Real-Time Price Formation: Fast-Start Pricing – A Survey

Technical Session #7

Feng Zhao and Matthew White
Format of These Sessions

• This is NOT a Markets Committee meeting, will not follow normal MC rules (posting, interactive WebEx, etc.)

• Sessions are meant to help the ISO frame the problem set and the potential solution set; ALL input is welcome and essential

• We may use flip charts, white boards or similar tools to help facilitate the discussion

• We will end the session summarizing the action items (additional examples/issues) for the next session

• We will review at the start of each session where the previous session left off and what our goals are for the current session
Basic Layout of the Fall Sessions

• Session #6 – September 22, 2014
  – Issues with fast-start pricing
    (A special case of generator lumpiness or “non-convexity”)
  – ISO-NE’s pricing method with fast-start units

• Session #7 – Today
  – Present & discuss other ISOs’ pricing methods with fast-start units

• Session #8 – December 15, 2014
  – Complete discussion of other ISOs’ pricing methods
  – Discuss pros & cons of fast-start pricing method elements
    and useful variations
This Session

I. Summarize and review:
   – Three pricing principles considered in previous sessions
   – Fast-start resource pricing: What’s the issue, precisely?
   – ISO-NE’s current fast-start pricing method

II. Discuss what four other ISOs do for fast-start pricing
   – PJM
   – CAISO
   – NYISO
   – MISO
Review Idea #1: Pricing Principles

Three key principles – “E. T. S.”

1) Efficiency
2) Transparency
3) Simplicity
Pricing Principle – “E”

1) **Efficiency.** *In the context of the energy market, this means:*
   a) Cleared (dispatched) MW will maximize social surplus, or equivalently, **minimize total production costs**
   b) In response to the price, each asset is equal or better-off by following **the ISO dispatch instruction** than doing anything else
      • Assets want to produce to the cleared (dispatched) MW amount, not deviate from that
Pricing Principle – “T”

2) Transparency
   
a) “Much is known by many“ about transaction price(s)
b) Everyone knows the price(s) that others receive or pay
Pricing Principle – “S”

3) Simplicity
   a) As few prices as possible
      • Uniform price for purchases/sales at the same location and time
   b) Price formation process should have a simple logic that buyers/sellers can understand
      • The prices are easy to interpret
Review Idea #2: Fast-start Pricing Issues

- **“Lumpiness”** is the primary source of fast-start pricing problems
  - Lumpiness is caused by unit **minimum output levels**, and by **commitment costs** (e.g., startup costs)
  - Terminology: The resulting problem is **“non-convex”**
- There is **no perfect solution** for lumpy problems
  - In general, no pricing solution meets all three (E+T+S) principles
- **Compromises** have to be made under any pricing method
  - To provide dispatch-following incentives, **“side payments”** cannot be completely eliminated
Review Idea #3: Processes in RT

1) Commitment
   – Commit (start-up) and de-commit (shut-down) FS units

2) Dispatch
   – Determine “Desired Dispatch Point” (DDP) for each asset

3) Pricing
   – Determine market prices

   • These three processes can be separate algorithms, or an integrated one

   • Our focus in this presentation is the pricing process (real-time commitment and dispatch processes will be summarized when important to pricing methods)
Ahead Next: Review of ISO-NE Practice

- **Elements** of ISO-NE’s current fast-start pricing method:
  1. **Process.** How are the three RT processes configured in ISO-NE?
  2. **Definition.** What are the “fast-start” (FS) resources in ISO-NE?
  3. **Qualification.** What FS resources are qualified for special treatment?
  4. **EcoMin.** Special treatment in the pricing & dispatch process
  5. **Commitment cost.** Special treatment in the pricing & dispatch process

- **Example** of ISO-NE’s method
  - A simple 4-unit example will be presented for ISO-NE’s method
  - This example will also be used to illustrate similarities and differences with four other ISOs’ methods
1. ISO-NE: Commitment, Dispatch and Pricing

- Real-time FS **commitment** is currently determined by a single time-interval **mixed-integer commitment program**
  - It minimizes the total production costs of meeting demand and reserves, including startup and no-load costs, for the time-interval

- Given the commitment solution, **DDPs & prices** are determined by a single time-interval **linear dispatch program**
  - Dispatch & pricing are integrated in one process
2. ISO-NE: Fast-start Resources

• “Fast-start” generator means a generating unit that the ISO may dispatch within the hour that meets these criteria:
  – Minimum run time does not exceed one hour
  – Minimum down time does not exceed one hour
  – Time to start does not exceed 30 minutes
  – Available for dispatch and manned or has automatic remote dispatch capability
  – Capable of receiving and acknowledging a start-up or shut-down dispatch instruction electronically
  – Has satisfied its minimum down time

• Some fast-start resources are “block-loaded”, while others have some dispatch range (i.e., offered EcoMin < EcoMax)
3. ISO-NE: Qualification of Fast-start Resources for Special Treatment in Pricing Process

• Offline Fast-starts instructed to be online, i.e., committed for the target time-interval but currently offline, are qualified for special treatment for price-setting purpose.

• Equivalently, only in the “first” time-interval of commitment period, the FS resource receives special treatment.
4. ISO-NE: EcoMin Treatment of Qualified Fast-start Resources in Pricing Process

• In the “first” committed interval (offline instructed to be online), the dispatch & pricing algorithm treats the FS resource as dispatchable from zero to EcoMax, ignoring offered EcoMin.

• This treatment assumes a larger dispatchable range for the FS than its actual range.

• And so the dispatch & pricing algorithm may think the FS resource could be “marginal” to meet the next MW of load.

• This makes it more likely that the FS resource will set price (relative to if the offered EcoMin MW was respected in FS dispatch & pricing).
ISO-NE: Consequences of EcoMin Relaxation

• When the EcoMin is treated as zero: The dispatch & pricing algorithm may yield a MW solution less than the FS resource’s offered EcoMin MW
  – BUT: ISO-NE’s DDP sent to the fast-start resource will be at least its offered EcoMin, respecting the unit’s offer

• Consequences and trade-offs:
  – The total dispatched MWs will exceed the system load, in this case
  – The over-generation MWs are offset by regulation service (down)
  – The over-generation is potentially economically inefficient
  – The over-generation could present a reliability concern, if large relative to available regulation down service

• See Example 1a (ahead...)
5. ISO-NE: Commitment Cost Treatment of Qualified Fast-start Resources in Pricing Process

• In the “First” interval (offline instructed to be online), its commitment costs (no-load + startup) are amortized over its EcoMax and then added into its incremental energy price.

• This special treatment allows the commitment costs to be reflected in the market price when the resource is “marginal”
  – There is no theoretical ‘best’ answer as to how commitment costs of FS resources should be treated in the pricing process.

• After the “first” interval, commitment costs are not included in the incremental energy price.
Summary of ISO-NE’s Fast-start Pricing

• Fast-start resources receive special treatment in the pricing process for the first committed time-interval only:
  – Special treatment of its EcoMin: Assumed 0, even if EcoMin > 0
  – Special treatment (amortization) of commitment costs is performed

• **Efficiency** (X): Some less expensive non-FS resources may need to back down to balance the system

• **Transparency** (X): FS units may (often) require make-whole payments to recover their total offer cost

• **Simplicity** (✔): Relatively easy to understand and implement (as FS pricing methods go... *and as we will see ahead...*)
Example 1a: ISO-NE First Commitment Interval

- This example will be used to illustrate other ISOs’ pricing methods as well
- Load = 375 MWh
- Two block-loaded FS’s Committed for the target time-interval (Assume both are offline currently)
- One block-loaded FS is Not Committed
- One online non-fast start Steam Unit

<table>
<thead>
<tr>
<th>Resource</th>
<th>Offer Price ($/MWh)</th>
<th>EcoMin (MW)</th>
<th>EcoMax (MW)</th>
<th>Commit. Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Committed FS1</td>
<td>100</td>
<td>100</td>
<td></td>
<td>1,000</td>
</tr>
<tr>
<td>Committed FS2</td>
<td>200</td>
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<td>1,000</td>
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<tr>
<td>Not-committed FS</td>
<td>250</td>
<td>25</td>
<td></td>
<td>500</td>
</tr>
<tr>
<td>Steam</td>
<td>30</td>
<td>30</td>
<td>300</td>
<td>3,000</td>
</tr>
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</table>
## Example 1a: ISO-NE Dispatch & Pricing

<table>
<thead>
<tr>
<th>Resource</th>
<th>Offer Price $/MWh</th>
<th>EcoMin MW</th>
<th>EcoMax MW</th>
<th>Commit. Cost ($)</th>
<th>Dispatch (MW)</th>
<th>DDP Sent (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Committed FS1</td>
<td>100 110</td>
<td>100 0</td>
<td>100</td>
<td>1,000</td>
<td>75</td>
<td>100</td>
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<tr>
<td>Committed FS2</td>
<td>200 220</td>
<td>50 0</td>
<td>50</td>
<td>1,000</td>
<td>0</td>
<td>50</td>
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<tr>
<td>Not committed FS</td>
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<td>25</td>
<td>500</td>
<td></td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Steam</td>
<td>30 30</td>
<td>30 30</td>
<td>300</td>
<td>3,000</td>
<td>300</td>
<td>300</td>
</tr>
</tbody>
</table>

