Procurement and Pricing of Ramping Capability

Technical Session 3

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This Session

• Review of important concepts

• Multi-interval dispatch and pricing
  – Review
  – Possible improvement
  – Pros and cons

• Ramp products and pricing
  – Review
  – Possible improvement
  – Pros and cons

• Key takeaways

Several slides are adapted from ISO-NE’s “Procurement and Pricing of Ramping Capability: Technical Session 2” (12/13/2017).
Format of these Sessions

• This is Not a Markets Committee meeting and will not follow normal MC rules (posting, interactive WebEx, etc.)
• Sessions are meant to help the ISO frame the problem and potential solution set
• All input is welcome and essential
• We will end the session by summarizing the general conclusions of this seminar series
REVIEW OF IMPORTANT CONCEPTS
Ramping Basics

- Capability: Maximum ability of generators to change output (up or down) over a specified time horizon
- Requirement: Total system net load change over a specified time horizon (forecasted and unexpected)
- Key question

\[ \text{Capability} \geq \text{Requirement} \quad \text{OR} \quad \text{Capability} < \text{Requirement} \]
Real-Time (RT) Dispatch: ISO New England

- Single-interval optimization is “shortsighted” and, if left to its own devices, may not maintain sufficient ramping capability.
Summary of Session 1

- Insufficient future ramping capability can cause problems
  - Avoidable reliability issues (e.g., reserve shortages)
  - Economic inefficiency (unnecessarily high production cost)

- Today, ISO New England can position the system to preserve future ramping capability using two methods
  - Reserve Bias method
  - Manual DDP method

- While these methods can (sometimes) avoid reliability issues, they are imperfect and inefficient
  - In practice, positioning for ramp is uncommon and its frequency has declined in recent years (see Session 1, slides 48 – 52)
Summary of Session 2

• Different methods for preserving ramping capability and reflecting the associated costs in prices have been proposed and implemented by certain ISOs
  – Multi-interval dispatch
  – Ramp products

• As currently implemented, each method has advantages and disadvantages
Summary of this Session

• This presentation will provide
  1. Summaries of the Session 2 methods
  2. Possible design improvements for these methods

• These design improvements can resolve some key disadvantages of each method in current implementations
  – These improvements have not been adopted (yet)

• Even with these improvements, there are still some outstanding issues and limitations
  – No method constitutes a “perfect solution”

• Examples in this presentation will build upon the example from Sessions 1 & 2
The ‘Big Picture’

- Multi-interval dispatch and ramp products are two alternative approaches to optimize and price system ramping capability.
- It would generally not make sense for an ISO to implement both — they seek to achieve the same goal.
- There is currently no technical consensus on “best practices” for procuring and pricing RT ramping capability.
- There are possible improvements to existing approaches, but issues remain (to be discussed).
MULTI-INTERVAL DISPATCH AND PRICING
Disclaimer

• The ISO-specific descriptions of this presentation are based on the best of our knowledge

• We have endeavored to ensure the accuracy of all explanations and examples

• However, it is possible that our information for other ISOs may not fully match other ISOs’ actual implementations

• Any errors are solely the author’s responsibility
Multi-interval Dispatch: Review

• Solve sequential **multi-interval** (instead of single-interval) RT dispatch optimizations
  – Typical time horizon: ~1 hour
  – Typical time step: 5-10 minutes

• This approach should generally result in a more efficient and reliable dispatch solution
  – Dispatch considers the future consequences of its actions

• Prices properly reflect the marginal costs of satisfying system ramping constraints foreseen over the dispatch optimization’s time horizon
  – LMPs include **multi-interval** impacts (see Session 2, slides 26 – 29)
Multi-interval Dispatch: Review

• Each multi-interval optimization produces a mathematically-linked sequence of prices

• These prices provide proper dispatch-following incentives for the time horizon as a whole (see Session 2, slides 29 – 32)

• As currently implemented, ISOs only settle on the quantity and price of the most immediate “binding” interval
  – All later quantities and prices are considered “advisory”
Multi-interval Dispatch: NYISO Settlement

- Conceptually, NYISO-type pricing is presented below

![Diagram showing multi-interval dispatch with legend](image-url)
Multi-interval Dispatch: CAISO Settlement

