Procuring flexible capacity to manage net load uncertainty — overview and issues

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Presentation outline

• Renewable integration in the California ISO (CAISO)
• Overview of the flexible ramping product
• Issues with the flexible ramping product
Solar and wind forecasts continue to cover a larger percent of load

Average CAISO wind and solar forecasts as a percent of load (2016-2022)
CAISO operation and market focused on *net load*, total load minus wind and solar

Average hourly CAISO load (2022)
Overview of flexible ramping product
Overview of flexible ramping product

- Enhance reliability and market performance by procuring flexible capacity to manage *net load uncertainty*
  - **Net load**: Load minus wind and solar
  - **Uncertainty**: Forecast error between expected and actual forecasts in the following interval
- Use demand curves to allow the market optimization to consider the trade-off between the cost and benefit of procure more or less flexible ramping capacity.
- The flexible ramping product was first implemented on November 2016, but significant enhancements were implemented on February 1, 2023.
Example, expected increase in the net load forecast in the next interval
The flexible ramping product procures upward and downward flexibility to meet uncertainty surrounding a net load forecast in the next interval.
The flexible ramping product procures upward and downward flexibility to meet uncertainty surrounding a net load forecast in the next interval.
Example distribution of historical net load forecast error

- **CAISO's end point for upward uncertainty**
- **CAISO's end point for downward uncertainty**
- **Net load forecast error centered around 0 MW**

**Historical net load forecast error (MW)**
Example distribution of historical net load forecast error

- Probability of a shortage with 250 MW of upward flexible capacity = 30%

- 250 MW (70th percentile)

- 2.5th percentile

- 97.5th percentile

Upward flexible capacity procured

Upward flexible capacity forgone
Example distribution of historical net load forecast error

Probability of a shortage with 250 MW of upward flexible capacity = 30%

Penalty price for a shortage under normal conditions is $1,000/MWh
Defining the price for flexibility

- Probability of a shortage with 250 MW of upward flexible capacity = 30%
- Penalty price for a shortage under normal conditions is $1,000/MWh
- Expected cost of a shortage is $300/MWh (willingness-to-pay for an additional MW of flexible capacity with 250 MW procured)
Issue 1
Stranded flexible ramping capacity
Regional integration through the real-time Western Energy Imbalance Market (WEIM)

- The WEIM allows balancing areas outside of the California ISO to participate in the real-time market.
- Twenty-one entities outside of the California ISO participate in the WEIM.
- Transmission capacity between areas allow market optimization to balance supply and demand across the footprint.
- Flexible ramping capacity was mostly procured to meet system-wide uncertainty needs.
Flexible ramping capacity was often stranded behind transmission constraints

- Original flexible ramping product implementation did not consider transmission constraints
- Flexible capacity procured to meet system-wide uncertainty needs was often stranded behind transmission constraints
- Transmission constraints prevents flexible capacity from being deployable if uncertainty materializes
- Low or zero prices for flexible capacity
Flexible ramping product was significantly enhanced on February 1, 2023

• Flexible ramping product is now modeled at each node to ensure that flexible capacity awards are feasible and appropriately priced.
  – Flexible capacity awards now produced through two deployment scenarios that adjusted the expected net load forecast in the following interval by the lower and upper ends of uncertainty that might materialize
  – Use these scenarios to produce deliverable flexible capacity awards that do not violate transmission or transfer constraints
Issue 2
Short-horizon for considering uncertainty
In real-time, the market software uses net load forecast for every interval up to 4.5 hours in future to determine optimal schedules at the current interval (e.g. 13:45 in this example).
At 13:45 the uncertainty over what net load may actually be at each point in time over the next 4.5 hours grows further out in the future.

- Uncertainty in net load realization at a future time, as estimated at 13:45
- Net load forecast at 13:45
- 97.5% confidence band
- 2.5% confidence band
Flexible ramping product has improved real-time software by considering some uncertainty around the net load forecast for every interval 4.5 hours in future used to determine optimal schedules at the current interval.

The “15-minute” uncertainty in the net load forecast made at 13:45 for 16:15 assumes forecast for 16:00 is accurate.
The “15 minute” uncertainty used by FRP is substantially less than actual uncertainty over what net load forecast may be 1 to 4 hours in future.
The real-time market software does not optimally position resource fleet to meet potential high net load outcomes 1 to 4 hours in the future.
For example, software will miss opportunity to start units with 3 hour start times that are needed by 17:00 to meet potential high net load outcomes—requires manual operator interventions

![Graph showing net load forecast and actual load realization with dashed line representing 15-minute uncertainty and red line indicating actual load realization. Yellow arrow indicates a unit with 3 hour start time needed to meet actual load at 17:00 needs to be started at 14:00.]
Considering actual net load uncertainty 1 to 4 hours in future would allow the real-time software to position resources to meet higher potential net load outcomes.
Technical appendix
Creating a demand curve from historical forecast error

97.5\textsuperscript{th} percentile of net load error (end point of upward demand curve)
Creating a demand curve from historical forecast error

Foregone upward flexible capacity (MW)

Percentile of net load forecast error

Upward flexible capacity procured (MW)

97.5th percentile of net load error (end point of upward demand curve)
Creating a demand curve from historical forecast error

The graph illustrates the relationship between forecast errors and the foregone upward flexible capacity. The 97.5th percentile of net load error (end point of upward demand curve) is highlighted.

- **Axes:**
  - X-axis: Upward flexible capacity procured (MW)
  - Y-axis: Percentile of net load forecast error
  - Price axis: $/MWh

- **Key Points:**
  - The graph shows the trade-off between the cost of upward flexible capacity and the frequency of forecast errors.

This visualization helps in understanding how historical forecast errors can impact the procurement of upward flexible capacity, which is crucial for ensuring reliability in the power grid.
5-minute market uncertainty
15-minute market uncertainty

[Diagram showing a grid with RTUC, RTD₁, RTD₂, RTD₃ on the y-axis and B, A on the x-axis. The grid cells are labeled with b₁, b₂, b₃. On the right, a bar chart shows Binding RTD Interval (MW) with bars b₁, b₂, b₃.]