Milestones in Restructuring: The ERCOT Experience so far…

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NCSL
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The ERCOT Region

The interconnected electrical system serving most of Texas, with limited external connections

- 90% of Texas electric load; 75% of Texas land
- 71,093 MW peak, August 11, 2016
- More than 46,500 miles of transmission lines
- 550+ generation units

**ERCOT connections to other grids are limited to ~1250 MW of direct current (DC) ties, which allow control over flow of electricity**
Independent System Operators and Regional Transmission Organizations are the ‘air traffic controllers’ of the bulk electric power grids (69kV and up).
Current Records as of October 2016

Peak Demand Record: 71,093 megawatts (MW)
- August 11, 2016, 4-5 p.m.

Weekend Record: 67,000 MW
- Sunday, August 7, 2016, 5-6 p.m.

Winter Peak Record: 57,265 MW
- 57,265 MW, February 10, 2011

Wind Generation Records (instantaneous)
- 14,023 MW, February 18, 2016, 9:20 p.m.
  - Non-Coastal Wind Output = 12,502 MW
  - Coastal Wind Output = 1,521 MW
  - Supplying 39.5% of the load
  - Active Wind Capacity = 16,246 MW

- 48.28% Wind Penetration, March 23, 2016, 1:10 a.m.
  - Total Wind Output = 13,154 MW
  - Total Load = 27,245 MW

Summer 2016 Monthly Peaks

June: 64,896 MW (June 15)
  June Record: 66,548 MW – June 26, 2012

July: 67,469 MW (July 14)
  July Record: 67,650 MW – July 30, 2015

August: 71,093 MW (Aug. 11)
  August Record: 71,093 – Aug. 11, 2016

September: 66,853 MW* (Sept. 19)

*Based on preliminary Operations data
Milestone 1: 1995

- **Wholesale market restructuring**
  - Texas Legislature passes SB 363
  - Provides for equal access to transmission grid for merchant generators
  - ~20,000 MW of combined cycle gas generation goes into the interconnection queue
  - PUC establishes ERCOT as the Independent System Operator
    - Formerly ERCOT was only the reliability coordinator – a reporting entity to the North American Reliability Council (NERC)
Milestone 2: 1999

- Retail Choice legislation passes
  - Senate Bill 7 splits investor-owned utilities into 3 parts:
    - Generation
    - Retail
    - Transmission & Distribution (to remain fully regulated)
  - Also included Renewable Portfolio Standard for 2,880 MW of renewables
    - Triggered the first wind boom
  - Once the merchant generators knew retail choice was a certain thing, 20,000 MW of combined cycle gas plants became reality in early 2000’s
ERCOT’s responsibilities

- SB 7 consolidated the region’s 10 control areas into a single control area, and assigned four primary responsibilities to the ERCOT ISO:

1. System reliability – planning and operations
2. Wholesale market settlement for electricity production and delivery
3. Retail switching process for customer choice
4. Open access to transmission
Milestone 3: 2002

- Retail Market Opened
  - Incumbent retailers were bound to a ‘price to beat’ that was lower than legacy rates
    - Affected residential and small commercial customers
      - Industrial customer market unconstrained
    - Price to Beat allowed to rise (but not drop) with fuel price adjustments
    - Price to Beat expired Jan. 1, 2007
  - Municipally-owned utilities and electric cooperatives not required to opt-in to competition

We got lucky
- Combined cycle gas units quickly came online
- Gas prices dropped, prices mostly stayed low
- Resource adequacy not an issue
Retail Market Experiences

• ERCOT assigned the role of market-neutral retail registrar
  – In other regions, incumbent utilities assumed that role
  – Meter data for each customer submitted to ERCOT by T&D utilities for wholesale market settlement
  – At launch, electronic transaction system worked well for retail switching
    • However, move-ins and move-outs were a big challenge
      – Sept. 2016: 67,000 switches; 232,000 move-ins; 114,000 move-outs
  – Eventually, ERCOT’s retail transaction system was adopted by NAESB as the model for retail markets
Retail Switching Status, 2016

- Residential
  - Affiliate: 34%
  - Non-Affiliate: 66%

- Small Commercial
  - Affiliate: 26%
  - Non-Affiliate: 74%

- Large Industrial
  - Affiliate: 19%
  - Non-Affiliate: 81%

Source: PUCT Market Share Data Report, March 2016

‘The commission estimates that retail consumers saved, at a minimum, over $1.5 billion in electricity costs during the first year of competition….’

