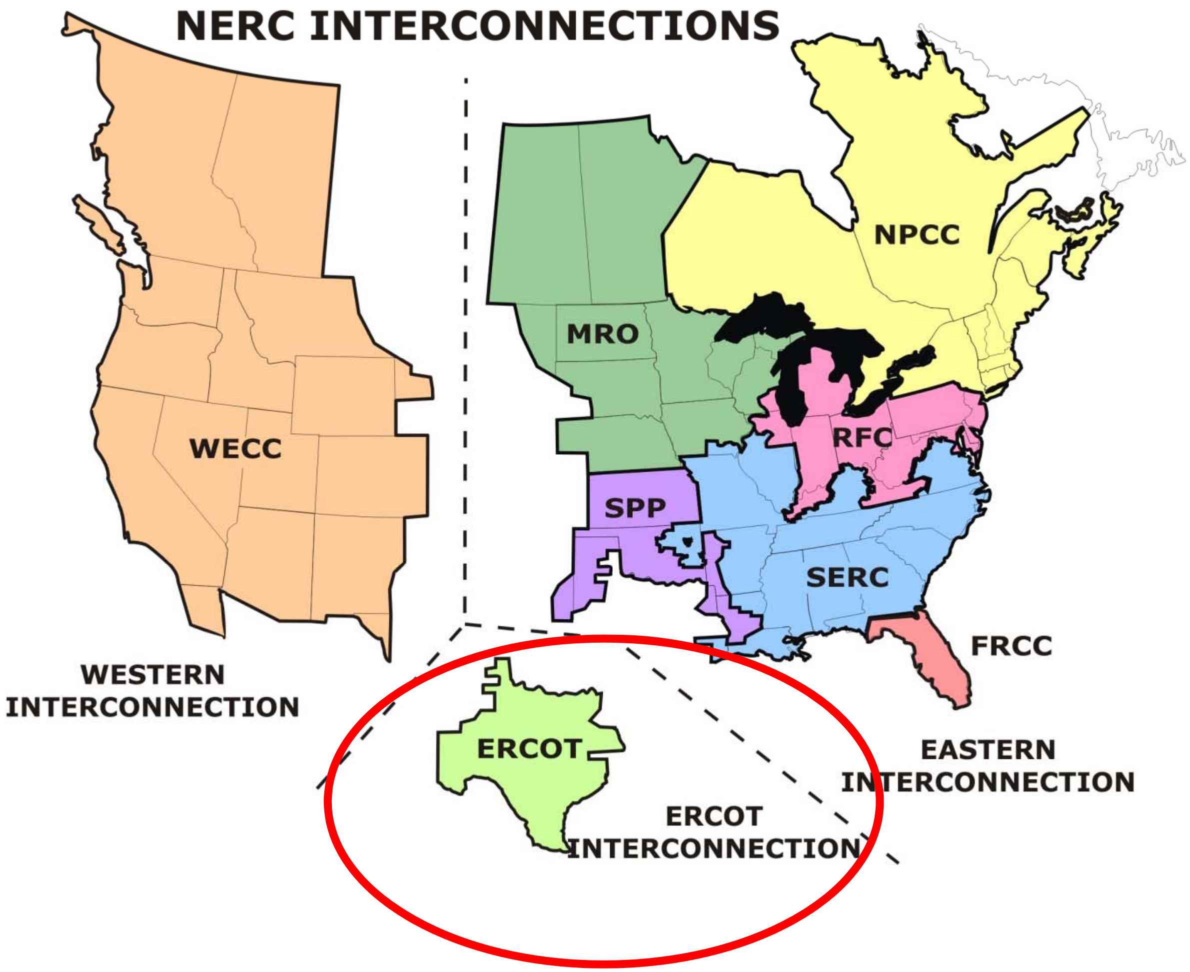
Overcoming Barriers to Smart Grids & New Energy Services

UT Smart Grid Conference
April 7th, 2011

Trip Doggett
President & CEO
Electric Reliability Council of Texas

North American Interconnected Grids



ERCOT connections to other grids are limited to direct current (DC) ties, which allow control over flow of electricity

- **The ERCOT Region is one of 3 North American grid interconnections**
- **The ERCOT grid:**
  - Covers 75% of Texas land
  - Serves 85% of Texas load
  - >40,000 miles of transmission lines
  - >550 generation units
  - Physical assets are owned by transmission providers and generators, including municipal utilities and cooperatives

We're using more energy than ever before

Winter peak demand

- **New record – 57,282 MW (February 10, 2011)**
- **Beats previous 2007 record by ~ 8,300 MW**

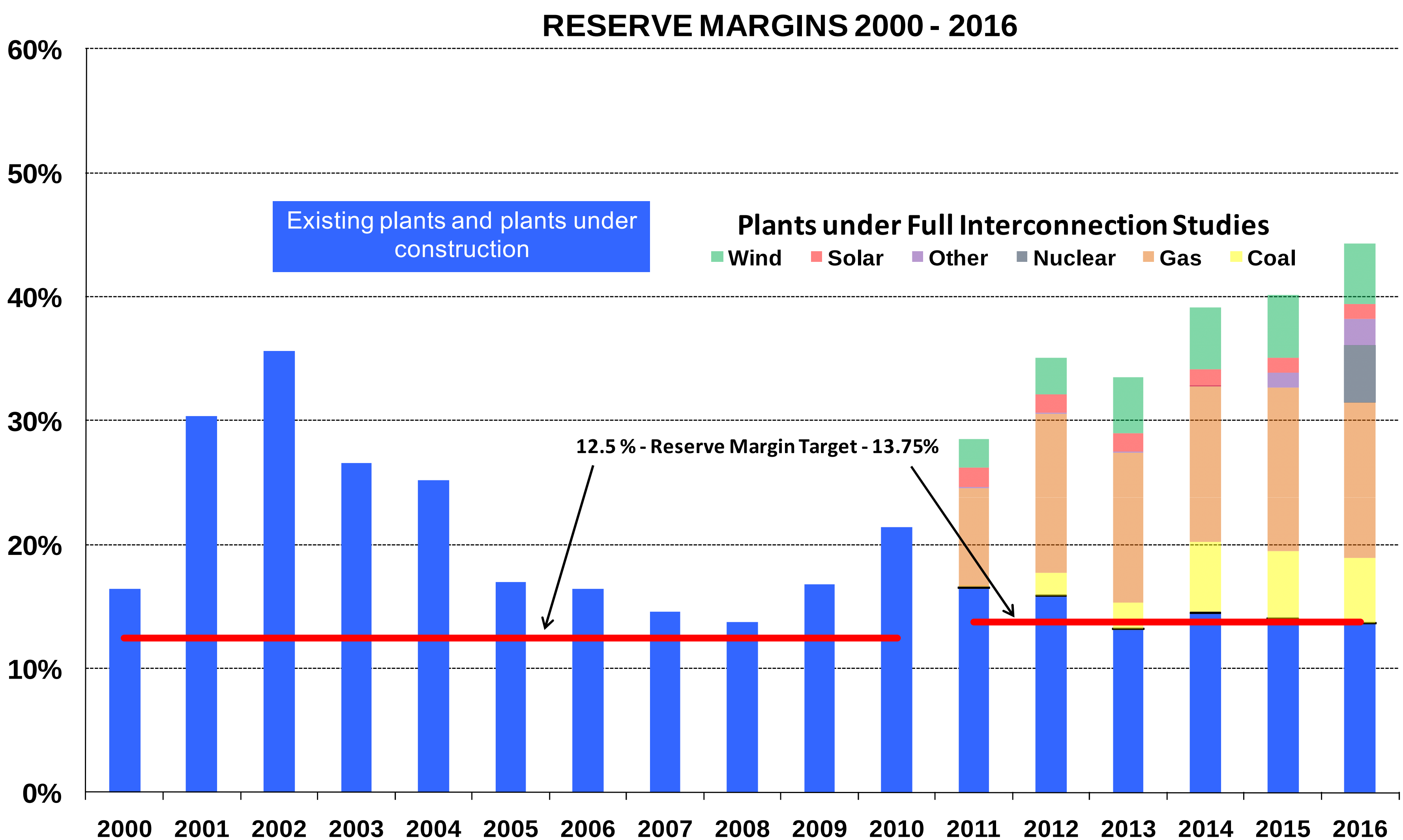
Summer peak demand

- **New record – 65,776 MW (August 23, 2010)**
- **Beats previous 2009 record by ~2,300 MW**