- FS1 is committed, currently offline → Special treatment:
  - EcoMin treated as 0; and Offer price $100/MWh is modified by adding the amortized commitment costs at EcoMax: $110/MWh = $100 + $1,000/100 MW

- FS2 is committed, currently offline → Special treatment:
  - EcoMin treated as 0; Offer price modified to $220/MWh = $200 + $1,000/50MW

- Dispatch solution: Committed units FS1 at **75 MW**, FS2 at **0 MW**

- The ISO’s DDPs respect the offered EcoMins of **100 MW** and **50 MW**
  - The resulting over-generation of 75MW (=100+50-75-0) is offset by regulation-down services → Inefficient (potentially, depends on cost of regulation service)

- Not-committed FS does not participate in the dispatch & pricing
- Committed FS1 is marginal → LMP is set to **$110/MWh**
Example 1a: ISO-NE Dispatch & Pricing

Load = 375 MW

Dispatch solution at 0 MW
Commit. Cost: $1,000

LMP = $110/MWh
DDP at 100 MW
Commit. Cost: $1,000

Dispatch solution at 75 MW
Commit. Cost: $1,000

Steam

Min (30MW)

300 MW @ $30/MWh

Committed
FS1

100 MW @ $110/MWh

Dispatch solution at 100 MW

Committed
FS2

50 MW @ $220/MWh

Commit Cost: $500

DDP at 50 MW

Min

25 MW @ $250/MWh

Not-committed
FS

Min
Example 1b: ISO-NE After The 1\textsuperscript{st} Committed Interval

- Load = 375 MWh, same as before
- The same set of resources
- Assume the committed FS1 and FS2 are currently online (Not qualified for special treatment in the dispatch & pricing process)

<table>
<thead>
<tr>
<th>Resource</th>
<th>Offer Price ($/MWh)</th>
<th>EcoMin (MW)</th>
<th>EcoMax (MW)</th>
<th>Commit. Cost ($)</th>
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<tbody>
<tr>
<td>Committed FS1</td>
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<td>100</td>
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<td>1,000</td>
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<tr>
<td>Committed FS2</td>
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<td>1,000</td>
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<tr>
<td>Not-committed FS</td>
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<tr>
<td>Steam</td>
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<td>3,000</td>
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</table>
## Example 1b: ISO-NE Dispatch & Pricing

<table>
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<tr>
<th>Resource</th>
<th>Offer Price $/MWh</th>
<th>EcoMin MW</th>
<th>EcoMax MW</th>
<th>Commit. Cost ($)</th>
<th>Dispatch (MW)</th>
<th>DDP Sent (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Committed FS1</td>
<td>100</td>
<td>100</td>
<td></td>
<td>1,000</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Committed FS2</td>
<td>200</td>
<td>50</td>
<td></td>
<td>1,000</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Not committed FS</td>
<td>250</td>
<td>25</td>
<td></td>
<td>500</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Steam</td>
<td>30</td>
<td>30</td>
<td>300</td>
<td>3,000</td>
<td>225</td>
<td>225</td>
</tr>
</tbody>
</table>

- Block-loaded FS1 and FS2 are both dispatched at their offered EcoMin (=EcoMax), pushing down the Steam Unit’s dispatch to 225MW
- No special treatment for relaxation of EcoMin or amortization of Startup & No-load costs
- Not-committed FS does not participate in the dispatch & pricing
- Committed Steam Unit is marginal → LMP is set to $30/MWh
Example 1b: ISO-NE Dispatch & Pricing

Load = 375 MW

- Steam: 300 MW @ $30/MWh (Min 30MW)
- Committed FS1: 100 MW @ $100/MWh
- Committed FS2: 50 MW @ $200/MWh
- Not-committed FS: 25 MW @ $250/MWh
- LMP = $30/MWh
- DDP at 225 MW
- Commit Cost: $1,000
- Commit Cost: $1,000
- Commit Cost: $500

Min
Next: Other ISOs’ Fast-Start Pricing Methods

- PJM Approach
- CAISO Approach
- NYISO Approach
- MISO Approach
First Things First: A Prominent Disclaimer

- The following descriptions of other ISO/RTOs’ RT pricing approaches are based on our best knowledge.
- We have endeavored to ensure the accuracy of all explanations and examples.
- However, it is possible that this information may not exactly match what other ISO/RTOs currently do, or plan to do in the future.
- Any errors that remain here are solely the authors’ responsibility, and corrections that refer to other ISO/RTOs’ documentation would be appreciated.
The Most Important Ideas Today:
Core Elements of All Fast-Start Pricing Methods

• ISOs use different FS pricing methods, with common core elements

• “Relaxation of Lumpiness” – In the pricing process, ISOs may treat a FS resource’s minimum output as less than its offered minimum MW
  – **Why?** By doing so, the pricing algorithm *thinks* a block-loaded FS unit could be dispatched to meet the next MW of load — and so sets price like a ‘marginal’ resource does
  – *This happens even if* the FS unit is *not* the actual marginal unit that provides the next MW (because the FS is block-loaded)
  – This “modified minimum output value for pricing” technique is termed **relaxation** of the minimum output parameter (EcoMin/Pmin, etc.)
The Most Important Ideas, Continued

• Each ISO has somewhat **different** ways of implementing this ‘relaxation’ as we will describe next:
  – Some are simple, some are complex
  – The details matter and can substantially affect pricing outcomes

• **Which ‘relaxation’ method is best?** There is no ‘perfect’ pricing solution with ‘lumpy’ offers. Relaxation technique may:
  – create inefficient dispatch (due to ignoring ‘real’ min output values), *or*
  – create potential incentive (dispatch-following) problems, *or*
  – require additional side payments, *or*
  – some combination of these 3 (depending on implementation)

• We will illustrate these issues and trade-offs with examples
Two other key elements have significant differences across ISOs for FS pricing methods:

- **Qualification.** What specific resource types are considered for the special pricing treatment, and what conditions qualify these resources for the special pricing treatment?
  - ISO-NE uses a ‘broader’ definition than most other ISO’s
  - We will explain the differences in detail

- **Commitment cost treatment.** How/whether commitment costs are amortized into ‘fast-start’ offer prices
  - Some include startup, some include no-load, some both, some neither
  - Amortization methods (over time and MW values) vary
  - No theoretical ‘best’ approach on this issue
For Each ISO: Keep In Mind Four Questions

1. **Which** resources are targeted?
   – Each ISO focuses on the price-setting ability of a *specific group* of resources. The resource groups *differ* across ISOs

2. **What** specific conditions “qualify” the resources in this group for special treatment in the pricing process?
   – Resources need to satisfy various *specific conditions* in real-time

3. **How** is the minimum output level treated in pricing?
   – What is the minimum ‘relaxed’ to? What effects does this have?

4. **How** is the commitment cost (Startup & No-load) treated?
   – Are they reflected in the market price? How are they amortized?
Quick Review: Answers For ISO-NE

1. **Which** resources are targeted?
   - Resources that satisfy ISO-NE’s FS definition, including 10/30 min FS, regardless of block-loaded or not

2. **What** specific conditions “qualify” the resources in this group for special treatment in the pricing process?
   - A FS during the first interval of its committed period is qualified for special treatment

3. **How** is the minimum output level treated in pricing?
   - Relaxed to zero, even though its actual EcoMin is not zero

4. **How** is the commitment cost (Startup & No-load) treated?
   - Amortized over EcoMax and added to the incremental cost
## Summary of ISO-NE Fast-start Pricing in Matrix

<table>
<thead>
<tr>
<th>Core Elements</th>
<th>ISO-NE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dispatch &amp; Pricing Processes</td>
<td>Integrated, Single time-interval optimization</td>
</tr>
<tr>
<td>Applicable Resource Types</td>
<td>10/30-min Fast-start Resources</td>
</tr>
<tr>
<td>Committed Resources Treatment</td>
<td>Qualification: First interval of committed period</td>
</tr>
<tr>
<td></td>
<td>Min. Output: Relaxed to zero</td>
</tr>
<tr>
<td></td>
<td>Commit. Cost: Amortized over EcoMax and added into the offer price</td>
</tr>
<tr>
<td>Not-committed Resources Treatment</td>
<td>Qualification: -</td>
</tr>
<tr>
<td></td>
<td>Min. Output: -</td>
</tr>
<tr>
<td></td>
<td>Commit. Cost: -</td>
</tr>
</tbody>
</table>
Ahead In This Presentation

• We will review four other ISOs’ fast-start pricing methodologies
  – PJM
  – CAISO
  – NYISO
  – MISO
• We will use simple examples to illustrate each ISO’s method
• We will compare features of different ISOs’ methods in a table
• We will explain some of the trade-offs of the different methods
Layout of Today’s Presentation

- PJM Approach
- CAISO Approach
- NYISO Approach
- MISO Approach
PJM: Commitment, Dispatch and Pricing

• **Commitment.** A multi-interval “look-ahead” commitment model for commitment and de-commitment of Combustion Turbines (CTs)
  – “Intermediate Term” Security Constrained Economic Dispatch (IT-SCED)

• **Dispatch and Pricing.** A single-interval, security constrained linear model determines dispatch and pricing
  – Real Time Security Constrained Economic Dispatch (RT-SCED)

