FEATURES OF ELECTRICITY EXCHANGES: U.S. AND CENTRAL AMERICA

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• Argonne is part of the U.S. Department of Energy (DOE) laboratory complex of 17 National Laboratories
• Managed by UChicago Argonne, LLC
• Main site: 30km southwest of Chicago, Illinois, USA
• Diverse basic and applied research portfolio

OPERATING BUDGET IN 2016
$760M

EMPLOYEES IN 2016
3,300+

EXTERNAL USERS OF RESEARCH FACILITIES
6,500+
ARGONNE HAS EXTENSIVE PORTFOLIO IN ELECTRICITY MARKETS/INTERCONNECTIONS

- Review of current and proposed market designs
- What are the new fundamental challenges and promising solutions to create better incentives and improved market design?
- How to achieve capacity adequacy and revenue sufficiency in the long-run?
- How to ensure and incentivize flexibility in short-run operations?
ARGONNE HAS EXTENSIVE PORTFOLIO IN ELECTRICITY MARKETS/INTERCONNECTIONS

- Developing and using our own tools with unique capabilities to address critical issues (GTMax, EMCAS, CHEERS, etc.); models used around the world

- Using commercial tools (PLEXOS, AURORA) for quick turn-around analyses
ARGONNE TOOLS ARE USED FOR REGIONAL INTEGRATION/POWER MARKET STUDIES

Master Plan for Central Asia Power System (Kazakhstan, Kyrgyz Republic, Tajikistan, Uzbekistan)

Source: Fichtner 2012
ARGONNE TOOLS ARE USED FOR REGIONAL INTEGRATION/POWER MARKET STUDIES

Kenya
Ethiopia
New Transmission Line

East Africa (AFDB)

Myanmar (ADB)

South Korea (KPX)

Caucusus (USAID)
Regional Electricity Market (REM) provides for better utilization of hydro power for ancillary services. REM leads to significant savings in all seasons and under all hydrological conditions: total benefits of the regional market operation reaching up to 10-15% in certain periods. Considerable volume of power transactions among the utilities in the region. Potential zones of congestion and higher LMPs identified. Several follow-on studies with Argonne tools (Price Waterhouse Coopers) funded by EU.
U.S.: ONE COUNTRY – MANY POWER POOLS/RTOS

- Colors: Centralized wholesale markets
- White: Traditional bilateral wholesale markets

REGIONAL TRANSMISSION ORGANIZATIONS

THIS MAP WAS CREATED USING ENERGY VELOCITY, NOVEMBER 2015
U.S.: ONE COUNTRY – MANY POWER POOLS/RTOS

- Common features for most markets with variations in details
  - Energy markets: Day-ahead, real-time
  - Ancillary services
  - Capacity markets
  - Financial transmission rights
  - Regional generation and transmission expansion planning processes to ensure future reliability

- In addition, participants engage in bilateral contracting on Intercontinental Exchange (ICE), via broker, or direct (dominant in non-RTO regions)

<table>
<thead>
<tr>
<th>Market</th>
<th>Peak Load (GW)</th>
<th>Installed Cap (GW)</th>
<th>Annual Volume (TWh)</th>
<th>Transmission (Miles)</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>PJM</td>
<td>165</td>
<td>176</td>
<td>792</td>
<td>82,550</td>
<td>1400 generators, 65 million people in 13 States; 990+ members</td>
</tr>
<tr>
<td>MISO</td>
<td>127</td>
<td>175</td>
<td>594</td>
<td>65,800</td>
<td>6,500 generators, 42 million people in 15 States, 440 members</td>
</tr>
</tbody>
</table>
U.S.: SIMILARLY, RETAIL SIDE VARIES WIDELY AS WELL

- Colors: Retail choice
- White: Traditional vertically integrated approach
1. In 2002, the Commission issued the Standard Market Design (SMD) Notice of Proposed Rulemaking (NOPR) in this proceeding. For the reasons given below, we are exercising our discretion to terminate this proceeding.
U.S.: ONE COUNTRY – MANY REGIONAL RESOURCES