- CAISO only posts the binding price from its multi-interval RT dispatch (advisory prices are produced but not posted)

**LEGEND**
- “Advisory” look-ahead time, price NOT DISTRIBUTED
- “Binding” look-ahead time, price USED for settlement

- RT optimization solved at Time 0
  - [ ]
- RT optimization solved at Time 10
  - [ ]
- RT optimization solved at Time 20
  - [ ]
- RT optimization solved at Time 30
  - [ ]
- RT optimization solved at Time 40
  - [ ]
Potential Issue

• There is no clear economic or mathematical rationale for distinguishing between binding and advisory prices
  – **All** prices are important

• There are ‘patterns’ in the sequence of binding and advisory prices
  – Binding peak prices tend to be lower than advisory peak prices
  – Binding off-peak prices tend to be higher than advisory off-peak prices

• **Key concern:** Settling on only binding prices can affect dispatch-following incentives (see Session 2, slides 37 – 49)
Potential Solution

• As before, perform multi-interval dispatch and pricing
• Improvement: Settle all quantities and prices from the multi-interval solution
• This improvement will be called the “multi-settlement method” in this presentation
• What would this method entail?
Multi-settlement Method

Steps

1. At each time, **solve the multi-interval dispatch** optimization

2. Calculate the price sequence for that multi-interval dispatch solution, yielding a price for each interval in the horizon

3. As time rolls forward and a new multi-interval dispatch/price sequence is determined, **settle the deviation** from each interval’s last dispatch point at the new price

An example will make this clear...
Multi-settlement Method

• Conceptually, this approach is shown below

[Diagram showing multi-settlement method with time points and optimization solutions at different times]
Multi-settlement Method: Example

- Consider a modification of the multi-interval dispatch optimization from Session 2
  - Two-interval optimization (15-minute time steps)

<table>
<thead>
<tr>
<th>Offer</th>
<th>Unit 1</th>
<th>Unit 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>EcoMin (MW)</td>
<td>10</td>
<td>170</td>
</tr>
<tr>
<td>EcoMax (MW)</td>
<td>100</td>
<td>300</td>
</tr>
<tr>
<td>Ramp rate (MW/min)</td>
<td>2</td>
<td>1.333</td>
</tr>
<tr>
<td>Time 0 output (MW)</td>
<td>80</td>
<td>170</td>
</tr>
</tbody>
</table>
Multi-settlement Method: Example

The Time 0 dispatch solution is shown

- Unit 2 is ‘pre-ramped’ at Time 15 to avoid an Operating Reserve violation at Time 30

(see Session 2, slide 23)
Multi-settlement Method: Example

• For the next dispatch optimization (solved at Time 15), the generators have existing “positions” for Time 30
  – Unit 1: 85MW energy, 15MW TMOR
  – Unit 2: 195MW energy, 40MW TMOR

• For the dispatch optimization solved at Time 15, assume that
  – Load forecast for Time 30 is updated to 250MW instead of 280MW
    • The ISO’s initial load forecast for Time 30 was too high
  – Load forecast for Time 45 is 278MW (same as Session 2)
  – Interpretation: Load ramp occurs later than was expected when the Time 0 dispatch optimization was solved
Multi-settlement Method: Example

1: Feasible dispatch ranges for Time 30 and Time 45 are shown.

2: Feasible dispatch ranges for Time 30 and Time 45 are shown.
Multi-settlement Method: Example

The Time 15 dispatch solution is shown

**Time 30**
- LMP = $60/MWh
- RMCP (Reserve Price) = $0/MWh

**Time 45**
- LMP = $300/MWh
- RMCP = $240/MWh

Load = 252MW
Op Res req = 55MW

Load = 250MW
Op Res req = 55MW

Load = 278MW
Op Res req = 55MW
Multi-settlement Method: Incentives

• By construction, these multi-interval prices perfectly incentivize each generator’s multi-interval dispatch
  – This property can derived from an equilibrium condition analysis
  – Example: See Session 2, slides 29 – 32

• Does the proposed multi-settlement method break this relationship?
  – In other words, do generators lose their dispatch-following incentives when only paid for deviations?

