



John Adams
Principal, Grid Integration
ERCOT

- **Awarded to CCET by DOE in 2010**
 - ERCOT, TOs, Electric Power Group – Lead
- **PMU Installations (as of 10/1/2014)**
 - 35 locations installed and operational (83 PMUs in service)
 - 5 additional locations planned
- **PDCs**
 - 4 (central) PDCs installed and operational (three TOs and ERCOT)
- **Communications**
 - TOs using internal utility networks between PMUs and TO.PDCs
 - ERCOT Private WAN being used for all TO.PDC—to—ERCOT.PDC communications – fully operational
- **Real Time Dynamics Monitoring System (RTDMS) deployed at ERCOT**
 - RTDMS upgraded for control room use in August, 2013
 - TOs have real time client access to ERCOT displays
 - 2 Operating Training sessions have been conducted (2013 and 2014)

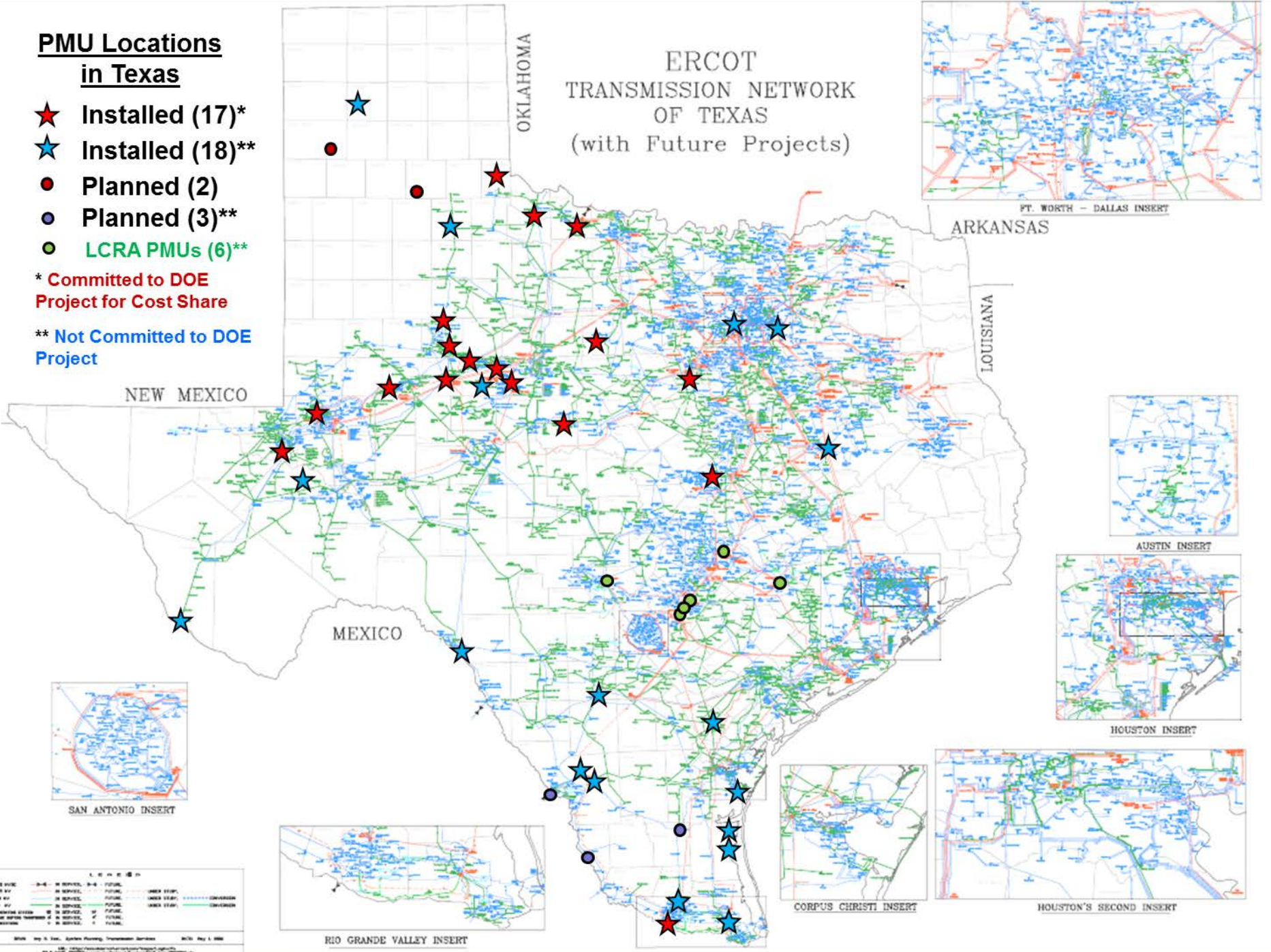
PMU Locations in Texas

- ★ Installed (17)*
- ★ Installed (18)**
- Planned (2)
- Planned (3)**
- LCRA PMUs (6)**

