Synchrophasor Based Oscillation Detection in ERCOT Operations

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Agenda

- ERCOT Synchrophasor Network
- System Mode Analysis
- RTDMS Mode Meter Configuration
- Forced Oscillations Vs. System Modes
- North-South and Wind High Frequency Modes
- RTDMS Oscillation Detection Configuration
- Forced Oscillation Events
- Next Steps

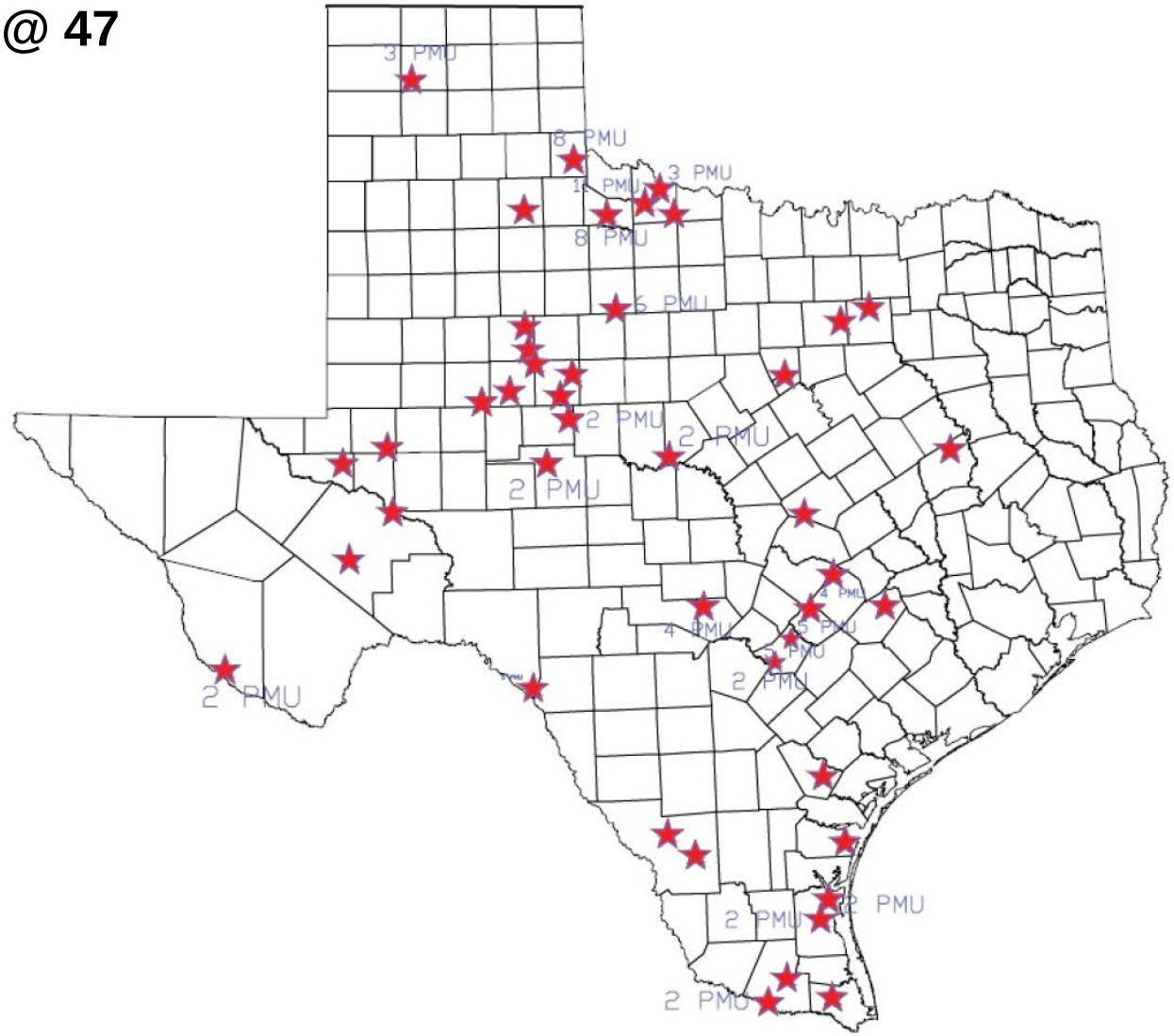
The ERCOT Synchrophasor Project

- DOE funded project awarded to the Center for Commercialization of Emerging Technologies in January 2010
- Project Title: *Discovery Across Texas: Technology Solutions for Wind Integration in ERCOT*
- Sychrophasor component of project to demonstrate improved management of increasing amount of wind in ERCOT Interconnection
- Sychrophasor Project Participants: ERCOT, TOs, Electric Power Group – Lead for Synchrophasor portion of the project
- Installed EPG's Real Time Dynamic Monitoring System (RTDMS) and Phasor Grid Dynamic Analyzer (PGDA) in test environments for use by ERCOT Operations and Planning Engineers
- Project completed and reports submitted to DOE in December 2014

