PJM System Operator Training: Synchrophasors and Oscillation Detection

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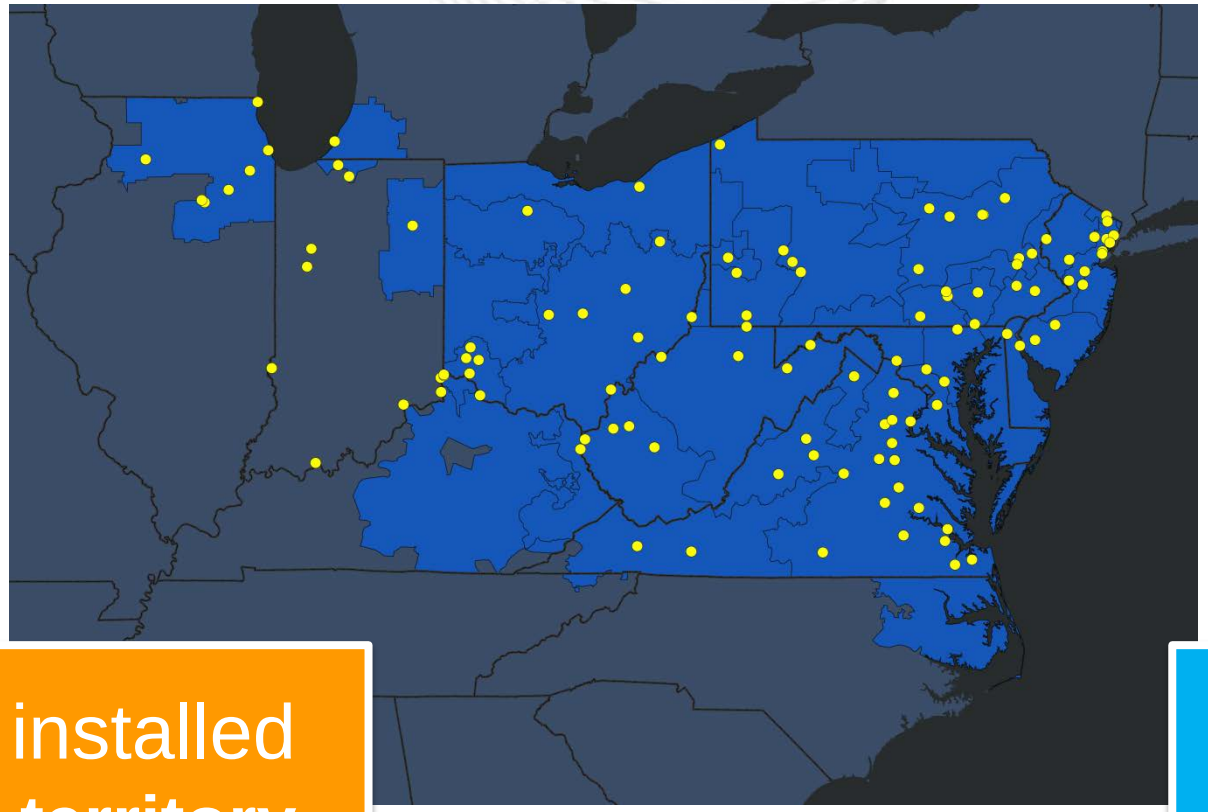
Outage Analysis Technologies

Vision: To enhance workforce performance through advanced and integrated tools, and increase study engineer visibility into outage conflicts through expanded automated study.

- Study automation and support tools
- Transient & voltage stability analysis (Real-time & study)
- Equipment life cycle management tool
- Automatic dispatch logging tool
- Dispatch situational awareness tool (Real-time & study)
- EPG’s RTDMS



~470 PMUs installed **within PJM territory**

PMUs installed at +120 substations

Course Objectives

1. Determine the size, frequency, and affected area of a system oscillation.
2. Interpret a Synchrophasor phase angle clock to identify a system island condition.
3. Identify and apply mitigating actions to an undampened oscillation

Agenda

1. Introduction
    a. What are synchrophasors
    b. PMU usage in operations
    c. PMU vs SCADA
    d. What is an oscillation
        i. Oscillation Types

PMU Refresher

2. How to find PMUs in DIMA and RTDMS
    a. Locate PMU in DIMA
    b. Locate signal in RTDMS

Oscillation Detection Applications

3. Break
4. Simulation
    a. Introduction to Oscillation event (~10 min slide presentation)
    b. Run base case (steady state)
    c. Operators select mitigating action (Interactive)
    d. Review outcome
5. Stream Oscillation Event
    a. Find PMU in DIMA (Interactive)
    b. Add signal to display in RTDMS (Interactive)

