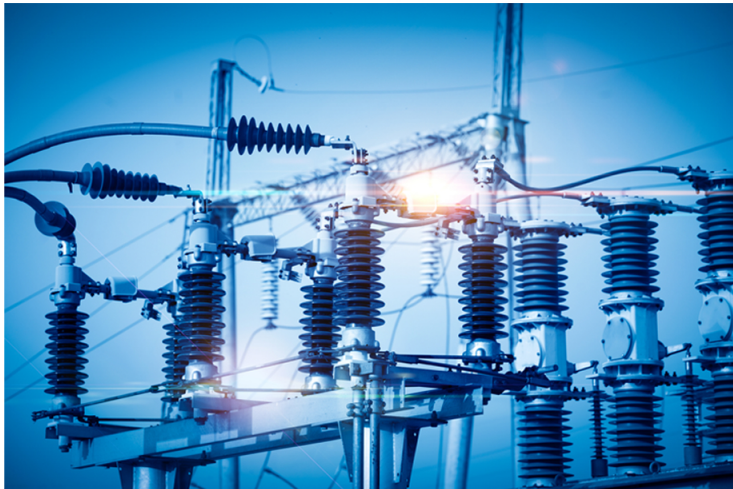




GENERATOR PARAMETER VALIDATION



Contents

Industry Need

Platform

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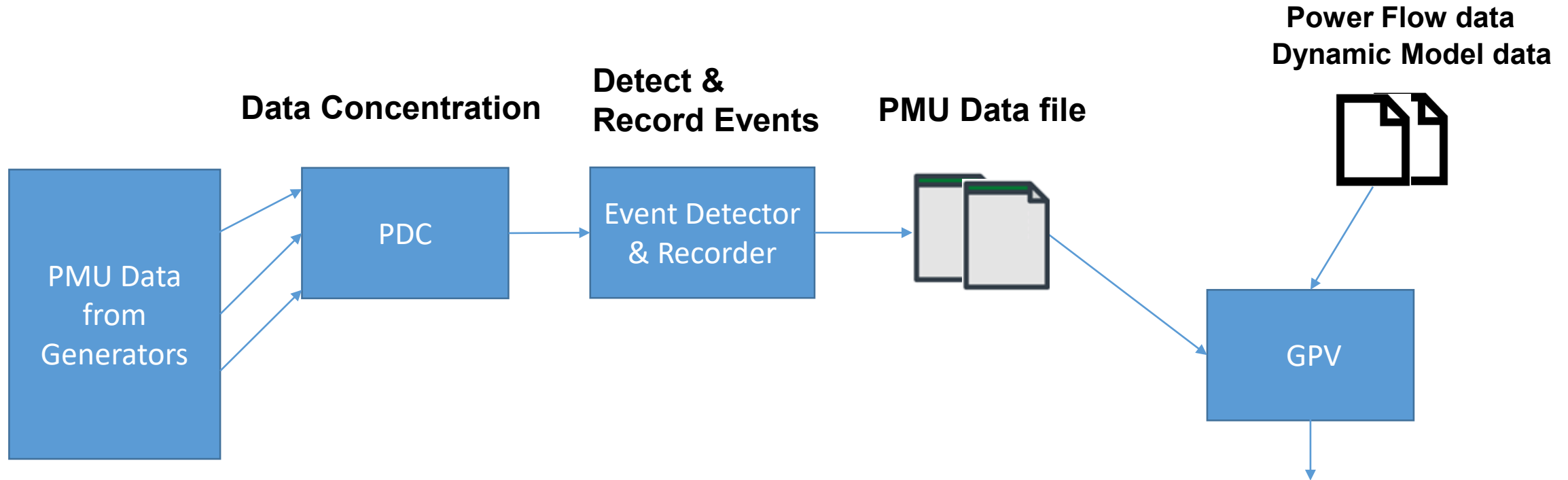
Calibration

Reports

Industry Need

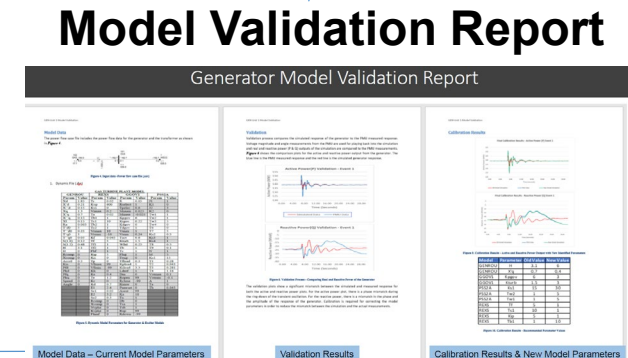
- Inaccurate models can cause blackouts For e.g. August 1996 blackout – models did not represent reality
- NERC requires model validation - MOD-026, MOD-027 require periodic verification of generator dynamic models including excitation controls, governor and turbine controls
- Traditional staged tests for Generator Model Validation
 - > Require units to be taken out of service
 - > Expensive and Time consuming