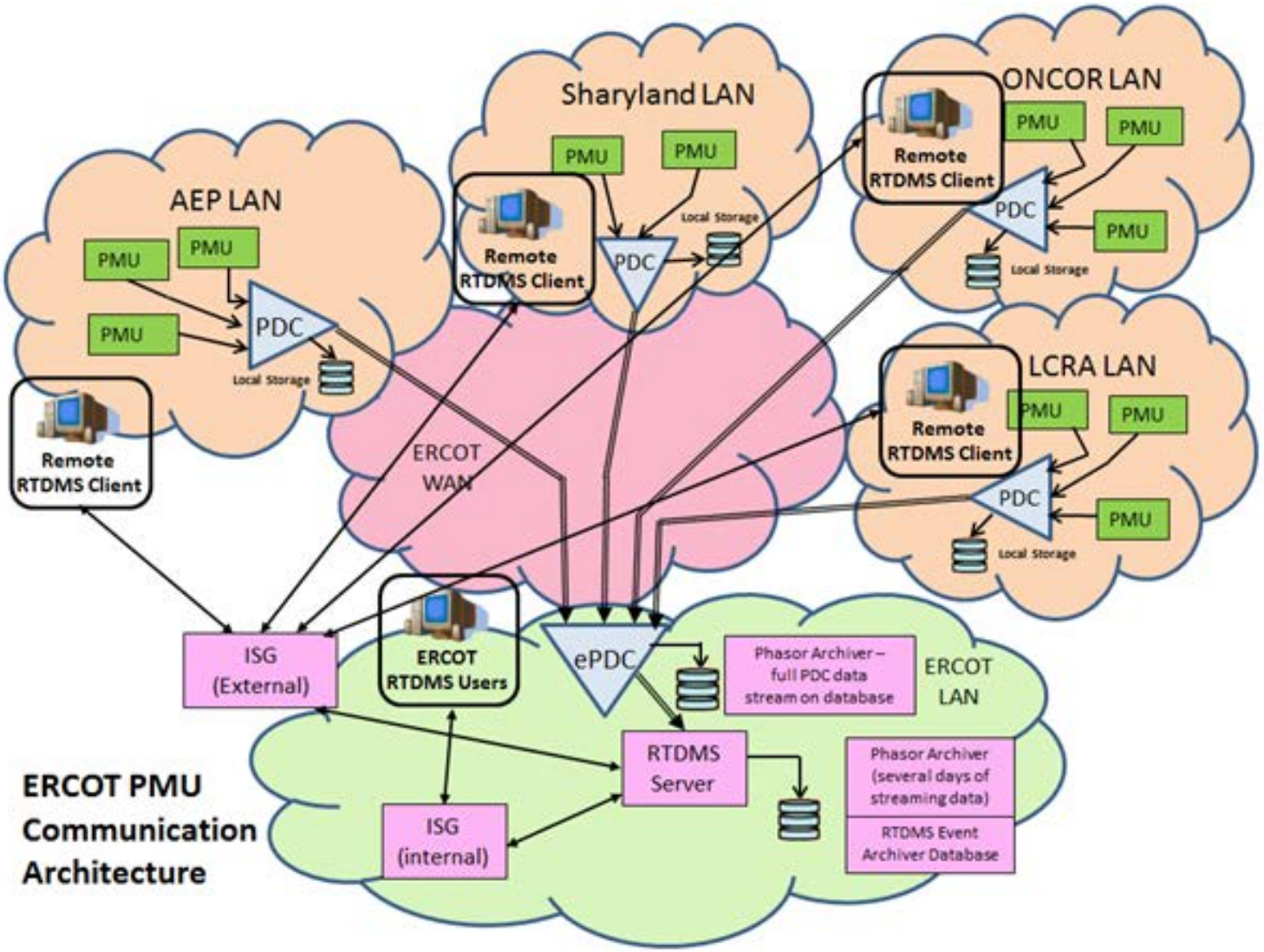
Details: http://www.ercot.com/gridinfo/etts/ccet/index.html

Number of PMUs Streaming Real Time Data to ERCOT

- **Total 109 PMUs @ 47 Locations**
  - AEP: 64
  - ONCOR: 17
  - Sharyland: 5
  - LCRA: 23



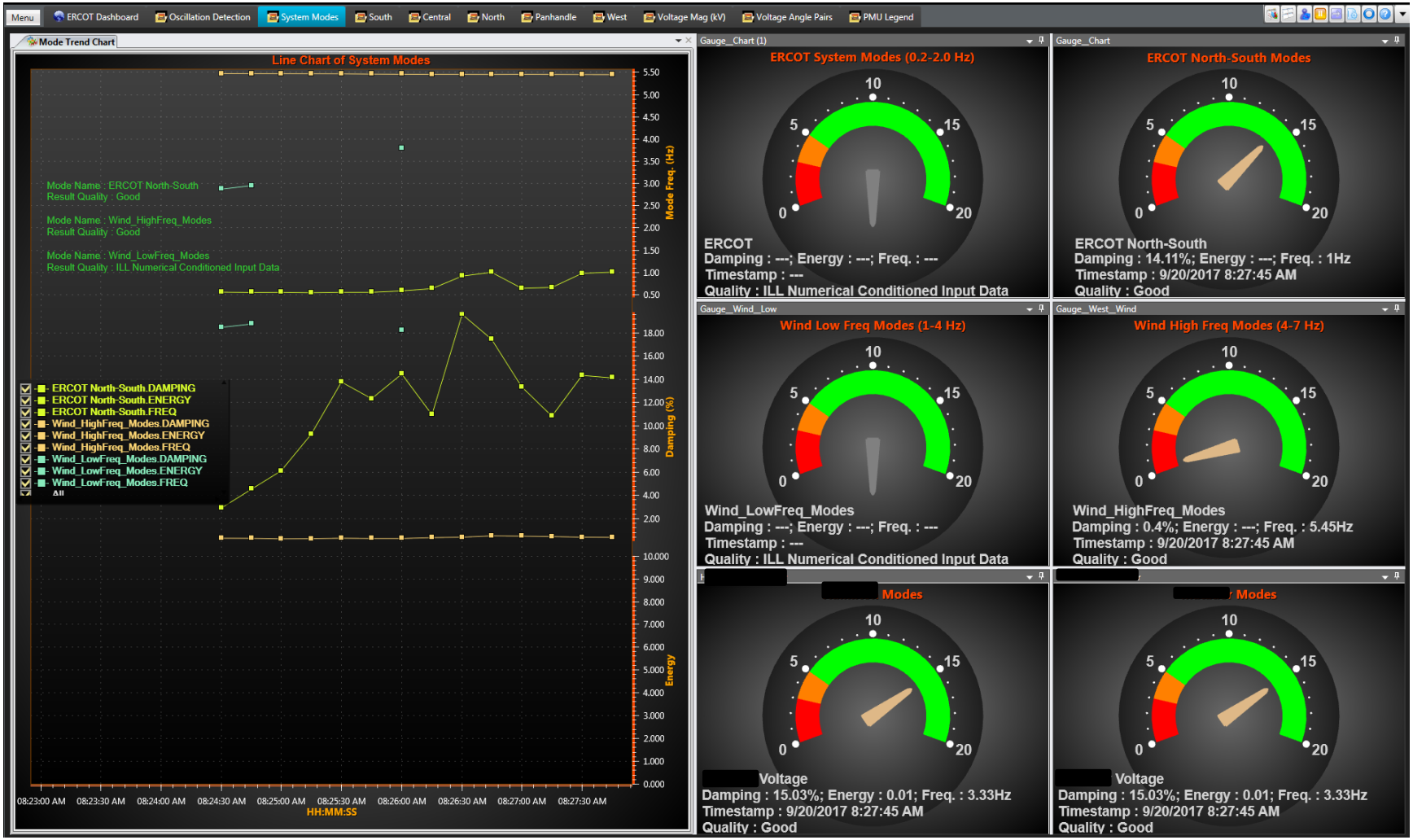
The Synchrophasor Data Communication Network



ERCOT System Modes Study

- As part of DOE project, EPG analyzed 3 years of PMU data to identify ERCOT system modes
- Used data from PMUs next to wind farms to identify oscillatory modes due to controllers
- Modes were analyzed to identify mode frequency, damping percentage, and energy level
- Mode meters in RTDMS were configured to track identified modes with the most common occurrence
- In addition, a mode meter was created to track the North-South system mode identified through PMU based event analysis

