

### 1.11 Real-time Dispatch.

The following procedures and principles shall govern the dispatch of the resources available to the Office of the Interconnection.

The Office of the Interconnection shall determine the least cost security-constrained economic dispatch and send Dispatch Targets to each Resource to Market Participants based on Offers in the Real-time Energy and Ancillary Service Markets, ~~which is the least costly means of serving load and meeting reserve requirements at different locations in the PJM Region is based on actual forecasted operating conditions existing on the power grid (including transmission constraints on external coordinated flowgates to the extent provided by Operating Agreement, Schedule 1, section 1.7.6) as described in the PJM Manuals and on the prices offers for energy and ancillary services at which Market Sellers have offered entered as described by the OA, Schedule 1, Section 1.10 and Section 2.4 to supply energy and on offers by Economic Load Response Participants to reduce demand that qualify to set Locational Marginal Prices in the PJM Interchange Energy Market.~~

- (a) ~~To determine actual operating conditions on the power grid in the PJM Region (including transmission constraints on external coordinated flowgates to the extent provided by Section 1.7.6), the Office of the Interconnection shall use a computer model of the interconnected grid that uses available metered inputs regarding generator output, loads, and power flows to model remaining flows and conditions, producing a consistent representation of power flows on the network as an input into the real-time security constrained economic dispatch. The computer model employed for this purpose, referred to as the State Estimator program, is a standard industry tool and is described in Operating Agreement, Schedule 1, Section 2.3.1.11A below. The State Estimator solution used by the real-time security constrained economic dispatch will be used to obtain information regarding the output of generation supplying energy to the PJM Region, loads at buses in the PJM Region, transmission losses, and power flows on binding transmission constraints for use in the calculation of Locational Marginal Prices.~~  
~~Additional information used in the calculation, including Dispatch Rates and real time schedules for external transactions between PJM and other Control Areas and dispatch and pricing information from entities with whom PJM has executed a joint operating agreement, will be obtained from the Office of the Interconnection's dispatchers.~~
- (b) The Office of the Interconnection shall use its real-time security-constrained economic dispatch software program to determine if the Office of the Interconnection is experiencing a *shortage of the Minimum 30-minute Reserve Requirement, the Minimum Primary Reserve Requirement and/or the Minimum Synchronized Reserve Requirement* as further described in the PJM Manuals.
- (c) The Office of the Interconnection shall execute real-time security constrained economic dispatch for each five (5) minute target time, unless the Office of the Interconnection is unable to generate real-time security constrained economic dispatch solutions due to operational or technical issues, including but not limited to those described in the PJM Manuals.. Each execution of the real-time security constrained

**Formatted:** List Paragraph, Numbered + Level: 1 + Numbering Style: a, b, c, ... + Start at: 1 + Alignment: Left + Aligned at: 0.25" + Indent at: 0.75"

**Commented [A1]:** Moved from 2.2d(actual changes are only "security constrained economic dispatch" in first sentence)

economic dispatch shall result in several solutions, taking into consideration different operational scenarios.

- (d) The Office of the Interconnection shall approve the applicable real-time security constrained economic dispatch solution for each five (5) minute target time, unless the Office of the Interconnection is unable to approve a real-time security constrained economic dispatch solution for the applicable target time due to a failure of the real-time security constrained economic dispatch program or other operational reasons. In such situations, either the most recently approved real-time security constrained economic dispatch solution shall persist, or the Office of the Interconnection shall manually dispatch the system.

#### **1.11A Determination of System Conditions Using the State Estimator.**

Power system operations, including, but not limited to, the determination of the least costly means of serving load and meeting reserve requirements, depend upon the availability of a complete and consistent representation of generator outputs, loads, and power flows on the network. In calculating Locational Marginal Prices performing the security constrained economic dispatch of the system, the Office of the Interconnection shall obtain a complete and consistent description of conditions on the electric network in the PJM Region by using the most recent power flow solution produced by the State Estimator program, and utilized in the PJM dispatch algorithm, which The State Estimator program is also used by the Office of the Interconnection for other functions within power system operations. The State Estimator is a standard industry tool that produces a power flow model based on available real-time metering information, information regarding the current status of lines, generators, transformers, and other equipment, bus load distribution factors, and a representation of the electric network, to provide a complete description of system conditions, including conditions at buses for which real-time information is unavailable. The Office of the Interconnection shall obtain the latest State Estimator solution at least every five minutes each time a new security constrained economic dispatch is executed, which shall provide the megawatt output of generators and the loads at buses in the PJM Region, transmission line losses, and actual flows or loadings on constrained transmission facilities as defined in the PJM Manuals.

