

Automated Power Plant Model Verification (APPMV) at ISO New England



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Business Needs and Motivations

- Determine dynamic model accuracy
 - Confidence when developing operating limits
 - Yes/no answer – no parameter estimation needed
 - In response to NERC MOD-26/27
- Available tools
 - EPRI (PPPD), PNNL, TSAT, PowerWorld, PSS/E, PSLF
- Major constraints about PPMV : Time and effort
 - Manual process
 - Retrieve PMU and SCADA data
 - Set up initial condition and prepare the simulation case
 - Analyze the result
 - Verify one generator at a time
 - About 2 hours per event per generator
- Need an automatic tool that
 - Integrates with our systems
 - Works continuously online
 - Verifies all PMU monitored generators



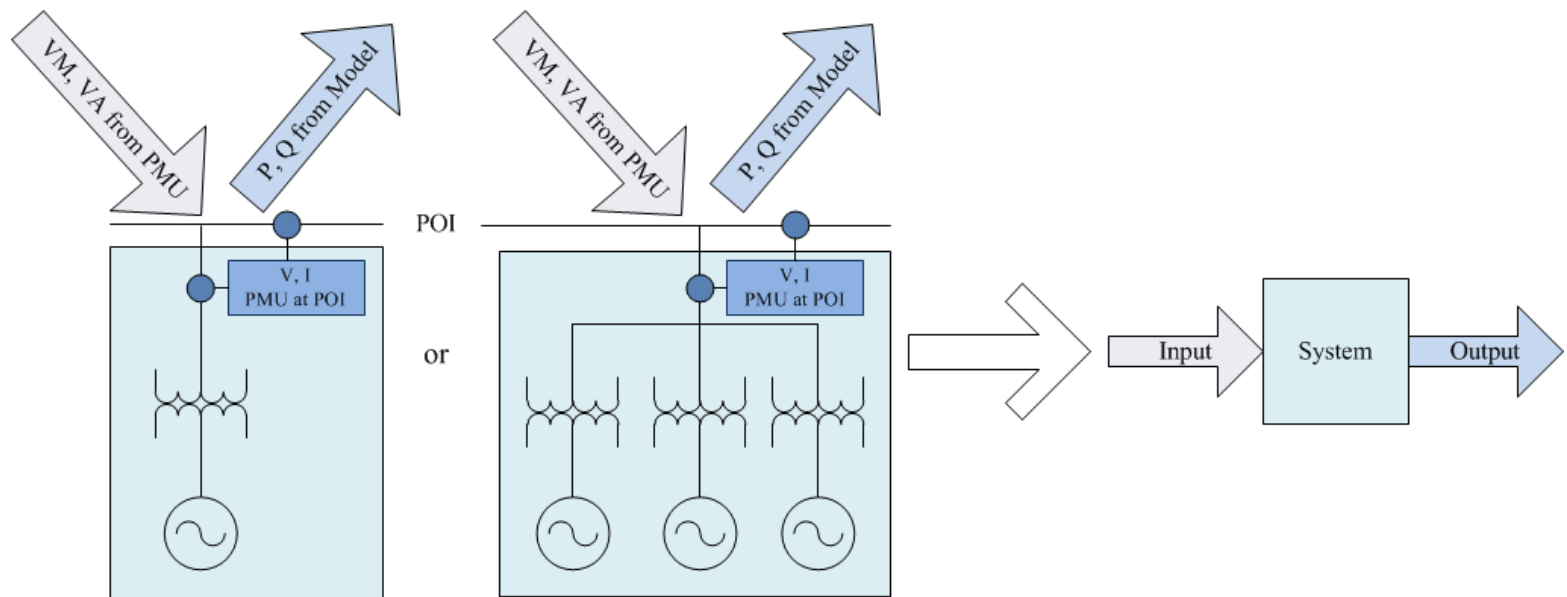
A Little History

- Batch Power Plant Model Verification Tool (BPPMV)
 - Meng Wu (Summer Intern, 2016)
- Added quantified result analyses to BPPMV
 - Weihong Huang (Fall Intern, 2016)
- Automated Power Plant Model Verification Tool (APPMV)
 - Weihong Huang (Summer Intern, 2017)
- Continued improvements afterwards