• **Comparison to ISO-NE:**
  – ISO-NE currently uses single-interval commitment, not multi-interval
  – ISO-NE dispatch and pricing is also determined in one RT-SCED run
PJM: Block-loaded Combustion Turbine (CT)

- **Block-loaded Combustion Turbine (CT):** Resources with CT as the prime mover and EcoMin = EcoMax

- **Comparison to ISO-NE:**
  - ISO-NE considers all types of FS resources, including:
    - CTs and other types of FS resources,
    - block-loaded and dispatchable resources
  - PJM focuses on a relatively narrow set of FS resources:
    - block-loaded CTs only
PJM’s View on Block-loaded CT Pricing Problem

• The majority of CTs bid in as block-loaded units
• Without special treatment of some form, these resources do **not** set price because they do not have a dispatchable range
• **Observation.** This is simply the “lumpiness” problem with block-loaded resources that we’ve noted before
PJM Approach to CT Pricing Problem

• **Idea.** Artificially increase the dispatch range of a qualified block-loaded CT by “relaxing” its EcoMin to a lower value
  – PJM’s dispatch & pricing algorithm will treat the EcoMin as *less* than the CT’s actual (offered) EcoMin value

• The CTs with **relaxed** EcoMins may set price:
  – The dispatch & pricing algorithm treats the CT as having dispatchable range that may provide the next MW to meet load
  – Thus, the algorithm may see the CT as the “marginal” unit
PJM: Qualification of CTs for Special Treatment

• Committed CTs are qualified for special treatment

• Not-committed CTs do not participate in the pricing process and therefore are not qualified for special treatment

• **Comparing to ISO-NE:**
  – ISO-NE’s FS resources are qualified only for the first commitment interval
  – PJM extends the qualification for all committed intervals *(Implication: This aspect of PJM’s treatment implies qualified resources may set price more frequently)*
  – Both ISOs do not use special treatment for not-committed resources
PJM: EcoMin Relaxation of Qualified CTs

• For committed CTs, RT-SCED relaxes the EcoMin to an operator adjustable factor of the unit’s offered values
  – The factor is set to 90% currently

• RT-SCED, the dispatch & pricing software, may yield a MW solution less than the offered EcoMin of a committed CT due to the relaxation

• However the dispatch signal sent will be its offered EcoMin
  – Issue: The total dispatch signal sent exceeds the system load
  – Such power imbalance caused by the EcoMin relaxation is left for regulation services to absorb

• Comparison to ISO-NE:
  – ISO-NE relaxes EcoMin of qualified FS resources to zero (in first interval)
  – PJM relaxes them to 90% (in all intervals)
  – Implication: A qualified PJM resource has a smaller dispatch range; The less relaxation potentially puts less pressure on regulation services
PJM: Commitment Cost Treatment of Qualified CTs

• For committed CTs, commitment costs (startup & no-load) are not considered in RT-SCED
  – The market price will not reflect the commitment costs of qualified CTs
  – This is consistent with the pricing practice for slow-start units

• **Comparison to ISO-NE:**
  – ISO-NE considers the commitment costs of qualified FS in pricing
  – PJM does not consider commitment costs of qualified CTs in RT pricing
    (A qualified PJM resource’s commitment cost is not reflected in the price, consistent with the pricing practice for slow-start units)
  – A FS resource in ISO-NE, if marginal, will set higher price than it would in PJM
Example 2a: Illustration of PJM’s RT Pricing

- Load = 375 MWh
- Same set of resources as Example 1a
- Terminology changed from “FS” to “CT”

<table>
<thead>
<tr>
<th>Resource</th>
<th>Offer Price ($/MWh)</th>
<th>EcoMin (MW)</th>
<th>EcoMax (MW)</th>
<th>Commit. Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Committed CT1</td>
<td>100</td>
<td>100</td>
<td></td>
<td>1,000</td>
</tr>
<tr>
<td>Committed CT2</td>
<td>200</td>
<td>50</td>
<td></td>
<td>1,000</td>
</tr>
<tr>
<td>Not-committed CT</td>
<td>250</td>
<td>25</td>
<td></td>
<td>500</td>
</tr>
<tr>
<td>Steam</td>
<td>30</td>
<td>30</td>
<td>300</td>
<td>3,000</td>
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</table>
## Example 2a: PJM Dispatch and Pricing

<table>
<thead>
<tr>
<th>Resource</th>
<th>Offer Price $/MWh</th>
<th>EcoMin MW</th>
<th>EcoMax MW</th>
<th>Commit. Cost ($)</th>
<th>Dispatch (MW)</th>
<th>DDP Sent (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Committed CT1</td>
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<td>100 90</td>
<td>100</td>
<td>1,000</td>
<td>90</td>
<td>100</td>
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<tr>
<td>Committed CT2</td>
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<td>50 45</td>
<td>50</td>
<td>1,000</td>
<td>45</td>
<td>50</td>
</tr>
<tr>
<td>Not committed CT</td>
<td>250</td>
<td>25</td>
<td>500</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Steam</td>
<td>30</td>
<td>30</td>
<td>300</td>
<td>3,000</td>
<td>240</td>
<td>240</td>
</tr>
</tbody>
</table>

- EcoMin of committed CTs are relaxed to 90%
- Commitment costs of the committed CTs are NOT considered
- CT1&CT2 dispatch solutions are at 90% of their offered EcoMin, but the DDPs sent are the offered EcoMins
  - The 15MW (=100-90+50-45) over-generation is offset by regulation services, and could be inefficient (depending on regulation service cost)
- The Steam unit is marginal \(\rightarrow\) LMP is set to $30/MWh
  - The committed CTs did not set price despite their relaxation of EcoMin
Example 2a: PJM Dispatch & Pricing

Load = 375 MW

Dispatched MW
Not-Dispatched

Dispatch Solution at 240 MW
LMP = $30/MWh

Min = 30MW
Online Steam

300 MW @ $30/MWh

Committed CT1
Min
100 MW @ $100/MWh

Committed CT2
Min
50 MW @ $200/MWh

Un-committed CT

25 MW @ $250/MWh

Commit Cost: $500

Dispatch solution at 180 MW
Commit Cost: $1,000

Dispatch solution at 90 MW
Commit. Cost: $1,000

Min = 30MW
Online Steam

300 MW @ $30/MWh

Committed CT1
Min
100 MW @ $100/MWh

Committed CT2
Min
50 MW @ $200/MWh

Un-committed CT

25 MW @ $250/MWh

Commit Cost: $500

Dispatch solution at 180 MW
Commit Cost: $1,000

Dispatch solution at 90 MW
Commit. Cost: $1,000

Min = 30MW
Online Steam

300 MW @ $30/MWh

Committed CT1
Min
100 MW @ $100/MWh

Committed CT2
Min
50 MW @ $200/MWh

Un-committed CT

25 MW @ $250/MWh

Commit Cost: $500

Dispatch solution at 180 MW
Commit Cost: $1,000

Dispatch solution at 90 MW
Commit. Cost: $1,000

Min = 30MW
Online Steam

300 MW @ $30/MWh

Committed CT1
Min
100 MW @ $100/MWh

Committed CT2
Min
50 MW @ $200/MWh

Un-committed CT

25 MW @ $250/MWh

Commit Cost: $500
### Example 2a: MWP and LOC Outcomes (Load = 375MW)

<table>
<thead>
<tr>
<th>Resource</th>
<th>Offer Price $/MWh</th>
<th>EcoMin MW</th>
<th>EcoMax MW</th>
<th>Commit. Cost ($)</th>
<th>DDP (MW)</th>
<th>MWP* ($)</th>
<th>LOC ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Committed CT1</td>
<td>100</td>
<td>100</td>
<td></td>
<td>1,000</td>
<td>100</td>
<td>8,000</td>
<td>0</td>
</tr>
<tr>
<td>Committed CT2</td>
<td>200</td>
<td>50</td>
<td></td>
<td>1,000</td>
<td>50</td>
<td>9,500</td>
<td>0</td>
</tr>
<tr>
<td>Not-committed CT</td>
<td>250</td>
<td>25</td>
<td>500</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Steam (Marginal)</td>
<td>30</td>
<td>30</td>
<td>300</td>
<td>3,000</td>
<td>240</td>
<td>3,000</td>
<td>0</td>
</tr>
</tbody>
</table>

- To cover its commitment and energy costs, Committed CT1 would require a MWP of $8,000 = ($100-$30)×100MW+$1,000
- To cover its commitment and energy costs, Committed CT2 would require a MWP of $9,500 = ($200-$30)×50MW+ $1,000
- Steam Unit incurs MWP of $3,000 for its commitment costs
- No resource has Lost Opportunity Cost (LOC)

* Simplified, ignores possible daily accounting, etc
Example 2b: Illustration of PJM’s RT Pricing

- Demand = 446 MWh (higher than Example 2a)
- The goal is to illustrate that Block-loaded CT may set price, if demand falls in a CT’s narrow ‘relaxation band’
- Same set of resources as Example 2a

<table>
<thead>
<tr>
<th>Resource</th>
<th>Offer Price ($/MWh)</th>
<th>EcoMin (MW)</th>
<th>EcoMax (MW)</th>
<th>Commit. Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Committed CT1</td>
<td>100</td>
<td>100</td>
<td></td>
<td>1,000</td>
</tr>
<tr>
<td>Committed CT2</td>
<td>200</td>
<td></td>
<td>50</td>
<td>1,000</td>
</tr>
<tr>
<td>Not-committed CT</td>
<td>250</td>
<td>25</td>
<td></td>
<td>500</td>
</tr>
<tr>
<td>Steam</td>
<td>30</td>
<td>30</td>
<td>300</td>
<td>3,000</td>
</tr>
</tbody>
</table>
# Example 2b: PJM Dispatch & Pricing (Load=446MW)