Simulation

6. Quiz
    a. 10 questions
7. Summary of course content and action items

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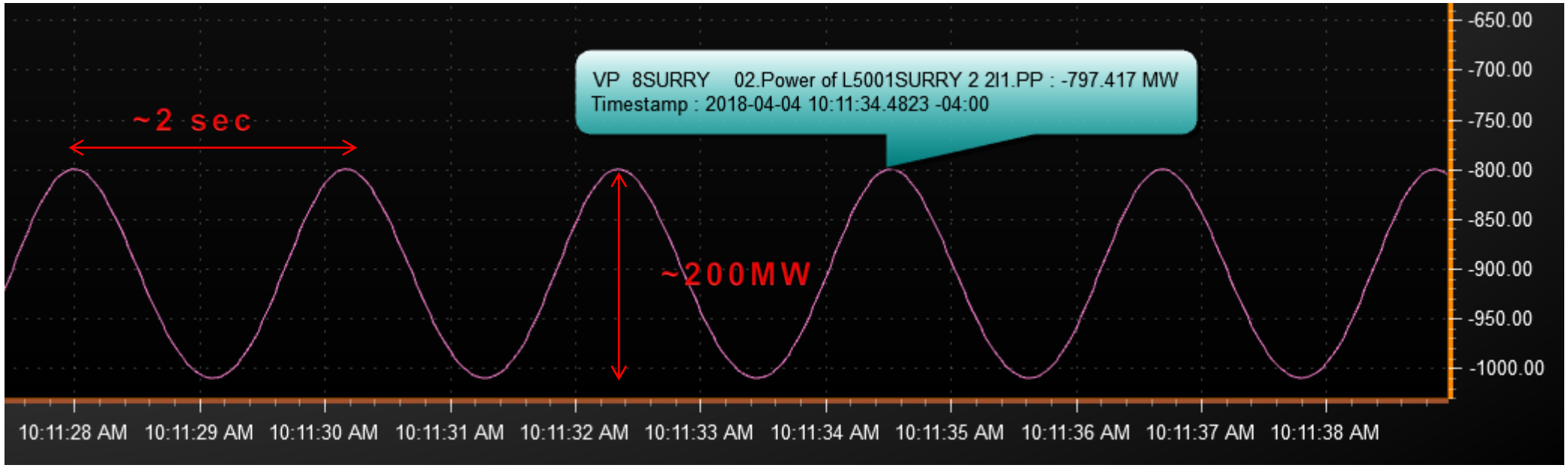
Oscillation Terminology

Mode – describes three of the major characteristics of a system oscillation:

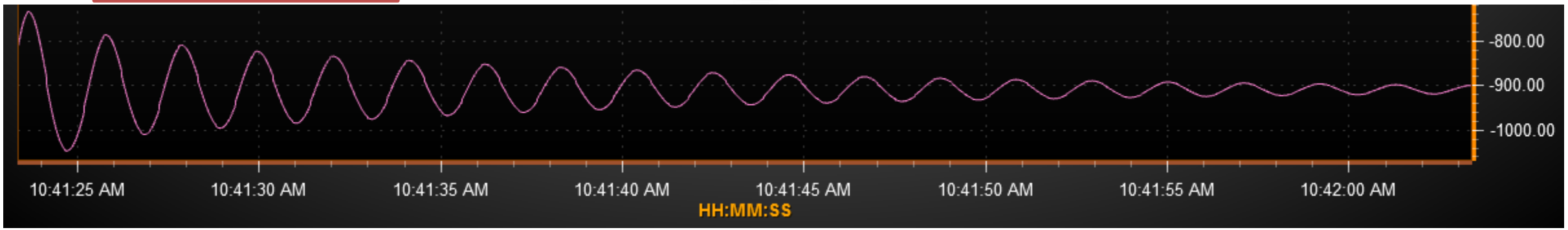
- Energy (Amplitude)
- Frequency
- Damping