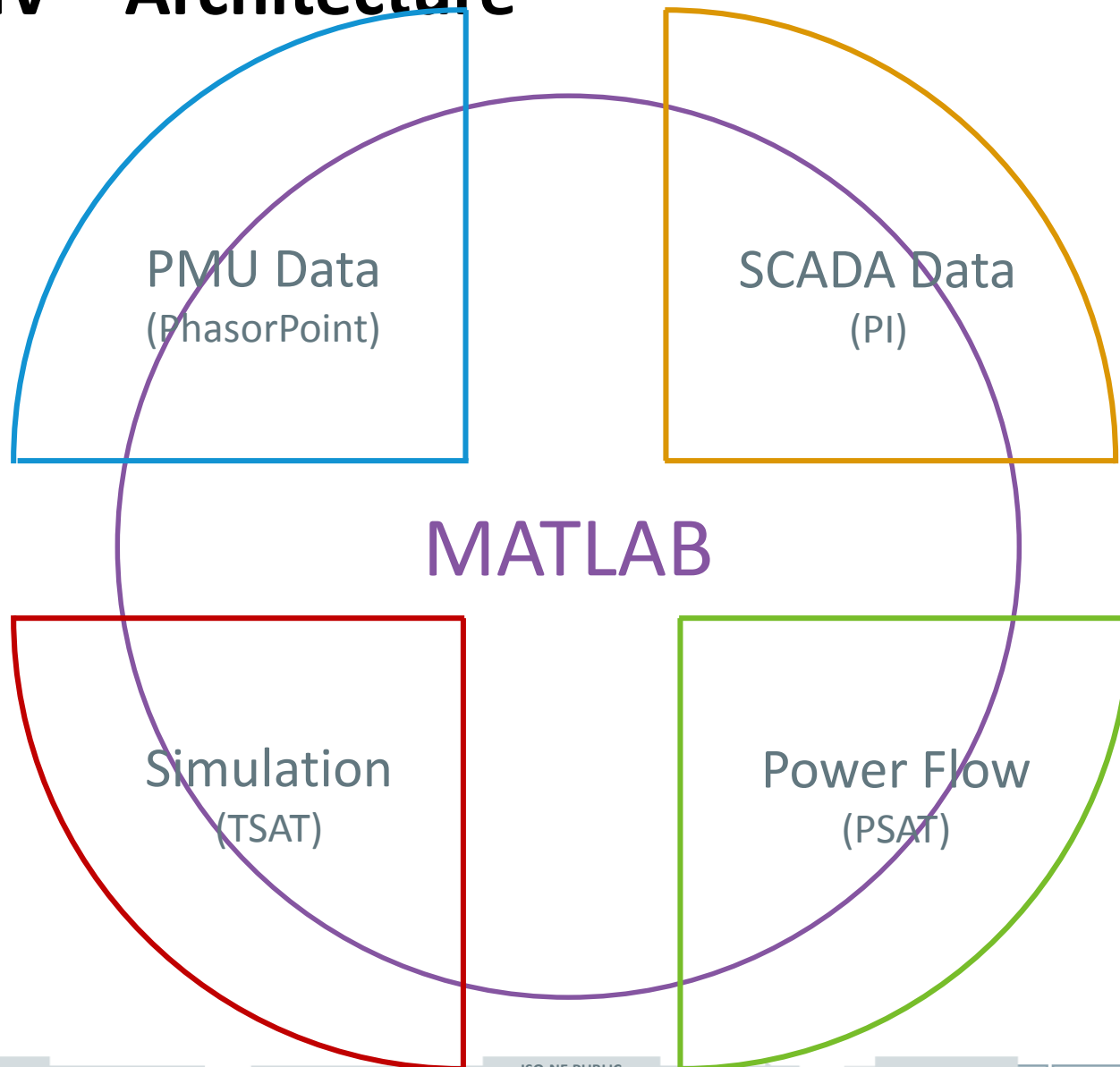


BPPMV

An Offline GUI Tool



BPPMV – Architecture



BPPMV – Main GUI Overview

The screenshot displays the BPPMV software interface, which is divided into several functional areas:

- File:** A menu bar at the top left.
- All Generator List:** A list of generators (1-16) with checkboxes and buttons for "Request Selected Generators" and "Request All Generators".
- Requested Generator List:** A list of selected generators (4, 11, 12) with buttons for "Cancel Selected Generators" and "Cancel All Generators".
- PMU & SCADA Raw Data Plots:** A central plot showing "Value (V / A / Deg / Hz / MW / MVar)" on the y-axis (ranging from 59.94 to 60) and "Time (s)" on the x-axis (ranging from 0 to 30). The plot shows a blue line with a sharp dip around 8 seconds and subsequent oscillations. A legend indicates "3-".
- Curve Viewer Selection:** A panel for selecting "Disturbance Date & Time (Local Time Zone)" (set to 2016 :38) and "Event Info" (set to Gen_ Trip). It includes "Draw Curves" and "Clear Curves" buttons.
- Parameter Settings:** A panel with "Set User Parameters" and "Set Program Parameters" buttons.
- Execute Separate Functions:** A grid of buttons for tasks like "1. Load DYR File", "2. Load PFB Files", "3. Load Mapping Table", "4. Pull PMU Data", "5. Pull SCADA Data", "6. Run Initialization", "7. Run Model Verification", and "8. Save Results".
- Run & Report:** A panel with "Run Full Process" and "Curves & Reports" buttons.
- File Path Selection:** A section with input fields and "Browse" and "Load" buttons for "TSAT_BATCH.EXE", "PSAT.EXE Path", "Zipped_DYR Path", "Zipped_PFB Path", "Mapping Table Path", and "Output Path".
- Program Running Status:** A log window showing messages such as "SUCCESS: Requested Raw Input Curves ..." and "SUCCESS: Requested Raw Input Data Plotted.".
- PhasorPoint (PMU) Database Connection:** A dialog box for "User Name", "Password", and "Server ID" (with a radio button selection).
- TSAT Simulation Settings:** A dialog box for "Simulation Start Time (sec)" (8), "Simulation Length (sec)" (30), "Simulation Step (cycle)" (0.25), and "Integration Method" (radio buttons for RK4, RK2, ME, TRAP).
- PMU Playback Signal Pair:** A dialog box with radio buttons for "Voltage Magnitude - Voltage Angle", "Voltage Magnitude - Frequency", and "Both Pairs".

BPPMV – Process

- User Inputs
 - Set parameters
 - First time use
 - Save as profile for later use
 - Enter the disturbance time
 - Enter the event info
 - Selects generators to verify
- Click “Run Full Process”
- BPPMV automatically
 - Pulls PMU data
 - At Point of Interconnection
 - Pulls SCADA data
 - For multi-generator power plants
 - Sets initial conditions
 - By running power flows in PSAT
 - Creates the TSAT simulation cases
 - Runs playback simulations
 - Analyzes the results
 - Generates the plots
 - Saves the results