RTDMS System Mode Display



Issue with Tracking System Modes

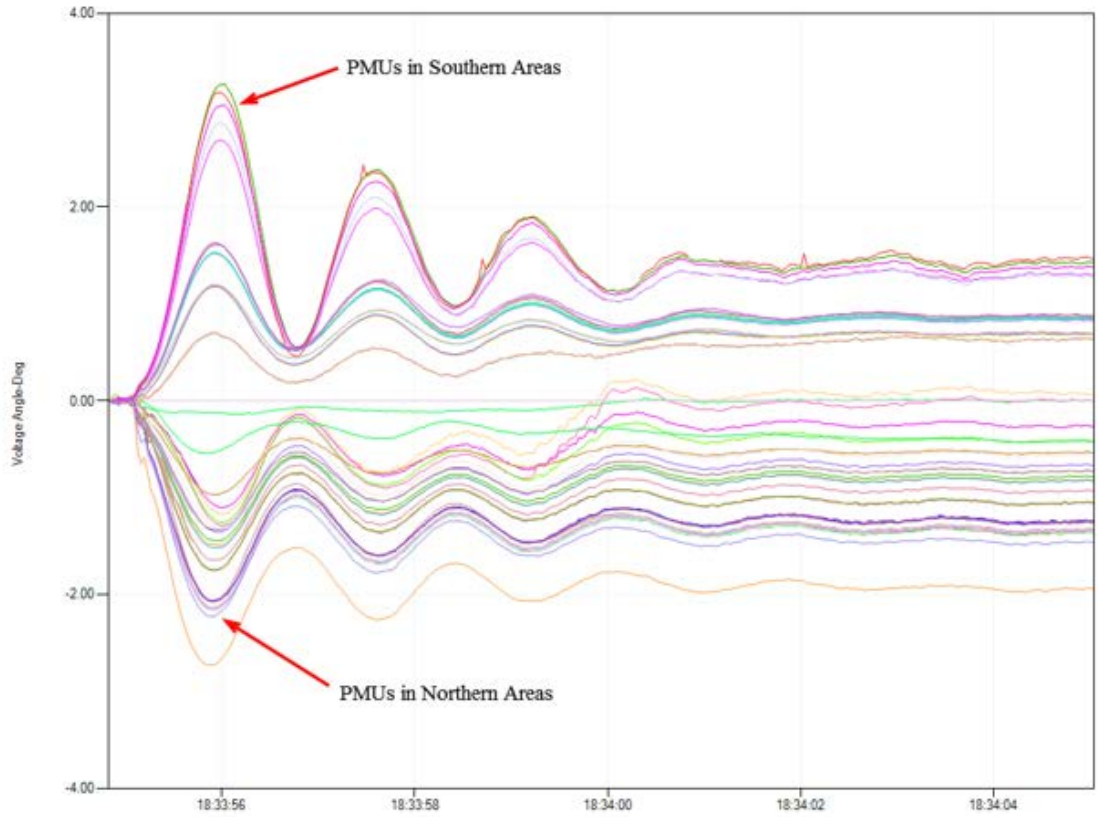
- Mode meters not capable of identifying oscillations not specifically tracked
- Difficult to determine if meters were configured correctly and working
- Long periods time without any mode meter movement
- Were the oscillatory modes now heavily damped due to build out of CREZ transmission lines?
- Update to RTDMS version 17 and adjustment of time windows improved mode meter tracking
- Low damped modes don’t usually show visible oscillations in PMU signal trends
- Studies will be needed to determine any possible control room procedures to address low damped modes. Is this even necessary?

System Modes Vs. Forced Oscillations?

- System modes are difficult to analyze and identify operational procedures for mitigation
- Forced oscillations seem to be more common and may be mitigated by finding the source signal and contacting responsible market participant
- Are the oscillatory modes found from the DOE/EPG study real system modes or reoccurring forced oscillations?
- Need for a tool to identify forced oscillations not tracked by system mode meters
- Have identified two common system modes, and will track all other oscillations with RTDMS' Oscillation Detection tool

ERCOT North to South System Modes

- Identified by PMU post event analysis using PGDA
- In most large unit trip events (>450 MW), units in the north and south are clearly shown to swing against each other
- Most common mode in the 0.6 – 0.7 Hz range, with a 0.9 Hz mode occasionally seen