<table>
<thead>
<tr>
<th>Resource</th>
<th>Offer Price $/MWh</th>
<th>EcoMin MW</th>
<th>EcoMax MW</th>
<th>Commit. Cost ($)</th>
<th>Dispatch (MW)</th>
<th>DDP Sent (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Committed CT1</td>
<td>100</td>
<td>100</td>
<td>90</td>
<td>1,000</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Committed CT2</td>
<td><strong>200</strong></td>
<td><strong>50</strong></td>
<td><strong>45</strong></td>
<td>1,000</td>
<td><strong>46</strong></td>
<td>50</td>
</tr>
<tr>
<td>Not-committed CT</td>
<td>250</td>
<td>25</td>
<td>25</td>
<td>500</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Steam</td>
<td>30</td>
<td>30</td>
<td>300</td>
<td>3,000</td>
<td>300</td>
<td>300</td>
</tr>
</tbody>
</table>

- EcoMin of committed CTs are relaxed to 90%
- Commitment costs of the committed CTs are NOT considered
- CT1 & CT2 dispatch solutions are at 90% of EcoMin, but the DDPs sent out respect the original offered EcoMins
  - The over-generation of 4MW (=50-46) is offset by regulation services, which can be inefficient (depending on regulation service cost)
- Committed CT2 is marginal \(\Rightarrow\) LMP is set to $200/MWh
Example 2b: PJM Dispatch & Pricing

Load = 446 MWh

Dispatch solution at 46 MW
LMP = $200/MWh

Commit Cost: $1,000

Dispatch MW
Not-Dispatched

Min = 30 MW

Steam

300 MW @ $30/MWh

Committed
CT1

100 MW @ $100/MWh

Committed
CT2

50 MW @ $200/MWh

Not-committed
CT

Commit Cost: $500

Min

25 MW @ $250/MWh
## Example 2b: MWP and LOC Outcomes (Load=446MW)

<table>
<thead>
<tr>
<th>Resource</th>
<th>Offer Price $/MWh</th>
<th>EcoMin MW</th>
<th>EcoMax MW</th>
<th>Commit. Cost ($)</th>
<th>DDP (MW)</th>
<th>MWP* ($)</th>
<th>LOC ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Committed CT1</td>
<td>100</td>
<td>100</td>
<td></td>
<td>1,000</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Committed CT2 (Marginal)</td>
<td>200</td>
<td>50</td>
<td></td>
<td>1,000</td>
<td>50</td>
<td>1,000</td>
<td>0</td>
</tr>
<tr>
<td>Not-committed CT</td>
<td>250</td>
<td>25</td>
<td></td>
<td>500</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Steam</td>
<td>30</td>
<td>30</td>
<td>300</td>
<td>3,000</td>
<td>300</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

- To cover its commitment costs, Committed CT2 would require a MWP of $1,000
- No resource has Lost Opportunity Cost (LOC)

* Simplified, ignores possible daily accounting, etc.
Summary of PJM RT Fast-start Pricing

1. **Which** specific group of resources are targeted?
   – Block-loaded Combustion Turbine (CT) resources

2. **What** specific conditions qualify these resources for special treatment?
   – Committed Block-loaded CTs only

3. **How** is the minimum output level of a qualified resource treated in pricing?
   – Relaxed to 90% of the original minimum output level (or EcoMin)

4. **How** is the commitment cost (Startup & No-load) of a qualified resource treated in pricing?
   – Not considered
## Comparison

<table>
<thead>
<tr>
<th>Core Elements</th>
<th>ISO-NE</th>
<th>PJM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applicable Resource Types</td>
<td>10/30-min Fast-start Resources</td>
<td>Block-loaded CTs</td>
</tr>
<tr>
<td>Committed Resources Treatment</td>
<td>Qualification</td>
<td>Qualification: First interval of committed period</td>
</tr>
<tr>
<td></td>
<td>Min. Output</td>
<td>Min. Output: Relaxed to zero</td>
</tr>
<tr>
<td></td>
<td>Commit. Cost</td>
<td>Commit. Cost: Amortized over EcoMax and added into the offer price</td>
</tr>
<tr>
<td>Not-committed Resources Treatment</td>
<td>Qualification</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Min. Output</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Commit. Cost</td>
<td>-</td>
</tr>
</tbody>
</table>
Layout of Today’s Presentation

- PJM Approach
- CAISO Approach
- NYISO Approach
- MISO Approach
CAISO: RT Commitment, Dispatch and Pricing

• **Commitment.** A multi-interval commitment that runs every 15 minutes and commits Fast Start Units and Medium Start Units
  – Real-Time Unit Commitment (RTUC)

• **Dispatch and Pricing.** A multi-interval dispatch that runs every 5 minutes to dispatch units and set prices on a 5-minute basis
  – Real-Time Dispatch (RTD)

• **Comparison to ISO-NE:**
  – ISO-NE runs single time-interval FS commitment and dispatch while CAISO uses multi-interval algorithm
  – Multi-interval algorithm may yield smoother dispatch between intervals, while single-interval process is simpler
  – Both ISOs use an integrated process to determine dispatch and price
CAISO: Constrained Output Generators (COG)

- **Constrained Output Generator (COG):** A generating unit with an operating range \((P_{Max} - P_{Min})\) no greater than the higher of 3 MW or 5% of its Pmax that registers, on an annual basis, its PMin as \(P_{Max} - 0.01\) MW \((P_{Min} = P_{Max} - 0.01\) MW\)

- **Comparison to ISO-NE:**
  - ISO-NE’s Fast-Start definition is based on the unit’s response time
  - CAISO’s COG definition is based on the size of dispatch range
  - CAISO’s COG classification is voluntary
CAISO: Qualification of COGs for Special Treatment in Pricing

• Committed COGs are qualified for special treatment in pricing
• COGs that are not committed will not receive special treatment in pricing
• Resources that do not elect COG status do not receive special treatment in pricing

• **Comparison to ISO-NE:**
  - ISO-NE’s special treatment for committed FS applies to the *first* committed interval only
  - CAISO expand the special treatment for committed COG to *all* committed intervals (**Implication**: Qualified COGs may set price more frequently)
  - Both ISOs have no special treatment for not-committed resources
CAISO: PMin Relaxation of Qualified COGs

• For a committed COG, the minimum generation level (or PMin) is relaxed to zero in the dispatch & pricing process

• **Comparison to ISO-NE:**
  – Both ISOs relax the EcoMin (or PMin) of qualified resources to zero
CAISO: Commitment Cost Treatment of Qualified COGs

• The submitted energy offer of a committed COG will be replaced by a Calculated Energy Bid (CEB):
  – For the ‘artificial’ dispatchable range between 0 and offered PMin,
    CEB Price = Minimum_Load_Cost/PMin
  – For the 0.01MW between PMin and PMax,
    CEB Price = max{Submitted_Bid_Price, Minimum_Load_Cost/PMin}

• **Comparison to ISO-NE:**
  – ISO-NE amortizes the commitment costs (start-up & no-load) while CAISO considers **only no-load costs** (Implication: The startup cost of qualified CAISO resources is not reflected in the price)
  – ISO-NE amortizes the costs over EcoMax, while CAISO amortizes the minimum load cost over ‘almost’ PMax (since PMin is 0.01MW different from PMax)
  – ISO-NE modifies offer price only in the dispatch & pricing process, while CAISO uses CEB for COGs in all processes (including commitment process)
Example 3: CAISO’s RT Pricing

- Same Demand = 375 MWh
- Same set of resources as Example 1a
- Separate the commitment cost into Startup and Minimum_Load_Cost

Minimum_Load_Cost (the generation cost at PMin) = No_Load_Cost + PMin \times \text{Offer Price}

- Terminology changed from “FS” to “COG” and “GT” (Gas Turbine)

<table>
<thead>
<tr>
<th>Resource</th>
<th>Offer Price $/MWh</th>
<th>PMin MW</th>
<th>PMax MW</th>
<th>Startup ($)</th>
<th>Noload ($/h)</th>
<th>Min. Load Cost ($/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Committed COG</td>
<td>100</td>
<td>99.99</td>
<td>100</td>
<td>500</td>
<td>500</td>
<td>10,499</td>
</tr>
<tr>
<td>Committed GT</td>
<td>200</td>
<td>50</td>
<td>PMax</td>
<td>500</td>
<td>500</td>
<td>10,500</td>
</tr>
<tr>
<td>Not-committed GT</td>
<td>250</td>
<td>25</td>
<td>250</td>
<td>250</td>
<td>250</td>
<td>6,500</td>
</tr>
<tr>
<td>Steam</td>
<td>30</td>
<td>30</td>
<td>300</td>
<td>1,500</td>
<td>1,500</td>
<td>2,400</td>
</tr>
</tbody>
</table>
Example 3: CAISO RT Dispatch & Pricing