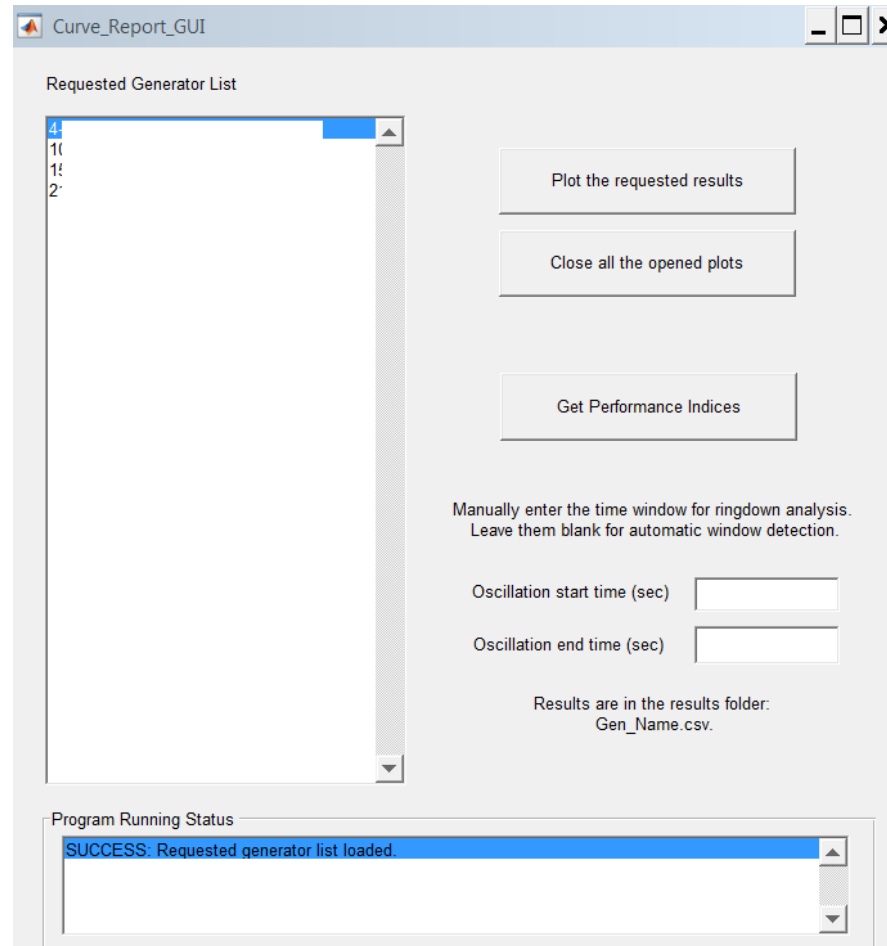


BPPMV – Built-in Intelligence

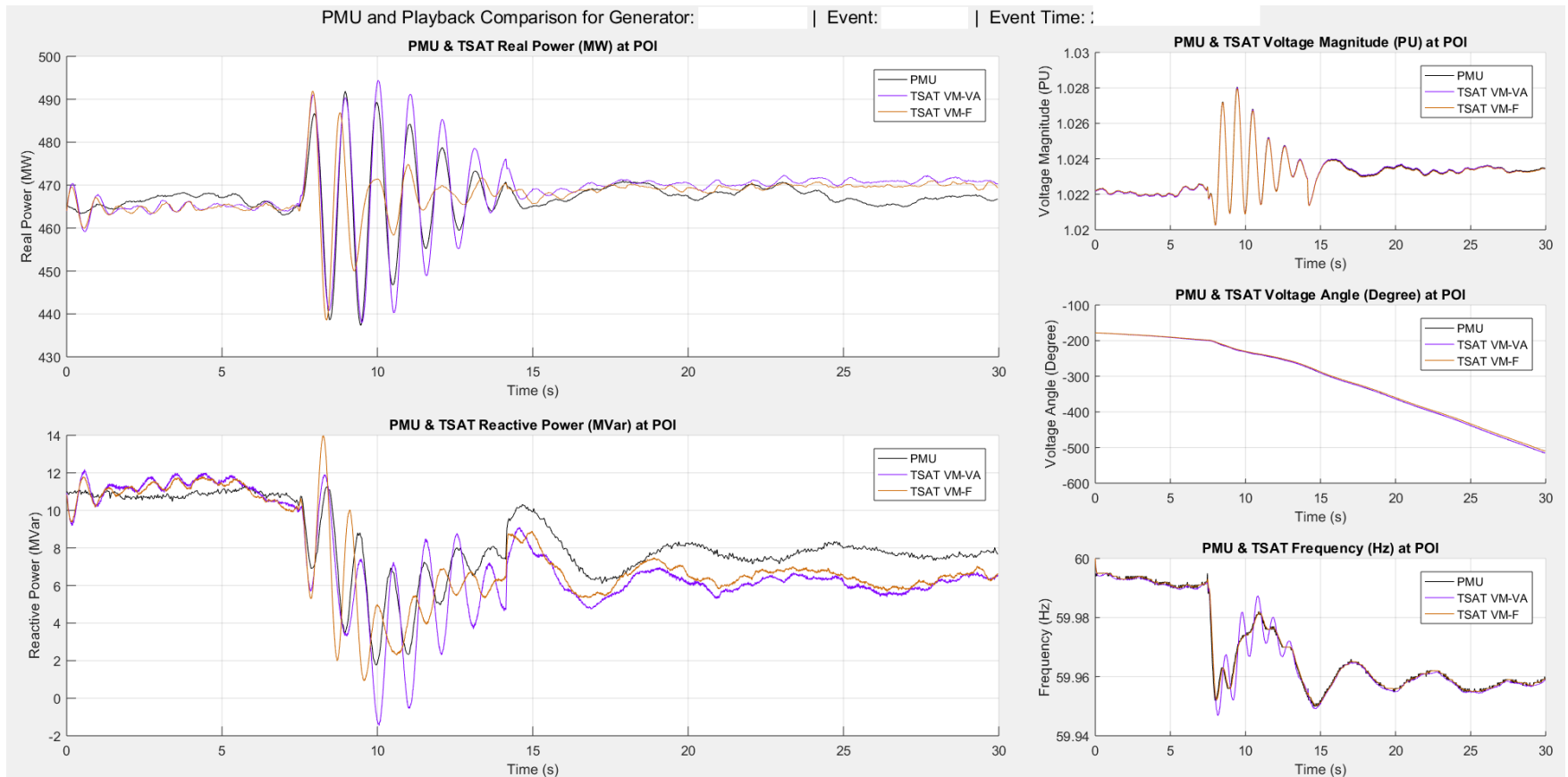
- Skip offline generators or PMUs
- Generator dispatch (SCADA)
 - Set individual generator's online/offline status
 - Set individual generator's output
- Special cases
 - Pump storage
 - Pumping mode or generating mode
- Result analyses
 - Automatically determine disturbance start/end time