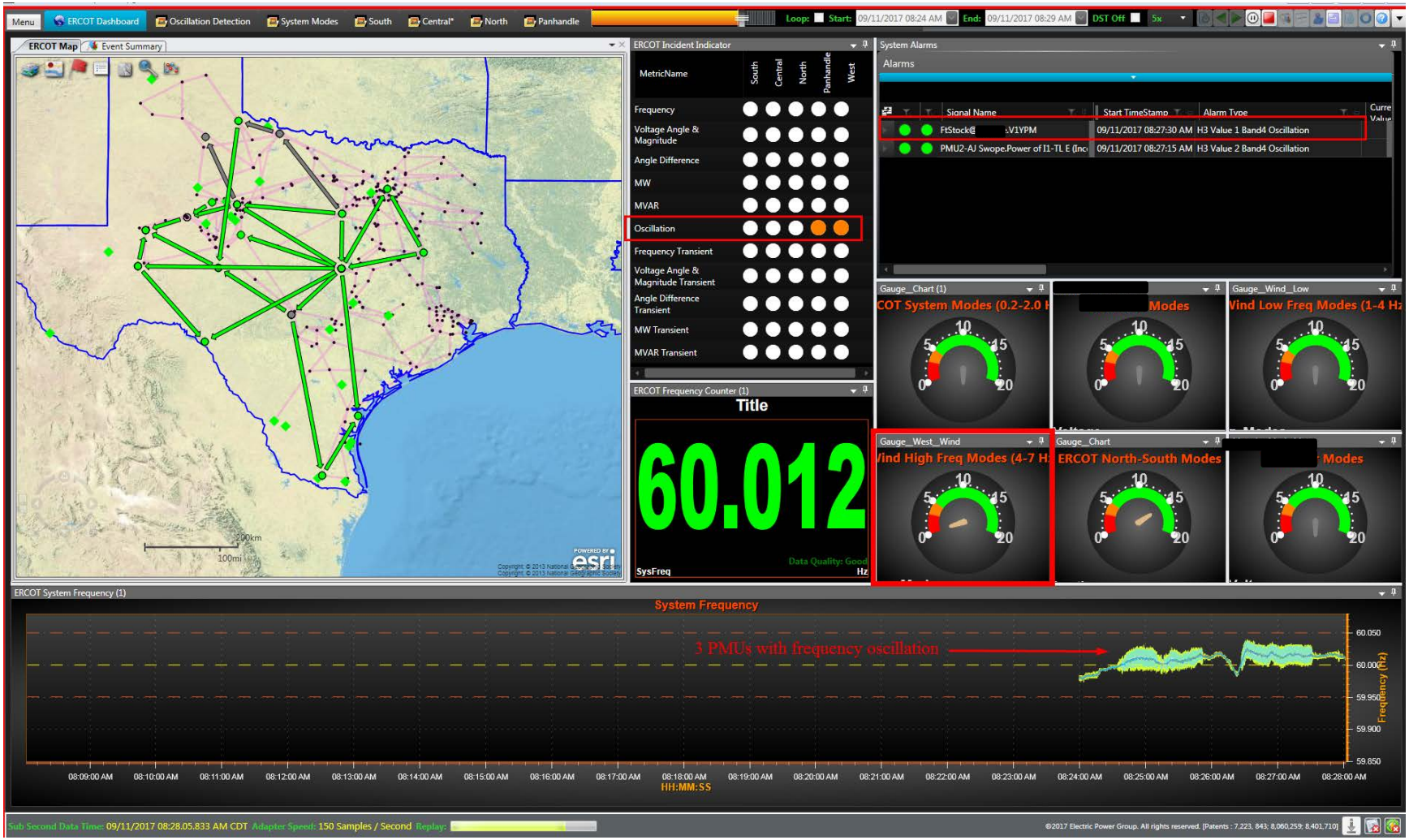
ERCOT North to South System Modes

- Post-event Ring Down Analysis in PGDA usually calculates a damping of 8% or greater
- Only three occurrences in past three years in which damping was 5% or lower
- Since upgrade to RTDMS v17, North-South Modes have been well-tracked with usual damping in the 15-20% range
- Occasionally see damping drop to 5%
- Need to correlate pre-event damping to post-event damping
- Operator actions? Need for it?

Wind High Frequency Modes

- EPG identified high frequency modes (5.0 – 6.0Hz) in DOE project due to wind farm control systems
- Modes were typically low energy with one intermittent high frequency mode
- RTDMS v16 mode meter did not track modes very well due to a lack of higher energy event triggers
- RTDMS v17 mode meter has consistently shown damping of these modes in the 0-5% range with very low energy levels
- Intermittent oscillations have been seen consistently in the voltage and current measurements in west Texas beginning Fall 2016
- New solar farms are main suspect
- Forced oscillation related to system mode or independent?

West Texas Oscillations



West Texas Oscillations

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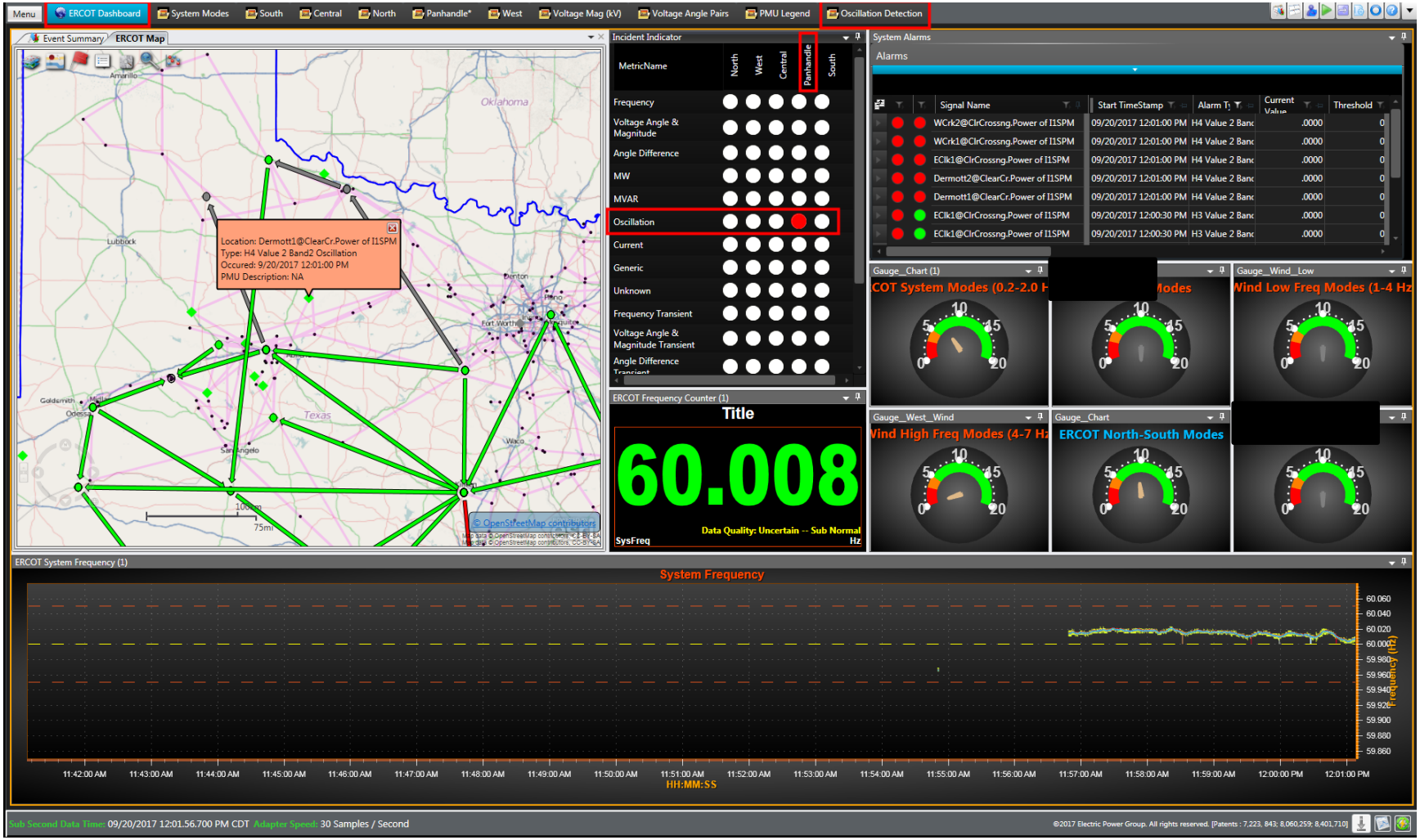
- Began to see oscillations in October of 2016 and continued through Spring 2017
- Contacted TO and RE to see about identifying root cause
- TO was able to start sending PMU data for two other PMUs in the area in question
- Saw same oscillations with smaller amplitudes through the summer months
- Amplitudes have begun to pick back up in September
- Difficult to track root cause due to intermittency and different control systems with different owners likely interacting

