History of the Texas Interconnection

Joel Mickey
Senior Director,
Market Design & Operations

Standards to Promote Interoperability:
Interconnection Code Compliance & Corrective Actions

U.S.-Africa Clean Energy Standards Program

Kigali, Rwanda
Oct. 1, 2018
Topics

- North America Power Grids
- ISOs and RTOs
- ERCOT
- Evolving Grid
- Interconnection Rules
The interconnected electrical system serving most of Texas, with limited external connections

90% of Texas electric load; 75% of Texas land

73,308 MW peak, July 19, 2018

More than 46,500 miles of transmission lines

570+ generation units

Note: ERCOT connections to other grids are limited to ~1,250 MW of direct current (DC) ties, which allow control over flow of electricity
HM2  note that the ERCOT website says 600+

Hilliard, Marie, 9/27/2018
## Comparing Rwanda to Texas

<table>
<thead>
<tr>
<th></th>
<th>Rwanda</th>
<th>Texas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>&gt;10,000 mi²</td>
<td>&gt;200,000 m mi²</td>
</tr>
<tr>
<td>Current Customers</td>
<td>&gt;3.5 million customers</td>
<td>&gt;25 million customers</td>
</tr>
<tr>
<td>Transmission Lines</td>
<td>unknown</td>
<td>&gt;4,650 miles</td>
</tr>
<tr>
<td>Generation Mix</td>
<td>HYDROELECTRIC: 53%</td>
<td>THERMAL: 77%</td>
</tr>
<tr>
<td></td>
<td>THERMAL: 47%</td>
<td>WIND: 21%</td>
</tr>
<tr>
<td></td>
<td>OTHER: 2%</td>
<td></td>
</tr>
<tr>
<td>Installed Capacity</td>
<td>209 MW</td>
<td>&gt;100,000 MW *</td>
</tr>
</tbody>
</table>

*This number uses installed capacity for intermittent resources; not peak capacity contribution.

*Scale is Approximate*
North American ISOs and RTOs

*Independent System Operators* and *Regional Transmission Organizations* are the ‘air traffic controllers’ of the bulk electric power grids (69kV and up)
ERCOT Installed Capacity (1999-2018)

- Wind and solar values are based on nameplate capacity (not adjusted for peak capacity contribution)
- Private Use Network capacity not included

Nuclear | Coal | Other | Gas CC | Gas Steam | Gas CT/IC | Wind | Solar

1999: 8.4%
2000: 5.3%
2001: 51.6%
2002: 4.8%
2003: 28.6%
2004: 1.0%
2005: 20,000
2006: 60,000
2007: 80,000
2008: 100,000
2009: 0.3%
2010: 5.1%
2011: 5.3%
2012: 8.4%
2013: 16.9%
2014: 34.7%
2015: 34.7%
2016: 20.8%
2017: 11.8%
2018: 6.6%
2019: 6.3%
2020: 6.3%
2021: 19.8%
2022: 20.8%
2023: 1%
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.

Financial security posted for funding interconnection facilities does not include CREZ security deposits, which are refunded to the Interconnecting Entity when an IA is signed.

As of August 31, 2018
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.

As of August 31,
## Regulatory Environment

<table>
<thead>
<tr>
<th>Federal</th>
<th>State</th>
</tr>
</thead>
</table>
| **DOE**  
Department of Energy | **FERC**  
Federal Energy Regulatory Commission |
| Responsible for the national energy program  
Propose and advocate policies and programmatic goals for economic welfare | Regulates the sale and transmission of electricity in interstate commerce  
Oversees development and enforcement of Electric Reliability Standards  
*For Texas: Subject to reliability  Not for markets* |
| **PUCT**  
Public Utility Commission of Texas | Oversees competitive electrical markets  
Oversees ERCOT budget and operations  
Enforces statutes and rules for electric industry |
Regulatory Environment

FERC
Federal Energy Regulatory Commission

Reliability Oversight

NERC
North American Electric Reliability Corporation

Reliability Standards

ERCOT NERC registrations-
BA, RC, PA, RP, TOP, TSP

Compliance
The Texas Interconnected System

During WW2, the 10 independent power grids interconnected so they could send their excess power to the coast for heavy manufacturing industry to support the war effort. Once connected, they formed TIS, Texas Interconnected System. Operating guides were produced to dictate how the control areas would operate as one. These control areas soon realized other benefits from being connected.
Benefits of the Interconnection

- Increased reliability
- Ability to share reserves
- Better Reactive control
- Lower costs to produce power
- Increased flexibility to integrate renewable and intermittent sources
The 1965 Northeast Blackout

On November 9, 1965 almost 30 million people in the northeastern United States lost power. It was the largest blackout in US history.

Utilities responded to this event by voluntarily creating the National Electric Reliability Council.

After several name changes, today it is the North American Electric Reliability Corporation (NERC).

In 1970 TIS joined NERC and became one of NERC’s ten regional reliability areas.

