Single Period Integer Relaxation Examples

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Separate Dispatch and Pricing Runs

**Dispatch Run**
- Make no modifications to resource parameters
- Determine desired dispatch points
- Do not calculate prices

**Pricing Run**
- Modify resource parameters
- Calculate prices
Example #1

- Load equals 455 MW
- Fixed costs (start-up and no-load) are considered in setting the price.
- Assume all resources are eligible for integer relaxation treatment
- **Note:** Offline resources do not participate in pricing
Example #1: Offer Blocks (MW) & Fixed Costs

Any resource that is “committed” must run at least at its minimum.

- Resource W:
  - $56/MWh: 30 MW
  - $53/MWh: 30 MW
  - $50/MWh: 200 MW

- Resource X:
  - $65/MWh: 40 MW
  - $63/MWh: 40 MW
  - $60/MWh: 100 MW

- Resource Y:
  - $241/MWh: 50 MW
  - $221/MWh: 50 MW
  - $200/MWh: 50 MW

Start-up $20,000
Start-up $4,000
No-load $10,000/h
No-load $1,000/h

Example:

- Start-up cost: $20,000
- No-load cost: $10,000/h
- Resource W: 200 MW
- Resource X: 100 MW
- Resource Y: 50 MW

Fixed costs:
- Start-up: $20,000
- No-load: $10,000/h
- Resource W:
  - $56/MWh: 30 MW
  - $53/MWh: 30 MW
  - $50/MWh: 200 MW

Resource W:
- $200/MWh: 200 MW

Resource X:
- $65/MWh: 40 MW
- $63/MWh: 40 MW
- $60/MWh: 100 MW

Resource Y:
- $241/MWh: 50 MW
- $221/MWh: 50 MW
- $200/MWh: 50 MW

Min

$50/MWh
$53/MWh
$56/MWh
$60/MWh
$63/MWh
$65/MWh
$200/MWh
$221/MWh
$241/MWh
The Commitment and Dispatch Run: Example #1

Load = 455 MW

<table>
<thead>
<tr>
<th>Resource W</th>
<th>Resource X</th>
<th>Resource Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 MW @ $50</td>
<td>30 MW @ $53</td>
<td>50 MW @ $200</td>
</tr>
<tr>
<td>30 MW @ $56</td>
<td>100 MW @ $60</td>
<td>50 MW @ $221</td>
</tr>
<tr>
<td>30 MW @ $56</td>
<td>40 MW @ $63</td>
<td>50 MW @ $241</td>
</tr>
<tr>
<td>(Start-up $20k, No-load $10k)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 MW @ $65</td>
<td>35 MW @ $65</td>
<td></td>
</tr>
<tr>
<td>Minimum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>35 MW @ $65</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50 MW @ $65</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Pricing Run Offer Modifications for Example #1

• Allow resources to be partially committed for pricing calculations:
  – Equivalently, resources are allowed to be fully dispatchable between 0 and their economic maximums.

• Start-up and No-load costs of X and Y are considered in setting the price.
  – Equivalently, the bid blocks of Resources X and Y can be modified to incorporate the proportional start-up and no-load costs.
Pricing Run Offer Modifications for Example #1

• For example, under integer relaxation with a single offer block, in the pricing run the total offer cost of dispatching a resource is:

\[
Total Offer Cost = \text{Incremental Energy Cost} \times \text{Dispatch} + \\text{Startup Cost} \times \text{Commitment Status} + \\text{Noload Cost} \times \text{Commitment Status}
\]

Where:

\[
\text{Commitment Status} = \frac{\text{Dispatch}}{\text{Economic Maximum}}
\]
As a result, the total offer cost of dispatching a resource in the pricing run can be rewritten as:

\[
\text{Total Offer Costs} = \text{Incremental Energy Cost} \times \text{Dispatch} + \frac{\text{Startup Cost}}{\text{Economic Maximum}} \times \text{Dispatch} + \frac{\text{Nolload Cost}}{\text{Economic Maximum}} \times \text{Dispatch}
\]

A resource’s equivalent offer is equal to the sum of all three components in the boxes above.
Pricing Run Equivalent Offers for Example #1

For example, the modified price of block 1 of Y is calculated as:

- $200/MWh + $4,000/150 + $1,000/150 = $233/MWh

Load = 455 MW

<table>
<thead>
<tr>
<th>Resource W</th>
<th>Resource X</th>
<th>Resource Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 MW @ $50</td>
<td>100 MW @ $227</td>
<td>50 MW @ $233</td>
</tr>
<tr>
<td>30 MW @ $53</td>
<td>40 MW @ $230</td>
<td>50 MW @ $254</td>
</tr>
<tr>
<td>30 MW @ $56</td>
<td>40 MW @ $232</td>
<td>50 MW @ $274</td>
</tr>
</tbody>
</table>

$/MWh

MW

No-load Cost
Start-up Cost
- The price is set by the modified block 1 of Y.
- Integer Relaxation LMP = $233/MWh
• The integer relaxation LMP is set by the first block of Resource Y, which includes its start-up and no-load costs in the price.

• The dispatch MWs for all resources come from the dispatch run where Resource X and Y incur their full start-up and no-load costs.

• Resource Y will need a make-whole payment since it is only recovering part of its start-up and no-load costs through the price since it is not being dispatched at its economic maximum.
The **Integer Relaxation LMP** is calculated at $233/MWh.