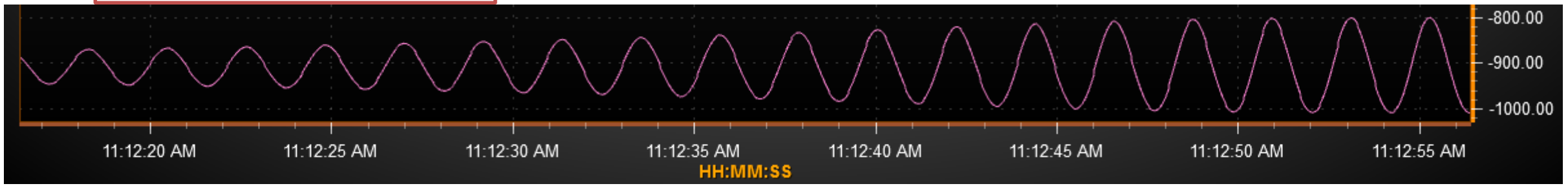
Oscillation Terminology

Damping: PJM considers anything more than 3% as well damped

Well Damped



Negative Damping



Oscillation Types

Forced: Occurs when a single generator has a failure in one of its control systems

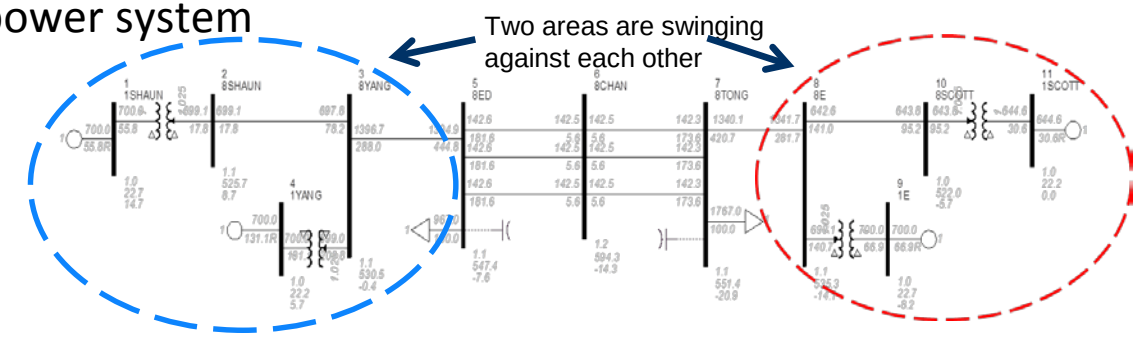
Oscillation Freq: Less than 15 Hz

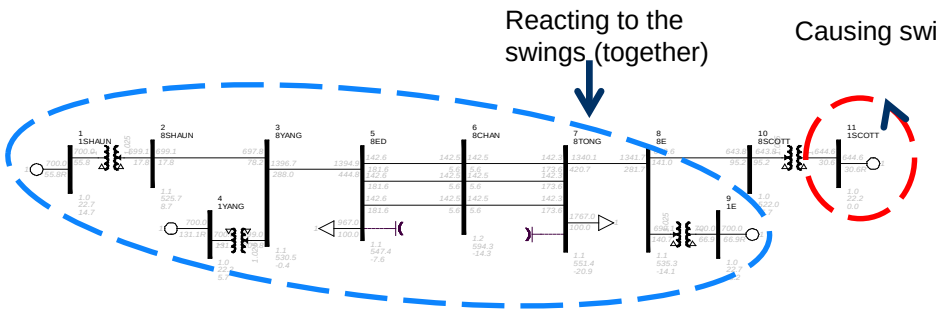
Inter - area : Occurs when a power system is weakened with equipment outages, light load, and large amounts of power are imported across the system

