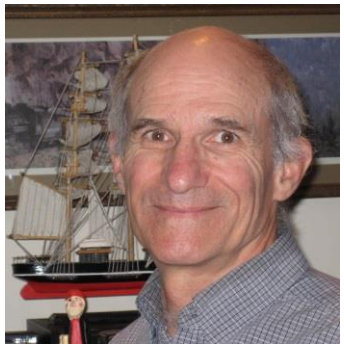
Operationalizing Phasor Technology

Model Validation

Webinar

March 4, 2014



Presented by

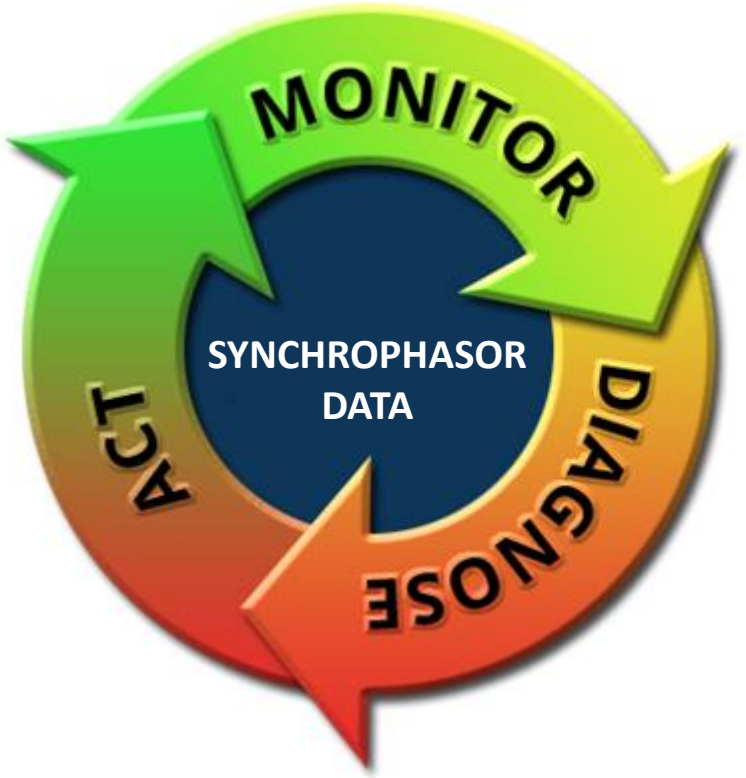
Ken Martin

Electric Power Group

Model Use and Validation for Operations and Planning

Compare System Performance with Model Prediction

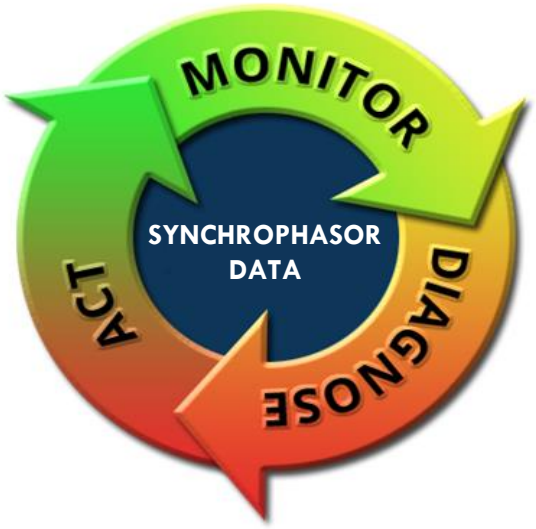
Tune Model to Match System Response



Identify Root Cause for Differences
e.g., Generator parameters

Presentation Outline

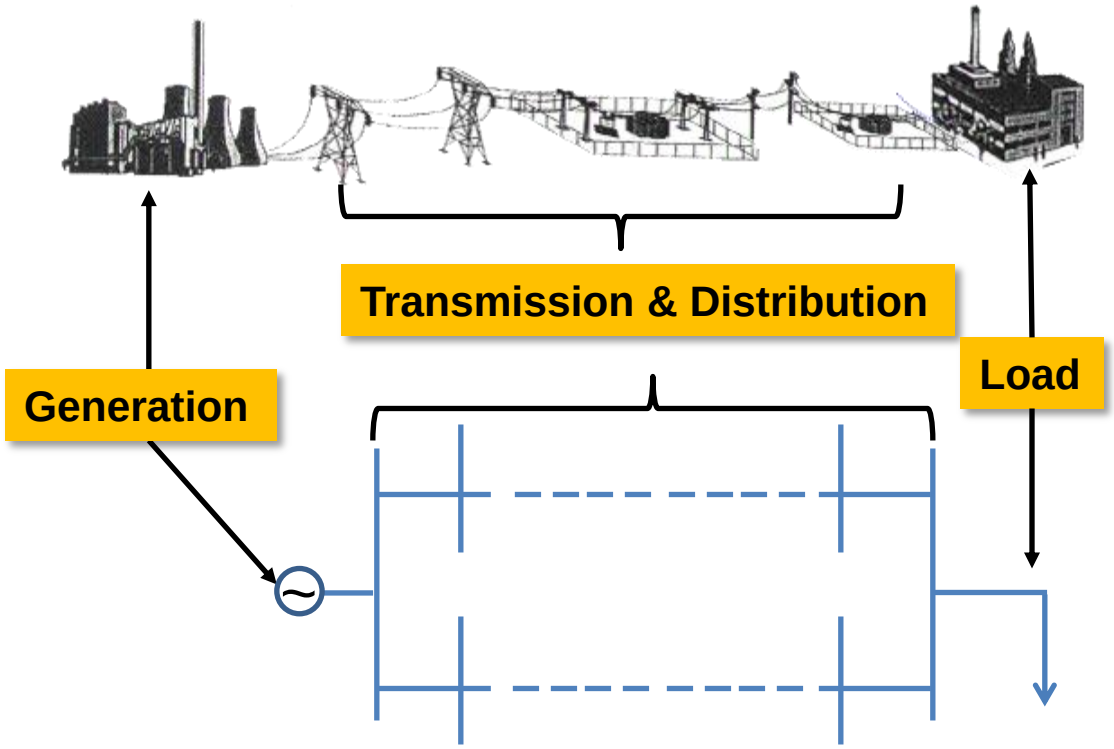
- Frequently asked questions
- What is a model?
- Types of power system models
- Why model validation is important
- How to validate models
- Model validation examples
- Summary
- Q & A



Frequently Asked Questions

- Why are models important?
- What models are used in operations and planning?
- Why do I need to validate a model?
- How do I validate the model?
- How do I prove that the model is accurate?
- Is phasor data sufficient to validate a model?

