



Center for the Commercialization of Electric Technologies



DISCOVERY ACROSS TEXAS

*Technology Solutions for Wind
Integration in ERCOT*



CCET Smart Grid Demonstration Project

ARRA Wind & Battery Project Workshop

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CCET President & COO
October 17, 2013

CCET Demonstration Project

- CCET defined a demonstration project to help address the **challenges of wind integration** into the ERCOT grid with 18 GW of wind resources.
- Key components to leverage and expand upon:
 - a) A **starter synchrophasor network**
 - b) Expected **AMS rollout** of 6 million units
 - c) A smart grid **future community** with residential solar, smart appliances, home energy monitoring, and electric vehicles
 - d) Smart Meter Texas Portal (**SMT**)
- ***Technology Solutions for Wind Integration in ERCOT***
 - a) Award Number: DE-OE-0000194
 - b) Value: \$27 million total; \$13.5 million DOE
 - c) Original Award Date: 4 January 2010
 - d) Term: Five-years



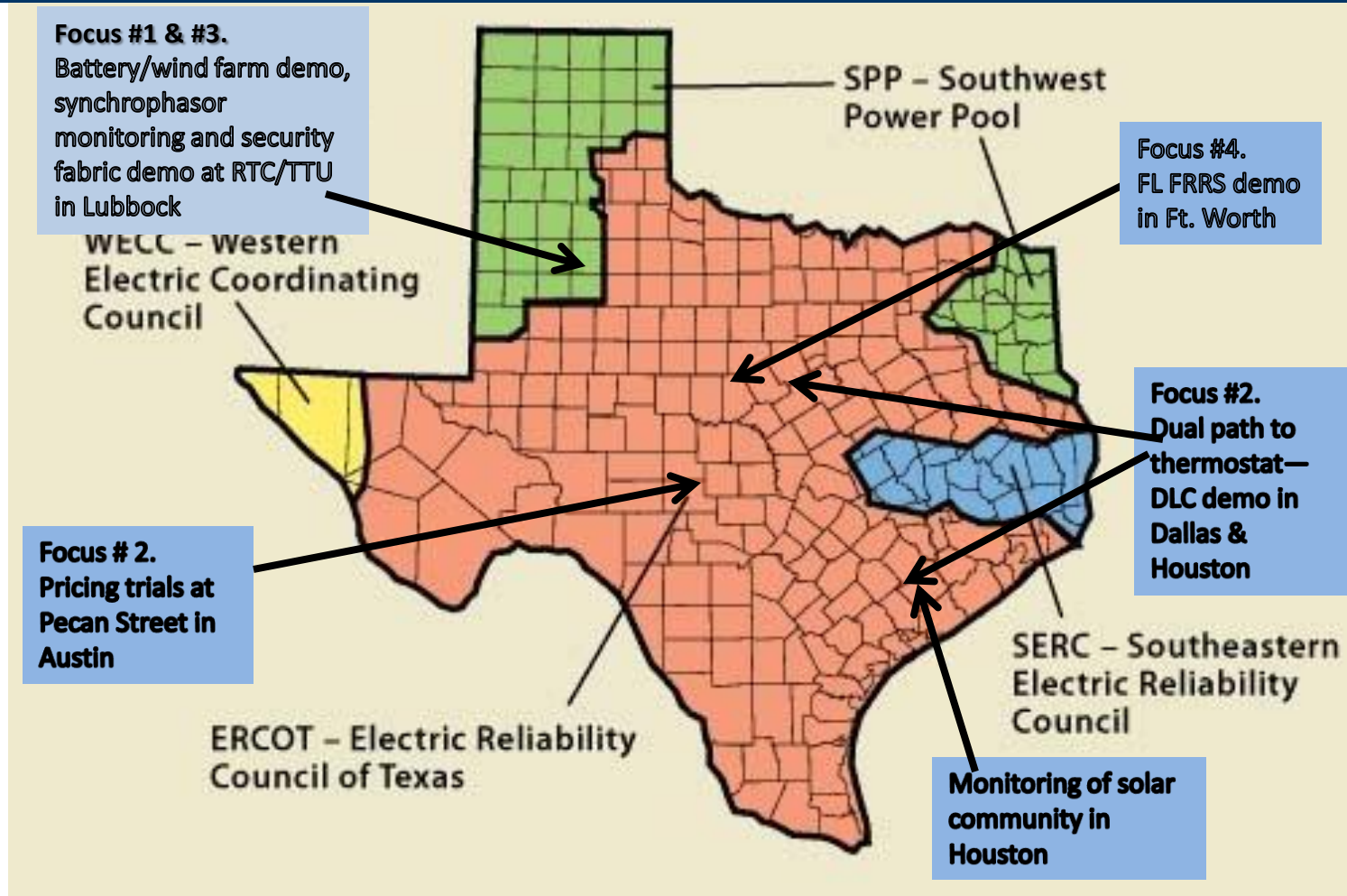
Desired Project Goals and Outcomes

Grid management solutions to facilitate 18 GW of wind

- Current installed wind capacity is 10,570 MW
 - Estimate for 2013 is now 11,732 MW
 - Generation requests for wind projects now total 21,669 MW
-
- **Focus #1:** Synchrophasor system deployment and operation with security fabric product demonstration
 - **Focus #2:** Demand response and residential pricing experiments that match available wind power
 - **Focus #3:** Utility-scale battery operated in conjunction wind turbines and testing FRRS capabilities
 - **Focus #4:** Plug-in Electric Vehicles influence on redistributing load to complement the wind



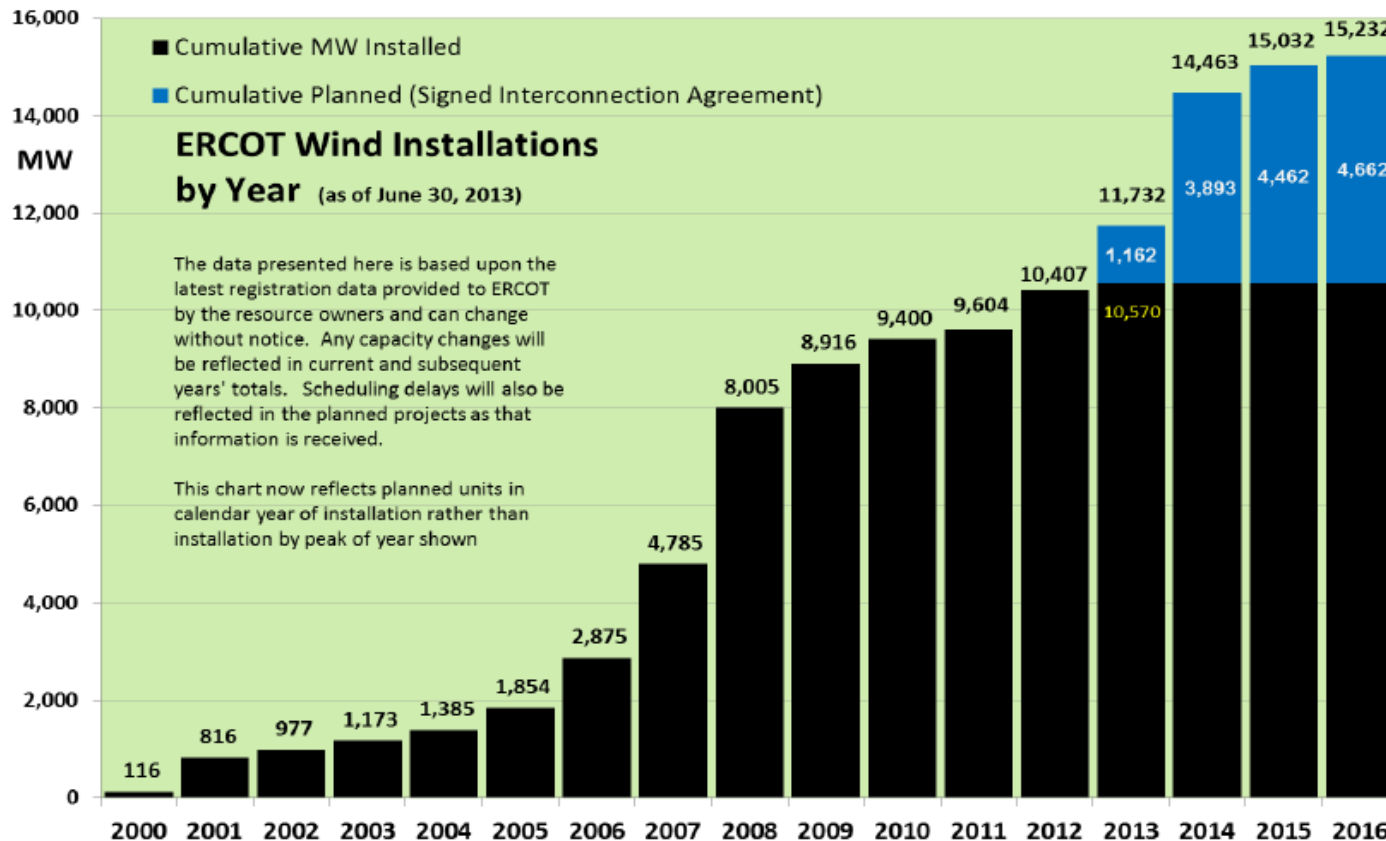
Discovery Across Texas Project



Context:

Continuing Investment in Wind Generation

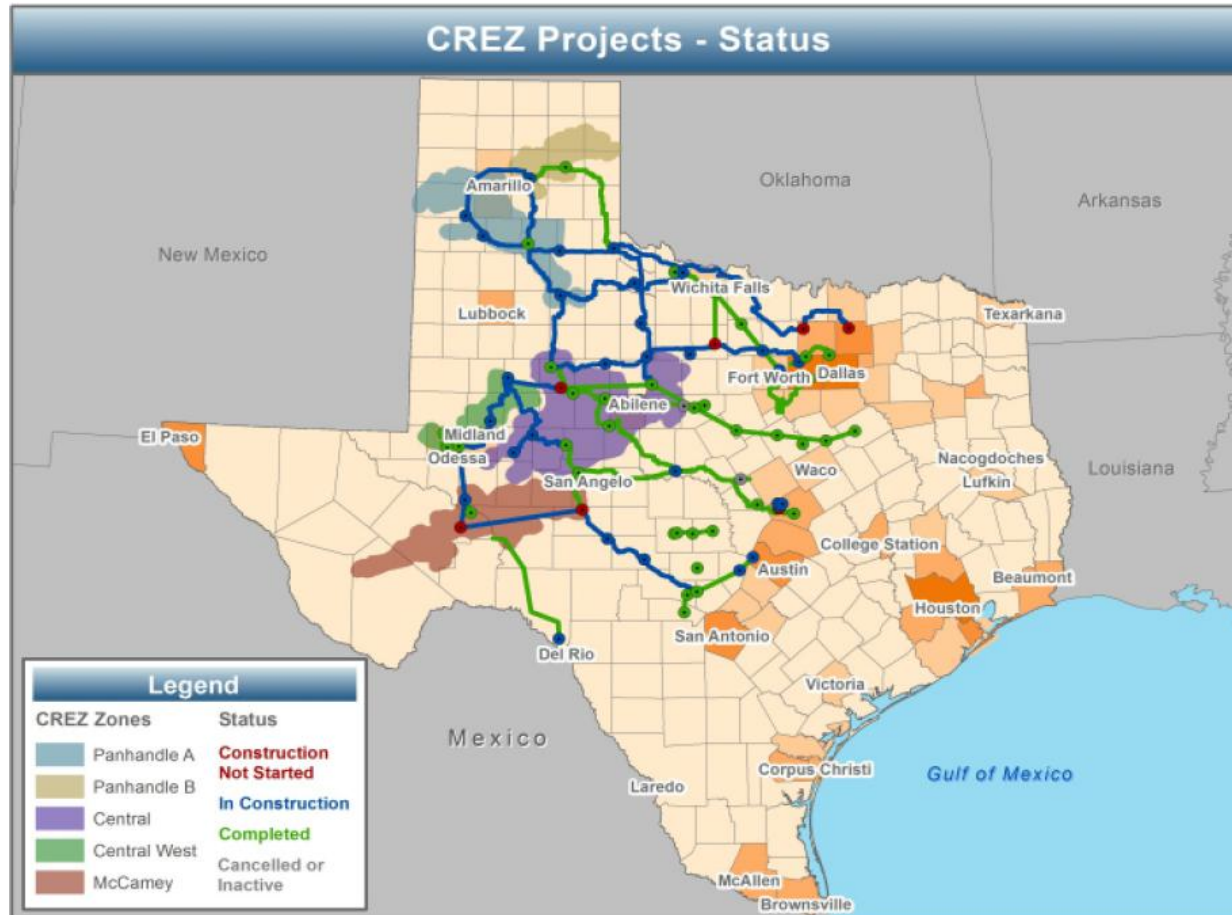
ERCOT Wind Capacity



Context:

Continuing Investment in Wind Capacity

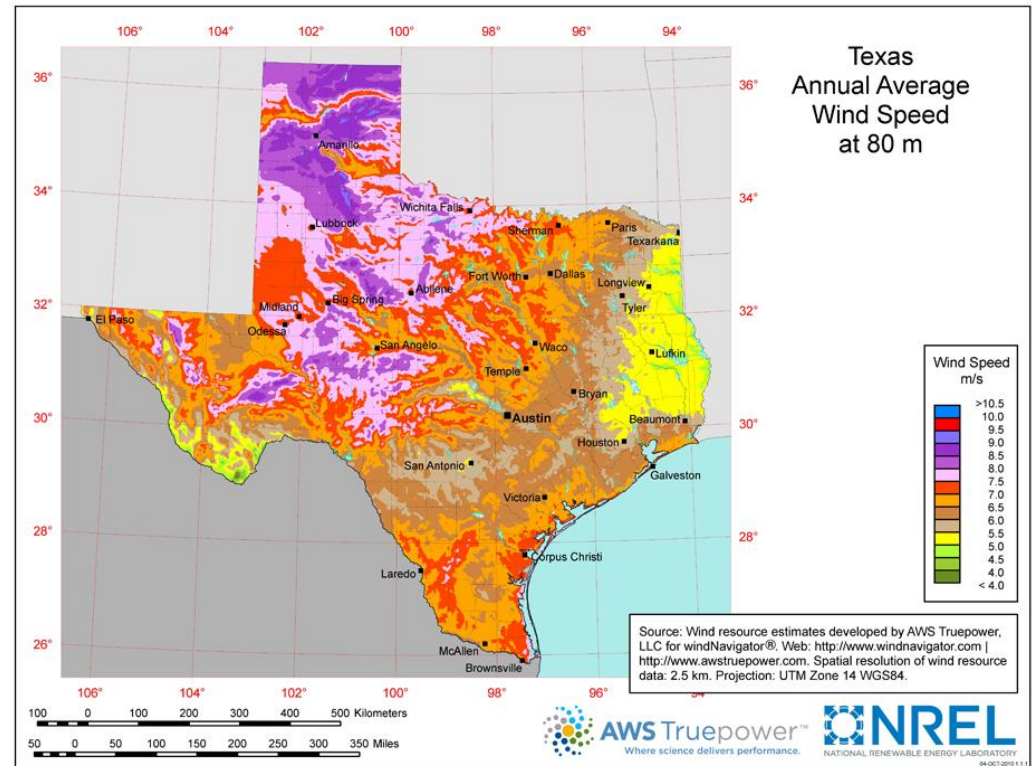
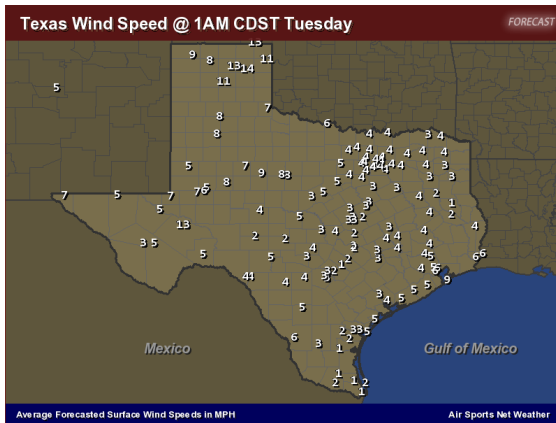
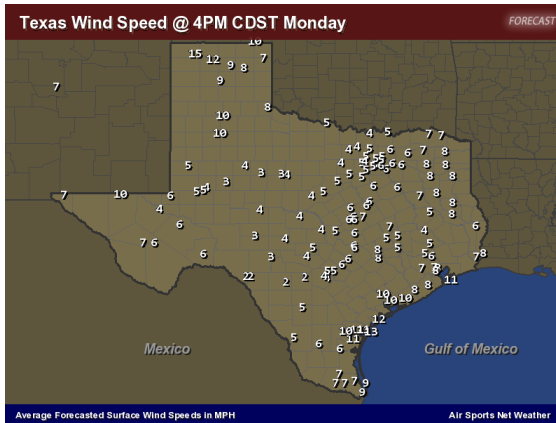
ERCOT CREZ Build-Out



Context:

The Wind Always Blows in West Texas

Wind Speed Charts for Texas



Context:

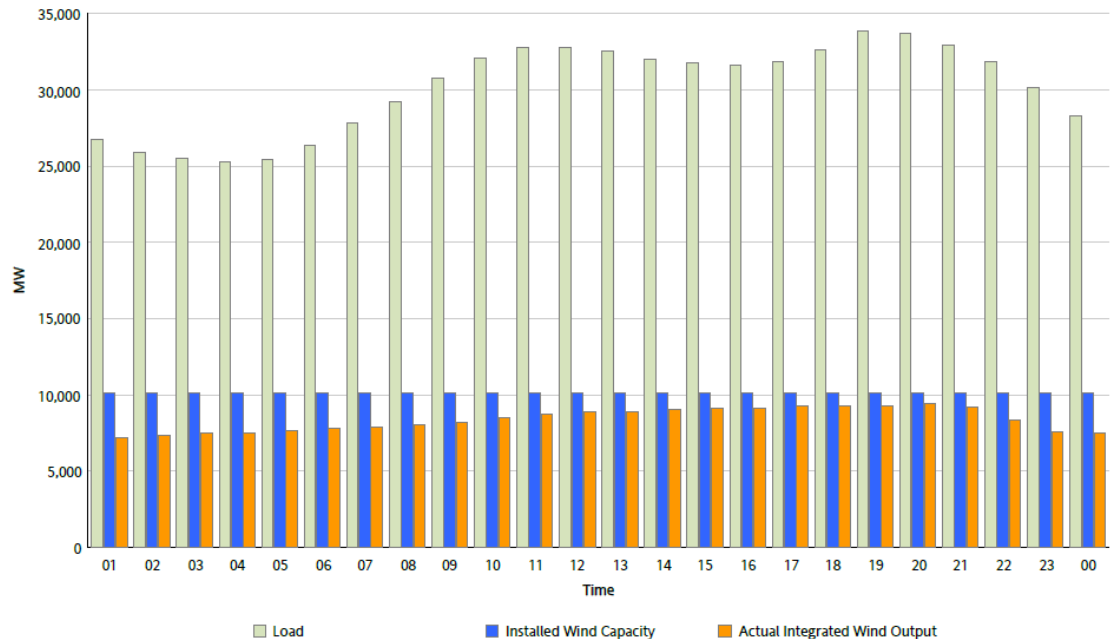
New ERCOT Wind Power Record

Hourly Average Actual Load vs. Actual Wind Output

ERCOT Grid Operations

Wind Integration Report : 02/09/2013

Peak Load **33,867 MW**
Load Peak Hour (HE) **19**
Wind Over Peak **9,306 MW**
Wind Record 02/09/13 **9,481 MW**
Max Wind Value* **9,481 MW**
Wind Peak Time **19:08**
Wind Integration % **27.82 %**