BPPMV – Result Analyses GUI Overview



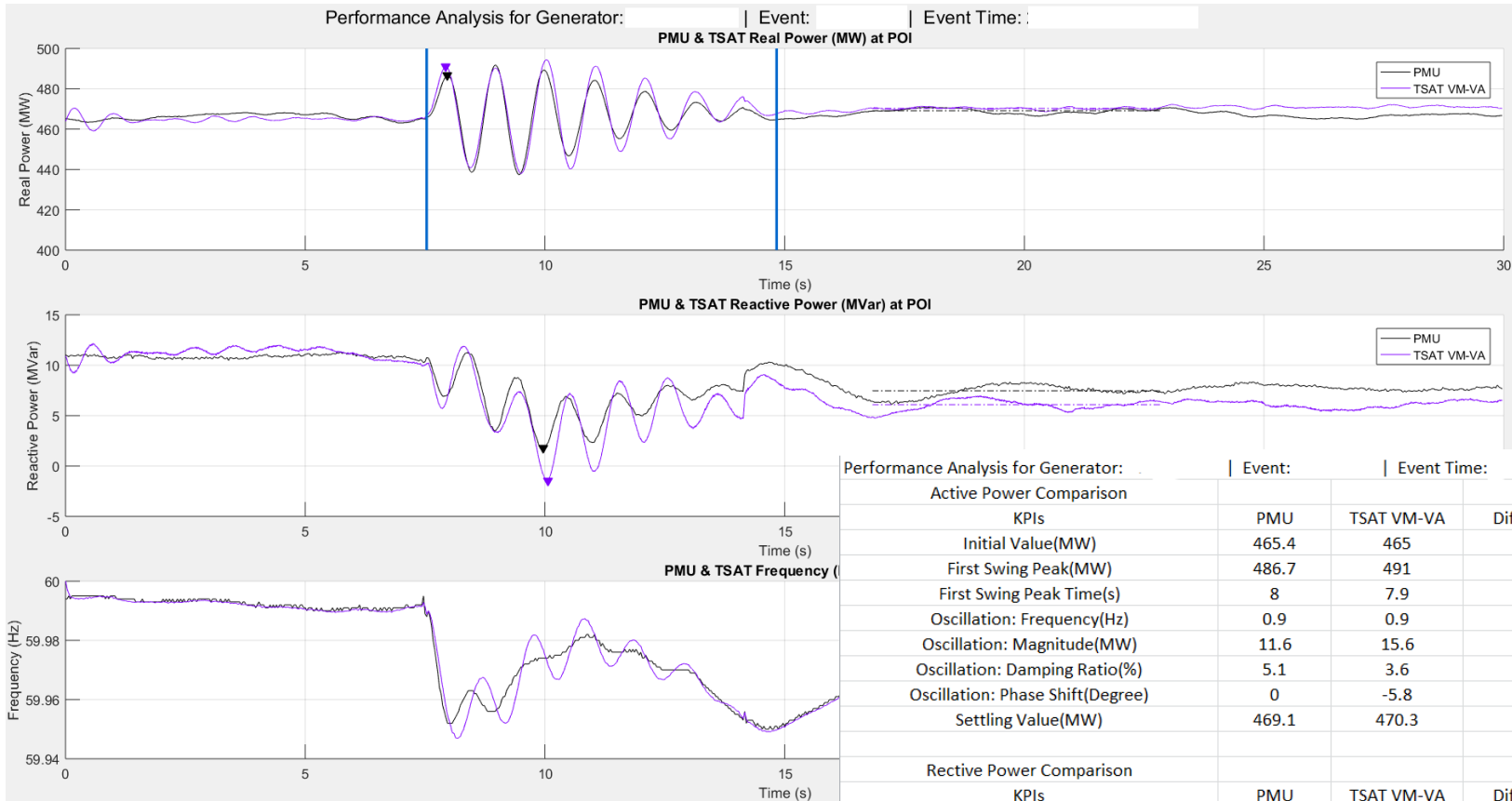
BPPMV – Result Plot



BPPMV – Quantified Result Analyses: Method

- Not based on RMS deviation between simulation and measurement
- Use engineering quantities
- Automatically extracted KPI List
 - Initial Value
 - First Swing Peak & Time
 - Oscillation
 - Frequency, Damping Ratio & Phase Shift
 - Settling Value

BPPMV – Quantified Result Analyses: Output



Performance Analysis for Generator: | Event: | Event Time: |

| Active Power Comparison | | | |
|---|-------|--|------------|
| KPIs | PMU | TSAT VM-VA | Difference |
| Initial Value(MW) | 465.4 | 465 | -0.4 |
| First Swing Peak(MW) | 486.7 | 491 | 4.3 |
| First Swing Peak Time(s) | 8 | 7.9 | 0 |
| Oscillation: Frequency(Hz) | 0.9 | 0.9 | 0 |
| Oscillation: Magnitude(MW) | 11.6 | 15.6 | 4 |
| Oscillation: Damping Ratio(%) | 5.1 | 3.6 | -1.5 |
| Oscillation: Phase Shift(Degree) | 0 | -5.8 | -5.8 |
| Settling Value(MW) | 469.1 | 470.3 | 1.2 |
| Reactive Power Comparison | | | |
| KPIs | PMU | TSAT VM-VA | Difference |
| Initial Value(MVar) | 10.9 | 10.8 | -0.2 |
| Peak(MVar) | 1.8 | -1.5 | -3.2 |
| Peak Time(s) | 10 | 10.1 | 0.1 |
| Settling Value(MVar) | 7.5 | 6.1 | -1.4 |
| PMU frequency vs. VA calculated frequency | | Different (may be due to PMU frequency errors) | |

APPMV

An Online Automated Service

APPMV – Architecture

- APPMV puts another wrapper around BPPMV
 - Runs 24*7 as a service
 - Checks disturbance alarms every minute
 - Runs BPPMV for real events
 - Sends out results through email
 - Ongoing effort: only sends out poorly matched models

