2.2 Definition of Locational Marginal Price

Locational Marginal Price (LMP) is defined as the marginal price for energy at the location where the energy is delivered or received and is based on forecasted system conditions and the latest approved real-time security constrained economic dispatch program solution. LMP is expressed in dollars per megawatt-hour ($/MWh). LMP is a pricing approach that addresses Transmission System congestion and loss costs, as well as energy costs. Therefore, each spot market energy customer pays an energy price that includes the full marginal cost of delivering an increment of energy to the purchaser's location.

- When there is transmission congestion in PJM, the PJM dispatcher dispatches one or more of the generating units out of economic merit order to keep transmission flows within limits. There may be many resources that are dispatched to relieve the congestion. The LMP reflects the cost of re-dispatch for out-of-merit resources and cost of delivering energy to that location.
- LMPs are calculated at all injections, withdrawals, EHVs (nominal voltage of 500 KV and above), Interfaces, and various aggregations of these points.
- LMPs are calculated in both the Real-time Energy Market and Day-ahead Energy Market.
    - The Day-ahead LMP is calculated based on the security-constrained economic dispatch for the Day-ahead Market as described in Section 5.2.6 of this Manual.
    - The Real-time LMP is calculated based on the approved security constrained economic dispatch solution for the target dispatch interval as described in Section 2.5 of this Manual.
- The LMP calculation calculates the full marginal cost of serving an increment of load at each bus from each resource associated with an eligible energy offer as the sum of three separate components of LMP. In performing this LMP calculation, the cost of serving an increment of load at each bus from each resource associated with an eligible energy offer is calculated as the sum of the following three components of Locational Marginal Price:
    - System Energy Price - is the price at which the Market Seller has offered to supply an additional increment of energy from a generation resource or decrease an increment of energy being consumed by a Demand Resource. The System Energy Price may include a portion of the defined reserve penalty factors should a reserve shortage exist.
    - Congestion Price - is the effect on transmission congestion costs (whether positive or negative) associated with increasing the output of a generation resource or decreasing the consumption by a Demand Resource, based on the effect of increased generation from or consumption by the resource on transmission line loadings. The Congestion Prices may include a portion of the defined reserve penalty factors should a reserve shortage exist. As further described in Section 2.17 of this Manual, the congestion price is set to the specified transmission

constraint penalty factor in the event a transmission constraint cannot be controlled below the penalty factor value. The Congestion Prices may include a portion of the defined reserve penalty factors should a reserve shortage exist.

- Loss Price - is the effect on transmission loss costs (whether positive or negative) associated with increasing the output of a generation resource or decreasing the consumption by a Demand Resource, based on the effect of increased generation from or consumption by the resource on transmission losses.
- The energy offer or offers that can serve an additional increment of load at a bus at the lowest cost, calculated in this manner, shall determine the Locational Marginal Price at that bus.

2.10 PJM Real-Ttime ~~Locational Marginal~~ Price Verification Procedure

During and after each Operating Day, PJM reviews all of the five minute Locational Marginal Prices (LMP) and ~~a~~Ancillary ~~S~~service ~~M~~market ~~C~~clearing ~~P~~prices (MCP) prior to finalizing the LMPs and MCPs for posting and use in settlements. The objective of price verification is to ensure prices reflect how the system was dispatched. If there are any instances where the five-minute price intervals do not reflect the dispatch of the system ~~where~~ with incorrectly calculated five-~~-~~minute LMPs and/or MCPs~~A~~a~~ncillary S~~s~~ervice clearing prices ~~were calculated inaccurately~~, PJM corrects those five-minute intervals ~~in the~~during the ~~LMP~~ Price Verification Procedure. In the event of a data input failure, program failure, data input discrepancy or logging error, corrective actions may be taken to ensure that the resulting Real-T~~t~~ime LMPs and MCPs are as reasonably accurate and reflect the dispatch of the system as appropriate. Additional details describing scenarios in which LMPs and MCPs may be recalculated are listed below.