Wind Turbines at RTC



Wind Technology Resources at RTC

Reese Technology Center and TTU National Wind Institute



DOE SWiFT Facility



200m Met Tower



Ka-Band Radar Trucks



AMI & SMT Portal

- ERCOT and the largest electricity companies in Texas have launched the most aggressive Advanced Metering System (AMS) deployment in the U.S. Now 6.5 Smart Meters Installed.
- The *Smart Meter Texas Portal* initiative is a several-year collaboration to:
 - Properly integrate AMS meters into the ERCOT market
 - Provide consumer tools for viewing 15-minute meter data
 - Provision devices for load control
- The PUCT formed an Advanced Metering Implementation Team (AMIT) which is currently defining a roadmap for future SMT Portal capabilities
- The CCET Project and all of its stakeholders will plan an extension of Portal capabilities that can be used to better support ERCOT as well as test aspects at the Texas Community of the Future.



Operational Strategies for Wind Integration

Advanced Decision Support Tools

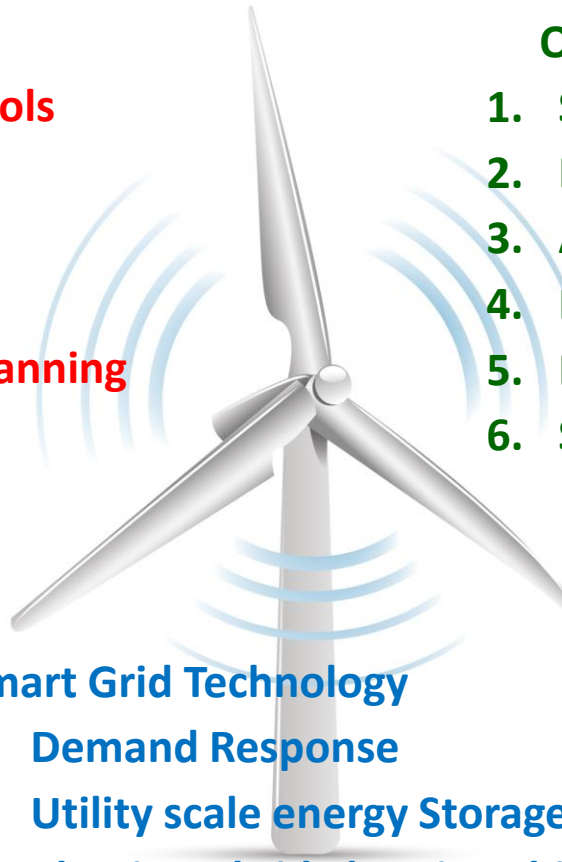
1. Voltage Stability Analysis
2. Optimum Power Flow
3. Transient Stability Analysis
4. Optimized Transmission Planning
5. Price-responsive DR

Operations Processes and Tools

1. System Condition Visualization
2. Load Resource Control
3. Automated Decision Support
4. Faster/More Accurate Ramping
5. Dynamic Interchange Scheduling
6. Surgical Load Shedding

Smart Grid Technology

1. Demand Response
2. Utility scale energy Storage
3. Plug-in Hybrid Electric Vehicles



CCET Project Activities Support Wind Integration

Synchrophasors

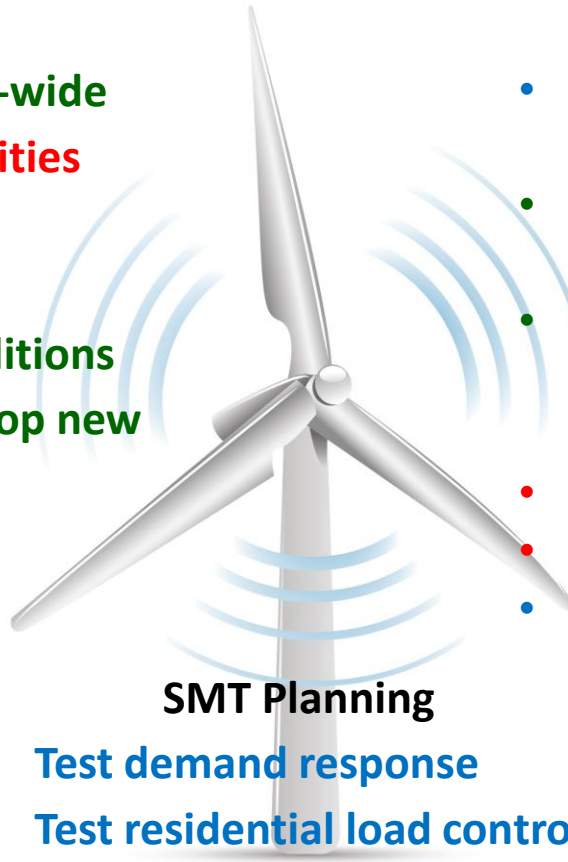
- Monitor transmission state-wide
- Analyze & report abnormalities
- Optimize power flow
- Aid planning
- Visualize transmission conditions
- Enhance existing and develop new decision support tools
- Enable quicker response

Future Community

- Study energy storage/wind combination
- Evaluate TDU impact of renewables
- Perform transient, load flow and steady state analysis of wind power on distribution grid
- Conduct pricing experiments
- Evaluate power quality factors
- Test charging of PHEVs

SMT Planning

- Test demand response
- Test residential load control



Use of Advanced Applications in Wind Integration Projects

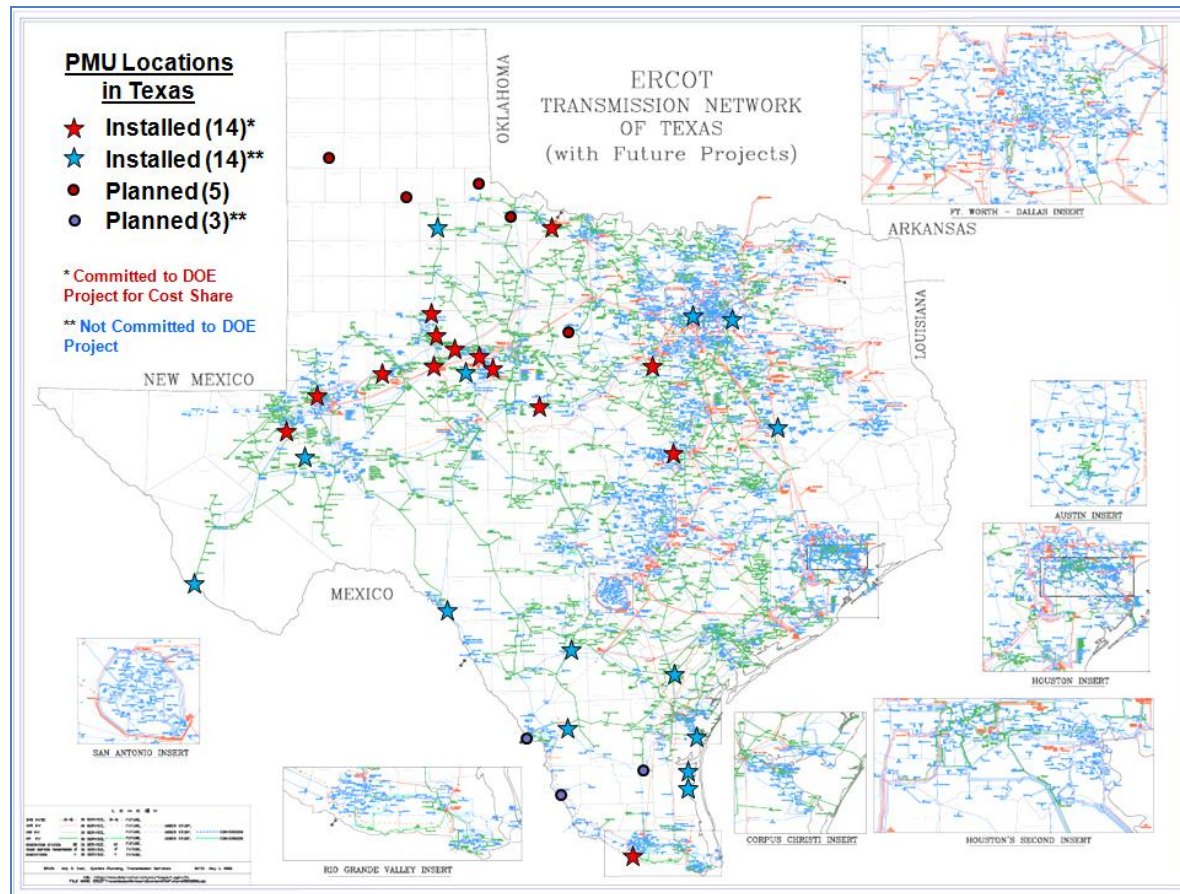
CCET Components Addressed in this Workshop