- Calculated Energy Bid (= Min_Load_Cost/PMin) is used for the COG
- PMin of the committed COG is relaxed to zero
- Not-committed COG units do not participate in Dispatch & Pricing

<table>
<thead>
<tr>
<th>Resource</th>
<th>Offer Price $/MWh</th>
<th>PMin MW</th>
<th>PMax MW</th>
<th>Startup $</th>
<th>Min. Load Cost ($/h)</th>
<th>Dispatch MW</th>
<th>DDP Sent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Committed COG</td>
<td>100</td>
<td>105</td>
<td>99.99</td>
<td>100</td>
<td>500</td>
<td>25</td>
<td>99.99</td>
</tr>
<tr>
<td>Committed GT</td>
<td>200</td>
<td>50</td>
<td>500</td>
<td>500</td>
<td>10,500</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Not-committed GT</td>
<td>250</td>
<td>25</td>
<td>250</td>
<td>6,500</td>
<td></td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Steam</td>
<td>30</td>
<td>30</td>
<td>300</td>
<td>1,500</td>
<td>2,400</td>
<td>300</td>
<td>300</td>
</tr>
</tbody>
</table>

- The COG’s dispatch solution is 25MW, but the DDP sent to the COG is 99.99 MW, respecting its offered PMin
  - The 74.99MW (=99.99-25) over-generation is offset by regulation services, which can be inefficient (depending on the cost of regulation service)
- COG is marginal: LMP is set by its calculated energy bid: $105/MWh
Example 3: CAISO’s Dispatch & Pricing

Demand = 375 MW

Dispatch solution at 25 MW
LMP = $105/MWh

Startup Cost: $500
Min Load Cost: $10,499

Commit Cost: $1000

Commit Cost: $500

Min (30 MW)

Steam

300 MW @ $30/MWh

Relaxed Min

COG

100 MW @ $105/MWh

Committed

Min

Committed

GT

50 MW @ $200/MWh

Not-committed

GT

25 MW @ $250/MWh

Min (30MW)

Dispatched MW

Not-Dispatched
### Example 3: MWP and LOC Outcomes

**Resource** | **Offer Price $/MWh** | **PMin MW** | **PMax MW** | **Startup $** | **Min. Load Cost $/h** | **DDP MW** | **MWP* ($)** | **LOC ($)**
---|---|---|---|---|---|---|---|---
Committed COG (Marginal) | 100–105 | 99.99 | 100 | 500 | 10,499 | 99.99 | 500 | 0
Committed GT | 200 | 50 | 500 | 10,500 | 50 | 5,750 | 0
Not-committed GT | 250 | 25 | 250 | 6,500 | 0 | 0 | 0
Online Steam | 30 | 30 | 300 | - | 2,400 | 300 | 0 | 0

- To cover its (startup) cost, the COG would need a Make Whole Payment (MWP) of $500
- To cover its commitment and energy costs, the committed GT would need a MWP of $5,750 = $500 + $10,500 – $105 x 50 MW
- The not-committed GT and online steam receives no MWP
- No resource has Lost Opportunity Cost (LOC)

* Simplified, ignores possible daily accounting, etc.
Summary of CAISO RT Fast-start Pricing

1. **Which** specific group of resources are targeted?
   - COGs

2. **What** specific conditions qualify these resources for special treatment?
   - Committed COGs

3. **How** is the minimum output level treated in pricing?
   - Relaxed to zero

4. **How** is the commitment cost (Startup & No-load) treated?
   - Minimum load costs are amortized over offered PMin, i.e., no-load costs are amortized over ‘almost’ PMax and added into the offer price
   - Startup costs are not incorporated in the price calculation
<table>
<thead>
<tr>
<th>Core Elements</th>
<th>ISO-NE</th>
<th>PJM</th>
<th>CAISO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applicable Resource Types</td>
<td>10/30-min Fast-start Resources</td>
<td>Block-loaded CTs</td>
<td>Constrained Output Gen (COG)</td>
</tr>
<tr>
<td>Committed Resources Treatment</td>
<td>Qualification: First interval of committed period</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td></td>
<td>Min. Output: Relaxed to zero</td>
<td>Relaxed to 90% of EcoMin</td>
<td>Relaxed to zero</td>
</tr>
<tr>
<td></td>
<td>Commit. Cost: Amortized over EcoMax and added into the offer price</td>
<td>Not Considered</td>
<td>Min_Load_Cost amortized over PMin</td>
</tr>
<tr>
<td>Not-committed Resources Treatment</td>
<td>Qualification: -</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Min. Output: -</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Commit. Cost: -</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Layout of Today’s Presentation

• PJM Approach
• CAISO Approach
• NYISO Approach
• MISO Approach
NYISO: Commitment, Dispatch and Pricing

- **Commitment**: A multi-period security constrained unit commitment model that determines the commitment and de-commitment of 10-min and 30-min fast resources
  - Real-Time Commitment (RTC)

- **Dispatch**: A multi-period security constrained dispatch model that runs every 5 minutes
  - Real-Time Dispatch (RTD)

- **Pricing**: Multiple “Passes” of RTD runs, separate from the dispatch RTD run, are used to determine the price

- **Comparison to ISO-NE**:  
  - ISO-NE runs single-interval commitment and single-interval dispatch & pricing, while NYISO uses multiple intervals for all three processes  
  - ISO-NE’s dispatch and pricing are integrated in one process, while NYISO has separate dispatch and pricing processes based on the same RTD model
NYISO: Fixed-Block ("Block-loaded") Resources

• “Fixed-block” Generation Resources: “Block-loaded” resources that, because of their operational characteristics, can only be dispatched in one of two states, i.e., they must either be turned completely off, or turned on and run at their maximum capacity
  – These resources are mostly Gas-Turbine (GT) units

• Comparison to ISO-NE:
  – ISO-NE’s fast-start definition covers also the fast-start resources with valid dispatchable ranges (i.e., EcoMin < EcoMax)
  – NYISO considers only the blocked-loaded resources for special treatment in pricing
NYISO’s View on Pricing Problems with Fixed-block Resources

• The inflexibility of fixed block units introduces a complication into the NYISO’s LBMP methodology that could conceivably be addressed by several different pricing rules. All of these rules involve trade-offs, and none presents a perfect solution.

• Without special treatment their costs would not be explicitly represented in prices.

1 NYISO’s FERC Filing, Docket No. ER00-3591-000
NYISO: Multiple RTD Runs For Dispatch and Pricing

• NYISO uses multiple RTD runs ("Passes") to determine the Real-time dispatch and price:
  – “Physical Pass” determines the physical dispatch and dispatch signal (DDP) sent to resources
  – “Hybrid Pass” determines the qualification of committed block-loaded resources for special treatment in the price-setting pass
  – “Price-setting Pass” calculates prices with special treatment for
    • Committed block-loaded resources that pass “Hybrid Test”
    • Not-committed fast-start resources with capacity not exceeding the limit (currently set as 80MW) \(^1\)

\(^1\)http://www.nyiso.com/public/webdocs/markets_operations/documents/Manuals_and_Guides/Guides/User_Guides/mpug.pdf (Section 5.7.2)
NYISO: Implementation Order of Multiple Passes

Physical Pass → Dispatch Signals
Hybrid Pass → Qualified Resources
Price-setting Pass → Prices
First Pass: Physical Pass

- A RTD run that determines the MWs for Energy, Regulation Service and Operating Reserves
- **Committed Fixed-block Resources**: Output fixed at their PMax
- **Not-committed (Offline) Resources**
  - **10-minute Resources with capacity ≤ 80MW**: Minimum output relaxed to zero → treated dispatchable from zero to PMax
  - All Other Resources: Output fixed at zero MW
- The physical dispatch pass establishes the dispatch signal sent to committed resources
Second Pass: Hybrid Pass

• A RTD run with the minimum outputs of all committed block-loaded resources and not-committed 10-minute resources relaxed to zero

• The hybrid pass was “designed to balance the needs of providing the ability for fast start, block loaded resources to set prices when they are economic” ¹

• The pass determines the price-setting eligibility (qualification) of committed block-loaded resources – See Next

Hybrid Pass – Continued

• For a committed block-loaded resource running within minimum run time:
  – If its Hybrid dispatch > 0 ("Economic") $\rightarrow$ Qualified for price setting
  – If its hybrid dispatch = 0 ("Uneconomic") $\rightarrow$ Not qualified

• Committed block-loaded resources operating past minimum run time are qualified to set price in the price-setting pass

• *See Example 4 (ahead) for how this is applied*
Third Pass: Price-Setting Pass

• A RTD run that determines the energy and reserve prices

• **Committed** block-loaded resources that are **not qualified**:  
  – Output **fixed at their PMax** → will not set price

• **Committed** block-loaded resources that are **qualified**:  
  – Minimum output levels are **relaxed to zero** → may set price  
  – Commitment costs (Startup & No-load) are **not considered**

• **Not-committed 10-min** resources are **qualified** for price-setting  
  – Minimum output levels are **relaxed to zero** → may set price  
  – Commitment costs are **amortized** over PMax and added into offer prices
Example 4: Illustration of NYISO’s RT Pricing

- Load = 375 MWh
- Same set of resources as Example 1a
- Assume both committed GTs are within their minimum run time
- Terminology changed from “FS” to “GT”