What is a Model?



$$Y_{bus}V = I \qquad Y_{bus} = \begin{bmatrix} Y_{11} & Y_{12} & \dots & Y_{1n} \\ Y_{21} & Y_{22} & \dots & Y_{2n} \\ \dots & \dots & \dots & \dots \\ Y_{n1} & Y_{n2} & \dots & Y_{nn} \end{bmatrix} \qquad S = VI^*$$

- A modern Power System Model is a set of equations representing a real power system
- All components including generators, transformers, transmission lines, reactive devices, and loads are represented as model elements
- The system model includes all elements connected as they are in the real system
- For any given condition, it should produce the same response as the real power system
- **Real-time operation depends on an accurate system model**

Types of Power System Models

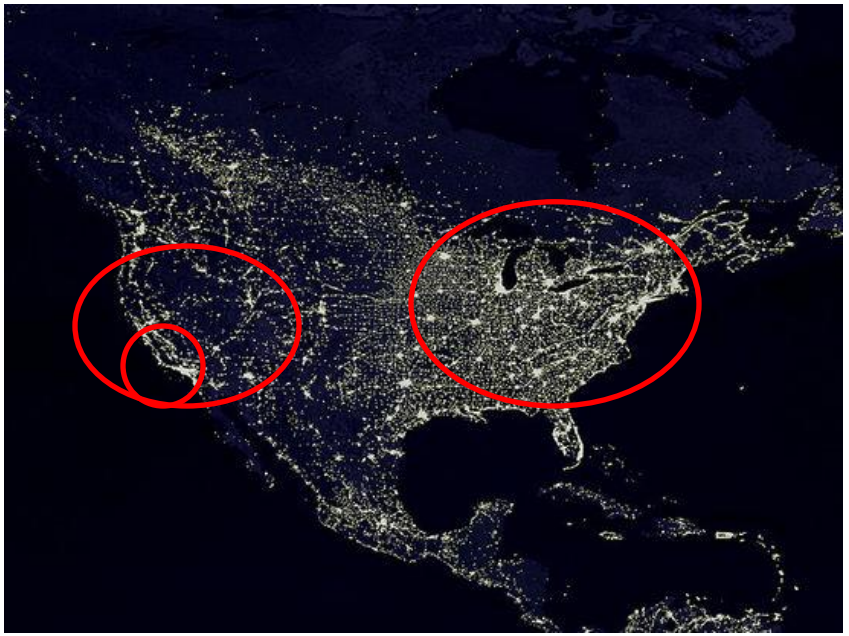
Model	Time	Use	Tools
Steady State	sec	Power Flows; Operating Conditions	PSLF; PSS\E; Power World; Eurostag
Dynamic	ms	System response to disturbances e.g. oscillations, phase angle change	PSLF; PSS\E; Power World; RSCAD-RTDS; ePHASORSim
Transient	μs	Faults, Transients	EMTP;RTDS; PSCAD; Aspen

Why Do We Use Models?

- **Power Systems Are Complex Networks**
  - Thousands of components
  - Loads are not clearly defined
  - Exact state unknown
  - Require models to understand system behavior
- **Correct Models are Used for Simulating Power System to:**
  - Establish safe operation limits
  - Develop operating guidelines
  - Study system contingencies
  - Analyze system events
  - Plan system expansion and resource integration

What Happens When Models Fail?

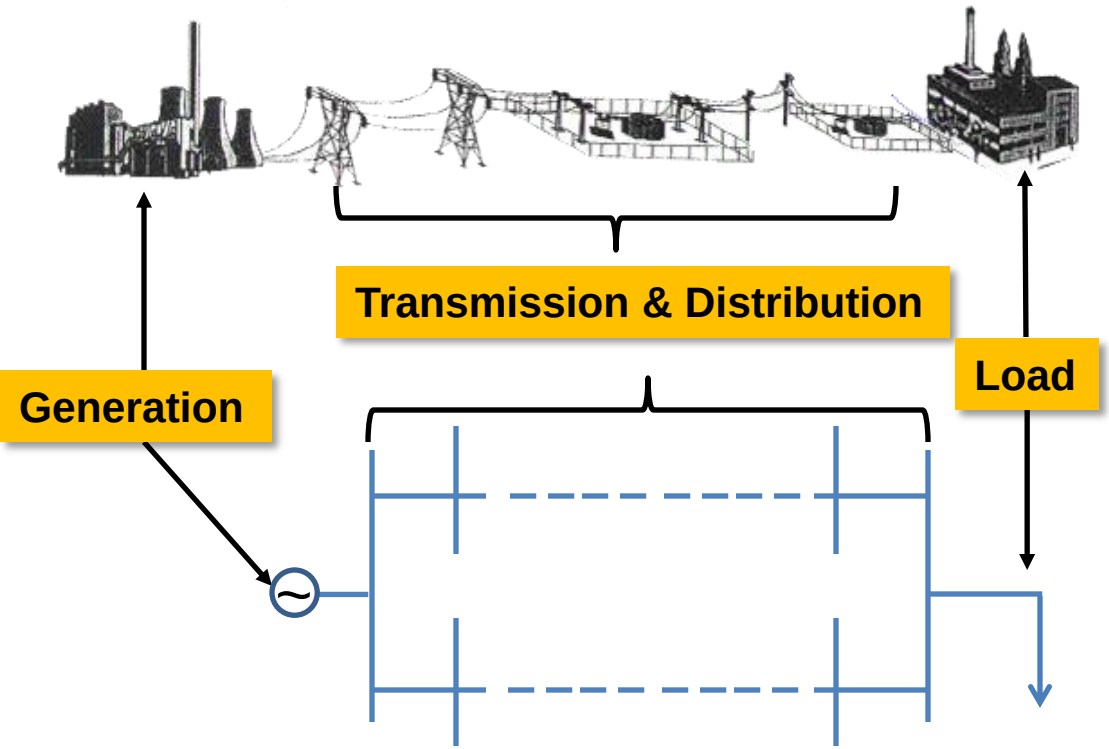
- WECC 1996 blackout
  - Model did not predict system oscillation
- EI 2003 blackout
  - Model did not predict power swing
- Pacific SW 2011 blackout
  - Model did not predict transmission overload
- Similar blackouts:
  - Italy 2003
  - Europe 2006
  - India 2012