- **Synchrophasor monitoring, visualization, and event reporting**
- **Distribution-level battery energy storage system**
- Synchrophasor cyber security protection
- **Residential time-of-use pricing trial (wind incentive pricing)**
- Residential demand response
- Residential circuit monitoring
- **Fast-response regulation service with fleet electric vehicles**



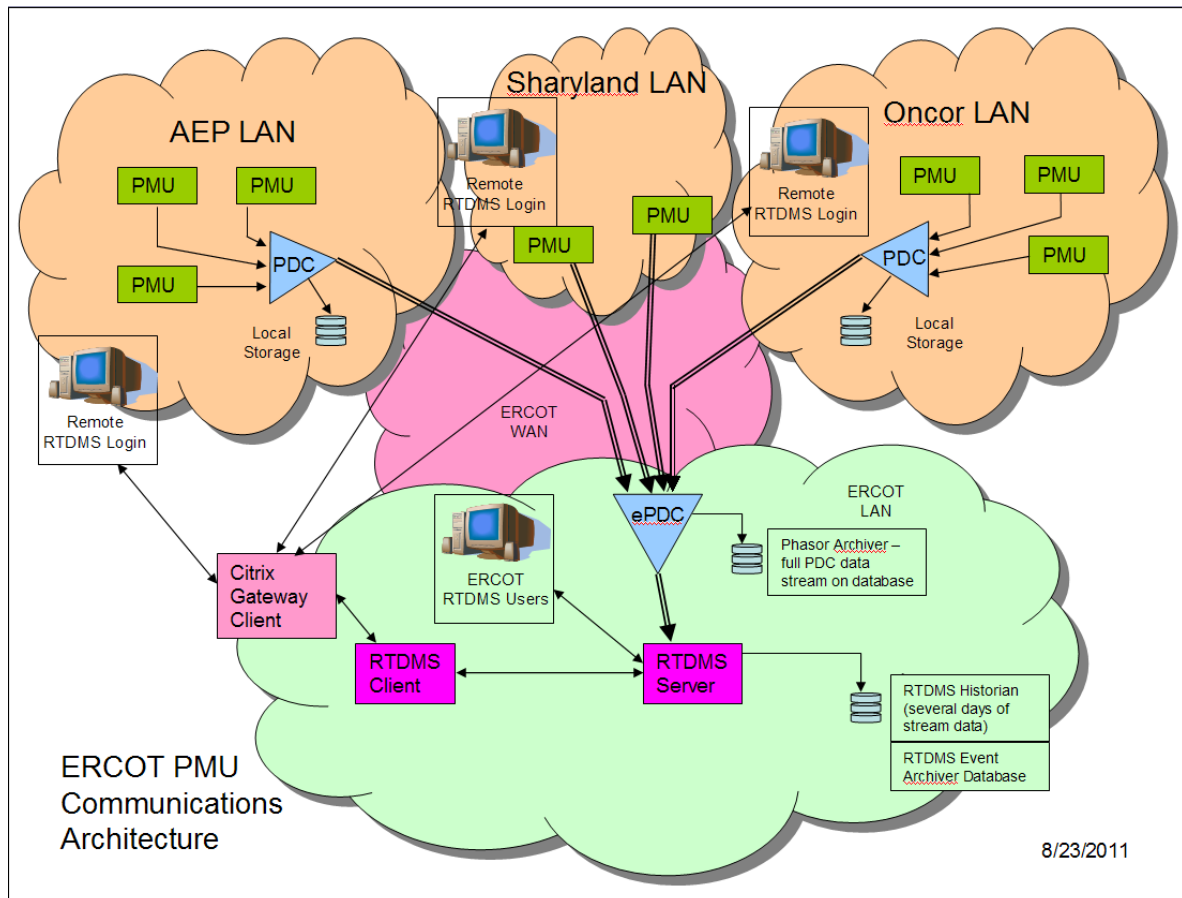
Use of Advanced Applications in Wind Integration Projects

Current Synchrophasor Deployments Across Texas



Use of Advanced Applications in Wind Integration Projects

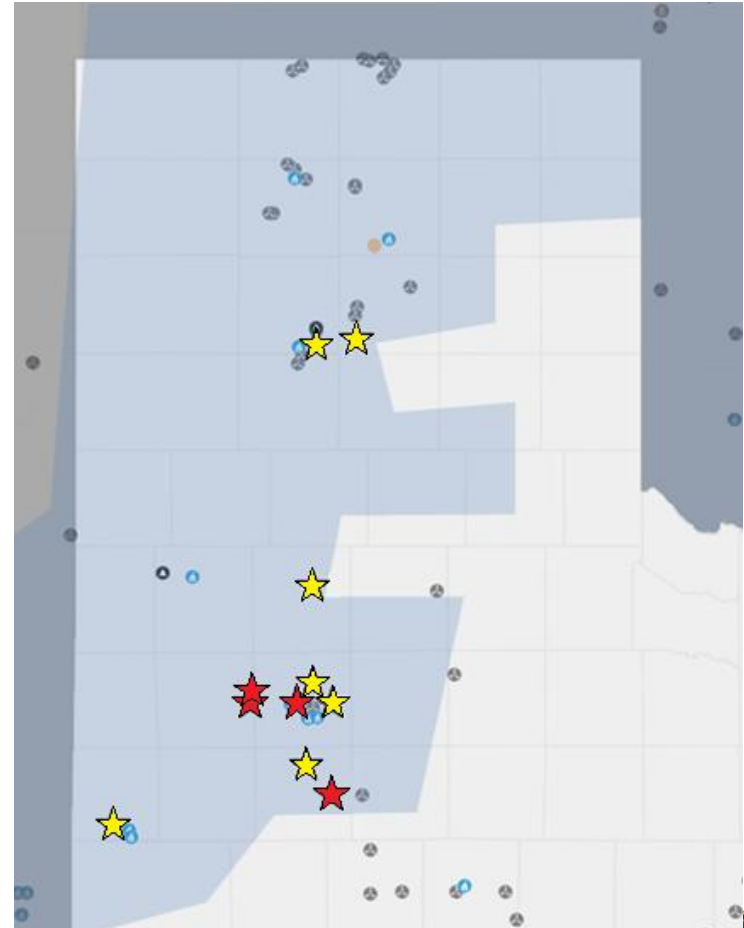
Synchrophasor Tools in Use by Project Participants



Use of Advanced Applications in Wind Integration Projects

TTU Synchrophasor Network

- Deployed in the panhandle portion of SPP (blue shaded area) which covers part of the Texas panhandle and SE New Mexico
- 4 Units Presently Installed (red stars)
 - Texas Tech Campus
 - Reese Center (Alstom)
 - Reese Center (Swift)
 - Draw, TX (Lyntegar)
- Possible Future Installs (yellow stars)
 - Mustang Station (486 MW)
 - GSPWR (78 MW)
 - Antelope Station (168 MW)
 - Sirrus Wind Farm (64 MW)
 - Plains Coop Oil Mill
 - XFAB Texas
 - Pantex
- Database Locations
 - Primary @ Reese Center
 - Backup @ TTU Campus

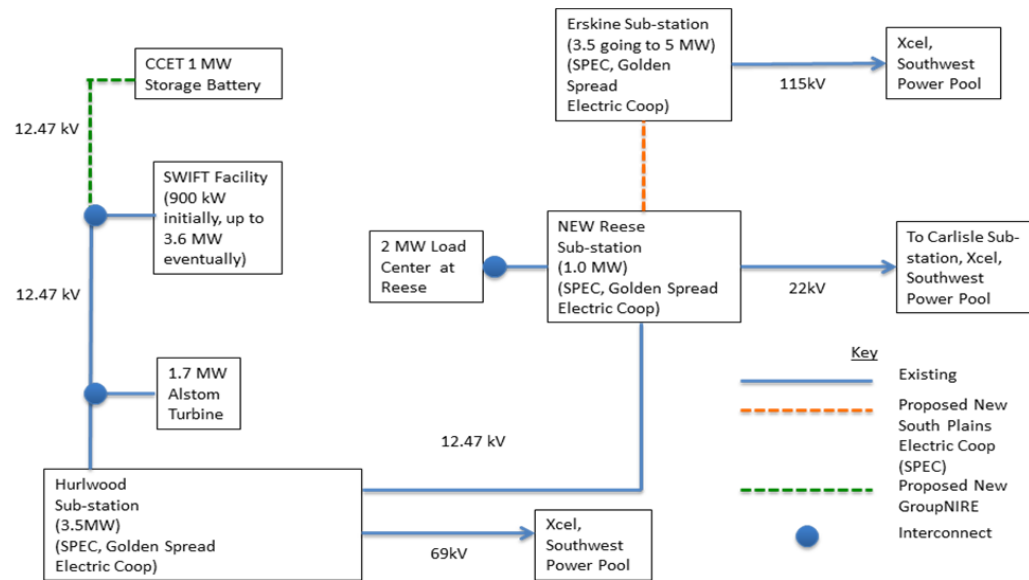


Use of Advanced Applications in Wind Integration Projects

1MW/1MWh Battery Energy Storage System (BESS)