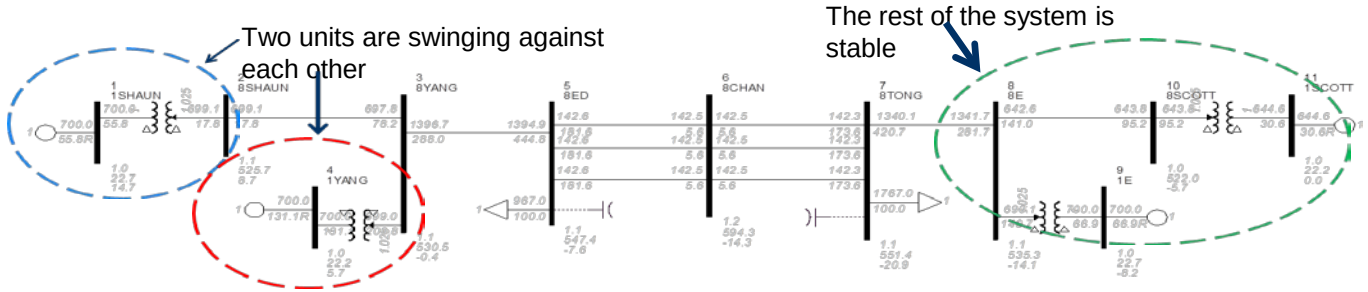
Oscillation Freq: below 0.8 Hz

Local: Similar to inter- area but restricted to a small area of power system

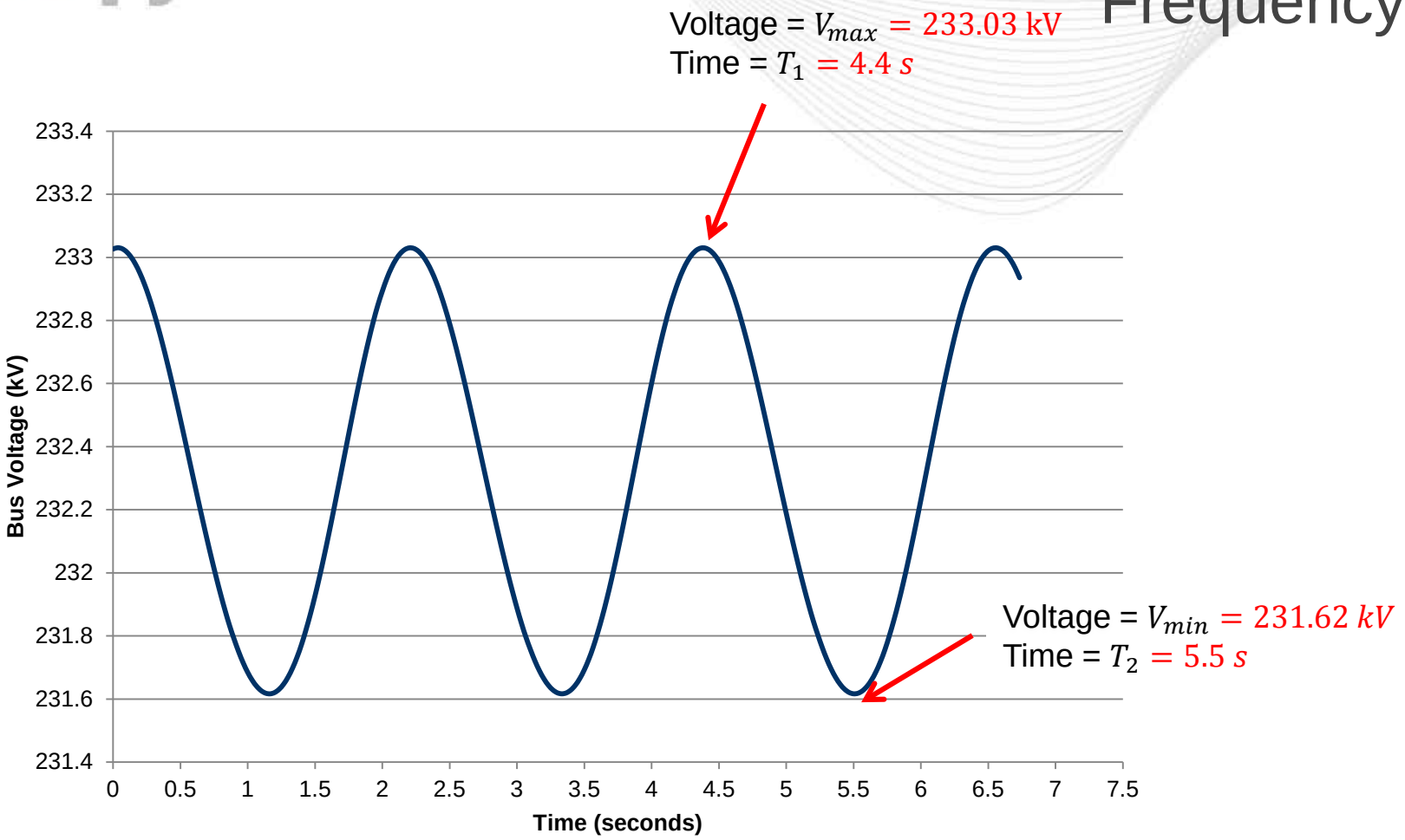
Oscillation Freq: 0.8 – 2.0 Hz







Determining Oscillation Amplitude and Frequency With Raw PMU Data



$$RMS\ Amplitude = \frac{V_{max} - V_{min}}{2\sqrt{2}}$$