<table>
<thead>
<tr>
<th>Resource</th>
<th>Offer Price ($/MWh)</th>
<th>EcoMin (MW)</th>
<th>EcoMax (MW)</th>
<th>Commit. Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Committed GT1</td>
<td>100</td>
<td>100</td>
<td></td>
<td>1,000</td>
</tr>
<tr>
<td>Committed GT2</td>
<td>200</td>
<td>50</td>
<td></td>
<td>1,000</td>
</tr>
<tr>
<td>Not-committed GT</td>
<td>250</td>
<td>25</td>
<td></td>
<td>500</td>
</tr>
<tr>
<td>Steam</td>
<td>30</td>
<td>30</td>
<td>300</td>
<td>3,000</td>
</tr>
</tbody>
</table>
Example 4: NYISO’s Physical Dispatch Pass

- The physical dispatch solution (Load=375 MW):

<table>
<thead>
<tr>
<th>Resource</th>
<th>Offer Price $/MWh</th>
<th>PMin MW</th>
<th>PMax MW</th>
<th>Commit. Cost ($)</th>
<th>Physical Disp. Solution (MW)</th>
<th>DDP Sent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Committed GT1</td>
<td>100</td>
<td>100</td>
<td></td>
<td>1,000</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Committed GT2</td>
<td>200</td>
<td>50</td>
<td></td>
<td>1,000</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Not-committed GT</td>
<td>250</td>
<td>25</td>
<td>25</td>
<td>500</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Steam</td>
<td>30</td>
<td>30</td>
<td>300</td>
<td>3,000</td>
<td>225</td>
<td>225</td>
</tr>
</tbody>
</table>

- The minimum output (PMin) of committed GT1&GT2 are **not** relaxed
- The PMin of not-committed GT is **relaxed to zero**, and commitment cost amortized over PMax and added into offer price
  - In this example, the not-committed GT dispatch solution is zero MW
  - **In general**: Not-committed GTs’ dispatch solution may be **above** zero, but the DDP sent will be 0 → **Energy imbalance** for regulation to absorb
Example 4: NYISO’s Physical Pass

Load = 375 MW

- **Online Steam**
  - 300 MW @ $30/MWh
  - Dispatched at 225 MW

- **Committed GT1**
  - 100 MW @ $100/MWh

- **Committed GT2**
  - 50 MW @ $200/MWh

- **Un-committed GT**
  - 25 MW @ $270/MWh
  - Commit Cost: $500

---

- **Dispatched MW**
- **Not-Dispatched**

---

Min
Example 4: NYISO’s Hybrid Pass

Determines the price-setting eligibility of committed GTs

<table>
<thead>
<tr>
<th>Resource</th>
<th>Price ($/MWh)</th>
<th>Pmin (MW)</th>
<th>Pmax (MW)</th>
<th>Commit. Cost ($)</th>
<th>Hybrid Dispatch (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Committed GT1</td>
<td>100</td>
<td>100 0</td>
<td>100</td>
<td>1,000</td>
<td>75</td>
</tr>
<tr>
<td>Committed GT2</td>
<td>200</td>
<td>50 0</td>
<td>50</td>
<td>1,000</td>
<td>0</td>
</tr>
<tr>
<td>Not-committed GT</td>
<td>250 270</td>
<td>25 0</td>
<td>25</td>
<td>500</td>
<td>0</td>
</tr>
<tr>
<td>Steam</td>
<td>30</td>
<td>30</td>
<td>300</td>
<td>3,000</td>
<td>300</td>
</tr>
</tbody>
</table>

- The minimum output of committed GTs are relaxed to zero
- Commitment costs of the committed GTs are not considered
- The hybrid pass GT2 dispatch solution is 0 → GT2 is considered “uneconomic” and not qualified to set price in price-setting pass
Example 4: NYISO’s Hybrid Pass

Demand = 375 MW

- Dispatched MW
- Not-Dispatched

- 300 MW @ $30/MWh
- 100 MW @ $100/MWh
- 50 MW @ $200/MWh
- 25 MW @ $270/MWh

Commit Cost:
- $1000
- $500

Min
Example 4: NYISO’s Price-setting Pass

The Price-setting pass determines the energy price

<table>
<thead>
<tr>
<th>Resource</th>
<th>Offer Price $/MWh</th>
<th>PMin MW</th>
<th>PMax MW</th>
<th>Commit. Cost ($)</th>
<th>Physical Dispatch</th>
<th>Pricing Dispatch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Committed GT1</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>1,000</td>
<td>100</td>
<td>25</td>
</tr>
<tr>
<td>Committed GT2</td>
<td>200</td>
<td>50</td>
<td>1,000</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Not-committed GT</td>
<td>250 270</td>
<td>25 0</td>
<td>25</td>
<td>500</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Steam</td>
<td>30</td>
<td>30</td>
<td>300</td>
<td>3,000</td>
<td>225</td>
<td>300</td>
</tr>
</tbody>
</table>

- The “uneconomic” GT2 is fixed at its block capacity → will not set price
- Minimum output of committed GT1 and not-committed GT are relaxed to zero
- Commitment cost is amortized and added to offer price for only the not-committed GT
- Committed GT1 is “marginal” → Sets price: $100/MWh
- The physical dispatch MW of the infra-marginal steam unit is less than its PMax → potential incentive problems (dispatched down, price goes up)
Example 4: NYISO’s Pricing Pass

Demand = 375 MW

- Dispatched MW
- Not-Dispatched

**Dispatcher at 25 MW**
- LMP = $100/MWh

**Commit Cost:**
- $1,000

**Online Steam**
- 300 MW @ $30/MWh

**Committed GT1**
- 100 MW @ $100/MWh

**Committed GT2**
- 50 MW @ $200/MWh

**Un-committed GT**
- 25 MW @ $270/MWh

**LMP Min**
Example 4: MWP and LOC Outcomes

To cover its commitment costs, GT1 would require a Make Whole Payment (MWP) of $1,000.

To cover its commitment and energy costs, GT2 would require a MWP of $6,000 = ($200 - $100 LMP) x 50 MW + $1,000.

Not-committed GT would require no MWP.

Online Steam Unit has a Lost Opportunity Cost (LOC) if it follows its assigned physical dispatch: LOC of $5,250 = (300 MW - 225 MW) x ($100 LMP - $30 offer)

- Not paid under the current Tariff.

*Simplified, ignores possible daily accounting, etc.
Summary of NYISO RT Fast-start Pricing

1. Which specific group of resources are targeted?
   – Block-loaded resources

2. What specific conditions qualify these resources for special treatment?
   – Committed block-loaded resources that are “economic”
   – Not-committed, 10-min available fast-start units (must also satisfy a capacity limit, currently ≤ 80 MW)

3. How is the minimum output level treated in pricing?
   – Relaxed to zero for qualified resources

4. How is the commitment cost (Startup & No-load) treated?
   – For qualified committed resources, these costs are not considered in pricing
   – For qualified not-committed resources, commitment costs are amortized over the block sizes and added into the energy offer prices
<table>
<thead>
<tr>
<th>Core Elements</th>
<th>ISO-NE</th>
<th>PJM</th>
<th>CAISO</th>
<th>NYISO</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Applicable Resource Types</strong></td>
<td>10/30-min Fast-start Resources</td>
<td>Block-loaded CTs</td>
<td>Constrained Output Gen (COG)</td>
<td>Block-loaded Resources</td>
</tr>
<tr>
<td><strong>Committed Resources Treatment</strong></td>
<td>Qualification</td>
<td>First interval of committed period</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td></td>
<td>Min. Output</td>
<td>Relaxed to zero</td>
<td>Relaxed to 90% of EcoMin</td>
<td>Relaxed to zero</td>
</tr>
<tr>
<td></td>
<td>Commit. Cost</td>
<td>Amortized over EcoMax and added into the offer price</td>
<td>Not Considered</td>
<td>Min_Load_Cost amortized over PMin</td>
</tr>
<tr>
<td><strong>Not-committed Resources Treatment</strong></td>
<td>Qualification</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Min. Output</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Commit. Cost</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
NYISO: MMU Recommendation for Hybrid Pass

- In 2011 and 2012, the MMU recommended that the NYISO evaluate the benefits of eliminating the hybrid step
- NYISO found that “eliminating the hybrid pass would tend to increase LBMPs”\(^1\)
- “NYISO is not compelled to recommend any changes to the treatment of the hybrid GT pricing”\(^2\)

\(^1,2\)http://www.nyiso.com/public/webdocs/markets_operations/committees/bic_miwg/meeting_materials/2013-12-20/Hybrid%20GT%20Pricing%20-%2020131220%20MIWG.pdf
Layout of Today’s Presentation

• PJM Approach
• CAISO Approach
• NYISO Approach
• MISO Approach
MISO: Commitment, Dispatch and Pricing

- **Commitment**: A multi-interval Look Ahead Commitment (LAC) determines the RT commitment and de-commitment of FS units.
- **Dispatch**: Currently, dispatch and prices are calculated through one single-interval Security Constrained Economic Dispatch (“SCED”).
- **Pricing**: A separate SCED-pricing process will be established for AELMP.
- **Comparison to ISO-NE**:  
  - ISO-NE’s RT commitment solves a single-interval optimization problem, while MISO solves a multi-interval commitment problem.
  - ISO-NE’s dispatch and prices are determined in one SCED run, while MISO will implement separate processes for dispatch and pricing.
MISO: 10-Min Fast Start Resources

- **10-Min Fast-Start**: A Generation Resource that can be started, synchronized and inject Energy, or a Demand Response Resource that can reduce its Energy consumption, within 10 minutes of being notified and that will participate in setting prices.

