Computational Frontiers in Electricity Markets: Increased Penetration of Distributed Energy Resources (DER)

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ERCOT

HEPG
Houston
October 1st, 2015
The ERCOT Region is one of 4 grid interconnections in USA-Canada

The ERCOT grid:
- Covers 75% of Texas land
- Serves 90% of Texas load
- 69,783 MW all-time peak (Aug. 10, 2015)
- >43,000 miles of transmission lines
- >550 generation units
- Physical assets are owned by transmission providers and generators, including municipal utilities and cooperatives

ERCOT connections to other grids are limited to ~1,250 MW of direct current (DC) ties
• Transmission Plan designed to serve approximately 18.5 GW:
  – ~3600 right-of-way miles of 345 kV
  – $6.8 billion project cost
• Lines are open-access; use not limited to wind
Texas leads the nation in installed wind (~20% of U.S. total)

Record wind generation:
11,467 MW on 9/13/15

36.1 million MWh in 2014

Majority of wind is in West Texas, with top production in shoulder months and overnight
Changing Resource Mix

Installed Capacity by Unit Type

Late 1990s
• Current Ancillary Services were designed for this world

2015
• The world has already changed significantly

The Future
• More renewables, especially distributed

ERICOT
Potential Impacts of Environmental Regulations

ERCOT reviewed potential impacts of new and pending environmental regulations on grid reliability.

- Included CSAPR, MATS, Regional Haze, Clean Water Act Section 316(b), Ash Disposal Regulations & Clean Power Plan

Studies indicate:

- Half of coal-fired generation capacity (about 9,000 MW) is likely to retire by 2022.
- Retirement of units serving urban areas may result in localized reliability issues.
- Growth in renewable resources may require development of new or additional generation and transmission facilities and technologies to manage operational issues (e.g., ramping, inertia, etc.).
- Costs of compliance could drive up consumer energy costs as much as 20%.
  - Does not include costs of transmission upgrades or other investments to support grid reliability

ERCOT and other grid operators support incorporation of “safety valve” provisions to allow sufficient flexibility to maintain system reliability.
Market Participants

Who are the Players?

- QSE: Qualified Scheduling Entities
- LSE: Load Serving Entities
- TSP: Transmission Service Providers
- DSP: Distribution Service Providers
- Resource Entity: Resource Entities
ERCOT’s Security Constrained Unit Commitment

Input Data
Network Model
>= 60 KV Offers/Bids Outages

Initialize Watch List Transmission Constraints
(Generic Transmission Constraints, Frequently Occurring Constraints from history)

SCUC
Commitment and Dispatch

Power Flow & Contingency Analysis
(N-1 Security)

Violations, Linearized Transmission Constraints (MW)

Converged?

Yes
STOP

No

Combined Cycle Resources:
• SCUC: Modeled as Configurations (1x0, 1x1, etc.)
• Power Flow: Modeled as physical components
MIP Gap averages around 0.01 % (relative), $100,000 (absolute)
Outliers in shoulder months
Some Ongoing Initiatives

- Future Ancillary Services (ERCOT)
- Improve Scarcity Pricing
  - Operational Reserve Demand Curves (ERCOT)
- Real-Time Energy + Ancillary Service Co-Optimization
- Multi-Interval Real-Time Market
- Minimize Uplift by incorporating Startup and Minimum Energy Costs into Locational Marginal Prices (LMPs)
  - Pricing Run by relaxing limits
  - Extended LMP?
- Corrective Dispatch
  - Default is preventive dispatch for Base Case and Contingency constraints (ERCOT)
  - If Special Protection Schemes or Remedial Action Plan present, ignore Transmission Constraint if developed from Power Flow/Contingency Analysis (SPS and RAP developed in off-line studies) (ERCOT)
  - (Future) Transmission Switching as part of SCUC to economically resolve congestion
  - (Future for Real-Time) Evaluate if ramping capability available to resolve Transmission Constraint

Addressing impact of Zero Marginal Cost Resources – How?
Increasing penetration of intermittent resources, including DERs, will require realigning AS to meet the changing technical needs of the ERCOT System

Goals of Future Ancillary Services:
- Flexible suite of resources to accommodate ramps
- Remove barriers to entry for new resource types that could meet fundamental requirements for AS
- Improve efficiency in procurement
- Market-based, technology-neutral
- Based on fundamental needs of the system, not resource characteristics
- Unbundled services

