Flexibility Procurement and Reimbursement

A Multi-period Pricing Approach

Dane A. Schiro
ANALYST
Outline

• Introduction

• Motivation: Real-time (RT) market shortcomings
  – Problems with current methods

• A recent improvement
  – Ramp product design
  – Identified issues

• Multi-period pricing proposal
  – Design
  – Advantages and disadvantages

• Conclusion
INTRODUCTION
Flexibility needs for RT processes

- Flexibility: Capability to cope with system condition changes over time

- Why is flexibility needed?
  - Expected load changes
  - Load changes caused by uncertainty (e.g., distributed generation)
Flexibility needs for RT processes

• Flexibility needs will likely increase with distributed renewable energy penetration
  – Steeper and longer ramps
Flexibility needs for RT processes

- Current flexibility procurement and reimbursement methods take a piecemeal approach that may not be satisfactory as system characteristics change
MOTIVATION: RT MARKET SHORTCOMINGS
Motivation

• Dispatch should follow load and maintain reliability, both objectives dependent on flexibility

• Current RT market designs have problems with
  – **Dispatch efficiency**
    Does the RT market maximize social surplus over the time?
    Is the RT dispatch reliable?
  – **Compensation**
    Does the RT settlement incentivize units to perform as requested?
    Does the RT settlement ensure cost recovery?
Single-period pricing

• Each Dispatch problem solves for one time
• Price is used for settlement

LEGEND

Look-ahead period, price USED for settlement
**Single-period pricing**

- ISO New England, MISO, PJM, and SPP

- Advantage
  - Easy to implement and understand

- Disadvantage
  - Actions must be taken to avoid solutions that cause future infeasibility
    - If actions fail, reliability can be compromised → Inefficient
    - If actions succeed, they are almost always suboptimal → Inefficient

- The **Dispatch efficiency** problem is illustrated next
<table>
<thead>
<tr>
<th>Time</th>
<th>Load</th>
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<tbody>
<tr>
<td>10</td>
<td>100</td>
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<tr>
<td>20</td>
<td>155</td>
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- If the future isn’t considered, Unit 1 output is decreased as quickly as possible for Time 10.
- It is then impossible to satisfy Time 20 load!
- The dispatch is inefficient.

**Unit 1** ($100/MWh)

**Unit 2** ($50/MWh)

LMP, Problem 1: $50/MWh
LMP, Problem 2: \(-\) \text{VIOLATION}
Single-period pricing with multiple look-ahead periods

• Each Dispatch problem solves for multiple times
• Only first price is used for settlement (i.e., binding)
Single-period pricing with multiple look-ahead periods

• CAISO and NYISO

• Advantage
  – If the horizon is longer than the required ramp, the dispatch is efficient

• Problem
  – Binding peak price can be systematically lower than advisory peak price (opposite for off-peak price)
  – Compensation may not be adequate → Deviation incentive

• The Compensation issue is illustrated next
Time | Load
--- | ---
10 | 100
20 | 155
30 | 150

**Unit 1**
- **($100/MWh)**
- EcoMax = 100MW

- Problem 1 solution dispatches Unit 1 up to maintain Time 20 feasibility
- The advisory peak price is $150/MWh but the realized price is only $100/MWh
- More realistic situations can result in the same behavior

**Unit 2**
- **($50/MWh)**
- EcoMax = 75MW

LMP, Problem 1
- $50/MWh

LMP, Problem 2
- $100/MWh

LMP, Problem 1
- $150/MWh
Summary

• Dispatch efficiency and Compensation problems mean that flexibility is not adequately procured or reimbursed by traditional dispatch

• These problems may become more important as the system continues to evolve

• Is there a better way to provide flexibility?
A RECENT IMPROVEMENT
Ramp products

- MISO and CAISO introduced “ramp products” to enhance and reimburse for flexibility
  - Up-ramp and down-ramp
  - Market clearing prices
Ramp products (MISO design)