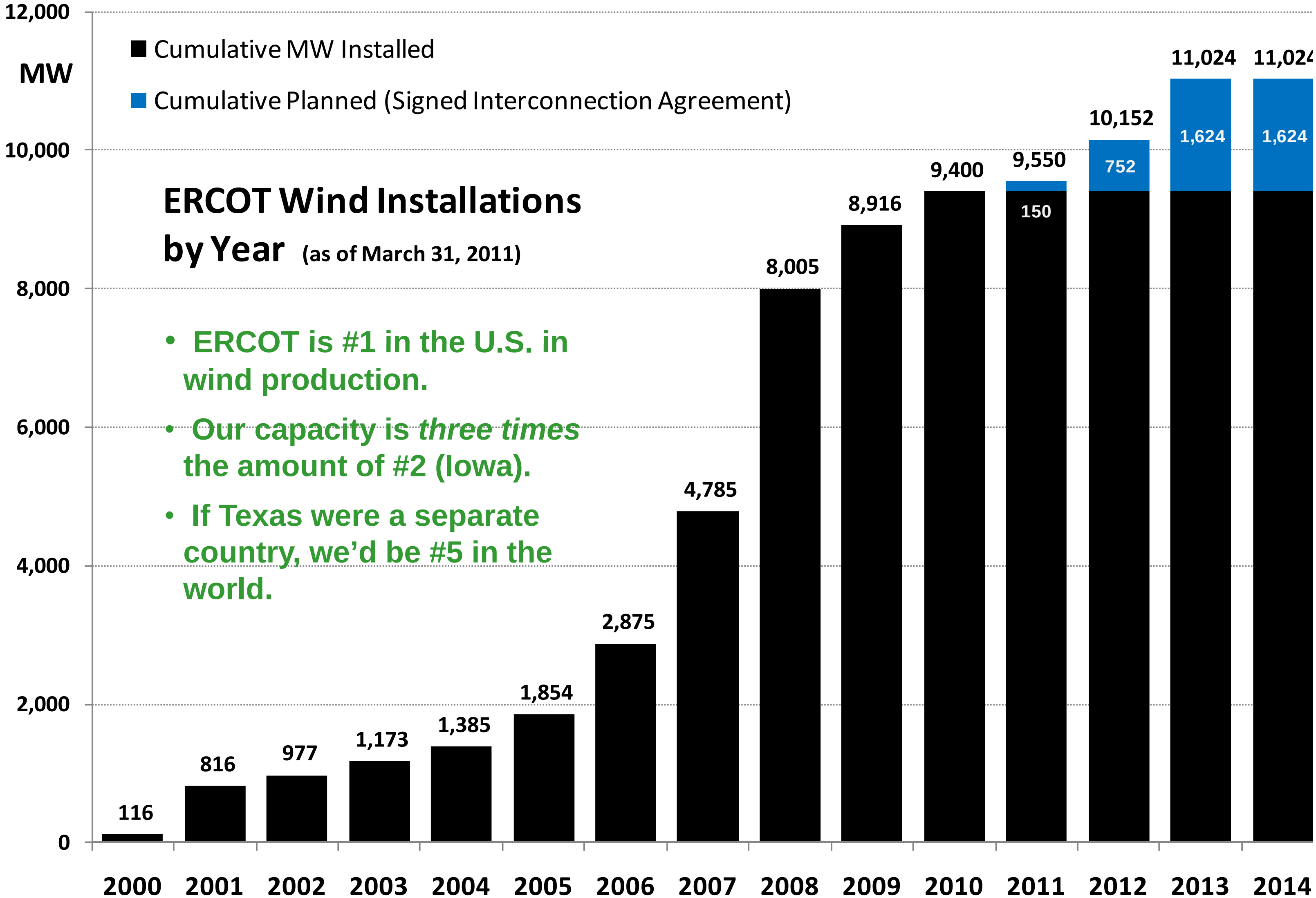
Wind output record

- **New record – 7,227 MW (December 10, 2010)**
- **Beats previous 2009 record by ~1,000 MW**

ERCOT expects adequate reserves up to 2013



We’re excelling at integrating variable resources

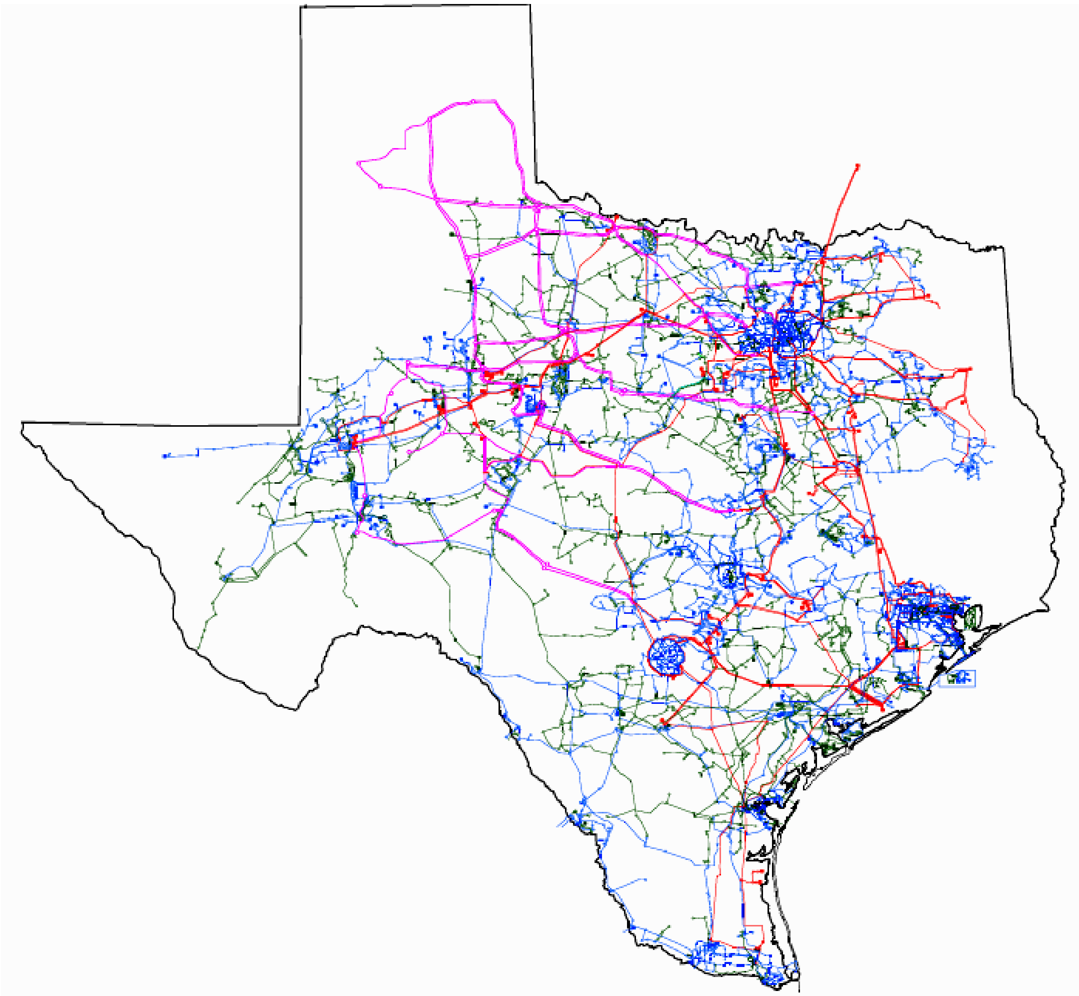


- ERCOT is #1 in the U.S. in wind production.
- Our capacity is *three times* the amount of #2 (Iowa).
- If Texas were a separate country, we’d be #5 in the world.

Source: Registration data provided by resource owners.

Our market is building transmission faster than any other

40,530 Miles of Transmission Lines in ERCOT



9,249 miles of 345 kV

19,565 miles of 138 kV

>8,000 circuit miles of transmission built since 1999

~8,000 circuit miles of transmission under study

$6 billion investment in transmission placed in service since 1999

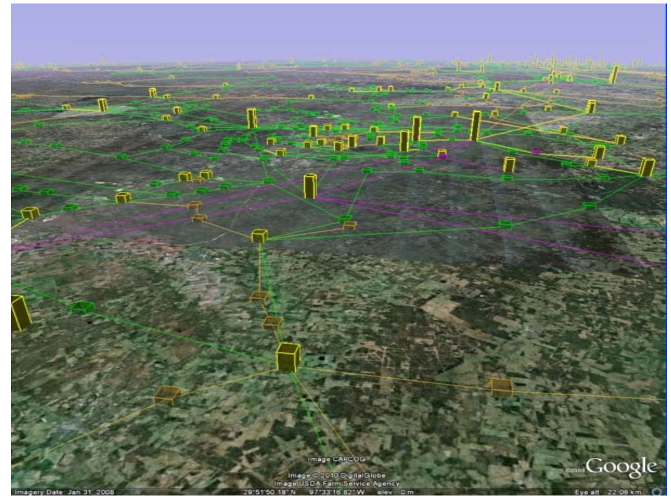
$9 billion under development (including CREZ transmission)

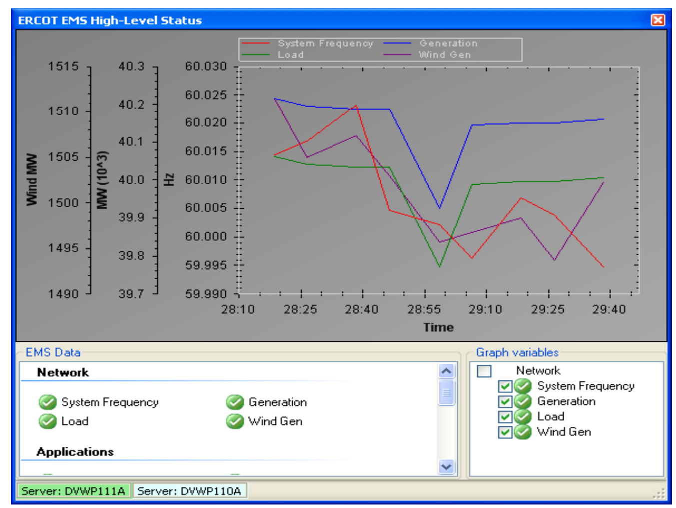
Smart grid at the bulk power level: ‘Macomber Map’

- **ERCOT identified the need for situation awareness and improved user experience in control rooms**
- **Main issues:**
  - Need for wide-area and high-level views
  - “Alarm storm”
  - “Dust storm”
  - Locations of equipment
  - Navigation between one-lines
  - Naming conventions for equipment
  - Data integration across multiple systems
  - Increased cognitive load as operators increasingly managing more tasks with more complex systems.
    - This trend is only continuing (e.g., AMI)

The ‘Macomber Map’

- **Visualization tool used by ERCOT operators for situational awareness**
- **Allows operators to see all data for single element (e.g., a generator), across applications and systems**
- **Used for many ERCOT applications:**
  - Control room
  - Network modeling group
  - Congestion Revenue Rights
  - Market Information System (contour map of LMPs and SPPs)
  - Training
  - Engineering
- **Developed in-house; named for one of the developers who passed away in 2008**