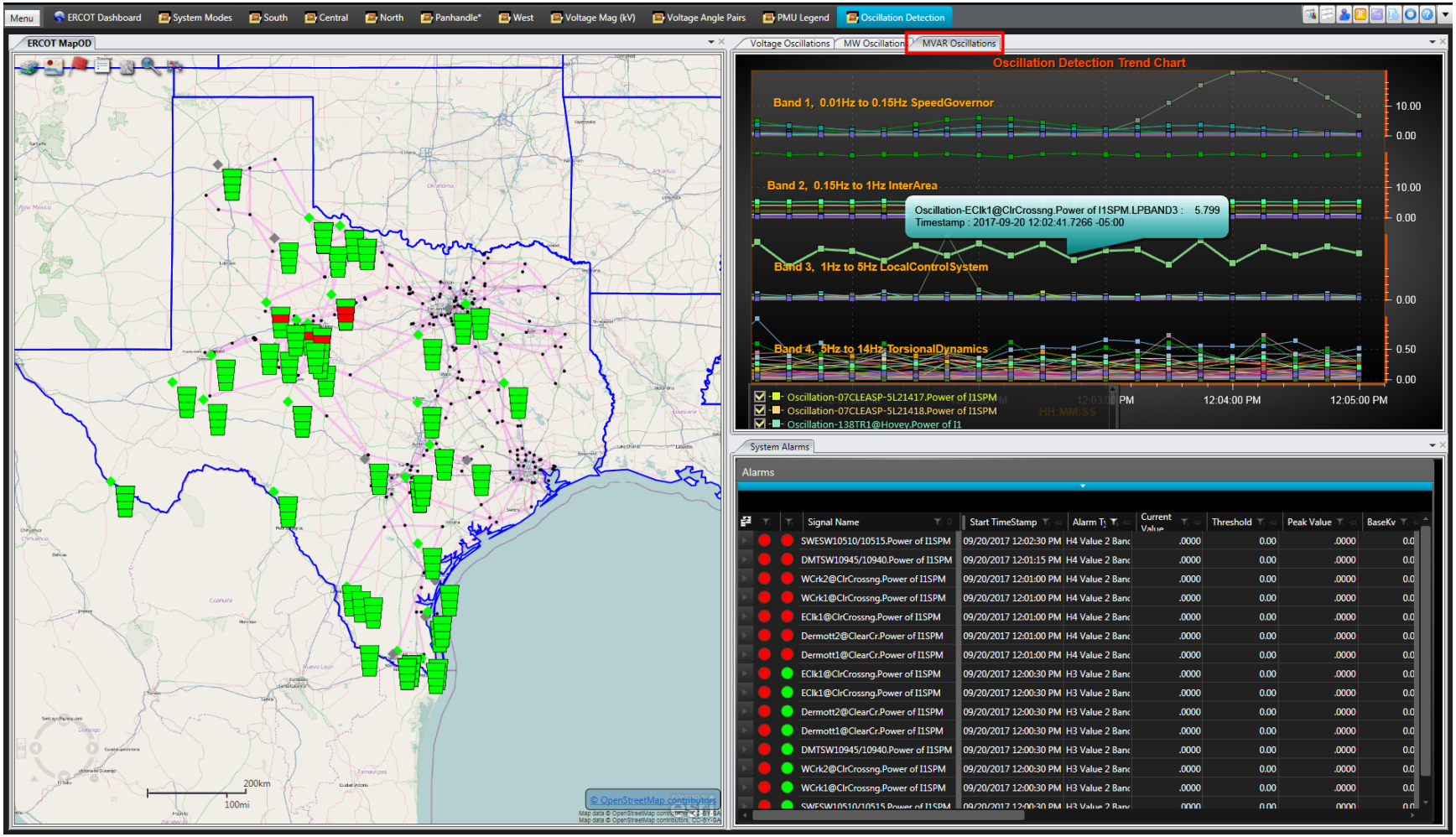
RTDMS Oscillation Detection

- Identified a need to alert operation engineers to oscillations not being tracked by mode meters
- On July 6, oscillation with MVAR swing of 90 MVAR in Panhandle not detected by RTDMS Dashboard or Alarms
- Decided to upgrade to v17 for new oscillation detection application
- Used 7/6 event to configure new tool in Phasor Simulation for Operator Training (PSOT) and test environments
- Test environment actively picking up forced oscillations in multiple areas
- Once appropriate thresholds are determined to prevent over alarming, oscillation detection tool will be implemented on shift engineer desk
- Past and future oscillation events will be used to create shift engineer procedures