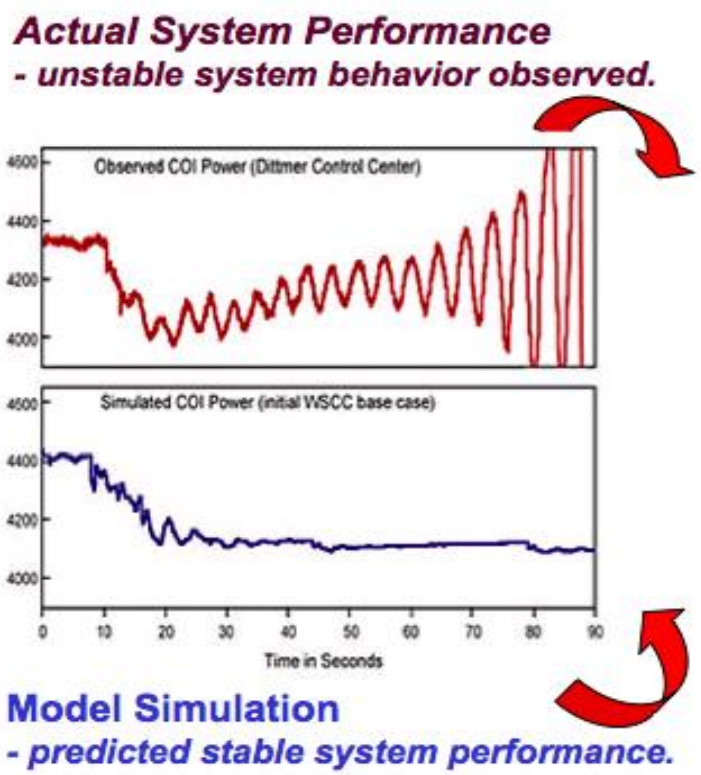


How Do We Validate Models?

- **Validate Models Using Events**
  - Significant operation (large generation loss, etc.)
  - Unexpected behavior
- **Calibrate Models Through Staged Tests**
  - Generator testing
  - System testing
- **Tune Models By Comparing Events and Simulations**
  - Run model with same conditions as recorded data
  - Compare measured performance with model results
  - Tune Model to match recording

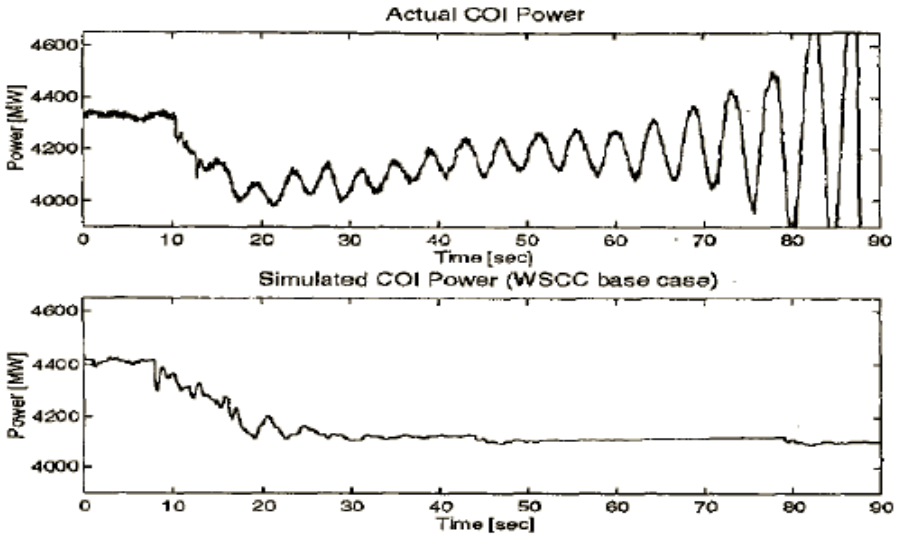
Validation Using a Significant Event



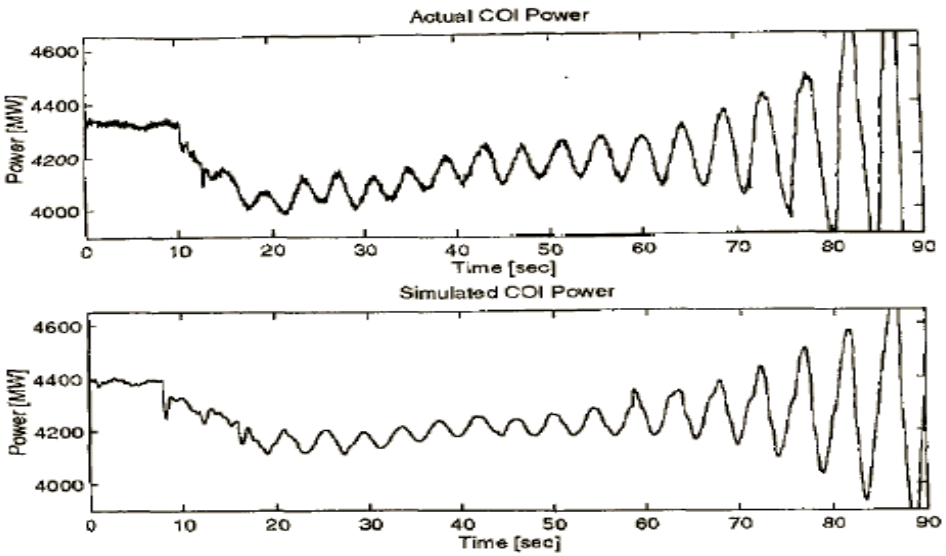


Model was NOT Accurate !

