# Objective Function and Production Cost

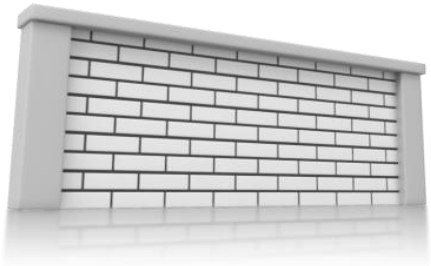
# Objectives

- Explain PJM's objective function
- Explain the difference between a Block Offer curve and a Slope Offer Curve
- Define Production Cost

# What is Optimization?

- Optimization seeks to minimize or maximize the value of a desired outcome:
  - The "Objective Function"

- Achievement of this outcome must consider the availability of resources or other limiting factors
  - Subject to "Boundary Conditions"



# Optimization in Energy Markets

- The "objective function" in the Day Ahead Market is to minimize total production costs
- The "boundary conditions" are extremely complex and include:
  - Thermal / reactive limits
  - Generator operating constraints
  - External transaction schedules
  - Regional reliability requirements
  - Synchronized Reserves Requirement
  - Regulation Requirement

# Optimization

- The objective in the Real Time Market is to maintain reliability and minimize Start-up and No-Load costs
- PJM Real-Time Market clearing is a joint optimization between energy, regulation, synchronized reserves and non-synchronized reserves products
- The goal of the optimization is to minimize the total cost of producing energy, regulation, and reserves

# Production Cost

# Production Cost

- It is the bids from suppliers (offers) that define the bid production cost that is to be minimized to meet energy balance while not violating other constraints in system operation, and consequently it is those supply offers that will determine the price in the Day-Ahead and Real-Time Energy Markets that is paid to generation or demand resources

# Production Cost

- Generation must be placed in and out of service and operated to achieve the lowest possible overall cost for the system
- Production Cost is the cost to operate a unit for a particular period of time
- Two types of Production Cost are used at PJM:
  - Hourly Production Cost
  - Total Production Cost

# Hourly Production Cost

- Cost per hour to operate a unit assuming a startup has already occurred
- Calculated by summing all costs which are incurred during one hour of operation
  - No-Load Cost
  - Total Energy Cost per Segment

**Hourly Production Cost**
**=**
**No-Load Cost**
**+**
**Sum of Total Energy Cost per Segment**

# No-Load Cost

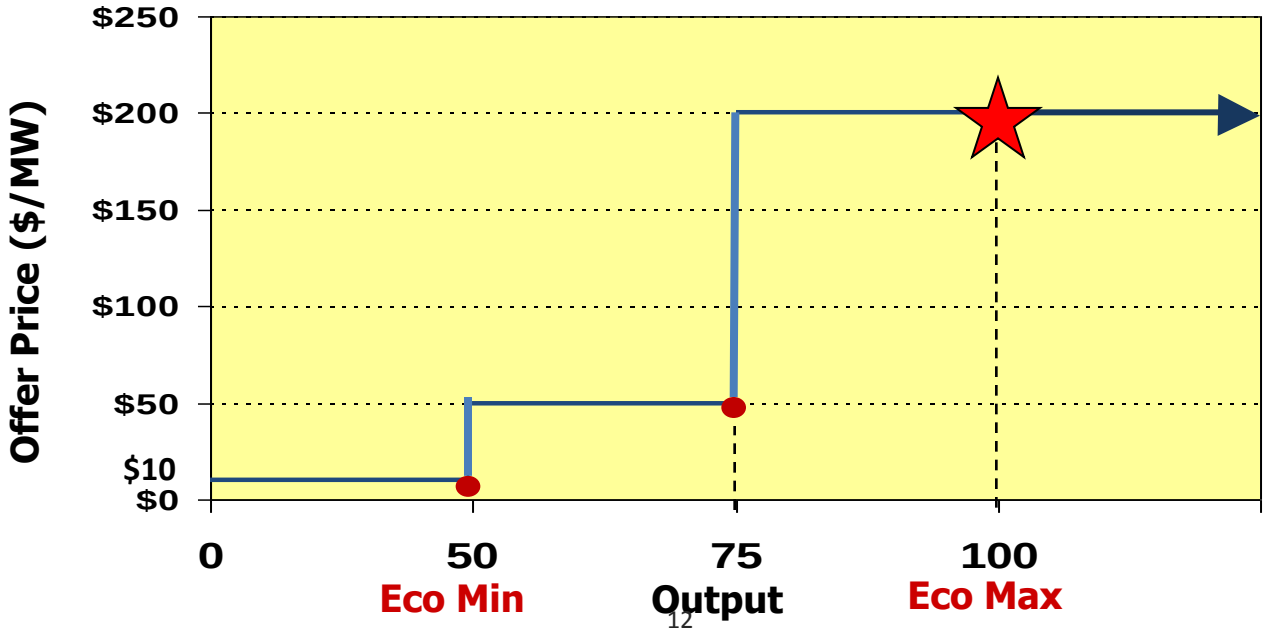
- No-load cost (or price) is the hourly fixed cost (or price), expressed in $/hr, to run the generating unit at zero net output
  - Needed to create the starting point of a monotonically increasing incremental cost curve

