Power Plant Model Verification using PMUs

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Importance of Accurate Models

Observed COI Power (Dittmer Control Center)

Simulated COI Power (initialWSCC base case)
Verifying Power Plant Component Models

- Fuel Source
- Prime Mover
- Turbine
- Generator
- Governor
- Load Controller
- Exciter
- Automatic Voltage Regulator
- Power System Stabilizer

Variables:
- $P_{Ref}$
- $P_{elec}$
- $\omega$
- $V_{term}$
- $V_{Ref}$
• **MOD-026**: Generator excitation control system or plant volt/var control functions

• **MOD-027**: Turbine/governor and load control or active power/frequency control functions

• **Applicability:**
  - Individual units greater than 100 MVA
  - Generating plants consisting of multiple units directly connected at a common BES bus with total generation greater than 100 MVA

• **Process:**
  - R1. TP provides instructions and model data to GO
  - R2. GO provides verified model back to TP
  - R3. TP can provide oversight of model and performance
  - R4. GO provides revised model/plans upon any changes made
• Requirement R3: “...receiving one of the following items for an applicable unit:”
  ▪ “Written comments and supporting evidence from its Transmission Planner indicating that the simulated excitation control system or plant volt/var control function model response did not match the recorded response to a transmission system event.”

• Requirement R5: “Each [GO] shall provide a written response to its Transmission Planner...following receipt of a technically justified* unit request from the [TP] to perform a model review of a unit or plant...”
  ▪ “Corrected model data including the source of revised model data...”
  ▪ **technical justified**: achieved by the [TP] demonstrating that the simulated unit or plant response does not match the measured unit or plant response.
NERC Standards

TRANSMISSION PLANNER

R1

Model Accurate?

Yes → R6

No → R3

List of appropriate models

"Verified model" *

R2

Notification that the model is usable or not. Usable is defined by:
1) successful initialization, 2) smooth flat run, 3) positive damping

R6

R3

Notification that model is not accurate or unusable *

Technical basis for current model, model changes, or plans for model verification

Revised model or plans to verify model due to changes in plant that impact model performance

R4

"Technically justified" request for model review *

R5

Plans to verify model or model changes including source of errors

R5

GENERATOR OWNER

Plans to verify model
PMU Disturbance-Based PPMV

Substation

Phasor Measurement Unit

Power Plant

Point of Interconnection

Record:
- POI bus voltage
- POI bus frequency
- Power plant MWs and MVARs
• PMU measurement data quality – watch out for archived data!
• Measurement Location – is flexible! high- or low-side of GSU, POI of power plant (radial connection)
• Signals – V, F, P, Q, (δ, I)
• Measurement duration – at least 10 seconds pre- and 30 seconds post-disturbance
• Events:
  ▪ Local or nearby fault events
  ▪ Major line or shunt switching
  ▪ Underfrequency events (interconnection-wide) – generator tripping
• Must perform disturbance-based verification for *multiple events*
**Model Validation Process**

**Model Validation**

- **Baseline Test**
  - Model Exist? (Yes)
    - Model accurate? (Yes) → Verified
    - Model accurate? (No) → Sufficient Info Known? (Yes) → Calibrate
    - Model accurate? (No) → Sufficient Info Known? (No) → No
  - Model Exist? (No) → No
Disturbance-Based Verification

- Play In: Voltage and Frequency Signals (V & f)
- Measures of Success: Active and Reactive Power (P & Q)
• The following tools all have playback models and capability to perform disturbance-based model verification:
  - GE PSLF
  - PTI PSS®E
  - Powertech TSAT and ModV
  - PowerWorld Simulator
  - EPRI PPPD
  - BPA-PNNL PPMV
  - MATLAB® and Simulink®
  - EPG GPV

• NERC SMS supporting industry use of vetted tools – user forum to share experience, code, examples, etc.
• NERC *advocated* using *Engineering Judgment* for any calibration
• *Avoid* numerical curve fitting methods
• Consider controller failures for very poor matches
• Understand parameter sensitivities – run example playbacks!
• A matching response does **not** mean a verified model
Gas Turbine Modeling

Combined Cycle Verification

Wind Plant Modeling
Hydro Machine Modeling

Generic Wind Model Testing
Power Plant Performance Monitoring

PMU Data

Power Plant Settings
Steady State Models
Dynamics Models
SCADA Data

PMU Data Historian

Automated Power Plant Model Verification
- Data Extraction
- Base Case Setup
- Stability Simulation

Event Detection Algorithm

Intelligent Model Characterization
- Model Comparison
- Report Generation
- Automated Model and Control Issue Detection
Mitigating and Detecting Failures or Control Issues

PSS failure

Unexpected action from plant controller

Abnormal runback in reactive power
• Disturbance-based PPMV is becoming a mainstream Planning function
  ▪ Does not necessarily require advanced programs or functions – commonly used tools have playback capability for PPMV

• NERC SMS building user forum for PPMV – sharing experiences
• NERC Staff supporting development of industry capabilities

• Testing thus far has shown that **majority** of models are “wrong”
  ▪ *Let’s work together to correct them!*
• Encourage all Transmission Planners, Planning Coordinators, and Generator Owners to get involved
Questions and Answers

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