• No! The multi-interval dispatch is still perfectly incentivized

• Let’s check...
Multi-settlement Method: Incentives

• Consider generator profitability from the following production options
  – Option 1: Follow existing ISO dispatch points
    • “I would rather produce according to my previous dispatch points”
  – Option 2: Follow new ISO dispatch points
    • “I would be happy to produce according to my new dispatch points”

• It will be shown that the Option 2 profit is at least the Option 1 profit

• The general mathematical logic will be provided later
## Multi-settlement Method

There are no existing positions for Time 45 (Time 0 clearing did not solve for Time 45)

- **Option 1:** Follow existing (Time 0 clearing for Time 30) positions for Time 30, choose most profitable output for Time 45

   Given the $300/MWh LMP and $240/MWh RMCP, these are the most profitable outputs based on ramping constraints from Time 30.

   Don’t follow the ISO’s new (Time 15 clearing for Time 30) dispatch signal unless the existing output for Time 45 clears.

### Table

<table>
<thead>
<tr>
<th>Product</th>
<th>New position (MW)</th>
<th>Existing position (MW)</th>
<th>Deviation (MW)</th>
<th>Profit per MWh ($/MWh)</th>
<th>Deviation profit ($)</th>
<th>Total deviation profit ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time 30 Energy</td>
<td>85</td>
<td>85</td>
<td>0</td>
<td>(60 – 60) = 0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Time 30 TMOR</td>
<td>15</td>
<td>15</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Time 45 Energy</td>
<td>85</td>
<td></td>
<td>85</td>
<td>(300 – 60) = 240</td>
<td>5,100</td>
<td>6,000</td>
</tr>
<tr>
<td>Time 45 TMOR</td>
<td>15</td>
<td></td>
<td>15</td>
<td>240</td>
<td>900</td>
<td></td>
</tr>
<tr>
<td>Unit 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time 30 Energy</td>
<td>195</td>
<td>195</td>
<td>0</td>
<td>(60 – 180) = -120</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Time 30 TMOR</td>
<td>40</td>
<td>40</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Time 45 Energy</td>
<td>215</td>
<td></td>
<td>215</td>
<td>(300 – 180) = 120</td>
<td>6,450</td>
<td></td>
</tr>
<tr>
<td>Time 45 TMOR</td>
<td>40</td>
<td></td>
<td>40</td>
<td>240</td>
<td>2,400</td>
<td></td>
</tr>
</tbody>
</table>
## Multi-settlement Method: Example

- **Option 2**: Follow new ISO dispatch points (Slide 25)

<table>
<thead>
<tr>
<th></th>
<th>Product</th>
<th>New position (MW)</th>
<th>Existing position (MW)</th>
<th>Deviation (MW)</th>
<th>Profit per MWh ($/MWh)</th>
<th>Deviation profit ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unit 1</strong></td>
<td>Time 30 Energy</td>
<td>77</td>
<td>85</td>
<td>-8</td>
<td>(60 – 60) = 0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Time 30 TMOR</td>
<td>23</td>
<td>15</td>
<td>8</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Time 45 Energy</td>
<td>85</td>
<td>–</td>
<td>85</td>
<td>(300 – 60) = 240</td>
<td>5,100</td>
</tr>
<tr>
<td></td>
<td>Time 45 TMOR</td>
<td>15</td>
<td>–</td>
<td>15</td>
<td>240</td>
<td>900</td>
</tr>
<tr>
<td><strong>Unit 2</strong></td>
<td>Time 30 Energy</td>
<td>173</td>
<td>195</td>
<td>-22</td>
<td>(60 – 180) = -120</td>
<td>660</td>
</tr>
<tr>
<td></td>
<td>Time 30 TMOR</td>
<td>40</td>
<td>40</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Time 45 Energy</td>
<td>193</td>
<td>–</td>
<td>193</td>
<td>(300 – 180) = 120</td>
<td>5,790</td>
</tr>
<tr>
<td></td>
<td>Time 45 TMOR</td>
<td>40</td>
<td>–</td>
<td>40</td>
<td>240</td>
<td>2,400</td>
</tr>
</tbody>
</table>
Multi-settlement Method: Example

• For both output options,
  – Unit 1 total profit = $6,000
  – Unit 2 total profit = $8,850

Conclusion:

– Generators (and dispatchable loads) have an incentive to follow the updated dispatch and receive the associated deviation settlement
Multi-settlement Method: General Logic

- The incentive conclusion from the example holds in general
- Notation

\[ x_{15}^0 \]: the cleared quantity for Time 15 from the dispatch solved at Time 0

\[ LMP_{15}^0 \]: the clearing price for Time 15 from the dispatch solved at Time 0

\[ Load_{15}^0 \]: the cleared load for Time 15 from the dispatch solved at Time 0
Multi-settlement Method: General Logic

• Option 1: Follow **existing** ISO dispatch points

- RT optimization solved at Time 0
- Previously-cleared quantities unchanged, most profitable (feasible) output for Time 55

• Option 2: Follow **new** ISO dispatch points

- RT optimization solved at Time 0
- New ISO-specified quantities for all times
Multi-settlement Method: General Logic

• For the dispatch optimization’s horizon and commitment, each generator earns its maximum profit from the ISO dispatch
  – Contact us for the mathematical proof of this property

• For simplicity, assume that the generator has a constant marginal cost $c$

• Since Option 2 is the optimal dispatch and Option 1 is only a feasible dispatch,

\[
\begin{align*}
\text{Option 2 profit} & \geq \left( LMP_{25}^{10} - c \right) x_{25}^{0} + \left( LMP_{35}^{10} - c \right) x_{35}^{0} + \left( LMP_{45}^{10} - c \right) x_{45}^{0} + \left( LMP_{55}^{10} - c \right) x_{55}^{0} \\
& \quad \left( LMP_{25}^{25} - c \right) x_{25}^{10} + \left( LMP_{35}^{25} - c \right) x_{35}^{10} + \left( LMP_{45}^{25} - c \right) x_{45}^{10} + \left( LMP_{55}^{25} - c \right) x_{55}^{10}
\end{align*}
\]
Multi-settlement Method: General Logic

• Rearranging,

\[
\left( LMP_{25}^{10} - c \right) \left( x_{25}^{10} - x_{25}^{0} \right) + \left( LMP_{35}^{10} - c \right) \left( x_{35}^{10} - x_{35}^{0} \right) + \left( LMP_{45}^{10} - c \right) \left( x_{45}^{10} - x_{45}^{0} \right) + \left( LMP_{55}^{10} - c \right) x_{55}^{10} \geq \left( LMP_{55}^{10} - c \right) x_{55}^{\text{max profit}}
\]

Deviation profit for Option 2

Deviation profit for Option 1

• Conclusion

Generators (and dispatchable loads) have an incentive to follow the updated dispatch and receive the associated deviation settlement
Multi-settlement Method: Pros

• The multi-settlement method is a conceptually familiar settlement framework
  – The DA-RT energy market settlement is similar to this idea but lacks the complications of ‘overlapping’ RT forward positions

• The method relies on multi-interval dispatch and pricing, which:
  – Is the efficient (least-cost) dispatch method over the time horizon
  – Properly reflects the costs of meeting ramping constraints in prices

• The multi-settlement method avoids the dispatch-following incentive issues of a “binding/advisory” settlement design
Multi-settlement Method: Issues

• Since nothing is perfect, it is important to acknowledge several outstanding issues with this approach
• First, issues with the multi-settlement rule itself are presented
• Then, pros and cons are presented for the overall ‘package’ of multi-interval dispatch, pricing, and the multi-settlement method
Multi-settlement Method: Issue 1

• The ISO’s dispatch optimization requires several assumptions
  – Will generator bid-in costs change over the time horizon?
  – Will unit commitments change over the time horizon?

• These assumptions affect dispatch and prices

• Longer time horizon $\rightarrow$ Less confidence in assumptions

• While these assumptions affect the market today, their effect would become more pronounced for a longer time horizon
Multi-settlement Method: Issue 2

• Today, cleared DA positions are settled at the difference between the DA price and the RT price

• Consider the Time 45 settlement (ignore the hourly nature of DA prices for simplicity)
Multi-settlement Method: Issue 2

- Virtual bid participation implies that the DA price should converge to the expected RT price
Multi-settlement Method: Issue 2

- The multi-settlement method generates *multiple* RT settlement prices for the same time interval.

