

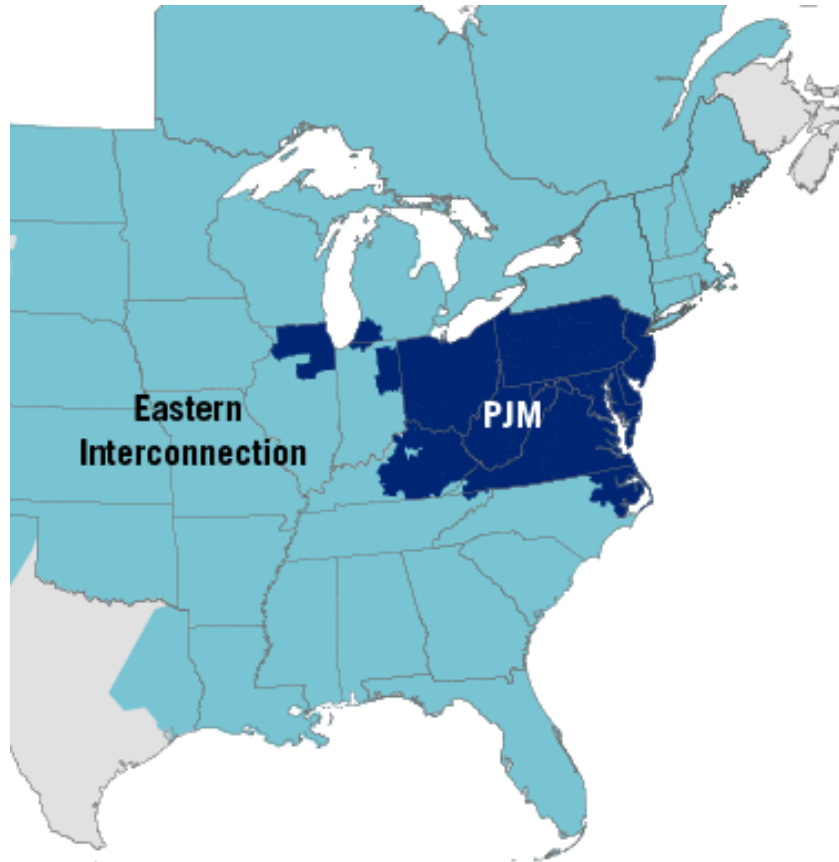
PMU Simulator for Operator Training

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PJM as Part of the Eastern Interconnection