* Committed to DOE Project for Cost Share

** Not Committed to DOE Project

ERCOT TRANSMISSION NETWORK OF TEXAS (with Future Projects)



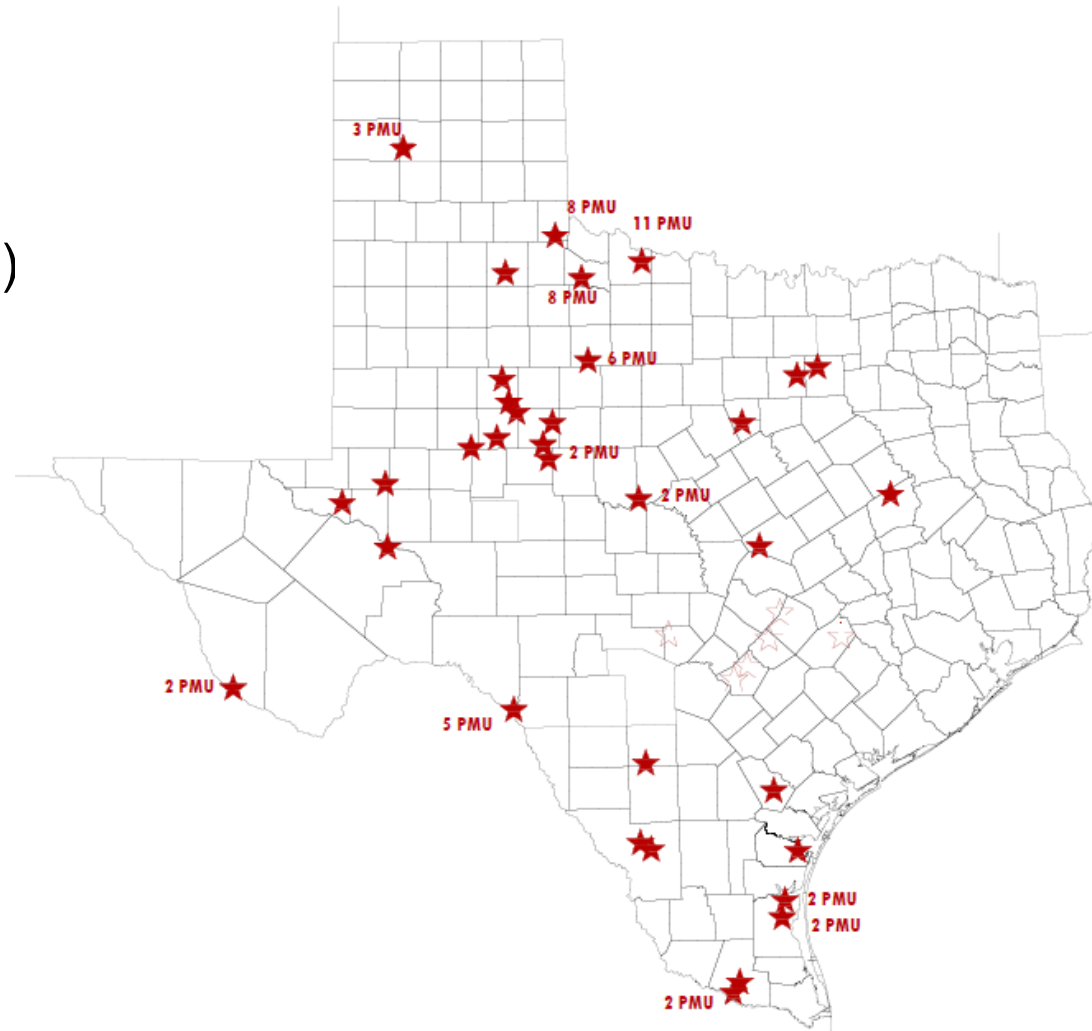
LINE TYPE	3-4	5-6	7-8	9-10	FUTURE	UNDER STUDY	CONVERSION
345 KV	—	—	—	—	—	—	—
500 KV	—	—	—	—	—	—	—
765 KV	—	—	—	—	—	—	—
INTERSTATE SYSTEM	—	—	—	—	—	—	—
NEARBY SYSTEMS	—	—	—	—	—	—	—
TRANSMISSION	—	—	—	—	—	—	—