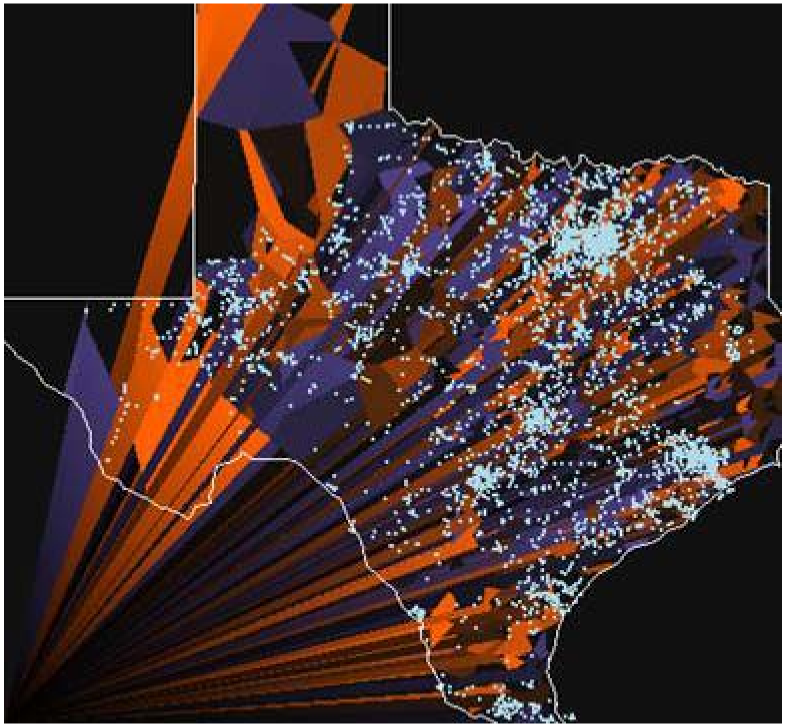


Macomber Map

- **Core functionality:**
  - Integrates numerous data sources in the control room -- network model, real-time and study energy data, market data -- across applications and systems.
  - “Google” approach to the transmission grid allows operators to locate elements by a series of keywords (e.g., name, county, voltage, owner)
  - Links all transmission elements to a point on the map, to prevent alarm and dust storms
  - Pyramid approach allows operators to drill down quickly from high-level to detailed data rapidly: “forest and trees”
  - Consistent positional awareness, regardless of detail level Linking equipment with ownership and operatorship information for rapid response.
  - When possible, linking problems with potential solutions.
  - Allows operators to aggregate data within regions (e.g., Hurricane Dolly)

Macomber Map ongoing enhancements

- **Integration with additional systems and data (e.g., TruWind)**
- **Using MM as a test platform for research, determining optimum color patterns, etc.**
- **Increased utility in viewing historical data**
- **Additional weather data**

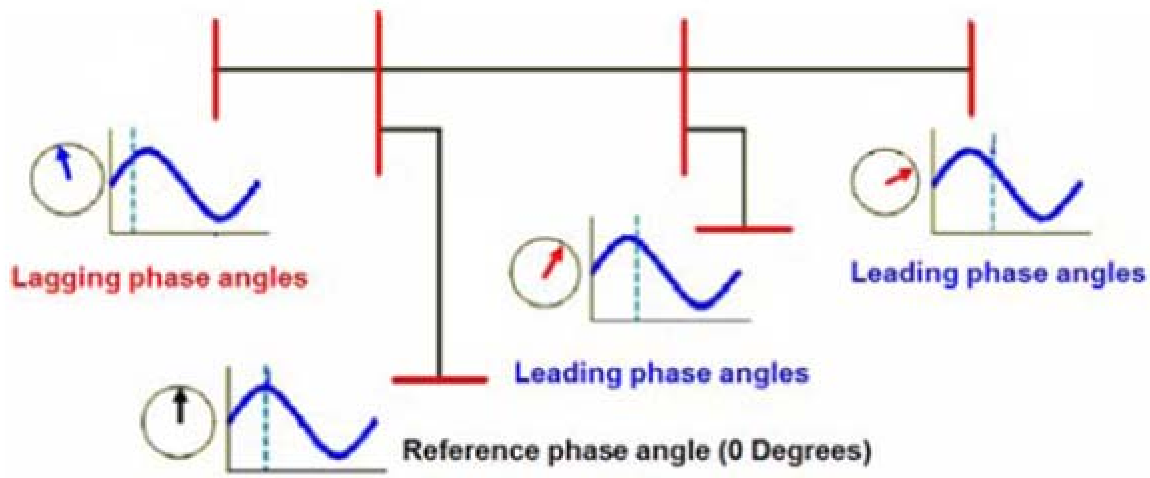


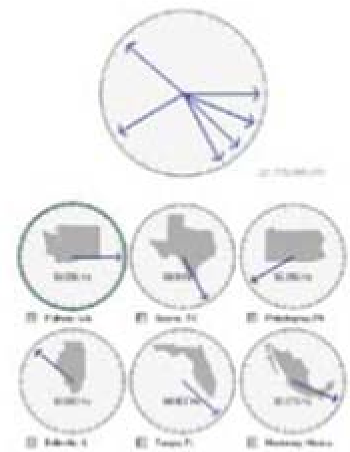
Smart grid at the bulk power level: Synchrophasors

- **Joint project of ERCOT, Transmission Owners (AEP, Oncor, Sharyland) and the Center for the Commercialization of Electric Technologies (CCET)**
- **Initiated in Fall 2008 with 3 AEP PMUs**
- **Currently 14 Phasor Measurement Units (PMUs) installed at 12 TO locations**
  - Real-Time Dynamic Monitoring System (RTDMS) at ERCOT
- **Expanding to 23 PMUs, provide TOs access to RTDMS visualization applications**
- **GOALS:**
  - Provide real-time dynamic information
  - Identify precursor conditions to undesirable grid performance and behavior
  - Identify changes in operating procedures or actions to facilitate integration of phasor measurements, hence improving grid reliability
  - Recalibrate dynamic models

What the Phasors Do

- **Phasor measurement technology offers a means of capturing wide-area snapshots of phase angle profiles and comparing them.**

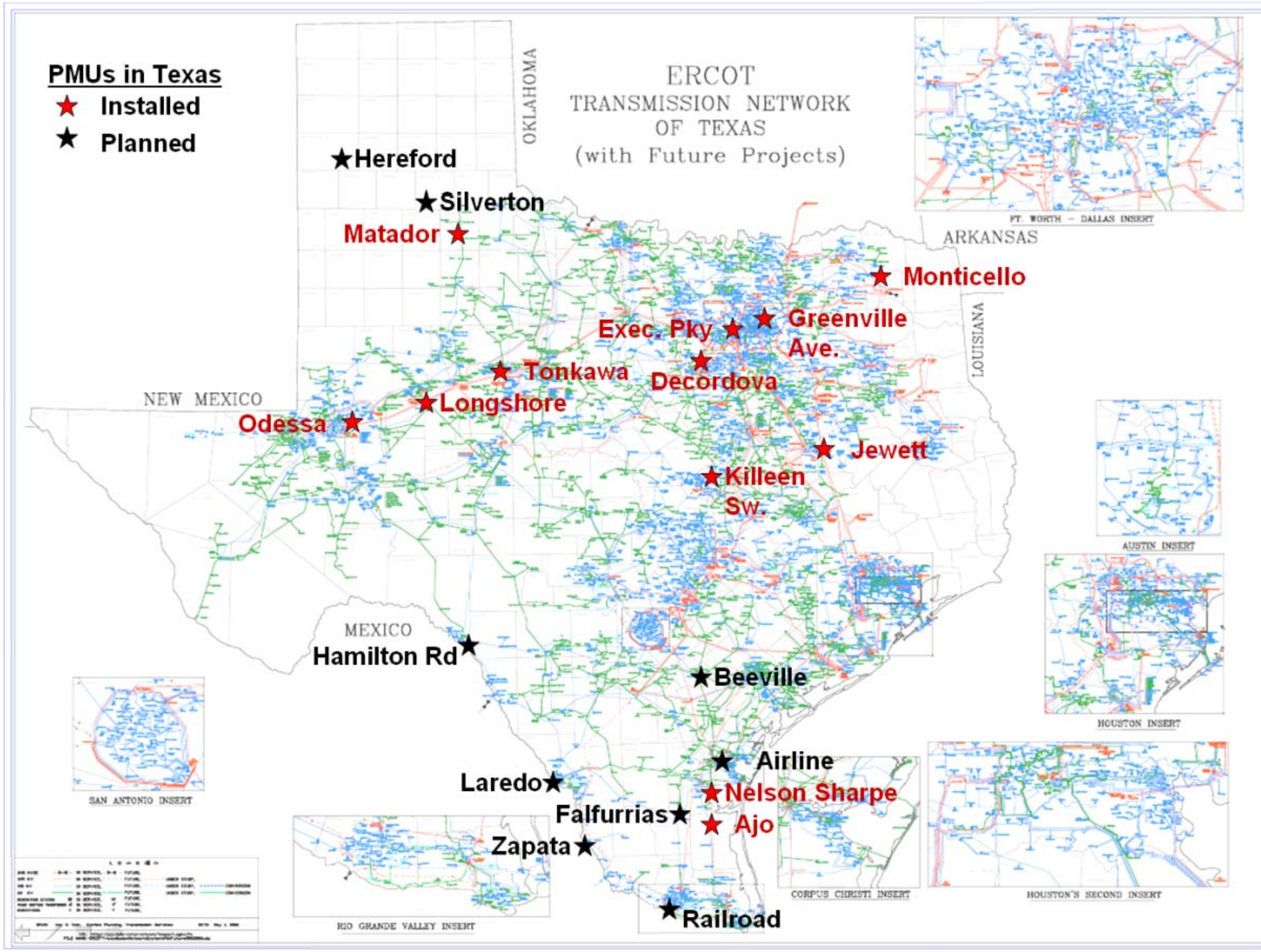




Definition: *A **leading** waveform is one that is **ahead** of a reference.*
*A **lagging** waveform is one that is **behind** a reference.*

The **phase angle difference** between two waveforms of the same frequency are good indicators of **grid stress.**