$$= \frac{233.03 - 231.62}{2\sqrt{2}} = 0.499\ kV$$

$$Frequency = \frac{1}{2(T_2 - T_1)}$$

$$= \frac{1}{2(5.5 - 4.4)} = 0.46\ Hz$$

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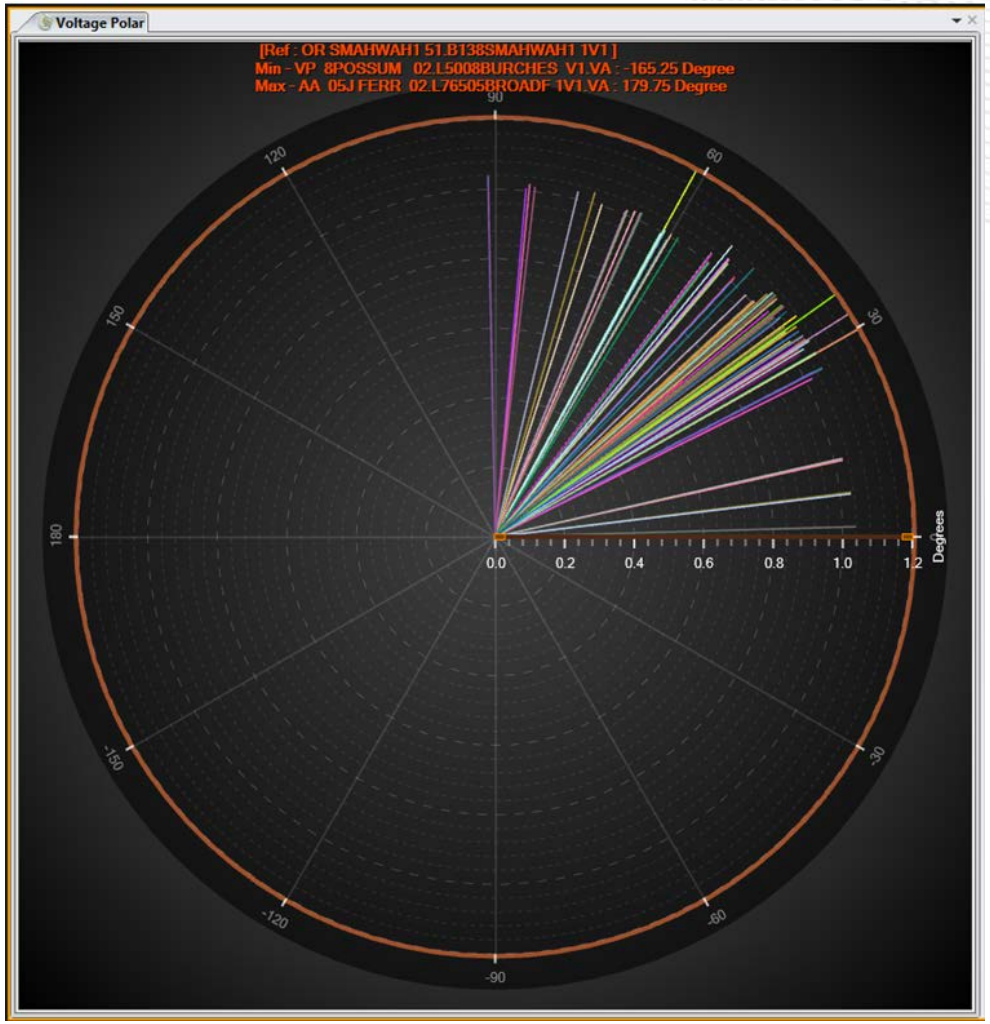
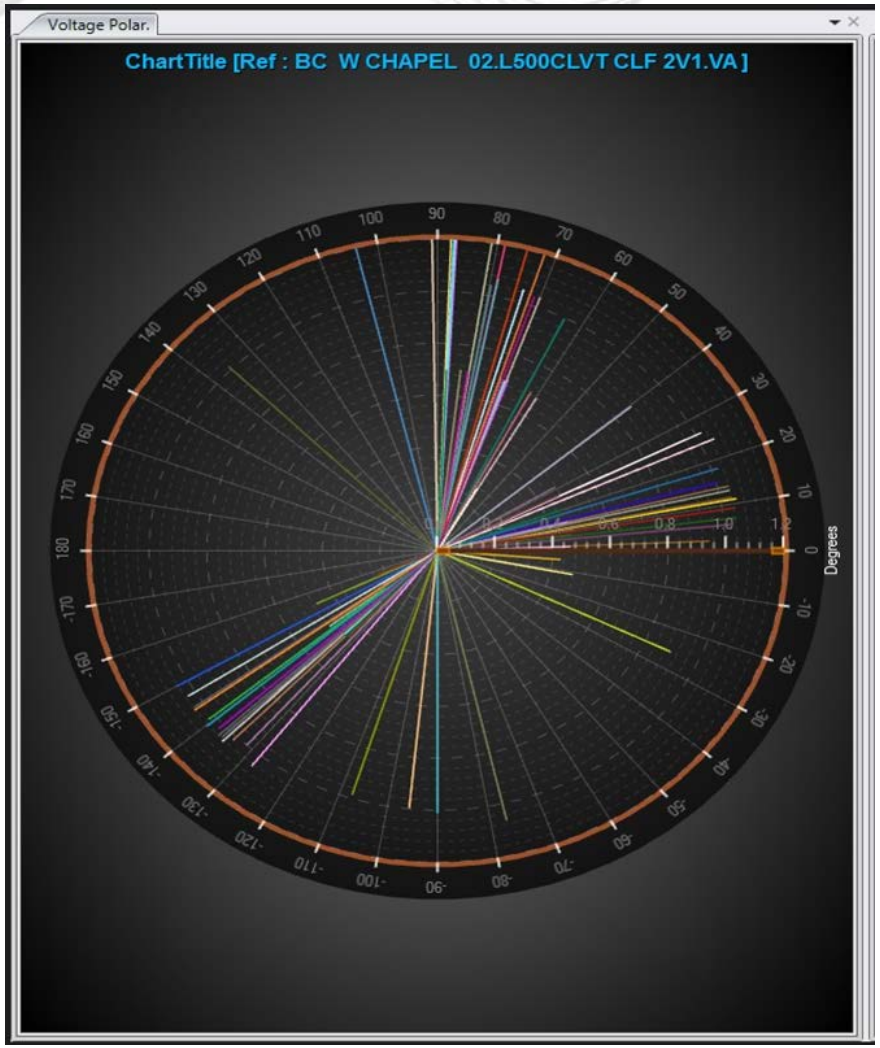
Polar Chart Behavior During an Island Condition





