Capacity Market Design: The PJM Experience

USEA EMI Webinar:
“Capacity Markets for Power Generation: Key Features and Potential Application to Southeast Europe

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PJM Interconnection
PJM – Primary Focus

Reliability
- Grid Operations
- Supply/Demand Balance
- Transmission monitoring

Market Operation
- Energy
- Capacity
- Ancillary Services

Regional Planning
- 15-Year Outlook
**Key Statistics**

<table>
<thead>
<tr>
<th>Category</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Member companies</td>
<td>1,010+</td>
</tr>
<tr>
<td>Millions of people served</td>
<td>65</td>
</tr>
<tr>
<td>Peak load in megawatts</td>
<td>165,492</td>
</tr>
<tr>
<td>MW of generating capacity</td>
<td>180,086</td>
</tr>
<tr>
<td>Miles of transmission lines</td>
<td>84,236</td>
</tr>
<tr>
<td>2018 GWh of annual energy</td>
<td>806,546</td>
</tr>
<tr>
<td>Generation sources</td>
<td>1,379</td>
</tr>
<tr>
<td>Square miles of territory</td>
<td>369,089</td>
</tr>
<tr>
<td>States served</td>
<td>13 + DC</td>
</tr>
</tbody>
</table>

- 26% of load in Eastern Interconnection
- 20% of transmission assets in Eastern Interconnection

PJM as Part of the Eastern Interconnection

As of 1/2019

21% of U.S. GDP produced in PJM
PJM’s energy mix is more diverse than ever.

Gas, 31.2%
Nuclear, 34.5%
Coal, 28.7%
Renewables, 5.4%
Oil, 0.2%
2005-2018 PJM Average Emissions

CO\(_2\) lbs/MWh

SO\(_2\) and NO\(_x\) lbs/MWh

- Carbon Dioxide
- Sulfur Dioxides
- Nitrogen Oxides
Evolution of Markets

PJM GRID OPERATIONS
Member to Member

PJM MARKETS
Real-Time Market
Ancillary Services

FINANCIAL MARKETS
Options
Swaps
Spreads

PJM Long-Term FTR Market
Reliability Pricing Model

HEAVY
RTO INVOLVEMENT
LIGHT
Some Context… PJM vs. Southeast Europe

Similarities

• Generation resources distant from load
• Mix of IPPs vs. legacy publicly-owned generation
• Long Term Purchase Power Agreements Available and Respected in the Dispatch
Some Context…PJM vs. Southeast Europe

Key Differences

• No one resource type (gas, nuclear, hydro coal) or owner dominant (PJM)
• Policies driven by both state and federal regulators (PJM)
• Most generation dependent on market revenues for recovery of costs
• Locational marginal price energy market
Capacity Market Options and their applications in the US:

• **Capacity Auctions**—PJM Model
• **Decentralized Obligation to Contract Capacity**—
  – MISO Model/Original PJM Model Before Retail Choice
• **Bundled purchase of capacity and energy**
• **Fixed long term contracts to agents to procure capacity**
  – Municipal Purchasing Authorities/ Fixed Resource Requirements
• **Strategic procurement of reserves in real time**
**PJM Forward Capacity Auction Goals:**

- Send long term locational investment signal
- Send forward closure signal for inefficient units
- Provide competition in procurement of capacity
- Provide revenue stability to lower risk premiums in energy markets
- Address the ‘hurdle rate’ for introduction of new technologies and demand side resources
- Ensure non-discrimination as between supply and demand side resources
Capacity Market Key Elements:

• 3 Year Forward Auction
• Call right on energy during emergencies
• Locational Pricing Based on Transmission Constraints
• All Resource Participation—Pricing to set future investment signal
• Incremental Auctions for Adjustments to Load
• Year round obligation with penalties for non-performance during emergencies
• Market Power mitigation
Long Term PPAs vs. the Capacity Market

