Section 4: Scheduling Philosophy & Tools

Welcome to the *Scheduling Philosophy & Tools* section of the PJM Manual for *Scheduling Operations*. In this section you will find the following information:

- A description of the PJM OI's scheduling philosophy (see "PJM OI Philosophy").
- A description of the tools that are used during the scheduling process (see "*Scheduling Tools*").

PJM OI Philosophy

The PJM OI scheduling philosophy in the Day-ahead Energy Market is to schedule generation to meet the aggregate Demand bids that results in the least-priced generation mix, while maintaining the reliability of the PJM Control Area. The PJM OI will also schedule additional generation as needed to satisfy the PJM Load Forecast and additional Operating Reserve Objective based on minimizing the cost to procure such reserves. PJM will also schedule resources based on economics to control potential transmission limitations that are binding in the Transmission Reliability analysis that is performed in parallel with and subsequent to the Day-ahead Market analysis. The scheduling process evaluates the price of each available generating unit compared with every other available generating unit. The philosophy for scheduling the PJM Control Area requires:

- scheduling sufficient generation in the Day-ahead Energy Market to cover aggregate Demand bids and Operating Reserve requirements calculated as a function of such demand bids
- scheduling sufficient generation in the reliability-based analysis subsequent to the Dayahead Energy Market to cover the PJM Load Forecast and additional Operating Reserve requirements
- scheduling sufficient generation to control potential transmission limitations that are binding in the Transmission Reliability analysis
- scheduling sufficient generation to satisfy the PJM Regulation Requirement and other ancillary service requirements of the PJM Control Area.
- ensuring PJM Members participate in the analysis and elimination of conditions that threaten the reliable operation of the PJM Control Area

Scheduling of generation resources by the PJM OI is performed economically on the basis of the prices and operating characteristics offered by the Market Sellers, using security, constrained dispatch and continuing until sufficient generation is dispatched in each hour to serve all energy purchase requirements, as well as the PJM Control Area requirements.

Scheduling Tools

Analytical scheduling tools exist to assist the PJM OI with the scheduling process. These tools permit the PJM OI scheduling staff to analyze numerous scheduling scenarios. The PJM OI personnel use several tools to assist in scheduling the generation resources for short-term and hourly activities. The scheduling tools include:

- Accounting Contracts and Energy Schedules (ACES) program
- PJM eSchedules
- Load Forecasting Algorithms
- Market Database System
- Hydro Calculator
- Two Settlement Technical Software (RSC, SPD and STNET)
- PJM Regulation Scheduling Software (REGO)
- Transmission Outage Data System

Together these tools recognize the following conditions:

- reactive limits
- unit constraints
- unscheduled power flows
- inter-area transfer limits
- unit distribution factors
- Self-Scheduled Resources
- limited fuel resources
- Bilateral Transactions
- hydrological constraints
- generation requirements
- reserve requirements

Enhanced Energy Scheduler (EES)

The EES program records and manages the interchange of bulk power between the PJM Control Area and other utilities, marketers, and brokers. The PJM OI personnel use EES to process daily non-firm (both those electing to curtail due to congestion and those electing to pay congestion charges) and firm Bilateral Transaction schedules that are submitted by PJM Members. In general, EES is used to perform the following activities:

- processes PJM Members' Bilateral Transactions
- validates transaction by verifying transaction rules

PJM eSchedules

PJM eSchedules is an internet program that is used, among other functions, to schedule internal Bilateral Transactions.

Load Forecasting

The PJM OI scheduling staff requires load forecasts for up to ten days in the future. For each day, a 24-hour load shape is needed.

- (1) The first step in developing a load forecast is to obtain the weather information for the time period. Weather information is provided to the PJM OI at regular intervals by a contracted-for weather service. Additional weather data sources include the National Weather Service, radio news, LSE weather information, and existing local PJM Control Area conditions.
- (2) The forecast period is reviewed to determine any conditions that could affect the PJM Control Area's load, including:
 - day of week
 - holidays
 - special events
 - daylight savings time changes
 - internal participant load forecasts
- (3) Peak loads and load shapes are determined using a similar day's forecast. The PJM OI retrieves the load data from a historical file and adjusts the forecasts, as needed, to reflect growth or other discrepancies.





Exhibit 4.1: Load Forecasting Process

The load forecasts for each 24-hour period are input in the Marginal Scheduler program. The PJM OI scheduling staff also posts these forecasts on the OASIS. (See Section 6: Posting OASIS Information for more information.)

Markets Database System

The Markets Database System is a two-part system:

- The Markets Database (UCDB) stores the basic unit data supplied by the PJM Members, including operating limits and unit availability (see Attachment A).
- The eMKT website that provides the internet-based (of PJM ENET-based) user interface that allows Market Participants to submit generation offer data, Demand bids, Increment Offers, Decrement bids and Regulation Offers into the Markets Database.

The Markets Database is a very large database that contains information on each generating unit that operates as part of the PJM Energy Market, Demand Information, Increment Offers, Decrement Bids, Regulation Offers, Day-ahead Energy Market results and Regulation Market Clearing Prices. A description of the Markets Database is outlined later in this section.