##### **1.11.1 Resource Output.**

The Office of the Interconnection shall have the authority to direct any Market Seller to adjust the output of any pool-scheduled or self-scheduled resource increment within the operating characteristics specified in the Market Seller's offer. The Office of the Interconnection may cancel its selection of, or otherwise release, pool-scheduled resources, subject to an obligation to pay any applicable start-up, no-load or cancellation fees. The Office of the Interconnection shall adjust the output of pool-scheduled or self-scheduled resource increments as necessary: (a) to maintain reliability, and subject to that constraint, to minimize the cost of supplying the energy, reserves, and other services required by the Market Buyers and the operation of the PJM Region; (b) to balance load and generation, maintain scheduled tie flows, and provide frequency support within the PJM Region; and (c) to minimize unscheduled interchange not frequency related between the PJM Region and other Control Areas.

##### **1.11.2 Operating Basis.**

In carrying out the foregoing objectives, the Office of the Interconnection shall conduct the operation of the PJM Region in accordance with the PJM Manuals, and shall: (i) utilize available generating reserves and obtain required replacements; and (ii) monitor the availability of adequate reserves.

### **1.11.3 Pool-dispatched Resources.**

As part of the real-time security constrained economic dispatch calculation, the Office of the Interconnection shall use submitted ramp rates to calculate the next dispatch point.

As part of the calculation, the Office of the Interconnection shall estimate the initial state of each generation resource based on its previous dispatch signal and the most recent state estimator output. In the event the Office of the Interconnection is unable to approve a real-time security constrained economic dispatch solution for a period of time, due to a failure of the real-time security constrained economic dispatch program or other operational reasons, the most recent state estimator shall be used as the initial state. This evaluation methodology is calculated for all online dispatchable resources for each market solution in accordance with the PJM Manuals.

(a) The Office of the Interconnection shall implement the dispatch of energy from pool-scheduled resources with limited energy by direct request, by following the Day-ahead Market clearing, or by following the direct request of the Market Seller, subject to the Office of the Interconnection's determination of actions necessary to maintain reliability.

~~In implementing mandatory or economic use of limited energy resources, the Office of the Interconnection shall use its best efforts to select the most economic hours of operation for limited energy resources, in order to make optimal use of such resources consistent with the dynamic load following requirements of the PJM Region and the availability of other resources to the Office of the Interconnection.~~

(b) The Office of the Interconnection shall implement the dispatch of energy from other pool-dispatched resource increments, including generation increments from Capacity Resources the remaining increments of which are self-scheduled, by sending appropriate signals and instructions to the entity controlling such resources, in accordance with the PJM Manuals. Each Market Seller shall ensure that the entity controlling a pool-dispatched resource offered or made available by that Market Seller complies with the energy dispatch signals and instructions transmitted by the Office of the Interconnection upon receipt.

### **1.11.3A Maximum Generation Emergency.**

If the Office of the Interconnection declares a Maximum Generation Emergency, all deliveries to load that is served by Point-to-Point Transmission Service outside the PJM Region from Generation Capacity Resources committed to service of PJM loads under the Reliability Pricing Model or Fixed Resource Requirement Alternative may be interrupted in order to serve load in the PJM Region.

## **2.1 Introduction.**

The Office of the Interconnection shall calculate the price of energy at the load buses and generation buses in the PJM Region and at the Interface Pricing Points between adjacent Control Areas and the PJM Region on the basis of Locational Marginal Prices. Locational Marginal Prices determined in accordance with this Section shall be calculated on a day-ahead basis for each hour of the Day-ahead Energy Market, and every five minutes during the Operating Day for the Real-time Energy Market.