Scale: 1/4" = 100 Miles, System Planning, Transmission Services, 05/10, May 1, 2008
 FILE NAME: 050217TransmissionNetworkMap.mxd

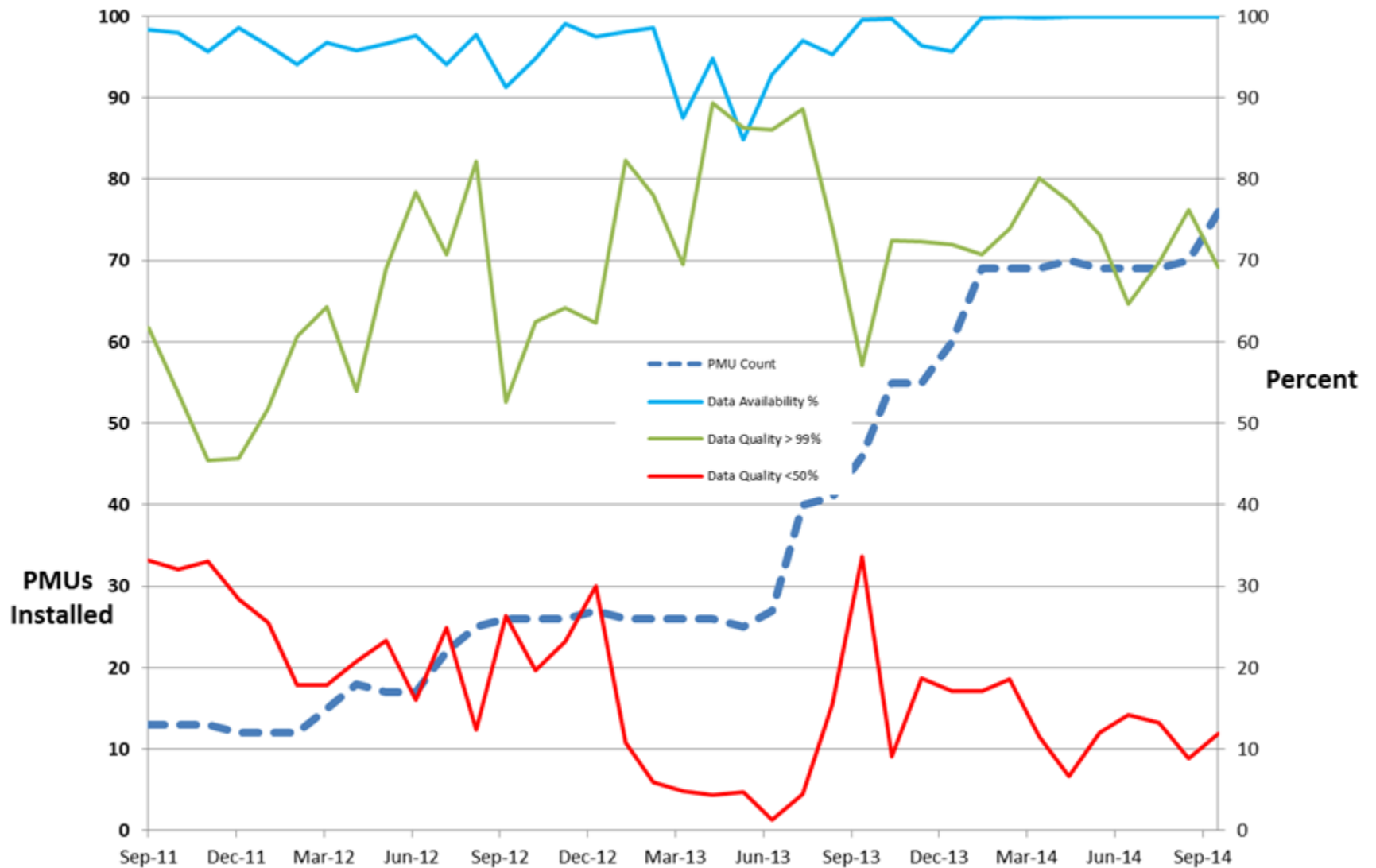
- **Total 93 PMUs**

Locations : 17 (AEP) + 15 (ONCOR) + 4 (Sharyland) + 6 (LCRA) = 42 locations

- AEP: 53
- ONCOR: 17
- Sharyland: 5
- LCRA: 18 (coming soon)



