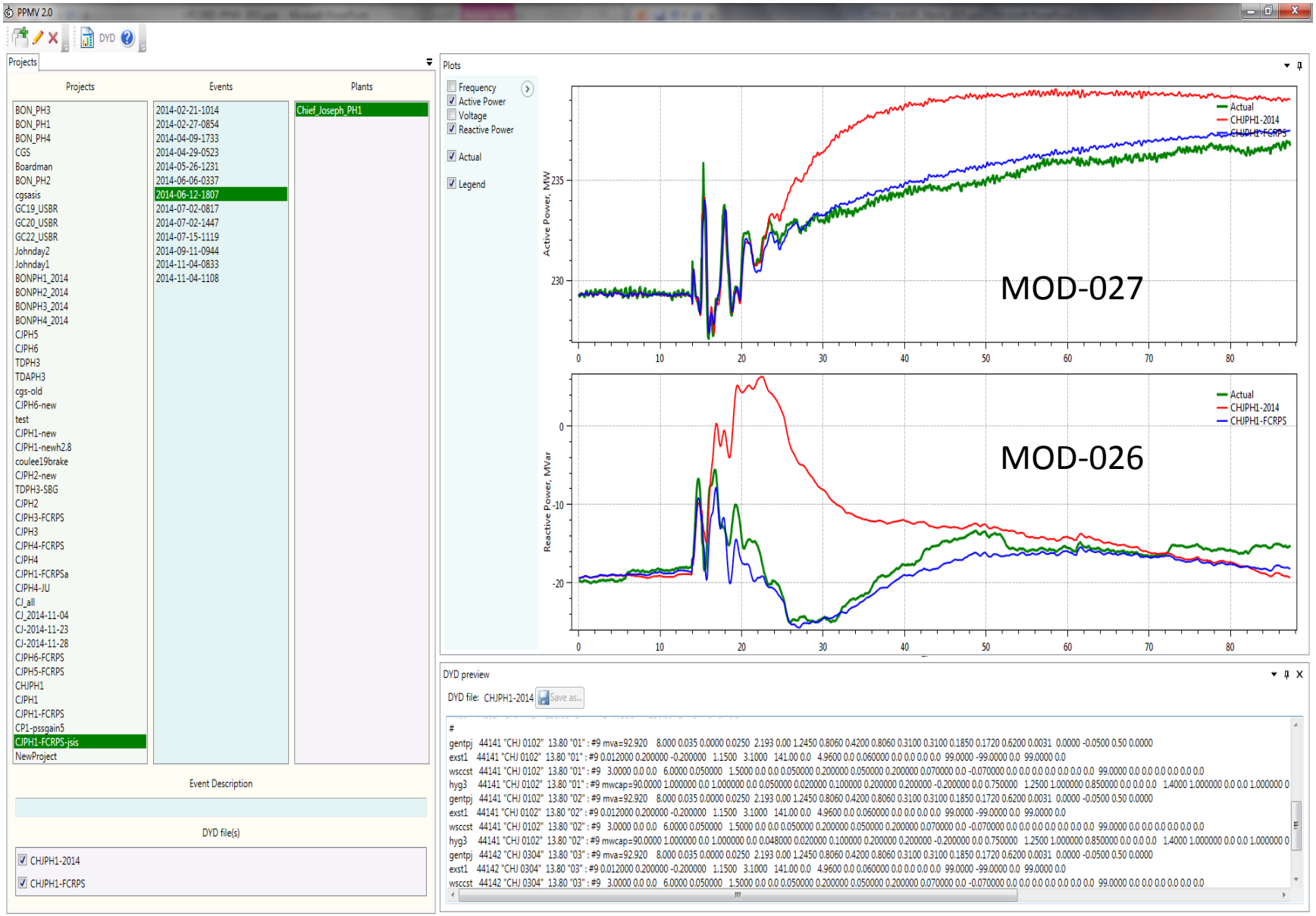
Voltage and frequency are inputs

Active and reactive power are “measures of un-success”