## 2.2 General.

~~The Office of the Interconnection shall determine the least cost security constrained economic dispatch, which is the least costly means of serving load and meeting reserve requirements at different locations in the PJM Region based on actual operating conditions existing on the power grid (including transmission constraints on external coordinated flowgates to the extent provided by Operating Agreement, Schedule 1, section 1.7.6) and on the prices at which Market Sellers have offered to supply energy and offers by Economic Load Response Participants to reduce demand that qualify to set Locational Marginal Prices in the PJM Interchange Energy Market. The Office of Interconnection shall calculate~~ Locational Marginal Prices for the generation and load buses in the PJM Region, including interconnections with other Control Areas, ~~will be calculated~~ based on the actual economic dispatch and the prices of energy and demand reduction offers, except that generation resources will be dispatched in economic merit order but limited to \$2,000/megawatt-hour for purposes of calculating Locational Marginal Prices. The process for the determination of Locational Marginal Prices ~~shall be as follows: in the Day-ahead Energy Market is described in Section 2.6 and the process for the determination of Locational Marginal Prices in the Real-time Energy Market is described in Section 2.5.~~

(a) ~~To determine actual operating conditions on the power grid in the PJM Region, the Office of the Interconnection shall use a computer model of the interconnected grid that uses available metered inputs regarding generator output, loads, and power flows to model remaining flows and conditions, producing a consistent representation of power flows on the network. The computer model employed for this purpose, referred to as the State Estimator program, is a standard industry tool and is described in Operating Agreement, Schedule 1, section 2.3. It will be used to obtain information regarding the output of generation supplying energy to the PJM Region, loads at buses in the PJM Region, transmission losses, and power flows on binding transmission constraints for use in the calculation of Locational Marginal Prices. Additional information used in the calculation, including Dispatch Rates and real time schedules for external transactions between PJM and other Control Areas and dispatch and pricing information from entities with whom PJM has executed a joint operating agreement, will be obtained from the Office of the Interconnection's dispatchers.~~

(b) ~~Using the prices at which energy is offered by Market Sellers and demand reductions are offered by Economic Load Response Participants, Pre-Emergency Load Response Program participants and Emergency Load Response Program participants to the PJM Interchange Energy Market, the Office of the Interconnection shall determine the offers of energy and demand reductions that will be considered in the calculation of Locational Marginal Prices. As described in Operating Agreement, Schedule 1, section 2.4, every qualified offer for demand reduction and~~

Commented [A2]: Moved to Section 1.11 (a)

Commented [A3]: Moved to Section 2.5 and 2.6

~~of energy by a Market Seller from resources that are dispatched by the Office of the Interconnection will be utilized in the calculation of Locational Marginal Prices, including, without limitation, qualified offers from Economic Load Response Participants in either the Day-ahead or Real-time Energy Markets or from participants in either the Emergency Load Response Program or Pre-Emergency Load Response Program in the Real-time Energy Market.~~

~~(e) Based on the system conditions on the PJM power grid, determined as described in (a), and the eligible energy and demand reduction offers, determined as described in (b), the Office of the Interconnection shall determine the least costly means of obtaining energy to serve the next increment of load at each bus in the PJM Region, in the manner described in *Operating Agreement, Schedule 1*, section 2.5. The result of that calculation shall be a set of Locational Marginal Prices based on the system conditions at the time.~~

Commented [A4]: Covered in 2.5

~~(d) (i) The Office of the Interconnection shall use its day-ahead market clearing software to forecast if the Office of the Interconnection will experience a shortage of the Minimum 30-minute Reserve Requirement, the Minimum Primary Reserve Requirement and/or the Minimum Synchronized Reserve Requirement as further described in the PJM Manuals. If the day-ahead market clearing software forecasts that a shortage of any of the minimum reserve requirement(s) exists, the Office of the Interconnection shall implement shortage pricing through the inclusion of the applicable Reserve Penalty Factor(s) in the Day-ahead Locational Marginal Prices. Shortage pricing shall exist until the day-ahead market clearing software is able to meet the specified minimum reserve requirements.~~

~~(ii) The Office of the Interconnection shall use its real-time security-constrained economic dispatch software program to determine if the Office of the Interconnection is experiencing a shortage of the Minimum 30-minute Reserve Requirement, the Minimum Primary Reserve Requirement and/or the Minimum Synchronized Reserve Requirement as further described in the PJM Manuals. If the real-time security-constrained economic dispatch software program determines that a shortage of any of the minimum reserve requirement(s) exists, the Office of the Interconnection shall implement shortage pricing through the inclusion of the applicable Reserve Penalty Factor(s) in the Real-time Locational Marginal Price software program. Shortage pricing shall exist until the real-time security-constrained economic dispatch solution is able to meet the specified minimum reserve requirements and there is no Voltage Reduction Action or Manual Load Dump Action in effect. If a shortage of the Minimum 30-minute Reserve Requirement, the Minimum Primary Reserve Requirement and/or the Minimum Synchronized Reserve Requirement exists and cannot be accurately forecasted by the Office of the Interconnection due to a technical problem with or malfunction of the security-constrained economic dispatch software program, including but not limited to program failures or data input failures, the Office of the Interconnection will utilize the best available alternate data sources to determine if a Reserve Zone or Reserve Sub-zone is experiencing a shortage of the applicable minimum reserve requirement.~~