PMU DATA QUALITY AND AVAILABILITY

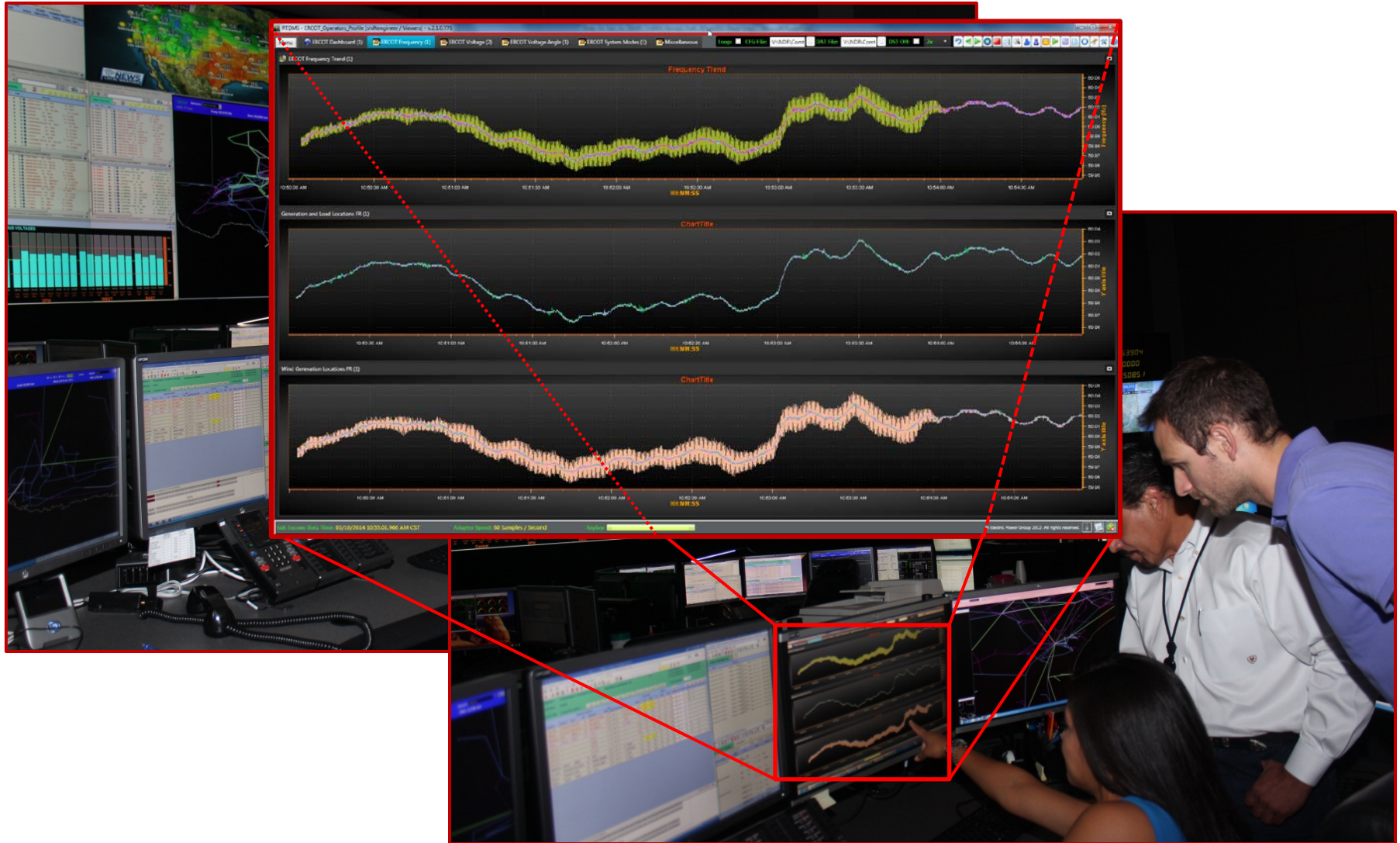


- The number of connected PMUs has tripled over the past 15 months
- Overall data availability has been essentially 100% for the past 9 months
- The percentage of high quality timely data is averaging 70%
- The percentage of poor quality data has fallen to 10%
- Data quality for new PMUs is initially low, but improves rapidly