Model Tuning



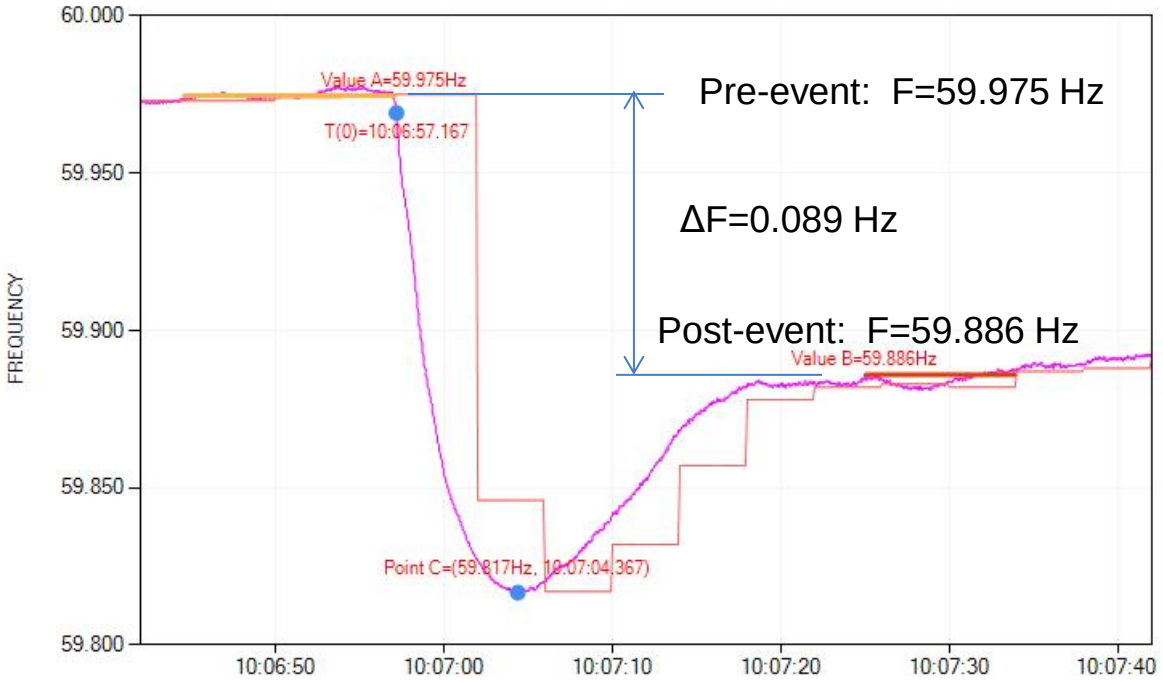
Model After Tuning – Matches System Performance



- **Models Tuned**
  - **Load**
  - **Governor**
  - **HVDC**

Model Validation Example – Frequency Response

- **Generation Trip Event**



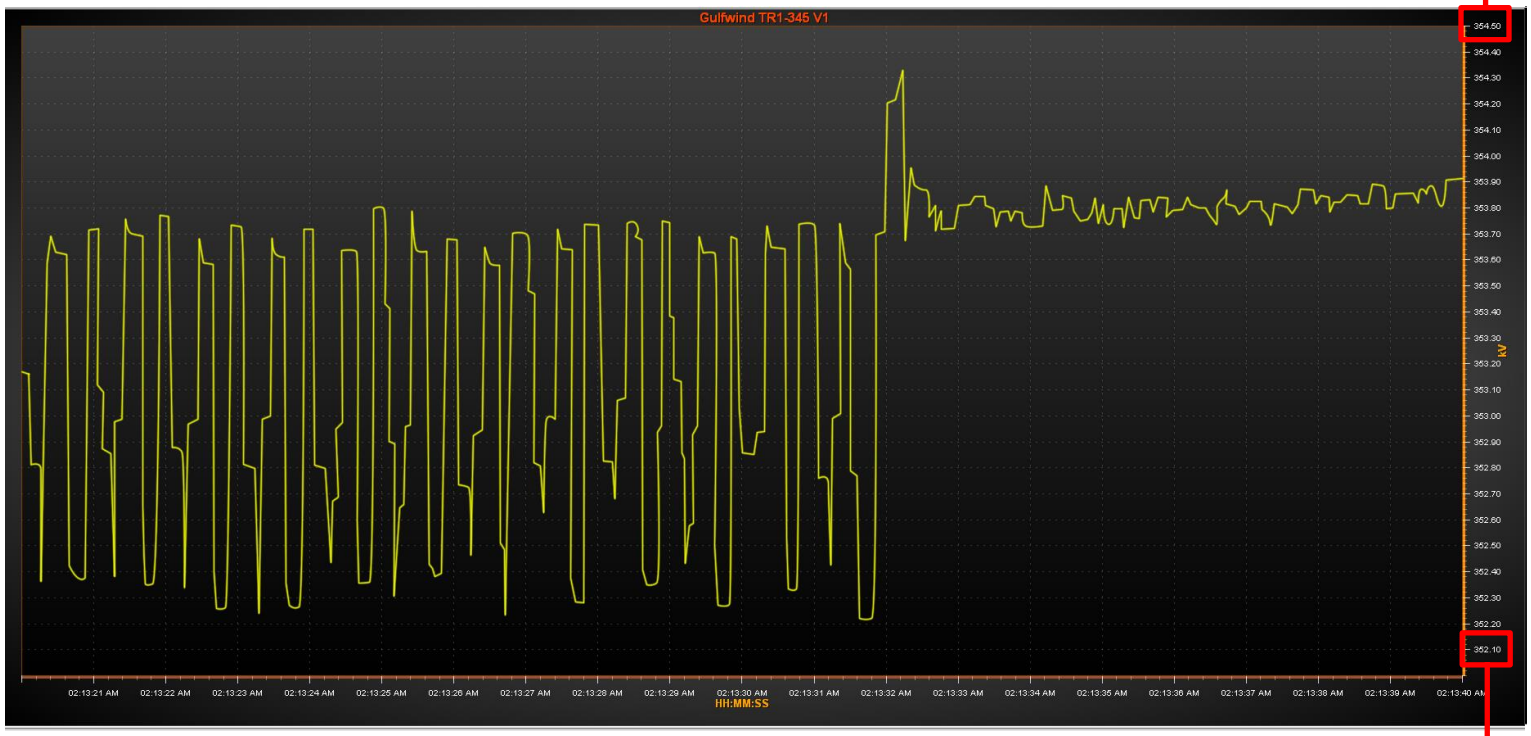
- Measured Frequency Response (per NERC methods)
  ΔP / (10 * ΔF)
- Generation loss: ΔP = 655 MW
- ΔF = 0.089 Hz
- Frequency Response =
- 736 MW/0.1Hz
- Area Frequency Bias =
  672 MW/0.1Hz
- % difference = (736-672)/736 = 8.7%

Frequency response is expected to match area bias within 10%. ⇨ Model valid!