<table>
<thead>
<tr>
<th>Asset</th>
<th>Commit.</th>
<th>Dispatch (MW)</th>
<th>EcoMax (MW)</th>
<th>Total Offer Cost ($)</th>
<th>Payment ($)</th>
<th>MWP ($)</th>
<th>LOC ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>On</td>
<td>260</td>
<td>260</td>
<td>13,270</td>
<td>60,580</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>X</td>
<td>On</td>
<td>145</td>
<td>180</td>
<td>38,845</td>
<td>33,785</td>
<td>5,060</td>
<td>820</td>
</tr>
<tr>
<td>Y</td>
<td>On</td>
<td>50</td>
<td>150</td>
<td>15,000</td>
<td>11,650</td>
<td>3,350</td>
<td>0</td>
</tr>
</tbody>
</table>

*Both X and Y receive a make-whole payment to make them whole to their total offer cost.*

*X receives a LOC payment since it would want to produce at its economic maximum at a $233/MWh clearing pricing since it would make a profit of $820.*

\[
LOC = (\text{Integer Relaxation LMP} \times \text{EcoMax}) - \text{Incremental energy offer} - \text{Start-up Cost} - \text{No Load Cost}
\]

\[
= (\$233 \times 180 \text{ MW}) - ((\$60 \times 100 \text{ MW}) + (\$63 \times 40 \text{ MW}) + (\$65 \times 40 \text{ MW})) - \$20,000 - \$10,000 = \$820
\]
Example #2

- Load equals 455 MW
- Fixed costs (start-up and no-load) are considered in setting the price.
- Assume all resources are eligible for integer relaxation treatment
- **Note:** Offline resources do not participate in pricing
Example #2: Offer Blocks (MW) & Fixed Costs

Any resource that is “committed” must run at least at its minimum.

**Resource W**
- $50/MWh: 200 MW
- $53/MWh: 30 MW
- $56/MWh: 30 MW

**Min**
- Start-up $20,000
- No-load $10,000/h

**Resource X**
- $60/MWh: 100 MW
- $63/MWh: 40 MW
- $65/MWh: 40 MW

**Min**
- Start-up $4,000
- No-load $1,000/h

**Resource Y**
- $200/MWh: 100 MW

**Min**
- $200/MWh
The Commitment and Dispatch Run: Example #2

Load = 455 MW

Resource W
- 200 MW @ $50
- 30 MW @ $53
- 25 MW @ $56
- 5 MW @ $56

Resource X
(Start-up $20k, No-load $10k)
- 100 MW @ $60
- 40 MW @ $63
- 40 MW @ $65

Resource Y
(Start-up $4k, No-load $1k)
- 100 MW @ $200

$/MWh
Cleared MW
Not Cleared MW
Minimum
• Allow resources to be partially committed for pricing calculations:
  – Equivalently, resources are allowed to be fully dispatchable between 0 and their economic maximums.

• Start-up and No-load costs of X and Y are considered in setting the price.
  – Equivalently, the bid blocks of Resources X and Y can be modified to incorporate the proportional start-up and no-load costs.
Pricing Run Equivalent Offers for Example #2

For example, the modified price of block 1 of Y is calculated as:
- $200/MWh + $4,000/100 + $1,000/100 = $250/MWh

Load = 455 MW

|$/MWh

$/MWh

MW

Resource W

200 MW @ $50

30 MW @ $53

30 MW @ $56

Resource X

100 MW @ $227

40 MW @ $230

40 MW @ $232

Resource Y

100 MW @ $250

No-load Cost

Start-up Cost
Load = 455 MW

- The price is set by the modified block 1 of Y.
- Integer Relaxation LMP = $250/MWh
• The integer relaxation LMP is set by the first block of Resource Y, which includes its start-up and no-load costs in the price.

• The dispatch MWs for all resources come from the dispatch run where Resource X and Y incur their full start-up and no-load costs.

• Resource Y will not need a make-whole payment since it is being dispatched to its economic maximum in the dispatch run and is recovering its entire start-up and no-load costs through the price.
The **Integer Relaxation LMP** is calculated at $250/MWh.

<table>
<thead>
<tr>
<th>Asset</th>
<th>Commit.</th>
<th>Dispatch (MW)</th>
<th>EcoMax (MW)</th>
<th>Total Offer Cost ($)</th>
<th>Payment ($)</th>
<th>MWP ($)</th>
<th>LOC ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>On</td>
<td>255</td>
<td>260</td>
<td>12,990</td>
<td>63,750</td>
<td>0</td>
<td>970</td>
</tr>
<tr>
<td>X</td>
<td>On</td>
<td>100</td>
<td>180</td>
<td>36,000</td>
<td>25,000</td>
<td>11,000</td>
<td>3,880</td>
</tr>
<tr>
<td>Y</td>
<td>On</td>
<td>100</td>
<td>100</td>
<td>25,000</td>
<td>25,000</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Resource X receives a make-whole payment to make it whole to its total offer cost.

*In addition, Resource W and X receive a LOC payment since at Resource W’s and X’s offer prices of $50–$56/MWh and $60–$65/MWh, they would want to produce at their economic maximums at a $250/MWh clearing pricing since they would make a profit of $970 and $3,880, respectively.*