Generator Parameter Validation (GPV)

NASPI Engineering Analysis Task Team

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Outline

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- **Generator Parameter Validation Process**
- **Testing & Findings Using Real PMU Data**
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Introduction

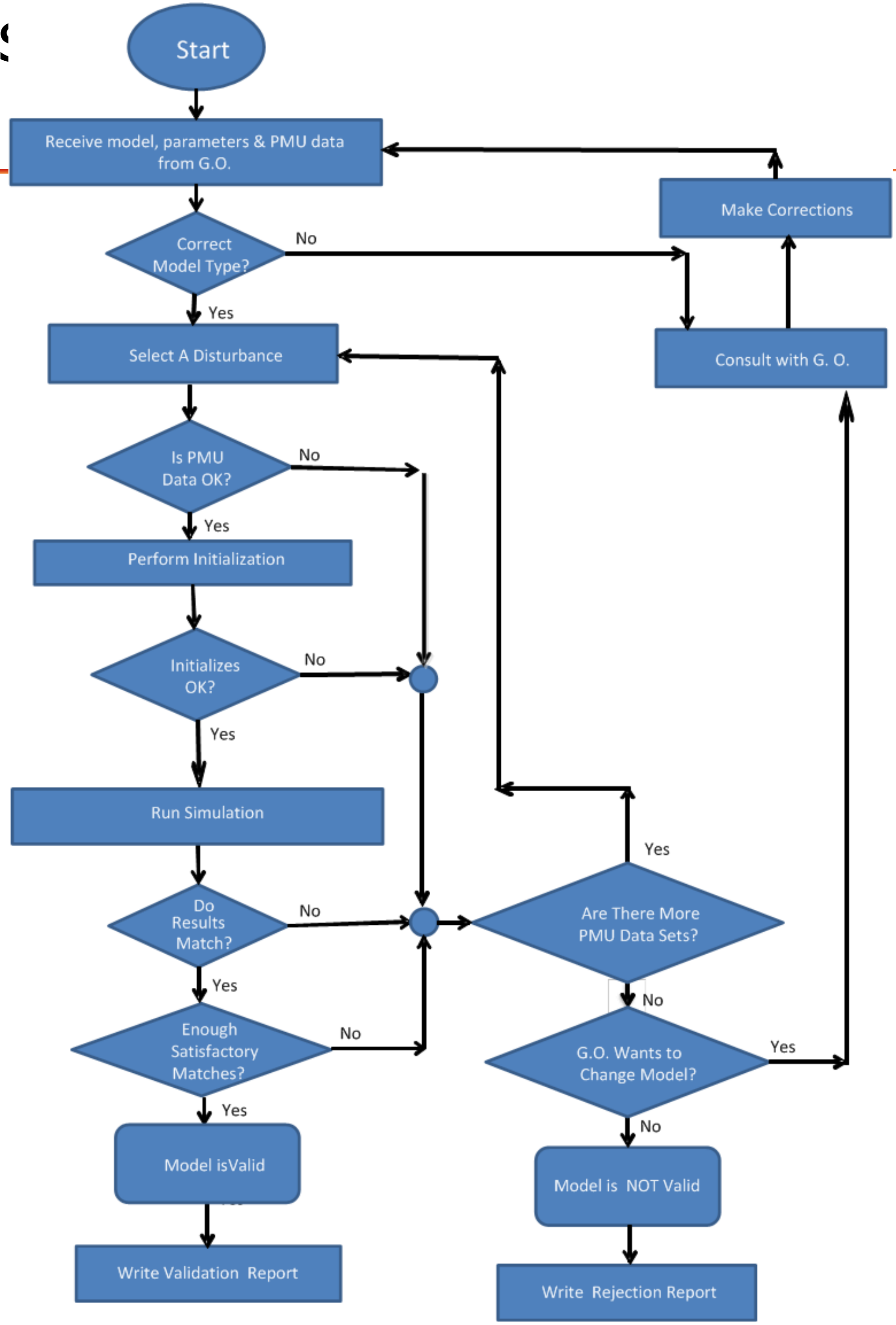
Methodology:

- **Use PMU measured event data to validate the generator model parameters**
- **Develop a model parameter validation process based on the following capabilities:**
  - PMU measured event data (P,Q,V,Angle) is available
  - System operation conditions corresponding to the disturbance are available
  - PSS/E case file (.sav) and dynamics file (.dyr) are available (Only applicable to PSSE models)
- **Types of Models that can be validated:**
  - Generators
  - Governors
  - Exciters
  - Stabilizers
- **Software Used : PSS/E Version 33.4.0, Python 2.7**

Verify Generator Models - The Process

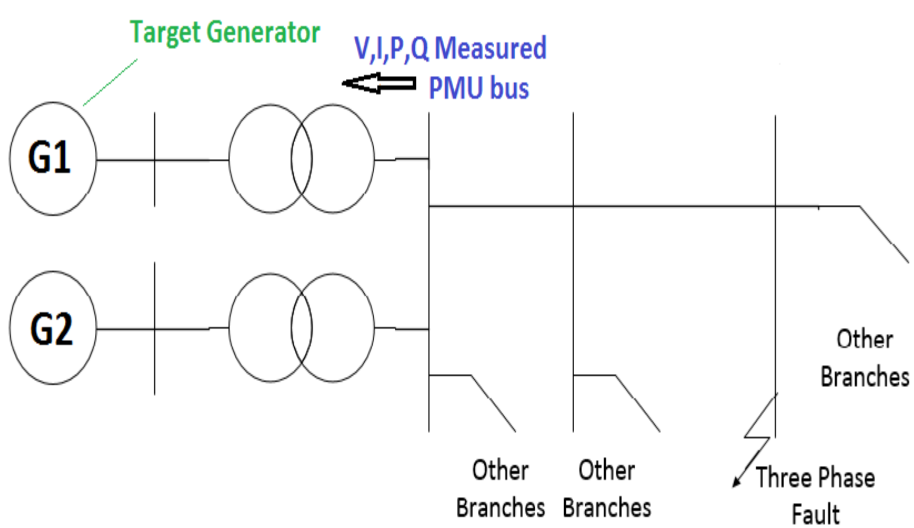
- **Observe and download events from RTDMS®**
- **Collect and store PMU event data**
  - Unique PMU channel for each generator
  - Desirable event data will contain frequency change, voltage change, and slow and fast changes
- **Derive equivalent system model**
- **Run Dynamic Simulation with PSLF or PSS/E**
- **Model forces high-side bus dynamics to match PMU event data**
- **Compare actual results vs. simulation results**