- Which RT price will the DA price converge to?
  - If virtual participation is not allowed after DA, all RT virtual positions are 0 MW.
  - From the deviation settlement concept, virtual settlement is a function of the DA price and the first RT price generated for the specified time (Time 45 in this example).
Multi-settlement Method: Issue 2

• The resulting DA-RT price convergence is shown below.

• Conclusion: Cleared DA virtual positions would be settled against the ISO’s [1-hour ahead] RT forecast price.
  – This behavior differs from the current settlement against the 15-minute ahead RT price.
Multi-settlement Method: Issue 3

• In the current DA market, load settlement is based on cleared demand bids
• In the current RT market, load settlement is based on metered consumption
Multi-settlement Method: Issue 3

• For the multi-settlement method, there are several load settlement quantities for each target interval
  – The circled Time 45 load settlement quantities are based on the ISO’s forecast, not demand bids or actual consumption
Multi-settlement Method: Issue 3

How should individual LSEs be charged for forecast-based cleared quantities?

• Consider the example’s load forecasts

<table>
<thead>
<tr>
<th></th>
<th>Dispatch</th>
<th>Time 0</th>
<th>Time 15</th>
<th>Time 30</th>
<th>Time 45</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISO</td>
<td>Time 0</td>
<td>250 (Observed)</td>
<td>252</td>
<td>280</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Time 15</td>
<td>252 (Observed)</td>
<td>250</td>
<td>278</td>
<td></td>
</tr>
</tbody>
</table>

• For settlement, the ISO must somehow “distribute” the forecasted system load to individual nodes/LSEs
  — State estimator weights (RT) or p-node weights (DA) are used today
Multi-settlement Method: Issue 3

Assume that there are two loads (Load 1 and Load 2) with state estimators of 100 MW and 150 MW at Time 0, respectively.

Using state estimator weights, the ISO would distribute its system load forecast as follows:

<table>
<thead>
<tr>
<th>Dispatch</th>
<th>Time 0</th>
<th>Time 15</th>
<th>Time 30</th>
<th>Time 45</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load 1</td>
<td>Time 0</td>
<td>100 (Observed)</td>
<td>100.8</td>
<td>112</td>
</tr>
<tr>
<td>Load 2</td>
<td>Time 0</td>
<td>150 (Observed)</td>
<td>151.2</td>
<td>168</td>
</tr>
<tr>
<td>Load 1</td>
<td>Time 15</td>
<td>100.8 (Observed)</td>
<td>100</td>
<td>111.2</td>
</tr>
<tr>
<td>Load 2</td>
<td>Time 15</td>
<td>151.2 (Observed)</td>
<td>150</td>
<td>166.8</td>
</tr>
</tbody>
</table>

With this load distribution, the ISO implicitly assumes that Load 1 and Load 2 were both forecast incorrectly for Time 30.

- Both loads would be affected by the Time 30 deviation settlement.
Multi-settlement Method: Issue 3

• The distribution of the forecasted load change to each LSE may be inaccurate even if the total load forecast is accurate
  – If the Time 30 forecast change was solely caused by an increase in residential PV output for Load 2, why should Load 1 face a deviation settlement?
  – Rules are necessary to charge LSEs for forecast-based clearings

• Another question relates to RT metering: How should the ISO reconcile its forecast-based cleared quantities with RT metered consumption?

• There are no clear answers for these implementation questions (at this point)
The “Improved” Multi-interval Approach: Pros

• Prices properly reflect the (marginal) costs of system ramping constraints over the optimization horizon
• More efficient (lower-cost) solutions than either single-interval dispatch or operator actions
• More reliable than current practice, *in principle*, by preserving ramping capabilities and reducing reserve shortages
• Combined, the prices and multi-settlement method provide adequate dispatch-following incentives
• *Conceptually* clear: Still least-cost energy and reserves co-optimization
The “Improved” Multi-interval Approach: Cons

• More complicated pricing logic: LMPs quantify the optimal production cost change over the entire horizon due to the next MW of demand (accounting for ramp constraints)

• Settles load quantities based on the ISO forecast instead of demand bids or actual consumption
  – How should costs of ‘purchases’ for forecasted load be allocated?