ERCOT Phasor Locations

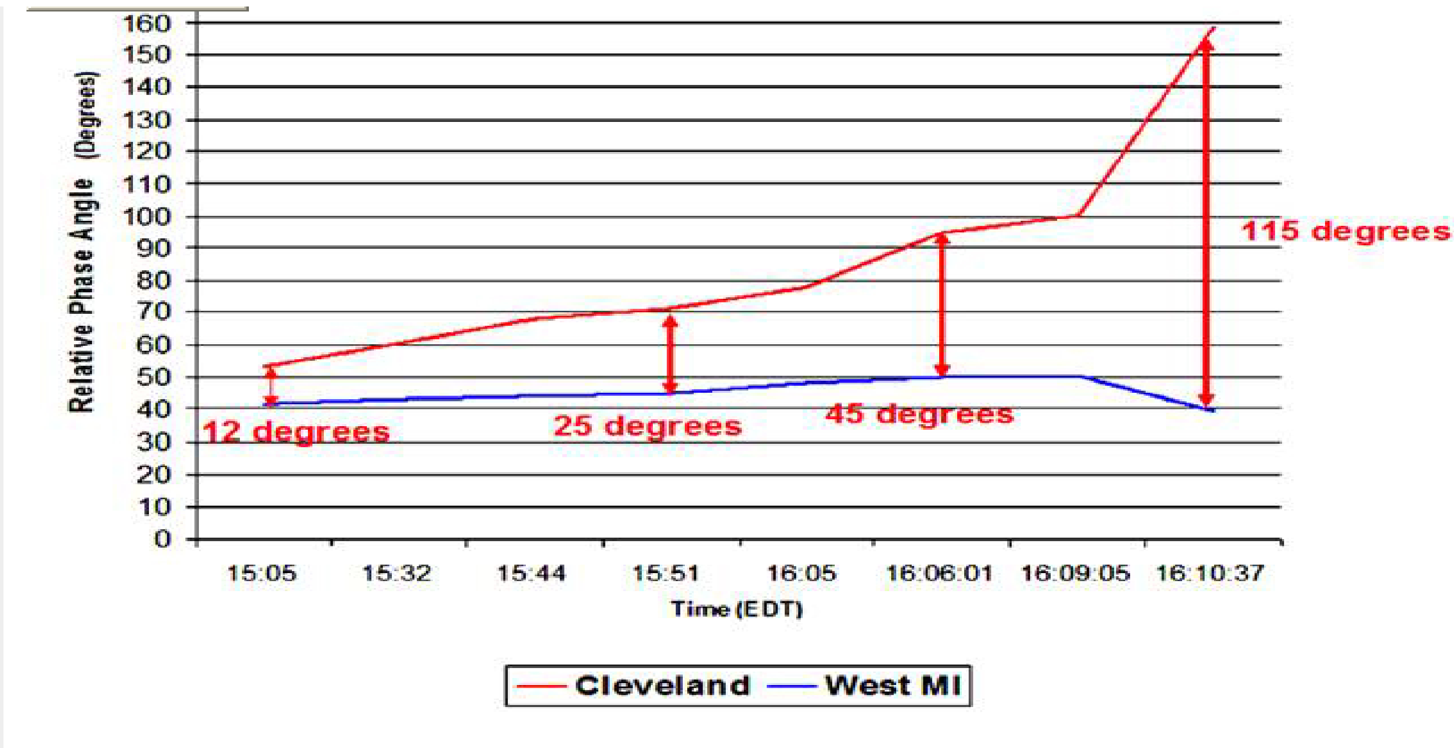


Benefits of Phasor Measurements

- **Direct measurement phasor angles**
  - In EMS, phasor (voltage or current) angles only can be calculated by State Estimator, which runs every 5 mins
  - PMUs continuously measure voltage/current angles with high sampling rate (≥ 30 samples/s)
- **High sampling rate**
  - Conventional SCADA measurements update in seconds
  - PMUs typically take 30 observations per second
- **Voltage phasor angle difference can be used as a good indicator of grid stress**

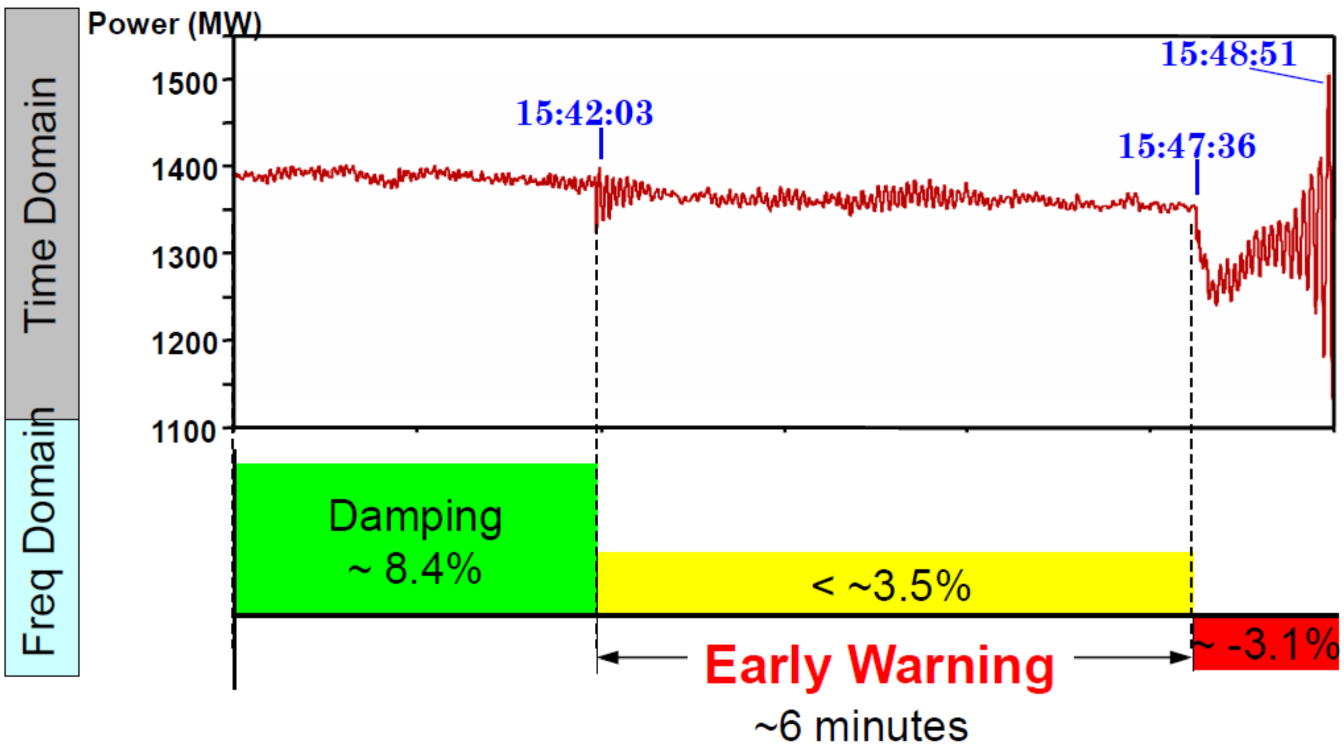
Phasor Measurements = Situational Awareness

Angular Separation during Northeast Blackout in 2003 (Normal Angle ~ 25°)

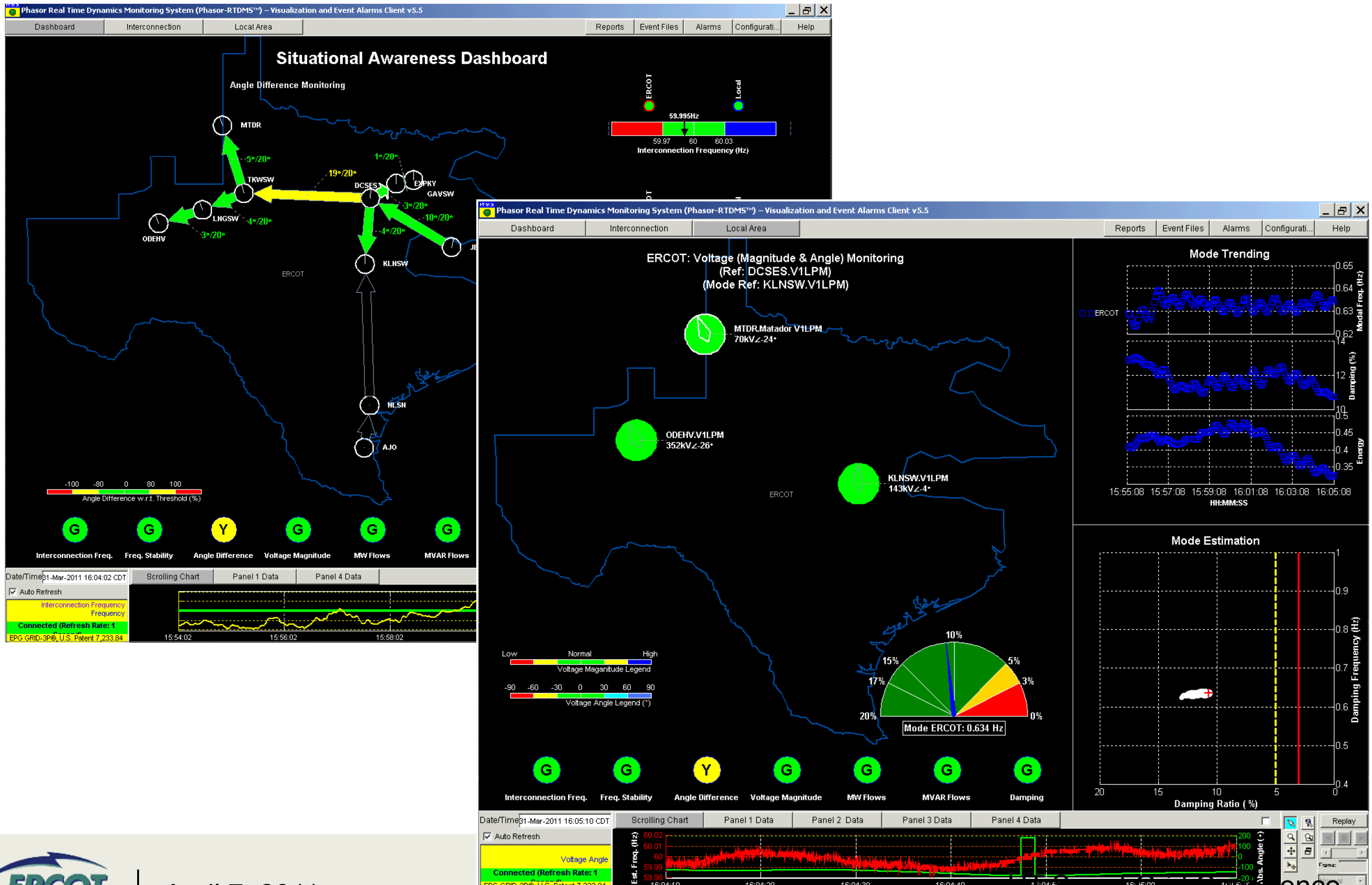


- **Frequency and angle data in high sampling rate can be used in real-time or off-line study to detect system oscillation and identify the instability by monitoring the damping ratio**