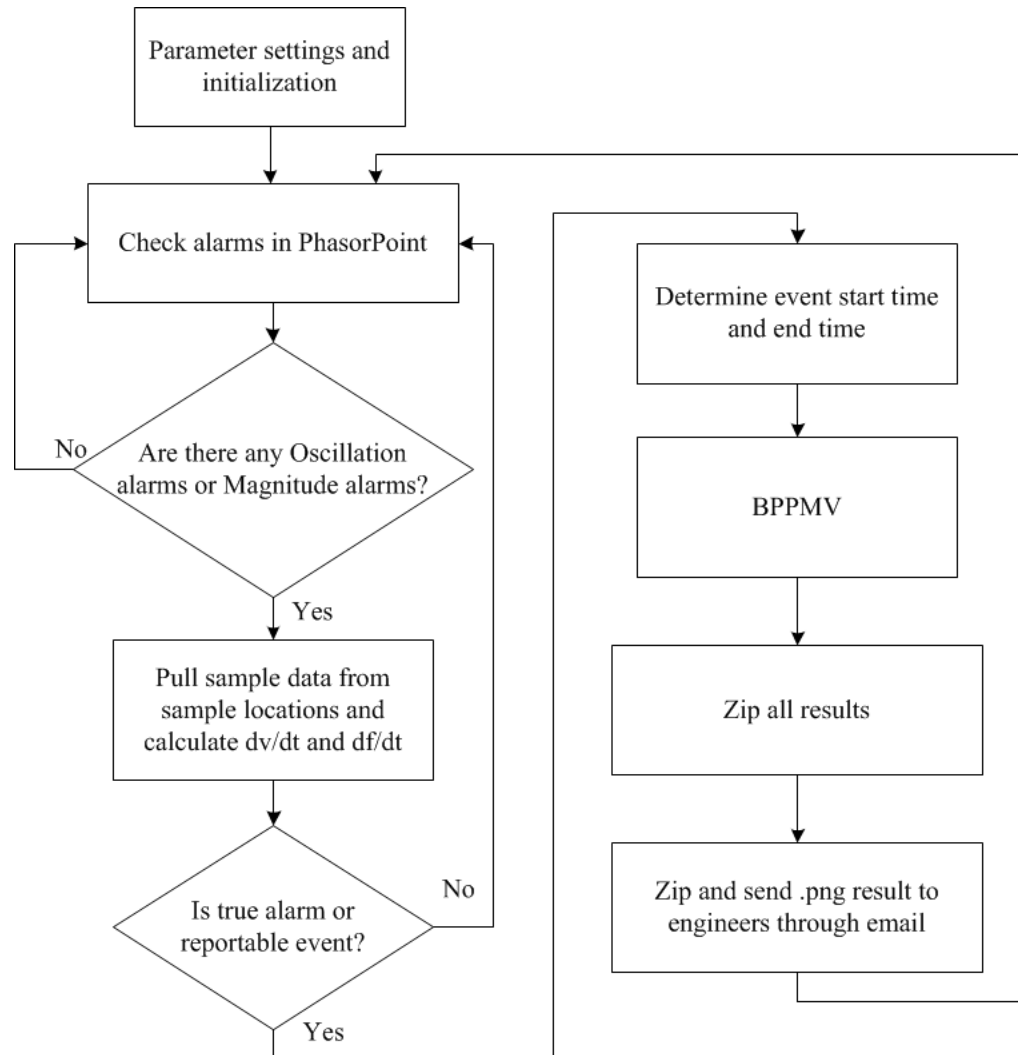
Gets event trigger
from PhasorPoint

Verifies
the event

Calls BPPMV

Sends out
results in email

APPMV – Flow Chart



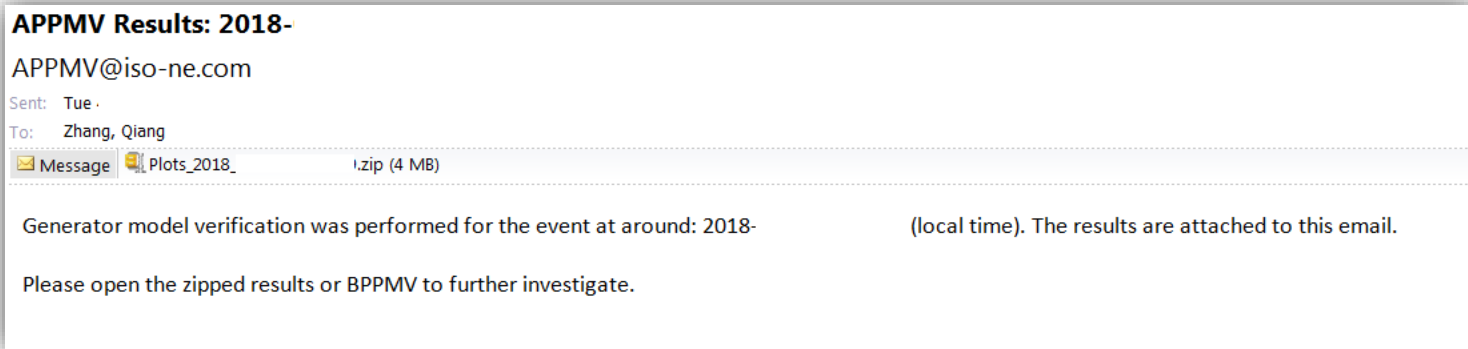
APPMV – Built-in Intelligence

- Event verification
 - Use sample PMU data across the system
 - Skip false event alarms
- Determine event start time
- Score the performances (ongoing)
 - Only send out questionable models through email



APPMV – Results

- Email
 - Only from real events and online generators



- Archive
 - For offline analysis
 - Event file has the whole BPPMV case



Questions