- Data Input Failures – May occur when telecommunication problems exist either internally on the PJM network or on the data paths between PJM and PJM members. If the failure occurs on the PJM network, PJM takes all possible steps to recover the original data for use in LMP and MCP calculation reruns. Examples of data input failures include, but are not limited to, stale offer data, stale dispatch runs, Business Service Process (BSP) failures and stale EMS data.
  ~~(stale cost data, stale dispatch rates, stale EMS data) or Program Failures (State Estimator failure, LPC Failure, Constraint logger failure) Data input failures can occur when telecommunication problems exist either on the PJM computer network or on the data lines between PJM and PJM member companies. If failures occur within PJM's network, all possible steps are taken to recover the original data for use in LMP calculation reruns.~~
- Program Failures –~~-~~ In the event of a program failure, PJM first ~~an attempt~~attempts ~~is first made~~ to correct the reason for the failure and ~~to~~ recalculates LMPs and MCP ~~values~~ for the affected intervals. If the ~~failure cannot be corrected~~attempt fails ~~(due to a data input failure), and the~~to recover the original data ~~cannot be recovered~~, PJM utilizes data from the best available alternate data sources including, but not limited to, backup systems, dispatcher logs, raw telemetry data~~,~~ and member company data sources. In the event of an inability to correct the failure, PJM uses ~~d~~data from a neighboring interval ~~will be used~~ and recalculates LMPs and MCPs ~~will be recalculated~~ for the ~~given~~ affected interval-(s). Examples of program failures include, but are not limited to, State Estimator failure, RTSCED failure or LPC failure. ~~or Constraint Logger failure.~~

- Logging Errors ~~(Transmission constraint logging, CT logging)~~ – ~~The two types of logs which impact pricing are~~ Transmission Constraint logging and resource ~~CT~~ logging errors can affect pricing. The reference for logging times is the transmission dispatcher manual log. In the event of a logging error, LMP or MCP ~~replacements are performed~~ are recalculated as outlined below:
    - Transmission constraint or ~~CT~~ resource logs entered ~~(~~or removed~~)~~ with a delay of less than four LPC intervals~~)~~ – No recalculation of LMPs and MCPs is required.
    - Transmission constraint or ~~CT~~ resource logs entered ~~(~~or removed~~)~~ with a delay of four LPC intervals or more~~)~~ – PJM corrects ~~T~~the constraint and/or ~~CT~~ resource data ~~is corrected and~~ and recalculates LMP and MCPs ~~values are recalculated~~.
    - Transmission constraint or ~~CT~~ resource logs entered incorrectly ~~–~~ PJM corrects ~~T~~the constraint and/or ~~CT~~ resource data ~~is corrected~~ and recalculates LMPs and MCPs ~~values are recalculated~~.

- ~~Other~~ Data Input Errors – Data input errors can occur when ~~the~~ applications or processes upstream of the LMP and MCP calculation complete successfully but produce erroneous results. These errors may include~~,~~ but are not limited to~~, :~~ errors with EMS inputs~~, -~~ such as distribution factors and loss sensitivity factors, constraint modeling errors that result in pricing that is inconsistent with the way PJM operators are managing a constraint, ~~and~~ unintentional approval of the RT SCED case ~~upon~~ for which the LPC case runs and produces LMPs and MCPs~~. Also is the~~, and Regulation performance score calculation engine (PSCE) related errors. In the event of a data input error, LMPs and MCPs are recalculated ~~replacements are performed~~ as outlined below:
    - If PJM determines ~~the~~ EMS data, such as distribution factors or loss sensitivity factors, ~~are found to have~~ is ~~errors~~erroneous, ~~the erroneous input~~ such data is replaced with that from a surrounding interval and LMPs and MCPs are recalculated, or the LMPs and MCPs of the impacted pnodes are replaced with those from electrically equivalent pnodes when the number of pnodes impacted is limited.
    - If ~~a constraint~~modeled constraints ~~is modeled~~ in the upstream applications ~~in a way that is~~are inconsistent with how PJM operators are managing the constraint, PJM corrects the modeling of the constraint ~~is corrected~~ in the LPC case inputs and recalculates the LMPs and MCPs ~~are recalculated~~.
    - If ~~the~~ an erroneously approved RT SCED case~~, upon which the~~ is the basis of an LPC case ~~runs and~~ that produces LMPs and MCPs~~, was approved in error~~, PJM recalculates LMPs and MCPs ~~are recalculated~~ using the last valid ~~intentionally~~ approved RT SCED case ~~as the basis for the LMP calculation~~.
    - If stale or missing regulation mileage or other Ancillary Service related data error is detected, PJM recalculates LMPs and MCPs of the affected intervals.
- In the event RT SCED application is unavailable or dispatchers are unable to Dispatch the system by approving new RT SCED cases, dispatch may go "OFF SCED". During the "OFF SCED" period, dispatch will use the EMS system to manage ACE and manually control any transmission constraints. During the "OFF SCED" period, LMPs will be calculated using the

