Power Plant Model Validation

i-PCGRID

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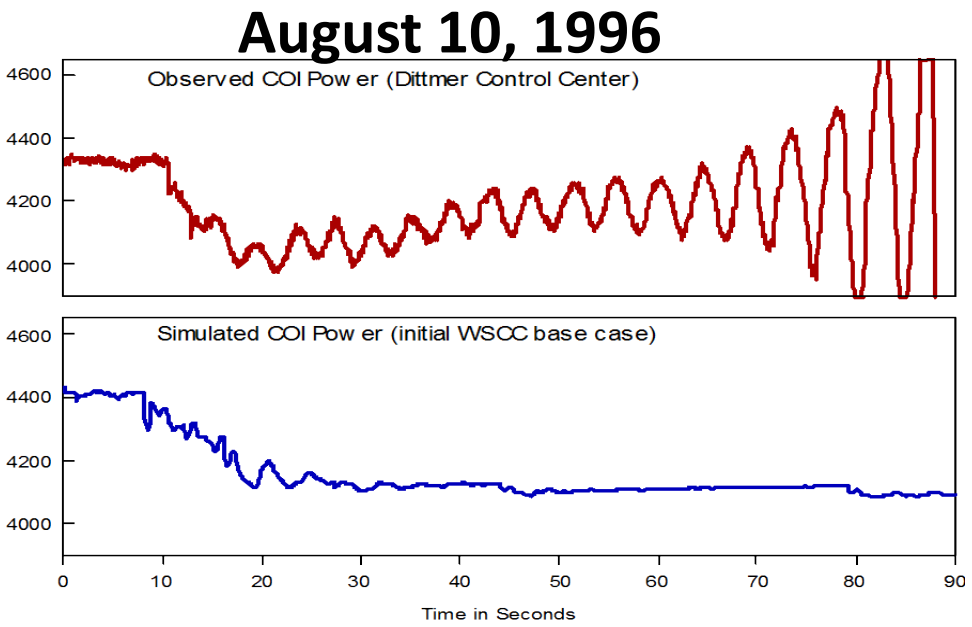
Motivation

1996: July 2nd and August 10th Outages

- Failure of models to predict or reproduce the 1996 disturbances
- Loss of confidence in model's ability to set transfer capability limits
- Intertie capacities de-rated by 33%



1996 – WSCC required that all generators larger than 10 MVA be tested for the purpose of model verification

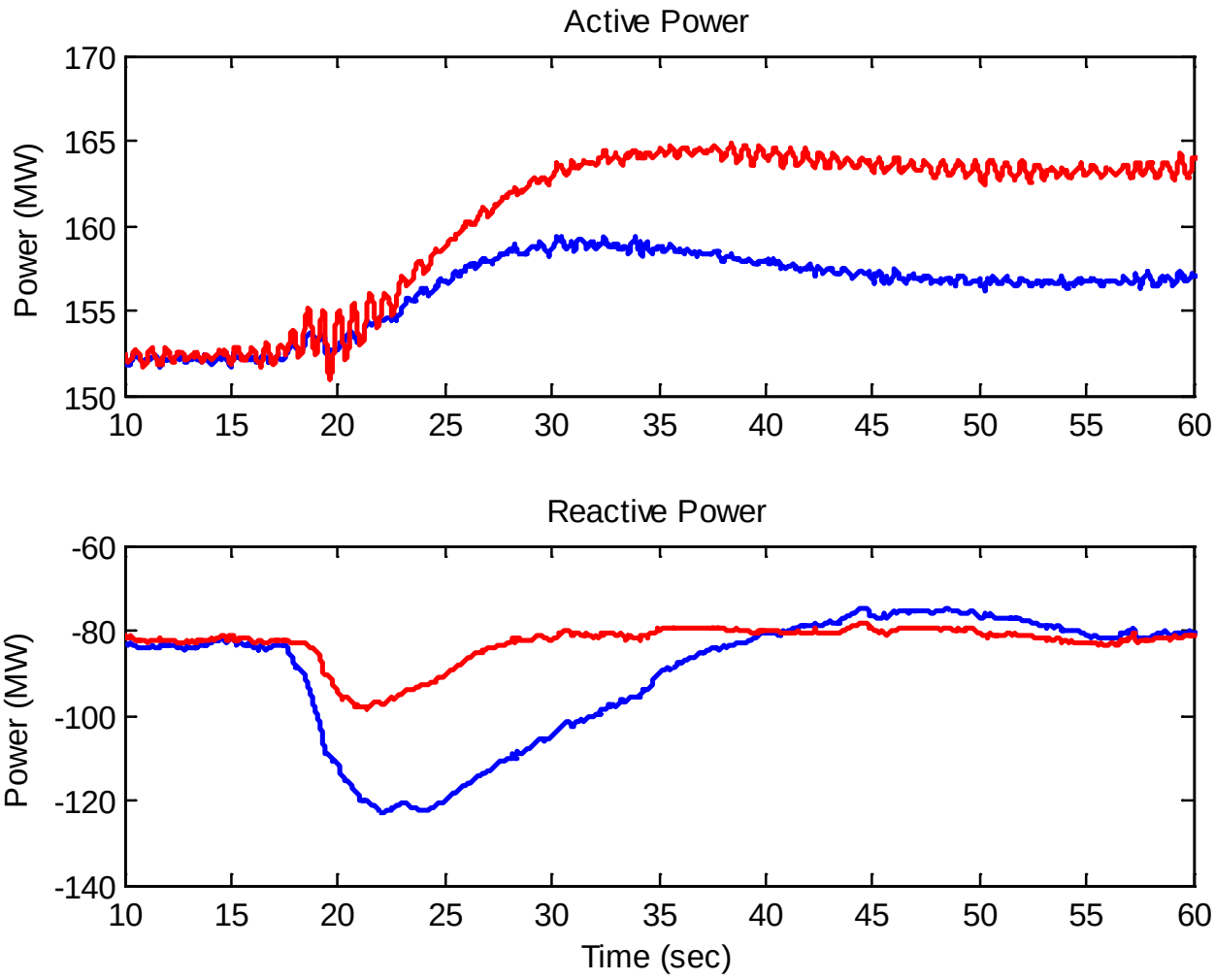
2006 WECC Generating Unit Model Validation Policy