Commented [A5]: Moved to section 1.11(b)

Commented [A6]: Moved to 2.5

### ~~2.3 Section Retired~~ Determination of System Conditions Using the State Estimator

Commented [A7]: Moved to Section 1.11.1A

~~Power system operations, including, but not limited to, the determination of the least costly means of serving load and meeting reserve requirements, depend upon the availability of a complete and consistent representation of generator output, loads, and power flows on the network. In calculating Locational Marginal Prices, the Office of the Interconnection shall obtain a complete and consistent description of conditions on the electric network in the PJM Region by using the most recent power flow solution produced by the State Estimator program and utilized in the PJM dispatch algorithm, which State Estimator program is also used by the Office of the Interconnection for other functions within power system operations. The State Estimator is a standard industry tool that produces a power flow model based on available real-time metering information, information regarding the current status of lines, generators, transformers, and other equipment, bus load distribution factors, and a representation of the electric network, to provide a complete description of system conditions, including conditions at buses for which real-time information is unavailable. The Office of the Interconnection shall obtain a State Estimator solution at least every five minutes, which shall provide the megawatt output of generators and the loads at buses in the PJM Region, transmission line losses, and actual flows or loadings on constrained transmission facilities. External transactions between PJM and other Control Areas shall be included in the Locational Marginal Price calculation on the basis of the real-time transaction schedules implemented by the Office of the Interconnection's dispatcher.~~

#### **2.4 Determination of Energy Offers Used in Calculating Real-time Prices.**

(a) During the Operating Day, real-time Locational Marginal Prices derived in accordance with this section shall be determined every five minutes.

(b) To determine the energy offers submitted to the PJM Interchange Energy Market that shall be used during the Operating Day to calculate the Real-time Prices, the Office of the Interconnection shall determine the applicable marginal energy offer [based on the latest approved real-time security constrained economic dispatch solution available for the target time](#) ~~for~~ of the resources being dispatched by the Office of the Interconnection. Offers for resources dispatched by the Office of the Interconnection in excess of \$2,000/megawatt-hour will be capped at \$2,000/megawatt-hour for purposes of calculating Real-time Prices.

(c) In determining whether a resource satisfies the condition described in (b), the Office of the Interconnection will determine the applicable marginal energy offer [based on the latest approved real-time security constrained economic dispatch solution available for the target time for as defined in the PJM Manuals, by comparing the requested megawatt output of the resource with the Market Seller's offer price curve.](#) The applicable marginal energy offer used in the calculation of Real-time Prices shall not exceed \$2,000/megawatt-hour. ~~Units that must be run for local area protection shall not be considered in the calculation of Real-time Prices.~~

#### **2.5 Calculation of Real-time Prices.**

(a) The Office of the Interconnection shall determine *Locational Marginal Prices based on the least costly means of obtaining energy to serve the next increment of load and meet reserve*

requirements (taking account of any applicable and available load reductions indicated on PRD Curves properly submitted by any PRD Provider) at each bus in the PJM Region represented in the network model and each Interface Pricing Point between PJM and an adjacent Control Area, based on the operating-forecasted system conditions and the submitted energy offers as described in Operating Agreement, Schedule 1, section 2.4. The process for the determination of Real-time Locational Marginal Prices occurs in the Real-time Marginal Price software program, which utilizes the input data from the latest approved real-time security constrained economic dispatch solution with a target time at the end of the current five minute interval. The process for the determination of Real-time Prices occurs in the Real-time Price software program, and is known as the pricing run for the Real-time Energy Market. The Real-time Price software program uses the input data from a reference real-time security constrained economic dispatch case as described in the PJM Manuals and performs the same optimization as the real-time security constrained economic dispatch program but additionally applies Integer Relaxation to Eligible Fast-Start Resources. The real-time security constrained economic dispatch program, which is considered the dispatch run for the Real-time Energy Market, performs a real-time joint optimization of energy and reserves, given operating conditions, a set of energy offers, a set of reserve offers, a set of Operating Reserve Demand Curves, and any monitored transmission constraints that may exist.

