Gaps in Current Pricing Methodology

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Missing Information in Prices

- There are times when the LMP is unable to send market signals that support the efficient commitment and dispatch of the system.
- When this occurs, market participants may have the incentive to deviate from PJM’s instructions.
- We use uplift (make whole and LOC) to remove the incentive for generation resources to deviate from dispatch.
- PJM believes all known pricing methods require some level of uplift to support commitment and dispatch instructions.
Example: Unit Commitment Process

**Goals (in no specific order):**
1. Achieve power balance (supply = demand)
2. Adhere to all limitations (ecomin/max, transmission limits, etc.)
3. Minimize bid production cost (BPC) in the process
Example 1: Commitment and Dispatch Solution

EcoMax = 300 MW  
EcoMin = 50 MW  
Offer = $50/MWh  
Startup Cost = $0  
No-Load = $200/hr  
Sched. Rate (EcoMax) = $50.67/MWh

G1 MW = 150 MW  

EcoMax = 200 MW  
EcoMin = 50 MW  
Offer = $80/MWh  
Startup Cost = $100  
No-Load = $200/hr  
Sched. Rate (EcoMax) = $81.50/MWh

G2 MW = 50 MW  

FLOW = 50 MW

G# COST = Start-up + No-load + (Offer * Output Level) = Cost

G1 COST = $0 + ($200/hr * 1hr) + (150 MWh * $50/MWh) = $7,700

G2 COST = $100 + ($200/hr * 1hr) + (50 MWh * $80/MWh) = $4,300

BPC = G1 COST + G2 COST = $12,000
Example 1: Commitment and Dispatch Solution

- If the limit on the line were 100 MW or greater only G1 would be needed to serve all load
  - LMP = $50/MWh across the system

- G2 has an EcoMin = 50 MW which must be adhered to in the commitment/dispatch process

- Because G2 is committed at 50 MW, G1’s output is reduced to 150 MW to maintain power balance
Example 1: Current LMP Calculation

EcoMax = 300 MW
EcoMin = 50 MW
Offer = $50/MWh
Startup Cost = $0
No-Load = $200/hr
Sched. Rate (EcoMax) = $50.67/MWh

G1 UPLIFT = MAX(0, COST – (LMP * OUTPUT))
G1 UPLIFT = $7,700 – ($50/MWh * 150 MWh) = $200
G2 UPLIFT = $4,300 – ($50/MWh * 50 MWh) = $1,800
TOTAL UPLIFT = $2,000

EcoMax = 200 MW
EcoMin = 50 MW
Offer = $80/MWh
Startup Cost = $100
No-Load = $200/hr
Sched. Rate (EcoMax) = $81.50/MWh
Example 1: Missing Information in Prices

• The next MW of load would be serve by G1 thus the LMP = $50/MWh
• The transmission constraint is not binding so prices are uniform across the system
  • Prices do not reflect G2 as being needed
  • The need for G2 is reflected through uplift payments which are not transparent and shift costs
Example 1: Uplift Allocation

• Assume this scenario occurs in the Day-ahead Market
  – DA Uplift is allocated to all withdrawal transactions on a pro-rata basis
    • Cleared DA demand, DECs, price-sensitive demand, exports
  – L1 and L2 will both be allocated a pro-rata share of the cost to make units G1 and G2 whole ($1,000 each)
  – L1 and L2 pay the same price despite the fact that G2 is needed to serve load at L2 and not L1
Example 2: Impacts on Balancing Settlement

- Units G1-G4 able to be scheduled to serve load in the DAM
- DA Demand = 550 MW
- G1 and G2 are flexible
- G3 and G4 are inflexible
## Example 2: Generator Offer Data

### G1 Unit Parameters
- EcoMax = 300 MW
- EcoMin = 100 MW
- Offer @ EcoMax = $60/MWh
- Offer @ EcoMin = $40/MWh
- Startup Cost = $0
- No-Load = $200/hr

### G2 Unit Parameters
- EcoMax = 400 MW
- EcoMin = 200 MW
- Offer @ EcoMax = $40/MWh
- Offer @ EcoMin = $20/MWh
- Startup Cost = $0
- No-Load = $200/hr

### G3 Unit Parameters
- EcoMin = EcoMax = 100 MW
- Offer = $70/MWh
- Startup Cost = $300
- No-Load = $0/hr

### G4 Unit Parameters
- EcoMin = EcoMax = 100 MW
- Offer = $75/MWh
- Startup Cost = $300
- No-Load = $0/hr
Example 2: DA Commitment

- At 550 MW of load
  - G1 = 150 MW
  - G2 = 400 MW
  - G3 = 0 MW
  - G4 = 0 MW

- G1 is marginal
  - LMP = $45.10/MWh
Example 2: Real-time

- G1 trips in real-time
- Load is still 550 MW
  - G1 = 0 MW
  - G2 = 350 MW
  - G3 = 100 MW
  - G4 = 100 MW

- G2 is marginal
  - LMP = $35.10/MWh
Example 2: Real-time

- G1 has tripped
- The real-time LMP is set by G2 as it is the only dispatchable unit on the system
  - LMP is set consistent with the cost of the next MW at $35.10/MWh
- G1 must purchase out of its DA commitment at the RT LMP
  - This nets a margin of $10/MWh
- The uplift costs to G3 and G4 (~$8,080) are allocated to deviations between DA and RT
  - Assuming G3 and G4 are not for conservative operations
Example 2: Shortcomings of Prices

- Real-time prices do not reflect the need or commitment of G3 and G4
- G1 is not held accountable for this deviation...it actually profits!
  - G1 will receive a pro-rata share of the deviation charges.*
- This significantly diminishes performance incentives.