Complete Process Diagram



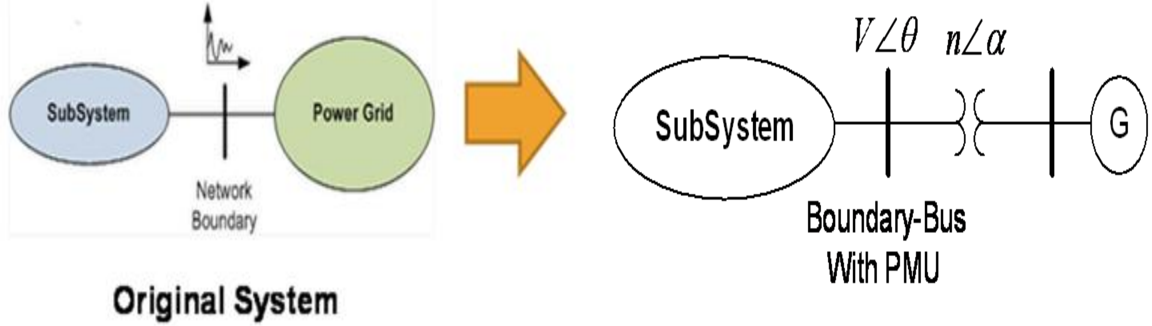
Input Data

- **Obtain PMU data (V,I,P,Q) at the generator point of interconnection for an event as shown below**
- **Individual generator data is required e.g., for validating G1, data for the branch PMU bus – G1 should be obtained**
- **Extract the PMU data into the Excel file format as shown**



T	V	Angle	P	Q
0	1.026683	24.728	-149.704	-109.731
0.026666	1.026683	24.728	-149.704	-109.731
0.059999	1.026683	24.728	-149.704	-109.731
0.093332	1.026682	24.72764	-149.708	-109.731
0.126665	1.02668	24.72699	-149.714	-109.731
0.159998	1.026678	24.72595	-149.722	-109.731
0.193331	1.026675	24.72445	-149.732	-109.732
0.226664	1.026671	24.72244	-149.741	-109.732
0.259997	1.026667	24.71987	-149.75	-109.733
0.29333	1.026662	24.71669	-149.757	-109.735
0.326663	1.026657	24.71289	-149.762	-109.738
0.359996	1.026652	24.70847	-149.763	-109.74
0.393329	1.026646	24.70344	-149.762	-109.743
0.426662	1.026644	24.69784	-149.758	-109.744
0.459995	1.026638	24.69175	-149.751	-109.749
0.493328	1.026637	24.6852	-149.743	-109.749
0.526661	1.026632	24.67833	-149.732	-109.753
0.559994	1.02663	24.67121	-149.721	-109.755
0.593327	1.02663	24.66394	-149.71	-109.756
0.626659	1.02663	24.65664	-149.7	-109.757
0.659992	1.026631	24.64941	-149.69	-109.757
0.693325	1.026632	24.64234	-149.682	-109.757
0.726657	1.026635	24.63551	-149.675	-109.756
0.75999	1.026637	24.62899	-149.671	-109.755
0.793323	1.026641	24.62283	-149.668	-109.754
0.826656	1.026647	24.61705	-149.667	-109.75