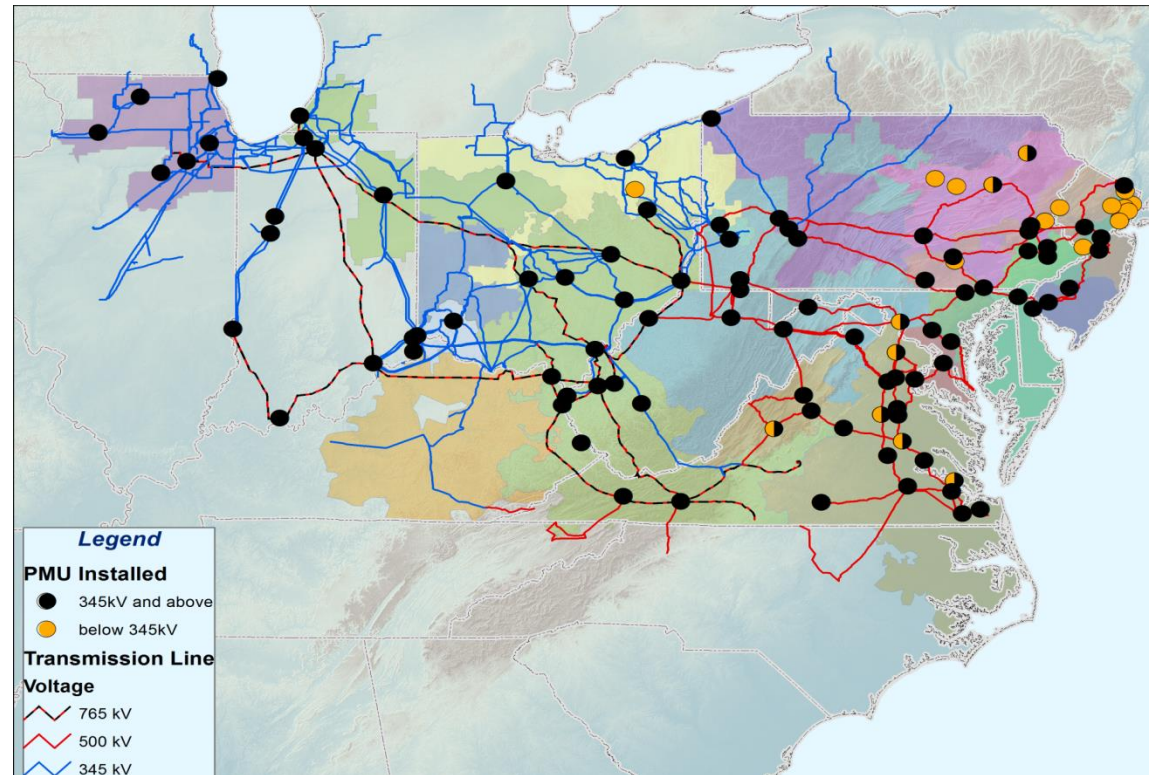
**21% of U.S. GDP
produced in PJM**

KEY STATISTICS

Member companies	940+
Millions of people served	61
Peak load in megawatts	165,492
MW of generating capacity	183,604
Miles of transmission lines	62,556
2013 GWh of annual energy	797,461
Generation sources	1,376
Square miles of territory	243,417
States served	13 + DC

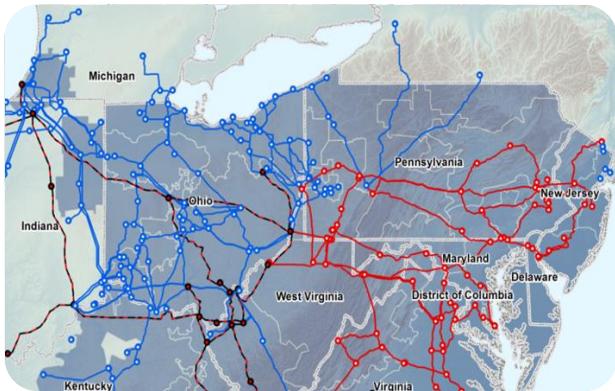
PJM's Synchrophasor Deployment

- +400 PMUs.
- +100 substations.
- GOs required to install PMUs.

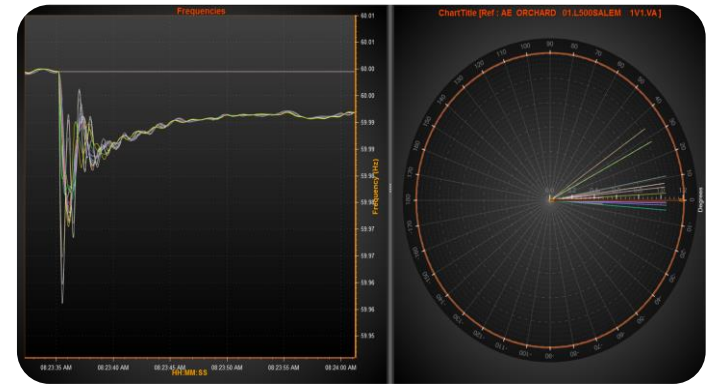


Introduction: PMU Simulator

- Objectives:
 - Enhance Operator training.
 - Scenarios: islands, oscillations, GMD, cascading, gas-electric interdependency, etc.
 - Application testing.