• Complex software implementation

• Horizon of multi-interval dispatch dependent on system conditions → needs may change over time
Multi-settlement Method: Conclusions

• Enjoys the efficiency and reliability benefits of multi-interval dispatch
• Provides adequate dispatch-following incentives
• Produces multiple RT settlement prices for each time interval
• Settles load quantities based on the ISO forecast instead of demand bids or actual consumption
• Substantial implementation effort
RAMP PRODUCTS AND PRICING
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Ramp Product: Review

- Ramp-up product: starting from the DDP, the maximum output increase (MW) over a specified time
- Ramp-down product: starting from the DDP, the maximum output decrease (MW) over a specified time
- Requirements are typically based on the net load forecast and historical uncertainty
Ramp Product: Review

• The goal of ramp products is to make the system more reliable
  – Reserves provide protection for generator and intertie contingencies
  – Ramp products provide protection for net load changes

• Ramp products are easier to implement than multi-interval dispatch and can increase reliability

• Designation rules are problematic in current implementations (this can be fixed, discussed next)

• More concerning: Ramp products do not assure feasibility of the dispatch ‘path’ when the system is ramping
  – Resulting solutions are less efficient (higher cost) than multi-interval dispatch
Ramp Product: Review

• Ramp product designation rules in certain ISOs have a ‘double-counting’ problem

• Ramp-up designation rules
  – Power + Reserves + Ramp-up ≤ EcoMax
  – Reserves ≤ (Ramp rate x Time)
  – Ramp-up ≤ (Ramp rate x Time)

• Ramp-down designation rules
  – DDP – Ramp-down ≥ EcoMin
  – Ramp-down ≤ (Ramp rate x Time)

Ramp rate limit is applied separately for reserve and ramp-up
Potential Issue: Example

• Assume that a generator can ramp at 1MW/minute
  – The ISO designates 10MW as TMSR and 10MW as ramp-up product (shown on right)

• Can the ISO access this TMSR and ramp-up product simultaneously?
  • No, only 10MW is available within 10 minutes
  • The unit’s 10-minute ramping capability is being double-counted

• Conclusion: In this example, the ISO overestimates system protection
Potential Solution

• To more accurately model the level of system protection, designation rules for the ramp-up product can be changed

• Instead of enforcing separate ramp limits for reserves and ramp-up products, use a joint [cumulative] ramp rate limit
  – Reserves + Ramp-up ≤ (Ramp rate x Time)

• This approach will be called a “modified ramp product” in this presentation
Modified Ramp Product: Example

• The most obvious advantage of this design is that there is no “double-counting” of upward ramping capability
  – In the example from Slide 55, the ISO’s total designation of TMSR and ramp-up product would be capped at 10MW

• The modified ramp product design is a more accurate representation of generator capability
Modified Ramp Product: Pros so far

• Provides a better representation of generator/system capabilities
• Is conceptually straightforward
• Does not significantly complicate RT settlement (conceptually similar to reserves)
Modified Ramp Product: Issues

• While the modified ramp product design has benefits, it has several of the same problems as the original ramp product design

• Session 2 discussed six issues with the original ramp product approach
  – See Session 2, slides 73 – 90

• The most important issues also apply to this modified ramp product approach and are discussed next
**Modified Ramp Product: Issue 3 from Session 2**

Assuming “correct” forecasted change + uncertainty, do ramp product requirements guarantee feasibility (no violations)?

- *No*, if the modified ramp product horizon is longer than the dispatch optimization frequency.

![Diagram showing ramp requirements and feasibility](image)

- Ramp requirements guarantee that Time 15 needs are feasible if ramping starts at Time 5 (from DDP).
- Ramp-up requirement.
- Ramp-down requirement = 0.
- This point may not be feasible (ramping to it may be impossible).
Modified Ramp Product: Issue 3 from Session 2

Assuming “correct” forecasted change + uncertainty, do ramp product requirements guarantee feasibility (no violations)?

- No, if the modified ramp product horizon is longer than the dispatch optimization frequency
Modified Ramp Product: Issue 3 from Session 2

Assuming “correct” forecasted change + uncertainty, do ramp product requirements guarantee feasibility (no violations)?

- Yes, if the modified ramp product horizon is equal to the dispatch optimization frequency
Modified Ramp Product: Issue 3 from Session 2

Assuming “correct” forecasted change + uncertainty, do ramp product requirements guarantee feasibility (no violations)?

