NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Reliability Considerations for PPMV

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RELIABILITY | ACCOUNTABILITY




MOD Standards Framework

NERC MOD Standards

Modeling, Data, and Analysis

MOD-032

Data for Power System Modeling and Analysis

System Modeling

- Load Forecasts
- System Components
- Reactive Devices
- Transfers

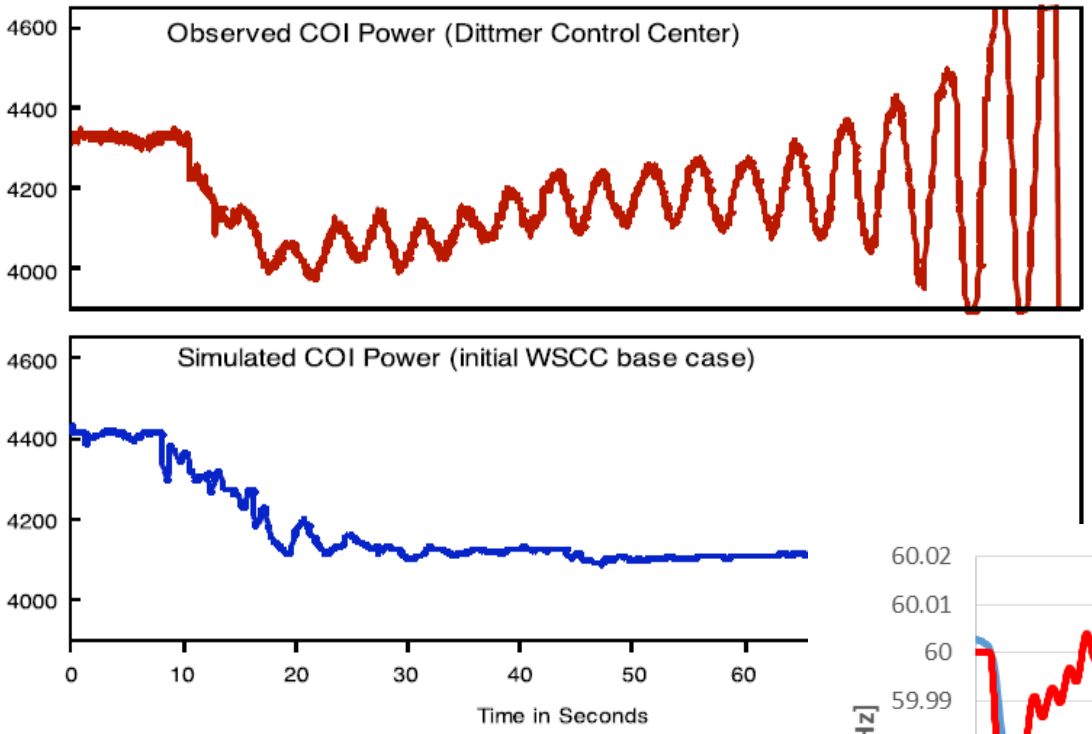
Plant Modeling

- **MOD-025-2** – Generator Capability
- **MOD-026-1** – Volt/Var Control
- **MOD-027-1** – Power/Frequency Control

