Regulation
Objectives

• Define performance based regulation

• Identify the types of resources that can provide regulation

• Explain the different types of regulation

• Identify the role regulation has in PJM Markets

• Calculate regulation offers
Balancing Authority’s Goal
**Imbalance Conditions**

**Over-Generation**
- Total Generation > Total Demand
- Frequency > 60 Hertz
- Generators momentarily speed up

**Under-Generation**
- Total Generation < Total Demand
- Frequency < 60 Hertz
- Generators momentarily slow down
What is Regulation?

Regulation is:

• A variable amount of generation energy under automatic control
• Independent of economic cost signal
• Obtainable within five minutes
• Responds to frequency deviations
  – These generating units or Demand Response Resources provide fine tuning that is necessary for effective system control
  – Regulating units correct for small load changes that cause the power system to operate out of balance (measured as “ACE”)
PJM Market with Market-Based Regulation

- Creates market for regulation
- Provides Market Clearing Prices for regulation
- Protects supplier by providing opportunity cost of energy
- Provides more incentive to provide regulation
Off-Peak Regulation Requirement = 525 MW

On-Peak Regulation Requirement = 700 MW
Fulfilling Regulation Obligation

• All LSEs have hourly Regulation Obligation
  – pro rata share of PJM Regulation assigned for hour
    • based on LSE total real time hourly load

• Obligation can be satisfied by:
  – self-scheduling own resources
  – enter bilateral transactions with other participants
  – purchasing from PJM Regulation Market
Providing Wholesale Ancillary Services

What types of Resource can provide regulation:

- **Generation:** Steam, Hydroelectric, Combustion Turbines, Combined Cycle
- **Grid Energy Storage:** Batteries, Flywheels
- **Behind-the-Meter Storage:** Water Heaters, Batteries, Plug-in Hybrid Electric Vehicles
- **Demand Response:** Variable Speed Pumps, Ceramic Thermal Storage
Characteristic Differences Between Resources

• **Ramp-Limited Resources**
  – Examples include Steam, Combustion Turbine (CT), Combined Cycle (CC), Hydroelectric Dams
  – Fuel-burning results in hours of operation at all deployment levels (sustain full raise/lower)
  – Energy output rate-of-change limited by mechanical processes
  – Operates on Traditional Regulation Signal

• **Energy-Limited Resources**
  – Examples include Batteries and Flywheels
  – Sub-second matching of control signal (infinite ramp rate)
  – Energy output determined by state of charge, storage capacity
  – Operates on Dynamic Regulation Signal
Regulation Signals

- Traditional Regulation Signal (REGA)
  - A function of slow filter of RTO Area Control Error (ACE)
  - Can remain full raise or lower for extended periods

- Dynamic Regulation Signal (REGD)
  - A function of fast filter of RTO ACE
  - Increases the amount of time the REGD signal opposes the ACE during a deviation
Regulation Signals

**RegA (blue)** – fleet level regulation signal sent by PJM to traditional units (some CTs, CC’s, steam)

**RegD (green)** – fleet level regulation signal sent by PJM to fast moving units (energy storage, hydro, some CT’s)

The RegD (D for Dynamic) has different time constants which speeds up the signal for resources that can move faster, allowing them to cross 0 more frequency and prevent excess discharge.
• A **performance score** is calculated for each regulation resource for each regulating hour
  
  – Performance scores reflect the benefits each resource provides to system control by focusing on the resource’s response to PJM control signals
  
  – PJM will provide continuous feedback to the regulation resources of their performance using near real time reporting
  
  – Data posting for each resource through Markets Gateway
Fulfilling Obligation: Bilateral Transactions

• Entered by Buyer using Markets Gateway
  – Entered as a MW amount to be transacted

• Confirmed by Seller in Markets Gateway

• Data entered and confirmed no later than 13:30 the day after the transaction starts
  – Transaction that have been reported and confirmed may not be changed; they must be deleted and re-reported
  – Deletion of a reported transaction after its start time has passed will result in a change in the end time to the current hour
  – Confirmation after 13:30 will default the transaction to starting the day of confirmation
Regulation Market Time Line

Regulation offers and cost data must be supplied by 14:15 day-ahead and is applicable for the entire 24 hour period for which it is submitted.