Generator Parameter Validation (GPV) - Architecture



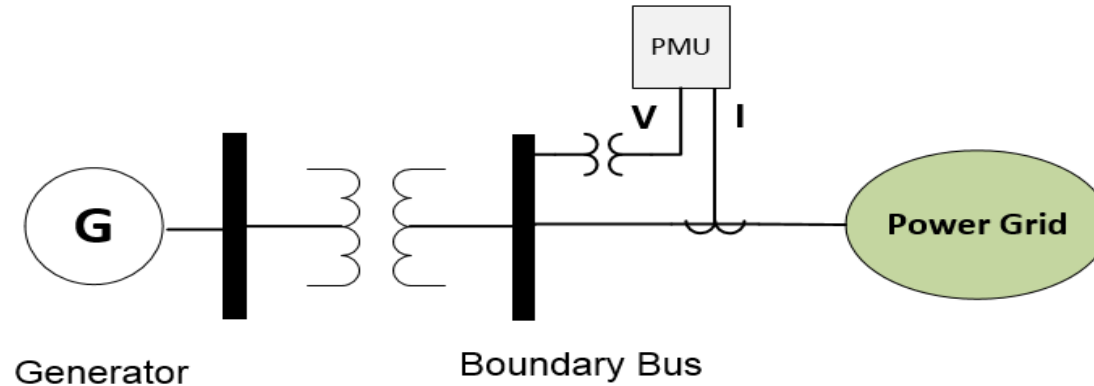
Event Detector and Recorder: RTDMS, *eGENS*, 3rd Party Apps

- Can be deployed in the field for individual plants
- Can be deployed at a central location for multiple generators



