Generation Dispatch
Objectives

- Explain the difference between Dispatch Rate and LMP
Agenda

• Generation Dispatch
Dispatch Rate

Definition:
The **Dispatch Rate** is expressed in dollars per MWh, calculated and transmitted to each generator to direct the output level of all generation resources dispatched by PJM based on the incremental offer data which was previously received from the Generators.

Where PJM wants The units to be loaded economically
Dispatch Rate

The Dispatch Rate is determined by the PJM economic dispatch solution as calculated by PJM’s Security Constrained Economic Dispatch program (SCED).

![Diagram showing offer price and economic basepoint](image)

- **Offer Price**
  - $35
  - $30
  - $25
  - $20

- **Economic Basepoint**

The Economic Basepoint is the MW value sent to the generating unit that indicates to what level the unit should be loaded based on the economic dispatch solution and the units incremental price curve.
Transmission Losses

- Real Power (MW) Losses
  - Power flow converted to heat in transmission equipment
  - Heat produced by current (I) flowing through resistance (R)
  - Losses equal to $I^2R$
  - Heat loss sets the “thermal rating” of equipment

\[ \text{Heat Disipated} = I^2R \]
Transmission Losses

- Real Power (MW) Losses
  - Increase with line length
    - Increased R
  - Increase with increased current flow (I)
  - Increase at lower voltages
    - Higher currents

\[
\text{Power} = \text{Current} \times \text{Voltage}
\]
Transmission Losses

Power In: 100 MW
Voltage In: 235 KV
Current In: 425.53 A

Power Out: 90.946 MW
Voltage out: 213.72 KV
Current Out: 425.53 A

Power Loss: 9.054 MW
Transmission Losses

Power In: 100 MW
Voltage In: 235 KV
Current In: 425.53 A

Power Out: 98.2 MW
Voltage out: 230.74 KV
Current Out: 425.53 A

Power Loss: 1.8 MW
Penalty Factors Effect on Dispatch

• The Incremental Loss for bus \( i \) is used to calculate a factor that can be used to include the effect of losses in the dispatch

• This factor is called the Loss Penalty Factor, or Penalty Factor

\[
Pf_i = \frac{1}{1 - \frac{\Delta P_L}{\Delta P_i}}
\]

- Change in Losses
- Change in Unit’s MW Output

• The Penalty Factors adjust the incremental cost of each generator so as to include the effects of losses

• Penalty factors applied to each and every location
  - Including generation, load, virtual transaction
Penalty Factors Effect on Dispatch

If an increase in generation results in an increase in system losses then:

- Penalty factor is greater than 1
- Units offer curve is adjusted higher
  - Unit offer curve is multiplied by penalty factor
  - Unit looks less attractive to dispatch

\[
0 < \frac{\Delta P_L}{\Delta P_i} < 1
\]

Increase in injection will result in higher overall system losses

\[
P_{fi} = \frac{1}{1 - \frac{\Delta P_L}{\Delta P_i}} > 1.0
\]
Penalty Factors Effect on Dispatch

• If an increase in generation results in a decrease in system losses then:
  – Penalty factor is less than 1
  – Units offer curve is adjusted lower
    • Unit offer curve is multiplied by penalty factor
    • Unit looks more attractive to dispatch
    • Total LMP would still at least equal unit’s original offer

Loss Factor

\[ 0 > \frac{\Delta P_L}{\Delta P_i} > -1 \]

Increase in injection will result in lower overall system losses

Penalty Factor

\[ Pf_i = \frac{1}{1 - \frac{\Delta P_L}{\Delta P_i}} < 1.0 \]
Penalty Factors Effect on Dispatch - Example # 1

Generating Unit # 1

<table>
<thead>
<tr>
<th>Offer Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10.00</td>
</tr>
<tr>
<td>$20.00</td>
</tr>
<tr>
<td>$30.00</td>
</tr>
<tr>
<td>$40.00</td>
</tr>
</tbody>
</table>

Generating 300 MW

Penalty Factor = 1.00

$20 * 1.00 = $20.00

Generating Unit # 2

<table>
<thead>
<tr>
<th>Offer Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10.00</td>
</tr>
<tr>
<td>$20.00</td>
</tr>
<tr>
<td>$30.00</td>
</tr>
<tr>
<td>$40.00</td>
</tr>
</tbody>
</table>

Generating 305 MW

Penalty Factor = 0.97

$20.50 * 0.97 = $19.89

Offer Price = $10.00

AGC ON
## Dispatch Optimized to Least Production Cost

<table>
<thead>
<tr>
<th>Generating Unit 1</th>
<th>Generating Unit 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penalty Factor = 1.0</td>
<td>Penalty Factor = 0.97</td>
</tr>
<tr>
<td>Offer Price</td>
<td>MW</td>
</tr>
<tr>
<td>10</td>
<td>200</td>
</tr>
<tr>
<td>20</td>
<td>300</td>
</tr>
<tr>
<td>20.25</td>
<td>302.5</td>
</tr>
<tr>
<td>20.5</td>
<td>305</td>
</tr>
<tr>
<td>30</td>
<td>400</td>
</tr>
<tr>
<td>30.5</td>
<td>405</td>
</tr>
<tr>
<td>40</td>
<td>500</td>
</tr>
</tbody>
</table>

### Production Cost

<table>
<thead>
<tr>
<th>Optimal Dispatch</th>
<th>Unit 1 (MW)</th>
<th>Unit 2 (MW)</th>
<th>Production Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>305</td>
<td>($3,500 * 1.00) + ($3,601.25 * 0.97) = $6,993.21</td>
<td></td>
</tr>
<tr>
<td>200</td>
<td>405</td>
<td>($2,000 * 1.00) + ($6,151.25 * 0.97) = $7,966.71</td>
<td></td>
</tr>
<tr>
<td>302.5</td>
<td>302.5</td>
<td>($3,550.313 * 1.00) + ($3,550.313 * 0.97) = $6,994.12</td>
<td></td>
</tr>
</tbody>
</table>
Offer Curve for Both Units
Optimal Dispatch – Unit 1 Production Cost

Production Cost at 200 MW = $2,000

Production Cost at 300 MW = $2,000 + $1,000 + $500 = $3,500
Optimal Dispatch – Unit 2 Production Cost

Production Cost at 305 MW = $2,000 + $1,000 + $500 + $100 + $1.25 = $3,601.25
Linear Interpolation to determine the $/MW between 300 and 400 MW

Slope = \[ m = \frac{d_y}{d_x} = \frac{\text{rise}}{\text{run}} \]

\[ m = \frac{\$ (30-20)}{MW (400-300)} = \$ 1/MW \]

Therefore:

\[ 0.1 = \frac{(y_1 - 20)}{(305-300)} \]

\[ 0.5 = (y_1 - 20) \]

\[ y_1 = 20.5 \]
Alternate Dispatch 1 – Unit 2 Production Cost

Production Cost at 405 MW = $2,000 + $1,000 + $500 + $2000 + $500 + $150 + $1.25 = $6,151.25
Alternate Dispatch 1 – Unit 1 Production Cost

Production Cost at 200 MW = $2,000
Alternate Dispatch 2 – Unit 1&2 Production Cost

Production Cost at 302.5 MW = $2,000 + $1,000 + $500 + $50 + $0.313 = $3,550.313
For questions related to this training, please contact:

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