Voltage Oscillations Before and After Controller Adjustment

Result

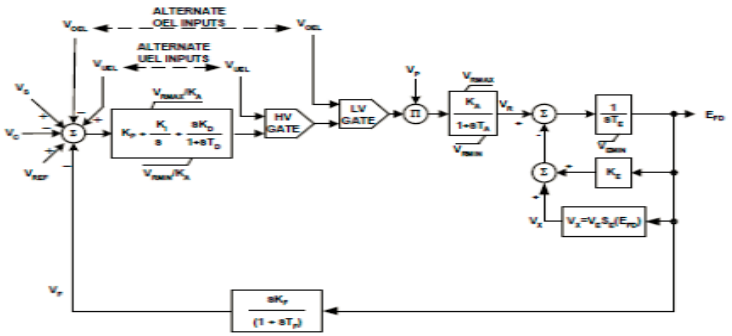
Observe that oscillation has ceased, system back to normal operating voltage



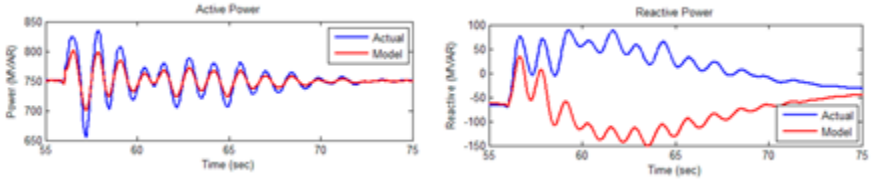
Screenshot of RTDMS – Real Time Dynamics Monitoring System

Generator Model Validation Process

- Monitor voltage, current, and frequency
- Compare MW & MVAR of measurement & model
- Tune the model, adjust
  - Generator
  - Governor
  - Exciter
  - Stabilizer
  - Etc.

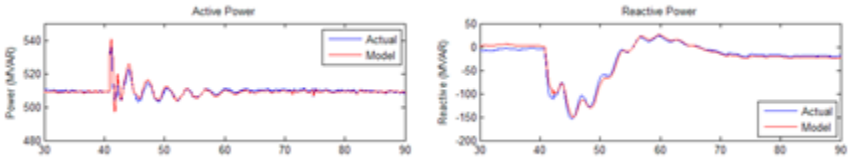


Bad Model



MW & MVAR responses very different

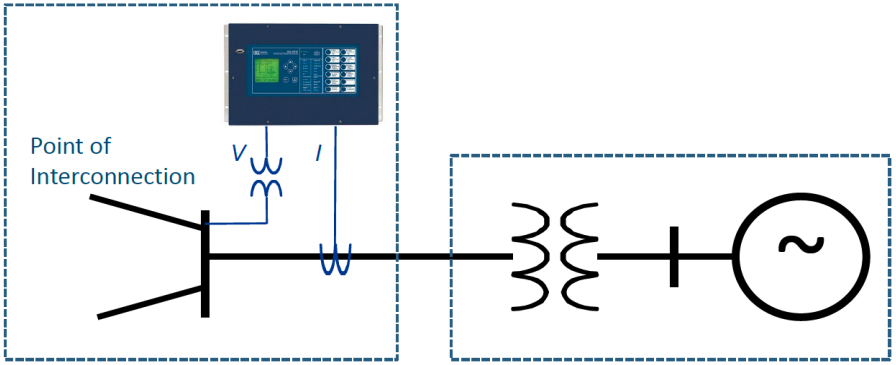
Good Model



MW & MVAR responses very close

On-line Generator Model Validation with PMUs

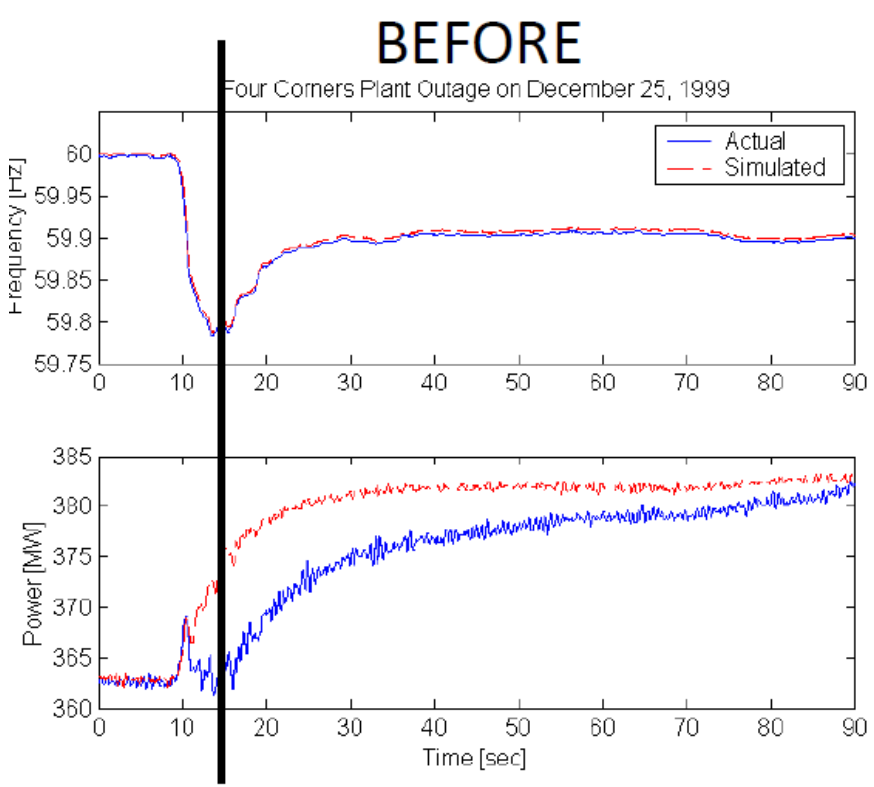
- **PMU Measurement**
  - At point of interconnection
  - Records V, I, & F
  - Equivalence system