- Data Requirements
  - Data must be provided using grid simulator models
- Baseline testing
  - Required for new plants, when equipment changes are made
  - When the model is in error
- Periodic model verification
  - Done every 5 years to make sure that models are up to date
- Reactive limit testing

Reliability Standards

- Existing NERC Standards
  - NERC MOD-010 and 012 - plant operator to provide accurate model data
- Upcoming/pending NERC Standards
  - NERC MOD-025 - reactive power capabilities verification
  - NERC MOD-026 – generator and excitation control model verification
  - NERC MOD-027 – generator turbine control model verification
  - NERC PRC-019 – coordination of generator protection and controls

More Motivation



The same power plant tested by two different consultants

Consultant A

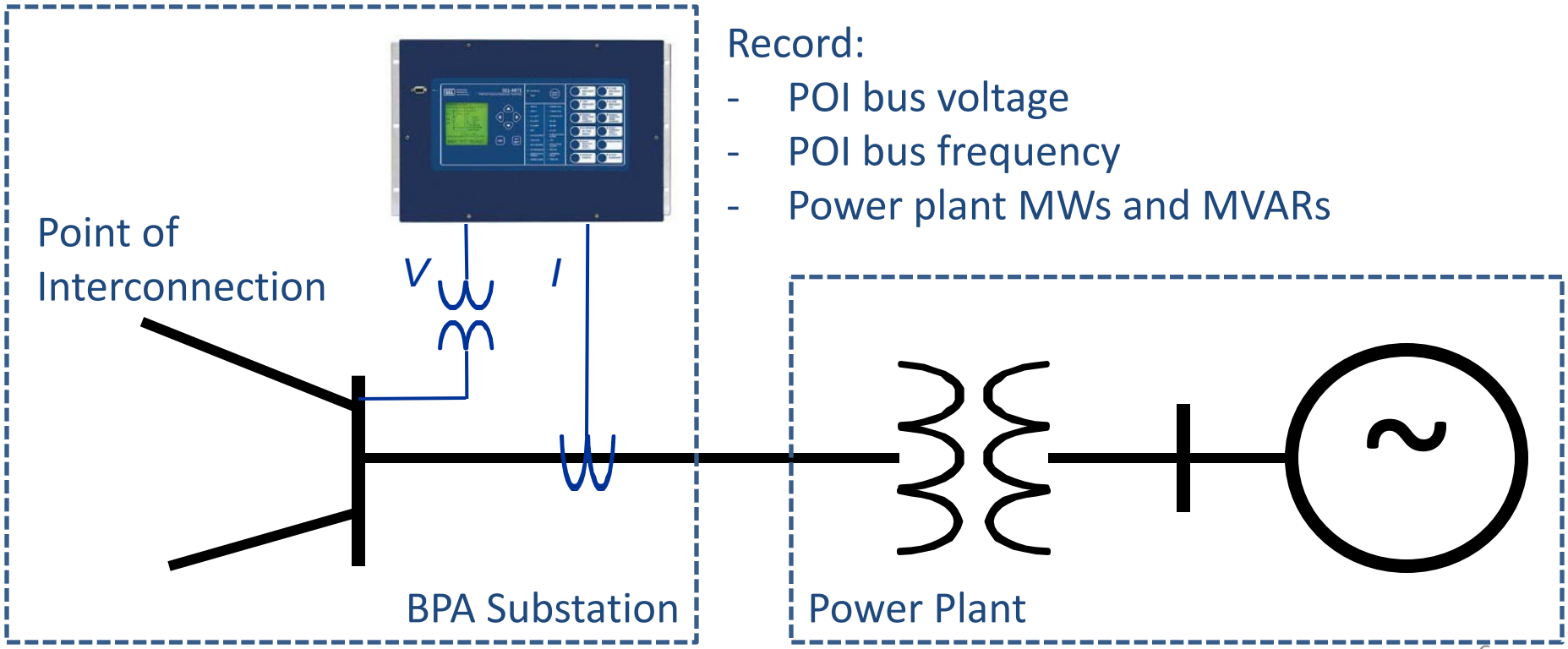
Consultant B

Which data is correct ?

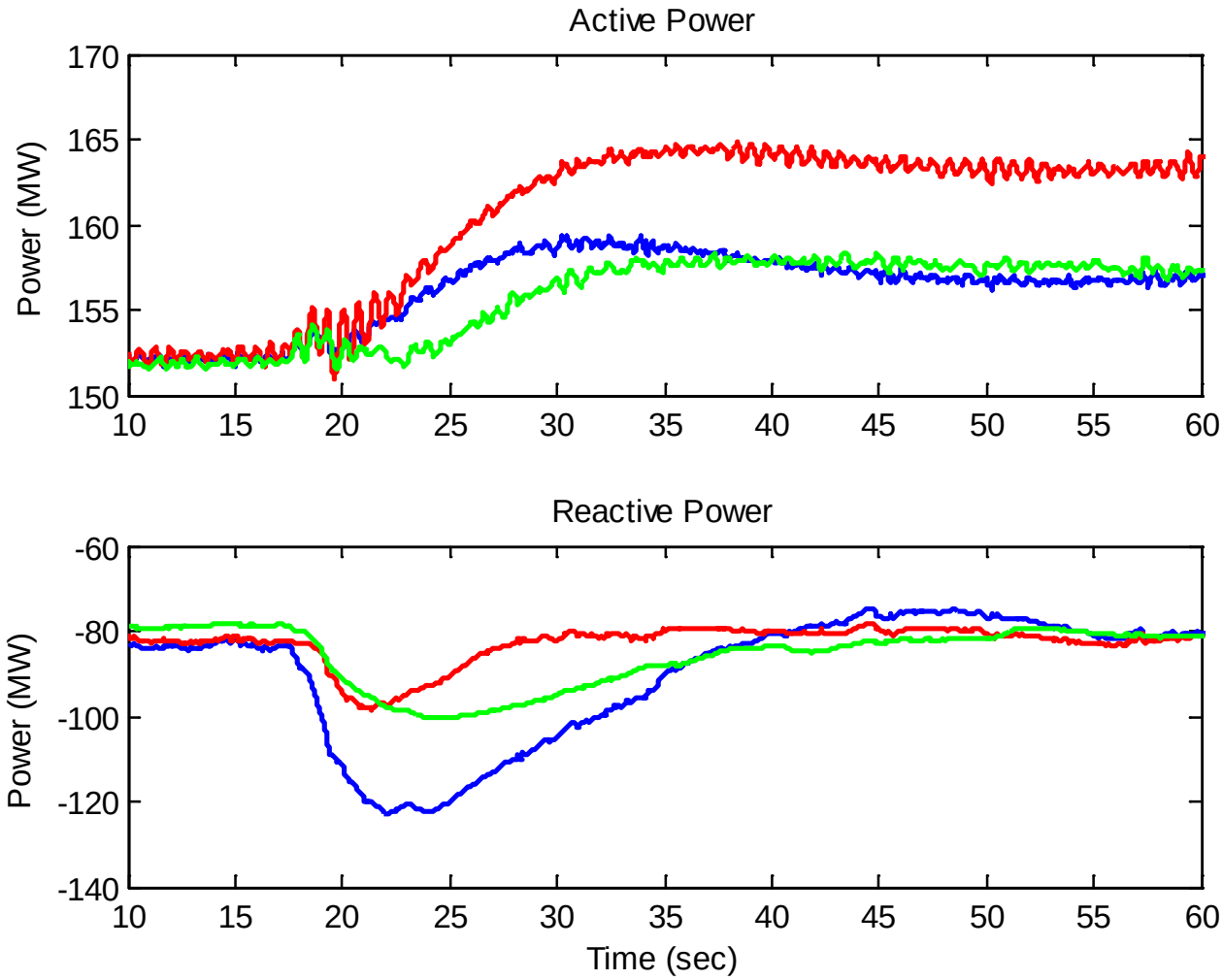
You do not know unless you have an independent way of verifying

Using PMU Data for Model Validation

- BPA has installed PMUs at power plant POIs
- BPA developed Power Plant Model Validation (PPMV) application using PMU data
- GE PSLF playback function



More Motivation Cont.