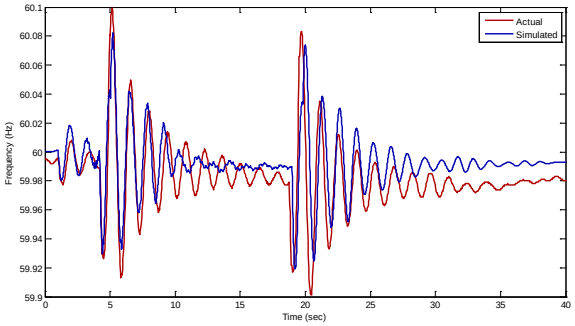
MOD-033

Steady-State and Dynamic System Model Validation

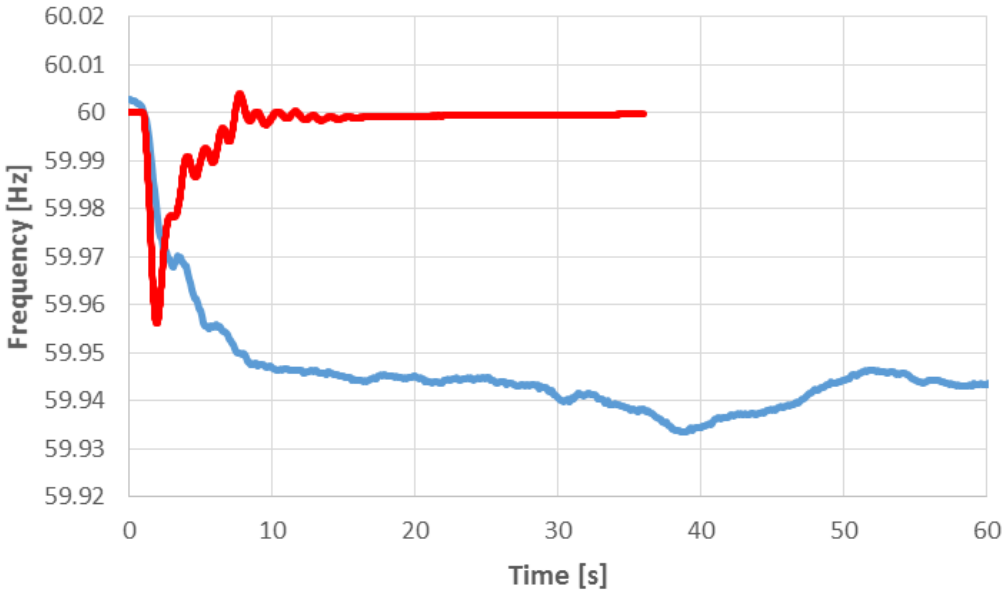
Importance of Modeling



THEN…
…20 Years Ago



NOW…
…2016 MMWG Base Case



MOD-026-1 / MOD-027-1 Terminology

Resource	Excitation control system or plant volt/var control function	Turbine/governor and load control or active power/frequency control
Synchronous Machine	Includes generator, exciter, voltage regulator, impedance compensation, and power system stabilizer	Includes turbine/governor and load control
Aggregate Generating Plant	Includes voltage regulator & reactive power control system controlling and coordinating plant voltage and associated reactive capable resources	Includes active power/frequency control

MOD-026-1 / MOD-027-1 Requirements

R1: Each TP provides information to the GO upon request:

- List of models acceptable to TP
- Block diagrams and/or data sheets for acceptable models
- Model data for GO's existing units

R2: GO provides verified generator dynamic model(s) for each unit

- Model verified by GO using one or more models acceptable to TP
- Each verification includes the following:
  - Unit's model response matches recorded response (*next page*)
  - Manufacturer, model number (if available), and type of system
    - e.g., digital vs. analog, static vs. rotating exciter, plant controls
    - e.g., turbine type, boiler type, fuel type, manufacturer and controls
  - Model structure and data
    - e.g., block diagram, time constants, gains, limits, generator data
  - Outer loop controls – blocked or nonfunctioning controls or modes of operation that limit response

MOD-026-1 / MOD-027-1 System Events and Tests

Standard	MOD-026-1	MOD-027-1