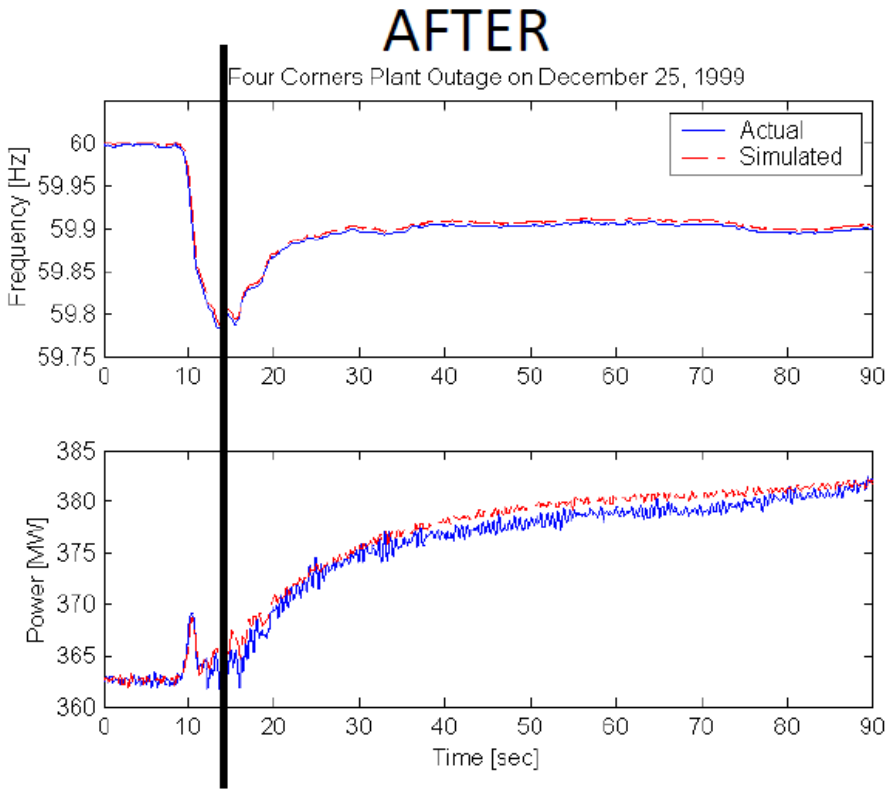


Source: Dmitry Kosterev, "Hydro-Turbine Model Validation in Pacific northwest", IEEE Transactions on Power Systems, vol. 19, no.2, pp.1144-1149, May 2004.

- **Simulate model response using the equivalence**
  - Compare with measurement
  - Tune the model
- **Generator validation on-line**
  - Can validate frequently