Blue line = actual recording

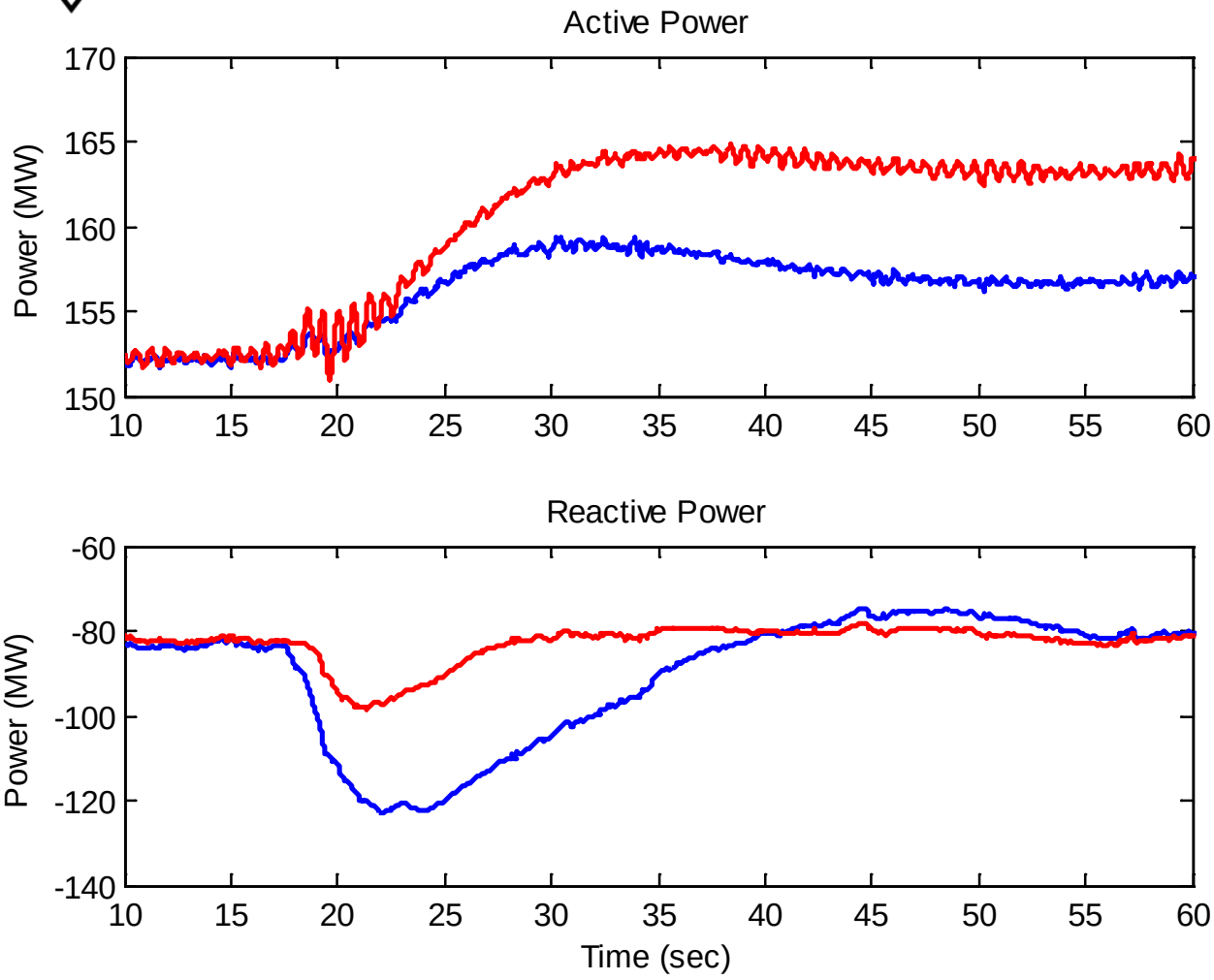
Red line = model

BPA-PNNL PPMV 2.0



Going Beyond the Standards

Verification of Consultant's Report