July 6 Oscillation Event in PSOT Dashboard

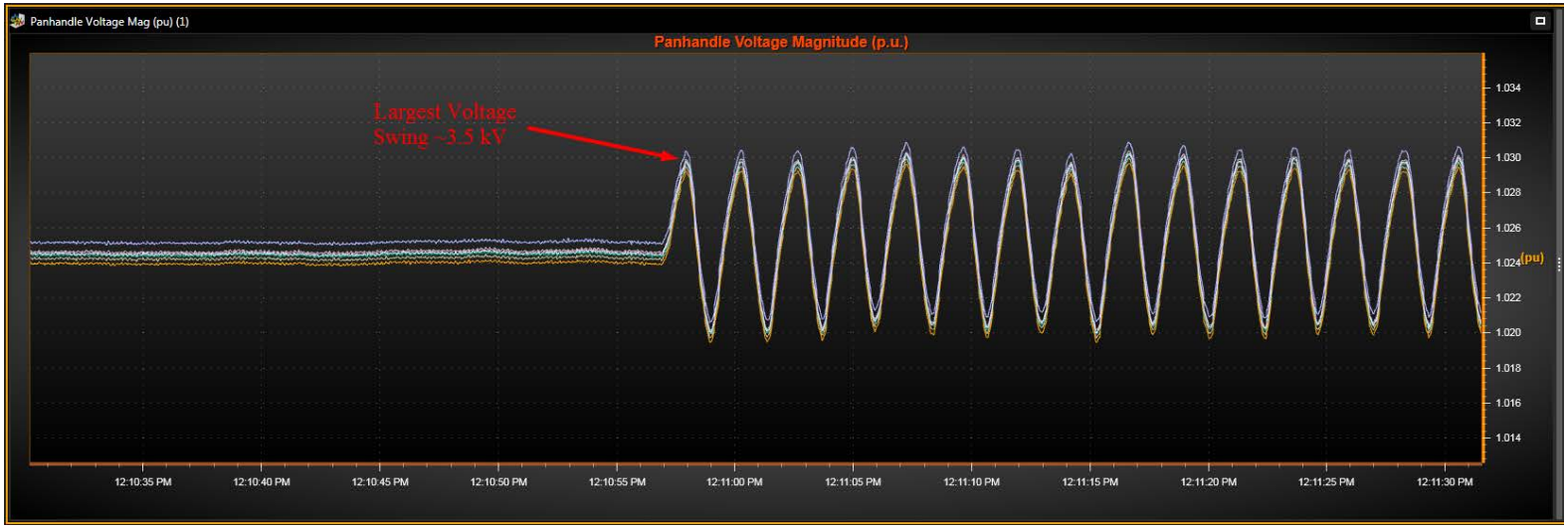


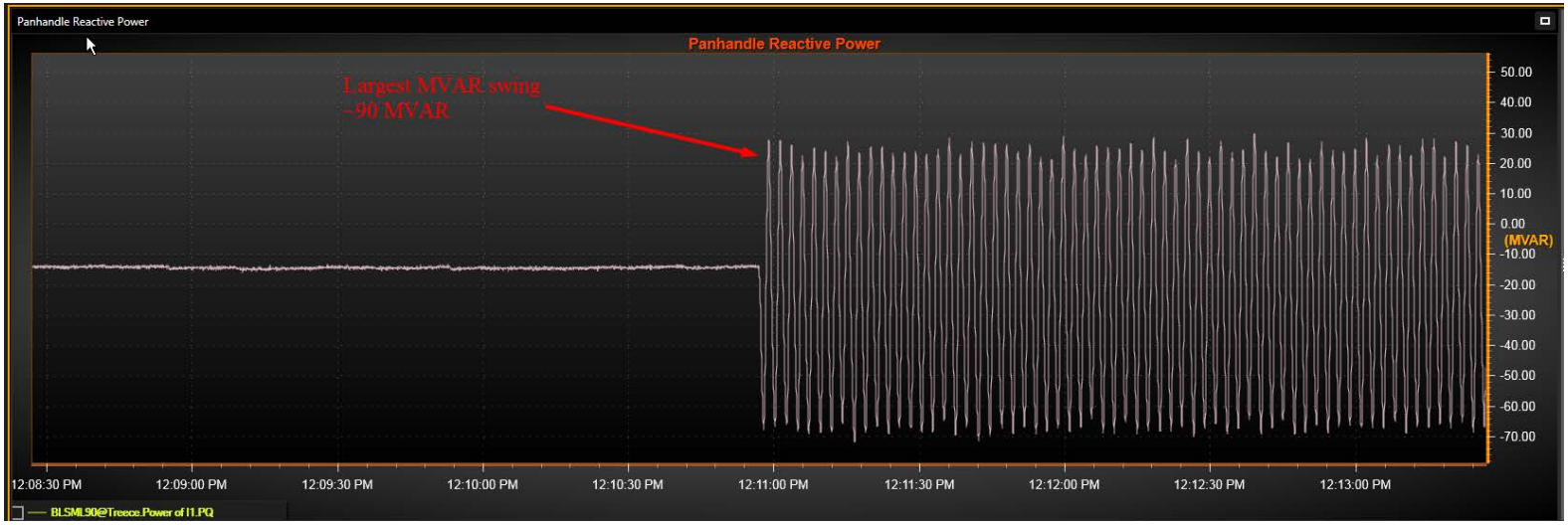
July 6 Event in PSOT Oscillation Detection Display



July 6 Event in PSOT Panhandle Display

Largest Voltage and Reactive Power Swings

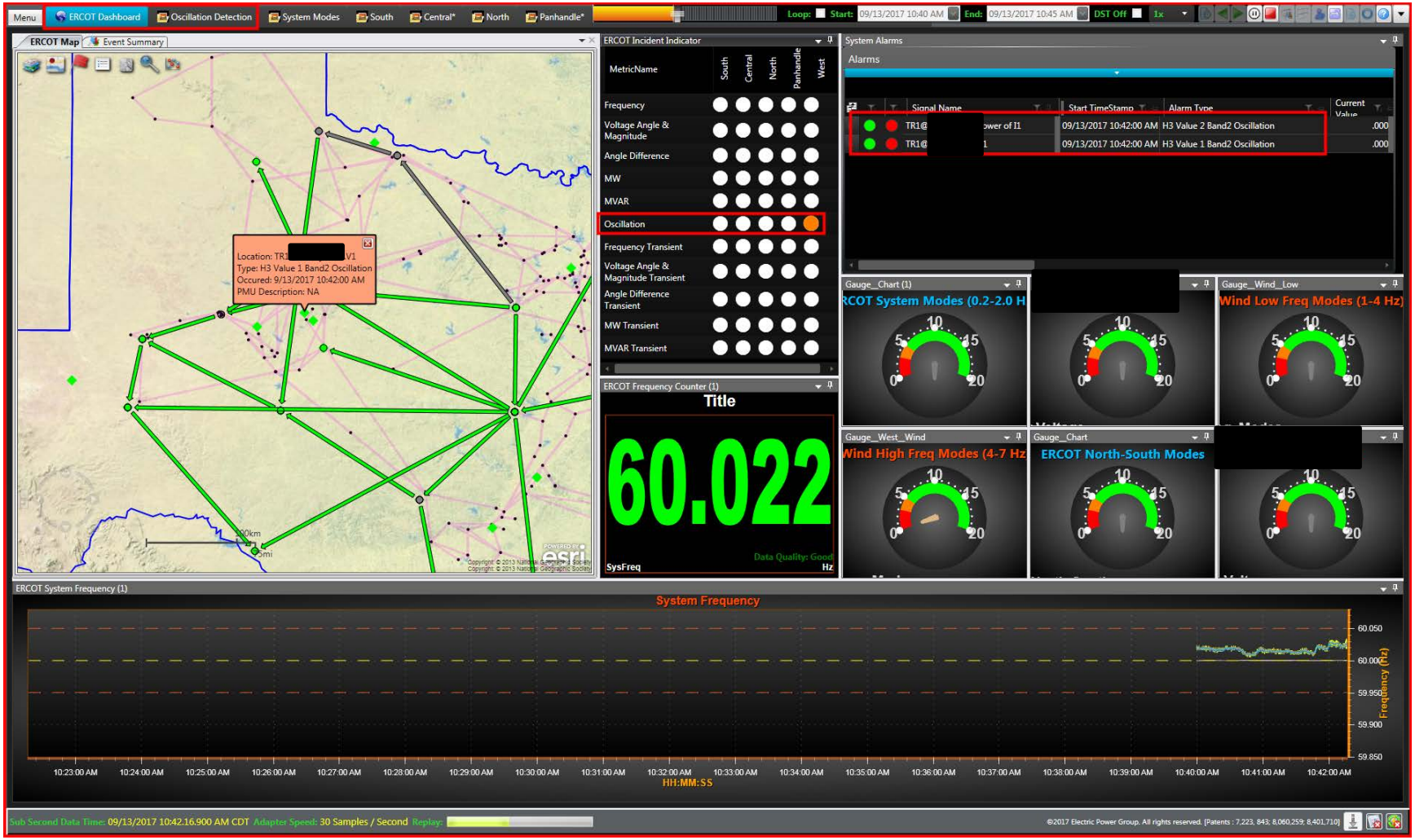




Oscillation Detection Configuration in PSOT and Test Environments

- Wanted to develop necessary displays to alert operation and shift engineers to any sustained oscillations of certain magnitude
- Needed oscillation detection to pick up oscillations in all PMUs, not just a few
- Displays should also quickly lead operation engineers to the PMU and area with the largest voltage and power swings
- Need PSOT to replay event as though it is in real time to test configurations and alarms
- Event files also being created for oscillations that are not noticed in real time so they made be replayed
- For July 6 event, solution was to contact RE and have them turn off AVR