Consultant A

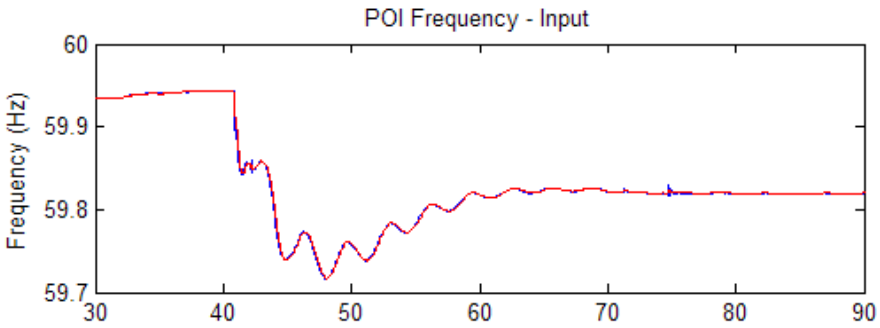
Consultant B

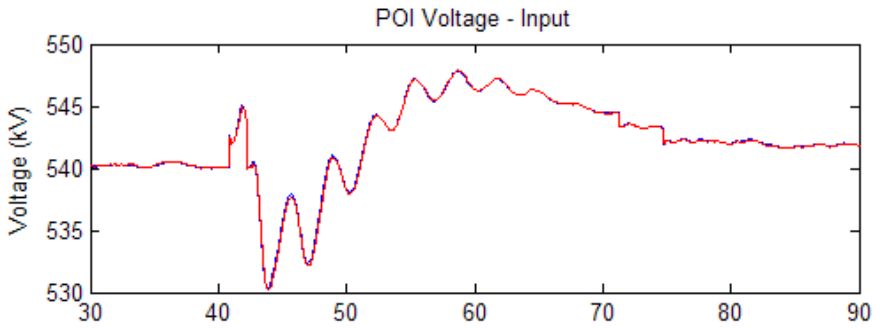
Reality

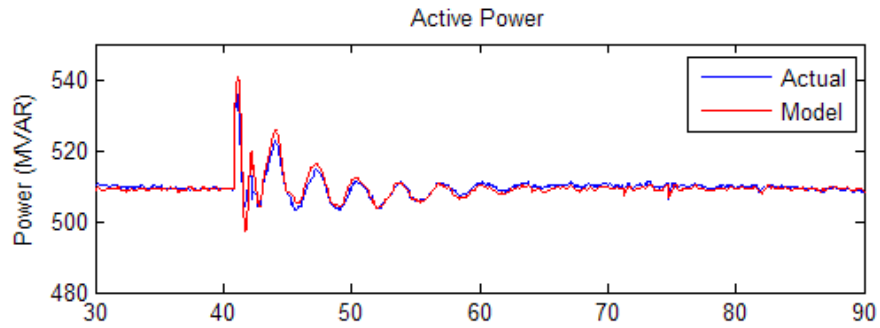
Turned out neither consultant was right

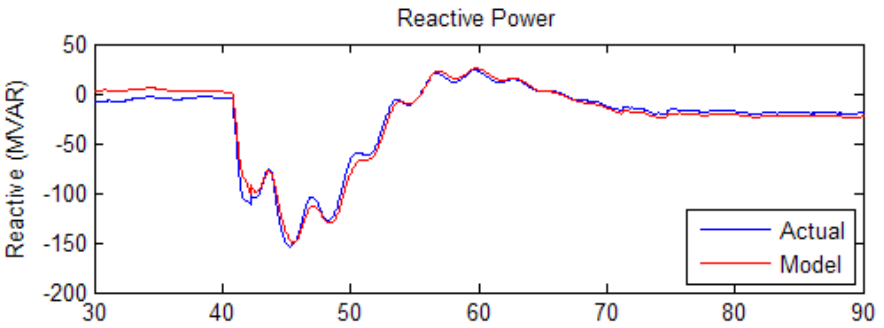
Power Plant Model Validation

- What a good models looks like:







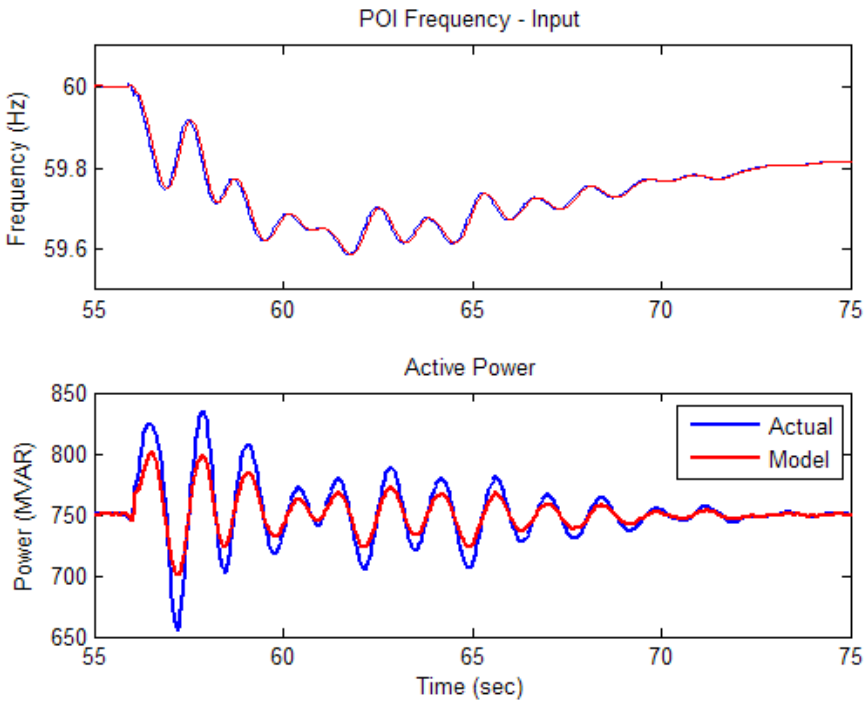


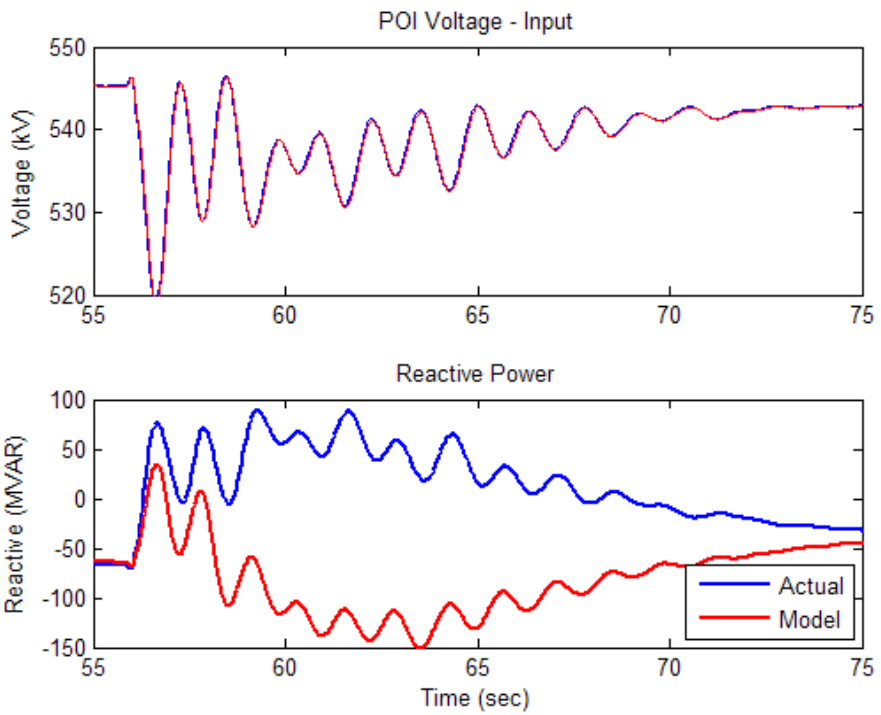
Voltage and frequency are inputs
Active and reactive power are “measures of success”

Blue line = actual recording
Red line = model

Power Plant Model Validation

- What a bad model looks like:





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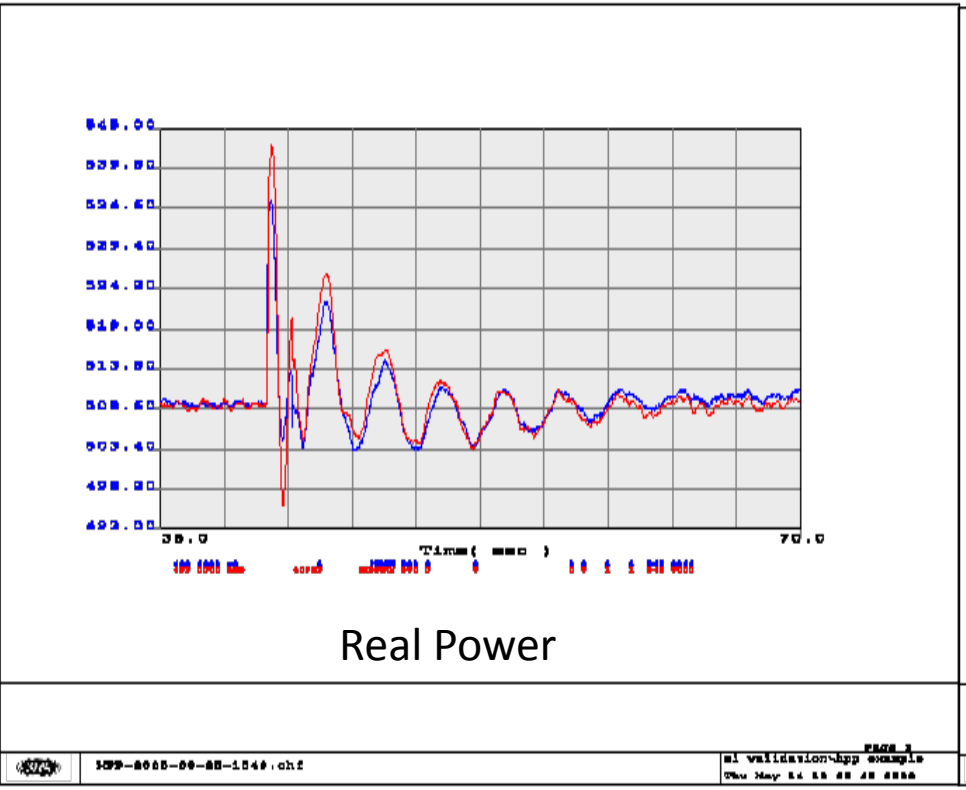
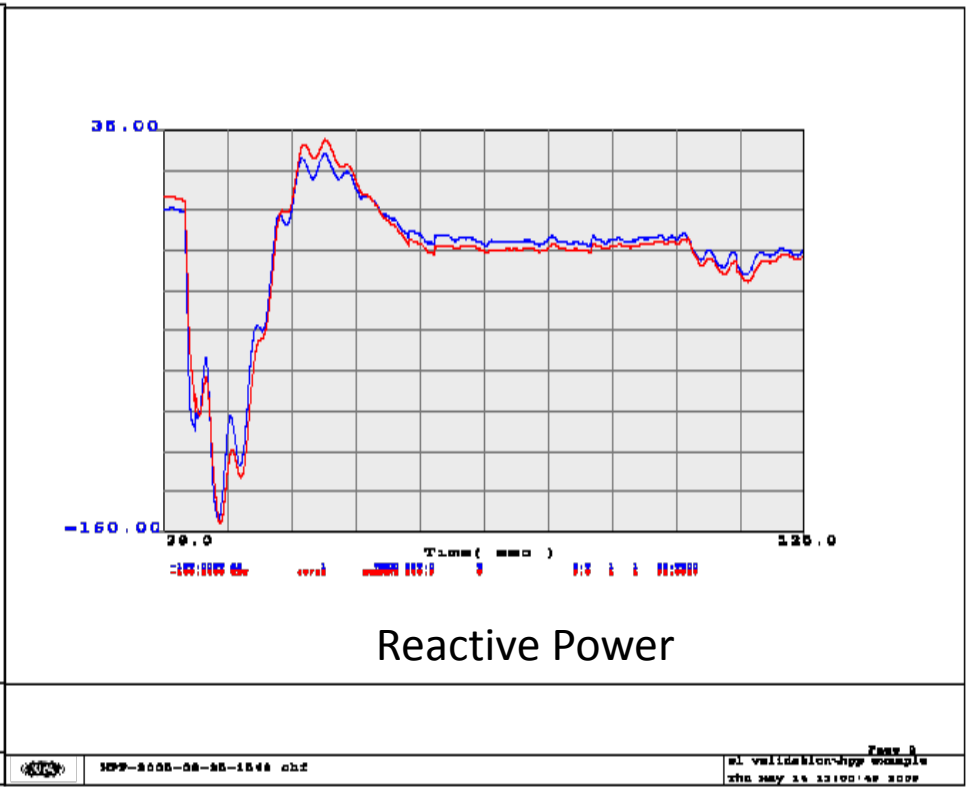
Recertification of Calpine Power Plant

- 2010 WECC recertified Calpine using BPA's report
  - There was no data adjustment
  - No re-test needed
  - Savings of $30k without loss of production
  - No wear and tear of the machines