*Due to the simplicity of this example, G1 is the only resource deviating. In reality there are many that will all pay a share of uplift created by G1 in this case.
Example 3: Reserve Pricing

$/MWh

$850/MWh

$300/MWh

Step 1

Step 2A

Step 2B

Single Largest Online Contingency

Step 1 + 190 MW

Step 2A + Extended

MWh
Example 3: Reserve Pricing

• Step 1 - $850/MWh
  – Largest single system contingency
  – Usually the largest unit

• Step 2A - $300/MWh
  – Additional reserves added July 2017
  – Intended to mitigate significant pricing impacts from transient shortages

• Step 2B (optional) - $300/MWh
  – Intended to reflect additional reserves added by operators
Example 3: Background and Interpretation

• Step 1
  – Load is not willing to pay more than $850/MWh to maintain the system’s largest single contingency in reserves
  – PJM system operators will commit reserves beyond this cost to maintain reliability and compliance
    – In these cases, the market prices are not reflecting operator actions
• $850/MWh was determined in 2007 based on the average cost of reserves during shortage events during that time
  – Offer cap was $1,000/MWh at that time
• There are similar interpretations for Steps 2A and 2B
Example 3: Reserve Pricing

The diagram illustrates the pricing structure for reserve capacity in PJM. It shows two steps:

1. **Step 1**: $850/MWh for the first 1000 MW of reserve capacity.
2. **Step 2A**: $300/MWh for the additional capacity beyond 1000 MW up to 1190 MW.

There is no Step 2B for the remaining capacity beyond 1190 MW.
Example 3: Alignment with Reliability Value

- PJM estimates the amount of Tier 1 on the system every 5 minutes
- If PJM estimates more than 1190 MW in Tier 1 (even by 1 MW) the price for Synchronized Reserves is $0/MWh
- This indicates reserves have no value. This is inconsistent with the reliability value in terms reducing the loss of load probability in real-time
- If PJM cannot meet the requirement at the specified price, even if its by 1 MW, the price goes to the applicable penalty factor
Example 4: Inflexible Reserve Resources and Pricing

• Similar to energy, there are resources in the PJM market that have lumpy reserve capabilities
  – Synchronous condensing resource with a non-zero economic min
  – Fast-start CT with a non-zero economic min
• For the same reason these resources cannot set prices in the energy market, they cannot set price in the reserve markets
• This results in these resources often requiring reserve LOC payments in addition to the market clearing price
• This accounts for about 65% of the total Synchronized Reserve market billing
Example 4: Inflexible Reserve Resources and Pricing

• Reserve Market Clearing:
  – 1 hour ahead commitment of inflexible reserve resources
    • Synchronous condensers
    • Demand response
  – 5 minute co-optimization of remaining amount of reserves needed
    • Tier 1 estimation
    • Tier 2 assignments on flexible resources
    • Clearing price calculation
Example 4: Generator Offer Data

<table>
<thead>
<tr>
<th>G1 Unit Parameters</th>
<th>G2 Unit Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>EcoMax = 300 MW</td>
<td>EcoMax = 400 MW</td>
</tr>
<tr>
<td>EcoMin = 100 MW</td>
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</tr>
<tr>
<td>Offer @ EcoMax = $60/MWh</td>
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</tr>
<tr>
<td>Offer @ EcoMin = $40/MWh</td>
<td>Offer @ EcoMin = $20/MWh</td>
</tr>
<tr>
<td>Reserve Offer = $5/MWh</td>
<td>Reserve Offer = $6/MWh</td>
</tr>
<tr>
<td>Reserve Capability = 20 MW (flexible)</td>
<td>Reserve Capability = 50 MW (flexible)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>G3 Unit Parameters</th>
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</tr>
</thead>
<tbody>
<tr>
<td>EcoMin = EcoMax = 40 MW</td>
<td>EcoMin = EcoMax = 30 MW</td>
</tr>
<tr>
<td>Offer = $70/MWh</td>
<td>Offer = $75/MWh</td>
</tr>
<tr>
<td>Reserve Offer = $4/MWh</td>
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<td>Reserve Capability = 40 MW (inflexible)</td>
<td>Reserve Capability = 30 MW (inflexible)</td>
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RESERVE REQUIREMENT = 75 MW
Example 4: Inflexible Reserve Resources and Pricing

- LOAD = 600 MW
  - LMP = $50/MWh
  - Reserve Allocations (done based on offer + LOC)
    - G1: 20 MW Tier 1 estimate ($0/MWh assessed offer because it is Tier 1)
    - G2: 0 MW (fully loaded for energy)
    - G3: 40 MW Tier 2 assignment ($4/MWh offer)
    - G4: 30 MW Tier 2 assignment ($5/MWh offer)
  - Total Reserves = 90 MW
    - 20 MW Tier 1
    - 70 MW Tier 2
  - Today’s rules produce an SRMCP = $0/MWh despite needing G3 & G4 to avoid a reserve shortage (prices don’t reflect operator actions)
  - This price is not transparent
    - Out-of-market LOC payments to G3 & G4 needed due to $0/MWh clearing price
    - Increase in energy dispatch of G1 and further tightening of reserve capability would result in $0/MWh SRMCP until the point of shortage