- **Comparison to ISO-NE**:  
  - ISO-NE considers both 10-min and 30-min resources for special pricing treatment  
  - MISO considers only 10-min resources (Implication: a broader range of FS resources can set price in ISO-NE)

---

1 FERC Filings/2011-12-22 Docket No. ER12-668-000, page 10
MISO’s View on Fast-start Pricing Problem

• The SCED prices “may not reflect the Start-Up/Shut-Down Offer costs and the No-Load Offer costs of resources. The SCED prices, thus, do not always cover a Market Participant’s Offer costs. Revenue Sufficiency Guarantee (RSG) payments compensate the Market Participant for its Offer costs” ¹

• A “key drawback” of the SCED pricing algorithm is that “it cannot allow certain Fast Start Resources to set price, even though such Resources often have the highest Offer cost” ¹

MISO’s AELMP: Qualification of 10-min FS for Special Treatment in Pricing

• **Committed 10-min resources:** Qualified for special treatment

• **Not-committed 10-min resources:**
  – If they can **relieve** transmission, energy, or reserve constraint violations → Qualified for special treatment in the pricing process
  – Otherwise → Not qualified (output fixed at 0 MW in pricing)

• **Slow-start resources are not qualified for special treatment**

• **Comparison to ISO-NE:**
  – In ISO-NE, FS resources are qualified for their first committed interval, while MISO extends the qualification to all committed intervals (**Implication:** Committed MISO FS may set price more frequently)
  – ISO-NE does not allow not-committed FS resources to set price, while qualified not-committed MISO resources may set price
MISO’s AELMP: PMin Relaxation of Qualified 10-min Resources

• AELMP is based on a linear program that “relaxes” the integer commitment decision of qualified FS resources
  – FS resources are allowed to be “partially committed” in pricing process (but not in actual commitment decisions!)

• This is a different “relaxation” technique than other ISO’s use for FS pricing, but is has some similar end results:
  – Minimum generation levels are relaxed to zero

• Comparison to ISO-NE:
  – Both ISOs relax the EcoMins of qualified fast-start resources to zero
  – Different relaxation techniques are used
MISO’s AELMP: Commitment Cost Treatment of Qualified 10-min Resources

• “Relaxation” of the integer commitment decision of qualified FS resources allows the commitment costs reflected in the pricing

• This yields similar outcome: Commitment costs of are amortized over EcoMax and added into the energy offer price for both qualified committed and not-committed resources

• **Comparison to ISO-NE:**
  – Both ISOs consider the commitment costs (startup & no-load) in pricing
Example 5: Illustration of MISO’s AELMP

- Load = 375 MWh
- Same set of resources as Example 1a
- Assume the not-committed CT is not needed for constraint relief

<table>
<thead>
<tr>
<th>Resource</th>
<th>Offer Price ($/MWh)</th>
<th>EcoMin (MW)</th>
<th>EcoMax (MW)</th>
<th>Commit. Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Committed CT1</td>
<td>100</td>
<td>100</td>
<td></td>
<td>1,000</td>
</tr>
<tr>
<td>Committed CT2</td>
<td>200</td>
<td></td>
<td>50</td>
<td>1,000</td>
</tr>
<tr>
<td>Not-committed CT</td>
<td>250</td>
<td>25</td>
<td></td>
<td>500</td>
</tr>
<tr>
<td>Steam</td>
<td>30</td>
<td>30</td>
<td>300</td>
<td>3,000</td>
</tr>
</tbody>
</table>
Example 5: MISO’s Dispatch

<table>
<thead>
<tr>
<th>Resource</th>
<th>Offer Price $/MWh</th>
<th>EcoMin MW</th>
<th>EcoMax MW</th>
<th>Commit. Cost ($)</th>
<th>Dispatch (MW)</th>
<th>DDP Sent (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Committed FS1</td>
<td>100</td>
<td>100</td>
<td></td>
<td>1,000</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Committed FS2</td>
<td>200</td>
<td>50</td>
<td></td>
<td>1,000</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Not-committed FS</td>
<td>250</td>
<td>25</td>
<td></td>
<td>500</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Steam</td>
<td>30</td>
<td>30</td>
<td>300</td>
<td>3,000</td>
<td>225</td>
<td>225</td>
</tr>
</tbody>
</table>

- No special treatment for FS units during the dispatch process
  - Block-loaded FS1 and FS2 are dispatched at EcoMax (=EcoMin)
- The DDPs sent to resources are the same as the dispatch solution MW
  - Resource ‘s offered minimums are respected in the dispatch process
  - There is no energy imbalance
- Without relaxation, the block-loaded FS units cannot set price
Example 5: MISO’s Dispatch

Load = 375 MW

- Dispatched MW
- Not-Dispatched

Min = 30 MW

Dispatched at 225 MW

- 300 MW @ $30/MWh
- 100 MW @ $100/MWh
- 50 MW @ $200/MWh

Commit Cost:
- $1000
- $1000
- $500

Commit Cost:
- $500

25 MW @ $250/MWh
Example 5: MISO’s AELMP Pricing

<table>
<thead>
<tr>
<th>Resource</th>
<th>Offer Price $/MWh</th>
<th>EcoMin MW</th>
<th>EcoMax MW</th>
<th>Commit Cost ($)</th>
<th>DDP MW</th>
<th>Pricing Dispatch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Committed FS1</td>
<td>100</td>
<td>1000</td>
<td>100</td>
<td>1000</td>
<td>100</td>
<td>75</td>
</tr>
<tr>
<td>Committed FS2</td>
<td>200</td>
<td>50</td>
<td>50</td>
<td>1000</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>Not-committed FS</td>
<td>250</td>
<td>25</td>
<td>500</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Online Steam</td>
<td>30</td>
<td>30</td>
<td>300</td>
<td>3000</td>
<td>225</td>
<td>300</td>
</tr>
</tbody>
</table>

- EcoMin of committed FS1 and FS2 are relaxed to zero
- Commitment costs of FS1 and FS2 are amortized over EcoMax and added into the offer prices
  - Modified offer price of FS1 = $100 + $1000/100 = $110/MWh
  - Modified offer price of FS2 = $200 + $1000/50 = $220/MWh
- Not-committed FS did not participate in the pricing process, as it is not needed for a constraint (e.g., transmission)
- Committed FS1 is marginal → LMP = $110/MWh
- The “pricing dispatch” MW solution deviates from the DDP due to EcoMin relaxation → potential incentive problems (the Steam unit’s dispatch of 225 MW is below its EcoMax, yet LMP > offer price)
Example 5: MISO’s AELMP

Load = 375 MW

Dispatched at 75 MW
LMP = $110/MWh

Commit Cost: $1000

Dispatched MW
Not-Dispatched

Min = 30 MW

Steam

300 MW @ $30/MWh

Commit Cost: $500

25 MW @ $250/MWh

100 MW @ $110/MWh

50 MW @ $220/MWh

Not-committed

Commit Cost: $1000

Committed FS1

Min

Committed FS2

Min

FS
Example 5: MWP and LOC Outcomes Under AELMP

<table>
<thead>
<tr>
<th>Resource</th>
<th>Offer Price $/MWh</th>
<th>Pmin MW</th>
<th>Pmax MW</th>
<th>Commit Cost ($)</th>
<th>DDP MW</th>
<th>MWP* ($)</th>
<th>LOC ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Committed FS1</td>
<td>100-110</td>
<td>100</td>
<td></td>
<td>1,000</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>(Marginal)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Committed FS2</td>
<td>200</td>
<td>50</td>
<td></td>
<td>1,000</td>
<td>50</td>
<td>5,500</td>
<td>0</td>
</tr>
<tr>
<td>Not-committed FS</td>
<td>250</td>
<td>25</td>
<td></td>
<td>500</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Online Steam</td>
<td>30</td>
<td>30</td>
<td>300</td>
<td>3,000</td>
<td>225</td>
<td>0</td>
<td>6,000</td>
</tr>
</tbody>
</table>

• To cover its commitment and energy costs, FS2 would need a Make Whole Payment (MWP) of $5,500 = ($200 - $110) x 50 MW + $1,000

• The Online Steam unit has a Lost Opportunity Cost (LOC) of $6,000 = (300 MW EcoMax - 225 MW DDP) x ($110 LMP - $30 offer)
  – Not paid under the current MISO Tariff

• Committed FS1 and Not-committed FS have no MWP or LOC

* Simplified, ignores possible daily accounting, etc
Summary of MISO AELMP Pricing

1. **Which** specific group of resources are targeted?
   - 10-min fast resources

2. **What** specific conditions qualify these resources for special treatment?
   - Committed; Or
   - Not-committed, but can relieve transmission/energy/reserve constraint violations

3. **How** is the minimum output level treated in pricing?
   - Relaxed to zero (by allowing partial commitment)

4. **How** is the commitment cost (Startup & No-load) treated?
   - Amortized over EcoMax and added into the offer price (by allowing partial commitment)
MISO’s IMM Comments on AELMP