Generator Model Validation Example – with Tuning

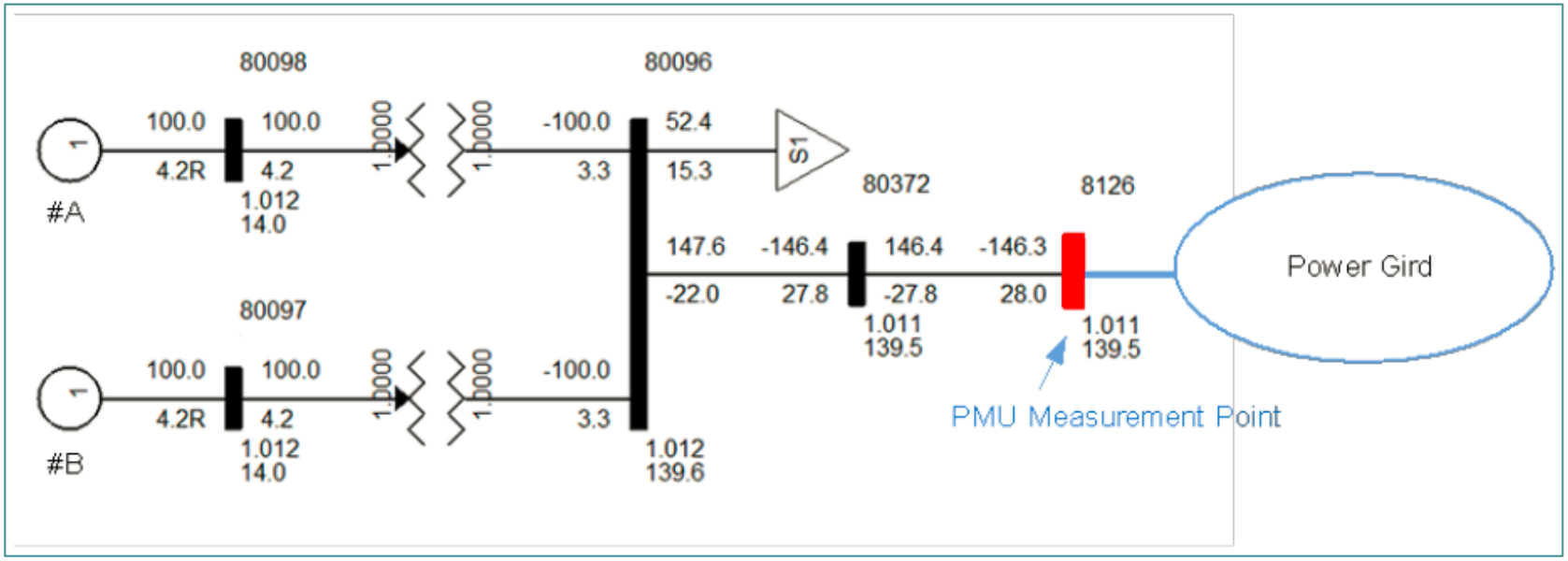


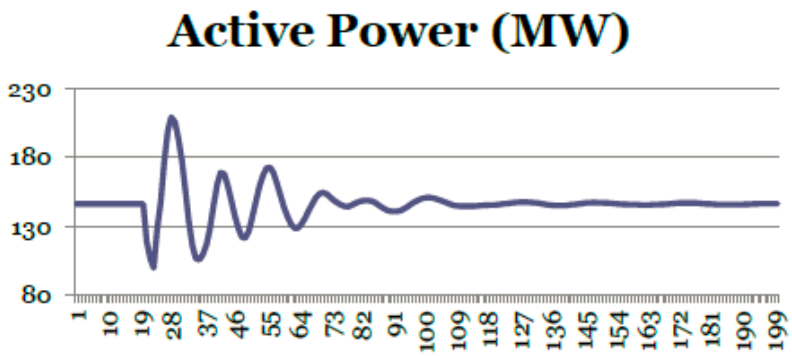


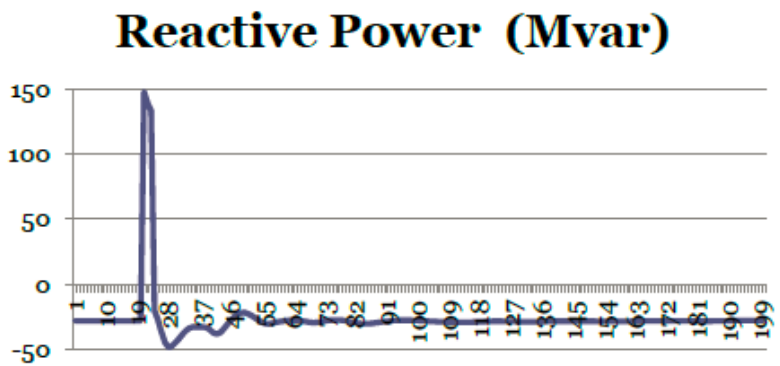
Blue = actual, Red = model

Source: Dmitry Kosterev, "Hydro-Turbine Model Validation in Pacific northwest", IEEE Transactions on Power Systems, vol. 19, no.2, pp.1144-1149, May 2004.