3-year timeline to implementation
Proposed Future Ancillary Services

<table>
<thead>
<tr>
<th>Current</th>
<th>Proposed</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Regulation Up</td>
<td>Regulation Up</td>
<td>Mostly unchanged</td>
</tr>
<tr>
<td>Fast-Responding Regulation Up</td>
<td>Fast-Responding Regulation Up</td>
<td></td>
</tr>
<tr>
<td>Regulation Down</td>
<td>Regulation Down</td>
<td></td>
</tr>
<tr>
<td>Fast-Responding Regulation Down</td>
<td>Fast-Responding Regulation Down</td>
<td></td>
</tr>
<tr>
<td>Responsive Reserves</td>
<td>Fast Frequency Response 1</td>
<td>59.8 Hz, Limited duration</td>
</tr>
<tr>
<td></td>
<td>Fast Frequency Response 2</td>
<td>59.7 Hz, Longer duration</td>
</tr>
<tr>
<td>Non-Spin Reserves</td>
<td>Primary Frequency Response</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Contingency Reserves 1</td>
<td>SCED dispatch</td>
</tr>
<tr>
<td></td>
<td>Contingency Reserves 2</td>
<td>Manual dispatch (10 min.)</td>
</tr>
<tr>
<td></td>
<td>Supplemental Reserves 1</td>
<td>SCED dispatch</td>
</tr>
<tr>
<td></td>
<td>Supplemental Reserves 2</td>
<td>Manual dispatch (30 min.)</td>
</tr>
<tr>
<td></td>
<td>Synchronous Inertial Response</td>
<td>Ongoing development</td>
</tr>
</tbody>
</table>

HEPG Houston, 2015
Real-Time Prices on September 13th, 2015:
Impact of zero marginal cost resources

<table>
<thead>
<tr>
<th>15 minute Settlement Interval</th>
<th>Houston 345 KV Hub ($/MWh)</th>
<th>North 345 KV Hub ($/MWh)</th>
<th>Houston Load Zone ($/MWh)</th>
<th>North Load Zone ($/MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:00 - 0:45</td>
<td>16.08</td>
<td>16.08</td>
<td>16.08</td>
<td>16.08</td>
</tr>
<tr>
<td>0:45 - 1:00</td>
<td>14.49</td>
<td>14.49</td>
<td>14.49</td>
<td>14.49</td>
</tr>
<tr>
<td>1:00 - 1:15</td>
<td>8.25</td>
<td>8.25</td>
<td>8.25</td>
<td>8.25</td>
</tr>
<tr>
<td>1:15 - 1:30</td>
<td>0.06</td>
<td>0.06</td>
<td>0.06</td>
<td>0.06</td>
</tr>
<tr>
<td>1:30 - 1:45</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>:</td>
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<td>&lt;=0</td>
<td>&lt;=0</td>
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<tr>
<td>5:15 - 5:30</td>
<td>-1.11</td>
<td>-1.11</td>
<td>-1.11</td>
<td>-1.11</td>
</tr>
<tr>
<td>5:30 - 5:45</td>
<td>-8.52</td>
<td>-8.52</td>
<td>-8.52</td>
<td>-8.52</td>
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<tr>
<td>5:45 - 6:00</td>
<td>-1.13</td>
<td>-1.13</td>
<td>-1.13</td>
<td>-1.13</td>
</tr>
<tr>
<td>:</td>
<td>&lt;=0</td>
<td>&lt;=0</td>
<td>&lt;=0</td>
<td>&lt;=0</td>
</tr>
<tr>
<td>8:15 – 8:30</td>
<td>8.92</td>
<td>8.92</td>
<td>8.92</td>
<td>8.92</td>
</tr>
</tbody>
</table>
Solar Potential & Grid-Scale Solar Queue

ERCOT Solar Installations by Year (as of July 2015)

- Cumulative MW Installed
- IA Signed-Financial Security Posted
- IA Signed-No Financial Security

Data Summary:
This data provides monthly average and annual average daily total solar resource averages over surface cells of 0.038 square degrees in both latitude and longitude, or nominally 4 km in size. The inclination values represent the resource available to horizontal flat plate collectors. The data are created using the Penn State algorithms for cloud identification and properties, the MMAC radiative transfer model for clear sky calculations and the SAMRE model for cloudy sky calculations. The data are averaged from hourly model output over 8 years (2005-2012). CRE2 data provided by NREL.