- Capacity Market provides a price signal to inform and value long term arrangements
- ‘Contract for Differences’ the principle tool to incorporate capacity market prices
- Three year forward requirement provides reasonable forward commitment while avoiding advent of uneconomic contracts driven by market design
Capacity Market Evolution in PJM:

- Traditional Regulation—Capacity obligation in retail rate base
- Retail Choice—Obligation on new LSEs, development of daily capacity market
- RPM—Three Year Forward Market
- Demand Response and Energy Efficiency Rules
- Capacity Performance—Clarifying the Obligation
- Addressing State Subsidies—Price Suppression vs. a Natural Smaller Market
RPM Structure

- **Base Residual Auction**
- **First Incremental Auction** in May
- **Second Incremental Auction** in July
- **Third Incremental Auction** in February

**Conditional Incremental Auction**

May be scheduled at any time prior to Delivery Year (DY)

**EFORd Fixed**

Delivery Year

- **Ongoing Bilateral Market**

Dimensions: 959.8x540.0

Page: 15

Note: This diagram provides a visual representation of the RPM (Reliability Pricing Model) structure, detailing the timing and sequence of various auctions and increments within a three-year delivery year.
What is the VRR?

The Variable Resource Requirement (VRR) Curve is a downward sloping demand curve that relates the maximum price for a given level of capacity resource commitment relative to reliability requirements.

- The price is higher when the resources are less than the reliability requirement and lower when the resources are in excess.
- VRR Curves are defined for the PJM RTO and for each constrained Locational Deliverability Area (LDA) modeled within the PJM region.
A VRR Curve is defined for the PJM Region & each LDA
Supply Resources in RPM

- **Generation**
  - Existing/Planned
  - Internal/External

- **Demand Resources**
  - Existing/Planned

- **Energy Efficiency Resource**
  - Existing/Planned

- **Aggregate Resource**
  - Existing/Planned

- **Qualifying Transmission Upgrade**
  - Existing/Planned
Capacity Market Results
Total=37,000 MW
Since 2007

Competitive Generation Investment

<table>
<thead>
<tr>
<th>Year</th>
<th>Capacity in Service</th>
<th>Capacity Cleared</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012/2013</td>
<td>1,108</td>
<td>4,054</td>
</tr>
<tr>
<td>2013/2014</td>
<td>1,320</td>
<td>1,837</td>
</tr>
<tr>
<td>2014/2015</td>
<td>415</td>
<td>708</td>
</tr>
<tr>
<td>2015/2016</td>
<td>4,899</td>
<td>4,293</td>
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<tr>
<td>2016/2017</td>
<td>4,282</td>
<td>7,142</td>
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<td>2017/2018</td>
<td>4,395</td>
<td>5,927</td>
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<td>2018/2019</td>
<td>2,954</td>
<td>7,244</td>
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<tr>
<td>2019/2020</td>
<td>5,374</td>
<td></td>
</tr>
<tr>
<td>2020/2021</td>
<td>2,389</td>
<td></td>
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<tr>
<td>2021/2022</td>
<td>893</td>
<td></td>
</tr>
</tbody>
</table>
2021/2022 RPM Base Residual Auction RTO Clearing Prices

$/MW-Day

2007/08: $40.80
2009/10: $102.04
2011/12: $16.46
2013/14: $27.73
2015/16: $136.00
2017/18: $164.77
2019/20: $100.00
2021/22: $76.53

www.pjm.com
The Good

- Market has attracted new investment and allowed for rapid turnover and de-carbonization of the fleet
- Market has encouraged development of new demand side technologies as alternatives to thermal generation
- Market has provided a home for renewables and hydro subject to deration to reflect variability
**The Challenges**

- Pricing very sensitive to changes in grid topology
- Potential dampening of impact of shortage pricing
- “All MWs the Same” does not account for other policy goals
- Prices have been well below authorized market mitigation caps
- Seasonal vs. annual procurements
- Subsidized resources competing with non-subsidized resources
- Impact on long term contracting
LET’S TALK…

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