• **Recommended design changes**
  
  – *(A1) Disable price-setting by offline FSRs until methodology is improved*
  
  – *(A2) Implement the following changes to ELMP:*
    • *(A2R1) Amortize commitment cost over one interval*
    • *(A2R2) Implement a Generation Shift Factor (GSF) cutoff of 10% for offline FSR to set price for transmission constraints*
    • *(A2R3) Remove PJM Market-to-Market constraints from transmission constraint exceedance treatment*
    • *(A2R4) Remove offline energy limited resources, mainly pumped storage resources, from price setting*

• **MISO currently agrees with (A2R2), (A2R3), and (A2R4), disagrees with (A1) and requires more time to evaluate (A2R1)**
<table>
<thead>
<tr>
<th>Core Elements</th>
<th>ISO-NE</th>
<th>PJM</th>
<th>CAISO</th>
<th>NYISO</th>
<th>MISO</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Applicable Resource Types</strong></td>
<td>10/30-min Fast-start Resources</td>
<td>Block-loaded CTs</td>
<td>Constrained Output Gen (COG)</td>
<td>Block-loaded Resources</td>
<td>10-min Fast-start Resources</td>
</tr>
<tr>
<td><strong>Committed Resources Treatment</strong></td>
<td>Qualification</td>
<td>First interval of committed period</td>
<td>v</td>
<td>v</td>
<td>v</td>
</tr>
<tr>
<td></td>
<td>Min. Output</td>
<td>Relaxed to zero</td>
<td>Relaxed to 90% of EcoMin</td>
<td>Relaxed to zero</td>
<td>Relaxed to zero</td>
</tr>
<tr>
<td></td>
<td>Commit. Cost</td>
<td>Amortized over EcoMax and added into the offer price</td>
<td>Not Considered</td>
<td>Min_load_cost amortized over PMin</td>
<td>Amortized over EcoMax and added into the offer price</td>
</tr>
<tr>
<td><strong>Not-committed Resources Treatment</strong></td>
<td>Qualification</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>If 10-min FS and capacity ≤ 80MW</td>
</tr>
<tr>
<td></td>
<td>Min. Output</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Relaxed to zero</td>
</tr>
<tr>
<td></td>
<td>Commit. Cost</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Amortized over PMax and added into the offer price</td>
</tr>
</tbody>
</table>

- **Not-committed Resources Treatment**

- **Qualification**: If relieving transmission /energy/reserve constraints

- **Min. Output**: Relaxed to zero

- **Commit. Cost**: Amortized over EcoMax and added into the offer price
SUMMARY OF CORE DESIGN ELEMENTS

And:

Five Key Takeaways for Fast-Start Pricing
Options for Dispatch & Pricing Processes

- Integrated process vs. Separate processes
- Single-interval vs. Multi-interval optimization

<table>
<thead>
<tr>
<th>Dispatch &amp; Pricing Processes</th>
<th>ISO-NE</th>
<th>PJM</th>
<th>CAISO</th>
<th>NYISO</th>
<th>MISO</th>
</tr>
</thead>
</table>

- Separate dispatch and pricing processes avoid energy imbalance problems, but, unless LOCs are paid, can cause “dispatch-following” incentive problems *(See Examples 4, 5)*
- Multi-interval process may yield smoother dispatch between intervals, while single-interval process is simpler
### Which Resources May Get Special Treatment?

<table>
<thead>
<tr>
<th>Applicable Resource Types</th>
<th>ISO-NE</th>
<th>PJM</th>
<th>CAISO</th>
<th>NYISO</th>
<th>MISO</th>
</tr>
</thead>
<tbody>
<tr>
<td>10/30-min Fast-start Resources</td>
<td>10/30-min Fast-start Resources</td>
<td>Block-loaded CTs</td>
<td>Constrained Output Gen (COG)</td>
<td>Block-loaded Resources</td>
<td>10-min Fast-start Resources</td>
</tr>
</tbody>
</table>

#### Diagram:

- **Dispatch Range**:
  - Block-loaded
  - Available Range including Small Range

- **Gen. Technology**:
  - CT
  - Non-CT

- **Response Time**:
  - 10-min
  - 30-min

- **ISO-NE**
- **PJM**
- **CAISO**
- **NYISO**
- **MISO**

- **Implication**: A wider range of FS resources are potentially eligible for price-setting under ISO-NE definition

- **ISO-NE’s FS definition covers a wider range of resources than other ISOs’ definitions**
Qualification Rules For Committed Resources

<table>
<thead>
<tr>
<th>Qualification for Committed Resources</th>
<th>ISO-NE</th>
<th>PJM</th>
<th>CAISO</th>
<th>NYISO</th>
<th>MISO</th>
</tr>
</thead>
<tbody>
<tr>
<td>First interval of committed period</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>If passing the Hybrid Test</td>
<td>✓</td>
</tr>
</tbody>
</table>

- Committed
- Not committed

Min Run Time

- Qualification rules are complex and vary
- In general, committed FS resources in ISO-NE sets price less frequently
# Treatment of Qualified Committed Resources

<table>
<thead>
<tr>
<th></th>
<th>ISO-NE</th>
<th>PJM</th>
<th>CAISO</th>
<th>NYISO</th>
<th>MISO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min. Output</td>
<td>Relaxed to zero</td>
<td>Relaxed to 90%</td>
<td>Relaxed to zero</td>
<td>Relaxed to zero</td>
<td>Relaxed to zero</td>
</tr>
<tr>
<td>Commit. Cost</td>
<td>Amortized over EcoMax and added into the offer price</td>
<td>Not Considered</td>
<td>Min_Load_Cost amortized over PMin</td>
<td>Not considered</td>
<td>Amortized over EcoMax and added into the offer price</td>
</tr>
</tbody>
</table>

- **PJM** has less EcoMin relaxation of qualified committed resources than other ISOs (making the resources less likely to set price, other things equal)
- No theoretical “best” answer as to whether/how startup and no-load costs should be amortized (over MW and time) and reflected in pricing
Qualification of Not-Committed Resources

<table>
<thead>
<tr>
<th>Qualification for Not-committed Resources</th>
<th>ISO-NE</th>
<th>PJM</th>
<th>CAISO</th>
<th>NYISO</th>
<th>MISO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qualification for Not-committed Resources</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>If 10-min FS and capacity ≤ Predefined limit</td>
<td>If relieving transmission /energy/reserve constraints</td>
</tr>
</tbody>
</table>

- Most ISOs do not allow, or apply restrictions, for not-committed (offline) resources to set price
# Treatment of Qualified Not-committed Resources

<table>
<thead>
<tr>
<th></th>
<th>ISO-NE</th>
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<th>NYISO</th>
<th>MISO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min. Output</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Relaxed to zero</td>
<td>Relaxed to zero</td>
</tr>
<tr>
<td>Commit. Cost</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Amortized over PMax and added into the offer price</td>
<td>Amortized over EcoMax and added into the offer price</td>
</tr>
</tbody>
</table>

- Not-committed resources, if qualified for special treatment, are treated as dispatchable between 0 and PMax (or EcoMax) in the pricing process
- The commitment costs (Startup & No-load costs) of qualified not-committed resources are amortized over PMax (or EcoMax) and added into the offer price
Five Key Takeaways

1. Each ISO targets a specifically defined group of resources
   - The definition could be narrow or wide, depending on the needs
   - Broader definition \(\rightarrow\) More resources have a chance of setting price

2. Each ISO uses a variety of qualifications to limit the price-setting eligibility of the targeted resources
   - The qualification could be loose or strict
   - The stricter the qualification, the less likely of the resources to set price
   - Qualification rules are complex and vary, including online/offline conditions, minimum run time conditions, constraint relief conditions, resource size (MW) limits, and so on
Five Key Takeaways, *Continued*

3. All ISOs approaches assume a qualified resource’s minimum output is *less* than its offered minimum MW (“Relaxation”)
   - Allows the qualified resource to have an artificially ‘wider’ (than offered) dispatch range in pricing process, increasing their chance of setting price
   - Actual dispatch signals may differ: Respect offered EcoMin/PMin limits

• **Relaxation methods have some undesirable consequences**
  - May create inefficient dispatch (*Examples 1, 2 and 3*), or
  - May create incentive (dispatch-following) problems (*Examples 4 & 5*), or
  - May create the need for additional side payments

• **Balancing these trade-offs**
  - The more relaxation you do, the worse these problems tend to become
  - There is no perfect solution
Five Key Takeaways, Continued

4. All ISOs approaches treat commitment costs in varied ways
   - Commitment cost consideration in pricing methods ranges from not considered, partially considered, to fully considered
   - More inclusion of commitment costs tends to:
     • Increase the energy price
     • Reduce the Make Whole Payment (MWP)
     • Increase the Lost Opportunity Cost (LOC)
   - These are trade-offs to be balanced - There is no perfect solution

5. One ISO’s solution may not be appropriate to meet another region’s needs - requires balancing many trade-offs
   - There is little or no rigorous economic foundation for what each ISO does with ‘lumpy’ resource pricing
   - All ISOs pricing methods rely on many ad hoc rules, including ISO-NE’s
Next Steps

- Session #8:
  - Complete discussion of other ISOs’ pricing methods
  - Discuss pros & cons of fast-start pricing method elements and useful variations
  - Comments and input on the methods and examples covered in this presentation are welcome in next session discussion as well
Questions

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mwhite@iso-ne.com