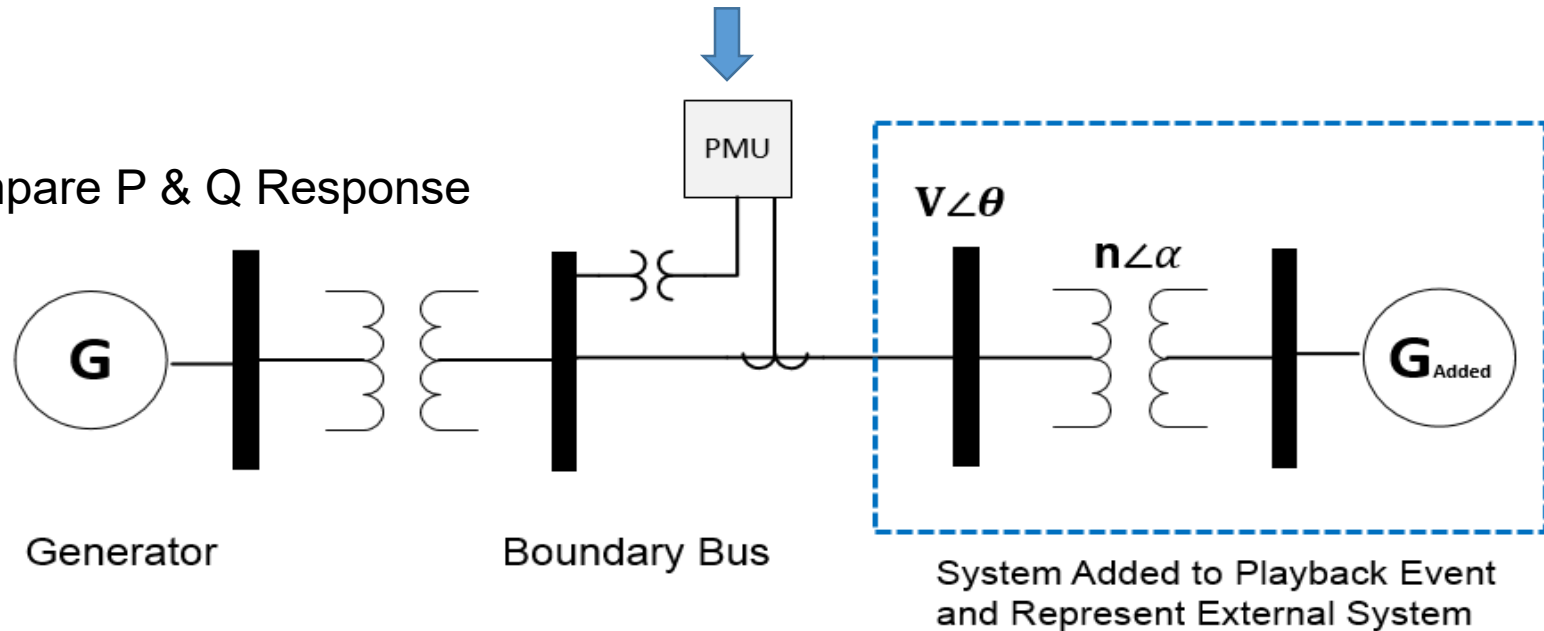
Methodology

PMU Measurements at the High Side or Low Side of Transformer



Reduced System for Event Playback

Compare P & Q Response



Generator Model Validation using Synchrophasors

- Synchrophasor data from PMUs and advanced algorithms enable online generator model validation
- Benefits
 - > No need to take Units Offline - Reduces Cost Significantly
 - > Can be repeated frequently for multiple events and multiple generators
 - > Can not only perform validation but also calibrate models

Generator Parameter Validation (GPV) - Introduction

- Comprehensive Platform for Generator Model Validation using PMU/DFR data
- Inputs
 - > PMU/DFR Measured Event Data
 - > Model – power flow & dynamic data (PSSE format)
- Methodology
 - > Validation – Comparing simulated response to PMU measurements
 - > Sensitivity Analysis -Automated Process of Identifying key Parameters
 - > Calibration – GPV provides parameters to update the model for matching PMU measured response
 - > Automated Report Generation & Emailing Capability
- Types of Models that can be validated: Generator, Governor, Exciter, Stabilizer for conventional power plants

GPV Overview - Real-Time and Offline

■ Online/Real-Time

- > Run Continuously as a service
- > Validate Multiple Events
- > Validate Multiple Generators
- > Quantify Mismatch and Identify Good vs Questionable (programmatic not visual)
- > Automated Report Generation and Email

■ Offline Generator Parameter Validation (GPV)

- > Perform Detailed Analysis Offline
- > Sensitivity Analysis
- > Calibration and Tuning
- > Generate Automated Report