COAL

NATURAL GAS

GEOTHERMAL

Source: EIA 2017
U.S.: ONE COUNTRY – MANY REGIONAL RESOURCES

United States - Land-Based and Offshore Annual Average Wind Speed at 100 m

WIND

Direct Normal Irradiation (DNI)

SOLAR

Source: EIA 2017; NREL 2017; DOE 2017

HYDRO
U.S.: ONE COUNTRY – MANY REGIONAL INCENTIVES

Renewable Portfolio Standard Policies

www.dsireusa.org / February 2017

29 States + Washington DC + 3 territories have a Renewable Portfolio Standard (8 states and 1 territories have renewable portfolio goals)

Source: http://www.dsireusa.org
U.S.: ONE COUNTRY – MANY REGIONAL GENERATION MIXES

Share of Total Generation by Fuel Type, 2010-2014

Source: FERC 2016
# General Differences in Electricity Markets

## United States
- Built into existing system operators (ISOs)
  - Emphasize physics of the power system
  - Short-term system operation
  - ISOs do not own transmission system
- Market design elements (United States)
  - Day-ahead market (ISO - hourly)
  - Real-time market (ISO - 5 min)
  - Complex bids/ISO UC
  - Locational marginal prices
  - Co-optimization of energy and reserves

## Europe
- Introduced new power exchanges (PXs)
  - Emphasize markets and economics
  - Includes long-term contracts
  - TSOs typically own transmission system
- Market design elements (Europe)
  - Day-ahead market (PX)
  - Real-time balancing (TSO)
  - Simple bids/generator UC
  - Zonal pricing/market coupling
  - Sequential reserve (TSOs) and energy markets (PXs)
U.S. MARKETS DETERMINE DAY-AHEAD AND REAL-TIME PRICE OF ENERGY BY NODE

Using complex ISO Unit commitment/dispatch model to clear markets and manage transmission congestion
U.S. MARKETS OFFER DIFFERENT PRODUCTS: ANCILLARY SERVICES

- Operating Reserves
  - Continuous Deployment
    - Regulation Reserve (up/down)
  - Contingency Deployment
    - Flexiramp Reserve (up/down)
    - Spinning Reserve (up)
    - Non-Spinning Reserve (up)
U.S. MARKETS OFFER DIFFERENT PRODUCTS: ANCILLARY SERVICES

<table>
<thead>
<tr>
<th></th>
<th>Spinning Reserves</th>
<th>Non-spinning Reserves</th>
<th>Regulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAISO</td>
<td>Spinning</td>
<td>Non-spinning</td>
<td>Regulation-up, Regulation-down, Regulation Mileage-up, Regulation Mileage-down</td>
</tr>
<tr>
<td>ERCOT</td>
<td>Responsive</td>
<td>Non-spinning</td>
<td>Regulation-up, Regulation-down</td>
</tr>
<tr>
<td>ISO-NE</td>
<td>Ten-minute Synchronized, Thirty-minute Non-synchronized</td>
<td>Thirty-minute Operating</td>
<td>Regulation</td>
</tr>
<tr>
<td>MISO</td>
<td>Spinning</td>
<td>Supplemental</td>
<td>Regulation</td>
</tr>
<tr>
<td>NYISO</td>
<td>Ten-minute Spinning, Thirty-minute Spinning</td>
<td>Ten-minute Non-synchronized, Thirty-minute Non-synchronized</td>
<td>Regulation</td>
</tr>
<tr>
<td>PJM</td>
<td>Synchronized</td>
<td>Primary</td>
<td>Regulation</td>
</tr>
<tr>
<td>SPP</td>
<td>Spinning</td>
<td>Supplemental</td>
<td>Regulation-up, Regulation-down</td>
</tr>
</tbody>
</table>

Regulation Market Size ($Millions)

Spinning Reserve Market Size ($Millions)

Source: Argonne 2016
Per FERC order (890/1000), RTOs coordinate and administer a centralized regional transmission planning process.