Throughout Operating Day
PJM clears Regulation Market hourly

Regulation Offers (price only) due by 14:15 EPT for next operating day
**Band of Regulation for Generator**

- **Economic Maximum**
- **High Regulation Limit**
- **Basepoint + Capability**

- **Economic Basepoint**

- **MW Regulation Capability Offered into Markets Gateway**

- **Basepoint - Capability**
- **Low Regulation Limit**

- **Economic Minimum**

* Band of regulation must fall within the economic limits of the generating unit

If high and low regulation limits are not most restrictive, then ASO uses most restrictive min and max*

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Regulation Offers – Cost

• Cost-Based Regulation Offer is split into two portions and is mandatory to clear in the market even when self scheduled
  – Capability portion ($/MW)
    • Fuel Cost Increase
    • Unit Specific Heat Rate Degradation due to Operating at Lower Loads
    • $12 margin adder
  – Performance portion ($/ΔMW)
    • Cost Increase due to Heat Rate Increase during non-steady state operation
    • Cost Increase in VOM
    • The $/ΔMW will be multiplied by the ratio of ΔMW/MW to convert to ($/MW)
Regulation Offers – Price

- Price-Based Regulation Offer is capped at $100/MW, and its submission is optional. It is split into:
  - **Capability** ($/MW) the price to reserve MWs for regulation
  - **Performance** ($/ΔMW) the price to provide regulation movement
    - The $/ΔMW will be multiplied by the ratio of ΔMW/MW to convert to ($/MW)
The Capability Offer is adjusted as follows:

\[
\text{Adjusted Regulating Capability Cost (\$)} = \left( \frac{\text{Capability Offer (\$ per MW)}}{\text{Benefits Factor of Offered Resource}} \right) \times \left( \frac{\text{ Qualified Regulation MW's}}{\text{Historic Performance Score}} \right)
\]

Benefits factor translates a specific fast moving resource's MWs into traditional MWs to estimate Effective MWs.

Resource owner’s Offer for reserving MW’s

Qualified Regulation MW’s

Average of last 100 hours of performance scores
Adjusted Performance Cost

The Performance Offer is adjusted as follows:

\[
\text{Adjusted Performance Cost (\$)} = \left( \frac{\text{Performance Offer} (\$/\Delta MW)}{\text{Benefits Factor of Offered Resource}} \right) \times \left( \frac{\text{Offered Resource Signal Type} (\Delta MW/MW)}{\text{Historic Performance Score}} \right) \times (\text{Capability (MW)})
\]

- **Adjusted Performance Cost ($)**
- **Resource owner’s Offer for MW’s movement**
- **30 day average of historical mileage**
- **Qualified Regulation MW’s**
- **Benefits factor translates a specific fast moving resource’s MWs into traditional MWs to estimate its Effective MWs**
- **Average of last 100 hours of performance scores**
Market Clearing Process

**Participant Data**
- Performance Offer ($/ΔMW)
- Capability Offer ($/MW)
- MW Offer (MW)

**TPS Test Results**
- Lost Opportunity Cost

**PJM Data**
- Historical Accuracy Score
- Benefits Factor
- Regulation Requirement
- Inter-Temporal Opportunity Cost

**Cross Product Opportunity Cost**

**Total Incremental Cost of Marginal Resource**
- Performance Clearing Price = Highest Adjusted Performance Offer
- Performance Clearing Price = Residual of Total Incremental Cost

**Regulation Market Clearing Prices**

**Clearing Process**

**Regulation Resource Commitments**
Optimization

• Resources cannot be committed for more than one of the non-synchronized reserve, synchronized reserve, or regulation products during the same interval
Questions?