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Complete Oscillation Mitigation Procedure defined in PJM Transmission Operation Manual

Suggested actions include:

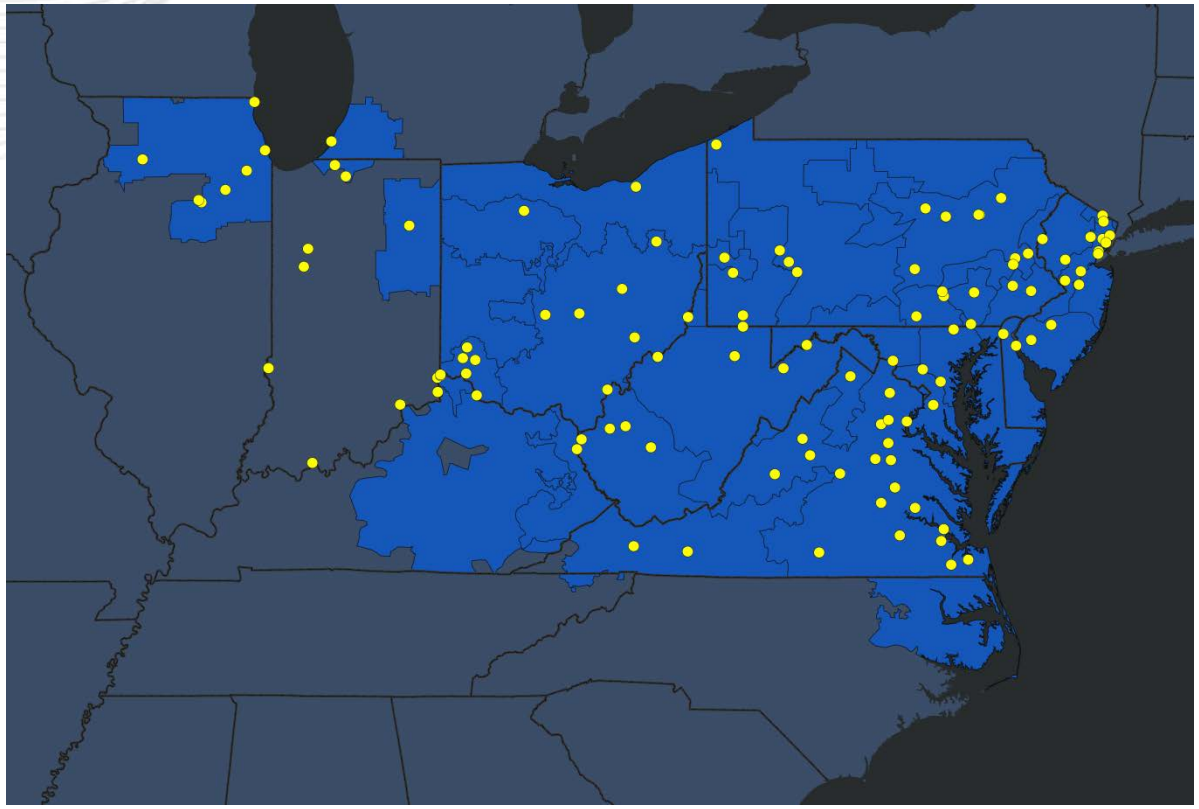
- Confirm whether or not an oscillation was observed at the plant
- Reversing any recently switched or outaged equipment
- Reducing power transfers
- Increasing area generator MVAR output
- Review any recent internal plant switching
- Check AVR setting and PSS status