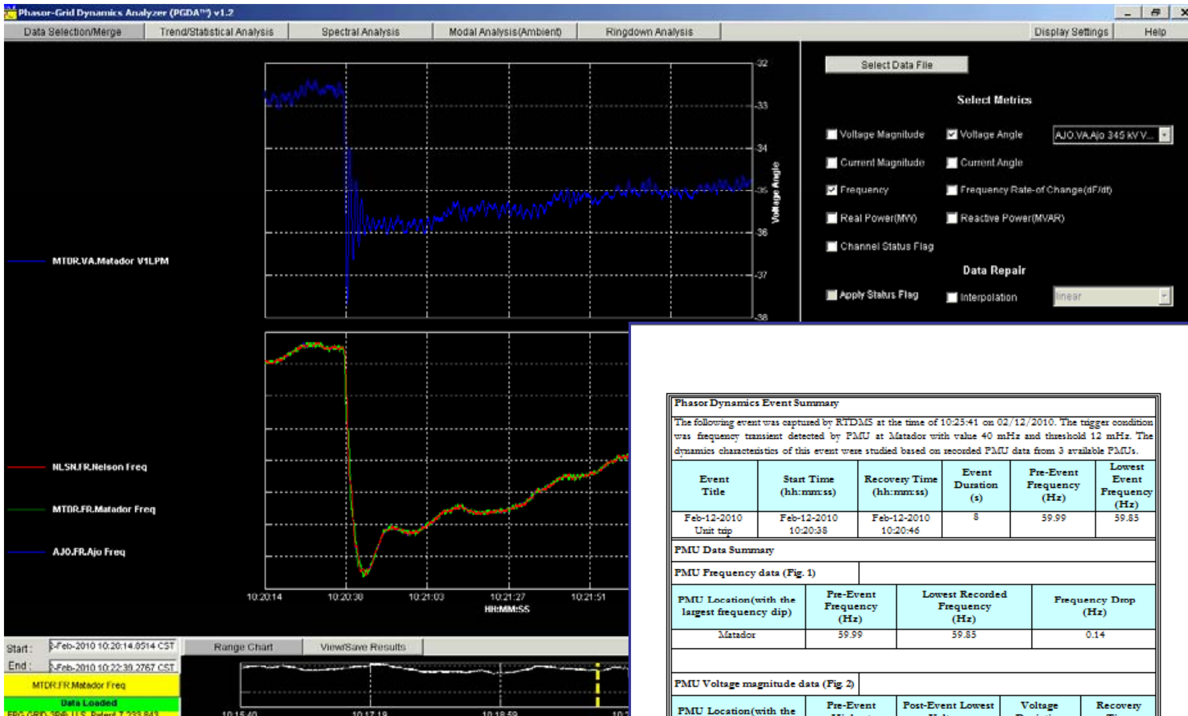
California–Oregon Interface Oscillation during Western Power System Breakup (August 10, 1996)



Real-time Phasor Application



Off-line Event Study



Phasor Dynamics Event Summary					
The following event was captured by RTDMS at the time of 10:25:41 on 02/12/2010. The trigger condition was frequency transient detected by PMU at Matador with value 40 mHz and threshold 12 mHz. The dynamics characteristics of this event were studied based on recorded PMU data from 3 available PMUs.					
Event Title	Start Time (hh:mm:ss)	Recovery Time (hh:mm:ss)	Event Duration (s)	Pre-Event Frequency (Hz)	Lowest Event Frequency (Hz)
Feb-12-2010 Unit trip	Feb-12-2010 10:20:38	Feb-12-2010 10:20:46	8	59.99	59.85

PMU Data Summary

PMU Frequency data (Fig. 1)

PMU Location(with the largest frequency dip)	Pre-Event Frequency (Hz)	Lowest Recorded Frequency (Hz)	Frequency Drop (Hz)
Matador	59.99	59.85	0.14

PMU Voltage magnitude data (Fig. 2)

PMU Location(with the largest voltage dip)	Pre-Event Highest Voltage (pu)	Post-Event Lowest Voltage (pu)	Voltage Deviation (pu)	Recovery Time (s)
Nelson Sharpe	1.039	1.035	0.004	5

PMU Voltage angle data (Fig. 3) | **Reference Bus** | Ajo

PMU Location(with the largest Angular Swing)	Pre-Event Angle (degree)	Post-Event Angle (degree)	Angle Deviation (degree)	Largest Swing (degree)	Dynamic Swing Time (s)
Matador	-32.5	-36	3.5	3.5	6

Oscillation-Mode Analysis Results

Dominant Modal Frequency (Hz)	Damping Rate (%)	Mode Shape Description
0.58	9.6	Identified by both frequency and angle data analysis. Matador oscillated against Nelson and Ajo.

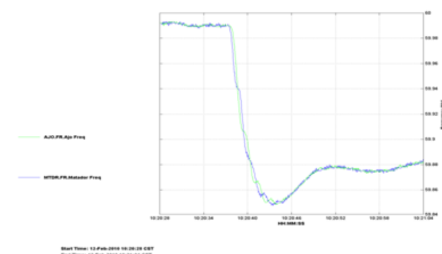


Fig. 1 The frequency captured by the PMUs located at station MATADOR and AJO.

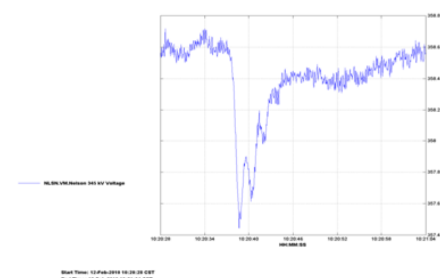
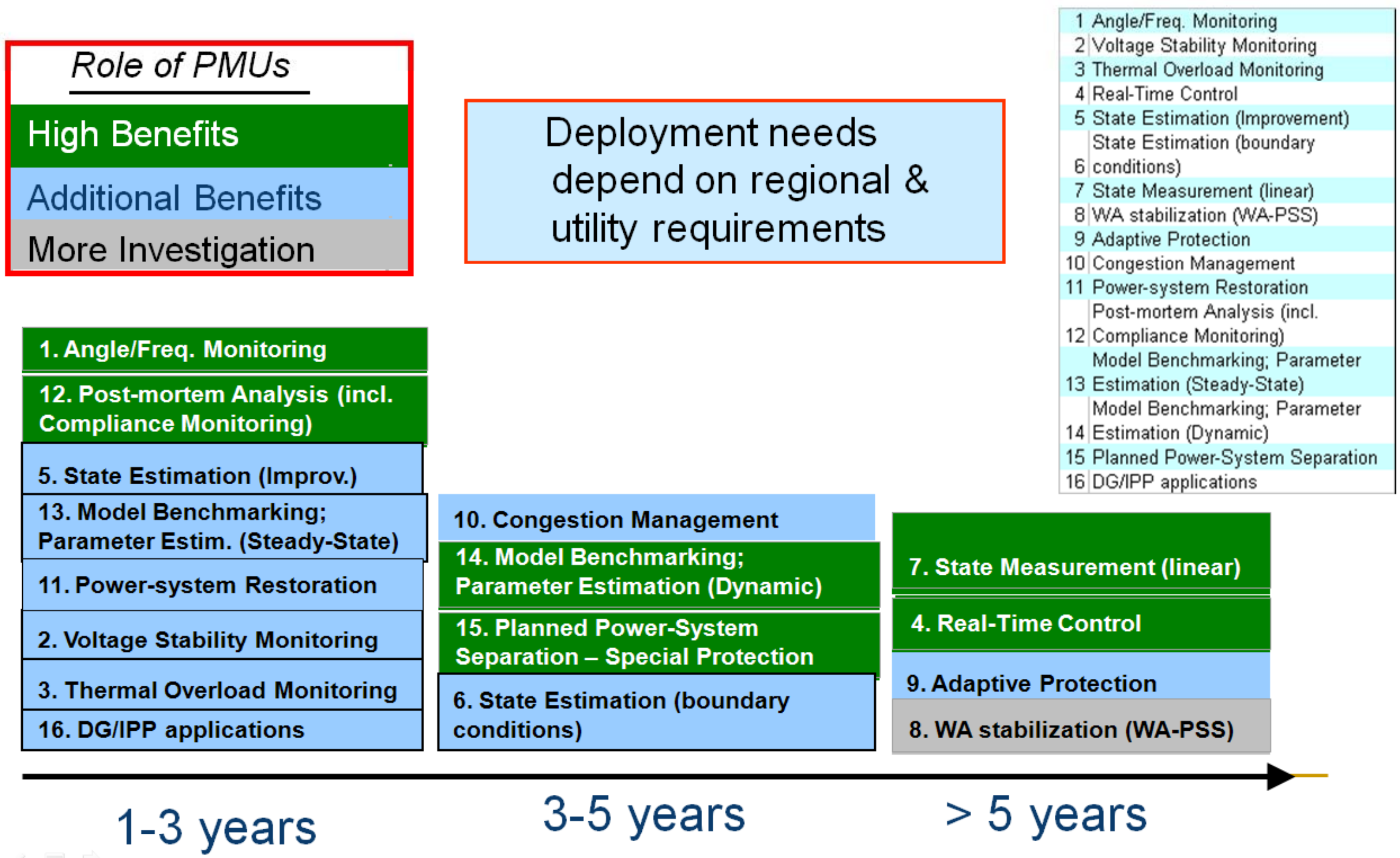


Fig. 2 The voltage magnitude measured at the station NELSON SHARPE.