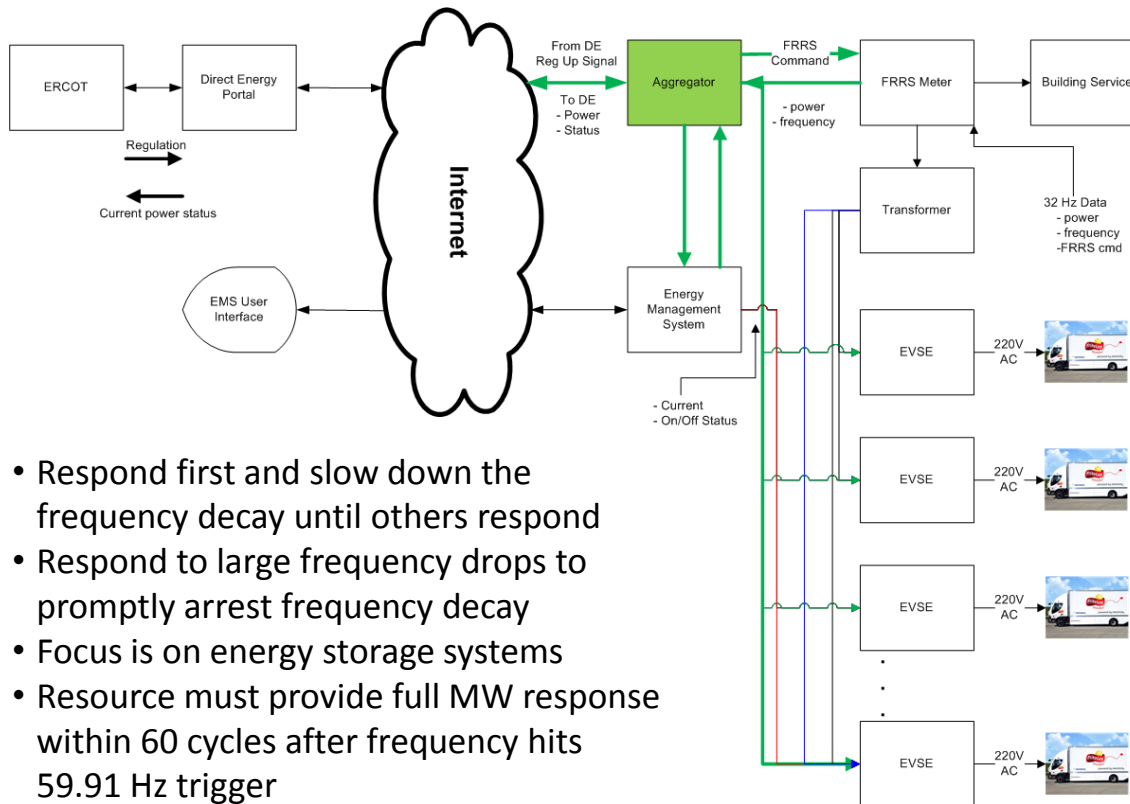
BESS



BESS Electrical Connection

Use of Advanced Applications in Wind Integration Projects

Fast Response Regulation Service (FRRS)



- Respond first and slow down the frequency decay until others respond
- Respond to large frequency drops to promptly arrest frequency decay
- Focus is on energy storage systems
- Resource must provide full MW response within 60 cycles after frequency hits 59.91 Hz trigger



Use of Advanced Applications in Wind Integration Projects

Pricing trials at Pecan Street



High efficiency
HVAC systems



Electronic Vehicle
(EV) charging



Rooftop solar for serving
as Distributed Generation
(DG) for each home



Home energy management services including
an in-home display & software applications to
help homeowners manage their electricity
more efficiently



2-way metering
capabilities to
support DG and
new-generation
demand response
programs



Wind Power Purchases
Available from AE



Extraordinary high
building envelope
efficiencies



Smart
appliances



Synchrophasor - Results and Accomplishments

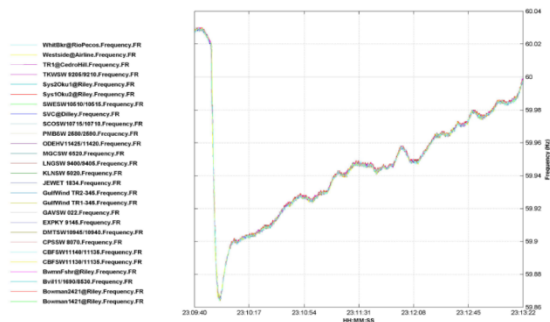
- **PMU deployments**
 - Beginning with 3 PMUs, the ERCOT grid now includes 48 PMUs at 28 locations, with plans to expand to 60 PMUs at 36 locations next year
 - In SPP, the network includes 4 PMUs with plans to upgrade to at least 8 PMUs next year
- **Innovative phasor data collection**
 - AEP is providing limited PMU data delivery via SCADA communications
 - Oncor is providing slow-scan phasor data from substation RTUs
- **ERCOT**
 - Perform event analysis – focusing on frequency analysis
 - Issue a daily performance report (PMU status, frequency, voltage, angle differences)
 - Recently installed production servers with RTDMS 2012
 - Established synchrophasor task force to engage stakeholders
- **Studies**
 - Data quality study performed to validate complete PMU data delivery
 - Baselining study to refine alarm limits – 2012 data completed; 2013 continuing
 - Generator model validation based on UT Arlington algorithms
 - Developed 15 use cases



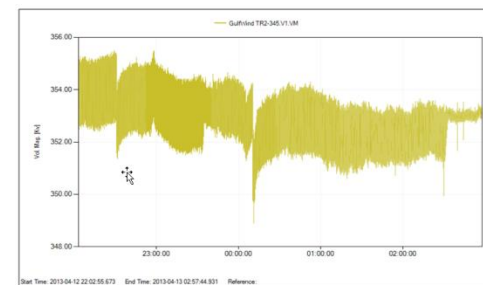
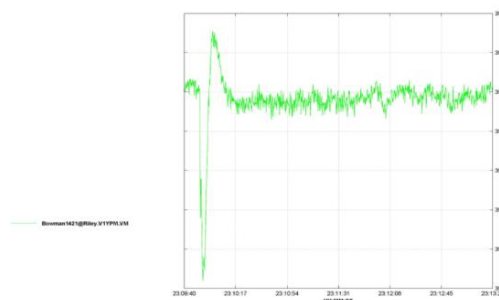
Synchrophasor - Results and Accomplishments

Post Events analysis

– Frequency analysis



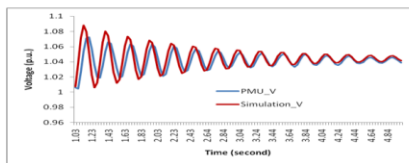
– Voltage Oscillations



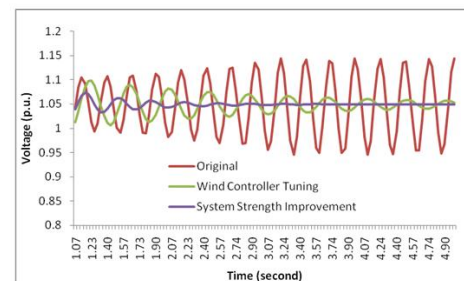
– Generator model validation/tuning

- 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



Voltage responses at WPP's POI



Synchrophasor - Results and Accomplishments

ERCOT Synchrophasor Measurements

I. Synchrophasor system with applications

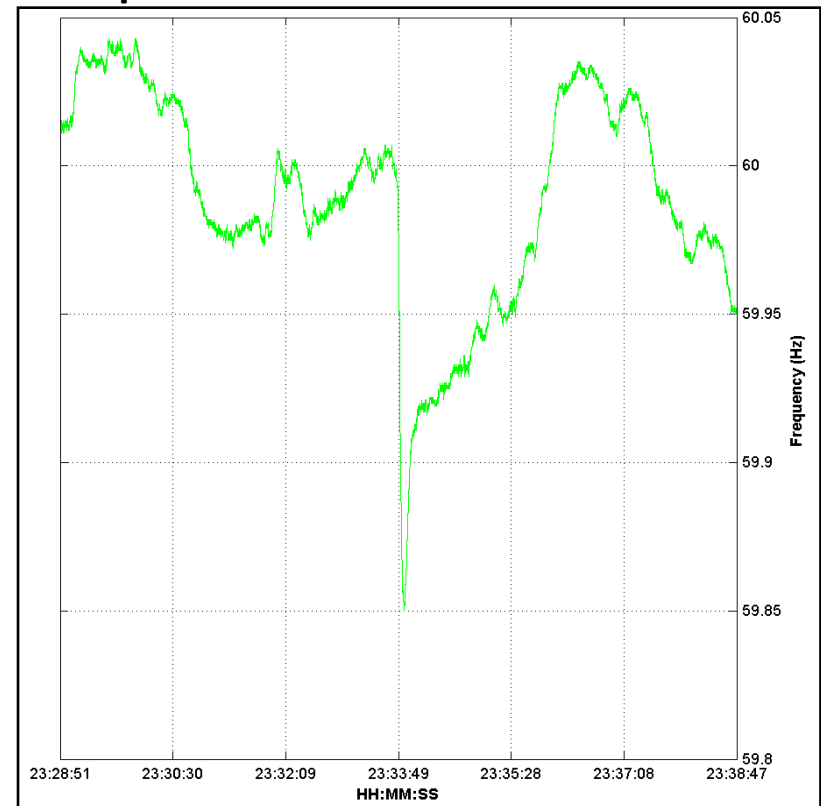
Time: 23:33 CDT

Wind Conditions: High (4835 MW)

Trigger Event: Generation Trip – 552 MW

- **Observations:**

- Frequency dips and recovers quickly
- Oscillations evident near wind generation:
 - 0.28 and 0.67 Hz oscillations are ERCOT post-event electro-mechanical grid oscillations
 - 3.2, 5.0, 5.4 and 5.5 Hz oscillations are present in both pre- and post-event voltage magnitude and angle near wind generation



ERCOT – Use of Advanced Applications

Type of Advanced Application	Use of Advanced Application					
	No plans to use	Planning to use; not yet acquired	Undergoing testing and evaluation	Completed testing and evaluation	Used in planning*	Used in operations
Post-Event Analysis:					X	
Model Validation:			X			
Wide-area Monitoring and Visualization:					X	
Oscillation Detection:					X	
Frequency Stability Monitoring:					X	
Voltage Stability Monitoring:					X	
Disturbance Detection and Alarming:					X	
Resource Integration:						
State Estimation:	X					
Transmission Pathway and Congestion Management:					X	
Islanding and Restoration:		X				
Other Applications (specify):						

* Used in Operations Planning

Security Fabric Demonstration

Align the EPG products with the seven tenets of security described in the NIST-IR 7628 by applying Security Fabric

1. Identity Management

- Ensures the device identity is authoritatively established

2. Mutual Authentication

- Allows both the Device Node and the Controller to verify the trustworthiness of their identity to each other.