The same power plant tested by two different consultants

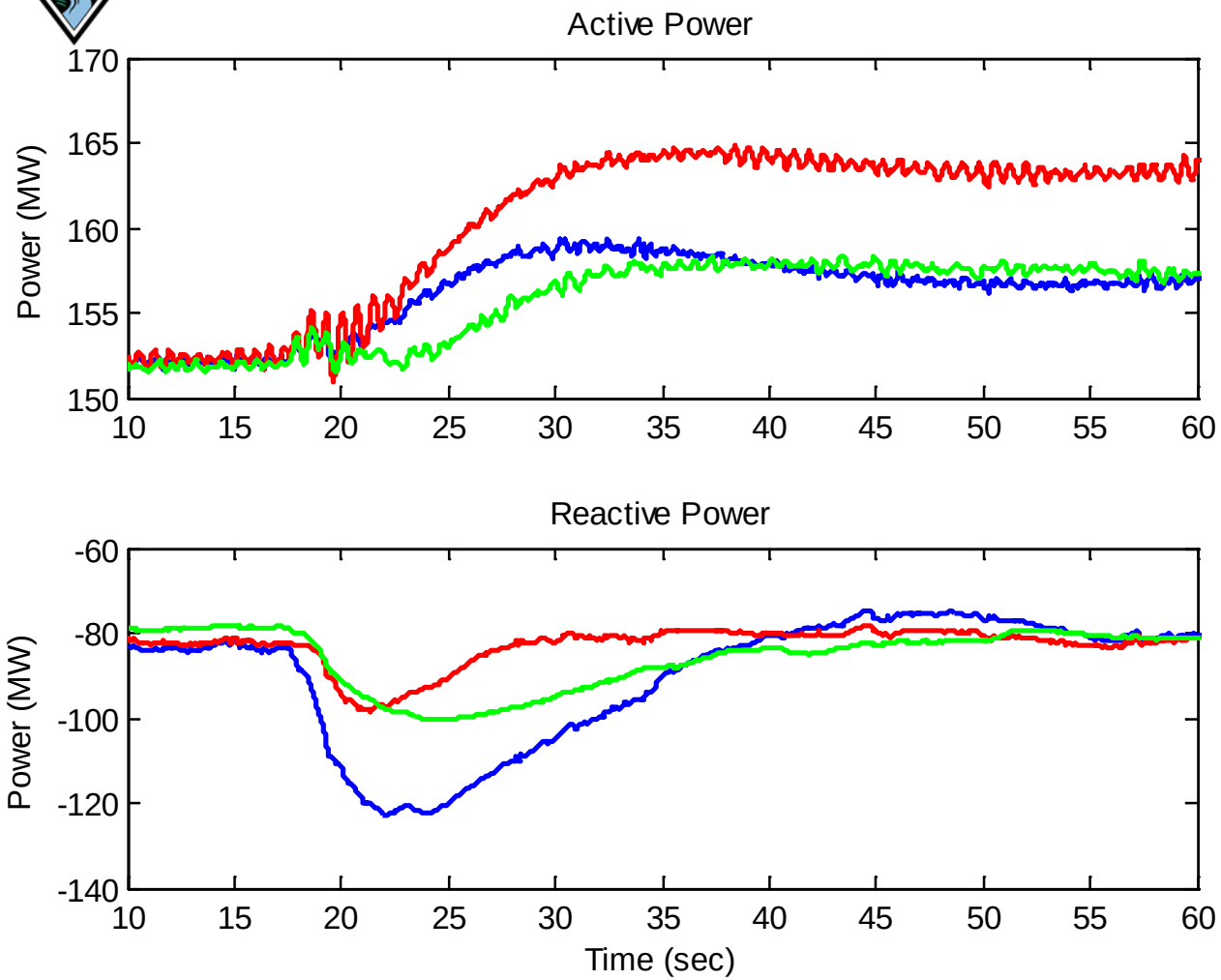
Consultant A

Consultant B

Which data is correct ?