System Event	"Voltage excursion from a measured system disturbance" – size not specified, should have noticeable perturbation to terminal voltage	Frequency excursion event, with unit operating in frequency responsive mode: • EI: $\Delta f \geq 0.05$ Hz • TI: $\Delta f \geq 0.10$ Hz • WI: $\Delta f \geq 0.10$ Hz • QI: $\Delta f \geq 0.15$ Hz
Staged Test	"Voltage excursion from a staged test" – for example, voltage reference step test* with unit online and PSS on/off	• Speed governor reference change with unit on-line • Partial load rejection test**

* PSS Off tests verify excitation system models while PSS ON tests verify PSS models.
** Differences in control modes between testing and final simulation model need to be identified. Most controls change gains or have a set point runback which takes effect when the breaker opens. This can skew results of load rejection tests if not properly accounted for and understood.

MOD-026-1 / MOD-027-1 Requirements

R3: GO provides written response to TP after receiving from TP:

- Notification that model is not usable
- Comments identifying technical concerns with verification documents
- Comments and supporting evidence indicating modeled response does not approximate recorded response for three or more events
- Response will include either technical basis for maintaining model, model changes, or plan to perform verification

R4: GO provides revised model or plans to perform PPMV within 180 days of making changes to controls or equipment that alters response characteristic.

MOD-026-1 / MOD-027-1 Requirements

MOD-026-1:

R5: GO provides response to TP within 90 days following receipt of technically justified* request to perform model review, including:

- Details of plans to verify model
- Corrected model data including source of revision

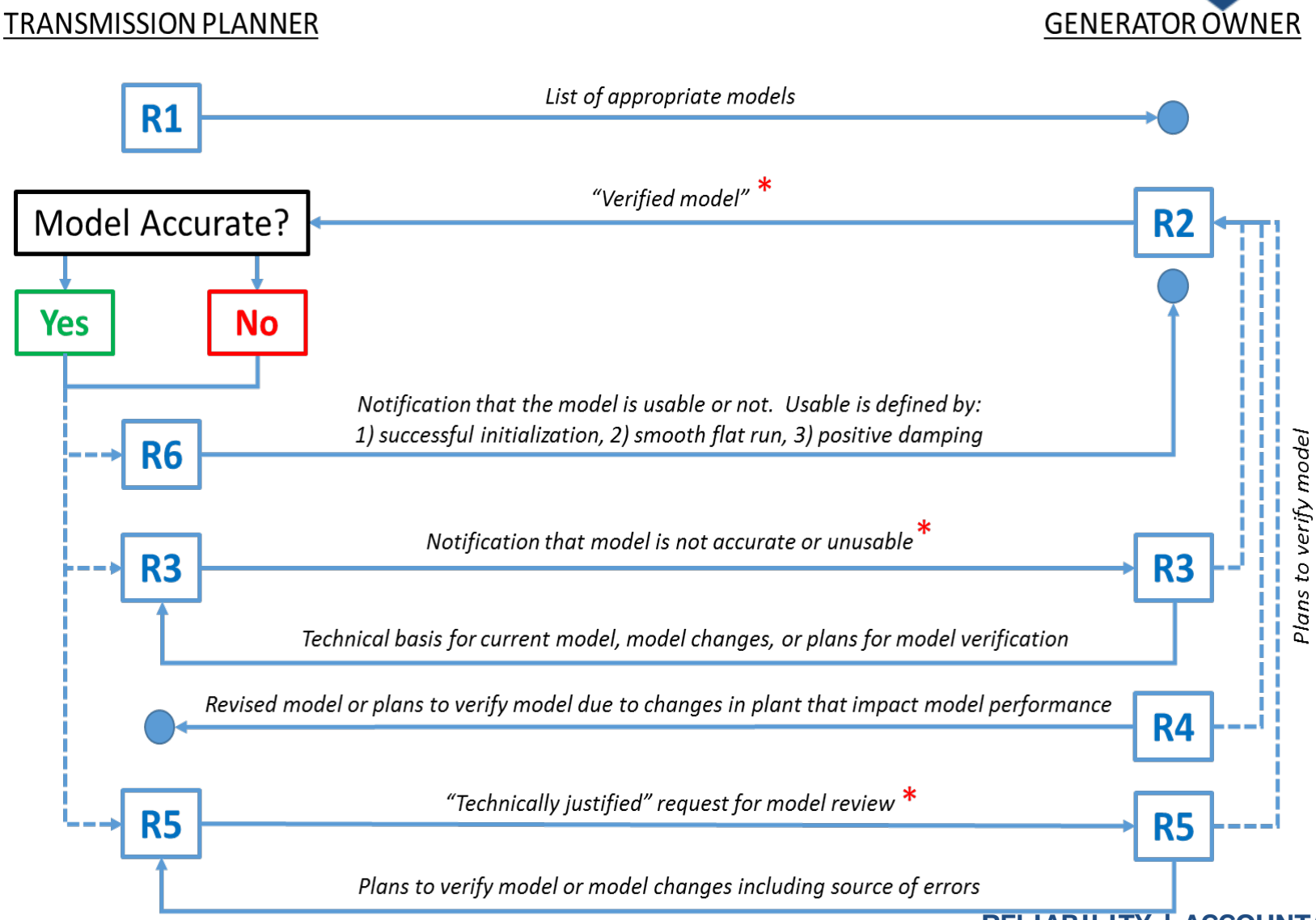
* TP demonstrates simulated vs. measured response does not match