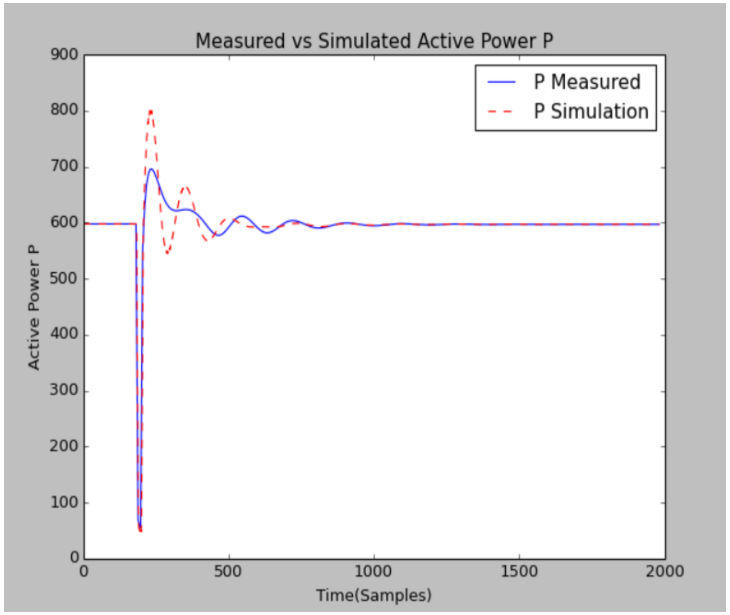
System Reduction

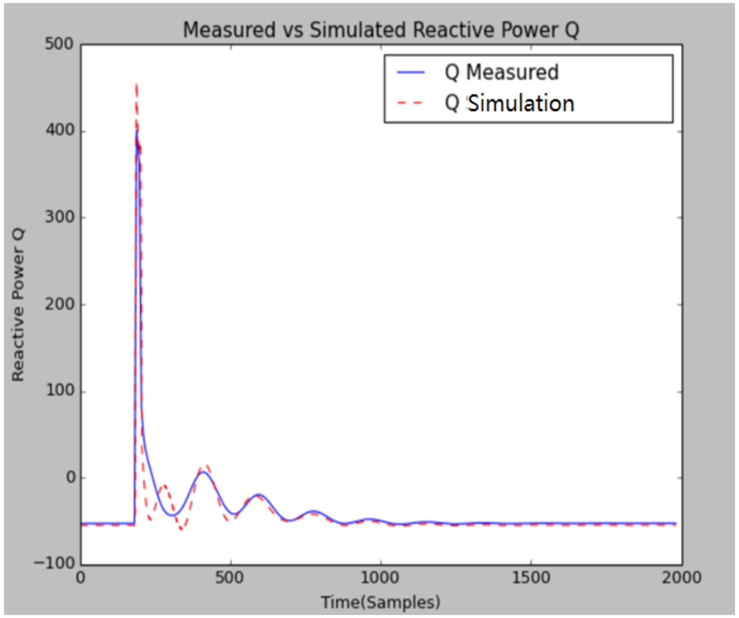


- An artificial generator and an ideal transformer are added at the boundary bus
- The turns ratio and the phase shift of the added transformer are adjusted to inject the measured voltage and angle signals at the boundary
- The model of the generator is a classical generator model with zero internal reactance, very high inertia constant, and zero damping ratio
- The transformer is a near zero impedance ideal transformer
- This method allows for the dynamic simulation of a subsystem with measured signals injected at its boundary without introducing errors caused by the external system model

Validation

- **Use the reduced system for event playback by injecting Voltage and Angle**
- **Compare measured P and Q with the simulated P and Q**
- **Calibration is not required if the models match**
- **Mismatch indicates some model improvements are required**