- All possible PMU applications and their positions in industrial

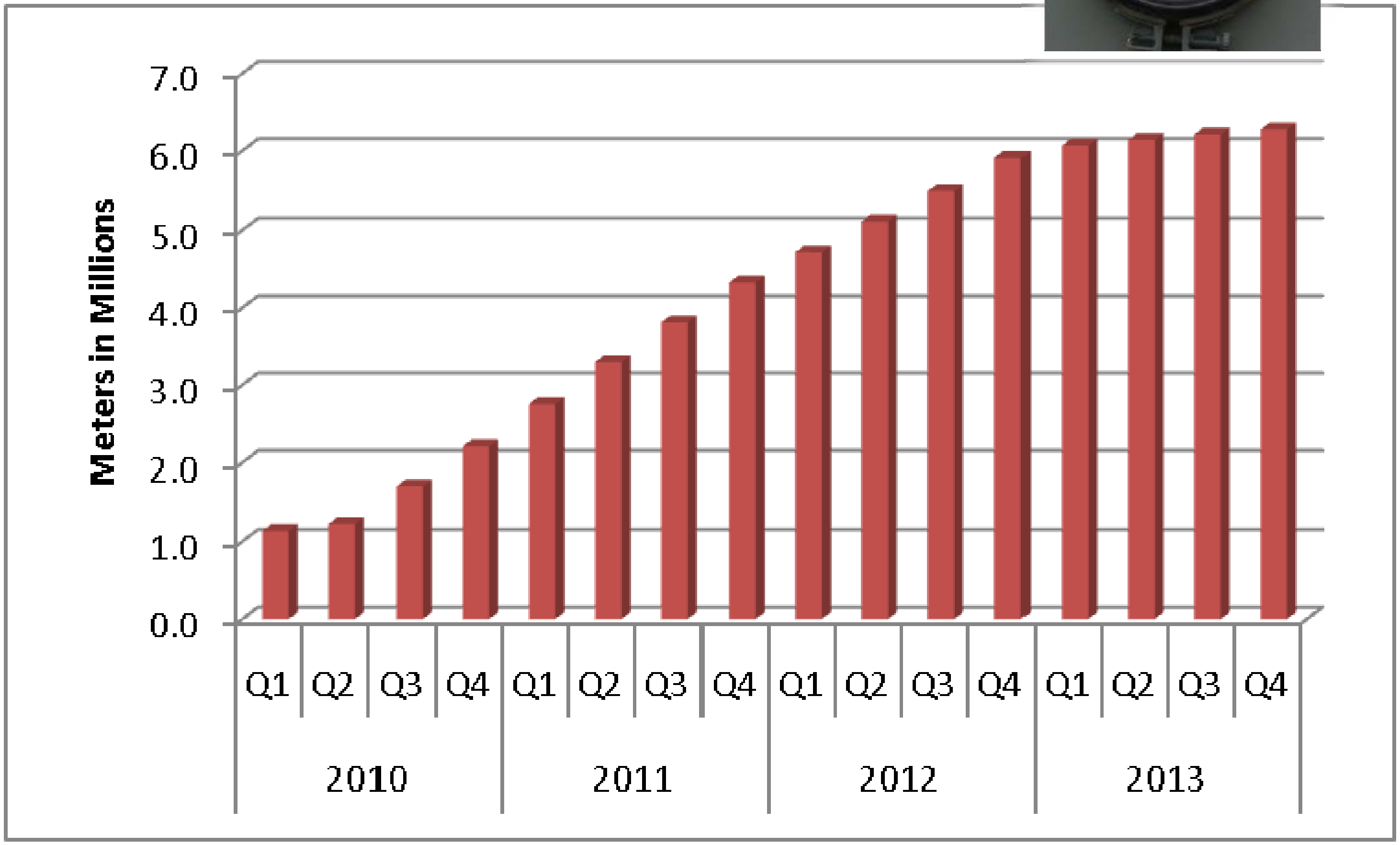


Smart grid at the distribution level

- **Improved elasticity of demand among small customers**
  - Advanced metering
  - Home Area Networks
  - Load control devices
  - Dynamic price offerings

- **A 'self-healing' grid that responds dynamically to shortages, disturbances or high price events**
  - Automatic response to signals at the device level
- **'Demand Response 2.0'**