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.

October 1, 2015
HEPG Houston, 2015
DERs on the horizon

- More PV is coming – we just don’t know how much or how fast
- 30% federal solar investment tax credit:
  - Residential credit expires completely 12/31/16
  - Commercial credit reduces to 10% after 12/31/16
- But PV prices keep plummeting….  

Meanwhile, efficiency keeps improving and costs are coming down for:
  - Firm backup/emergency DG
  - Distribution-level storage devices
On-peak DR Potential by Customer Type

- Based on customer class breakdown in competitive choice areas and extrapolated to ERCOT
- Large C&I are IDR Meter Required (>700kW)

Wednesday
March 9, 2011
5:15 PM
ERCOT Load: 31,262 MW
Temperature in Dallas: 64°

Residential 27.4%
~8,500 MW

Small Commercial 28.9%

Large C&I 43.7%

Residential 51.2%
~35,000 MW

Small Commercial 25.2%

Large C&I 23.7%

3/9/2011 IE 17:15
8/3/2011 IE 17:00

5:00 PM
ERCOT Load: 68,416 MW
Temperature in Dallas: 109°

Approx. 37,000 MW of weather sensitive load (54% of peak)

- ERCOT staff is working on Aggregated Load Response (ALR) enablement with market participants in both NOIE and competitive choice areas
4CP Transmission Tariff Demand Response

Examples of peak response during summer 2014

• For large loads (≥700kW in peak demand, transmission charges are based on usage during peak system intervals in each of the four summer months

• These tariffs are a strong demand response incentive: each MW reduced saves >$40,000 in transmission charges in following calendar year

ERCOT analysis of loads identified as changing behavior on 4CP actual and candidate days
Future Trends

Blurring lines between Consumers and Suppliers!!
Typical Distribution Grid Topology

Distribution Grid
- Predominantly Radial Operation
- Urban Areas more meshed
- Limited telemetry relative to what is available at transmission level
- More resilient to unbalanced 3 phase flow
- Mainly Designed for power flow from transmission to consumer

ERCOT Transmission Grid \( \geq 60 \text{ KV} \)

ERCOT Distribution Grid \(< 60 \text{ KV} \)
• DERs potentially include:
  – Rooftop solar
  – Fossil fuel generators
  – Storage devices
  – Fuel cells
  – Combinations of the above at single or multiple points of interconnection at <60kV

• ERCOT published a concept paper on 8/20/15, detailing two primary goals:
  – Collection of data that ERCOT anticipates it will need to ensure grid reliability as DER penetration increases
  – Development of a market framework that can better accommodate DERs and enable effective, efficient market participation

URL:
http://www.ercot.com/content/wcm/key_documents_lists/72784/DER_Whitepaper_082015.docx
New Opportunities: Smart Inverters

Smart Inverter functions (future IEEE standards, CPUC Rule 21,…)

a. Two-way communication/control between DER and remote entity
b. Anti-Islanding Protection
c. Low and High Voltage Ride-Through
d. Low and High Frequency Ride-Through
e. Dynamic Volt-Var Operation
f. Ramp Rates
g. Fixed Power Factor
h. Soft Start Reconnection
## DER Types

<table>
<thead>
<tr>
<th>Features</th>
<th>DER Minimal</th>
<th>DER Light</th>
<th>DER Heavy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Settled at:</td>
<td>Load Zone SPP</td>
<td>Price at Local electrical bus(es)</td>
<td>Logical Resource Node (price at Local electrical bus(es))</td>
</tr>
<tr>
<td>Energy Market Participation</td>
<td>Self-responding</td>
<td>Self-responding</td>
<td>SCED-dispatched</td>
</tr>
<tr>
<td>Ancillary Service Market Participation</td>
<td>Not eligible</td>
<td>Not eligible</td>
<td>Eligible</td>
</tr>
<tr>
<td>Aggregation Allowed?</td>
<td>N/A</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Metering Required</td>
<td>Single meter OK (15-minute revenue quality) at POI</td>
<td>Separate (dual) metering for Generation and native Load</td>
<td>Separate (dual) metering for Generation and native Load</td>
</tr>
<tr>
<td>Telemetry or telemetry-light to and from ERCOT</td>
<td>Not required</td>
<td>Real-time or near real-time with multiple attributes</td>
<td>Real-time or near real-time with multiple attributes</td>
</tr>
<tr>
<td>COP, Outage Schedule, Offers/Bids, etc.</td>
<td>N/A</td>
<td>Possible “light” version required</td>
<td>Required</td>
</tr>
<tr>
<td>CRR/PTP Implications</td>
<td>None</td>
<td>None</td>
<td>Yes</td>
</tr>
</tbody>
</table>
• ERCOT has developed a concept paper to help integrate DERs into the wholesale market
• Main concept is to allow DERs to be settled at local (Nodal) prices instead of zonally-averaged prices
• Would provide proper incentives for DER locating and could contribute to local congestion management