last valid approved RT SCED case prior to the start of the “OFF SCED” period. Should the “OFF SCED” period extend beyond two full hours, the LMPs may be further modified to reflect system conditions. Additionally, LPC case may be adjusted to reflect system conditions in LMPs and MCPs, including but not limited to Reserve Shortage, Voltage Reduction and Manual Load Dump actions during OFF SCED periods.

5.2 Scheduling Tools

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

- PJM ExSchedule
- PJM InSchedule
- Load Forecasting Algorithms
- Markets Gateway and Market Database System
- Hydro Calculator
- Energy Market Technical Software (RSC, SPD and SFT)
- PJM Ancillary Service Optimizer (ASO)
- Real-Time Market Applications
- Transmission Outage Data System

Together these tools recognize the following conditions:

- Reactive limits
- Resource constraints
- Unscheduled power flows
- Inter-area transfer limits
- Resource distribution factors
- Self-Scheduled Resources
- Limited fuel resources
- Bilateral Transactions
- Hydrological constraints
- Generation requirements
- Reserve requirements

5.2.1 ExSchedule

ExSchedule is an application that facilitates the scheduling of interchange transactions between PJM and other Balancing Authorities. Market participants can view and reserve a portion of PJM's Net Ramp capability, review Tags linked to their account, and submit Day-Ahead Bids that align with their Real-Time interchange transactions. ExSchedule is also used to automatically assess and validate bilateral interchange transactions per PJM's interchange scheduling business rules.

Bilateral interchange transactions that are reported to PJM must be for the physical transfer of electric energy. Payments and related charges associated with such bilateral interchange transactions reported to PJM shall be arranged between the parties to the bilateral transaction. A buyer under a bilateral interchange transaction reported to PJM agrees that it guarantees and indemnifies PJM, PJM Settlement, and the market participants for the costs of any Spot Market

Backup, as determined by PJM, to supply the reported bilateral interchange transaction and for which payment is not made to PJM Settlement by the seller. Upon any default in obligations to PJM or PJM Settlement by a Market Participant, PJM shall not accept any new bilateral interchange transaction reporting by the Market Participant and shall terminate all of the market participant's reporting of associated with its bilateral interchange transactions previously reported to PJM for all days where delivery had not yet occurred.

5.2.2 PJM InSchedule

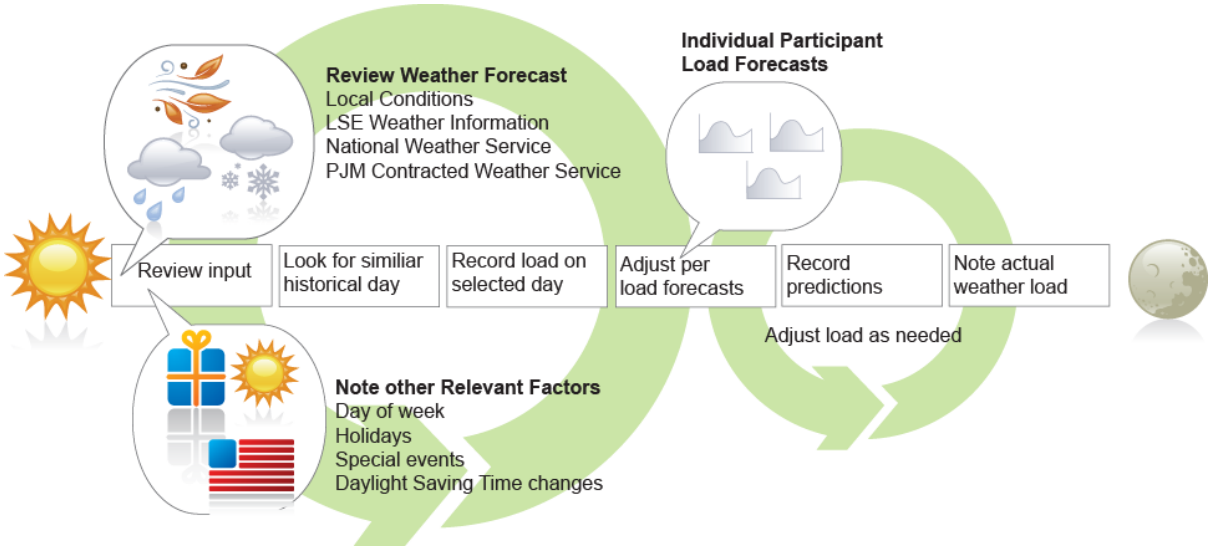
PJM InSchedule is an Internet application that is used, among other functions, to report internal Bilateral Transactions.