~~(b) To determine operating conditions on the power grid in the PJM Region (including transmission constraints on external coordinated flowgates to the extent provided by Operating Agreement, Schedule 1, section 1.7.6), the Office of the Interconnection shall use a computer model of the interconnected grid that uses available metered inputs regarding generator output, loads, and power flows to model remaining flows and conditions, producing a consistent representation of power flows on the network as an input into the real time security constrained economic dispatch. The computer model employed for this purpose, referred to as the State Estimator program, is a standard industry tool and is described in Operating Agreement, Schedule 1, section 2.3. The State Estimator solution used by the real time security constrained economic dispatch will be used to obtain information regarding the output of generation supplying energy to the PJM Region, loads at buses in the PJM Region, transmission losses, and power flows on binding transmission constraints. Additional information used in the calculation, including Dispatch Rates and real time schedules for external transactions between PJM and other Control Areas and dispatch and pricing information from entities with whom PJM has executed a joint operating agreement, will be obtained from the Office of the Interconnection's dispatchers.~~

**Commented [A8]:** This language is covered in 1.11.1A.

(be) Using the prices at which energy is offered by Market Sellers and demand reductions are offered by Economic Load Response Participants, Pre-Emergency Load Response participants and Emergency Load Response participants to the PJM Interchange Energy Market, the Office of the Interconnection shall determine the offers of energy and demand reductions that will be considered in the calculation of Locational Marginal Prices. As described in Operating Agreement, Schedule 1, section 2.4, every qualified offer for demand reduction and of energy by a Market Seller from resources that are dispatched by the Office of the Interconnection will be utilized in the calculation of Locational Marginal Prices, including, without limitation, qualified Real-time Energy Market offers from Economic Load Response Participants, Emergency Load Response and Pre-Emergency Load Response.

**Commented [A9]:** This was moved as part of the FS Filing from section 2.2 to 2.5

(c) In performing the Real-time Price calculation, the Office of the Interconnection shall calculate the cost of serving an increment of load at each bus from each resource associated with an eligible energy offer as described in Operating Agreement, Schedule 1, section 2.4 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 generation resource or decrease an increment of energy being consumed by an Economic Load Response Participant resource, (2) Congestion Price, which is the effect on transmission congestion costs (whether positive or negative), including Transmission Constraint Penalty Factors, associated with increasing the output of a generation resource or decreasing the consumption by an Economic Load Response Participant 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 an Economic Load Response Participant resource based on the effect of increased generation from or consumption by the resource on transmission losses. The Real-time Prices at a bus shall be determined through the joint optimization program based on the lowest marginal cost to serve the next increment of load at the bus taking into account resource constraints, transmission constraints, marginal loss impact, and the applicable Operating Reserve Demand Curves. When the marginal energy megawatts is provided by converting ~~a~~-megawatts of reserves into ~~a~~-megawatts of energy, the resulting Locational Marginal Price takes into account the opportunity cost of that exchange.

(d) During the Operating Day, the calculation set forth in Operating Agreement, Schedule 1, section 2.5 shall be performed every five minutes, using the Office of the Interconnection's Real-time Price software program, producing the Real-time Prices for the current five minute interval based on forecasted system conditions and the latest approved PJM security-constrained economic dispatch solution with a target time at the end of the current five minute interval. If no security-constrained economic dispatch solution was approved for the target time at the end of the current five minute interval, the Locational Marginal Price program will use the most recently approved security-constrained economic dispatch solution with a target time prior to the end of the Locational Marginal Price program five minute interval. If a technical problem with or malfunction of the security-constrained economic dispatch or Locational Marginal Price software programs exists, including but not limited to program failures or data input failures, the Office of the Interconnection will utilize the best available RT SCED solution to calculate LMPs.

### **2.5.1 Declaration of Shortage Pricing**

(a) ~~The Office of the Interconnection shall use its Real-time Price software program, to determine if the Office of the Interconnection is experiencing a Primary Reserve shortage and/or a Synchronized Reserve shortage for the purposes of declaring shortage pricing as further described in the PJM Manuals. If the latest approved security constrained economic dispatch solution for the target time at the end of the current five minute interval determines all reserve requirements in every modeled Reserve Zone and Reserve Subzone can be met at prices less than or equal to the applicable Reserve Penalty Factor for those Reserve Requirements, real-time Marginal Prices shall be calculated as described in Section 2.5(a) above and no Reserve Penalty Factors shall apply beyond the normal lost opportunity costs incurred by the reserve requirements. When the latest approved real-time security constrained economic dispatch solution determines~~



the reserve requirement cannot be met at a price less than or equal to the applicable Reserve Penalty Factor(s) associated with a Reserve Zone or Subzone, the Real-time Locational Marginal Price shall be calculated by incorporating the applicable Reserve Penalty Factor(s) for the deficient reserve requirement as the lost opportunity cost impact of the deficient reserve requirement, and the components of the Locational Marginal Prices referenced in Section 2.5 (a) above shall be calculated as described below.