You do not know unless you have an independent way of verifying

Verification of Consultant's Report



Consultant A

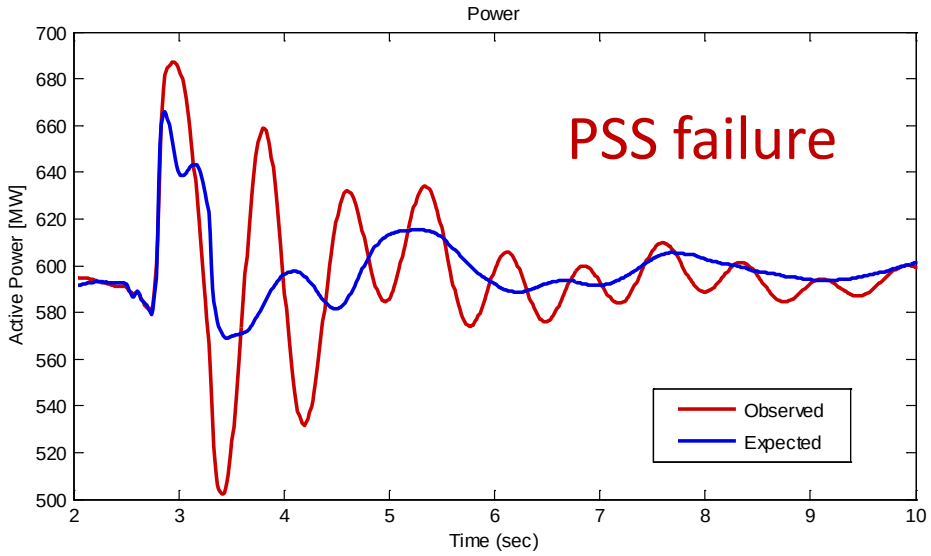
Consultant B

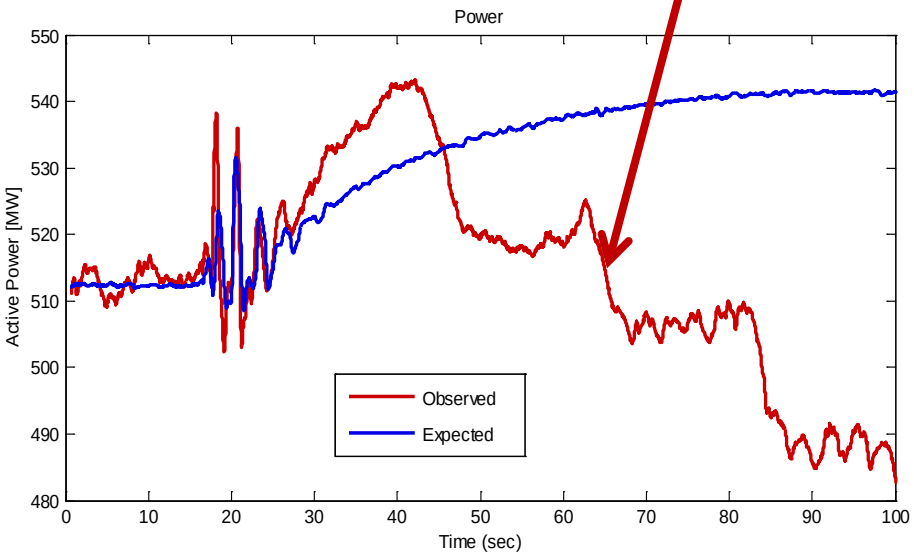
Reality

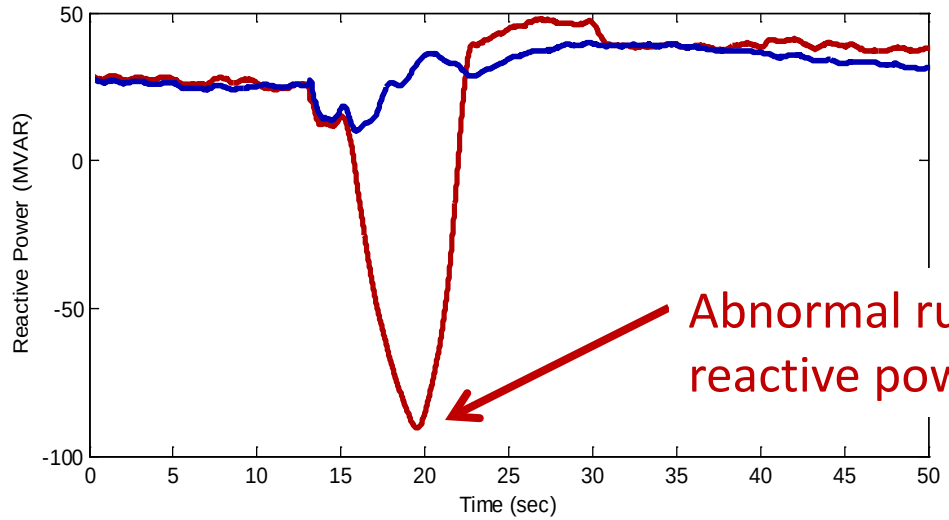
- Turned out neither consultant was right
- BPA experience suggests that 60 to 70% of models did not match disturbance recordings even after the baseline test was performed