Hypothetical DER configuration: Generator and storage device combination metered separately from native and auxiliary load; DER mapped to one or more Load Points in the transmission network model
<table>
<thead>
<tr>
<th>Metering Type</th>
<th>Description</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unidirectional</td>
<td>Measures Load (consumption) only.</td>
<td>If DG is present, it is not accounted for in this type of metering.</td>
</tr>
<tr>
<td>Traditional Net Metering</td>
<td>Single-channel non-directional. Single data point representing net Load minus net on-site generation over a billing period, typically monthly (could be a negative number).</td>
<td>Disallowed in competitive choice areas of ERCOT by PUC Rule §25.213.</td>
</tr>
<tr>
<td>Bi-Directional</td>
<td>Two data points for each 15-minute interval: measures net in-flow to the Service Delivery Point (i.e., may be reduced by on-site DG), and net exports to the grid from the Service Delivery Point.</td>
<td>Required by PUC Rule §25.213 for competitive choice areas. Suitable for DER Minimal.</td>
</tr>
<tr>
<td>Dual Metering</td>
<td>Two bi-directional meters, two data points for each 15-minute interval, configured to measure gross native Load and gross generation behind the Service Delivery Point. This is a new concept in competitive choice areas.</td>
<td>Would enable DER Light and DER Heavy by allowing Load to be settled at LZ SPP and generation to be settled at Nodal price. Also could allow DSP to bill customer based on gross consumption (assuming permitted by tariff) and would enable LSE/REP to pay customer for gross generation. This metering scenario is in place for customers with DG in at least one NOIE territory in ERCOT.</td>
</tr>
</tbody>
</table>
From the diagram below, for a given 15-minute Settlement Interval X, the two meters will each provide net outflow and inflow readings.

Meter 1 reads:
- A for net outflows and,
- B for net inflows

Meter 2 reads:
- C for net outflows and,
- D for net inflows

For a given 15-minute Settlement Interval X:
- Energy consumption by Native Load + Aux Load = B+C-(A+D)
- Energy generated by DER = C
- Energy consumed for charging storage = D
Integrating Demand Response into a DER involves some issues specific to ERCOT.

The Public Utility Commission Rule that established ERCOT’s Nodal Market Design requires:
- Generation to be settled at a (Nodal) Locational Marginal Price
- Load to be settled at the weighted average price of all LMPs in a Load Zone
  - Exception: Load (energy) used to charge a storage device
  - There are 4 competitive Load Zones in ERCOT: North, South, West and Houston

This implies that DR cannot be part of a DER that is being settled at a Nodal price, absent a Rule change.

For a DER to be settled at LMP, gross Load must be separately metered from the gross generation (and any storage load if storage is present).
Addressing DER impact on ERCOT ISO functions

- **ERCOT proposal is NOT to model the distribution network**
  - Currently insufficient infrastructure to determine sufficiently accurate Real-Time state of distribution grid (network parameters, telemetry, etc.)
  - Proposal is to obtain information on DER (capacity, location, etc.) from the distribution utility and use this information for forecasting, planning, and map the DER to closest load in the transmission grid for pricing

- **Storage**
  - Develop new model
  - Optimizing State of Charge (ISO function or responsibility of Resource or both?)

- **Forecasting renewable generation (Solar) in the distribution grid**
  - Challenge is when storage is also present behind the same meter as solar

- **Aggregated DER**
  - Modeling – ERCOT proposal based on combined cycle model
    - ERCOT current proposal allows for multiple generation technologies (Solar, Solar+Storage, etc.) to make up a given DER aggregation
  - Managing aggregation membership (move-in, move-out)
  - Measurement & Validation
    - Required for ensuring telemetry of aggregation (virtual in many cases) is sufficiently accurate
    - Big Data Analytics & statistical sampling
Questions?

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