- Yes, if the modified ramp product horizon is equal to the dispatch optimization frequency
Modified Ramp Product: Issue 3 from Session 2

Conclusion

• Ramp products do not ensure dispatch feasibility unless the modified ramp product horizon equals the ISO’s dispatch solution frequency
  – If not, times will not “match up” and infeasibilities may not be avoided

• In ISO New England, a modified ramp product would need a 10-minute horizon
  – The Reserve Bias and Manual DDP methods would still be needed for longer (~1 hour) ramping concerns
Modified Ramp Product: Issue 4 from Session 2

Why can’t modified ramp products address multi-interval (e.g., 1 hour) ramping concerns?

- A modified ramp product for Time 60 would be considered by the optimization at Time 0 but ignored by the optimization at Time 10!
Modified Ramp Product: Issue 4 from Session 2

Why can’t modified ramp products address multi-interval (e.g., 1 hour) ramping concerns?

- Maybe we could introduce more ramp products...

- **WAIT A MINUTE!** Issue 3 showed that this combination of ramp products doesn’t guarantee feasibility.
Modified Ramp Product: Issue 4 from Session 2

Why can’t modified ramp products address multi-interval (e.g., 1 hour) ramping concerns?

• What we really need are ramp products between 0 and 10, 10 and 20, 20 and 30, ...

• **WAIT A MINUTE!** This approach looks like multi-interval dispatch
  – Single-interval dispatch knows nothing about dispatch points after Time 0. How can it enforce ramp constraints between 10 and 20, 20 and 30, ...?
Modified Ramp Product: Issue 4 from Session 2

Conclusion

• In a single-interval dispatch framework, feasibility for multi-interval ramping concerns cannot be assured by modified ramp products no matter how many are introduced

• From an operational perspective, this is bad news

• However, ISO New England’s current methods cannot assure dispatch feasibility for multi-interval ramping either

• Still, this problem undermines the core reliability objective of ramp products
Modified Ramp Product: Issue 5 from Session 2

Are ramp products efficient?

• Ramp products (try to) provide feasibility, not optimality
• The feasible solution for the future identified by the ramp product implementation may not be the least-cost solution

Conclusion

• Ramp product approaches are generally not as efficient (cost-effective) as multi-interval dispatch
Modified Ramp Product: Pros

• Can help preserve ramping capabilities and avoid some reserve violations
• Provides an explicit market price for ramping capability
• Designation rules can be tricky, but modifications can fix double-counting problems
• Requirements can incorporate a “safety margin” to address uncertainty in net load over the ramp product time horizon
• Simpler to implement than multi-interval dispatch
Modified Ramp Product: Cons

• Ramp products cannot guarantee feasibility if the system is ramping over multiple intervals

• As a consequence, ramp product prices may not reflect the true cost of preserving sufficient ramping capability (because sufficient ramping capability may not actually be preserved!)

• Less efficient (higher cost) than multi-interval dispatch
  – Ramp products cannot ensure optimality in general
Modified Ramp Product: Conclusions

• Ensures that ramping capability is not double-counted
  — This gives the ISO a better understanding of system capability
• Is not as efficient as multi-interval dispatch
• Cannot guarantee multi-interval feasibility
• Lower implementation effort than multi-interval dispatch
KEY TAKEAWAYS
Key Takeaways

• This presentation described two modifications to existing ISO methods for procuring and pricing resource “flexibility”
  – The multi-settlement method avoids the dispatch-following incentive issue of a “binding/advisory” settlement process, but it introduces settlement questions for load
  – The modified ramp product design avoids ramp capability double-counting, but it cannot guarantee feasibility or reliability for longer time horizons

• Either of these approaches may be an improvement to current ISO New England methods in theory
Key Takeaways

• Although neither method is perfect, the efficiency, reliability, and incentive properties of the multi-settlement method seem preferable to a ramp product
  – The multi-settlement method, however, introduces a number of implementation questions

• It is unclear whether ramping problems (necessitating operator actions) in New England are frequent enough to undertake major changes at this time
  – Assessing costs and benefits would require further study

• System ramping challenges depend on the resource mix and could become more significant in the future