Performance Monitoring and Detection of Control Failures

- PMU monitoring provides detection of generator abnormalities



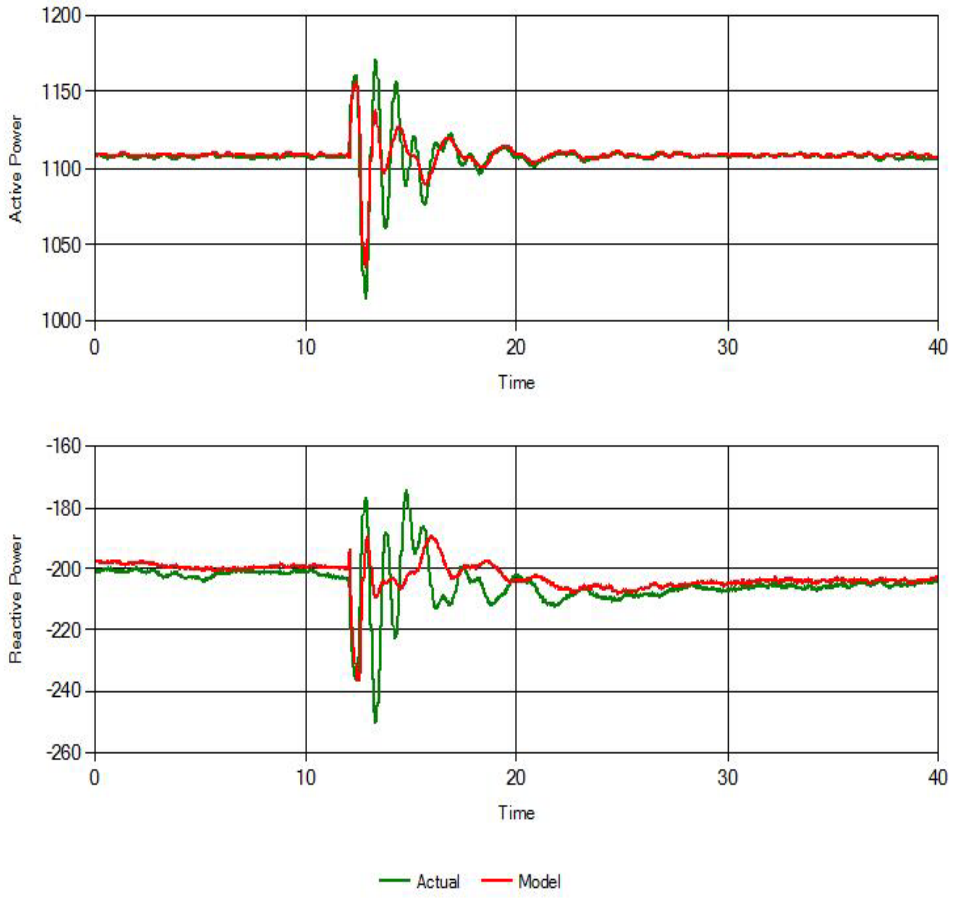


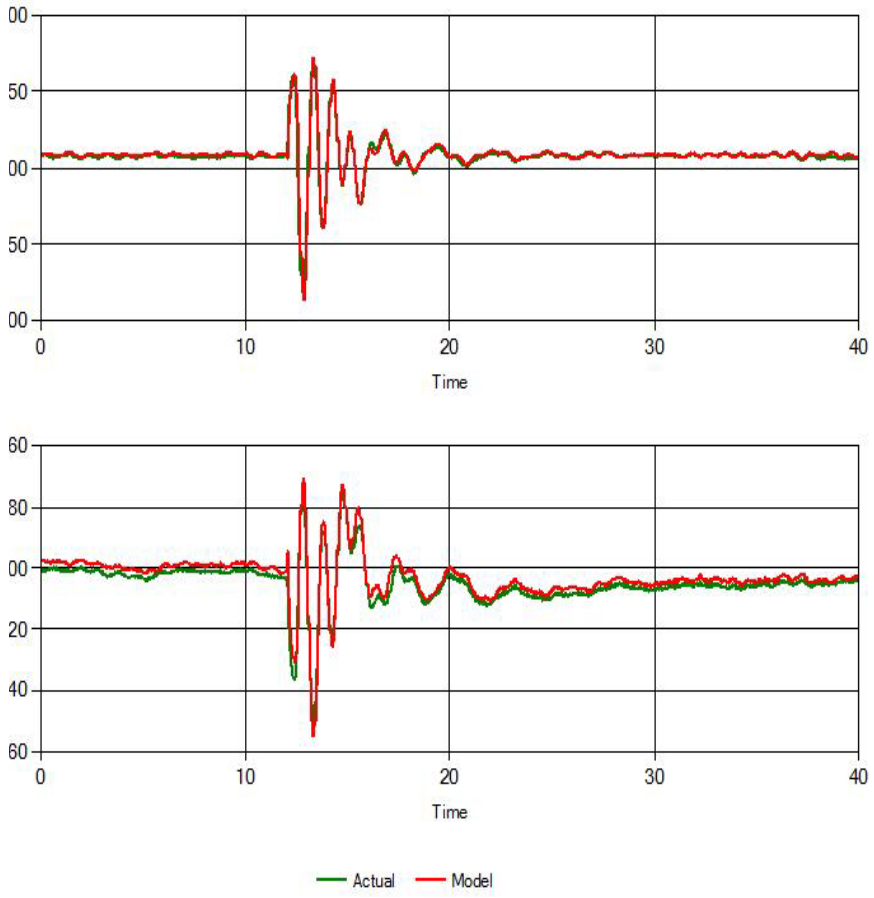


Calibration

Before calibration

After calibration





BPA Experience with Disturbance-Based Model Validation

- Most common model issues:
  - Power System Stabilizer models
  - Turbine control mode of operation / governor models
  - Generator inertia
  - Deficiencies in model structure
- Other reasons for model mismatch
  - Automatic Generation Controls
