Two Settlement
Objectives

• Describe Two-Settlement process
  – Day-Ahead Market
  – Balancing Market

• Explain Virtual Transactions and their settlement
  – Inc Offers
  – Dec Bids
  – Up-to Congestion Transactions
Agenda

• Two-Settlement:
  – Overview
  – Market Timelines
  – Virtual Bids
    • INC Offers
    • DEC Bids
  – Up-to Congestion Transactions
What is Two-Settlement?

• Provides PJM Market Participants with the option to participate in a forward market for electric energy in PJM
  – Consists of two markets
    • Day-Ahead
    • Real-Time (Balancing)
  – Separate settlements performed for each market
Two-Settlement Markets

• Day-Ahead Market
  – Develop Day-Ahead schedule using least-cost security constrained unit commitment and security constrained economic dispatch programs that simultaneously optimize energy and reserves
  – Calculate hourly LMPs for next Operating Day using generation offers, demand bids, and bilateral transaction schedules

• Real-Time Energy Market
  – Calculate 5 minute LMPs based on actual operating conditions as described by the PJM State Estimator
  – Actual financial settlement performed on hourly integrated LMP
Two-Settlement Markets

• Day-Ahead Market Settlement
  – Based on scheduled hourly quantities and Day-Ahead hourly prices

• Real-Time Market Settlement
  – Based on actual hourly deviations from Day-Ahead schedule, priced at Real-Time LMPs
Day Ahead Energy Market

• Day-Ahead hourly forward market

• Objective is to develop set of financial schedules that are physically feasible
  – Full transmission system model
  – Unit commitment constraints
  – Reserve requirements model

• Day-Ahead market results based on participant demand bids and supply offers
Day-Ahead Market Information Flow

- **Generation Offer**
- **System Condition**
- **Demand**
- **Demand Side Response**

**PJM Systems**

**Operational Results**
- Day-Ahead binding constraints
- Day-Ahead net tie schedules
- Day-Ahead reactive interface limits

**Participant Results**
- Schedules for next day (generation, demand, DSR & Virtuals)
- Transaction schedules

**Settlements**

PJM©2016 12/06/2016
Day-Ahead Data Flow

Market User Interface
- Generation Offer Data
- Demand Bids
- DSR
- Incr Offers/Dec Bids/Up-tos
- Agg. Bus Distributions

PJM EMS
- Network Model
- Transmission Outages
- Equipment Ratings
- Breaker positions

Other PJM Systems
- PJM Load Forecast
- Hydro Schedules
- Reserve Requirements

PJM ExSchedule
- Energy Transaction Schedules
- External Energy Schedules
- Net Tie Schedules

PJM OASIS
- Energy Transactions
- External Energy Offers
- Net Tie Schedules

Day-Ahead Software
- Hourly LMPs
- Hourly Demand, DSR & Generation Schedules
- Transmission Limitations
- Inc/Dec, Up-to schedules

Settlements
Determining Schedules & LMPs

**RSC** = Resource Scheduling and Commitment (Unit Commitment)

**SPD** = Scheduling, Pricing and Dispatch (Economic Dispatch)

**SFT** = Simultaneous Feasibility Test
Resource Scheduling & Commitment (RSC)

- Performs **security-constrained unit commitment** (SCUC) based on generation offers, demand bids, and transaction schedules submitted by participants

- Enforces constraints – physical unit specific and generic transmission
Scheduling, Pricing & Dispatch (SPD)

- Performs **security-constrained economic dispatch** (SCED), using unit commitment produced by RSC, to determine generator MW dispatch while honoring ramp limits
- Determines LMPs for all load and generation buses
- Considers additional generic constraints that affect dispatch, such as reactive interface limits
- Day-Ahead Scheduling Reserve Clearing Prices
Simultaneous Feasibility Test (SFT)

- Creates a model for each hour of scheduling day based on:
  - Network topology
  - Generation MW profile produced by SPD
  - Equipment's limits

- Performs contingency analysis using contingency list

- Develops violations as constraints and passes them back to SPD for resolution

- Help ensure the Day-Ahead Market results are physically feasible
Day-Ahead Posting Results

• Public
  – Transaction Schedules
  – Day-Ahead LMPs
  – Day-Ahead Binding Constraints
  – Day-Ahead Net Tie Schedules
  – Day-Ahead Reactive Interface Limits
  – Day-Ahead Summary

• Private
  – Schedules for Next Day (generation, demand, DSR & virtuals)
**Posted Generation Schedules**