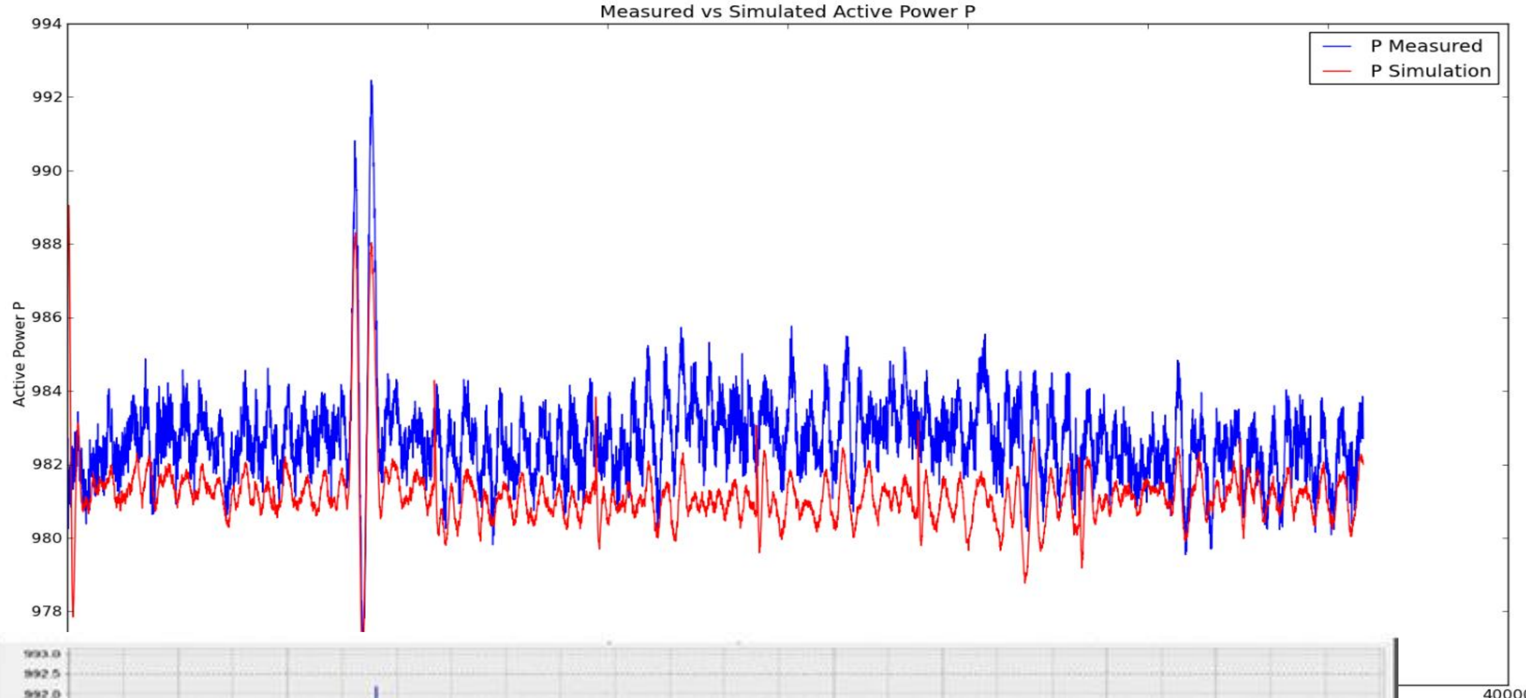




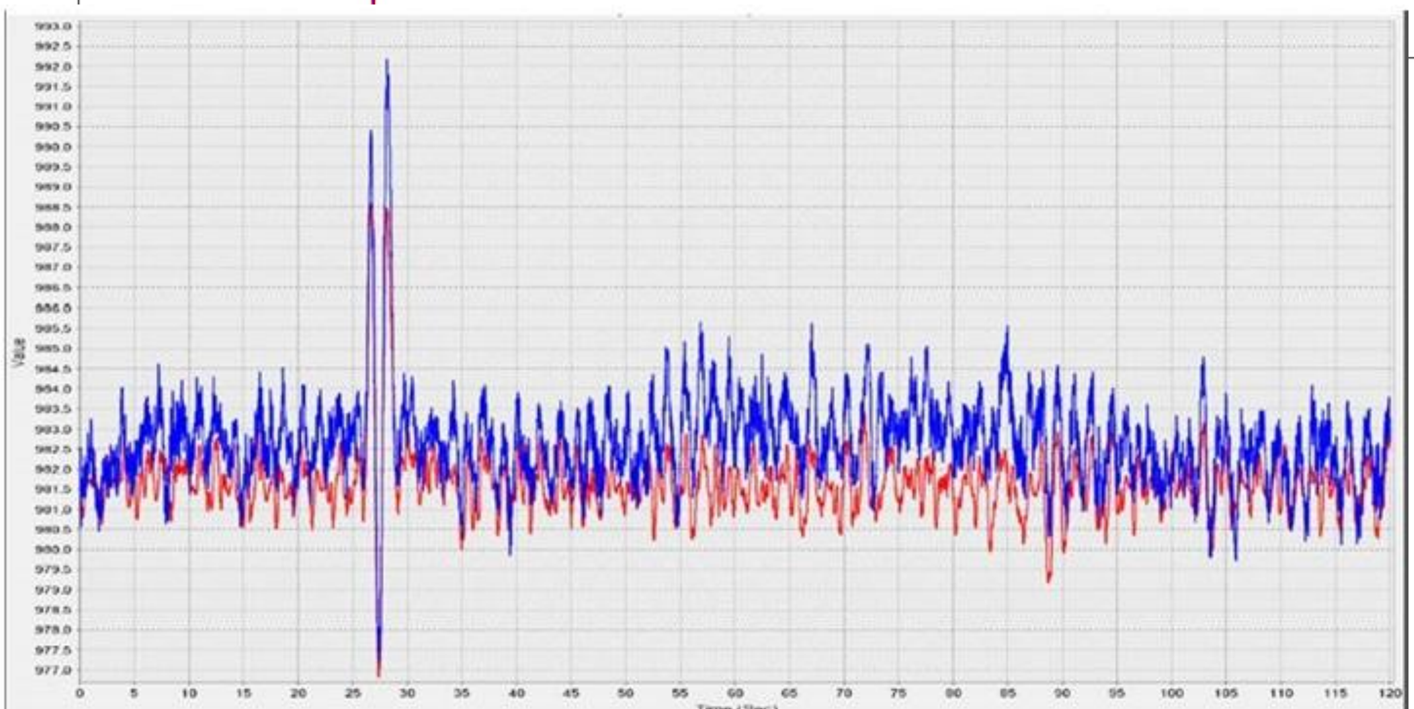
Testing on Real PMU Data

- **Using data sets obtained from an electric utility**
- **Data obtained:**
  - PMU recorded Voltage and Current Phasors at the output of a generator corresponding to an event
  - PSS\E Model data – Case file and Dynamic file
- **Performed Validation on generator, exciter, governor and stabilizer models**

Validation Results – Real Power (P)