- “Clinical” experience:
  - Plants with modern digital systems have good models that stay accurate over time
  - Plants with legacy analog controls have most errors and tend to change in time and break without indication

Industry Outreach

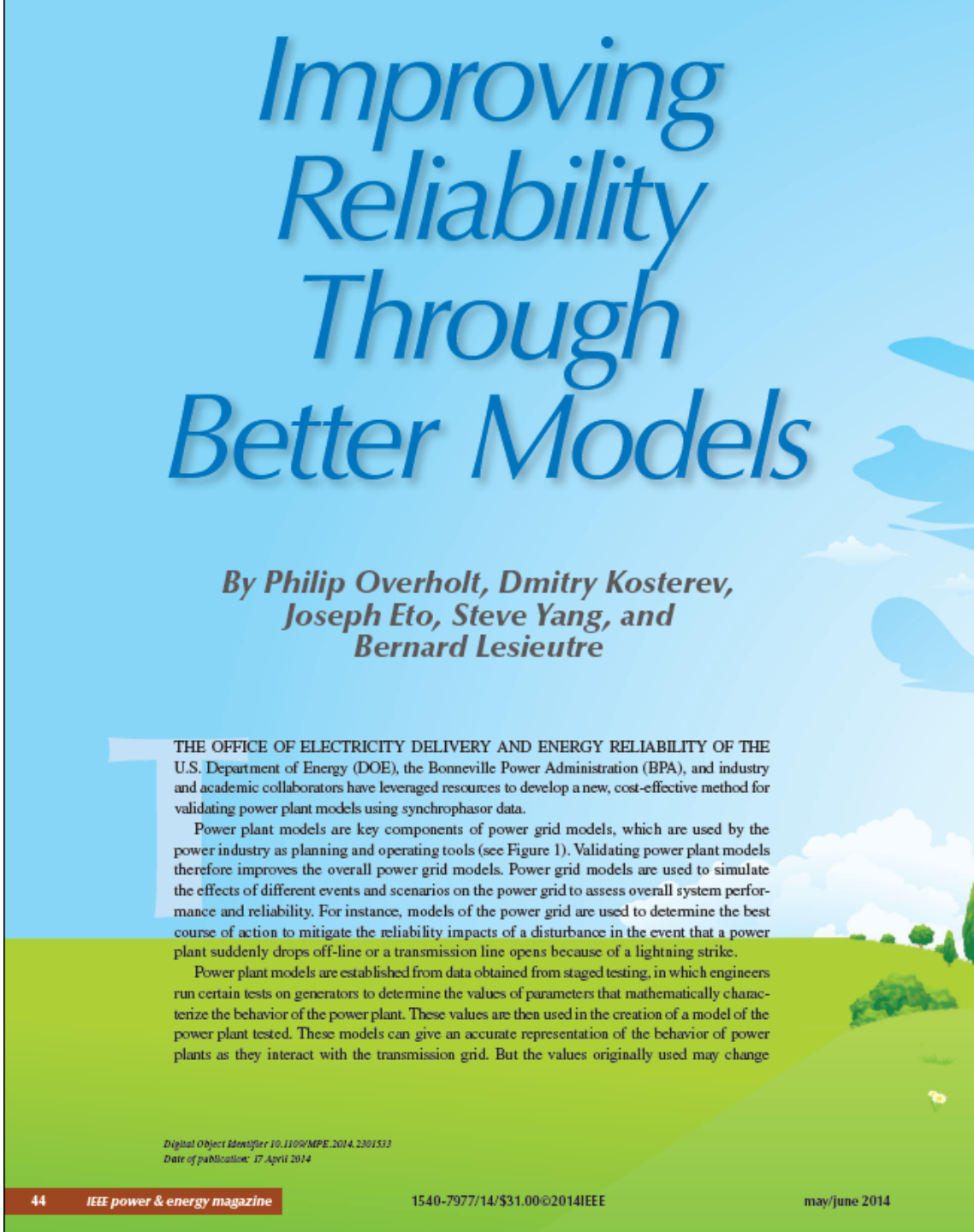
- Promoted PPMV to other utility since 2008
- PG&E recently completed validation using PPMV
  - "inspired by BPA-PNNL PPMV" Ron Markham – PG&E
- PNNL PPMV 2.0 tool development
  - User friendly UI
  - Automated
  - Sensitivity study
  - Enhanced plotting
  - Better data management
  - Report generator