Oscillation Simulation

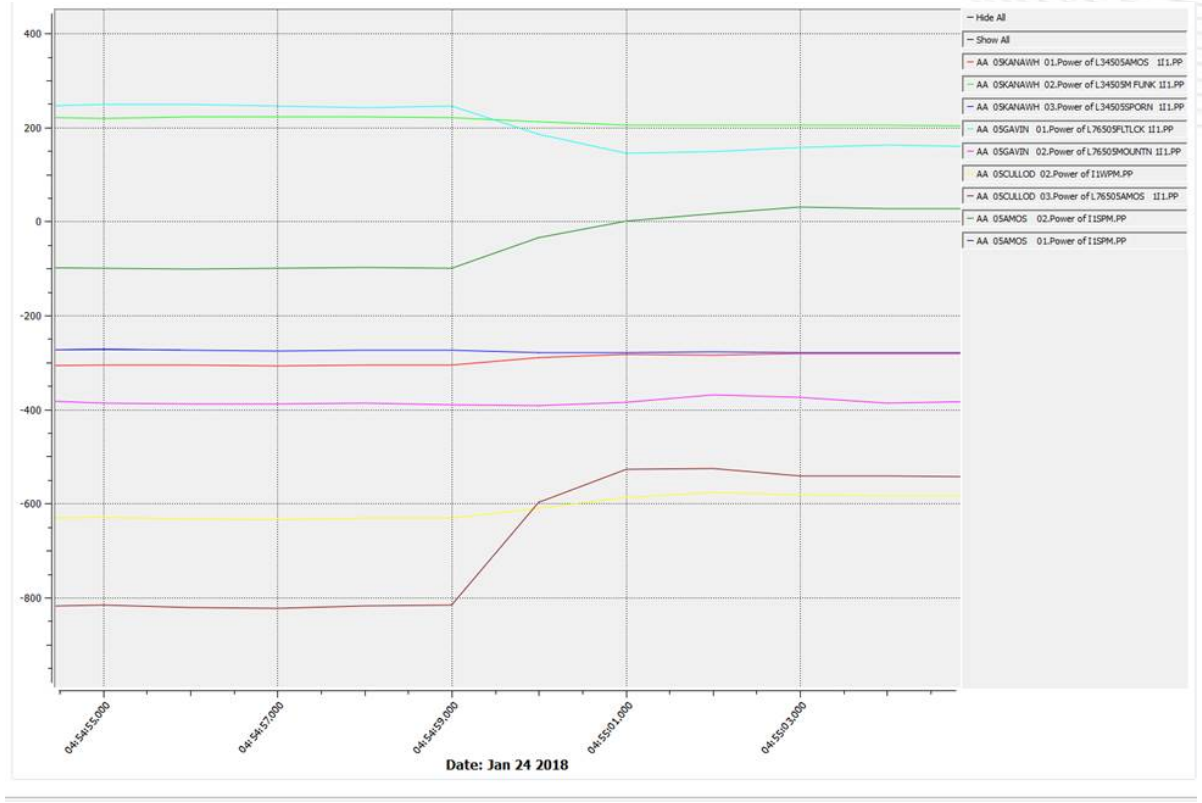
1. Map each PMU to a bus in PSS/E
2. Initialize PSS/E Case
3. Loop through PSS/E mapping
4. Adjust channels for initial conditions
5. Run steady state for 30 seconds
6. Trigger oscillation
7. Write channel output to .csv file