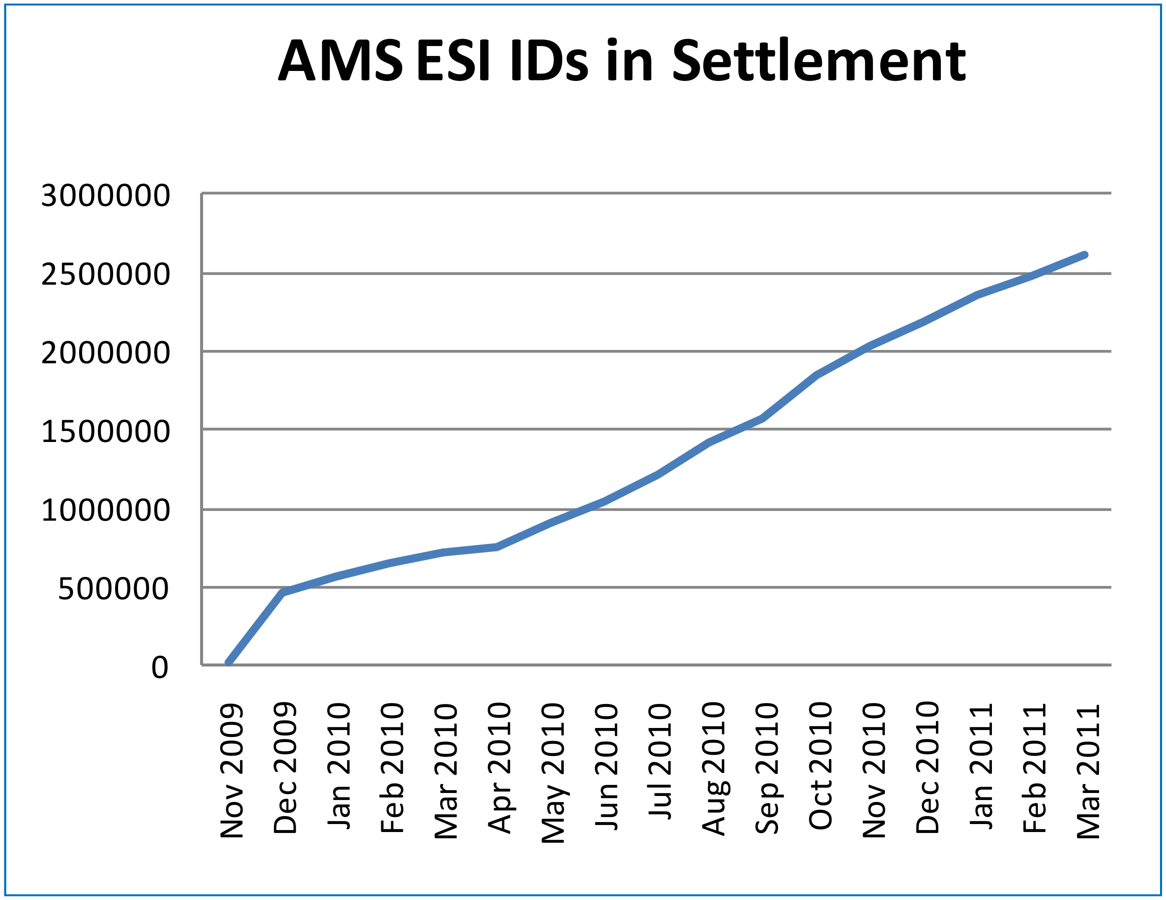
AMI Meter Deployment Plan



2.97 million advanced meters now deployed by 3 investor-owned TDSPs

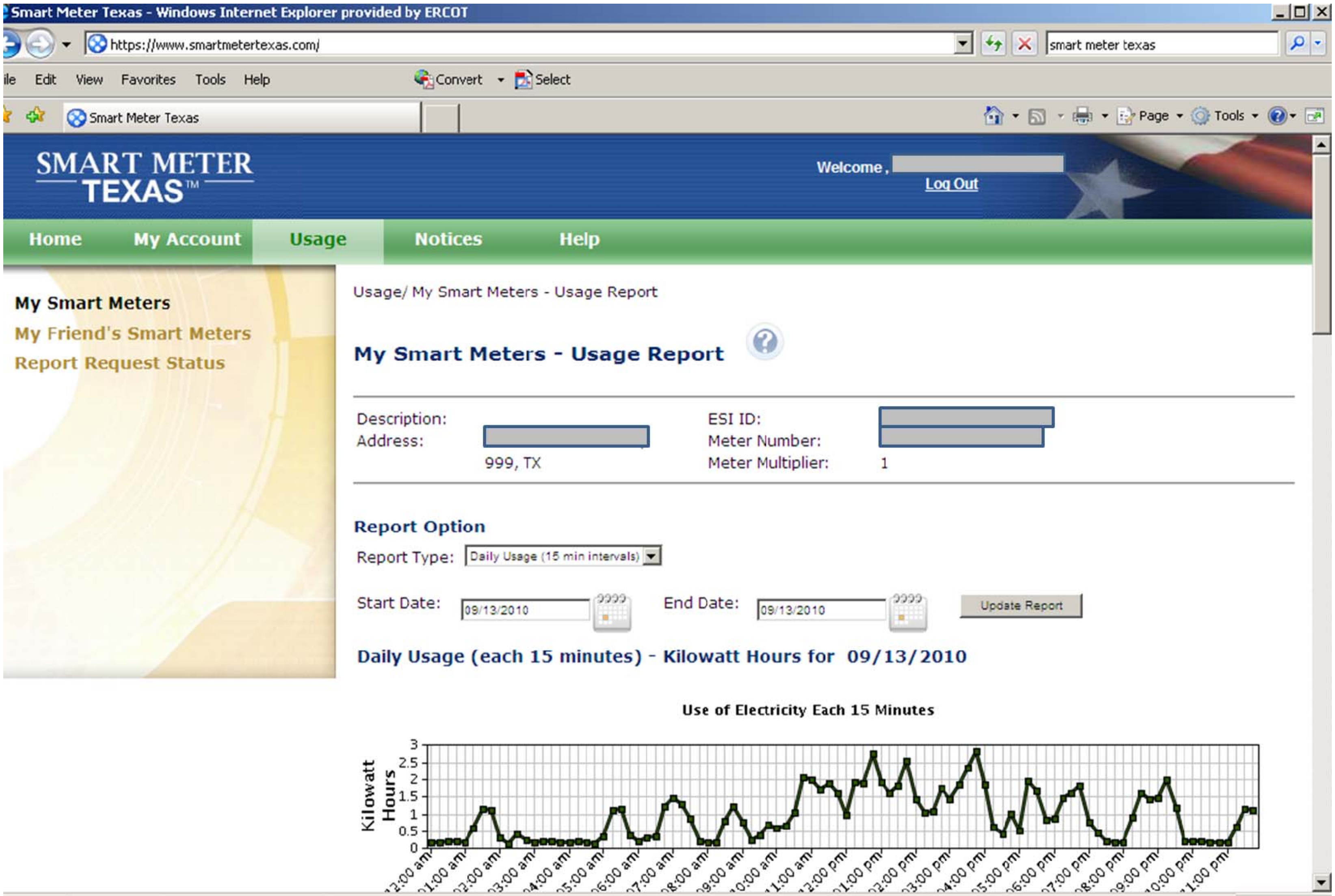
AMI settlement keeping pace

ERCOT is now settling nearly 2.7 million ESIIDs with 15-minute Advanced Meter Data



• First Operating Day Settling Advanced Meters:	November 29, 2009	263 ESIIDs
• Current Status:	March 31, 2011	2,693,726 ESIIDs

www.smartmetertexas.com



Definitions of Demand Response

- **'The short-term adjustment of energy use by consumers in response to price changes or incentives.'** (FERC)
- **'Changes in electric use by demand-side resources from their normal consumption patterns in response to changes in the price of electricity, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized.'** (NERC)
- **'A temporary change in electricity consumption by a Demand Resource in response to market or reliability conditions.'** (NAESB)

Definitions of Demand Response

- **The common threads:**
  - Change in Load
  - In response to a signal (economic or operational)

- **2 key questions relative to any DR:**

1. What is the signal?

2. Who pushes the button?

Load Participation opportunities in ERCOT

Today ⇒

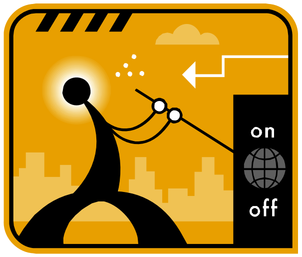
Resource Type	Service	Requirements
Voluntary Load Response (VLR)	Curtailment or reduction in response to Market Price or other factors	• Metering • Curtailment technology • Retail contract with price response incentives
Load Resources (LRs)	Responsive Reserves	• Interval metering • Telemetry • Under-Frequency Relay • Curtailment technology • ERCOT Qualification
Emergency Interruptible Load Service (EILS)	Curtailment in response to ERCOT Verbal Dispatch (10 minutes)	• Interval metering • Curtailment technology • ERCOT Qualification
Controllable Load Resources (CLRs)	Regulation Service Responsive Reserves	• Interval metering • Telemetry • Ability to receive AGC-type signals • Governor-type frequency response • ERCOT Qualification

Future? ⇒

All of the above PLUS :		
Load Participation in Security-Constrained Economic Dispatch	Real-Time Energy Market and all Ancillary Services	• To be determined • Loads would submit DR energy offer curves to compete with generation in the energy market

DR triggers

- **Today's triggers in ERCOT:**



  – Operations/reliability
    - Energy Emergency Alert
    - Grid frequency drop (Under-frequency relay trip)
    - Frequency recovery (NERC Disturbance Control Standard)
    - Local congestion management (rarely used)

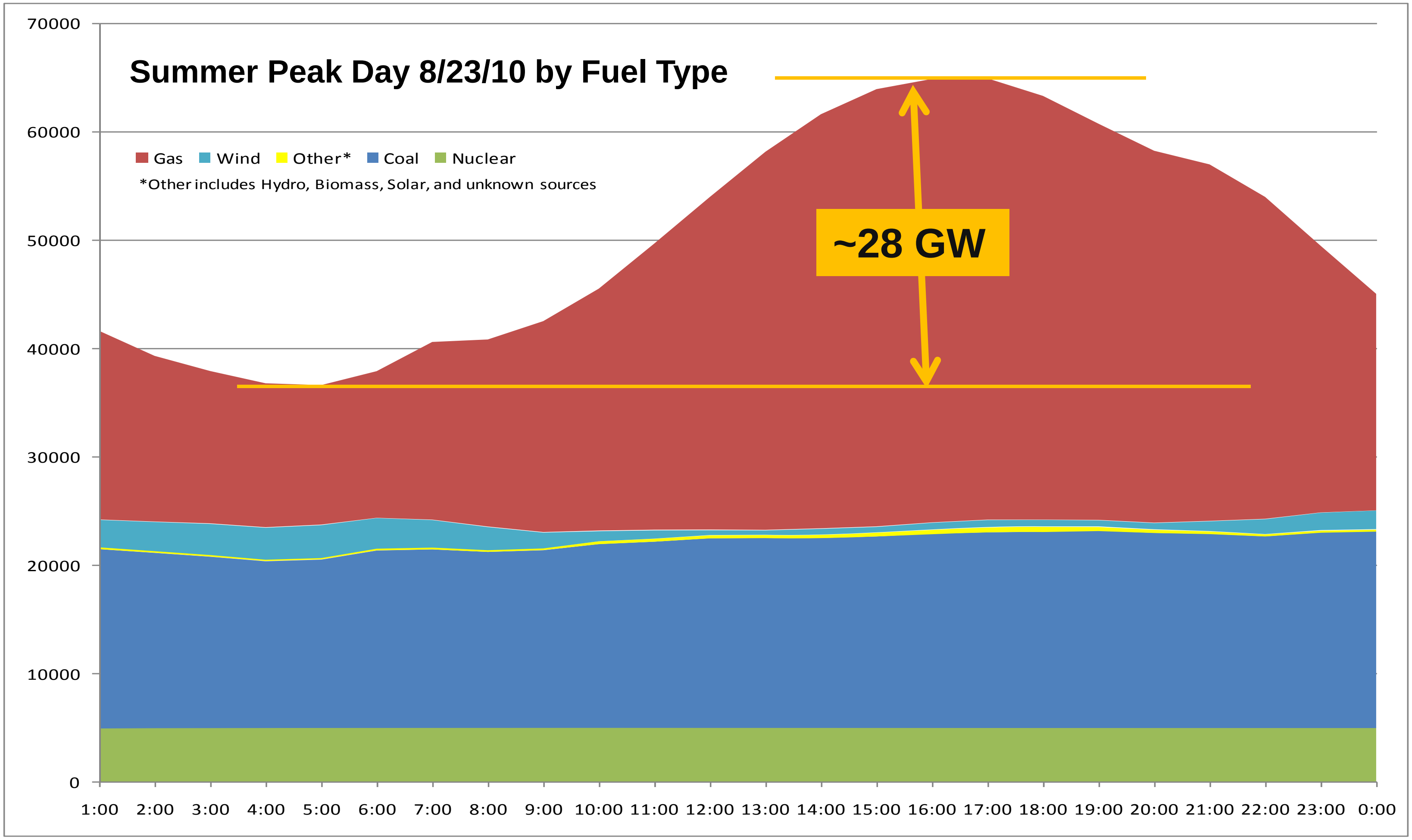
  – Economic
    - Energy price response (MCPE) – real-time pricing, critical peak pricing, etc.
    - 4CP response – large customer transmission rates are based on usage during summer peak intervals

ERCOT DR today

- **Operational DR:**
  - 181 Load Resources with 2382 MW of registered DR capacity
    - Participation in Responsive Reserves capped at 1150 MW
  - 473 MW of EILS provided by ~130 individual Loads and aggregations (~1,000 individual meters)
- **Economic DR:**
  - 2007 ERCOT survey of LSEs indicated >1000 MW:
    - Curtailing to 4CP signals
      - 11,000+ IDR-metered Loads subject to tariffs
      - Difficult to quantify due to multiple players involved
      - Several predictor products available in the market
      - Behavior is well-baked into ERCOT load forecasting
    - Curtailing based on real-time price exposure
    - Curtailed by LSE through direct load control

Summer Day Load Shape with Fuel Mix

- **The region has plenty of off-peak capacity**



DR Potential in ERCOT

- **FERC estimates >18 GW of DR potential in Texas by 2019**
  - Attributed to high peak demand
  - This would represent 20-25% of total ERCOT peak