- For steam units, use Day-ahead schedule for the time to be online and ready to follow dispatch rate
  - Once online, unit should follow real-time dispatch and NOT Day-Ahead schedule
    - Unless unit is self-scheduled
  - Changes to posted schedules will be communicated verbally to generation owner
    - Earlier start time, cost-capping, additional commitments

**Combustion Turbines that have a startup and notification time greater than two hours should follow their Day-Ahead schedule**

  - CT’S with less than 2 hour startup and notification time will be dispatched in real-time as needed by the PJM Operators
Self-Scheduling Generation

• Generation Owners may self-schedule (must-run) generation at any time

• Implications:
  – Can not set LMP (but will receive LMP at their bus)
  – Still must bid in Day-Ahead
  – 20 minute notice required to self-schedule in real-time
  – May be subject to Balancing Market Operating Reserve charges (if deviation from Day-Ahead schedule)
  – NOT eligible for Operating Reserve credits
Features of Two-Settlement

• Enhance robust & competitive market in the PJM RTO

• Provide additional price certainty to Market Participants by allowing them to ...
  – Commit & obtain commitments to energy prices and transmission congestion charges in advance of Real-Time dispatch (forward energy prices)
  – Submit price sensitive demand bids
  – Submit increment offers, decrement bids, and up-to-congestion transactions
Participant Responsibilities

- **Load Serving Entity (LSE) – Market Buyers**
  - Submit Day-Ahead demand bids
    - (hourly demand schedules)
  - Submit Day-Ahead price sensitive demand bids
  - For any demand they wish to lock in at day ahead prices
  - Participation is optional for an LSE in the Day-Ahead market

- **Generators – Market Sellers**
  - Any generator that is a capacity resource that has an RPM commitment must submit a schedule into the Day-Ahead market **even** if self-scheduling or unavailable due to an outage
  - Non-capacity generators have the option to participate in the Day-Ahead energy market
• LSEs will pay the Real-Time LMP for any demand that exceeds their Day-Ahead scheduled quantity

• LSEs will receive Real-Time LMP for any demand that is below their Day-Ahead scheduled quantities

• Generators are paid Real-Time LMP for any generation that exceeds their Day-Ahead scheduled quantities

• Generators will pay for any generation that is below their scheduled quantities
Locational Pricing Calculator (LPC)

LPC (every 5 minutes in real-time)

• Runs every 5 minutes and provides real-time pricing
  – LPC prices on a five minute basis all valid system pricing points for the energy market: Buses (Gen and Load), Hubs, Aggregates, Interfaces
  – LPC prices on a 5 minute basis all reserve market clearing prices by locale (Regulation, Synchronized Reserve and Non-Synchronized Reserve)

• Performs joint optimization of energy and reserves

• Current approved RT SCED case is the basis for LPC run
Day-Ahead schedules are financially binding

Demand scheduled day-ahead
- Pays Day-Ahead LMP for Day-Ahead MW scheduled
- Pays Real-Time LMP for actual MW above scheduled
- Paid Real-Time LMP for actual MW below scheduled

Generation scheduled day-ahead
- Paid Day-Ahead LMP for Day-Ahead MW scheduled
- Paid Real-Time LMP for actual MW above scheduled
- Pays Real-Time LMP for actual MW below scheduled
Examples

• **Example 1:** LSE with Day-Ahead Demand < Real-Time Demand

• **Example 2:** LSE with Day-Ahead Demand > Real-Time Demand

• **Example 3:** Generator with Day-Ahead MW < Real-Time MW

• **Example 4:** Generator with Day-Ahead MW > Real-Time MW

Note: Examples Use Total LMP
LSE with Day-Ahead Demand Less than Actual Demand

Day-Ahead Market
Scheduled Demand

Real-Time Market
Actual Demand

Day Ahead LMP = $20.00

\[ \$ = 100 \times 20.00 = \$2000.00 \text{ charge} \]

Real-Time LMP = $23.00

\[ \$ = (105 - 100) \times 23.00 = \$115.00 \text{ charge} \]

Total Charge = $2000 + $115 = $2115
LSE with Day-Ahead Demand Less than Actual Demand

Day-Ahead Market
Scheduled Demand

Real-Time Market
Actual Demand

Day Ahead LMP = $20.00

\[ \text{Day Ahead LMP} = 100 \times 20.00 = \$2000.00 \text{ charge} \]

Real-time LMP = $15.00

\[ \text{Real-time LMP} = (105 - 100) \times 15.00 = \$75.00 \text{ charge} \]

Total Charge = $2000 + $75 = $2075
LSE with Day-Ahead Demand Greater than Actual Demand

