Why Are We Talking About Capacity Markets?

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So, why ARE we talking about capacity markets?

Reliability

Goal of power system is to ensure reliable delivery of electricity at lowest cost to consumers

Market complexities → “Missing Money” → concerns over resource adequacy
• Market “Failure” and resource adequacy

• Capacity market design considerations for high variable generation (VG) systems

• Towards an optimum capacity market design
Electricity markets are uniquely complex

**Fundamental Market Issues**
- Demand curve not visible to supplier
- Reliability is public good
- Missing markets
- Uncertainty over future economic and policy factors
- Lumpiness (costs and time)
- Omission of externalities
- Market power

**Amplifiers**
- Low- or zero-marginal cost generation
- Out-of-market subsidies
- Lack of ample and cost-effective storage
- VG variability and uncertainty

**Regulatory Response**
- Policy-based reliability requirements
- Administrative pricing rules

Electricity markets are fundamentally different than any other market
United States observations reveal this complexity

- ISO/RTO market monitor reports noting low energy prices, driven by historically low natural gas prices and demand (and wind/solar to lesser degree)
- Nuclear premature proposed/planned shut downs due to insufficient revenues, resulting in subsidies

Are these symptoms of a deeper problem or an appropriate response to an evolving system?
Current market designs to ensure revenue sufficiency

1) Supplement energy-only market with A/S products and scarcity pricing

2) Forward capacity markets or capacity payments

3) Power purchase agreements or other contracting approaches paid for with retail rates/cost recovery

Strategies to deal with this problem depend on existing market designs, and it remains unclear if/which of these can provide proper incentives to ensure longer-term reliability
What is Resource Adequacy (RA)?

- Having sufficient resources (generation, DR, storage) to supply all demand at a future date/time period/location
- Measured with reliability-based metric(s) that account for system performance
  - Set by policy: often 1 day/10 years loss of load, but any reliability target can be chosen (1d/y, 1d/20y, 4h/10y)
Preferred RA metric is based on LOLP

At the same load level, LOLE is reduced

Additional load that can be served to bring the LOLE back to the target

= ELCC
(Effective Load Carrying Capability)

Milligan et al. 2016)
Recommended approaches for RA

- Adopt a reliability target *such as 1d/10y*
- Derive the percentage reserve margin that corresponds to the reliability target
- Use ELCC to determine any generator’s contribution
  - Wind and solar from net load time series
  - Conventionals with forced outage rates
- Use multiple years of data, and revisit as more data becomes available
- Interconnection or regional analysis
Linking RA with markets

• Ideally want to map LOLP-based methods to the markets to achieve
  o Optimal quantity of “sufficient” capacity
  o Revenue sufficiency

• US capacity markets have used various ‘true-ups’ with LOLP
  o E.g., NYISO – acquires installed capacity (ICAP) based on UCAP estimates (unforced capacity)

• ERCOT energy-only market includes LOLP in its reserve scarcity pricing (Operating Reserve Demand Curve, or ORDC)
Outline

• Market “Failure” and resource adequacy

• Capacity market design considerations for high VG systems

• Towards an optimum capacity market design
Declining CV with VG penetration level

Solar PV sees a similar decline, with marginal capacity values approaching 0 around 20% energy penetration (e.g., Munoz and Mills 2016)
...And inconsistent methods for calculating CV

<table>
<thead>
<tr>
<th>Operator</th>
<th>Geographic Resolution</th>
<th>Sampling Period</th>
<th>Intra-annual distinction</th>
<th>Historical Window</th>
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<tbody>
<tr>
<td>CAISO</td>
<td>Site-specific</td>
<td>Summer afternoons, Winter evenings</td>
<td>Monthly</td>
<td>3 years</td>
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<tr>
<td>ERCOT</td>
<td>System-wide (solar), Coastal vs non-coastal (wind)</td>
<td>Top 20 load hours</td>
<td>Summer, Winter</td>
<td>3 years (solar) 10 years (wind)</td>
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<tr>
<td>MISO</td>
<td>Nodal disaggregated from system-wide</td>
<td>Top 8 load hours</td>
<td>Annual</td>
<td>11 years (wind)</td>
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<tr>
<td>NE-ISO</td>
<td>Site-specific</td>
<td>Summer afternoons, Winter evenings, shortage events</td>
<td>Summer, Winter</td>
<td>5 years</td>
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<tr>
<td>PJM</td>
<td>Site-specific</td>
<td>Summer afternoons</td>
<td>Summer only</td>
<td>3 years</td>
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Increased need for flexible capacity

NREL’s Eastern Renewable Generation Integration Study (2016)
Market designs must incentivize the building of resources with the flexibility attributes for long-term needs so that flexibility is available for short-term operational needs.

- e.g., CAISO flexible capacity requirement based on projected maximum 3-hour upward net load ramp by month.
Merit Order Effect

modified from (Gallo, 2016)
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What is the objective of a capacity market?

Provide units that are needed for reliability sufficient opportunity to recover their fixed costs that cannot be recovered in energy and A/S markets

- Planning – will market encourage investors to build needed resources?
- Flexibility – will market ensure that future capacity is flexible enough for a high-VG world?
- How deal with unintended consequences?
- Is market design robust to resource mix? (eg. lots of recips or aeros or DR or ??)
- Is there an optimal mix of market pricing and administrative pricing/subsidies?

Need to consider expected revenues and capabilities (as incentivized) from energy and A/S markets...
Reliability and revenue sufficiency require full-market view

NREL collaborative work with ANL and EPRI

- Create a **multi-timescale market and reliability modeling framework**
- Quantify **reliability** and **revenue sufficiency** challenges and solutions under a wide range of market design options in an evolving power system

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<tr>
<th>Resource Adequacy</th>
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<th>Essential Reliability Services Incentives</th>
<th>Price Impacts and Formation</th>
<th>Differing decision making criteria</th>
<th>Market Solver</th>
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<tr>
<td></td>
<td>Flexible Capacity</td>
<td>Operational Flexibility</td>
<td>A/S</td>
<td>FESTIV PFR model rules</td>
<td>Self-Commit</td>
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<tr>
<td>Capacity payments (link with ANL)</td>
<td>Add flexible capacity incentive</td>
<td>High Gen Outage</td>
<td>Spin, Reg, Flex Up</td>
<td>FESTIV SFR model rules (e.g., net provision vs. &quot;mileage&quot; payments)</td>
<td>Self-Dispatch</td>
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<td>Premature retirement (nuclear)</td>
<td>Lower Ramp Rates</td>
<td>Up and Down</td>
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<td>High Trans. Outage</td>
<td>Vary reserve code uncertainty bands</td>
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<td>High Congestion</td>
<td>Multi-mode CC</td>
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<td>High Forecast Errors</td>
<td>ERCOT Reserves</td>
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<td>Limited gas fuel supply</td>
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<td>Low/High storage</td>
<td>Add nonspin</td>
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<td>Low/High DR</td>
<td>Adjust reserve requirement during curtailment</td>
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Resource Adequacy: Includes sufficient reserves, load forecasts, and fuel availability.

Flexibility Needs and Incentives: Includes capacity payments, operational flexibility, and availability.

Essential Reliability Services Incentives: Includes FESTIV PFR and SFR model rules.

Price Impacts and Formation: Includes self-commit, static markups, and price caps.

Differing decision making criteria: Includes different ownership structures.

Market Solver: Includes market operational sequence and storage dispatch methods.
GridMod RTS parametric analysis

Frequency of unit-specific “uplift” across 5-min intervals

![Graph showing frequency of unit-specific uplift across 5-min intervals for different scenarios and generator types.]
References and additional resources