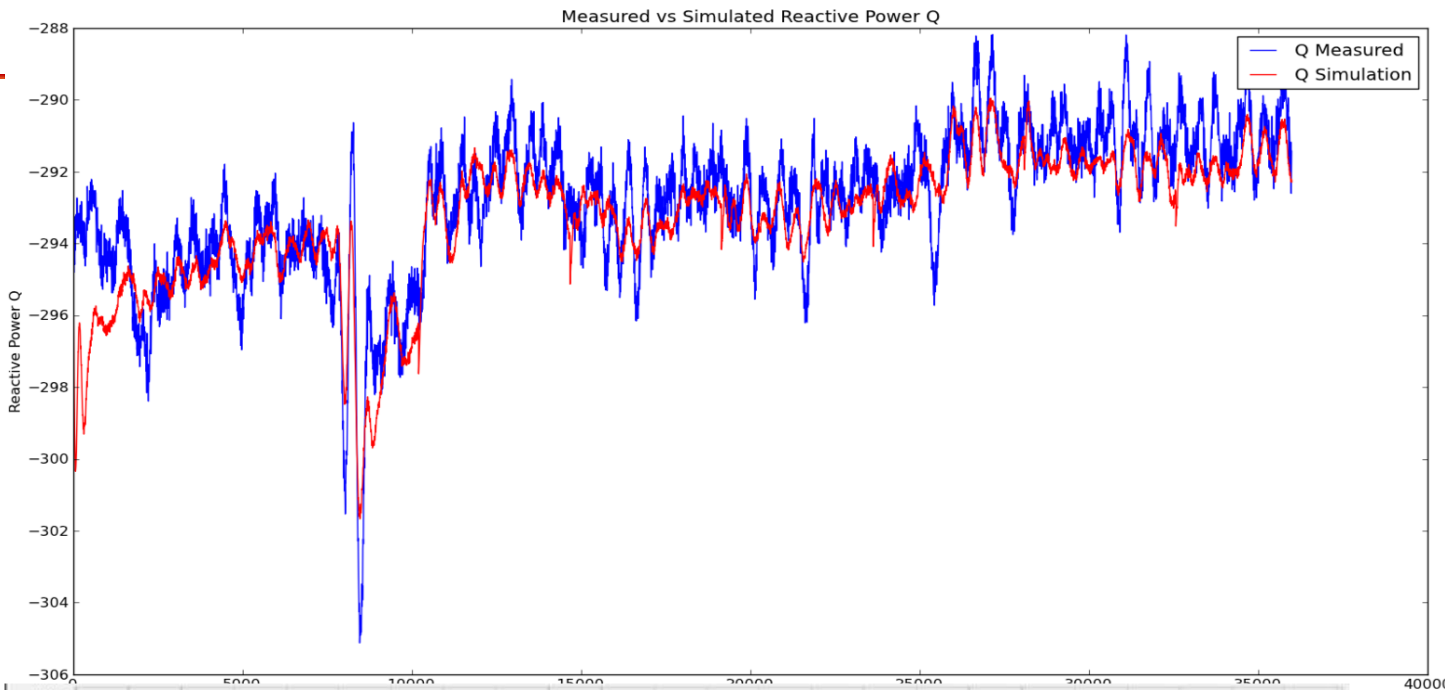


from GPV

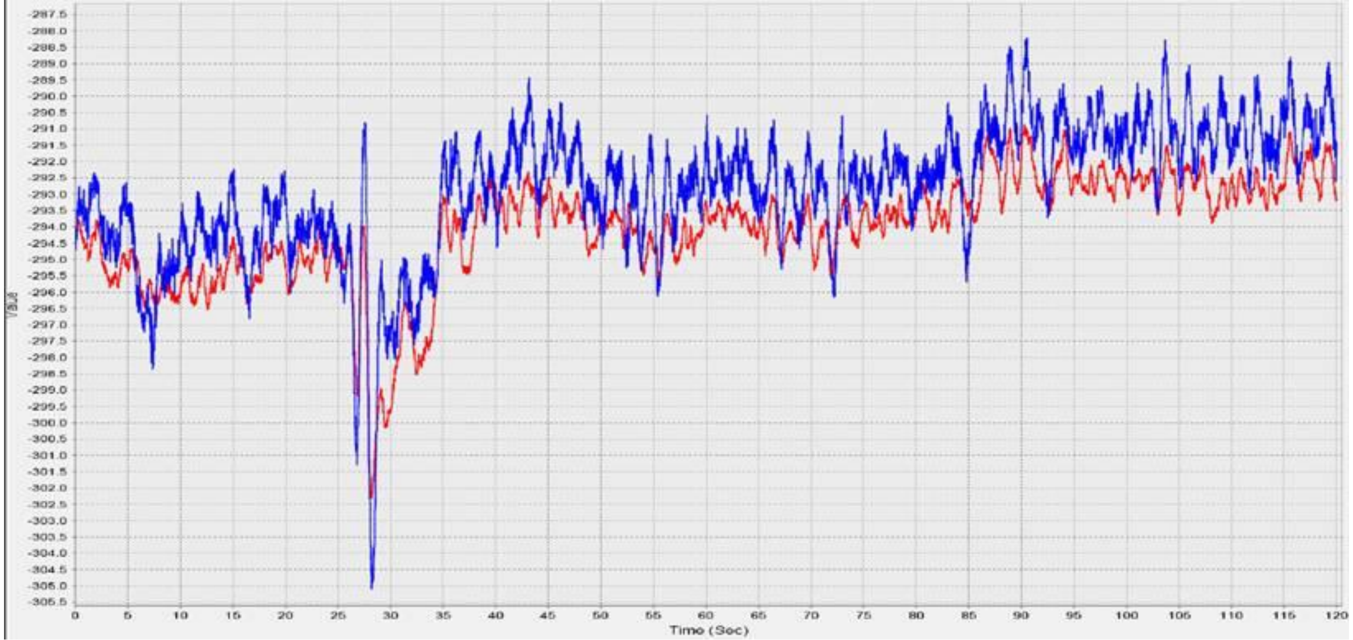


from PSLF Inbuilt Playback Functionality (benchmark)

Validation Results – Reactive Power (Q)



from GPV



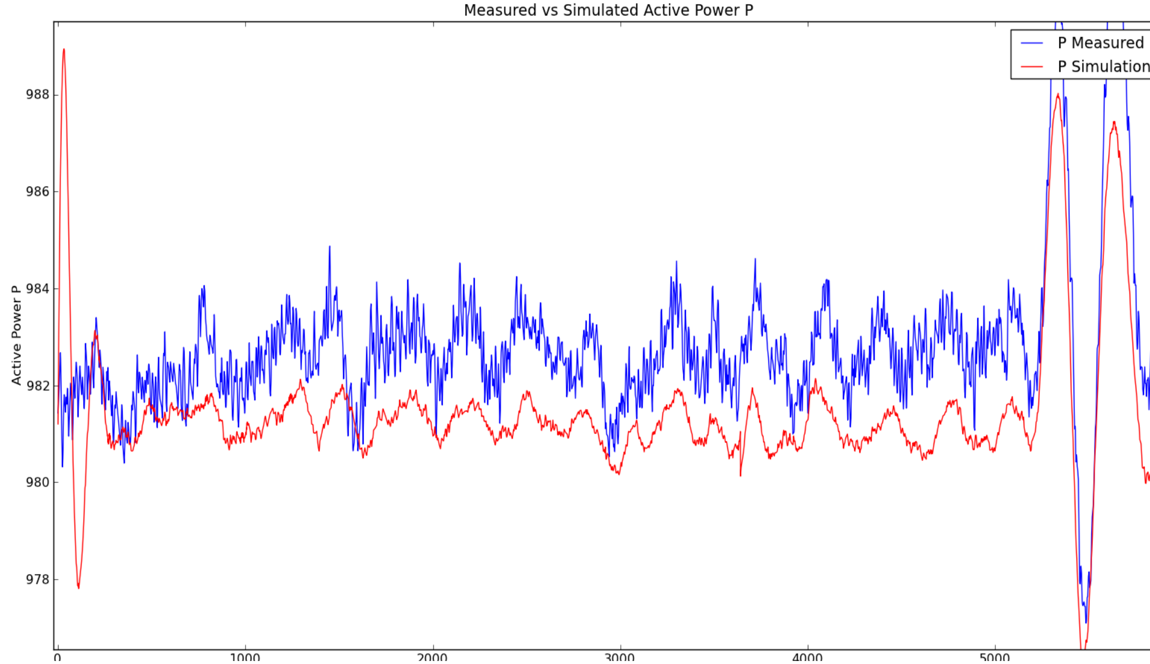
from PSLF Inbuilt Playback Functionality (benchmark)