Sept. 13 Oscillation in Test Environment Replay



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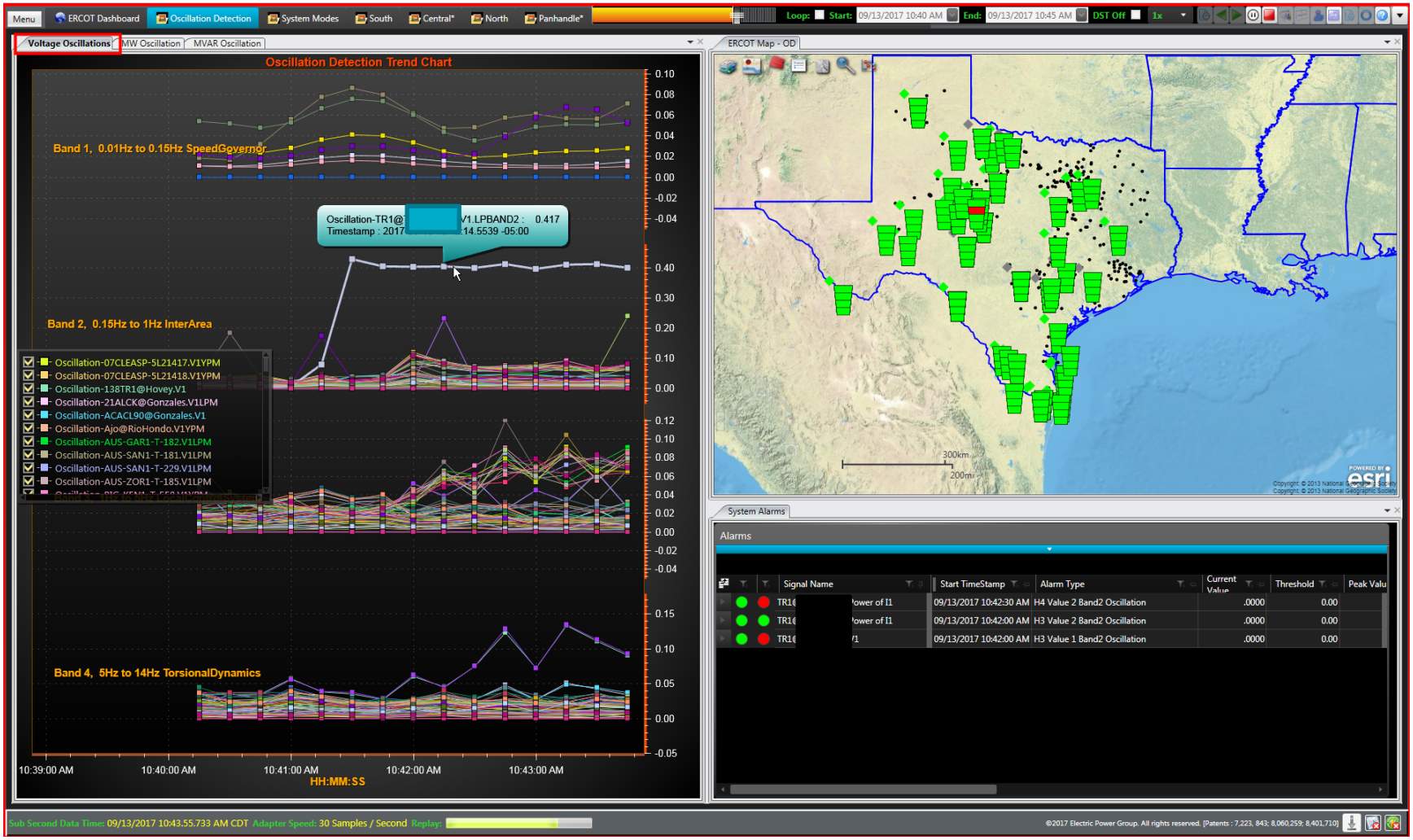

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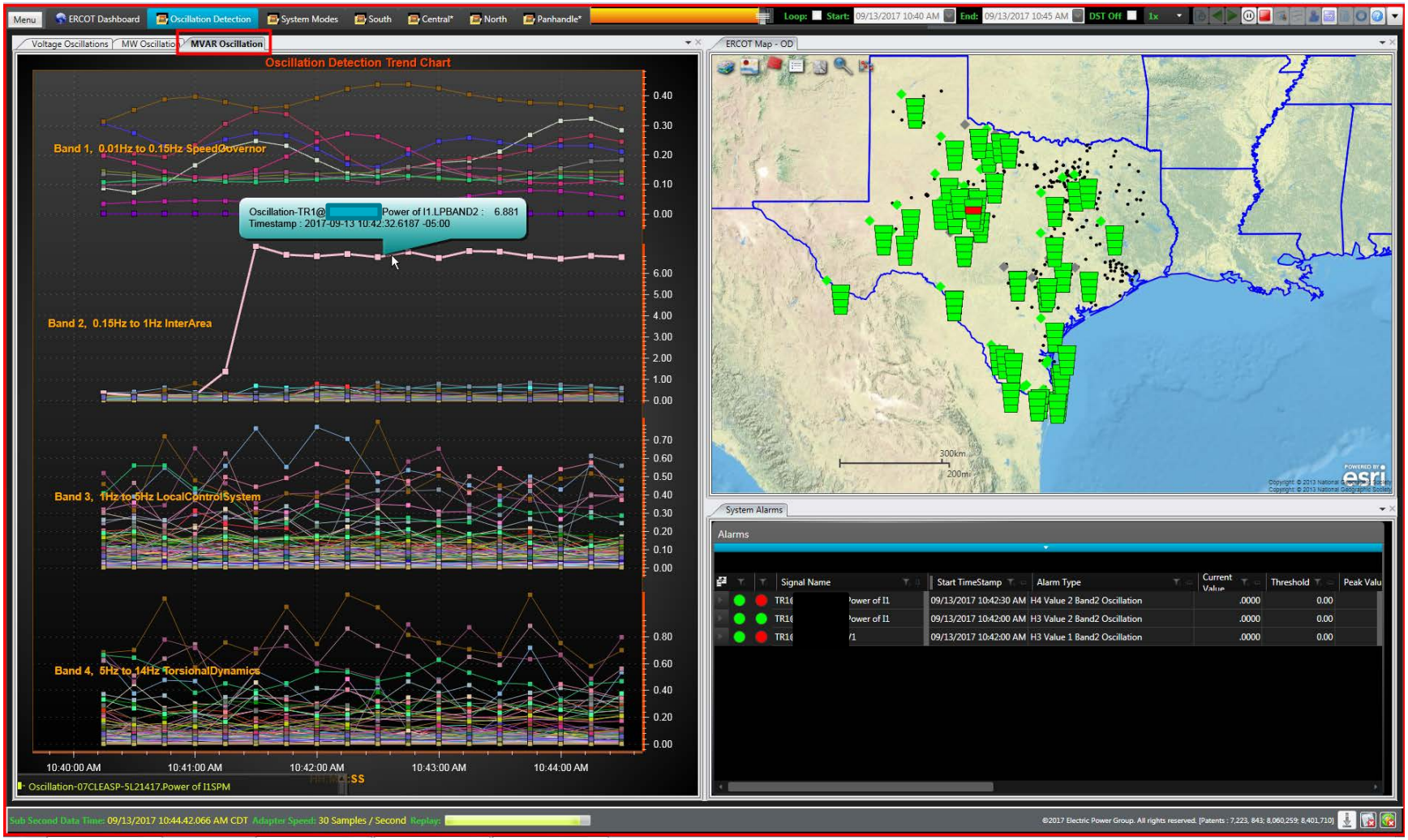