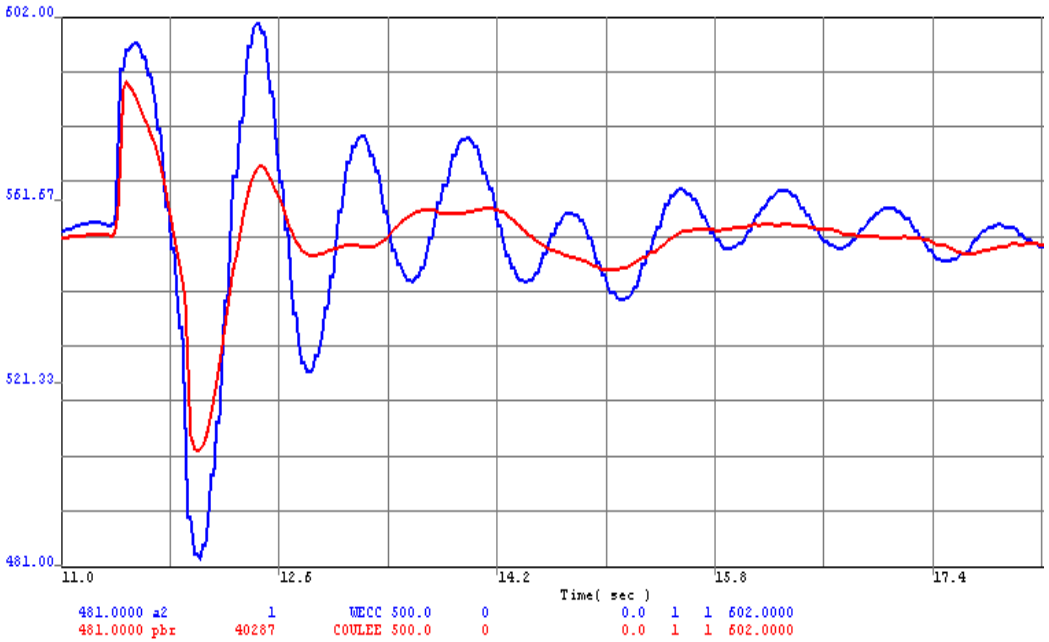
Real Power



Reactive Power

Performance Monitoring and Detecting Generator Control Failures

- Once a good baseline is developed, PMU is used for "clinical" assessment of power plant performance



Blue line = actual response

Red line = expected response

- Controller status at the generator was indicating normal state
- PMU disturbance data indicated actual response very different from what was expected
- Power plant was contacted, controls inspected, found internal failure of Power System Stabilizer

Model Calibration

- Can do pass / fail check (PSS)
- Simple sensitivity tests
- BPA has worked with Bernie Lesieutre at University of Wisconsin to determine how the PMU data can be used for model calibration (pattern matching)

