Dispatch Signal & Locational Marginal Pricing (LMP)
Objectives

Students will be able to:

• Identify how PJM dispatches & utilizes LMP
Dispatch Rate

- Economic control signal is called Dispatch Rate ($/MWh) or Economic Basepoint (MW)
- Moves operating point of generating unit to change MW output to assist ACE in returning to zero
  - If ACE<0, signal increases
  - If ACE>0, signal decreases
Incremental Offer Curve

<table>
<thead>
<tr>
<th>Output</th>
<th>Offer ($)/MWhr</th>
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<tbody>
<tr>
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<tr>
<td>300</td>
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<td>24.1</td>
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<td>27.3</td>
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<td>31.0</td>
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<tr>
<td>700</td>
<td>34.5</td>
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Incr. Offer Curve ($/MWhr)

Output (MW)
## System Incremental Curve

### Control Signal

<table>
<thead>
<tr>
<th>HR</th>
<th>Unit 1</th>
<th>Unit 2</th>
<th>Unit 3</th>
<th>Unit 4</th>
<th>Unit 5</th>
<th>Unit 6</th>
<th>Unit 7</th>
<th>Unit 8</th>
<th>Unit 9</th>
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Load Demand = 853 MW
Dispatch Rate = $29/MWh
Computing the 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.

<table>
<thead>
<tr>
<th>Generating Unit # 1</th>
<th>Generating Unit # 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Offer Price = $ 10.00 ---- 200 MW</strong></td>
<td><strong>Offer Price = $ 15.00 ---- 220 MW</strong></td>
</tr>
<tr>
<td>$ 20.00 ----- 300 MW</td>
<td>$ 22.00 ----- 310 MW</td>
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<tr>
<td>$ 30.00 ----- 400 MW</td>
<td>$ 32.00 ----- 425 MW</td>
</tr>
<tr>
<td>$ 40.00 ----- 500 MW</td>
<td>$ 41.00 ----- 500 MW</td>
</tr>
<tr>
<td>$ 50.00 ----- 600 MW</td>
<td>$ 54.00 ----- 600 MW</td>
</tr>
</tbody>
</table>
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.
Out of Merit Operation (Off Cost)

<table>
<thead>
<tr>
<th>Dispatch Signal</th>
<th>$/MW</th>
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<tbody>
<tr>
<td></td>
<td>hr</td>
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<tr>
<td>26.0</td>
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<tr>
<td>31.0</td>
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</tr>
</tbody>
</table>

Load Demand = 853 MW  
Zonal Dispatch Rate = $29/MWh
Manual Dispatch
Manual Dispatch

What is Manual Dispatch?

• Manual dispatch is when PJM has to take steps to manually determine which resource should be used to help resolve a constraint on the system

• Manual dispatch is used after all economic resources have been exhausted
Manual Dispatch

**How does PJM perform Manual Dispatch?**

- PJM must identify the amount of relief needed to resolve the constraint
- PJM uses a report from the PJM EMS to determine which resources would be effective in resolving the constraint
- PJM will contact the required resources and request the curtailment
- PJM will continually assess the constraint and make any necessary changes
LMP Basics
What is LMP?

• Locational Marginal Price

• Pricing method PJM uses to:
  • price energy purchases and sales in PJM Market
  • price transmission congestion costs to move energy within PJM RTO
  • price losses on the bulk power system

• Physical, flow-based pricing system:
  • how energy actually flows, NOT contract paths
How does PJM Use LMP?

- Generators get paid at generation bus LMP
- Loads pay at load bus LMP
- Transactions pay differential in source and sink LMP
Economic Dispatch Exercise

**MW**

- **$20**
- Not Dispatched
- Capacity: 200 MWs

**MW**

- **$15**
- 199 MWs @ $15
- Capacity: 200 MWs

**MW**

- **$10**
- 300 MWs @ $10
- Capacity: 300 MWs

Load 499 MWs

*I need MWs. Sale goes to the lowest offer with capacity. Going once....*

**LMP = $15**
Locational Marginal Price

$LMP = \text{System Energy Price} + \text{Transmission Congestion Cost} + \text{Cost of Marginal Losses}$

LMP is made up of 3 independent components.
LMP Components - System Energy Price

\[ \text{LMP} = \text{System Energy Price} + \text{Transmission Congestion Cost} + \text{Cost of Marginal Losses} \]

- **System Energy Price**
  - Represents optimal dispatch ignoring congestion and losses
  - Same price for every bus in PJM
  - Calculated both in day ahead and real time
LMP Components - System Energy Price

Installed = 2,000 MW

Dispatch 1500 MW

$20 Power

System Energy Price = $20
Congestion =
Losses =
LMP = $20

Note: ignoring losses and congestion
LMP Components - Congestion

\[ \text{LMP} = \text{System Energy Price} + \text{Transmission Congestion Cost} + \text{Cost of Marginal Losses} \]

- **Congestion Price**
  - Represents price of congestion for binding constraints
    - Calculated using cost of marginal units controlling constraints and sensitivity factors on each bus
    - Will be zero if no constraints
      - Will vary by location if system is constrained
    - Calculated both in day ahead and real time
## LMP Components - Congestion

### Installed

- Installed = 2,000 MW

### Dispatch

- **Dispatch 1000 MW**
  - Flow = 1000 MW
  - Limit = 1000 MW
  - **LMP = $20**
  - System Energy Price = $20
  - Congestion = $0
  - Losses = $0
  - **Note:** ignoring losses

- **Dispatch 500 MW**
  - **$50 Power**
  - Installed = 700 MW

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System Energy Price = $20
Congestion = $30
Losses = $50
LMP = $50
Load = 1500MW
LMP Components - Marginal Losses

\[ \text{LMP} = \text{System Energy Price} + \text{Transmission Congestion Cost} + \text{Cost of Marginal Losses} \]

☑️ Loss Price
- Represents price of marginal losses
  - Calculated using penalty factors
  - Will vary by location
- Calculated both in day-ahead and real-time
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

• Losses increase with:
  • Lower voltage
  • Longer lines
  • Higher current
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
LMP Components Marginal Losses

System Energy Price = $20
Congestion = $30
Losses = $2
LMP = $52

Installed = 2,000 MW

Dispatch 1010 MW
$20 Power
Flow = 1000 MW
Limit = 1000 MW

Load 1500 MW
$50 Power

System Energy Price = $20
Congestion = $0
Losses = ($1)
LMP = $19

Installed = 700 MW

Dispatch 520 MW

Note: assume 2% (30mw) losses – allocation of losses in this example are theoretical
Losses on a real system are optimized based on system topology
Questions?