MOD-027-1 / MOD-026-1:

R5/R6: TP provides written response to GO within 90 days of receiving verified model that model is usable or not usable, including:

- Initializes without error
- No-disturbance simulation results in negligible transients
- Exhibit positive damping

Process Flowchart



Model Development and Verification

Baseline Model Development

- Choose appropriate model representing equipment
  - Consult with TP for acceptable models and model questions
- Create initial model data set using tests, measurement, calculation, etc.
- Best done during commissioning of new plants, otherwise offline testing of existing plants

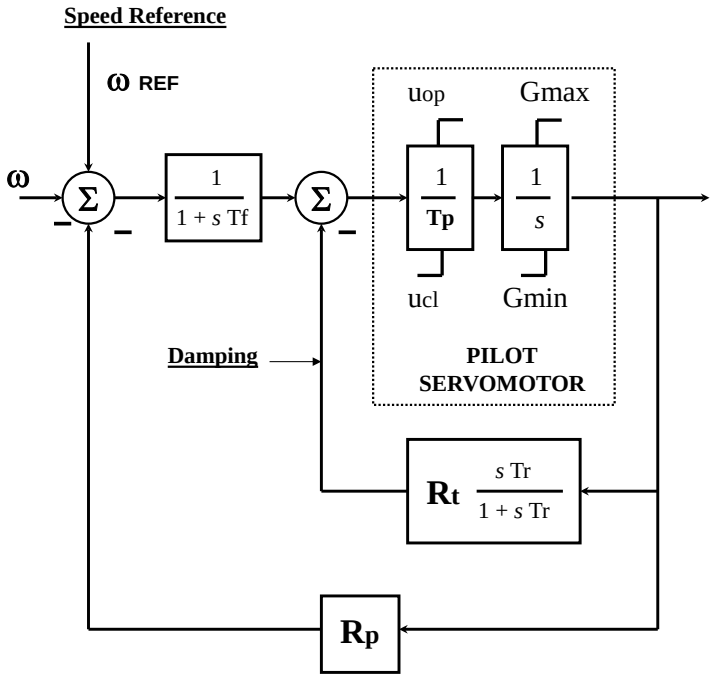
Periodic Model Verification

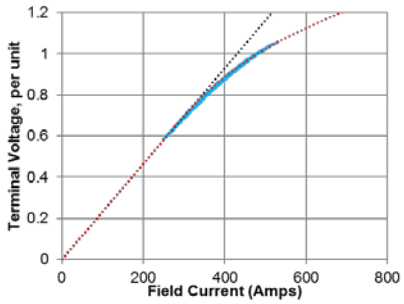
- Ensures model remains accurate representation AFTER good baseline model established
- Should not be substituted for baseline model development
- 'Yes-No' check of model vs. actual performance