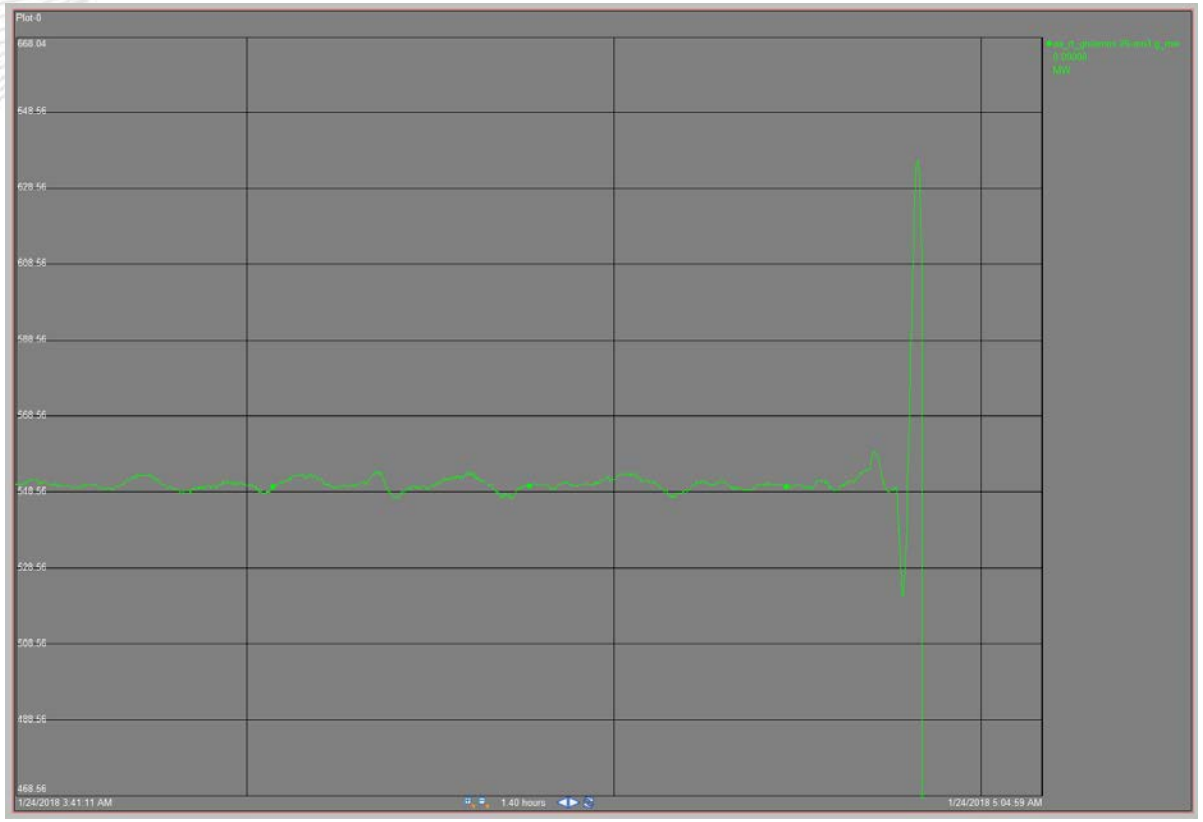
Simulation Scenarios

- Adjust north-south transfers
  - A. Increase north-to-south transfers
  - B. Decrease north-to-south transfers
- Adjust voltage schedule
  - C. Raise voltage
  - D. Lower voltage
- Change system topology
  - E. Return transmission lines to service
  - F. Remove transmission lines from service
- Other
  - G. Increase load (pumps)
  - H. Return PSS
  - I. Switch on reactor
  - J. Trip units



Control Room Impact





2018 Goals

- Deliver additional training on the use of RTDMS automatic Oscillation Detection Module (ODM)
- Incorporate Synchrophasor data heat maps (frequency, voltage magnitude, and voltage angle) into Dispatcher Interactive Map Application (DIMA)
- Compare static models between EMS and PSS/E cases to identify discrepancies in modeling parameters like impedance and generator dynamics.