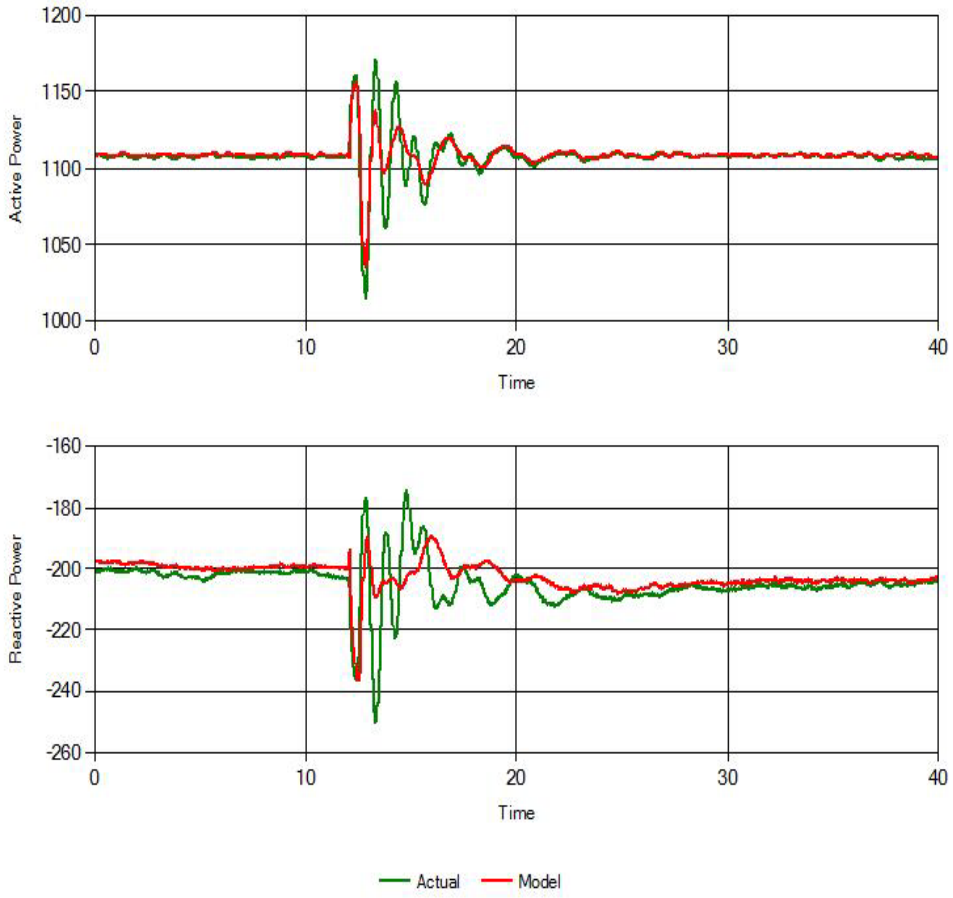
CGS Model Calibration

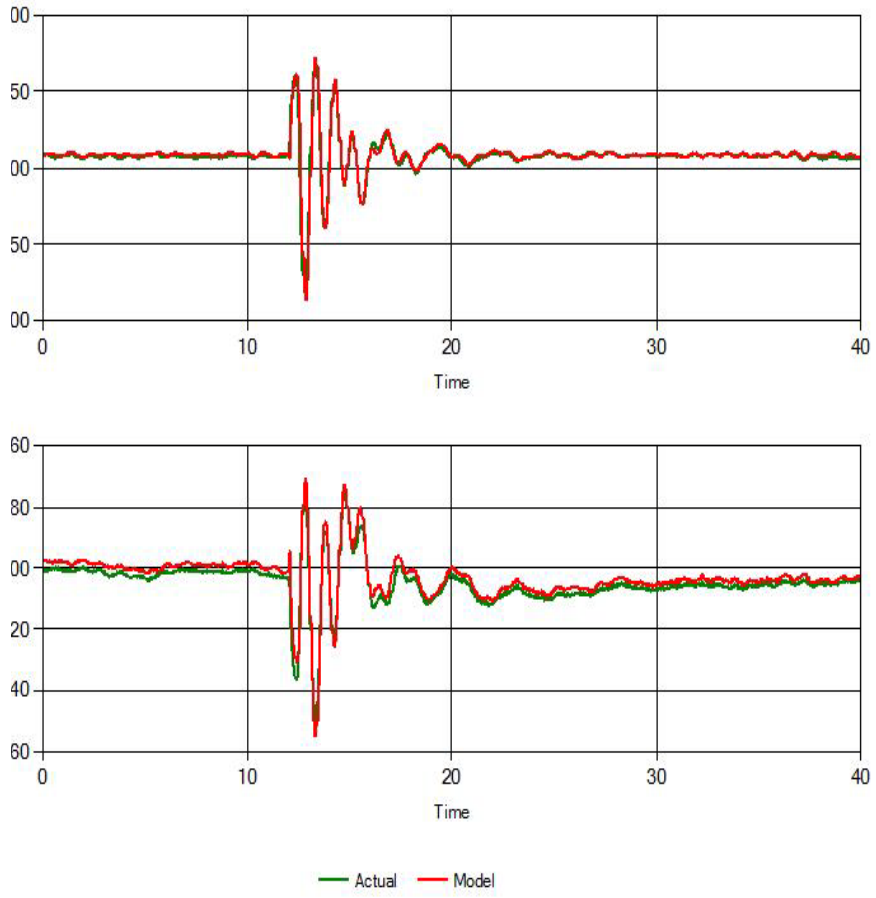
- The dynamic model adjustments included (old model data in in parenthesis):
  - Generator-turbine inertia, H = 4.89 sec (5.1211)
  - Exciter:
    - AVR gain, Ka = 400 (250) – low impact
    - AVR feedback gain, Kf = 0.0331 (0.06)
    - AVR feedback time constant, Tf = 0.9163 (1.0)
    - AC exciter field time constant, Te = 1.500 sec (1.04)
  - Power System Stabilizer
    - PSS Gain, Kqs = 1.5253 (1.24)
    - PSS Wash-out time constant, Tq = 30 sec (10)
    - Lag time constant, Tq1 = 0.05 sec (0.173)
    - Lead time constant, Tpq1 = 0.20 sec (1.2650)

Recertification of CGS Power Plant

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

Benefits of PMU-based Model Validation

- Disturbance recordings can complement the baseline model development (e.g. TransAlta – BPA work at Centralia)
- 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 (e.g. Grand Coulee and Colstrip) than once every 10 years (per NERC) or 5 years (per WECC)

Industry outreach

- Promoted PPMV to other utility since 2008
- Idaho Power started using PPMV application
- PNNL PPMV tool development
  - User friendly UI
  - Automated
  - Better data management
  - Report generator
- PG&E just started to use PNNL tool