- Up-ramp and down-ramp requirements are based on expected load change + uncertainty
Ramp products may not maintain reliability

- Ramp products can only provide flexibility between the dispatch time and the specified target time
Ramp products may not maintain reliability

- If longer-term flexibility becomes a problem, additional ramp products may not help
Ramp products are not well-defined

- 10-minute reserves represent ramping capability 10 minutes after the dispatch time
- Reserve designations and up-ramp products naturally overlap

- The ISO can’t double-pay for capability

What are the true ramp product designation and requirement definitions?
Ramp products. Conclusion

• Poorly defined
  – Ramp products and reserves

• Does not guarantee reliability
MULTI-PERIOD PRICING PROPOSAL
**Multi-period pricing**

- ISO New England’s DA-RT market is a two-settlement design
  - The cleared DA quantities are [cash-settled] futures positions
Multi-period pricing

- Consider extending this framework to the RT market itself
  - RT market must be multi-period
  - This treatment expands on the CAISO and NYISO approach
Multi-period pricing

- Deviations from net existing positions are new positions
  - Existing positions for Time 4 are shown below
  - Time 4 is new in the Time 1 problem → No existing position

LEGEND
- Look-ahead period, price USED for settlement

RT market solved at Time 1

RT market solved at Time 2

RT market solved at Time 3

RT market solved at Time 4

RT market solved at Time 5
Multi-period pricing. Settlement

• Consider the settlement for Time $T$
  – $\Delta p_t^T$: the cleared deviation from the net existing position in problem $t$
  – $LMP_t^T$: the cleared price in problem $t$
  – $p^T, LMP^T$: the final (spot) cleared quantity and price

• The total settlement for a generator is

$$\left( LMP_0^T - LMP^T \right) \Delta p_0^T + \left( LMP_1^T - LMP^T \right) \Delta p_1^T + \cdots + \left( LMP_{T-1}^T - LMP^T \right) \Delta p_{T-1}^T$$

$$+ \underbrace{LMP^T p^T}_{\text{Spot market settlement}}$$

Cash settlement of futures positions
Multi-period pricing. Uncertainty

- Multi-period pricing is useful for expected load changes but may not help with load uncertainty
  - Load uncertainty for Time 10 is handled by AGC
  - Load uncertainty for Times 20-30 can be problematic (economic dispatch runs the system “as lean as possible”)

![Graph showing load profile over time with expected load and load uncertainty](image-url)
**Multi-period pricing. Uncertainty**

- Consider increasing the Total-10 reserve requirement to address load uncertainty for Times 20 – 30
- NERC standards specify a lower bound for reserves
  - *Important question: How is an unexpected net load increase different from a generator contingency?*

A dispatch solution with this amount of Total-10 reserves can handle load uncertainty without “activating” the reserves held for contingencies

- 10-minute load uncertainty (up direction)
- Total-10 requirement (based on largest contingency)
Advantages

- If the horizon is longer than the required ramp, the dispatch is efficient
- Each ISO dispatch decision is paid at the associated clearing price
  - Adequate dispatch-following incentives (i.e., no guessing about how much binding price will differ from advisory price)
Disadvantages

• Appropriate time horizon for a multi-period dispatch problem is difficult to determine, especially when commitment optimization and hourly bidding are considered

• More complex RT settlement and uplift calculations

• Uncertainty is not directly addressed
  – Possible solution: Increased Total-10 requirement
CONCLUSION
• ISOs need flexibility to address expected load changes and uncertainty, both expected to increase over time

• Current RT methods have problems with Dispatch efficiency or Compensation

• Ramp products are poorly defined and can only address certain reliability issues

• Multi-period pricing is promising for expected load changes
  – Difficult to implement
  – Additional changes needed for load uncertainty

• NEXT STEPS: Quantify ($) the benefits and consequences of the current and proposed flexibility approaches