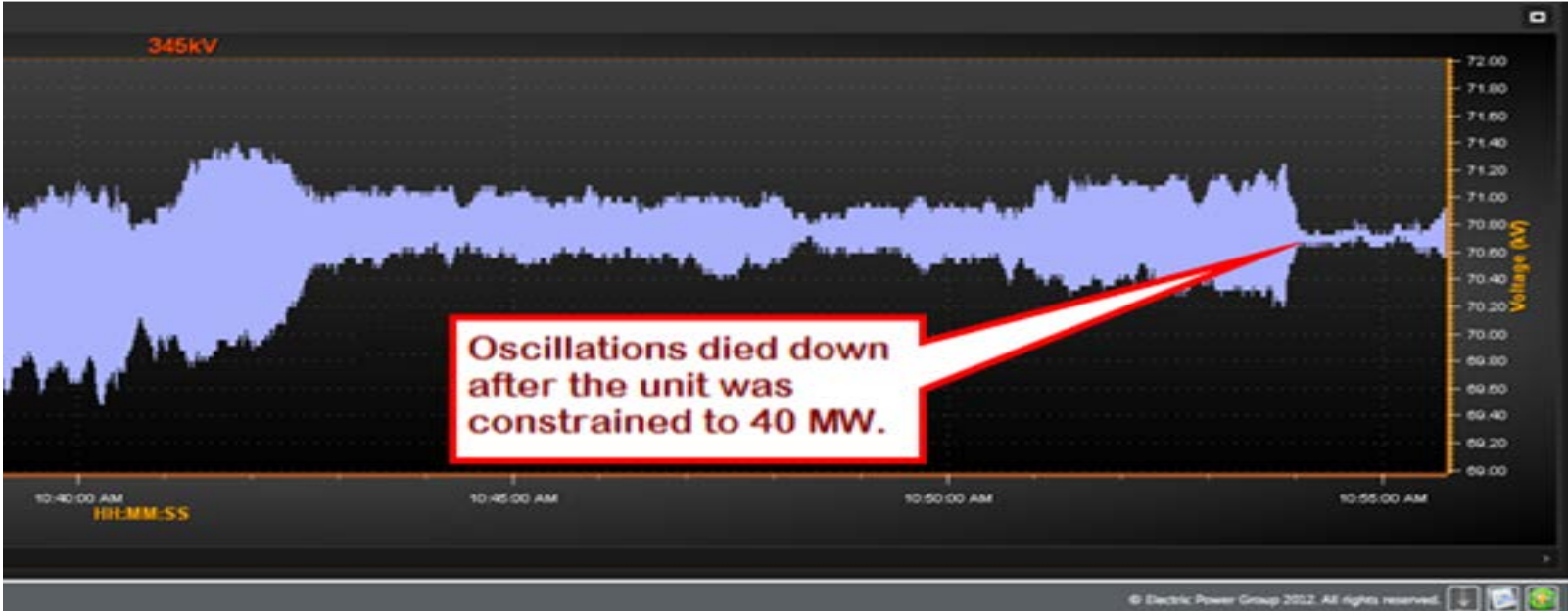
USE CASE OVERVIEW

Use Case	Grid Scope	Streaming 30 samples/sec	Slow Speed 3 samples/min	Local Event Capture
High Stress Across System (High Phase Angle) Observed	Wide Area	Yes	Yes	
Small Signal Stability – Damping is Low	Wide Area	Yes		
Small Signal Stability – Emerging Oscillation Observed	Wide Area and Local	Yes		
Voltage Oscillation Observed	Regional	Yes		
Voltage Instability Monitoring (real-time P-V or Q-V curve)	Regional	Yes		
Detection of Subsynchronous Interactions (Not necessarily resonance, just below 60 hz)	Local Regional	Yes		
Integrate PMU Data Into State Estimator	Wide Area	Yes	Yes	
System Disturbance – Capture and Interpretation	Regional	Yes	Yes, not high resolution	Yes
Generator Parameter Determination	Local	Yes		Yes
Major Load Parameter Determination	Local	Yes		Yes
PMU-Based Fault Location	Local Regional	Yes		Yes
Phase Angle Across Breaker for Reclosing Action		Yes	Yes	
Subsynchronous Resonance Identification and Mitigation (PGRR027)	Regional	Yes		
Transmission Characteristics Determination	Regional	Yes		Yes
Dynamic Transmission Line Ratings using PMU monitoring	Regional	Yes		
Validation of Control Devices (e.g. SVC) performance	Regional	Yes		Yes