5.2.3 Load Forecasting

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

- The first step in developing a load forecast is to obtain the weather information for the time period. Weather information is provided to PJM 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 RTO conditions.
- The forecast period is reviewed to determine any conditions that could affect the PJM RTO's load, including:
    - Day of week
    - Holidays
    - Special events
    - Daylight savings time changes
    - Internal participant load forecasts
- Peak loads and load shapes are determined using a similar day's forecast. PJM retrieves the load data from a historical file and adjusts the forecasts, as needed, to reflect growth or other discrepancies.

Exhibit below presents the typical approach PJM uses to forecast load.



Load Forecasting Process

The load forecasts for each 24-hour period are input in the Marginal Scheduler program. PJM scheduling staff also posts these forecasts on the OASIS.

5.2.3.1 PJM Member Load Forecasts

Each PJM Electric Distribution Company (EDC) within the PJM RTO provides PJM with a forecast of its requirements by 1100 on the day before the Operating Day. Regardless of how the PJM EDC's load is supplied, the PJM EDC submits the following Operating Day forecast information to the PJM:

- Midnight valley MW
- Morning peak MW
- Afternoon peak MW
- Evening peak MW

The hours for which the forecasts apply are specified and changed periodically by PJM and communicated to the PJM Members.

PJM compares the forecasts submitted by the PJM EDCs against the PJM RTO load forecast which is developed by PJM. The PJM EDCs' forecasts cover only four specified hours, while the PJM RTO forecast is for each hour of the Operating Day. Any significant discrepancies between the PJM EDCs' forecasts and the corresponding PJM RTO forecasts are reported to the PJM dispatcher. In general, the PJM RTO forecast takes precedence over the aggregate of the individual PJM EDCs' forecasts.

5.2.4 Markets Database System

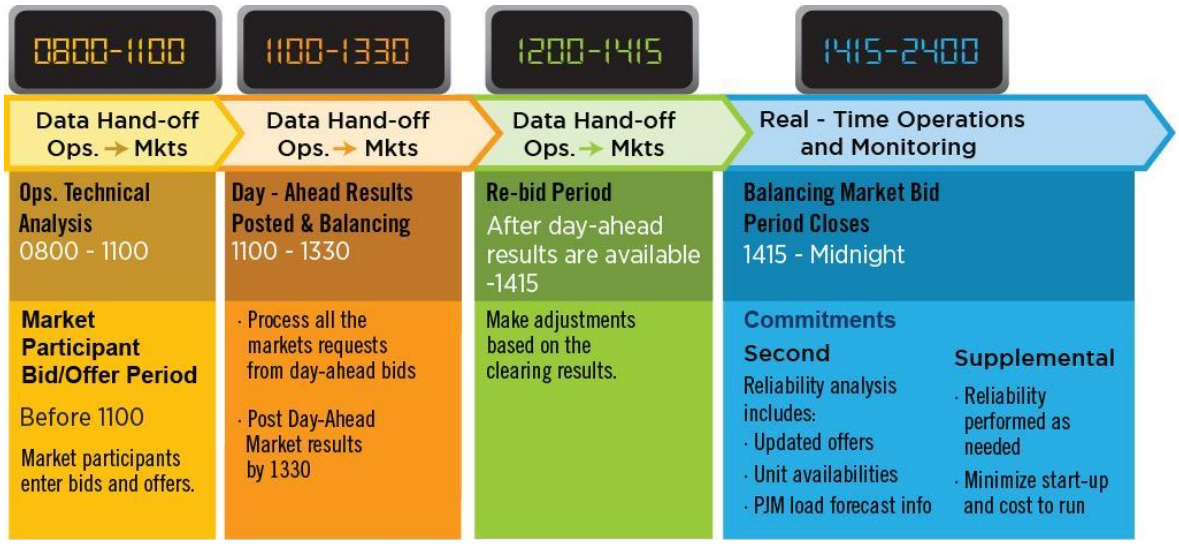
The Markets Database System is a two-part system:

- The Markets Database stores the basic resource data supplied by the PJM Members, including operating limits and resource availability.
- The Markets Gateway Web site that provides the Internet-based user interface that allows Market Participants to submit generation offers, Demand resource offers, Demand bids, Increment Offers, Decrement bids Regulation Offers and Synchronized Reserve Offers into the Markets Database.

The Markets Database is a very large database that contains information on each generating resource that operates as part of the PJM Energy Market, Demand resource information, Demand Information, Increment Offers, Decrement Bids, Regulation Offers, Synchronized Reserve Offers, Day-ahead Energy Market results, Day-ahead Scheduling Reserve Market Clearing Prices, Regulation Market Clearing Prices and Synchronized Reserve Market Clearing Prices. A description of the Markets Database can be found in the Markets Database Dictionary (https://www.pjm.com/-/media/etools/markets-gateway/market-database-data-dictionary.ashx?la=en).

Market participants may access the Markets Database by using the PJM Markets Gateway Web site via the Internet using manual entry or bulk upload/download via XML format.

Please refer to the Energy Market Daily Exhibit below:



Energy Market Daily

- PJM clears the Synchronized Reserve and Regulation markets on an hourly basis. The following is the timeline by which this hourly clearing is accomplished:
    - 60-minutes prior to the operating hour PJM executes the Ancillary Services Optimizer (ASO). The ASO jointly optimizes energy, synchronized reserves, non-synchronized reserves and regulation based on forecast system conditions to

determine an economic set of inflexible reserve resources to commit for the operating hour

The data that needs to be submitted by PJM Members to participate in the Day-ahead Energy, Synchronized Reserve, and Regulation Markets is described in detail in the Markets Database Dictionary.