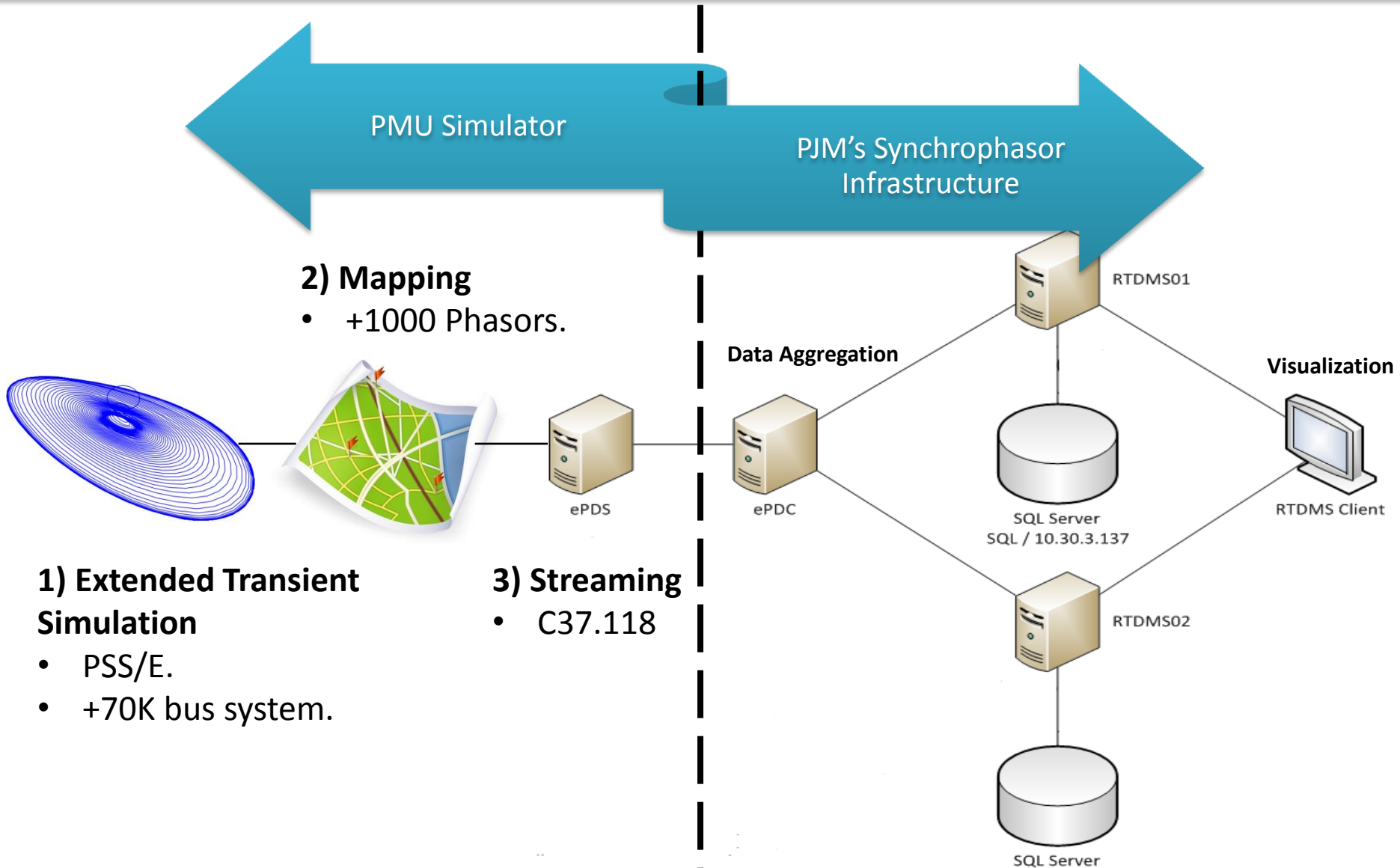


Extended Transient Simulations



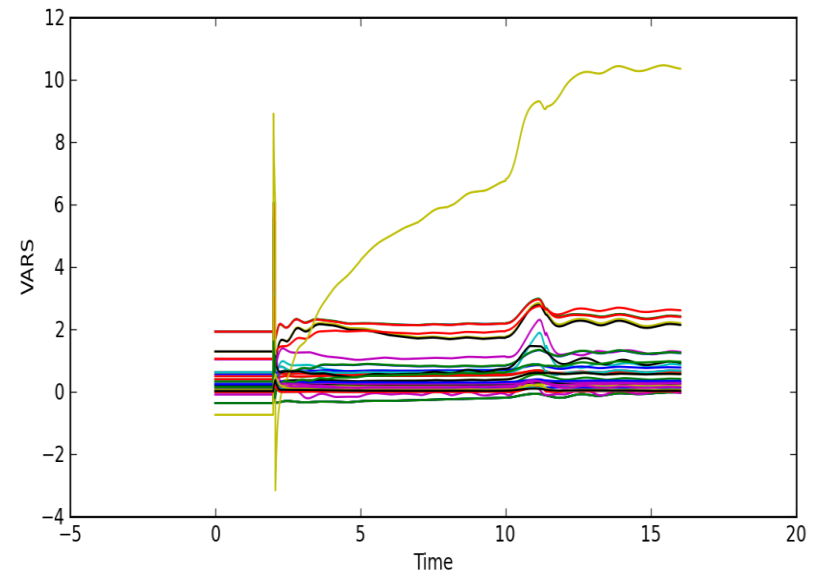
Real Time Data Visualization

Architecture



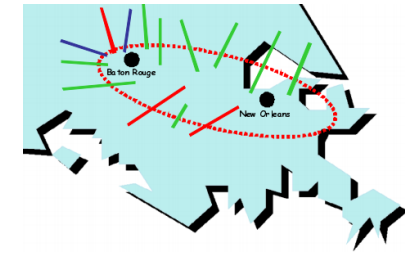
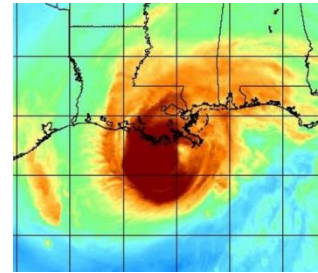
Modeling

- Enhancements to perform *extended* transient simulations.
- Protection:
 - OOS.
 - OEL.
 - Impedance encroachment.
 - UVLS.
 - Etc.
- Random load fluctuations.
- LTC.
- AGC.