SYNCHROPHASOR TECHNOLOGY IN ERCOT CONTROL CENTER

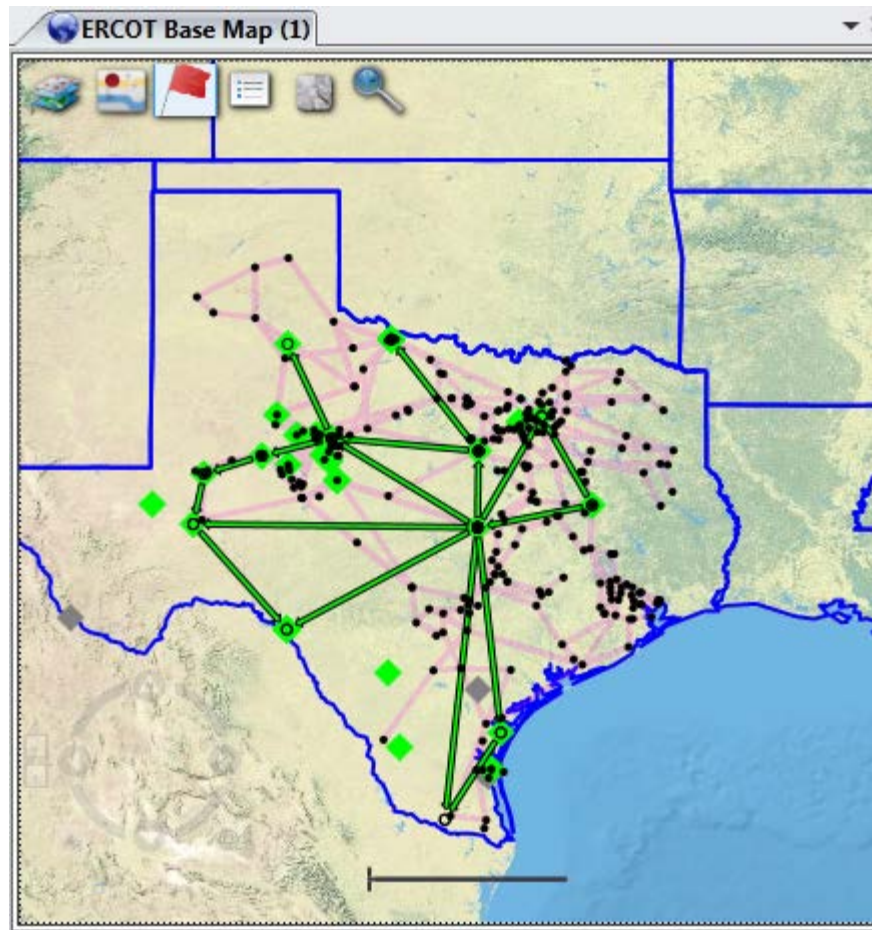


- Reduction of oscillations after constraining the plant to 40 MW



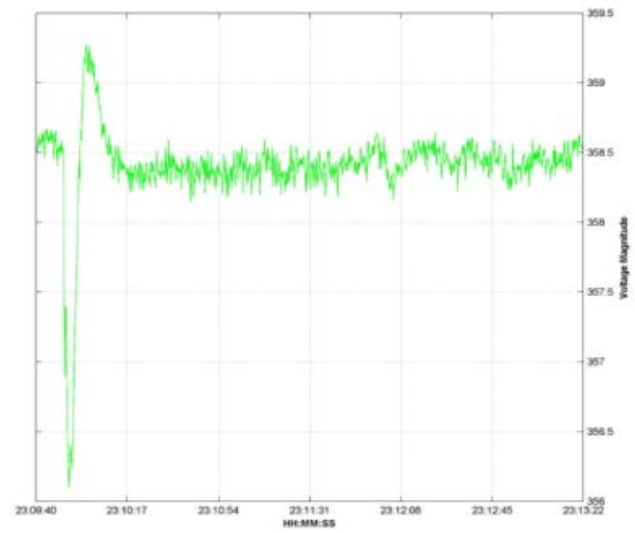
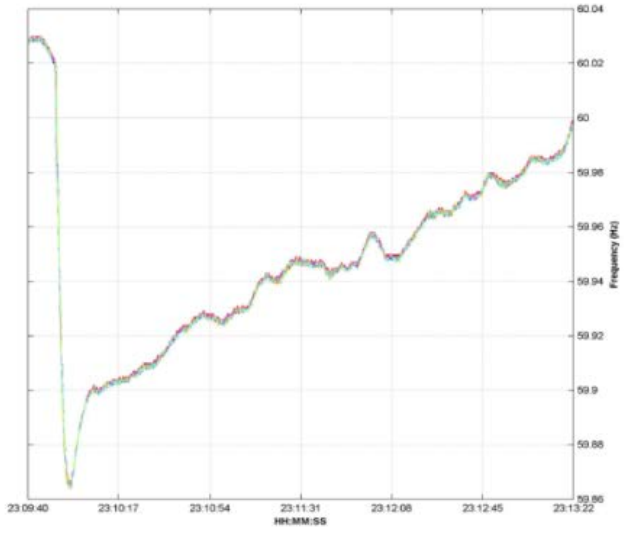
MONITORING ANGULAR DIFFERENCES

- Monitoring on angular differences



- Generator trips, etc

- WhBkr@RioPecos.Frequency.FR
- Westside@Arlene.Frequency.FR
- TR1@CedroHl.Frequency.FR
- TKWSW 9205/9210.Frequency.FR
- Sys2Oku1@Riley.Frequency.FR
- Sys1Oku2@Riley.Frequency.FR
- SWESW10510/10515.Frequency.FR
- SVC@Dilley.Frequency.FR
- SCOSW10715/10710.Frequency.FR
- PMB6W 2600/2600.Frequency.FR
- ODEHV11425/11420.Frequency.FR
- MGCSW 6520.Frequency.FR
- LHOSW 9400/9405.Frequency.FR