Generator Model Validation for TVA

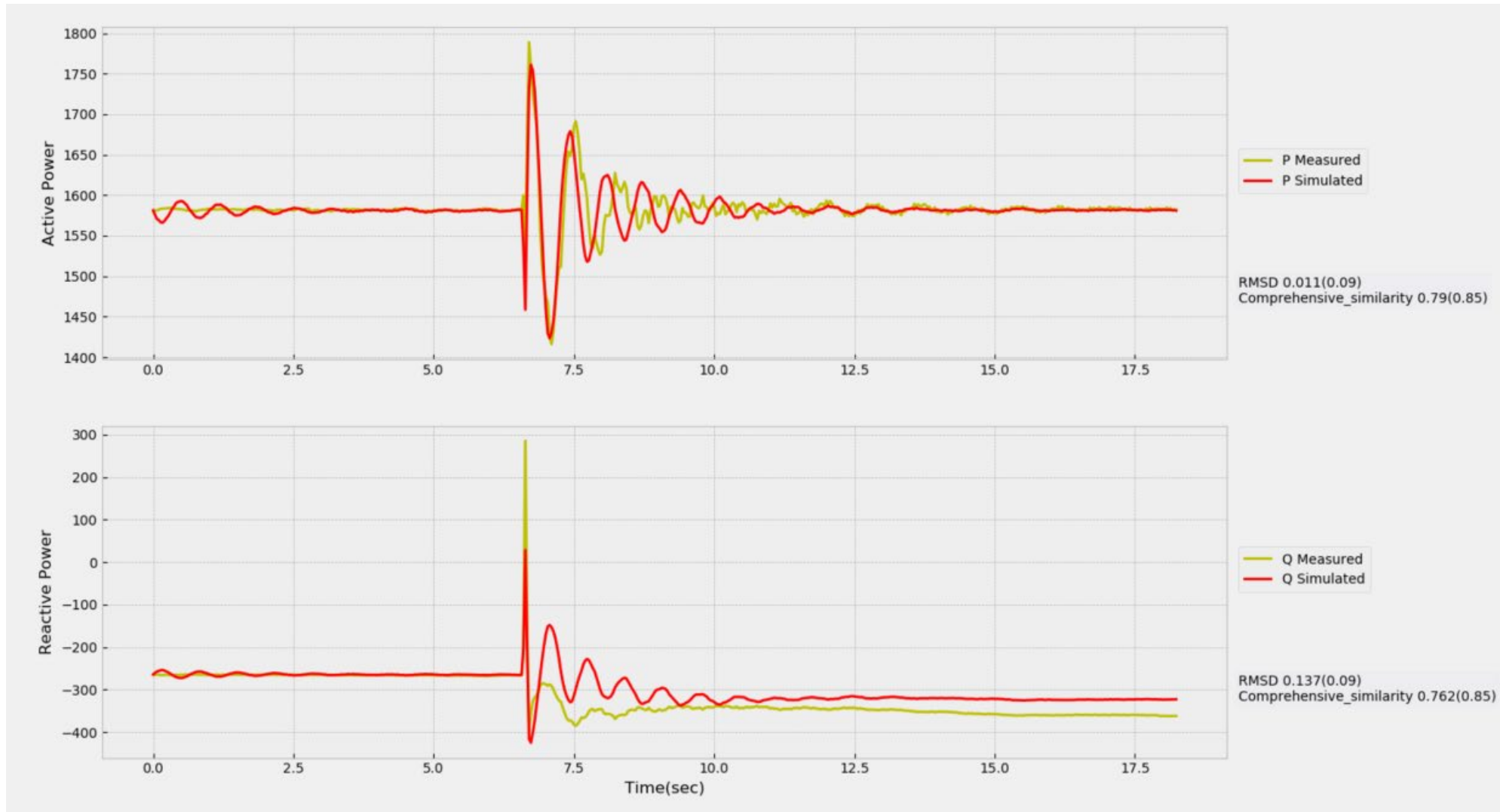
- Large Unit (> 500 MW) at TVA
- Models – Generator and Exciter
- TVA Provided us the data for the event – fault caused nearby unit to trip
- Model response did not match the PMU measurement
- Performed Sensitivity Analysis and Calibration
- Identified two key parameters that were corrected
 - > Inertia (H)
 - > Exciter Model Parameter (Va Max)
- Updated model matched the PMU response

5 Step Process for Model Validation for TVA

- Input Data
- Validation – Model not valid
- Sensitivity Analysis – Identifying key parameters for calibration
- Calibration – 2 out of 37 Parameters updated
- Revalidation – Model matched the PMU event data
- Report Generation

Validation Results

- Comparison of PMU and Simulated Data for P and Q
- Quantify Mismatch between the two using RMSD and Comprehensive Similarity