The TIS renamed itself: ERCOT – the Electric Reliability Council of Texas.
Vertically-integrated utilities

Prior to 1996, the ERCOT Region was operated by 10 separate Control Area Utilities

- Owned most generation and transmission
- Controlled access to the grid
- Control Areas did all transaction scheduling and staffed the committees that established the operating and business rules
- Load captive to their utility

Note: Some areas were certificated to more than one utility. And areas are approximate.
Vertically-integrated utilities (through 1995)

- Captive customer base
- Multiple control areas with limited power flows between utilities
- Regulated rate of return
  - Regulated price for customers
  - Approved through "rate case"
  - Based on utility’s cost plus reasonable profit margin

Investor-owned utilities regulated by the Public Utility Commission of Texas (PUCT), created in 1975

Municipally-owned utility rates regulated by city governments (and still are)

Electric cooperative rates regulated by co-op boards (and still are)

**System Operations**

- Generation
- Transmission
- Distribution
- Customers

**Utility**

**ERCOT Reliability Coordinator**

**Physical Power Flow**

**Scheduling and Dispatch**
Wholesale market deregulation (mid-1990s)

Texas Legislature opened the doors to competitive wholesale producers
- Ensured open access to transmission system

ERCOT Independent System Operator (ISO)

- Generation
- Transmission
- Distribution
- System Operations
- Customers

Physical Power Flow
- Scheduling and Dispatch
- Financial Relationships

Merchant Generation

- Wholesale Marketers
- Other Utilities
Reasons behind wholesale deregulation

Competitive Pressure
New companies wanted to build generation and market energy to buyers
Customers wanted to select their energy provider
General belief it would bring more efficient resources to market and lead

Grid Operations & Reliability
State regulators and many market participants supported an impartial ISO
ISO would ensure that the electric grid remained reliable and there was fair access to the transmission system

**Transmission Providers:**
May or may not own distribution or generation; may or may not be a control area

**Generators:**
Utility-owned or independent

**Power Marketers:**
Independent or operated by independent generators or utilities

---

**Bilateral Market**
Transactions between buyer and seller

No Power Exchange or market clearing price

ISO does not know the price of transactions

Control areas - Same as before

ERCOT transitions from reliability coordinator to Independent System Operator
The Big Game Changer: Retail Competition

1999: Texas Legislature Passed Senate Bill 7

Public Utility Commission issued series of rules and orders to enable market launch
ERCOT given responsibility as the Independent Organization for the region:
- Maintain reliability
- Operate wholesale market
- Ensure equal access to the grid for new entrants
- Operate retail market

January 1, 2002: Go-live
Retail & wholesale market deregulation (2002)

Texas Legislature in 1999 unbundled Investor-Owned Utilities
- Generation companies sell into the competitive wholesale market
- Retail Electric Providers buy wholesale power and re-sell to retail customers
- Retail customers allowed to choose among competing REPs
- T&D companies move power from generation to customer and remain regulated
- Municipally-owned utilities and co-ops exempted from retail competition

ERCOT ISO
System Operations (single control area)

Wholesale Marketers

Retail Electric Providers

Physical Power Flow
Scheduling and Dispatch
Financial Relationships
Texas Competitive Model

Generating units are owned by privately owned companies. Except for municipal and cooperative units, they compete in ERCOT market to serve load. Market is overseen by PUC.

Transmission and distribution lines and related facilities are owned and operated by regulated utilities. Utilities are regulated by PUC.

Consumer’s electric load is served by competitive retailers. Except in municipal and cooperative utility areas.
this was slide 23 but I have moved for clarity/continuity of topic
Hilliard, Marie, 9/26/2018
ERCOT Zonal Market v2 – Retail, Wholesale (2002-2010)

Bilateral
Zonal dispatch
Balancing Energy Services
Not a true ‘spot market’
Directly assigned costs of inter-zonal congestion, but not intra-zonal
Ancillary Services
No Day-ahead Energy Market
Portfolio-based schedules
Transmission Congestion Rights
Single Control Area
## ERCOT Zonal Market

<table>
<thead>
<tr>
<th>Zonal Portfolio Model</th>
<th>Local Congestion Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Five wholesale pricing “nodes” (congestion zones)</td>
<td>Unit specific deployments -- ‘out of merit’ commitment &amp; dispatch</td>
</tr>
<tr>
<td>Commercially Significant Constraints (CSCs) for inter-zonal congestion management</td>
<td>Mitigated offers</td>
</tr>
<tr>
<td>Average shift factors within congestion zones</td>
<td>Local congestion costs uplifted to all load</td>
</tr>
<tr>
<td>Zonal balancing energy deployed by ERCOT</td>
<td></td>
</tr>
<tr>
<td>Zonal congestion costs directly assigned based upon cost causation</td>
<td></td>
</tr>
</tbody>
</table>
The Next Big Game Changer: Transition to Nodal

Zonal → Nodal

Commerically Significant Constraint
ERCOT Nodal Market v3 (2010 to present)

- 5 minute Locational Marginal Prices
  - >550 Resource Nodes
  - >4,000 Load points

- 15-minute settlement
- Day-Ahead Energy Market with co-optimized energy and Ancillary Services
- Congestion costs directly assigned based upon cost causation
- Transmission capacity auctioned off point to point
- Congestion Revenue Rights to enable hedging
ERCOT Control Room (Taylor, TX)
Interconnection Dependencies

- System Control
- System Security
- Emergency Operation
- Operating Personnel
- Operations Planning
- Communications and Metering
System Control

Automatic Control Systems
Time correction
Generating Unit Operating Capability Verification
Interruptible Load Used as Capability verification Procedure
Interchange classifications
Application of under-frequency Relaying
Application of ancillary services
Maintaining voltage Profile
System Security

Responsive Reserves

Unit and Line Outages
Emergency Operations

Emergency assistance
Operation to Maintain Transmission System security
Adverse Weather Operation
Short Supply operations
Emergency Load shedding Plan
Black start plan
Operating Personnel

Selection and training of System Operators
Annual Training Classes
Certification of Operators
Operations Planning

Generation facilities
Transmission security criteria
System protective relaying
Communications and Metering

Inter-control area communications guidelines
Inter-control Area telemetry guidelines
Inter-Control Center Protocol (ICCP)
Multiple data points from all Resources every 2 seconds
Inter-control area Metering Guidelines
Questions

joel.mickey@ercot.com

(512) 248-3925