2003 Scope of Competition Report

Percent of customers that have switched from their original incumbent REPs

Source: PUCT Market Share Data Report, March 2016
Retail Market Score

- ERCOT’s retail market has ranked No. 1 on the ‘ABACCUS’ scorecard for 8 consecutive years
  - Compiled annually by the Distributed Energy Financial Group
  - Evaluates markets based on 49 different attributes

There are more than 50 active Retail Electric Providers in the ERCOT market

<table>
<thead>
<tr>
<th>Jurisdiction</th>
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<th>2014 Score</th>
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Milestone 4: 2005

• Legislation again changes the course of the market
  – Renewable Portfolio Standard expanded to 5,880 MW
    • Transmission providers given incentives to bring West Texas wind to the eastern Load centers
    • ‘Competitive Renewable Energy Zones’ eventually leads to $7B in high-voltage power line investment
    • RPS exceeded within 2 years
  – Advanced Metering accelerated cost recovery authorized
    • PUC followed with key rulemaking
Milestone 5: 2005

• Transition to Nodal market begins
  – Original Zonal market directly assigned costs of *inter*-Zonal congestion to the entities causing the congestion
    • But did not address *intra*-Zonal congestion, which was solved by out-of-merit generator dispatch with costs uplifted to market at large
  – Shortly after original market opened, local congestion costs vastly exceeded predictions
  – PUC Rule set in motion a project that eventually resulted in a new Nodal market design
    • A nodal market solves for power balance and congestion management economically every 5 minutes
    • Implemented Dec. 1, 2010
Milestone 6: 2006

- Rolling blackouts during spring heat wave triggers debate over resource adequacy
  - ERCOT market had always been energy-only
  - Would a forward capacity market be a better mechanism for ensuring adequate dollars to invest in future generation?
  - PUC and stakeholders debated for 8 years
  - Energy-only market design prevailed, with new mechanisms adopted:
    - System-wide offer caps increased to $9,000/MWh (highest in northern hemisphere)
    - Operating Reserve Demand Curve implemented to help insure proper price formation during scarcity conditions
Milestone 7: 2008-present

- Low energy prices prevail
  - Hydraulic fracturing boom causes price of natural gas (marginal fuel in ERCOT) to plummet
  - CREZ transmission projects spawn major increases in zero fuel cost wind energy
  - Retail competition continues to surge

- Texas is #1 in the U.S. in wind capacity.
- If the ERCOT Region was a separate country, we’d be #6 in the world in wind generation capacity (as of end of 2015).
Milestone 8: 2014

• Advanced meter deployment mostly completed in competitive choice areas
  – Total of 7 million deployed across all customer classes
  – PUC Rule requires AMI meters to measure consumption in 15-minute intervals, and for that data to be used in wholesale market settlement
    • This means that benefits of any load reductions during a period of high wholesale prices will accrue directly to the Retail Electric Provider
  – This has spawned numerous dynamic pricing and demand response-related retail offerings
    • ‘Free Nights’ or ‘Free Weekends’ time-of-use pricing, etc.
Milestone 9: 2015-16

- ERCOT market is attracting new Load seeking vibrant competition and low priced-energy
  - Lubbock Power & Light (municipally-owned utility in West Texas) has applied to switch 430 MW of Load from Southwest Power Pool to ERCOT
  - Rayburn Country (electric cooperative in northeast Texas) has proposed to migrate 190 MW of Load from Eastern Interconnection to ERCOT
Milestone 10: The future

- Distributed Energy Resources move to the mainstream
  - ERCOT now has ~ 1,100 MW of generation connected at distribution voltage
  - >80% of that is diesel, natural gas or landfill gas
    - Much of it is backup generation on critical infrastructure vulnerable to weather (i.e., hurricanes)
    - Some of it is price-responsive
  - ERCOT is now working with T&D utilities to:
    - Establish better reporting of DG
    - Create a framework for DG to participate directly in the ERCOT markets
Questions?
Thursday, March 24, 2016 5:00 PM
ERCOT Load: 33,597 MW
Temperature in Dallas: 62°

Thursday, Aug. 11, 2016 5:00 PM
ERCOT Load: 71,093 MW
Temperature in Dallas: 106°