3. Authorization

- Manages permission to proceed with specific operations.

4. Audit

- Records noteworthy events for later analysis

5. Confidentiality

- Encrypts sensitive data for matters of privacy.

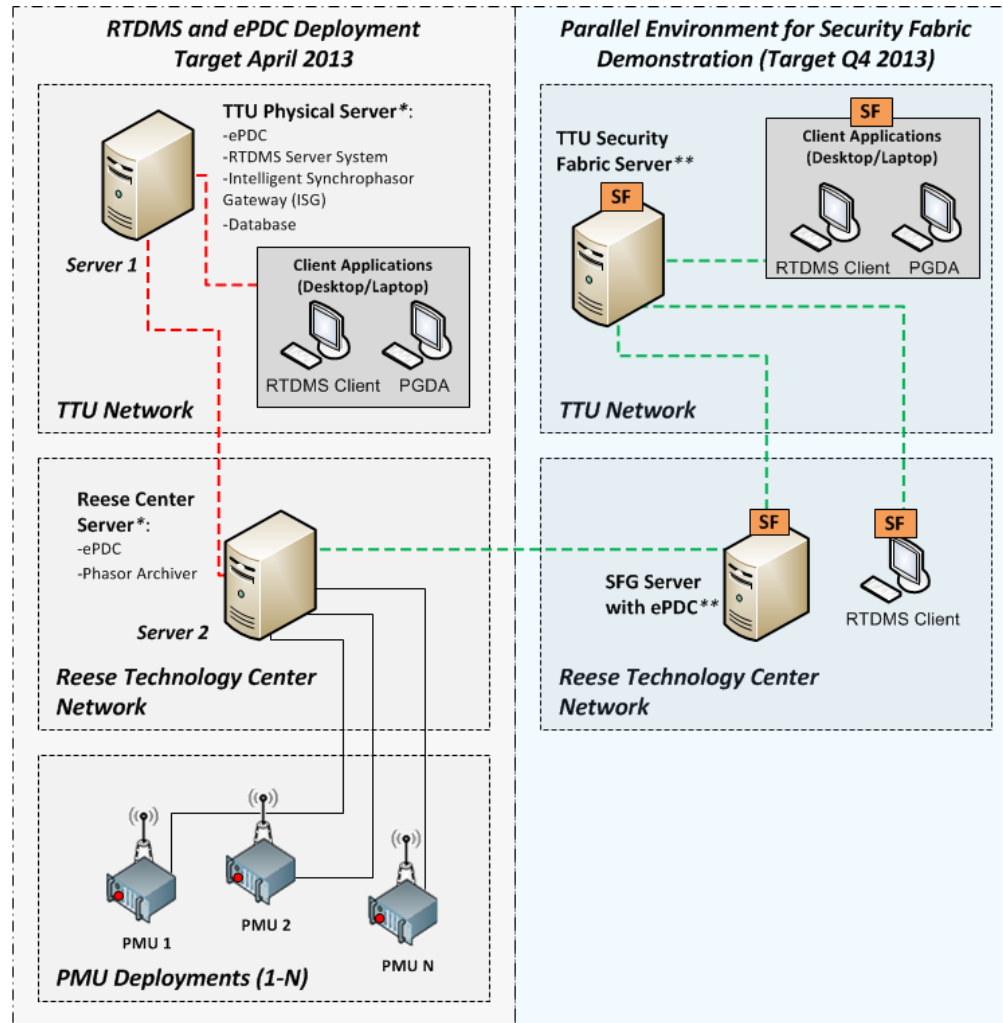
6. Integrity

- Ensures that messages have not been altered.

7. Availability

- Prevents denial of service attacks

TTU Synchrophasor Network – Security Fabric Demonstration



* Provided by TTU

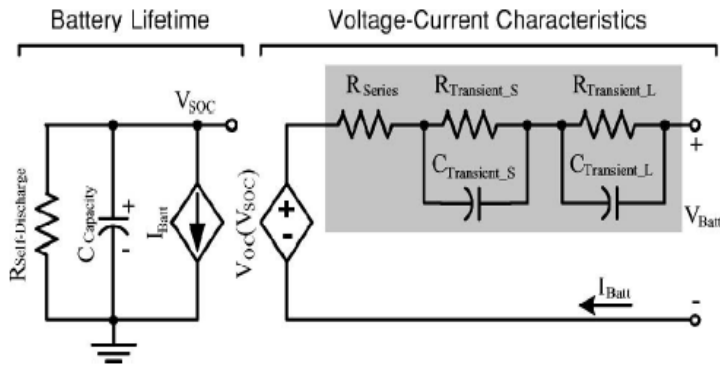
** Provided by SF Project

BESS - Results and Accomplishments

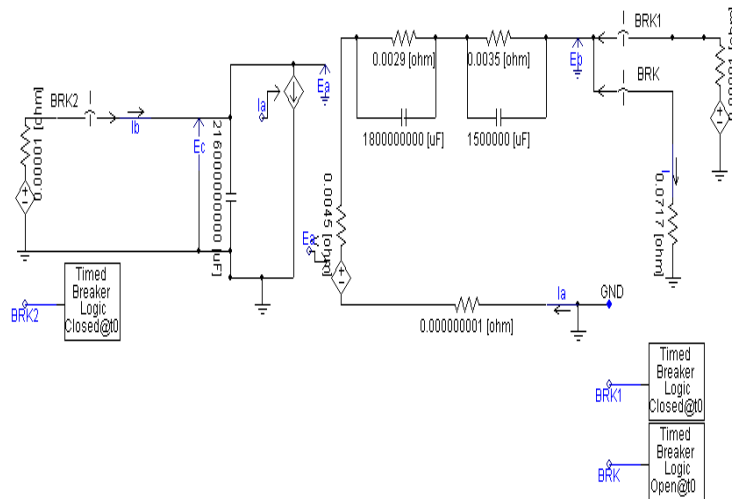
- **Procurement process**
 - Competitive RFP for BESS was released on November 5, 2012
 - After evaluating written responses, hosting orals, and conducting formal Q&A sessions, CCET awarded contract to Xtreme Power on March 14, 2013
 - BESS officially field commissioned on September 17, 2013
- **Unique Solution**
 - BESS will be powered by wind and perform functions on a distribution network
 - Ownership transferred to electric cooperative
- **Early testing verifies functionality to support:**
 - Frequency regulation
 - Voltage regulation
 - Power smoothing



Modeling & Simulation Results



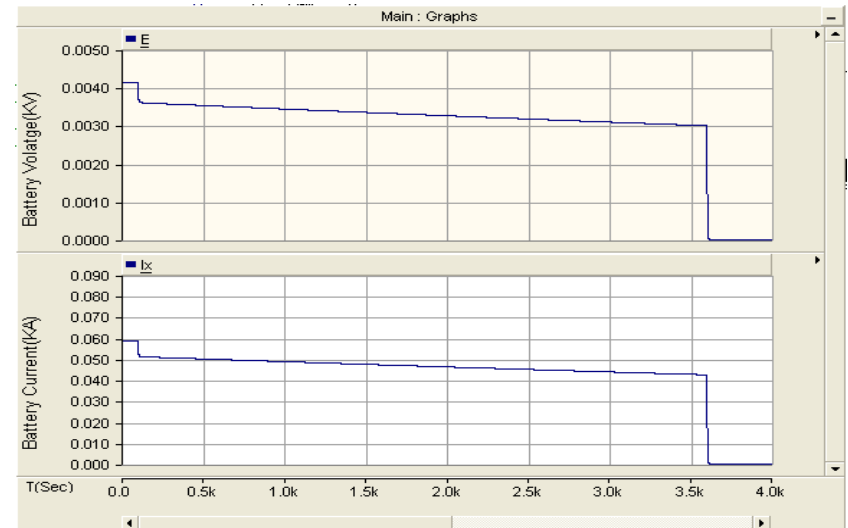
Accurate model



Battery Cell model in PSCAD

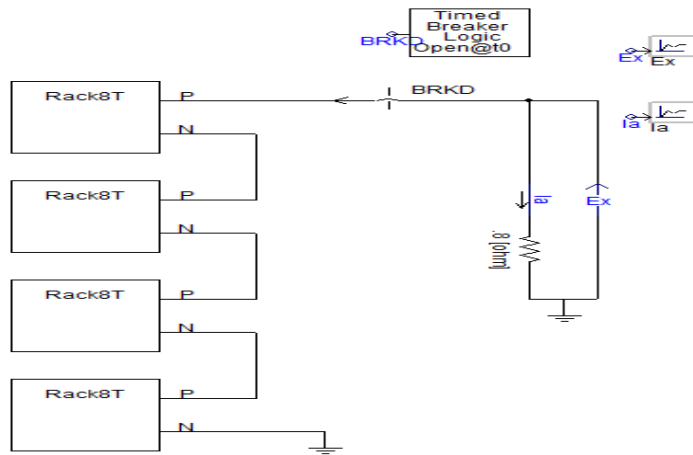
Battery Model:

- Initially a single cell of the battery system was modeled with the specified ratings of 4.12 V and 60 A using PSCAD
- The initial cell was stacked in series to form modules and trays. The 16 trays form a rack with a nominal voltage of 947.2 V. Multiple racks are operated in parallel to obtain 1200Ah of storage capacity.