Market participants may access the Markets Database by using the PJM eMKT website via the internet or PJM ENET using manual entry or bulk upload via xml format.

The deadline for submission of Generation Offers, Demand Bids, Increment Offers and Decrement Bids into the Day-ahead Energy Market is 12:00 Noon of the day before the Operating Day. After this deadline, no further offers are accepted for the Day-ahead Market and the Markets Database is locked until the Generation Rebidding Period commences at 4:00 PM. The deadline is only extended when there is a computer problem at the PJM OI. The Generation Rebidding Period allows generation that was not selected in the Day-ahead Market to submit revised offer data for the Real-time Market. The Generation Rebidding Period for the next Operating Day is open from 4:00 PM to 6:00 PM each day. The Regulation Market Offer period closes at 6:00 PM each day.

Please refer to Exhibit 4.2: Regulation Market Timeline.



Exhibit 4.2: Regulation Market Timeline

Attachment A presents data that needs to be submitted by PJM Members.

Hydro Calculator

For PJM Control Area-Scheduled Resources, the PJM OI is responsible for developing the schedules for the run-of-river and pumped storage plants located within the PJM Control Area and turned over to the PJM OI for coordination. To assure hydraulic coordination of the hydro plants, the PJM OI uses a computer program called Hydro Calculator. The Hydro Calculator computes hourly reservoir elevations and plant generation from input river flows and plant discharges. The PJM OI scheduling staff uses the Hydro Calculator to concentrate on economic placement of available hydro energy.

Two-Settlement Technical Software

The PJM Two-settlement Technical Software is a set of computer programs, which performs security-constrained unit commitment an economic dispatch for the Day-ahead Market. The individual programs are:

Resource Scheduling & Commitment (RSC) - Performs security-constrained *unit commitment* based on generation offers, demand bids, Increment Offers, Decrement bids and transaction schedules submitted by participants and based on PJM Control Area reliability requirements. RSC will enforce physical unit specific constraints that are specified in the generation offer data and generic transmission constraints that are entered by the Market Operator. RSC provides an optimized economic unit commitment schedule for the next seven days and it utilizes a linear programming solver to create an initial unit dispatch for the next operating day.

Scheduling, Pricing, & Dispatch (SPD) - Performs security-constrained *economic dispatch* using the commitment profile produced by RSC. SPD calculates hourly unit generation MW levels and LMPs for all load and generation buses for each hour of the next operating day. SPD utilizes a linear programming solver to develop the economic dispatch solution while respecting generic transmission constraints that affect dispatch, such as reactive interface limits, and thermal limits.

Study Network Analysis (STNET)- Creates a powerflow model for each hour of operating day based on the scheduled network topology, the generation and demand MW profile produced by SPD and the scheduled PJM Net Tie Flow with adjacent control areas. STNET performs AC contingency analysis using contingency list from PJM EMS and creates generic constraints based on any violations that are detected. These generic constraints are then passed them back to RSC and/or SPD for resolution STNET ensures that the Day-ahead Market results are physically feasible considering PJM Control Area security constraints and reliability requirements.

Settlement Subsystems



Exhibit 4.3: Settlement Subsystems

The Two-settlement technical software develops the Day-ahead Market results based on minimizing production cost to meet the Demand bids and Decrement bids that are submitted into the Day-ahead Market while respecting the PJM Control Area security constraints and reliability requirements that are necessary for the reliable operation of the PJM Control Area. Subsequent to the close of the generation Rebidding Period at 6:00 PM, the RSC is the primary tool used to determine any change in steam unit commitment status based on minimizing the additional startup costs and costs to operate steam units at economic minimum in order to provide sufficient operating reserves to satisfy the PJM Load Forecast (if greater that cleared total demand in the Day-ahead Market) and adjusted operating reserve requirements. The purpose of this second phase of unit commitment is to ensure that PJM has scheduled enough generation in advance to meet the PJM Load Forecast for the next operating day and for the subsequent 6 days. CTs units are included in the scheduling process and are scheduled in the Day-ahead Market. However, the decisions concerning actual operation of pool-scheduled CT units during the operating day are not made until the current operating hour in real-time dispatch.

Download Data from Markets Database



- Demand Bids
- Increment Offers & Decrement Bids
- Load Forecast
- Hydro Unit Schedules
- Scheduled Transmission
 Outages
- Bilateral Transactions
- Facility Ratings
- Net Tie Schedules
- PJM Network Model
- Aggregate Definitions

Exhibit 4.4: Download Data from Markets Database

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Two-Settlement Technical Software

Two-Settlement Data Flow



Exhibit 4.5: Two-Settlement Data Flow

Regulation Scheduling Software (REGO)

REGO determines the forecast of an optimal set of generators to satisfy the PJM Regulation requirement for each hour of the next Operating Day using the commitment profile produced by RSC and the hourly unit generation MW levels and hourly Day-ahead LMPs produced by SPD as a set of initial conditions. REGO also determines the hourly Regulation Marginal Clearing Price (RMCP). It utilizes a linear programming solver to develop the Regulation solution and the hourly RMCP values.