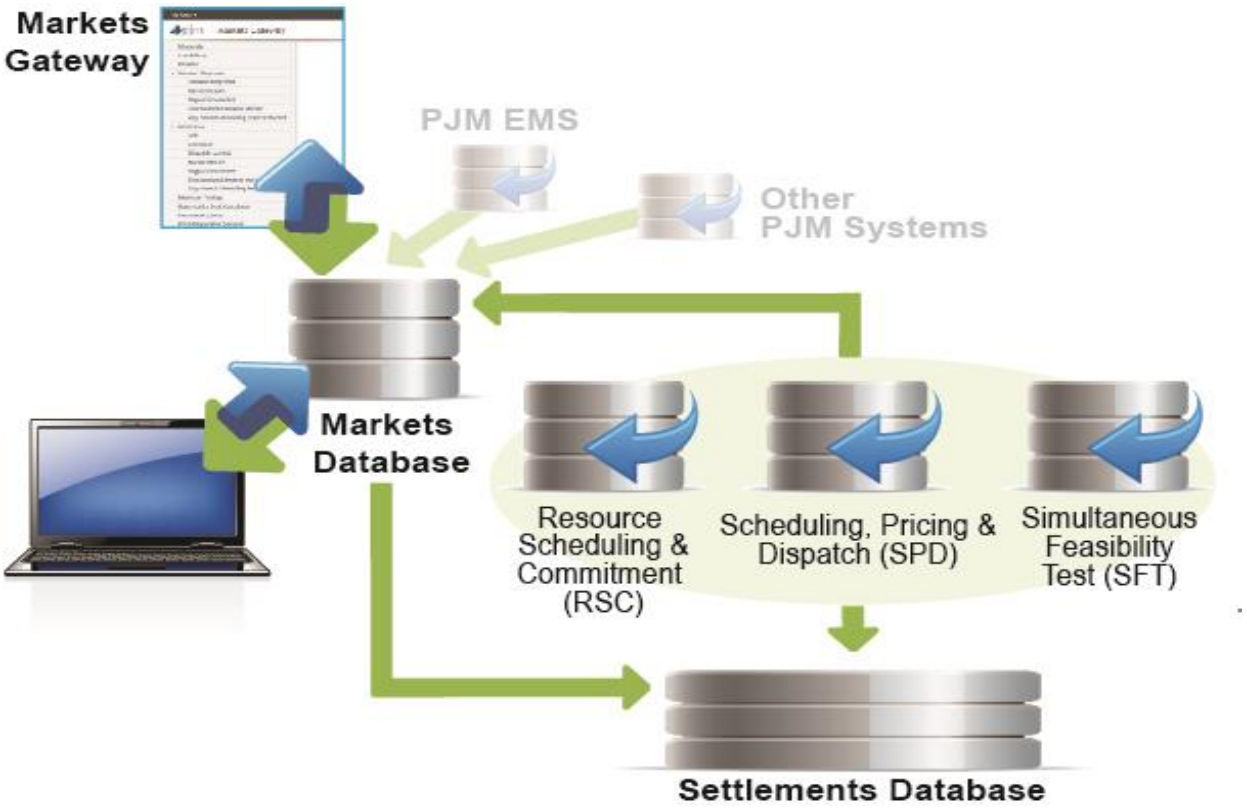
5.2.5 Hydro Calculator

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

5.2.6 PJM Day-ahead Energy Market Technical Software

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

- **Resource Scheduling & Commitment (RSC) –** Performs security-constrained resource commitment based on generation offers, Demand resource offers demand bids, Day-ahead Scheduling Reserve Offers, Increment Offers, Decrement bids and transaction schedules submitted by participants and based on PJM RTO reliability requirements. RSC enforces physical resource 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 resource commitment schedule for the next ~~seven days~~48 hours and it utilizes a Mixed Integer linear programming solver to create an initial resource 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 resource generation MW levels, LMPs and Day-A~~a~~head Scheduling Reserve Clearing Prices 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.
- **Simultaneous Feasibility Test (SFT) –** SFT performs AC contingency analysis using a contingency list from PJM EMS and creates generic constraints equations based on any violations that are detected. These generic constraints equations are then passed back to SPD for resolution. SFT ensures that the Day-A~~a~~head Market results are physically feasible considering PJM RTO security constraints and reliability requirements.



Settlement Subsystems

The Energy Market technical software develops the Day-Aahead Market results based on minimizing production cost of energy and reserve to meet the Demand bids and Decrement bids that are submitted into the Day-Aahead Market while respecting the PJM RTO security constraints and reliability requirements that are necessary for the reliable operation of the PJM RTO.

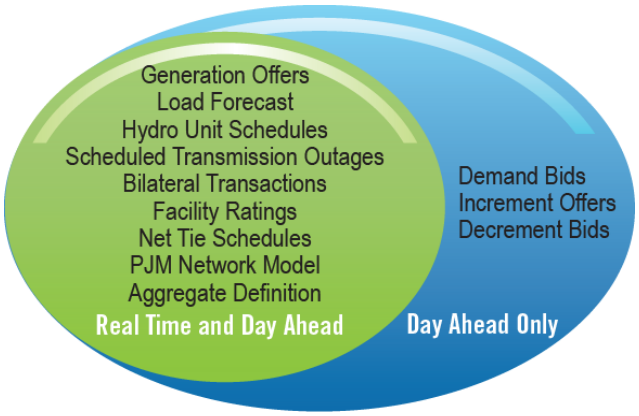
Subsequent to the close of the generation Re-bidding Period at 1415, the RSC is the primary tool used to determine any change in steam resource commitment status based on minimizing the additional startup costs and costs to operate steam resources at economic minimum in order to provide sufficient operating reserves to satisfy the PJM Load Forecast (if greater thant cleared total demand in the Day-Aahead Market) and adjusted Day-Aahead Scheduling Reserve (Operating Reserves) requirements. The purpose of this second phase of resource commitment, known as the Reliability Assessment and Commitment (RAC) run, 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 resources are included in the scheduling process and are scheduled in the Day-Aahead Market. However, the decisions concerning actual operation of pool-scheduled CT resources during the operating day are not made until the current operating hour in real-time dispatch.

Calculation of Day-Ahead Prices.