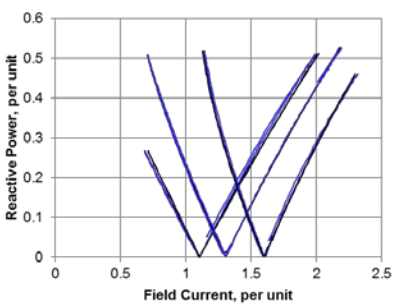
Baseline Model Development

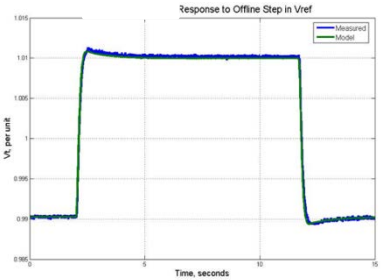
Equipment

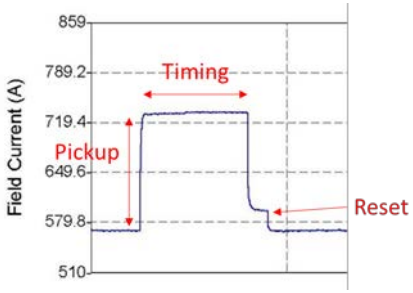
Model



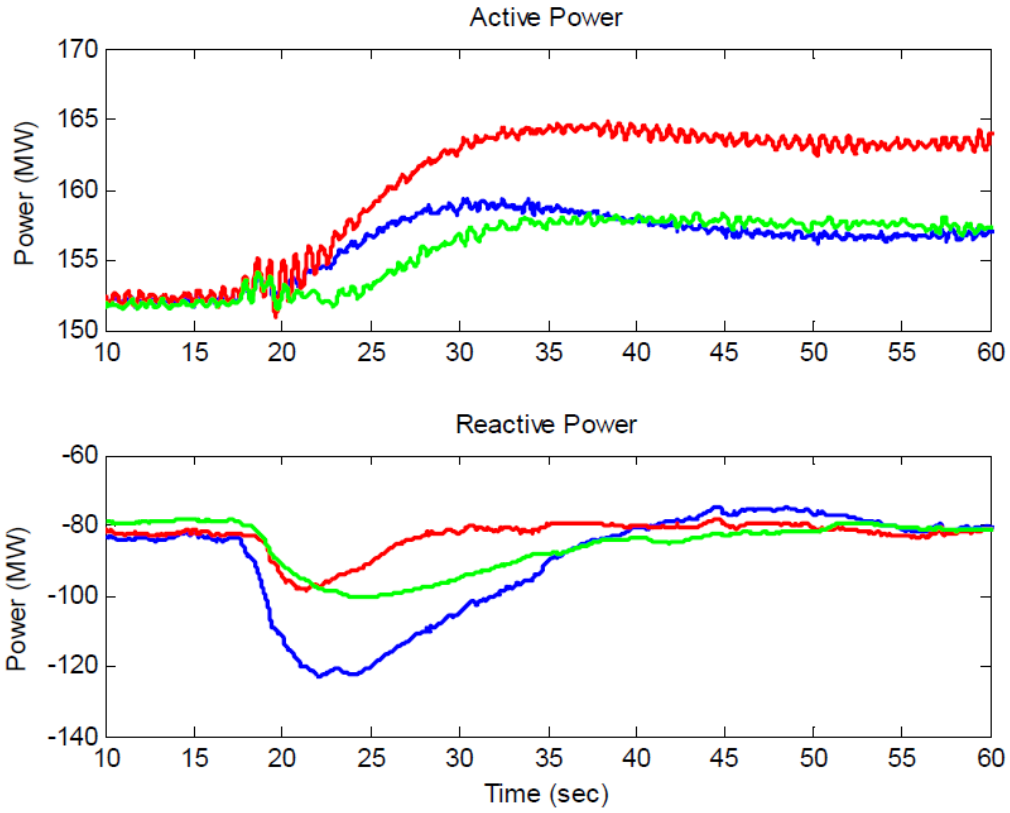








Independent Verification



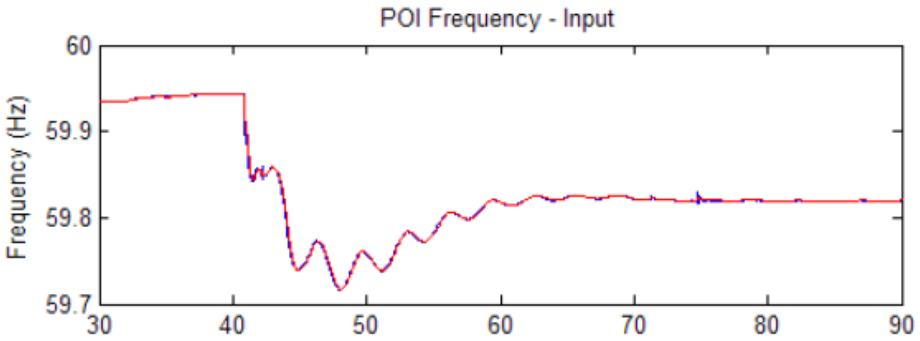
Consultant A

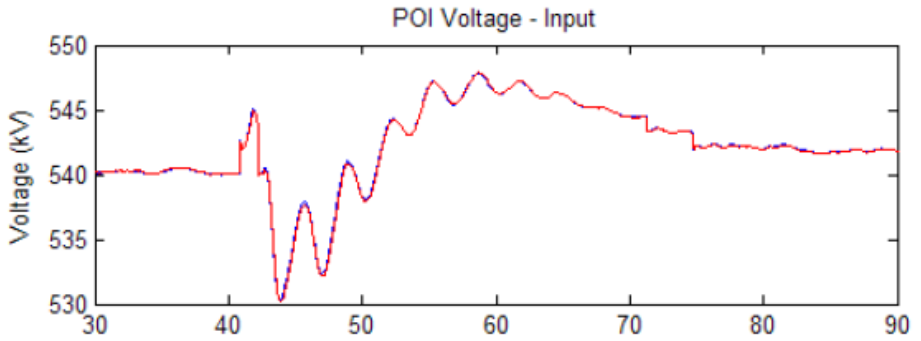
Consultant B

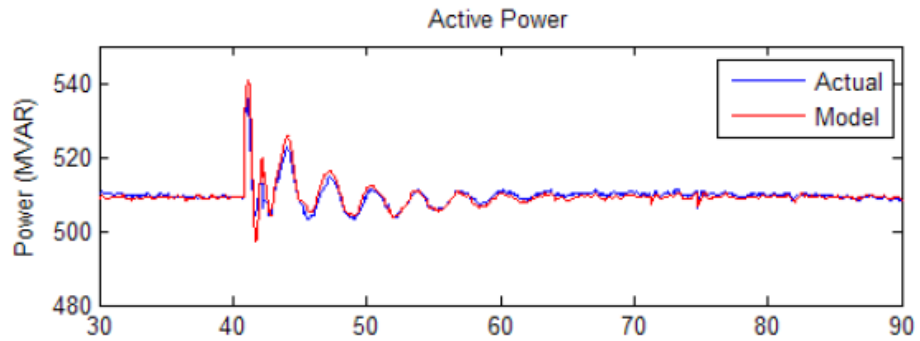
Reality

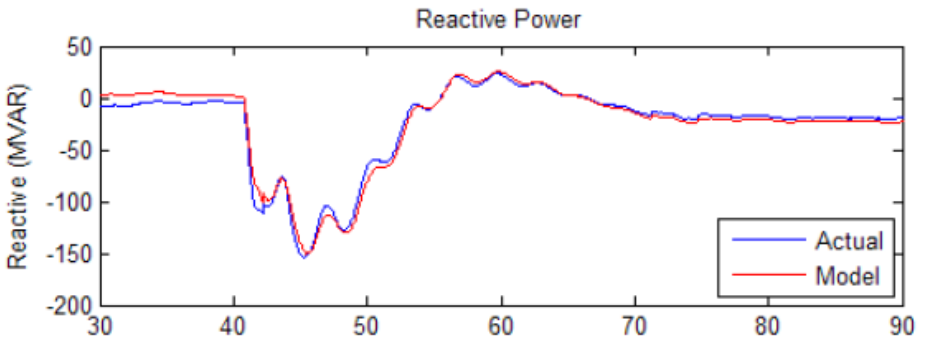
- Which data is correct? Turns out neither were correct…
- "1 good measurement is worth 1000 expert opinions"