- KLNSW 6020.Frequency.FR
- JEWET 1834.Frequency.FR
- GulfWind TR2-348.Frequency.FR
- GulfWind TR1-348.Frequency.FR
- GAVSW 022.Frequency.FR
- EXPKY 9148.Frequency.FR
- DMTSW10945/10940.Frequency.FR
- CPSW 8070.Frequency.FR
- CBFSW11140/11135.Frequency.FR
- CBFSW11130/11135.Frequency.FR
- Buenfshr@Riley.Frequency.FR
- B-v111/1890/EE30.Frequency.FR
- Bowman2421@Riley.Frequency.FR
- Bowman1421@Riley.Frequency.FR



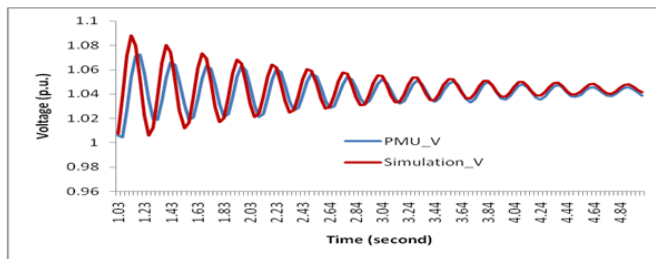
Start Time: 26-Jun-2013 23:09:40 CDT
End Time: 26-Jun-2013 23:13:22 CDT

- Generator Model Validation/Tuning

- Post Event Analysis

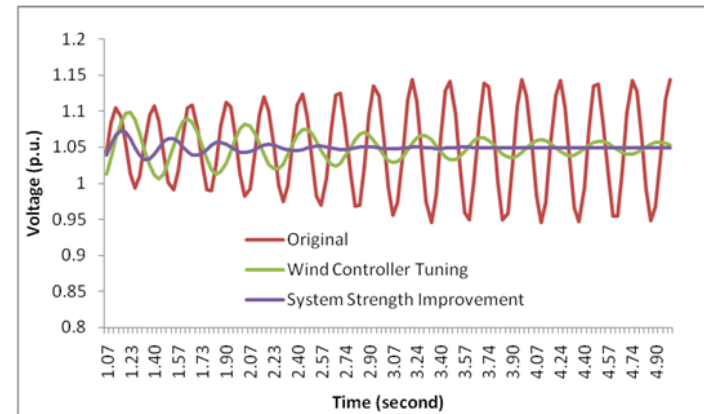
- Re-create the oscillations as captured by the PMU
 - Identify the cause and solutions to mitigate the oscillations