# Hourly Production Example

| Parameter | Unit X | |
|---|---|---|
| Hot Start Price ($) | 500 | |
| Intermediate Start Price ($) | 1000 | |
| Cold Start Price ($) | 1500 | |
| No-Load ($/hr) | 500 | |
| | | |
| **Offer Curve (max 10 points)** | **MW** | **Price ($/MWh)** |
| segment 1 | 50 | 10 |
| segment 2 | 75 | 50 |
| segment 3 | 100 | 200 |
| | | |
| Eco Min (MW) | 50 | |
| Eco Max (MW) | 100 | |
| Min Run Time (hours) | 16 | |

# Generator Offer Curve – Using Block Offer

- Block Offer rather than a Slope Offer curve
  - (i.e. Use Slope field in Markets Gateway is unchecked)
- The block offer is a step function rather than a line with a slope



# Hourly Production Cost - Using Block Offer

- Hourly No-Load = $500
- Cost of 1st segment:
  - 50 MW * $10 = $500
- Cost of 2nd segment:
  - (75MW – 50 MW)* $50 = $1,250
- Cost of 3rd segment (Eco Max):
  - (100 MW – 75 MW)* $200 = $5,000

# Hourly Production Cost - Using Block Offer

- Hourly production Cost at Eco Min =

  No Load + 1st Increment to Min = $500 + $500 = $1,000/hour

- Hourly production Cost at Eco Max =

  No Load + 1st Segment + 2nd Segment + 3rd Segment = $7,250/hour

- Operating Rate =

  (Hourly Production Cost at Eco Max / Eco Max MW) = $7250/hour / 100 MW = $72.50/MWH

# Total Production Cost

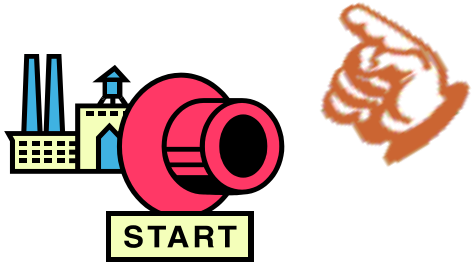
- Calculated by adding all of the costs associated with starting a unit and operating it over a period of time

- Two cost components:
  - Startup Costs
  - Hourly Production Costs

**Total Production Cost**
**=**
**Startup Cost**
**+**
**(Hourly Production Cost**
**x**
**Number of Hours)**

# Start Cost

- Start Cost (or price) is associated with the cost to supply steam to operate the turbine and bring the generating unit to synchronous speed. There are three states for Start Costs (or prices):
  - Hot
  - Intermediate
  - Cold