>37,000 MW of weather-sensitive load -- 53% of peak

- Customer class breakdown is for competitive choice areas; percentages are extrapolated for municipals and co-ops to achieve region-wide estimate
- Large C&I are IDR Meter Required (>700kW)
- Hourly integrated demand values
Fuel mix on those same days

Power Dispatch Summary per fuel type for March 24, 2016

Power Dispatch Summary per fuel type for August 11, 2016

- Diesel
- Renewables
- Hydro
- Wind
- Combined Cycle

Max Gen: 34593 MW at 07:20:21 AM
Load Factor: 0.9234

Max Gen: 71636 MW at 03:55:19 PM
Load Factor: 0.8021
Wholesale market price caps

- Escalating offer caps in the energy-only market
  - 2002: $1,000
  - 2007: $1,500
  - 2008: $2,250
  - 2011: $3,000
  - 2012: $4,500
  - 2013: $5,000
  - 2014: $7,000
  - 2015: $9,000

- Applies to offers for energy (MWh) and Ancillary Services (MW/hr)
- The energy market has never cleared at the $9,000/MWh cap
Real-time energy prices

<table>
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<th>Intervals</th>
<th>2015</th>
<th>2016</th>
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<td>$0-$30</td>
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<td>&gt;$30-$75</td>
<td>3,110</td>
<td>1,930</td>
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<tr>
<td>&gt;$75</td>
<td>406</td>
<td>298</td>
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Wind Generation Capacity – September 2016

- Texas is #1 in the U.S. in wind capacity.
- If the ERCOT Region was a separate country, we’d be #6 in the world in wind generation capacity (as of end of 2015).
# Utility Scale Solar Generation Capacity – September 2016

## ERCOT Solar Installations by Year (through September 30, 2016)

<table>
<thead>
<tr>
<th>Year</th>
<th>Cumulative MW Installed</th>
<th>IA Signed - Financial Security Posted</th>
<th>IA Signed - No Financial Security</th>
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<tr>
<td>2019</td>
<td>394 MW</td>
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<td>2020</td>
<td>394 MW</td>
<td>1,759 MW</td>
<td>2,573 MW</td>
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The data presented here is based upon the latest registration data provided to ERCOT by the resource owners and can change without notice. Any capacity changes will be reflected in current and subsequent years’ totals. Scheduling delays will also be reflected in the planned projects as that information is received. This chart reflects planned units in the calendar year of submission rather than installations by peak of year shown.
CREZ Transmission

Connecting West Texas and Panhandle wind power to the ERCOT grid
Solar trends

PV growth & cost trends

Distributed solar costs

Source: LBNL
Planning Summary

As of Aug. 31, 2016:

- ERCOT is tracking 236 active generation interconnection requests totaling 57,931 MW, including:
  - Wind: 26,038 MW
  - Solar: 9,538 MW
  - Storage: 644 MW

ERCOT is reviewing proposed transmission improvements with a total cost of $747 million:
- Transmission Projects endorsed in 2016 total $271 million
- Transmission Projects energized in 2016 total about $1.26 billion (as of June 1, 2016)
Integrating and managing renewables

- ERCOT has developed a 7-day wind forecast and improved the overall performance of wind forecast.
- Inclement weather preparation, including capability to manually overwrite wind forecast for icing events.
- Recently implemented a utility-scale solar forecast.

**Day-ahead Wind Forecast Performance**

- **MAPE**

  - **Jan**
  - **Feb**
  - **Mar**
  - **Apr**
  - **May**
  - **Jun**
  - **Jul**
  - **Aug**
  - **Sep**
  - **Oct**
  - **Nov**
  - **Dec**
Operational Demand Response

Load Resource MW registered
Deployed as Responsive Reserves, via:
• Manual dispatch, 10-minute ramp requirement
• Instantaneous trip via Under-Frequency Relay
Procurement capped at 50% of RRS (~1400 MW)

Emergency Response Service MW procured
Deployed via:
• Manual dispatch during grid emergencies
• 10- and 30- minute ramp options
Special rules for weather-sensitive loads

Load Resource MW registered
Deployed as Responsive Reserves, via:
• Manual dispatch, 10-minute ramp requirement
• Instantaneous trip via Under-Frequency Relay
Procurement capped at 50% of RRS (~1400 MW)
Distributed generation on the rise