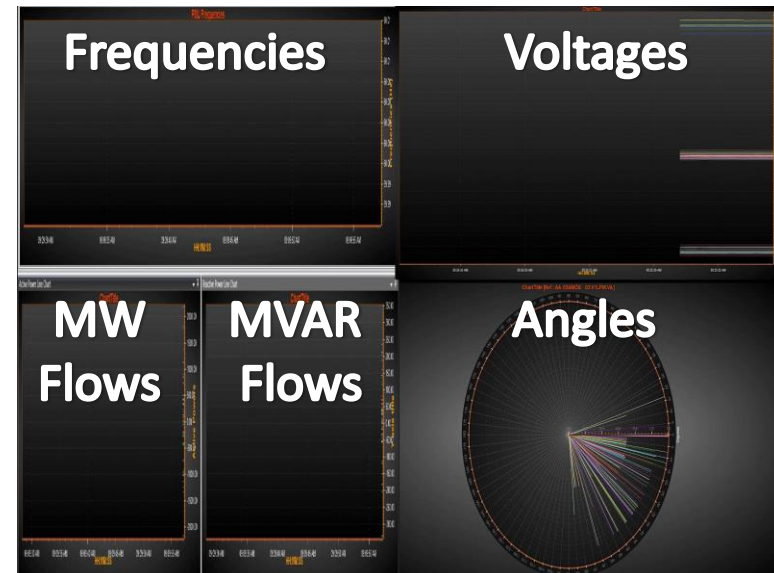


Example 1: Islanding Event

- Inspired by Entergy's experience with Gustav.
- Objective:
 - Recognize island.
 - Stabilize island.
 - Re-synchronize with the system.

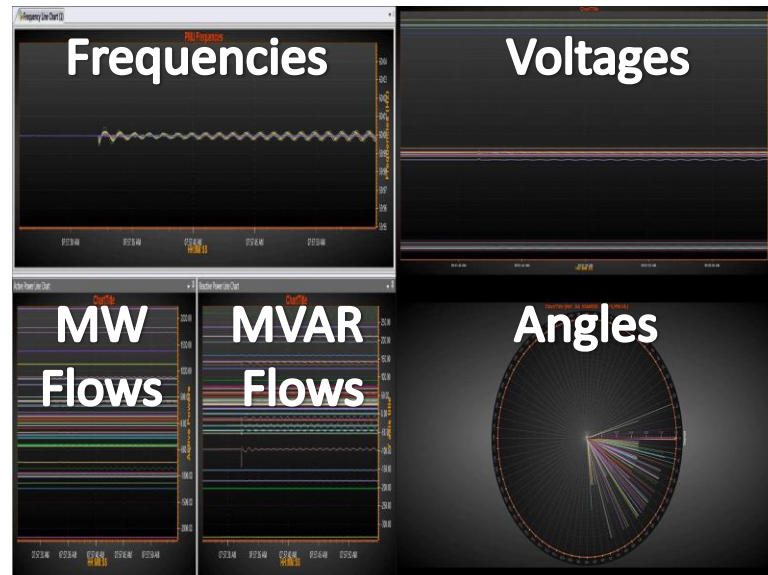
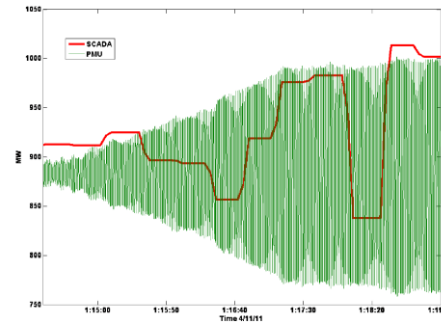


Galvan, F.; Mandal, S.; Thomas, M., "Phasor Measurement Units (PMU) instrumental in detecting and managing the electrical island created in the aftermath of Hurricane Gustav," *Power Systems Conference and Exposition, 2009. PSCE '09. IEEE/PES*, vol., no., pp.1,4, 15-18 March 2009



Example 2: Large Oscillation

- Inspired by Surry event.
 - ~ 0.8 Hz.
 - 200 MW peak-to-peak.
- Objective:
 - Recognize oscillation.
 - Identify participating units.
 - Damp the oscillation.
- Oscillation detection tools.
- PJM Operations Manual.



Conclusion

- Question:
 - How to introduce synchrophasors to the control room?
- Answer:
 - Easy, enhanced training!
- PJM's PMU simulator goes in production 2016.
- Complement traditional simulator (load flow based).