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

i-PCGRID
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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

Observed COI Power (Dittmer Control Center)

Simulated COI Power (Initial WSOC base case)
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

Record:
- POI bus voltage
- POI bus frequency
- Power plant MWs and MVARs

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

Controllable Voltage and Frequency

• Measured and responded MWs and MVARs are compared for measures of success
PPMV Results – Good Models

• What a good model 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
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
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

**Graphs:**

- **Active Power [MW]:**
  - Observed vs. Expected
  - PSS failure

- **Reactive Power (MVAR):**
  - Observed vs. Expected
  - Abnormal runback in reactive power

- **Time (sec):** 0 to 100

- **Active Power [MW]:** 480 to 680

- **Reactive Power (MVAR):** -100 to 50
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
R.O.I.

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

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