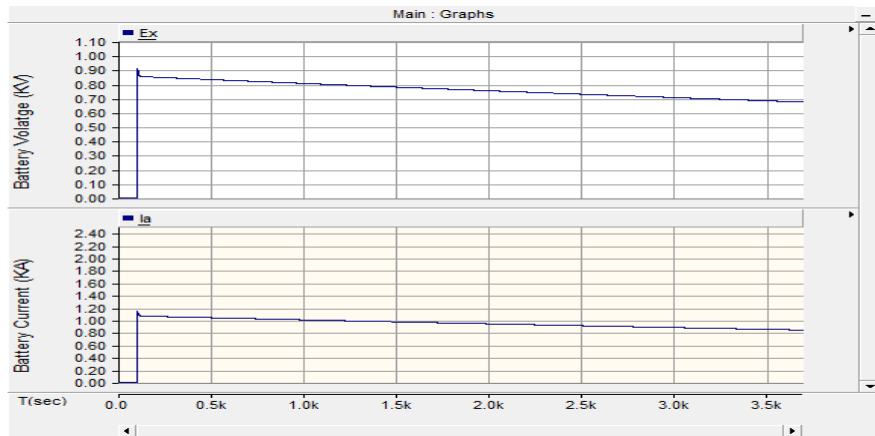


Battery cell - 4.12V, 60 Ah

Simulated Results & Economy Analysis



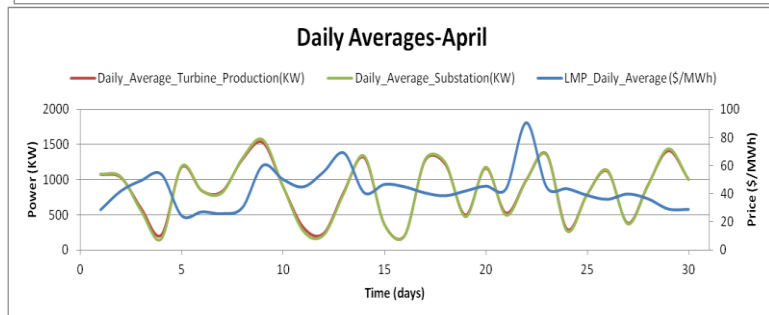
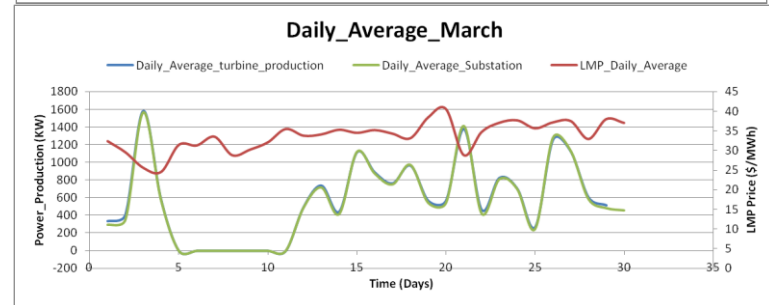
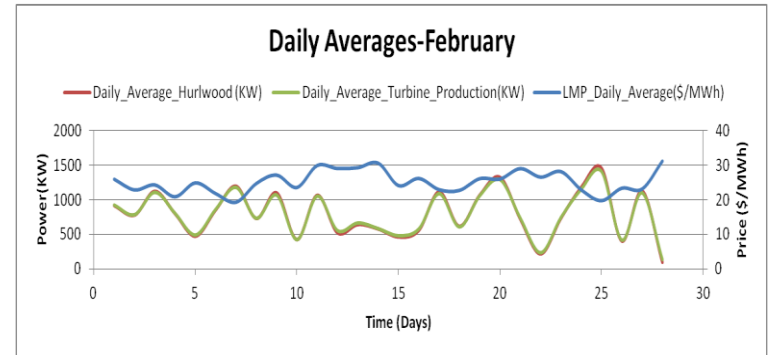
BEES - 947.2 V and 1200 Ah



BEES with 913V, 1138Ah

The completed battery model will be used to perform transient and steady state analysis simulations to understand energy flow, ramp rate and the various use cases.

Production data for the wind turbines deployed at Reese Center is being collected which, combined with daily LMP prices, be used to preform economic dispatch analysis to determine optimal battery charge / discharge schedules



FRRS – Results and Accomplishments

➤ **Pilot process**

- ERCOT defined FRRS pilot concept in November 2012
- CCET proposal to use fleet plug-in electric vehicles fully defined in February 2013
- Frito Lay agrees to participate in April 2013
- Agreements between QSE and other parties, May – September 2013
- Final approval from PepsiCo in October 2013

➤ **First phase of project** will control charging stations

- Developing software package with interfaces and aggregation software capabilities
- Preparing to install equipment

➤ **ERCOT pilot**

- Began in February 2013 – extended until end of February 2014
- Primarily supported by two large battery systems (30MW+)
- ERCOT interested in demonstrating the capability of using fleet vehicles for FRRS



Wind Incentive Pricing at Pecan Street – Results and Accomplishments

Wind Incentive Pricing in Shoulder Months and CPP in the Summer

Experiment Description & Data Collection

- Participation:
Pricing Trial Group Customer Number: 61
Control Group Customer Number: 61
- Time Range:
March – April – May – June – July – August – September



Wind Price Period

Low price is applied daily to consumption from 10pm-6am



Summer (Subject to Critical Peak Price)

High Price is applied during 4pm-7pm window on “critical peak” days called day-ahead