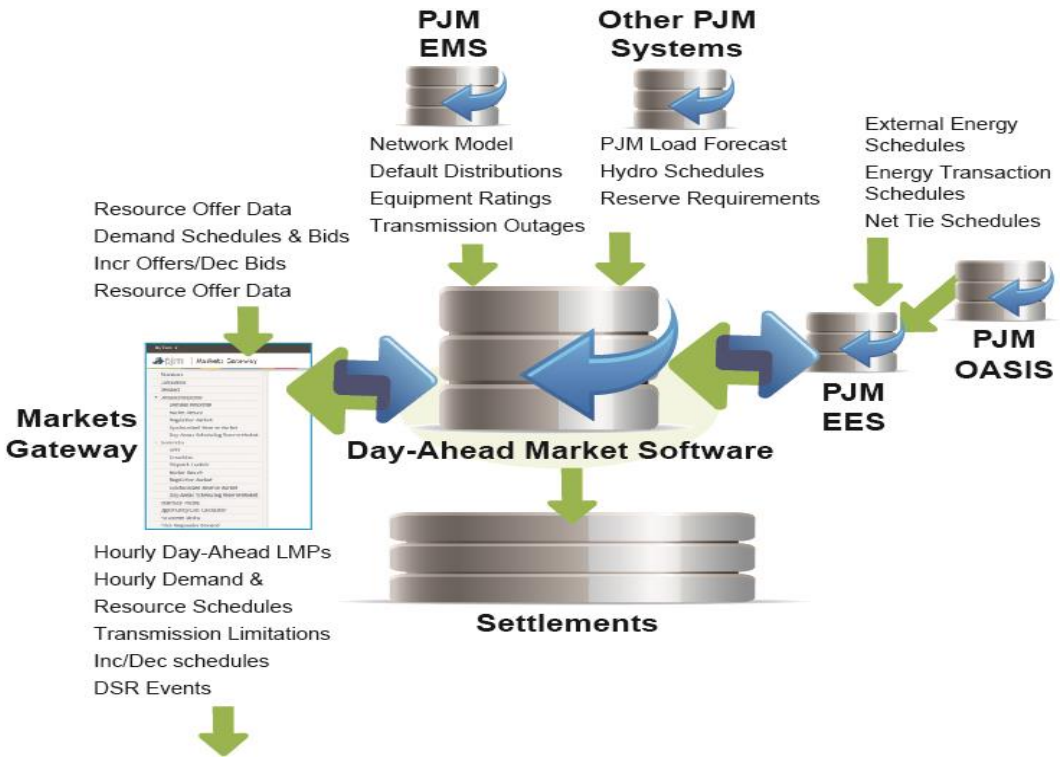
PJM's Day-Ahead energy market uses security constrained economic dispatch optimization software to determine the least-cost means of procuring supply to meet demand and meet day-ahead scheduling reserve requirements in the PJM Region. The Day-Ahead market includes offers for energy and reserves from generation, bids from fixed and price-sensitive load, Increment Offers, Decrement Bids, Up-to Congestion Transactions, offers for demand reductions, and interchange transactions. Day-Ahead Locational Marginal Prices (LMPs) and reserve Market Clearing Prices (MCPs) are calculated for each hour, using the set of programs described in Section 5.2.6.

In performing this calculation, the Day-Ahead market shall calculate the cost of serving an increment of load at each bus from each eligible offer as the sum of the following components of Locational Marginal Price: (1) System Energy Price, which is the price at which the Market Seller has offered to supply an additional increment of energy from a resource, increment offers, import transactions, and/or has offered to decrease consumption by an Economic Load Response Participant resource, Decrement Bid, export transaction or price sensitive demand bid (2) Congestion Price, which is the effect on transmission congestion costs (whether positive or negative) associated with increasing the output of a generation resource or decreasing consumption by a Demand Resource, based on the effect of increased generation from the resource on transmission line loadings, and (3) Loss Price, which is the effect on transmission loss costs (whether positive or negative) associated with increasing the output of a generation resource or decreasing the consumption by a Demand Resource based on the effect of increased generation from or consumption by the resource on transmission line losses. The offers that can serve an increment of load at a bus at the lowest cost, calculated in this manner, shall determine the Day-Ahead Price at that bus for each hour. These LMPs and MCPs shall be the basis for purchases and sales of energy and transmission congestion charges resulting from the Day-Ahead Energy Market.

Download Data from Markets Database



Download Data from Markets Database



Energy Market Data Flow