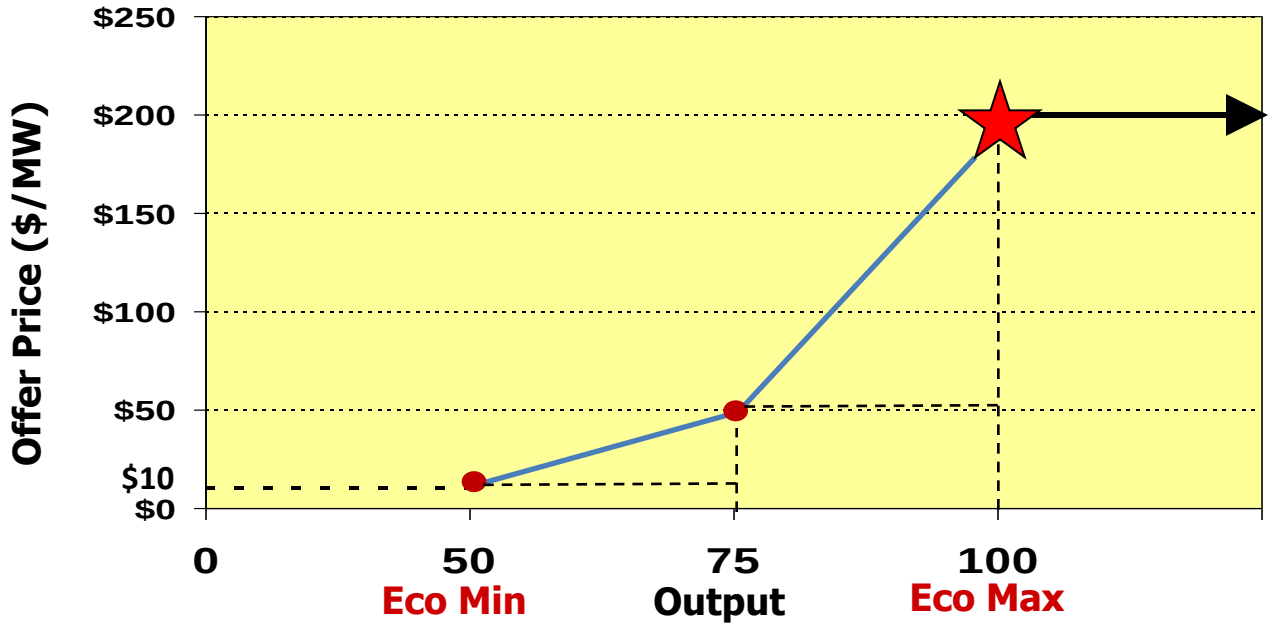

- Start Cost is the dollars per start as determined from start fuel, total fuel-related cost, performance factor, electrical costs, start maintenance adder, and additional labor cost

# Total Production Cost - Using Block Offer

- Using the results from the hourly production cost problem with min run time of 16 hours, the range of production cost is:
  - 16 hours at Eco Min (50 MW):
    - $1,000/hour * 16 hours = $16,000
  - 16 hours at Eco Max (100 MW):
    - $7,250/hour * 16 hours = $116,000
  - Assume unit is still in a "hot" condition
    - Add the Hot Start Cost ($500)
  - Total production cost range:
    - $16,500 (eco min) to $116,500 (eco max) per day

# Generator Offer Curve – Using Slope Offer Curve

- Slope Offer Curve rather than an Block curve
  - (i.e. Use Slope field in Markets Gateway is checked)
- The Slope Offer Curve is a straight line connected to the offer points



# Hourly Production Cost - Using Slope Offer Curve

- Hourly No-Load = $500
- Cost of 1st segment:
  - 50 MW * $10 = $500
- Cost of 2nd segment:
  - ((75MW – 50 MW)* $10) + ((75MW – 50MW)*($50 - $10) / 2) = $750
- Cost of 3rd segment (Eco Max):
  - ((100 MW – 75 MW)* $50) + ((100MW – 75MW)*($200 - $50) / 2) = $3,125

# Hourly Production Cost - Using Slope Offer Curve

- Hourly production Cost at Eco Min =

  No Load + 1st Increment to Min = $500 + $500 = $1000/hour

- Hourly production Cost at Eco Max =

  No Load + 1st Segment + 2nd Segment + 3rd Segment = $4,875/hour

- Operating Rate =

  (Hourly Production Cost at Eco Max / Eco Max MW) = $4,875/hour / 100 MW = $48.75/MWH

# Total Production Cost - Using Slope Offer Curve

- Using the results from the hourly production cost problem with min run time of 16 hours, the range of production cost is:
  - 16 hours at Eco Min (50 MW):
    - $1,000/hour * 16 hours = $16,000
  - 16 hours at Eco Max (100 MW):
    - $4,875/hour * 16 hours = $78,000
  - Assume unit is still in a "hot" condition
    - Add the Hot Start Cost ($500)
  - Total production cost range:
    - $16,500 (eco min) to $78,500 (eco max) per day

# Production Cost Exercise

| Parameter | Unit X | |
|---|---|---|
| Hot Start Price ($) | 600 | |
| Intermediate Start Price ($) | 1200 | |
| Cold Start Price ($) | 1800 | |
| No-Load ($/hr) | 250 | |
| | | |
| **Offer Curve (max 10 points)** | **MW** | **Price ($/MWh)** |
| segment 1 | 100 | 50 |
| segment 2 | 150 | 75 |
| segment 3 | 250 | 100 |
| | | |
| Eco Min (MW) | 100 | |
| Eco Max (MW) | 250 | |
| Min Run Time (hours) | 4 | |

What is the total production cost to run Unit X at Maximum output?

Calculate the production cost for both block and slope offer curve.

Assume Intermediate Start Price

# Questions?