Sensitivity Analysis

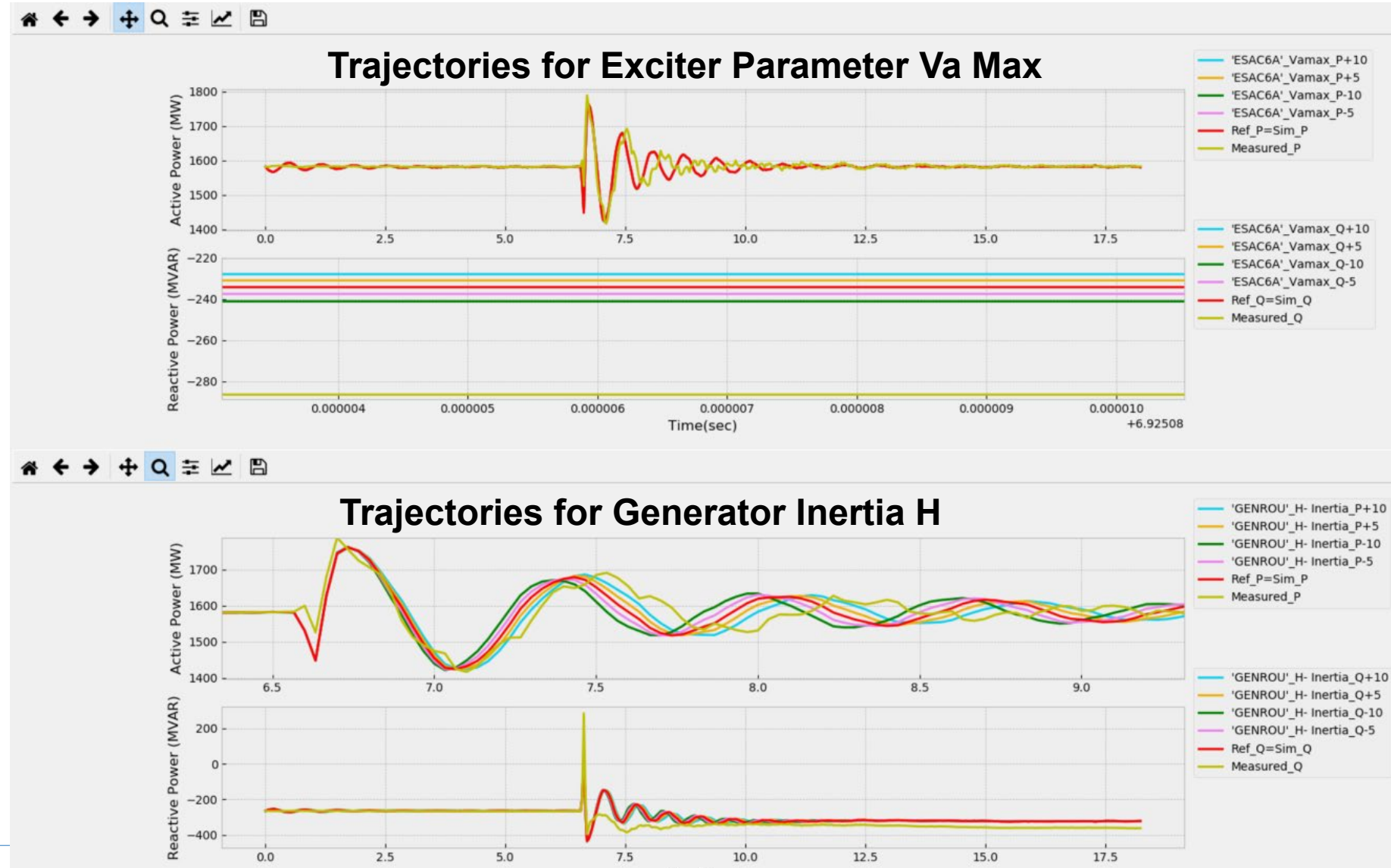
- Identify Key Parameters that change the generator response
- Rank Parameters as per Sensitivity Results
- Ability to Select Parameters for Calibration
- Specify Range for each parameter Variation

	Models	Model Parameters	Current Value	Calibrated Value	MSE-P	MSE-Q	Rank	Minimum	Maximum
1	<input type="checkbox"/>	Select All							
2	<input type="checkbox"/>	GENROU	T'do(>0)(sec)	5.85	0.0154	0.24384	13		
3	<input type="checkbox"/>	GENROU	T''do(>0)(sec)	0.044	0.17222	0.09429	16		
4	<input type="checkbox"/>	GENROU	T'qo(>0)(sec)	0.65	0.00656	0.01027	21		
5	<input type="checkbox"/>	GENROU	T''qo(>0)(sec)	0.062	0.00993	0.0234	19		
6	<input type="checkbox"/>	GENROU	H- Inertia	3.223	30.33625	15.14905	1		
7	<input type="checkbox"/>	GENROU	D-Speed damping	0.0	0.0	0.0	NaN		
8	<input type="checkbox"/>	GENROU	Xd	1.73	0.11781	0.17748	15		
9	<input type="checkbox"/>	GENROU	Xq	1.682	0.07249	0.14803	17		
10	<input type="checkbox"/>	GENROU	X'd	0.457	19.74647	11.75749	2		
11	<input type="checkbox"/>	GENROU	X'q	0.573	0.13598	0.28038	11		
12	<input type="checkbox"/>	GENROU	X''d=X''q	0.351	14.6057	7.94303	3		
13	<input type="checkbox"/>	GENROU	XI	0.258	0.02276	0.01871	20		
14	<input type="checkbox"/>	GENROU	S(1.0)	0.028	9e-05	0.00031	24		
15	<input type="checkbox"/>	GENROU	S(1.2)	0.273	0.00022	0.00778	22		
16	<input type="checkbox"/>	ESAC6A	Tr(sec)	0.02	0.00933	0.26141	12		
17	<input type="checkbox"/>	ESAC6A	Ka	500.0	0.0355	1.51837	8		
18	<input type="checkbox"/>	ESAC6A	Ta(sec)	49.9	0.03255	1.54982	7		
19	<input type="checkbox"/>	ESAC6A	Tk(sec)	4.0	0.03812	1.88223	5		
20	<input type="checkbox"/>	ESAC6A	Tb(sec)	0.04	0.01477	0.37737	10		
21	<input type="checkbox"/>	ESAC6A	Tc(sec)	0.2	0.04604	1.86142	6		
22	<input type="checkbox"/>	ESAC6A	Vamax	13.6	0.07254	2.20297	4		
23	<input type="checkbox"/>	ESAC6A	Vamin	-12.6	0.0	0.0	NaN		
24	<input type="checkbox"/>	ESAC6A	Vrmax	999.0	0.0	0.0	NaN		
25	<input type="checkbox"/>	ESAC6A	Vrmin	-999.0	0.0	0.0	NaN		
26	<input type="checkbox"/>	ESAC6A	Te(>0)(sec)	0.67	0.06902	0.19416	14		