What a Good Model Looks Like



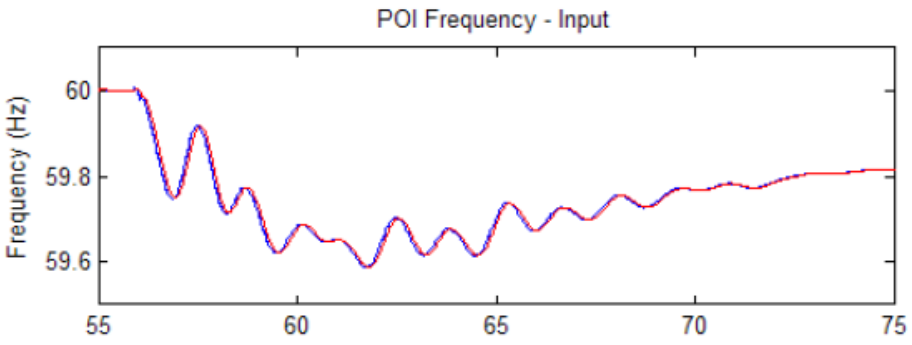


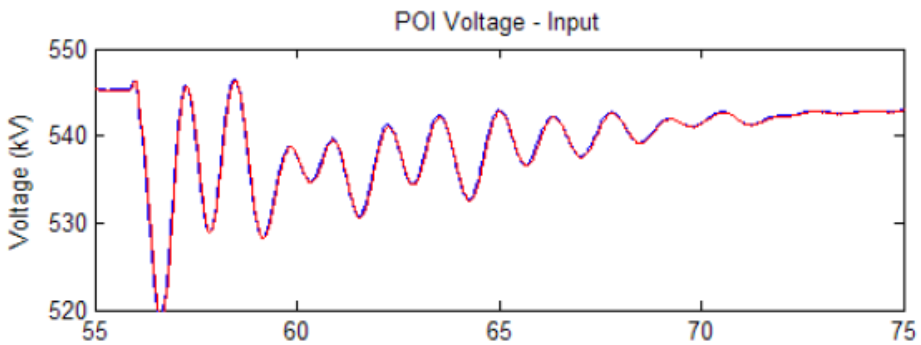


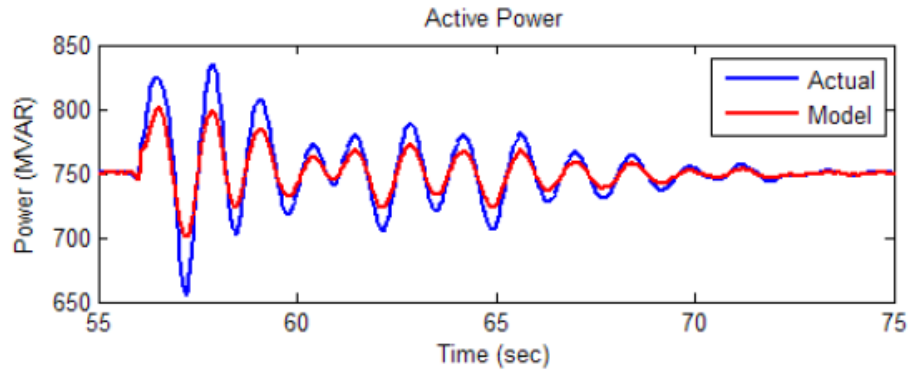


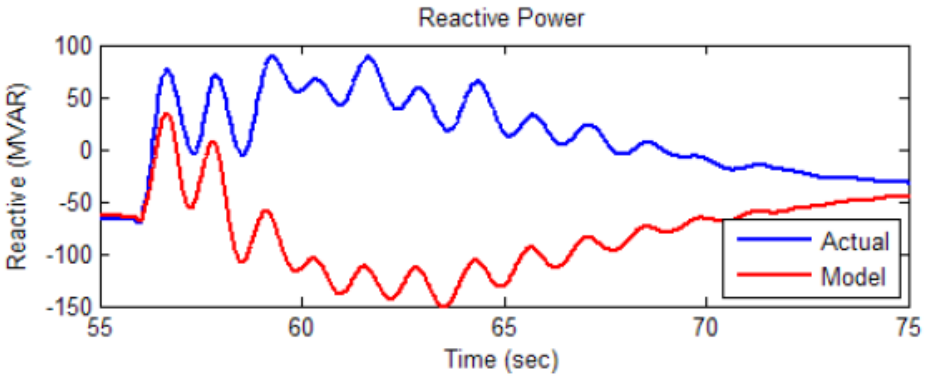
- Approximates general shape of response very well
- Minor differences between events

What a Bad Model Looks Like





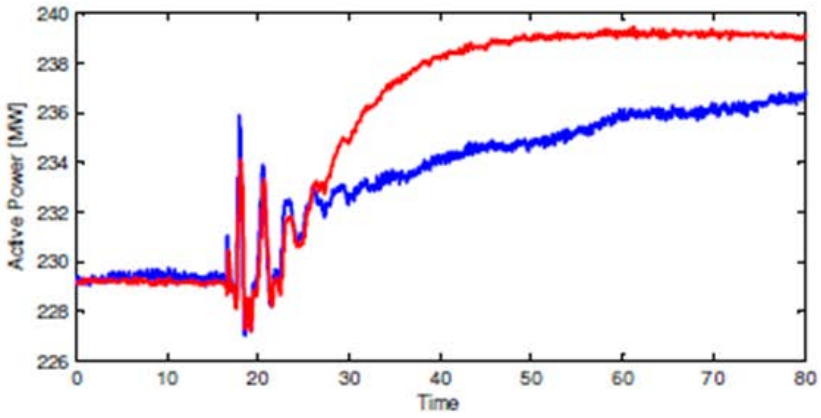


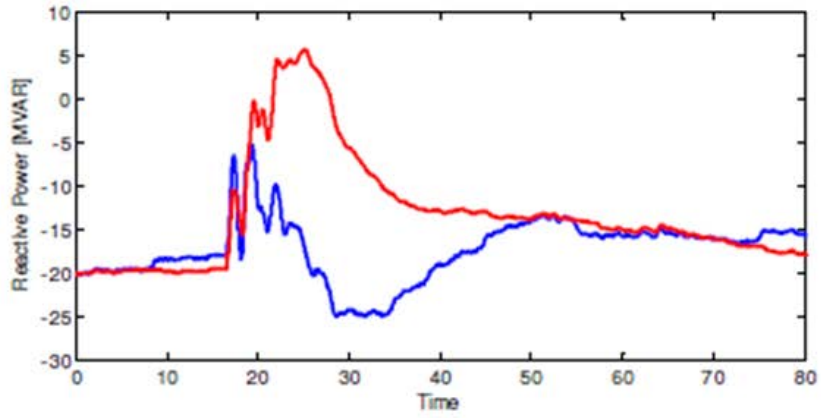


- Does not approximate general shape of response well
- Substantial differences in comparison (between events)