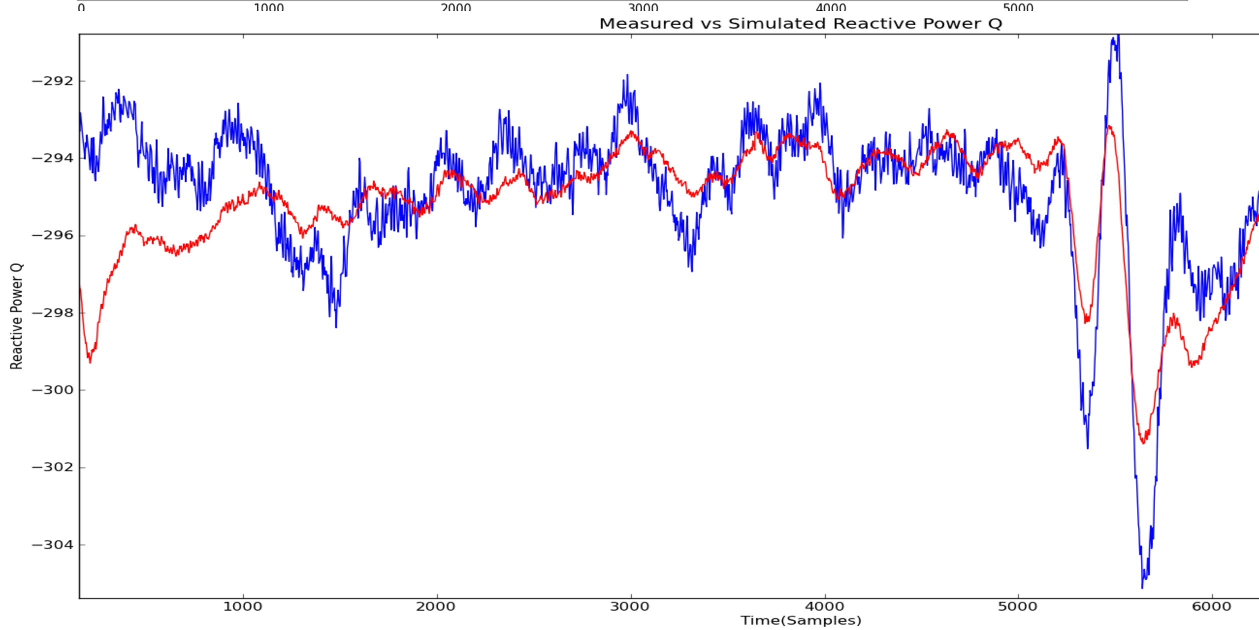
Observations

- **Simulation results capture the actual event response**
- **Pattern of results obtained with GPV matches well with PSLF benchmark**
- **Simulation results do not contain the high frequency dynamics in the measurement signal – open issue**
- **Unwanted transients in the beginning of simulation require special procedures**

Issue: Initial Transient

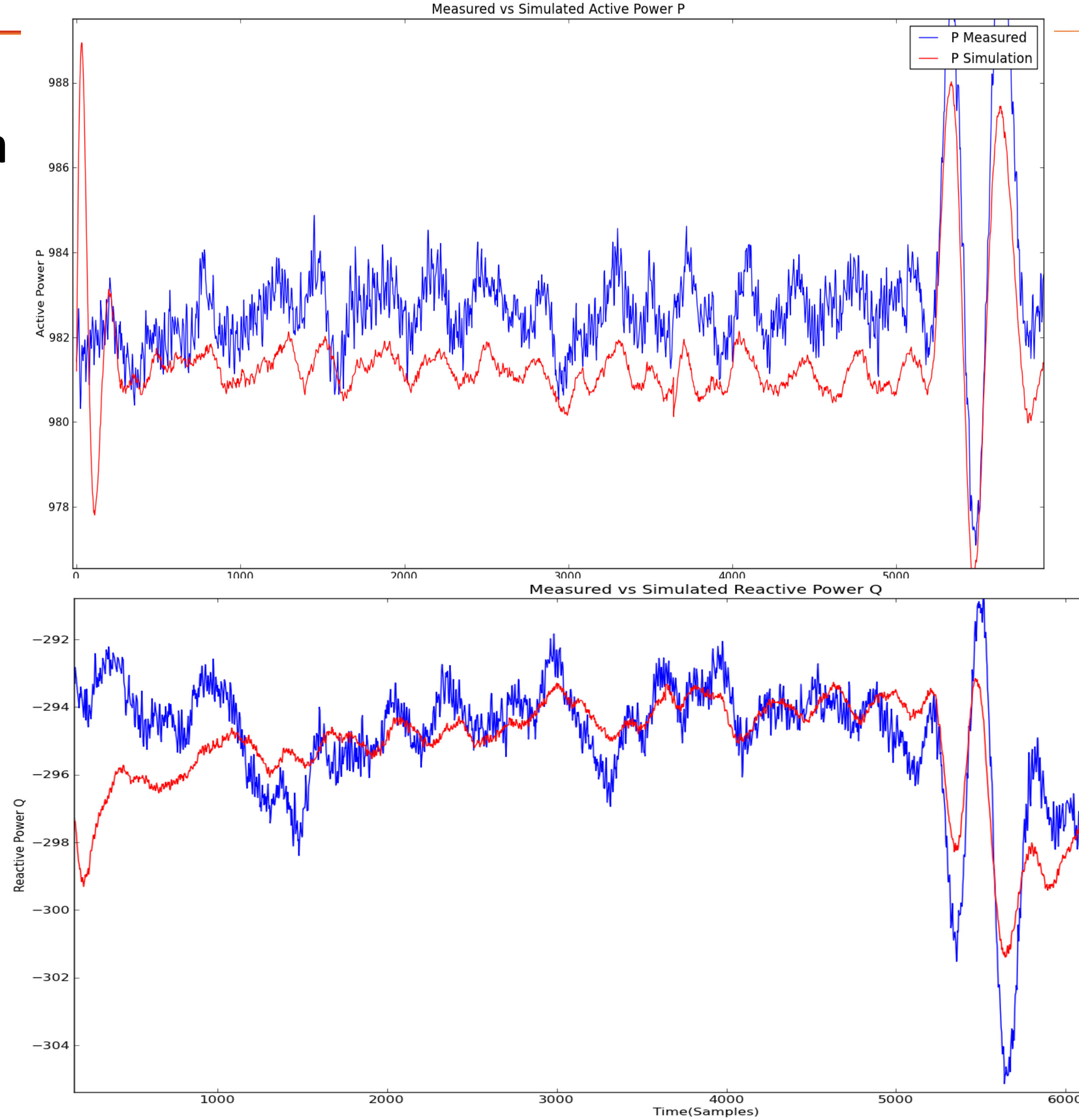
- **Mostly caused by initial frequency mismatch**
- **Actual rotor speed of synchronous generator may not be exactly 60Hz as required by PSS/E**