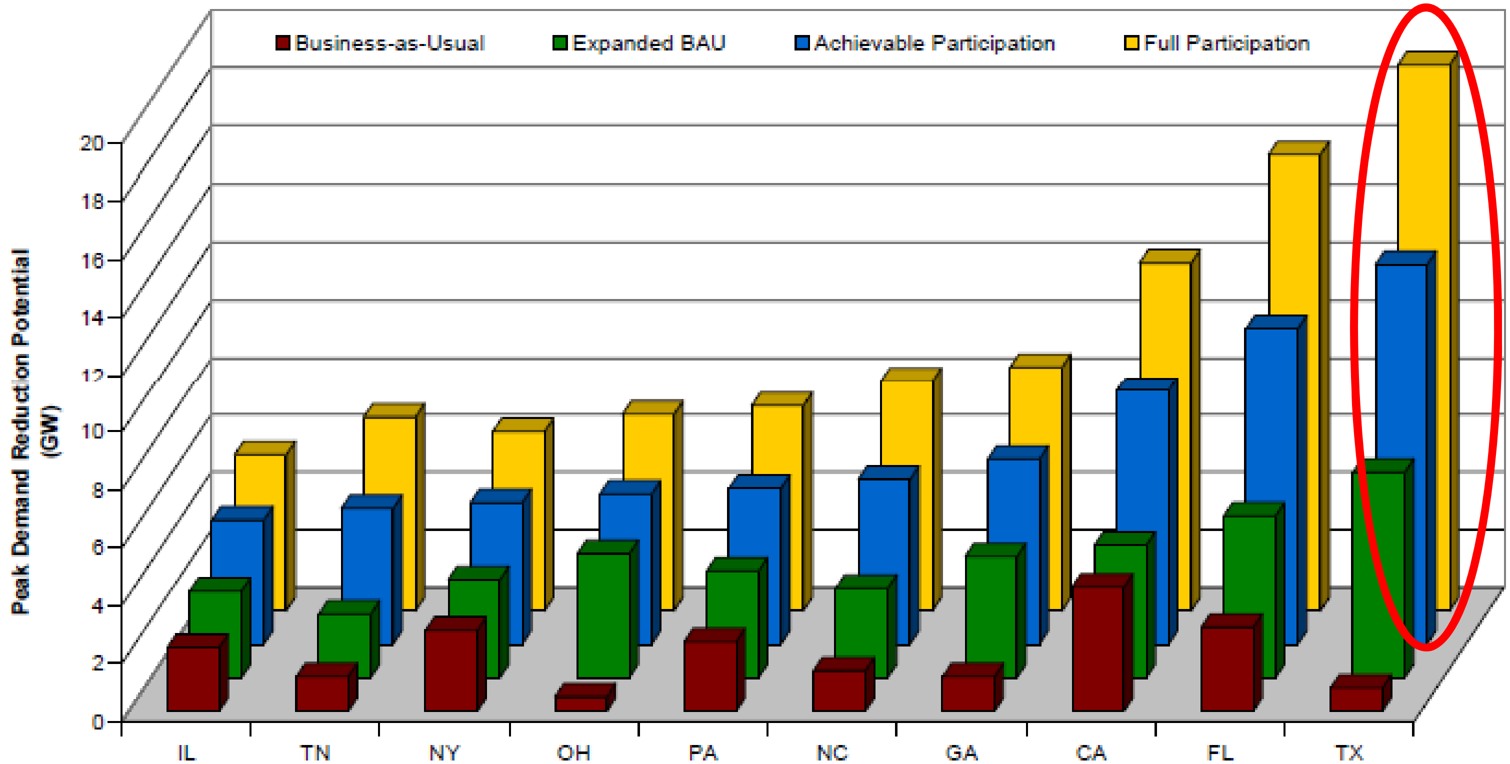


Figure 16: Top Ten States by Achievable Potential in 2019 (GW)

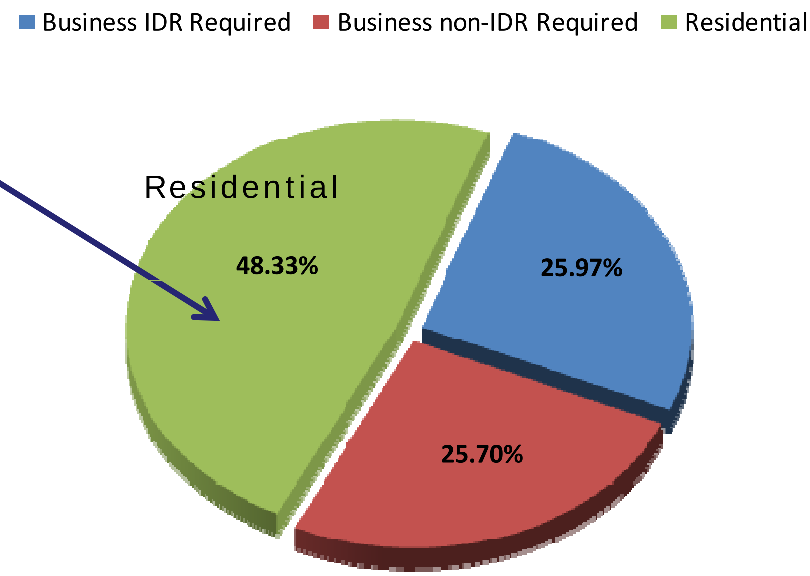
Source: FERC 2009 National Assessment of DR, page 42

Off-peak vs. on-peak load

21,000 MW of residential summer peak load

Hot day, high A/C load

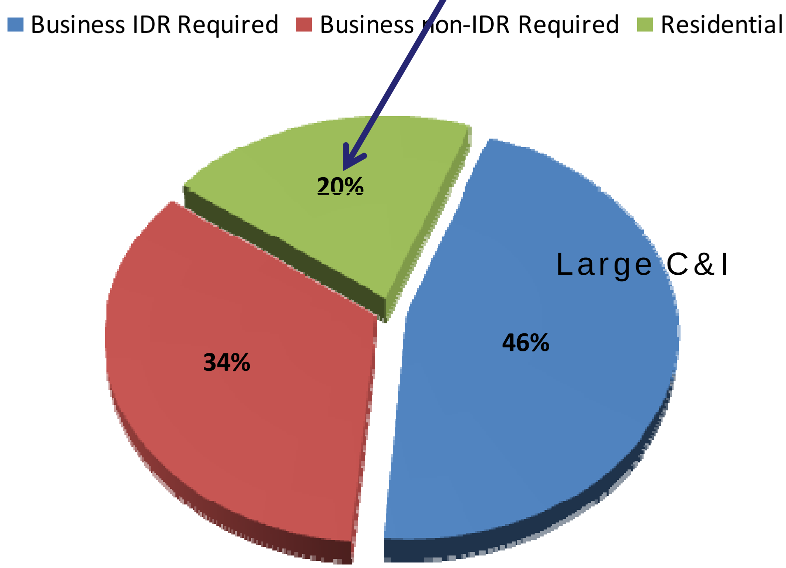
4-5 PM, Aug. 4, 2010



ERCOT load for this hour: **63,594 MW**

Moderate day, low A/C load

10-11 AM, March 31, 2010



ERCOT load for this hour: **30,697 MW**

- **Both days were Wednesdays**
- **Customer class breakdown is for competitive choice areas only**
- **IDR meters are required at >700kW**

- **Municipals and Co-ops (24% of ERCOT Load) have a number of existing and developing smart grid initiatives**
  - AMI deployments
  - Smart thermostats
  - Other DLC
- **House Bill 2129 (2005 Texas Legislature) and ensuing PUC Rulemakings jump-started the smart grid with AMI incentives and requirements for TDSPs in competitive choice areas**
  - Accelerated cost recovery via AMI surcharge
- **3 TDSPs are well along in their deployments; others coming shortly**
  - Mass deployment gets meters in the field faster and lowers the cost per customer

Path to the ERCOT Smart Grid

TDSP Back Office

15-minute Settlement

REP Back Office

Customer Education

Incentives

Home Area Network

Load Control Equipment

Path to the Smart Grid -- Incentives

- **The incentives may come in many forms:**
  - Time of Use pricing (behavioral load-shifting)
  - Real-time pricing
  - Subsidized HANs or controls in exchange for centralized dispatch
    - By the REP or a third party
  - Direct load control (DLC) by the REP to manage its load shape based on Day-Ahead market positions
  - Critical peak pricing combined with REP DLC
  - Combinations of the above
  - Others

How can the smart grid benefit ERCOT operations?

- **ERCOT's main responsibility is always grid reliability**
- **DR is needed round-the-clock, not just on peak**
  - Of 18 Load Resource deployments since 2006, only 3 have occurred during traditional summer peak hours (3-7 PM weekdays, June through September)
  - Less DR available off peak
- **Most smart grid actions will occur in the distribution system behind the customer meter**
- **We expect better <u>price elasticity of demand</u>**
  - As prices correlate to system conditions, this equates to 'self-healing'
- **As customers adopt the smart grid, ERCOT will need to adapt its load forecasting tools**

Questions we have

- **How many REPs will build AMI DR portfolios?**
  - Does DR capability = smarter energy consumers = enhanced customer loyalty?
- **How much mass market DR potential is out there?**
  - Residential and small commercial?
- **How fast will it develop?**
- **Who is most likely to push the button?**
  - REP, customer, third party?
- **Will the signals all be economic?**
  - What energy prices are needed to stimulate DR?
- **Will shortage/scarcity conditions always correlate to high prices?**
- **Would mass-market DR aggregations participate in the real-time Nodal energy market or ancillary services, if they could?**
- **Is EILS attractive to mass market DR aggregations?**

Advanced Metering Implementation Team

- **AMIT has made much progress**
  - Smart Meter Texas portal development
  - Business rules for AMI and SMT
- **But:**
  - Low sign-up rate for SMT access among AMI customers
  - Home Area Networks are slowly rolling out
  - Customer education initiatives not really evident
  - Low participation by REPs and aggregators in the AMIT process
- **Expectations are out ahead of the reality!**

- **Let's make the Smart Grid happen – GET INVOLVED!**