Generator Model Parameter Tuning Tool
Measurements – Equivalence – Tuning



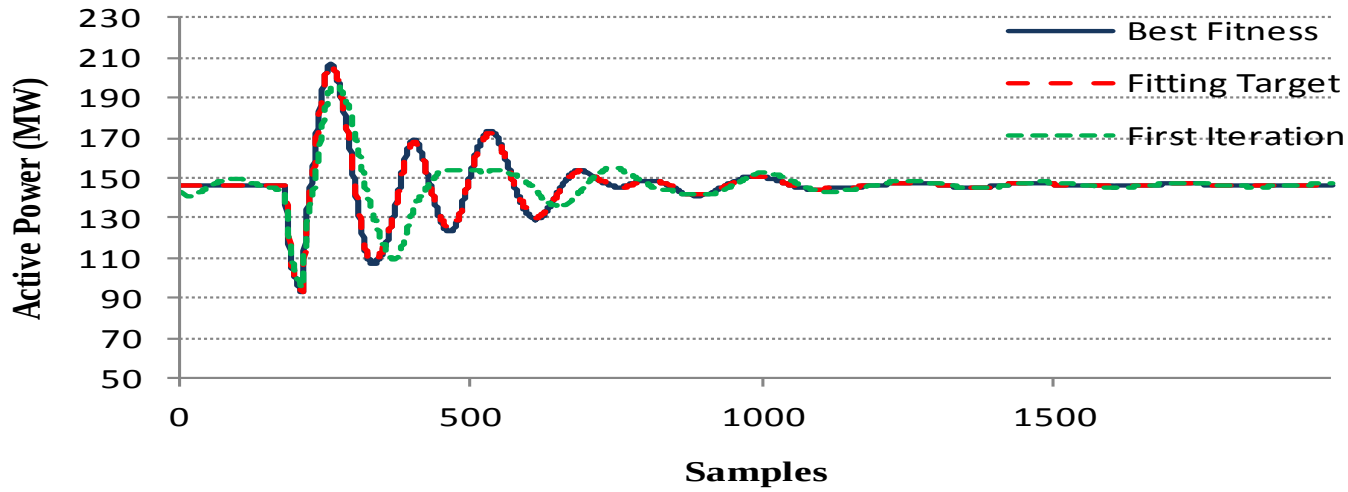


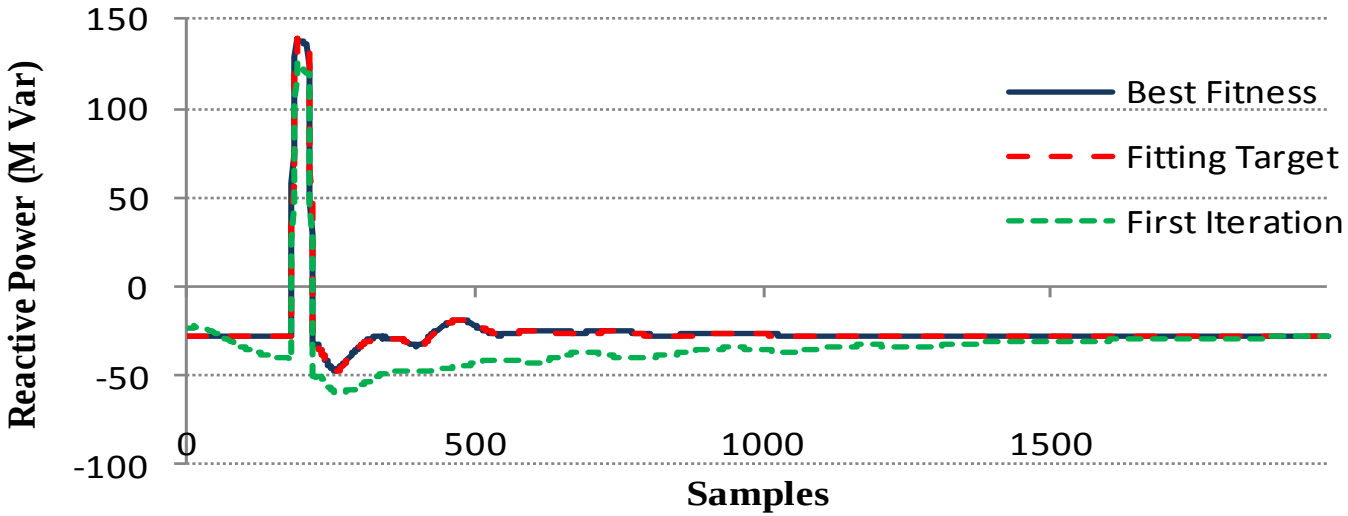


Source: Chin-Chu Tsai, Wei-Jen Lee, Nashawati, E., Chin-Chung Wu, Hong-Wei Lan, "PMU based generator parameter identification to improve the system planning and operation," *2012 IEEE Power and Energy Society General Meeting*, vol., no., pp.1,8, 22-26 July 2012

Generator Model Parameter Tuning Tool Automated Tuning

- **Simulation Results (50 Iteration)**



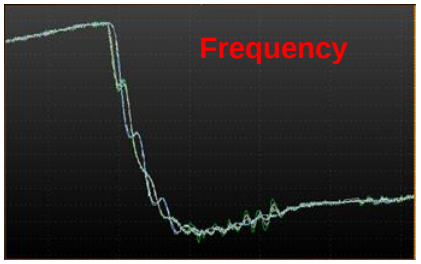


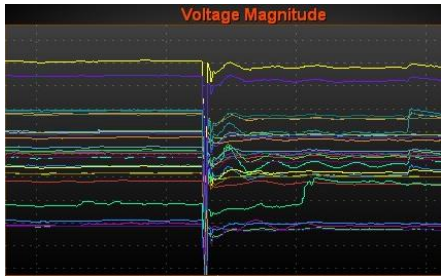
NERC Requirements
Standards on Model Validation

- **MOD-012** requires power plant owners to provide power plant data for dynamic simulations
- **MOD-026** requires power plant owners to verify that the provided dynamic models of excitation controls are accurate and up to date
- **MOD-027** requires power plant owners to verify that the provided dynamic models of governors and turbine controls are accurate and up to date
- **MOD-032-1** exists in conjunction with **MOD-033-1**, both of which are related to system-level modelling and validation

What Can *YOU* Do?

- **Analyze System Events**
  - Validate model prediction with actual system performance
  - Check response as indicated by key measurements using tools such as RTDMS and PGDA
    - Frequency response
    - Voltage response
    - Oscillations
    - P&Q power flow





- **Periodically validate generator and load models**
  - Tune models when event and model data do not match
- **Encourage PMU deployment at key locations (such as POI)**

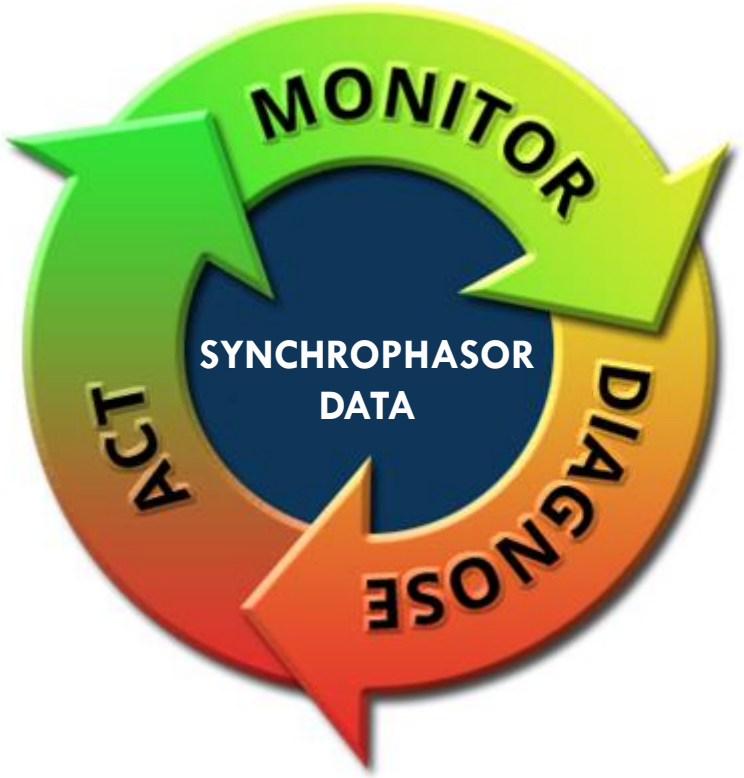
Key Model Validation Facts

- Power system operation and planning are based on models
- The model must be accurate for reliable operation and efficient planning
- Models need to be validated against actual operations
- Synchrophasor measurement provides the data needed for dynamic model validation
- Models have been improved using phasor data!

Model Use and Validation for Operations and Planning

Compare System Performance with Model Prediction

Tune Model to Match System Response



Identify Root Cause For Differences

e.g., Generator parameters

EPG Webinar Series

URL: http://www.electricpowergroup.com/solutions/index.html

Webinars are planned monthly, on a Tuesday from 11 a.m. to 12 Noon Pacific. The webinar topic list includes:

- System Events - Deciphering the Heartbeat of the Power Grid (Jul 16, 2013)
- Using Synchrophasor Technology For Real-Time Operation and Reliability Management (Aug 20, 2013)
- Phase Angle Differences – What They Mean and How to Use Them For Operations (Sep 17, 2013)
- Establishing Alarm Limits For Use in Operations (Oct 8, 2013)
- Phasor Simulations – How Can They Be Used in Operations? (Nov 19, 2013)
- Synchrophasor Data Diagnostics: Detection & Resolution of Data Problems for Operations and Analysis (Jan 28, 2014)
- **Model Validation (Mar 4, 2014)**
- **Voltage and Angle Sensitivities – What Do They Mean and How Can They Be Used (April, 2014)**

Feedback

Your feedback and suggestions are important!
PLEASE do let us know…

Q&A

Thank You!

For questions, please contact **Frank Carrera**:
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