Trajectory Sensitivity Analysis

- Analyze Trajectories of Generator Response for Key Parameters
- Identify how the generator response changes with key parameter values



Calibration

- Identifies correct model parameters that match measured response
- Performs revalidation to show comparison of simulated with PMU data with new model
- Performs goodness of fit assessment on the new response

GPV Automated Report - For NERC Compliance

- Includes all results and plots from the analysis
- Provides all information required for compliance
- Generated Automatically

Real-time Generator Parameter Validation Report

Event 1: March 23rd, 2019 3:15:22 PM

Number of Generators

Number of generator models validated	15
Number of good generator models	13
Number of questionable generator models	2

Summary of Validation Results

Generator	Result
G1	Questionable
G2	Questionable
G3	Good
G4	Good
G5	Good
G6	Good
G7	Good
G8	Good
G9	Good
G10	Good
G11	Good
G12	Good
G13	Good
G14	Good
G15	Good

Parameter Used for Quantifying Mismatch

Criteria	Threshold
Accumulated Error Ratio	0.025
First Swing Peak Value	0.1
First Swing Peak Time(s)	0.5
Settling Time(s)	0.5

Validation Results for G1

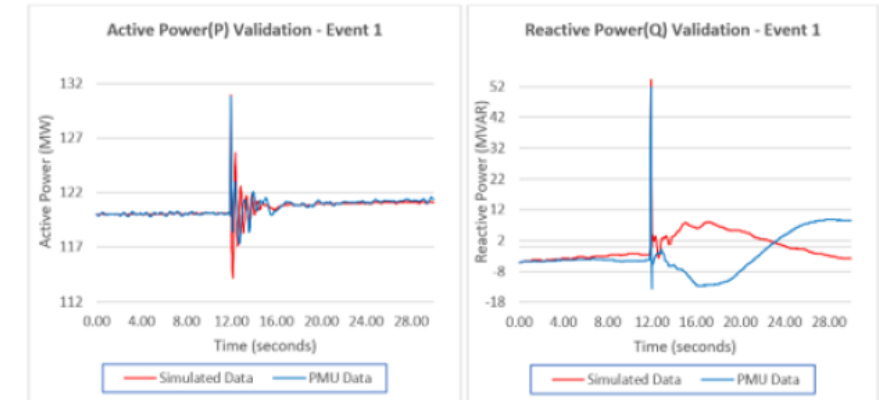


Figure 1. Active power & Reactive Power Comparison

Active Power Comparison

Criteria	PMU measurement	Simulated data	Difference
Accumulated Error	0.098927913	0.098927913	0
First Swing Peak Value	695.7307436	800.7687378	105.038
First Swing Peak Time	0.245	0.3	0.055
Settling Time	7.44499399	7.50499399	0.05

Reactive Power Comparison

Criteria	PMU measurement	Simulated data	Difference
Accumulated Error	0.144973111	0.144973111	0
First Swing Peak Value	399.3055053	459.6365356	60.325
First Swing Peak Time	0.035	0.085	0.05
Settling Time	8.64499399	1.52499399	-7.12

GPV Summary

- Comprehensive Platform for Generator Model Validation and Calibration
- Validated – Nuclear, Steam Turbine, Gas Turbine, Hydro, Combined-Cycle
- Renewables (Wind, Solar etc.) – On the Roadmap
- Key Functionality and Capabilities
 - > Automatic Validation after significant events
 - > Automatic quantification/identification of good vs questionable models
 - > Detailed analysis and tuning – sensitivity analysis, trajectory analysis and calibration
 - > Automated Report Generation
 - > Easy to use Interface
- Available for deployment





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