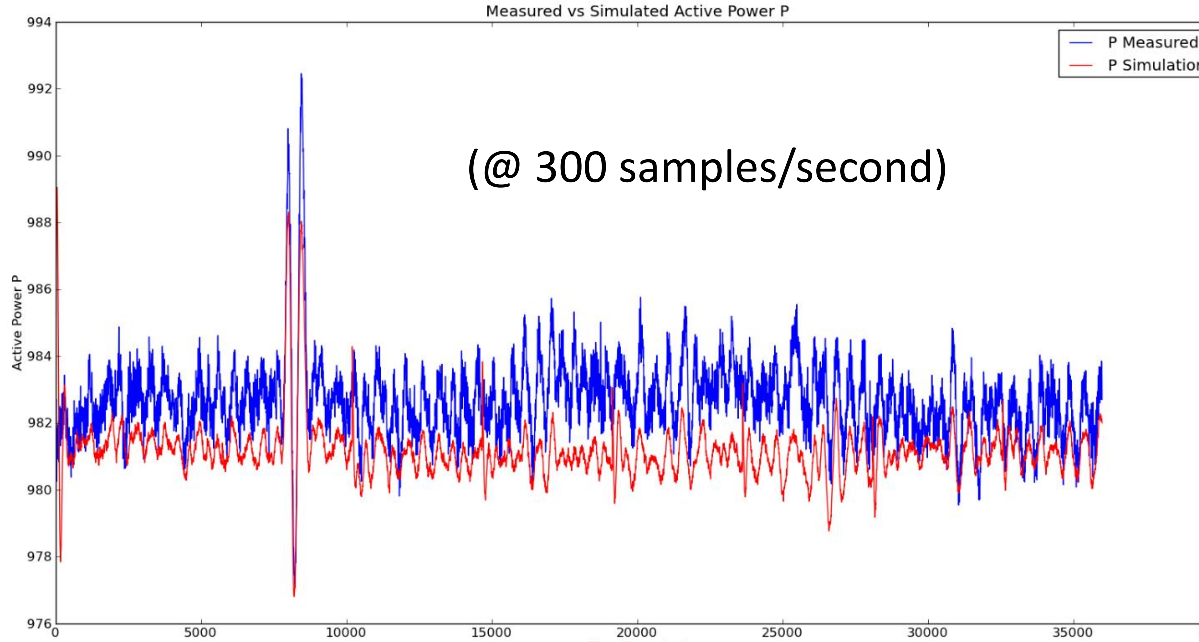
Issue: Initial Transient (continued)

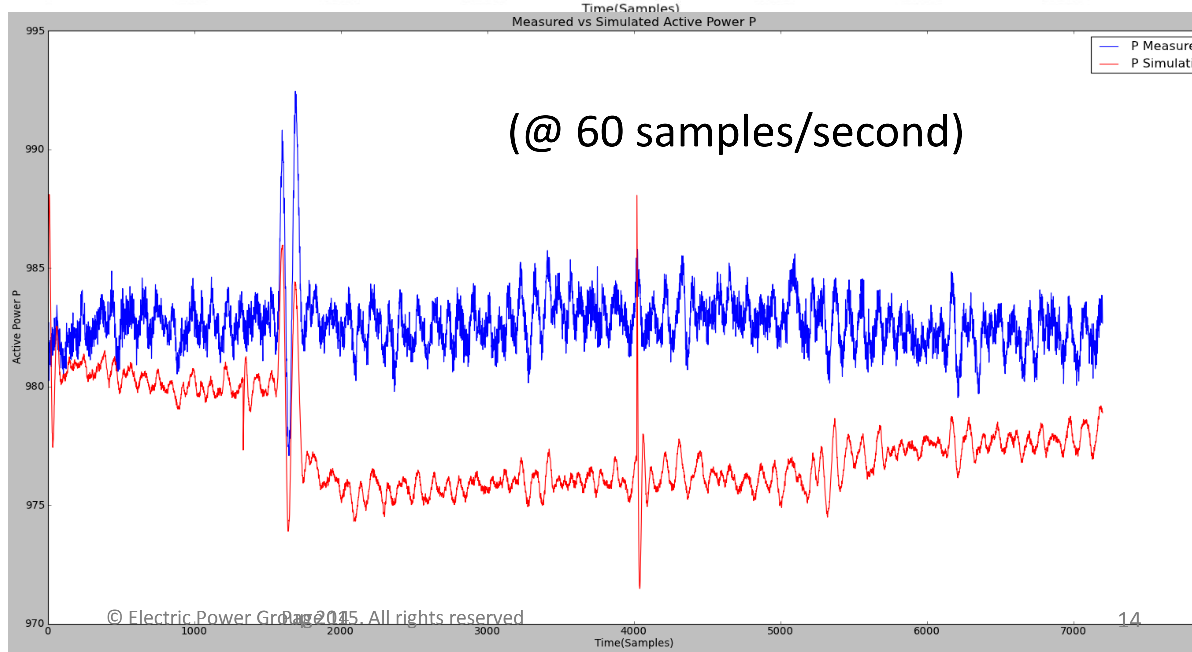
- **Simulations must run a few seconds with <u>no disturbance</u> to allow frequencies match up**
- **The PSLF based results do not have any initial transient because an offset can be applied at the start of simulation**



Issue: Simulation Interval in PSS/E

- **Offset in active power occurs with larger step interval**
- **Reducing the interval helped to reduce offset**
- **Simulation step size should be less than the smallest dynamic model time constant**
- **A very small interval is needed to capture the dynamics**

