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Principal, Grid Integration
ERCOT

NASDAQ Meeting at Houston, 22-23 October 2014
SYNCHROPHASOR PROJECT SUMMARY

- 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)
• **Total 93 PMUs**
  
  Locations: 17 (AEP) + 15 (ONCOR) + 4 (Sharyland) + 6 (LCRA) = 42 locations
  
  - AEP: 53
  - ONCOR: 17
  - Sharyland: 5
  - LCRA: 18 (coming soon)
• 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
<table>
<thead>
<tr>
<th>Use Case</th>
<th>Grid Scope</th>
<th>Streaming 30 samples/sec</th>
<th>Slow Speed 3 samples/min</th>
<th>Local Event Capture</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Stress Across System (High Phase Angle) Observed</td>
<td>Wide Area</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Small Signal Stability – Damping is Low</td>
<td>Wide Area</td>
<td>Yes</td>
<td></td>
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<tr>
<td>Small Signal Stability – Emerging Oscillation Observed</td>
<td>Wide Area and Local</td>
<td>‘Yes</td>
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<tr>
<td>Voltage Oscillation Observed</td>
<td>Regional</td>
<td>Yes</td>
<td></td>
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<tr>
<td>Voltage Instability Monitoring (real-time P-V or Q-V curve)</td>
<td>Regional</td>
<td>Yes</td>
<td></td>
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<tr>
<td>Detection of Subsynchronous Interactions (Not necessarily resonance, just below 60 hz)</td>
<td>Local Regional</td>
<td>Yes</td>
<td></td>
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<tr>
<td>Integrate PMU Data Into State Estimator</td>
<td>Wide Area</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>System Disturbance – Capture and Interpretation</td>
<td>Regional</td>
<td>Yes</td>
<td>Yes, not high resolution</td>
<td></td>
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<tr>
<td>Generator Parameter Determination</td>
<td>Local</td>
<td>Yes</td>
<td></td>
<td>Yes</td>
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<tr>
<td>Major Load Parameter Determination</td>
<td>Local</td>
<td>Yes</td>
<td></td>
<td>Yes</td>
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<tr>
<td>PMU-Based Fault Location</td>
<td>Local Regional</td>
<td>Yes</td>
<td></td>
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<tr>
<td>Phase Angle Across Breaker for Reclosing Action</td>
<td>Regional</td>
<td>Yes</td>
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<tr>
<td>Subsynchronous Resonance Identification and Mitigation (PGRR027)</td>
<td>Regional</td>
<td>Yes</td>
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<td>Transmission Characteristics Determination</td>
<td>Regional</td>
<td>Yes</td>
<td></td>
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<tr>
<td>Dynamic Transmission Line Ratings using PMU monitoring</td>
<td>Regional</td>
<td>Yes</td>
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<tr>
<td>Validation of Control Devices (e.g. SVC) performance</td>
<td>Regional</td>
<td>Yes</td>
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</tbody>
</table>
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
• 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

**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
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)
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