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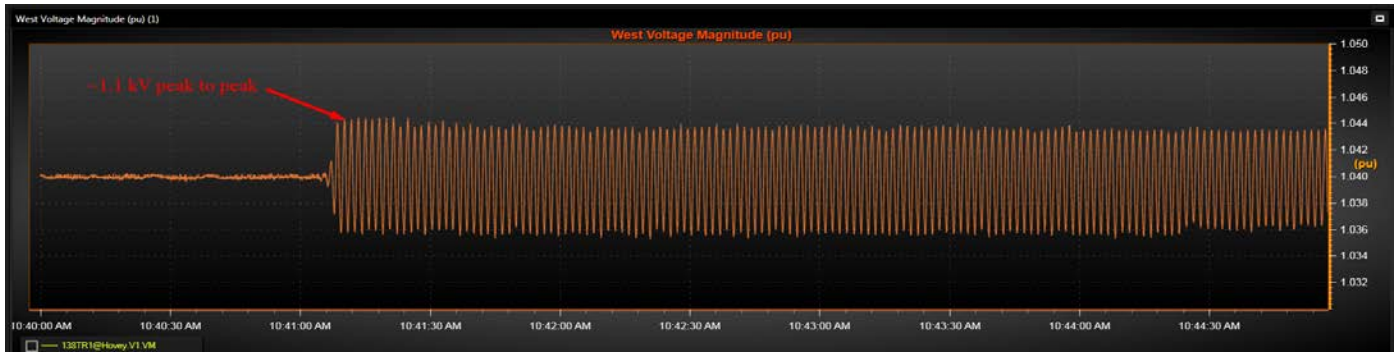

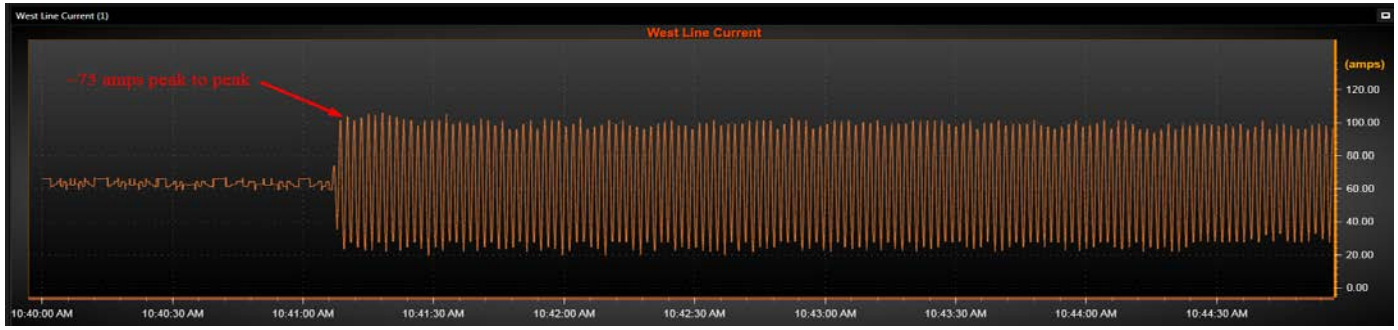

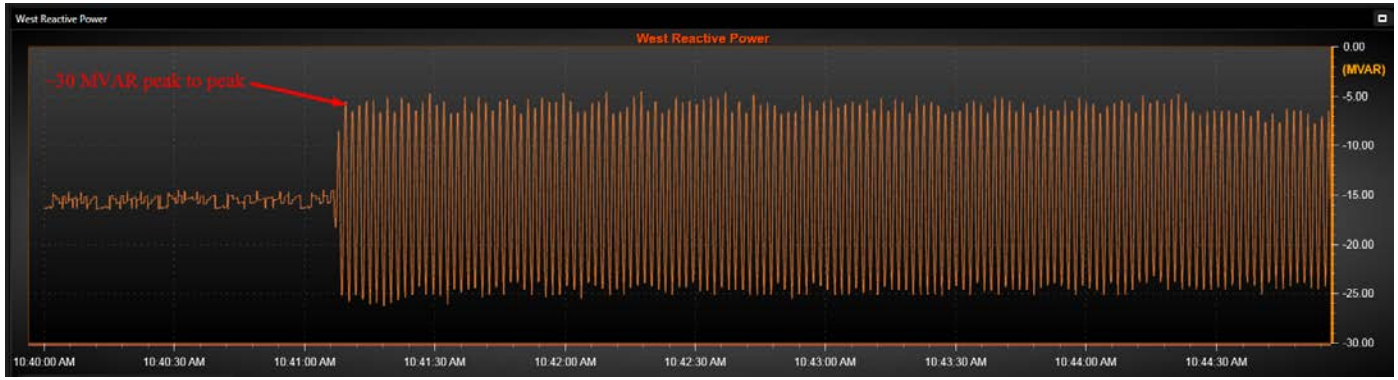

Oscillation Event Summary

- July 6 Oscillation – 0.45 Hz mode, ~3.5 kV pp,~90 MVAR pp, ~65 Amp pp
  - Intermittent MVAR swings started om 6/28
  - Turned off AVR to mitigate oscillations
  - Event used in PSOT to configure Oscillation Detection in RTDMS
- August 18 – August 21 Oscillation – 0.66 Hz mode, ~40 MVAR pp
  - Occurred on 138 kV system, nearest PMU was on 345 kV so oscillation was damped down to ~4 MVAR at nearest PMU
  - Oscillation Detection in RTDMS was not configured at this time
  - RE was instructed to turn off AVR to mitigate oscillation
- September 11,12, &13 Oscillation – 0.60 Hz mode, ~1.1 kV pp, ~30 MVAR pp, ~75A pp
  - Occurred three consecutive days around noon for 1-2 hrs.
  - Contacted RE and they are looking into the issue but no solution yet
  - Oscillations from plant traced back to March with Data Mining
  - Oscillation detected in real time by RTDMS Oscillation Detection and event files created
- September 13-14 Oscillation – 0.1 Hz mode,~14 MW pp,~6 MVAR pp,~25A pp
  - Oscillation started 11pm 9/13 lasted until 8:35am 9/14
  - No contact with RE but will observe

Next Steps

- Continue to tweak alarm and event thresholds for oscillation detection
- Bring oscillation detection to shift engineer desk
- Catalog oscillation events to begin development of shift engineer procedures for oscillations
- Upgrade PGDA with Automatic Event Mining tool to search for any missed oscillations or system modes
- Coordinate with appropriate market participants to find root cause and mitigate West Texas oscillations
- Determine if operation procedures are needed to mitigate low damped system modes and develop procedures if necessary

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Questions?