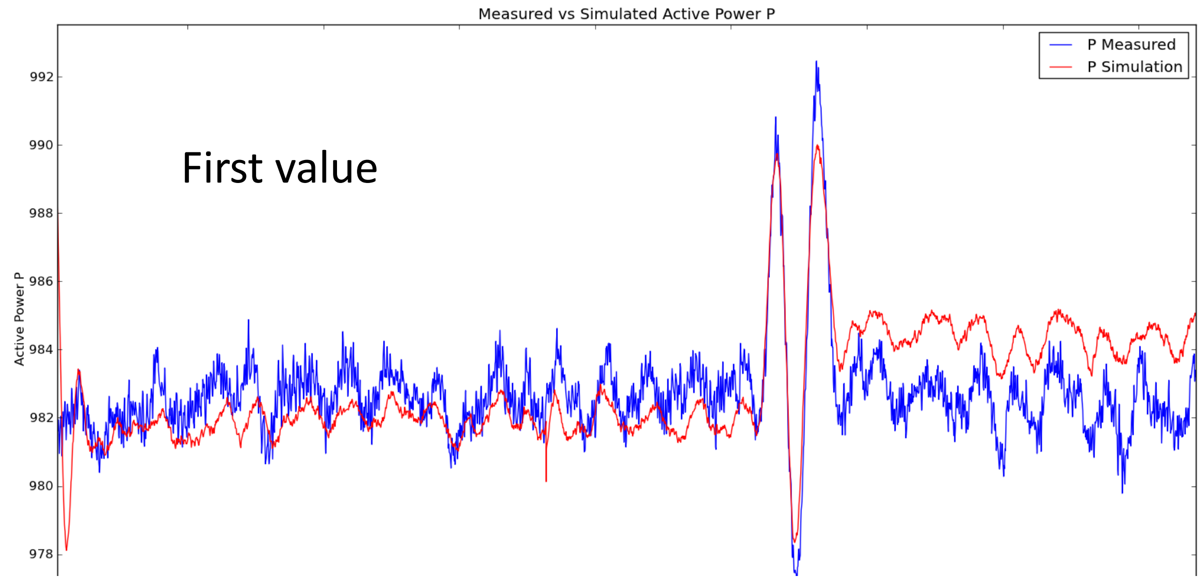


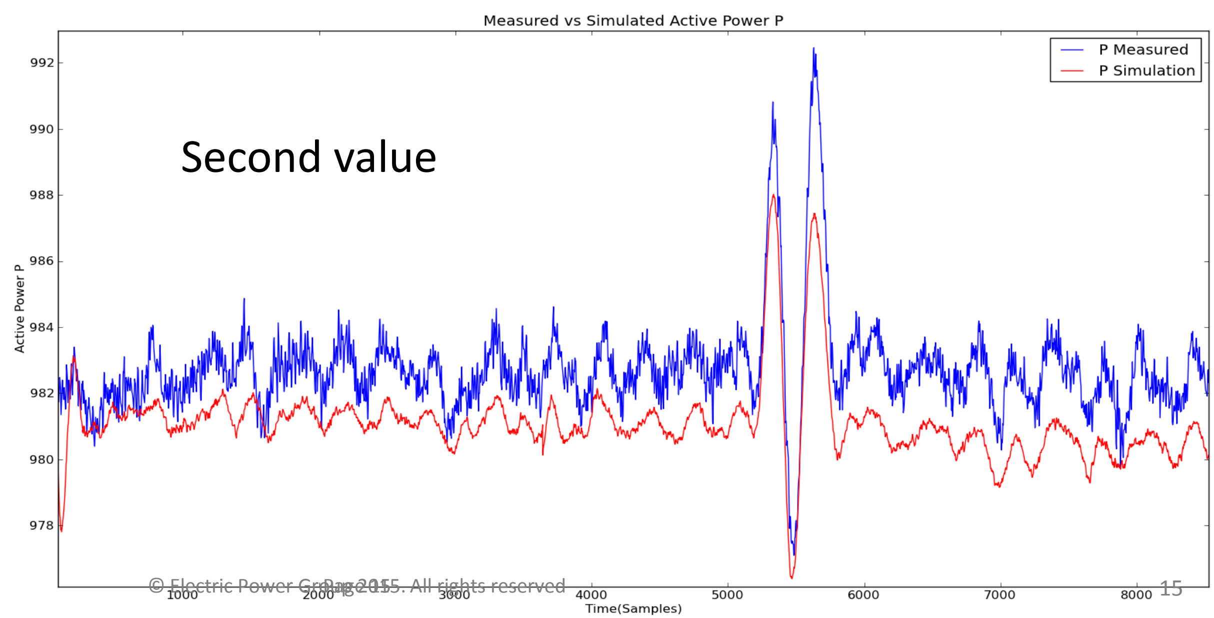


Issues: Two Values for Each Simulation Step

Two values for each simulation step in PSS\E:

- **Two values for the instant when the network conditions change**
- **E.g. for fault at t = 5.0 sec, there will be two bus voltage entries:**
  - **5.0s - : 1.01 pu**
  - **5.0s +: 0.0 pu**
  - **Best to use the value after change**





Next Steps

- **Obtain additional PMU data sets for testing**
  - **Validate with multiple events**

- **Define a quantitative metric to evaluate the closeness of validation plots**

Next Steps (continued)

- **Extend the Capability to Wind Models and User-defined Models**
  - **Validate the Wind Collector System Equivalent Model Used by ERCOT**
  - **Obtain Event Data at the Combined Output of Wind Generators**
  - **Obtain Model Data From ERCOT Which Includes Wind Models and Additional Python Scripts to Run User-defined Models**
  - **Merge the GPV Code Into the ERCOT Developed Code For Running the Simulations for User-defined Models**

Summary

- **Proved benefits of Synchrophasor measurements:**
  - Verify good models
  - Minor parameter adjustments (one or possibly two parameters in question)
  - Low Cost
- **Prototype of Concept of proposed complete process to validate model**
- **EPG/Dominion would like to work with utilities/ISOs to test with more PMU data sets**

Thank You.

Any questions ?

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