Day-Ahead Market
Scheduled Demand

Real-Time Market
Actual Demand

Day-Ahead LMP = $20.00
Real-Time LMP = $23.00

$ = 100 * 20.00 = $2000.00 charge
$ = (95 - 100) * 23.00 = $-115.00 charge

Total Charge = $2000 - $115 = $1885
LSE with Day-Ahead Demand Greater than Actual Demand

Day-Ahead Market
Scheduled Demand

95 MW

100 MW

Real-Time Market
Actual Demand

Day-Ahead LMP = $25.00

$ = 100 * 25.00 = $2500.00 charge

Real-Time LMP = $20.00

$ = (95 - 100) * 20.00 = $-100.00 charge

Total Charge = $2500 - $100 = $2400
Generator with Day-Ahead MW Less than Actual MW

Day-Ahead Market
Scheduled MW

Real-Time Market
Actual MW

Day Ahead LMP = $20.00

\[ \text{Total Credit} = \$4000 + \$110 = \$4110 \]
Generator with Day-Ahead MW Less than Actual MW

Day-Ahead Market
Scheduled MW

Real-Time Market
Actual MW

Would only occur if unit was self-scheduled

Day Ahead LMP = $30.00

$ = 200 * 30.00 = $6000.00 credit

Real-time LMP = $10.00

$ = (205 - 200) * 10.00 = $50.00 credit

Total Credit = $6000 + $50 = $6050
Generator with Day-Ahead MW Greater than Actual MW

Day-Ahead Market
Scheduled MW

\[\text{Day-Ahead LMP} = \$20.00\]

\[\text{Real-Time LMP} = \$22.00\]

\[\$ = 200 \times 20.00 = \$4000.00 \text{ credit}\]

\[\$ = (100 - 200) \times 22.00 = \$2200.00 \text{ credit}\]

\[\text{Total Credit} = \$4000 - \$2200 = \$1800\]

Real-Time Market
Actual MW
Due to a problem on a unit
Generator with Day-Ahead MW Greater than Actual MW

Day-Ahead Market
Scheduled MW

Real-Time Market
Actual MW

\[ \text{Day-Ahead LMP} = \$20.00 \]

\[ \text{Real-time LMP} = \$15.00 \]

\[ \$ = 200 \times 20.00 = \$4000.00 \text{ credit} \]

\[ \$ = (100 - 200) \times 15.00 = \$-1500.00 \text{ credit} \]

\[ \text{Total Credit} = \$4000 - \$1500 = \$2500 \]
Agenda

• Two-Settlement:
  – Overview
  – Market Timelines
  – Virtual Bids
    • INC Offers
    • DEC Bids
  – Up-to Congestion Transactions
Unit Commitment Analysis

10:30 a.m.
Day-Ahead Market Closes

First Commitment

• Determines commitment profile that satisfies fixed demand, price sensitive demand bids, virtual bids and offers, and PJM Operating Reserve Objectives
• Minimizes total production cost

1:30 p.m.
Day-Ahead Results Posted and Balancing Market Bid Period Opens

2:15 p.m.
Balancing Market Bid Period Closes

Reserve Adequacy Assessment

• Focus is reliability
• Updated unit offers and availability
• Based on PJM load forecast
• Minimizes startup and cost to run units at minimum

Transmission Security Assessment

• Focus is reliability
• Performed as necessary starting two days prior to the operating day
• Based on PJM Load Forecast
PJM Markets Timeline

**Data Hand-off Ops. → Mkts**

**Ops. Technical Analysis**
0800 - 1030

- Market Participant Bid/Offer Period
  - Before 1030
  - Market participants enter bids and offers.

**Data Hand-off Ops. → Mkts**

**Day-Ahead Results Posted & Balancing**
1030 - 1330

- Process all the markets requests from day-ahead bids
- Post Day-Ahead Market results by 1330

**Data Hand-off Ops. → Mkts**

**Re-bid Period**
1330 - 1415

- After day-ahead results are available -1415
- Make adjustments based on the clearing results.

**Real-Time Operations and Monitoring**

**Balancing Market Bid Period Closes**
1415 - Midnight

**Commitments**

**Second**
- Reliability analysis includes:
  - Updated offers
  - Unit availabilities
  - PJM load forecast info

**Supplemental**
- Reliability performed as needed
- Minimize start-up and cost to run
Agenda

• Two-Settlement:
  – Overview
  – Market Timelines
  – Virtual Bids
    • INC Offers
    • DED Bids
  – Up-to Congestion Transactions
Increment Offers and Decrement Bids

• Market participants can submit increment offers and decrement bids at any hub, transmission zone, aggregate or single bus or eligible external interface for which an LMP is calculated.