Summary and Benefits

- PMU-based model validation is an acceptable method for GOs to comply with NERC MOD-026 & 027 and WECC policy
  - assuming a correct baseline model is developed
- PMU-based model validation can be used by TPs to independently verify that the models provided by GOs are accurate
  - BPA experience suggests that 60 to 70% of models did not match disturbance recordings even after the baseline test was performed
  - TPs need independent method of model verification – it is difficult to police traffic if you do not have a speed radar
- PMU-based model validation allows more frequent model verification and detection of control failures than once every 10 years (per NERC) or 5 years (per WECC)

Publications

- DOE Report on Model Validation
- CIGRE Tutorial
- CIGRE Paper
- **IEEE Magazine paper**
- ERCOT Technical Conference
- NASPI Meetings



Improving Reliability Through Better Models

By Philip Overholt, Dmitry Kosterev, Joseph Eto, Steve Yang, and Bernard Lesieutre

THE OFFICE OF ELECTRICITY DELIVERY AND ENERGY RELIABILITY OF THE U.S. Department of Energy (DOE), the Bonneville Power Administration (BPA), and industry and academic collaborators have leveraged resources to develop a new, cost-effective method for validating power plant models using synchrophasor data.

Power plant models are key components of power grid models, which are used by the power industry as planning and operating tools (see Figure 1). Validating power plant models therefore improves the overall power grid models. Power grid models are used to simulate the effects of different events and scenarios on the power grid to assess overall system performance and reliability. For instance, models of the power grid are used to determine the best course of action to mitigate the reliability impacts of a disturbance in the event that a power plant suddenly drops off-line or a transmission line opens because of a lightning strike.

Power plant models are established from data obtained from staged testing, in which engineers run certain tests on generators to determine the values of parameters that mathematically characterize the behavior of the power plant. These values are then used in the creation of a model of the power plant tested. These models can give an accurate representation of the behavior of power plants as they interact with the transmission grid. But the values originally used may change

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R.O.I.

- PMU - $8k
- Local PDC network - $25k
- Blackout – Billions of dollar
- Not to be the one to cause one – “Priceless”

Thank You!

Contact information:

Steve Yang (hyang@bpa.gov)

Dmitry Kosterev (dnkosterev@bpa.gov)