- Benchmark study using PMU data

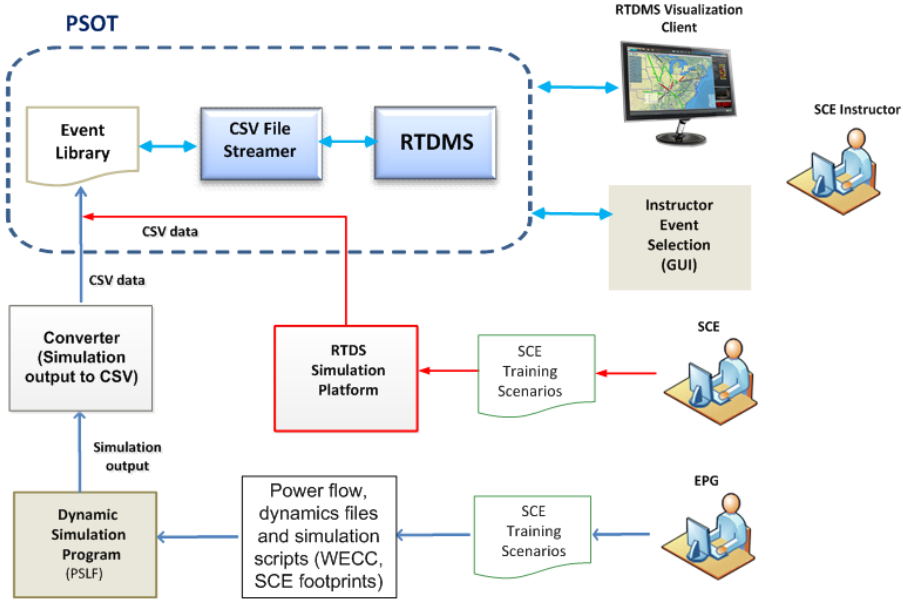


Voltage responses at WPP's POI

Proposed solution based on simulation studies



- **PMU Simulation Systems for Operator Training**
 - DOE Project on 'Phasor Simulator for Operator Training (PSOT)' jointly with EPG, Dominion Power, Southern California Edison

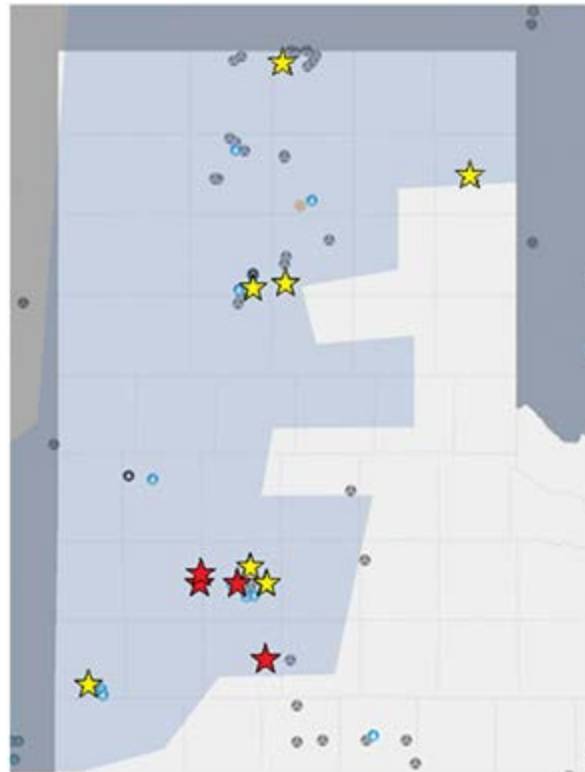




TTU Synchronphasor Network



- Texas Tech University is deploying a synchrophasor network in the SPP portion of the Texas Panhandle working in partnership with several electric cooperatives to acquire data at the distribution substation level as well as directly monitoring alternative energy resources.
- 5 Units presently installed (red stars)
 - Texas Tech Campus
 - Reese Center (Alstom)
 - Reese Center (Swift)
 - Reese Center (Battery)
 - Draw, TX(Lyntegar)
- Possible Future Installs (yellow stars)



CCET provided a 1 MW utility scale battery system at Reese Technology Center.



Reese Technology Center had six wind turbines operating in 2013.

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