- ERCOT operates the grid at transmission voltage (>60 kV)
- But a greater share of the future resource mix will come from the distribution system

5 Year Comparison: Registered DG

- Majority of ERCOT Distributed Generation (DG) today is ‘self-dispatched’
  - Many units installed as backup power for critical infrastructure during severe weather events; e.g., Hurricane Ike (2008)
Zonal to Nodal

- ERCOT Nodal market launched in Dec. 2010
  - Security Constrained Economic Dispatch (SCED) gives unit-specific dispatch instructions every 5 minutes instead of portfolio-level dispatch every 15 minutes
  - Congestion is better managed by accurate modeling of a unit’s locational impact on the congested element, rather than an aggregated portfolio across a wider area
  - Locational Marginal Prices will vary if there is congestion anywhere on the system
  - Load Serving Entities pay for the energy at the weighted average of all LMPs in a Load Zone
DER conundrum #1

• Distributed Generation is still paid Load Zone prices

• Zonal prices can dilute local incentives for DG to contribute to congestion management
  – See Rio Grande Valley example 10/8/14

After making the investment to bring the efficiency of Locational Marginal Pricing to the market – will we be retreating from the Nodal concept if we continue to pay DG at Zonal?

• ERCOT has proposed a framework for DERs to be settled at local (Nodal) pricing
  – Either via self dispatch (DER Light) or ERCOT dispatch (DER Heavy)
DER conundrum #2

- PUC Rule §25.501 requires Load to be settled at the Load Zone price
  - This was implemented to avoid penalizing customers who happened to be located in a constrained area
- So even if we can enable local settlement of DG, absent further clarification of the rule:

  Demand response cannot be part of the performance of a DER being settled at a Nodal price.
Retail competition

- Thanks to restructuring law, since 2002 ~75% of ERCOT customers may now select their Retail Electric Provider
- Over 50 active REPs in the residential sector
  - PUC maintains PowerToChoose.org shopping site
- ERCOT is the retail market registrar and settlement agent
  - Clearinghouse for all REP switches, move-ins and move-outs
  - Clearinghouse for meter data used in market settlement

Former investor-owned vertically integrated utilities (municipally-owned utilities and electric cooperatives not required to offer retail choice)
Advanced metering

• 2005 Texas Legislature authorized accelerated cost recovery for AMI deployment by investor-owned TDSPs
• PUC Substantive Rule §25.130 -- Advanced Metering (2007) implemented the law.
• Among the provisions and goals:
  – Authorized the TDSPs to recover AMI costs via a special surcharge;
  – Required each meter to record 15-minute interval usage;
  – Required ERCOT to use the actual 15-minute data in wholesale market settlement;
    • Replacing Load Profiles which were estimates of usage
  – Encouraged dynamic pricing and demand response.
Advanced metering benefits

• 6.9 million advanced meters now blanket the competitive choice areas of ERCOT

• TDSP benefits:
  – Reduced meter-reading costs
  – Advanced outage detection
  – Faster and easier switching and move-ins/move-outs

• REP benefits:
  – Settlement accuracy (no more load profiles)
  – Real money if customers reduce load during high-priced periods

• ISO benefits:
  – Settlement accuracy: as of July 2016, 99.0% of ERCOT load was settled on 15-minute actual data
    • AMI, competitive IDR, and NOIE IDR

• Customer benefits:
  – Access to granular energy usage data
AMI and the smart grid

- AMI can be thought of as the foundation of the retail smart grid
- Numerous REPs are now pairing their retail contracts with smart thermostats
  - Often with WiFi capability and an agreement to allow direct load control
  - This provides the REP with insurance against wholesale market price spikes
- In addition, retail demand response and dynamic price offerings are now common in the market
- ERCOT has worked with REPs since 2013 to try to quantify these products and identify trends
Retail DR and Dynamic Price Offerings

Enabled by advanced metering, a significant percentage of the retail market now has some kind of incentive for demand response, price response, or a behavioral shift from on-peak to off-peak.

- **Time of use (residential)**
  - 2013: 135,320
  - 2014: 290,328
  - 2015: 328,642

- **Peak time rebate * (residential and C&I)**
  - 2013: 2,468
  - 2014: 413,772
  - 2015: 499,085

*Events not necessarily called, rebates not necessarily issued. Numbers are based on snapshots submitted by REPs to ERCOT: 6/15/13; 9/30/14; 9/30/15.*