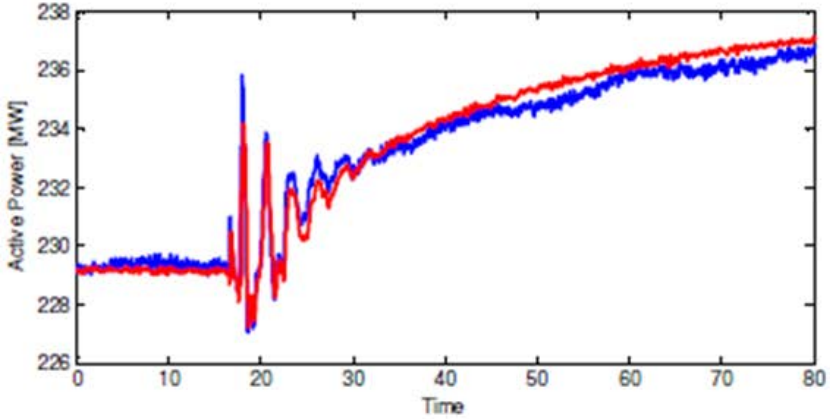
Success Story #1

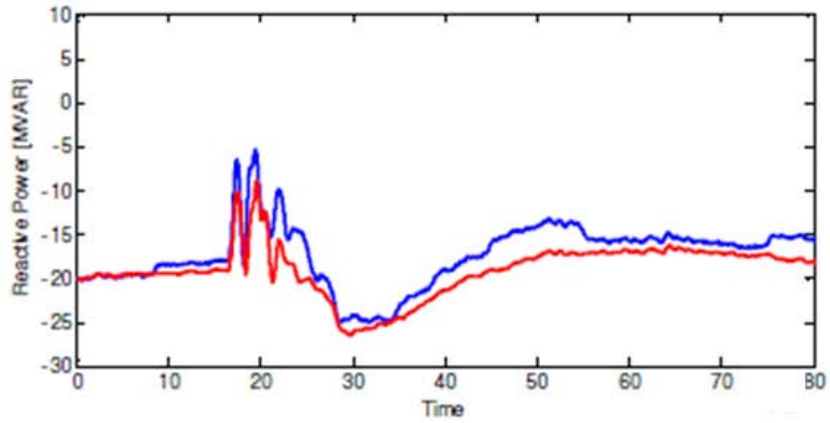
BEFORE-2014





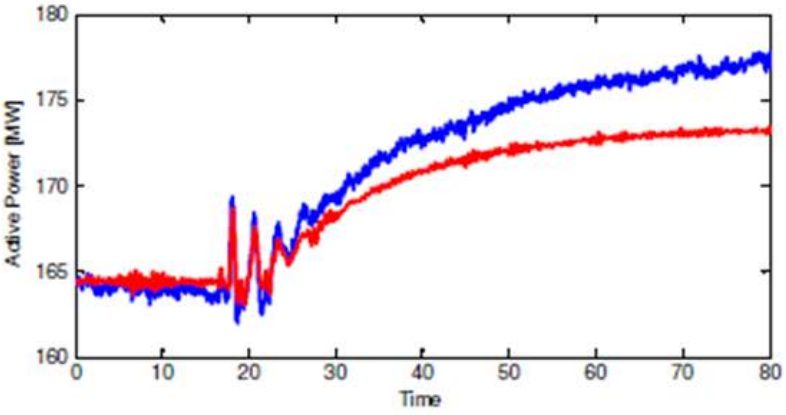
AFTER-2015

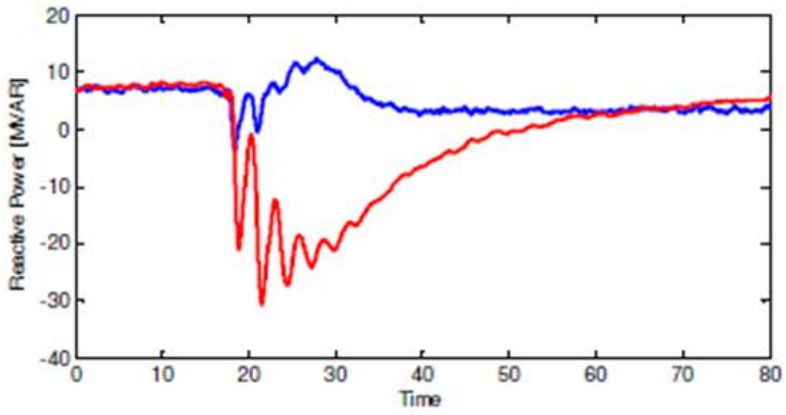




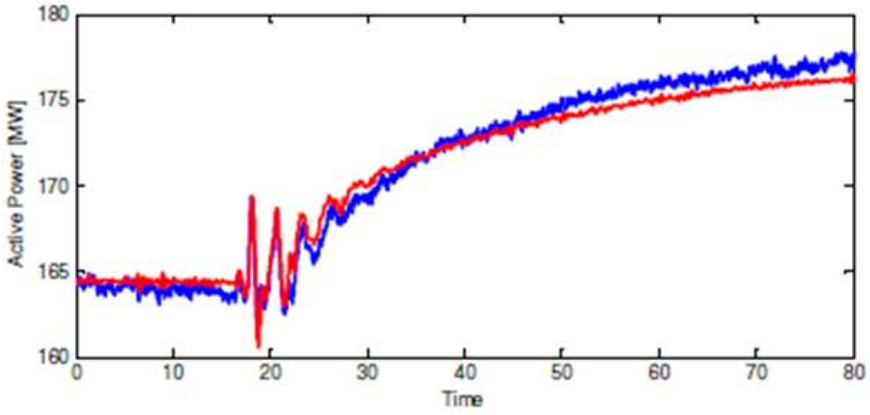
Success Story #2

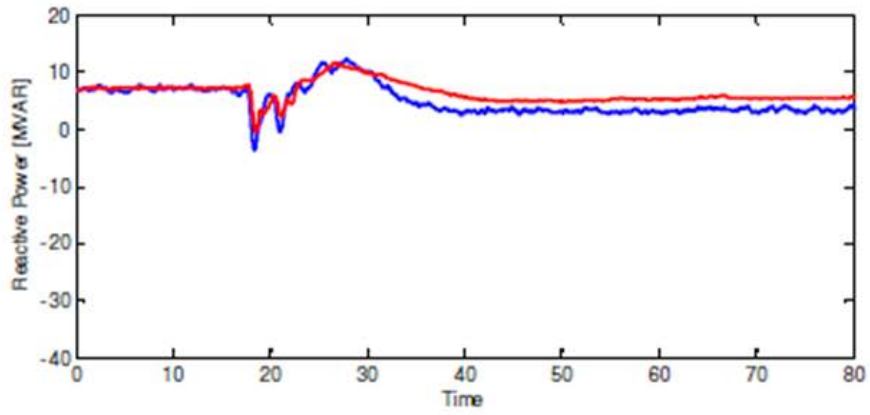
BEFORE-2014





AFTER-2015

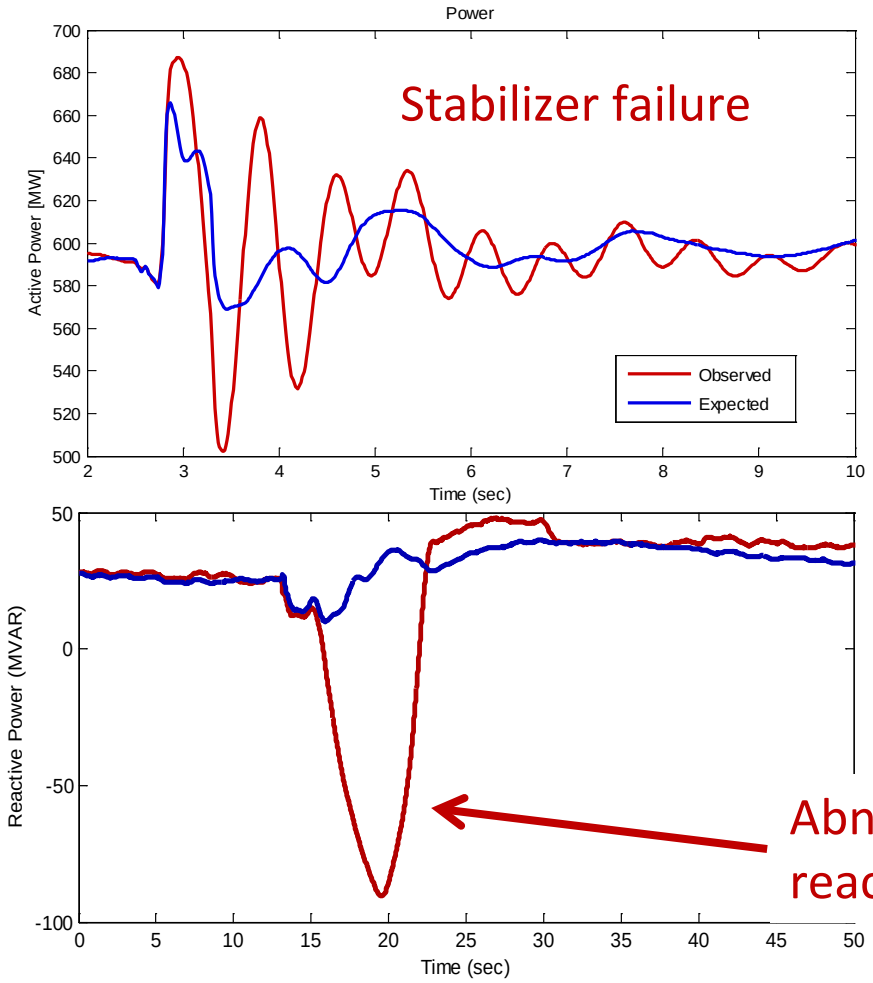




TO/GO Coordination

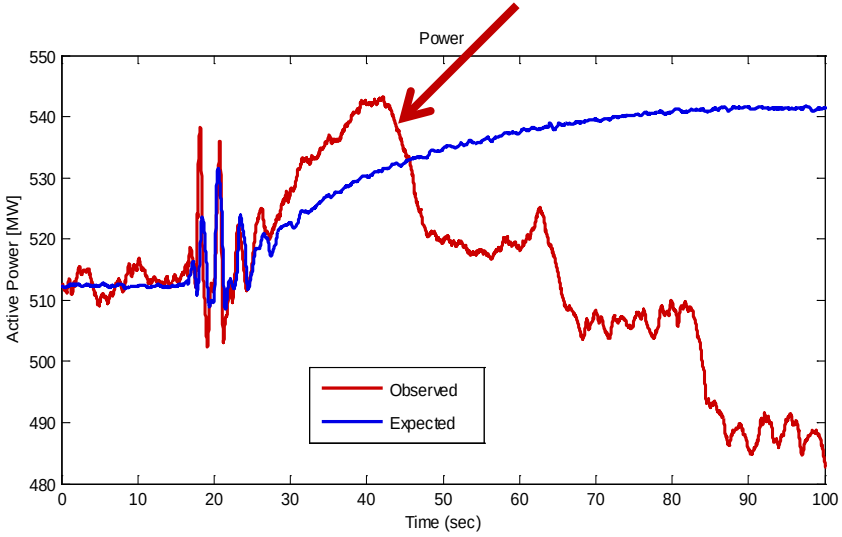
- Not required in the standard
- Processes can be developed - information from TOs to GOs
- Collaborative disturbance-based testing between TO/GO
  - GO – model owner / responsibility
  - TO/TP – model user / simulation capability
- Variety of technologies and proven solutions to get data to meet standards
  - Most modern digital relays have DDR/PMU capability
  - TOs have DFRs which can be used with longer-term recording

Detecting Control Abnormalities



Abnormal runback in reactive power

Unexpected action from plant MW controller



Next Steps
Disturbance Data Quality and Point-on-Wave

- Phasors:
  - P-class vs. M-class – P-class preferred, less filtering better for capturing sudden voltage changes
  - Beware of PMU-reported frequency, often has time lag, better to calculate frequency from voltage phasor angle

- Point-on-Wave Data:
  - Phasors calculated from point-on-wave data, can optimize data filtering
  - Preferred solution for monitoring electronically connected wind and solar resources

Questions?