• Increment Offer (INC) looks like a “virtual generator”

• Decrement Bid (DEC) looks like a “virtual load”

• It is not required that physical generation or physical load exists at the location that is specified in the increment offer or decrement bid

• Increment Offers and Decrement Bids are financial instruments in the Day-Ahead market ONLY!
How Do Virtual Bids Work?

**INC Offer**
- Sells MW into Day-Ahead Market at Day-Ahead LMP
- Buys replacement MW from Real-Time Market at Real-Time LMP
- Profits when Day-Ahead Prices are Higher than Real-Time Prices

**DEC Bid**
- Buys MW from Day-Ahead Market at Day-Ahead LMP
- Sells those MW in Real-Time Market at Real-Time LMP
- Profits when Day-Ahead Prices are Lower than Real-Time Prices
How Do Virtual Bids Make Money?

INC Sells MW into Day-Ahead Market at $50

Buys replacement MW at $40 in Real-Time Market

Gets paid $50 and pays back $40 = $10 profit
Why Use an Inc or Dec?

• Cover one side of a bilateral transaction
• Cover inSchedule transaction
  – allows opposite party access to Real-Time LMP while you participate in Day-Ahead
• Protect a Day-Ahead generation offer
  – Use a decrement bid
Self-Scheduled Generator (200 MW) Wants to See Real-Time Pricing

**Day-Ahead**

- Generator self-schedules unit at 200 MW
- Decrement bid at same bus for 200 MW at $100

Assume Day-Ahead LMP = $30

Day Ahead Settlement (Gen) = 200 MW * $30 = $6000 credit

Day Ahead Settlement (Dec) = 200 MW * $30 = $6000 charge

Net Day Ahead Position = 0

**Real-Time**

Assume Generator produces 200 MW

Assume Real-time LMP = $35

Deviation from DA schedule (Gen) = 0 MW

Decrement bid at same bus for 200 MW at $100

Balancing Settlement (Gen) = 0 MW * $35 = 0

Balancing Settlement (Dec) = 200 MW * $35 = $7000 credit

Balancing Position = $7000 credit

Net Position = 0 + $7000 = $7000 Credit
Example - Decrement Bid with Generator

Generator in Danger of a Forced Reduction in Real-Time (i.e. Mechanical Failure)

Day-Ahead Generator
- 200 MW Scheduled Generation
- Dec bid 100 MW @ $20
- Assume Day-Ahead LMP = $15

Day Ahead Settlement (Gen) = 200 MW * $15 = $3000 credit
Day Ahead Settlement (Dec) = 100 MW * $15 = $1500 charge

Net Day Ahead Position = 1500 credit

Real-Time Generator
- Generator produces 100 MW
- Assume Real-time LMP = $20
- Deviation from DA schedule (Gen) = -100 MW
- Deviation from DA schedule (DEC) = 100 MW

Balancing Settlement (Gen) = -100 MW * $20 = $2000 charge
Balancing Settlement (Dec) = 100 MW * $20 = $2000 credit

Balancing Position = $0

Net position = $1500 + $0 = $1500 credit

Without DEC Net credit = $1000
Agenda

• Two-Settlement:
  – Overview
  – Market Timelines
  – Virtual Bids
    • INC Offers
    • DED Bids
  – Up-to Congestion Transactions
Up-to Congestion Transactions

• An up-to congestion transaction is a conditional transaction that permits a market participant to specify a maximum of a (+/-) $50/MWh price spread between the transaction source and sink in the Day-Ahead Market.

• Up-to congestion transactions are cleared based on the price difference between source and sink (Congestion and Loss component of LMP):
  – Day-Ahead Charge = Transaction MWh * (Sink DA LMP – Source DA LMP)
  – Balancing Credit = Transaction MWh * (Sink RT LMP – Source RT LMP)
Up-to Congestion Transactions Example

Day-Ahead Charge = 100 MWh * ($30/MWh-$5/MWh) = $2,500
Balancing Charge = -100 MWh * ($40/MWh-$10/MWh) = -$3,000
Up-to Congestion Transactions

• PJM will maintain an up-to date list of source/sink combinations that will be available for ‘Up to ‘congestion bidding on the PJM OASIS

• Up-to congestion transactions are supported in the Day-Ahead Market ONLY
Questions?

PJM Client Management & Services
Telephone: (610) 666-8980
Toll Free Telephone: (866) 400-8980
Website: www.pjm.com

The Member Community is PJM’s self-service portal for members to search for answers to their questions or to track and/or open cases with Client Management & Services