Several RTOs adopted a competitive solicitation process to identifying viable transmission solutions.

- Typically, transmission owners submit their transmission construction plans to RTO for evaluation and possible inclusion in the RTO Transmission Expansion Plan.
- After evaluation, projects identified as the best solution for a particular issue or opportunity are included in the report and recommended for approval by the RTO Board of Directors.

Source: FERC 2016
LONG-TERM PLANNING: GENERATION

- Mandatory reliability standards developed by NERC and approved by FERC
- NERC delegated authority to monitor and enforce to its 8 regional entities
- Markets must comply with all approved standards
- In states with vertically integrated companies, States oversee a utility’s resource planning and procurement

- RTOs/FERC have challenge of aligning transmission planning with procurement of market-driven solutions (generation, demand response) to induce the most efficient outcome
- Struggle between the states: had historically regulatory responsibility for assuring generation resource adequacy; and still have in non-RTO regions
LONG-TERM PLANNING: GENERATION: CAPACITY MECHANISMS

- Capacity markets: PJM, MISO, ISO-NE, NYISO
- Capacity obligation: CAISO
- Integrated resource planning in non-RTO/ISO regions (vertically integrated utilities)

<table>
<thead>
<tr>
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<th>PJM</th>
<th>MISO</th>
<th>NYISO</th>
<th>ISO-NE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Procurement</td>
<td>Reliability Pricing</td>
<td>Resource Adequacy Requirement</td>
<td>Installed Capacity Market</td>
<td>Forward Capacity Market</td>
</tr>
<tr>
<td>Framework</td>
<td>Model (RPM)</td>
<td>(RAR)</td>
<td>(ICAP)</td>
<td>(FCM)</td>
</tr>
<tr>
<td>Most Recent</td>
<td>167,003.7 MW (Cleared in</td>
<td>136,912 MW (Cleared in PRA for</td>
<td>3290 MW / 2619.4 MW (Cleared in</td>
<td>33,712 MW (Cleared in FCA for</td>
</tr>
<tr>
<td>Volume Cleared*</td>
<td>BRA for 17/18 DY**)</td>
<td>14/15 DY**)</td>
<td>Summer 14 / Winter 13-14 Strip</td>
<td>17/18 CCP**)</td>
</tr>
</tbody>
</table>
LONG-TERM PLANNING: GENERATION

Each RTO establishes planned reserve margin; compares with actual reserve margin to see how well generation resource planning processes are ensuring long-term resource adequacy and reliability (1 day in 10 years LOLE)

Processes include: Market-driven resource adequacy (capacity markets), administrative capacity mechanisms (capacity obligation); dynamic operating reserve demand curves, etc.

Figure 16: Planned and actual reserve margins, 2010-2014. Source: FERC 2016
MEXICO’S NEW POWER MARKET

- State-owned CENACE manages the grid as an ISO and also runs the wholesale electricity market (started in 2016)
- Ministry of Energy and the Comisión Reguladora de Energía (CRE) has regulatory and supervisory authority; CRE will be responsible for setting tariffs for transmission, distribution and basic retail services

Source: Chadbourne 2014
MEXICO’S NEW POWER MARKET

- Includes day-ahead and real-time market, as well as mid-term and long-term energy and capacity auctions
  - The Mid-Term auction is carried out yearly with the auctioned products to be delivered over the next three years
  - The Long-Term auction considers delivery periods of up to 20 years.
- Short-term, bilateral financial rights trading is available for hedging purposes
- Clean energy certificate market targeted for 2018
- Discussion to create a NERC-affiliated Electric Reliability Organization for closer coordination with U.S. reliability standards

Source: EIA 2016
IN SUMMARY

- U.S. power markets keep evolving; upcoming FERC conference on attempt to reconcile State policies with market operations

Challenges

- Renewables and impact on prices and revenue sufficiency of existing fleet
- Better coordination across RTOs/ISOs
- Implementation of intra-day balancing market
- Higher time-resolution of real-time markets

- A step-by-step implementation might be the most prudent pathway forward
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