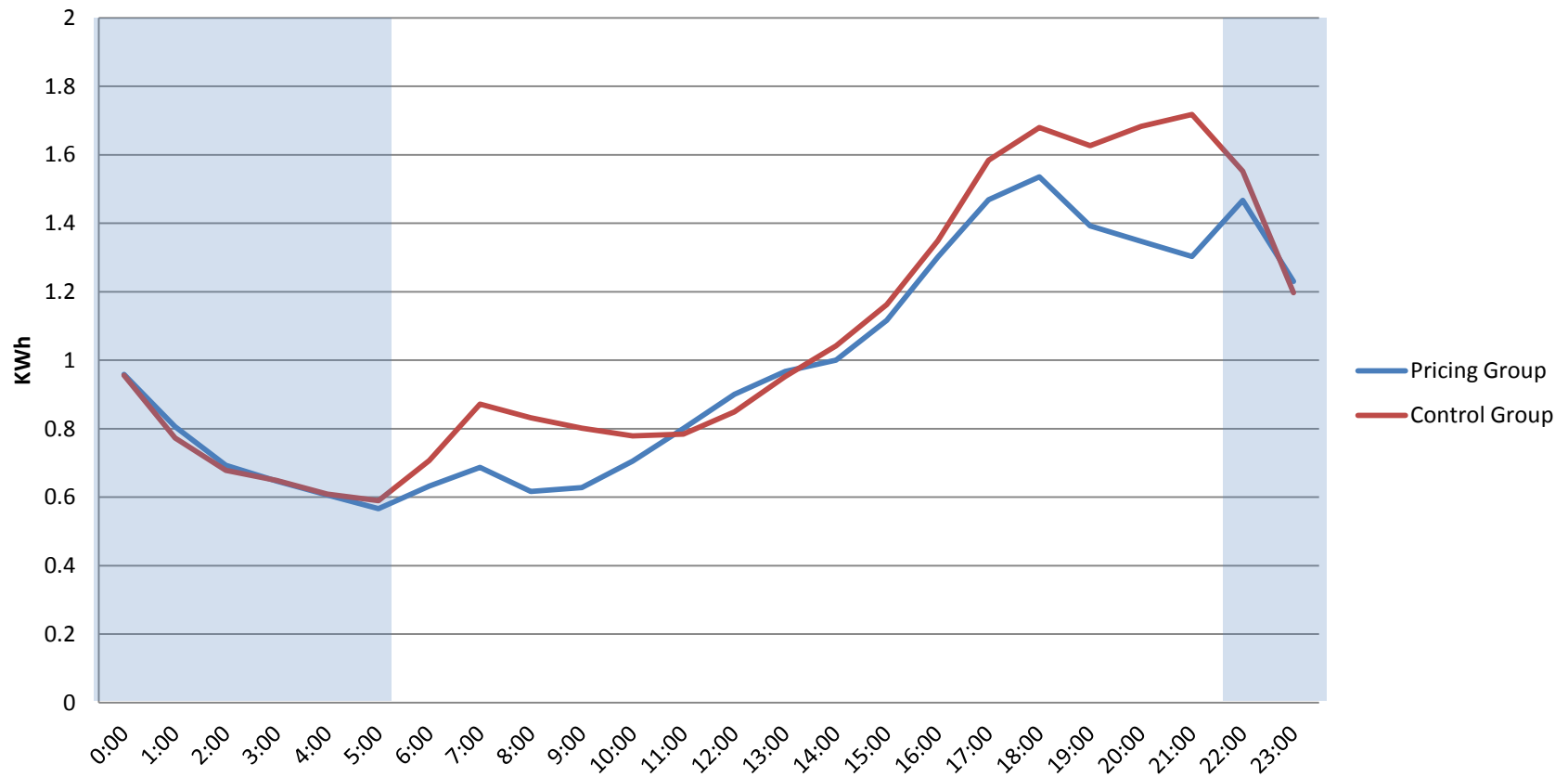
Summary of Wind Price Months Analysis

- The pricing trial group consumes more electricity during the “wind pricing periods” (overnight, 10pm-6am every day from March to May) than the control group. *Note: review of subsequent (summer) months indicates that the pricing trial group does not shift load to overnight during the “non-wind” months.*
- Much of the shifting during “wind” months is from electric vehicle charging. Pricing trial group members are charging their electric cars primarily overnight. The control group has a small number of electric vehicles, so confidence in the usage pattern is low.
- Low overnight wind enhancement pricing has little effect on kitchen usage by pricing trial group.
- There is a slight shift towards late night laundry use (after 10pm) by the pricing trial group.



Average Daily Pattern – Overall Usage - May

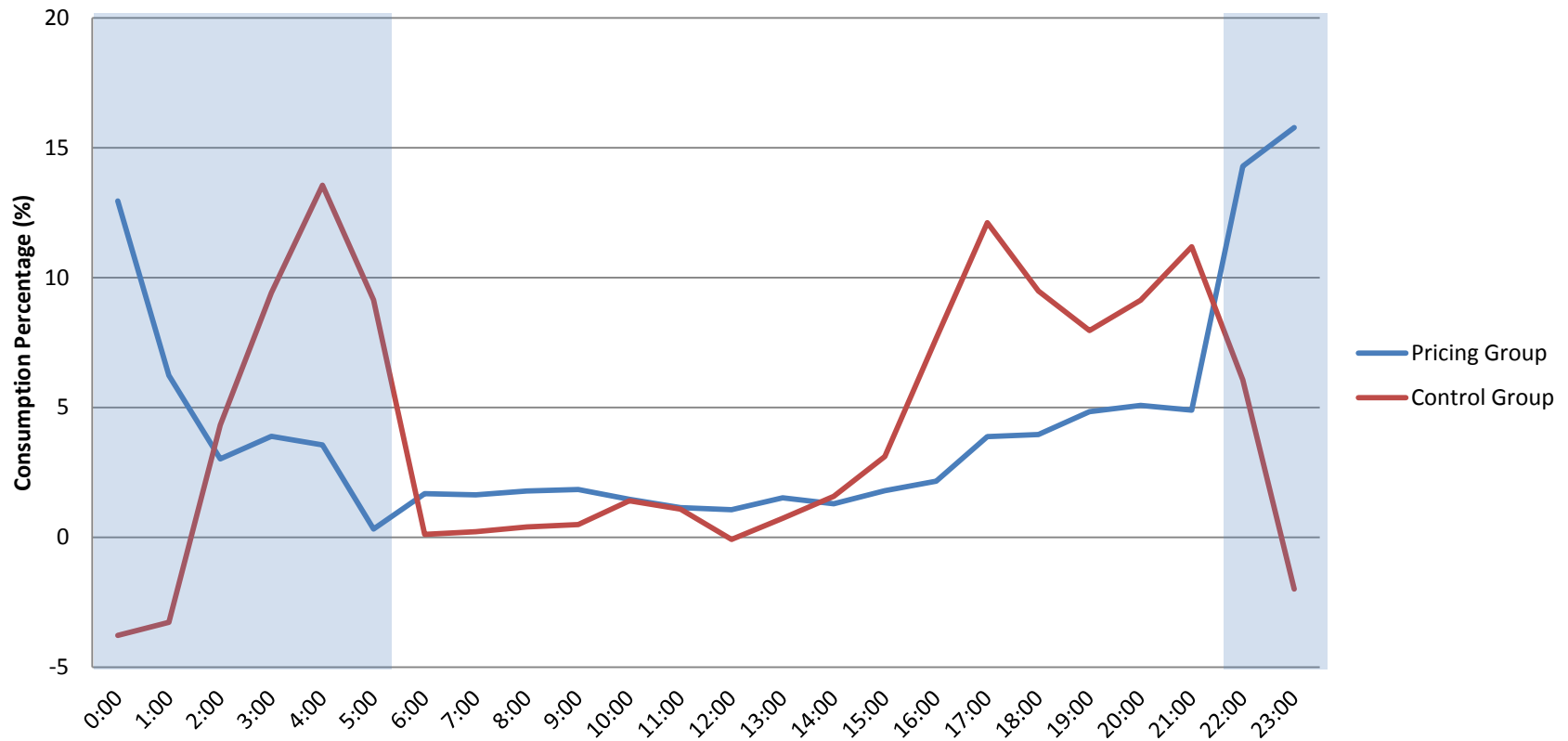
Average Daily Use Pattern - May





Average Daily Pattern – Electric Car (%) March to May

Average Daily Consumption (%) - Electric Car



Much of the shifting is in EV charging. Pricing Trial Group members are charging their EVs primarily at night. The control group has a small number of EVs, so confidence in the usage pattern is low.

Discovery Across Texas: Technology Solutions for Wind Integration in ERCOT

This material is based upon work supported by the Department of Energy under Award Number DE-OE0000193."

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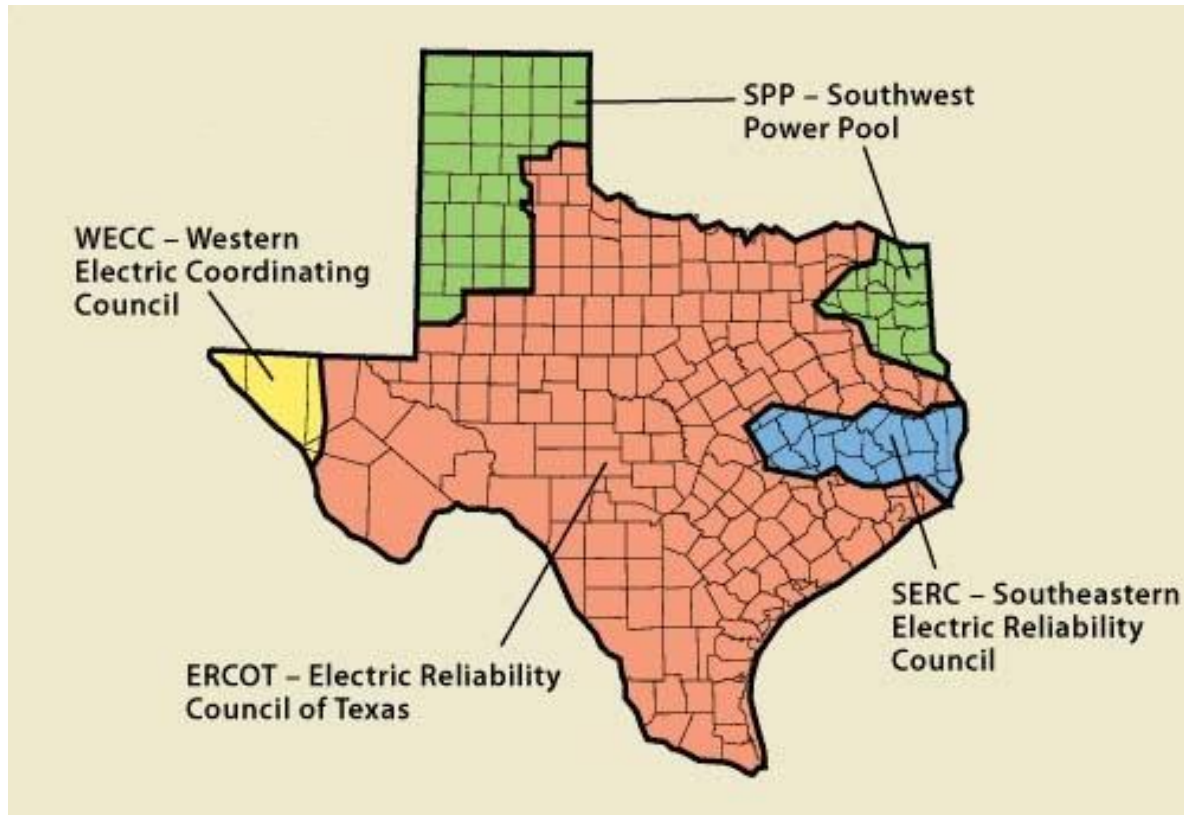
Discovery Across Texas

Questions?



Texas – One Interconnect and One ISO

Project Participants - ERCOT and SPP Regions





Pricing Experiment Summary

- Experiment Description & Data Collection
- Wind Price Months Analysis (March – May)
 - Whole House
 - Electric Car
 - Kitchen Appliances
 - Laundry
- Summer Months Analysis (June – September)
 - Whole House
 - Electric Car
 - Kitchen Appliances
 - Laundry
- 12 Critical Peak Days Analysis – kW Savings Estimate