(b) Shortage pricing shall exist until the latest approved real-time security-constrained economic dispatch solution is able to meet the specified reserve requirements and there is no Voltage Reduction Action or Manual Load Dump Action in effect. If a Primary Reserve shortage and/or Synchronized Reserve shortage exists and cannot be accurately forecasted by the Office of the Interconnection due to a technical problem with or malfunction of the security-constrained economic dispatch software program, including but not limited to program failures or data input failures, the Office of the Interconnection will utilize the best available alternate data sources to determine if a Reserve Zone or Reserve Sub-zone is experiencing a Primary Reserve shortage and/or a Synchronized Reserve shortage. Shortage pricing will be terminated in a Reserve Zone or Reserve Sub-Zone when demand and reserve requirements can be fully satisfied with generation and Economic Load Response Participant resources and any Voltage Reduction Action and/or Manual Load Dump Action taken for that Reserve Zone or Reserve Sub-Zone has also been terminated.

*(c) If a Primary Reserve shortage and/or Synchronized Reserve shortage exists and cannot be accurately forecasted by the Office of the Interconnection due to a technical problem, including but not limited to failures of data input into the Real-time Price software program, the Office of the Interconnection will utilize the best available alternate data sources to determine if a Reserve Zone or Reserve Sub-zone is experiencing a Primary Reserve shortage and/or a Synchronized Reserve shortage.*

*(d) The Office of the Interconnection shall issue day-ahead alerts to PJM Members of the possible need to use emergency procedures during the following Operating Day. Such emergency procedures may be required to alleviate real-time emergency conditions such as a transmission emergency or potential reserve shortage. The alerts issued by the Office of the Interconnection may include, but are not limited to, the Maximum Generation Emergency Alert, Primary Reserve Alert and/or Voltage Reduction Alert. These alerts shall be issued to keep all affected system personnel informed of the forecasted status of the PJM bulk power system. The Office of the Interconnection shall notify PJM Members of all alerts and the cancellation thereof via the methods described in the PJM Manuals. The alerts shall be issued as soon as practicable to allow PJM Members sufficient time to prepare for such operating conditions. The day-ahead alerts issued by the Office of the Interconnection are for informational purposes only and by themselves will not impact price calculation during the Operating Day.*

*(e) The Office of the Interconnection shall issue a warning of impending operating reserve shortage and other emergency conditions in real-time to inform members of actual capacity*

shortages or contingencies that may jeopardize the reliable operation of the PJM bulk power system. Such warnings will generally precede any associated action taken to address the shortage conditions. The Office of the Interconnection shall notify PJM Members of the issuance and cancellation of emergency procedures via the methods described in the PJM Manuals. The warnings that the Office of the Interconnection may issue include, but are not limited to, the Primary Reserve Warning, Voltage Reduction Warning, and Manual Load Dump Warning.

The purpose of the Primary Reserve Warning is to warn members that the available Primary Reserve may be less than the Minimum Primary Reserve Requirement. If the Primary Reserve shortage condition was determined as described above, the applicable Reserve Penalty Factor is incorporated into the Synchronized Reserve Market Clearing Price, Non-Synchronized Reserve Market Clearing Price and Locational Marginal Price as applicable.

The purpose of the Voltage Reduction Warning is to warn PJM Members that the available Synchronized Reserve may be less than the Minimum Synchronized Reserve Requirement and that a voltage reduction may be required. Following the Voltage Reduction Warning, the Office of the Interconnection may issue a Voltage Reduction Action during which it directs PJM Members to initiate a voltage reduction. If the Office of the Interconnection issues a Voltage Reduction Action for the Reserve Zone or Reserve Sub-Zone the Reserve Penalty Factors for the Minimum 30-minute Reserve Requirement, the Minimum Primary Reserve Requirement and the Minimum Synchronized Reserve Requirement are incorporated in the calculation of the Synchronized Reserve Market Clearing Price, Non-Synchronized Reserve Market Clearing Price, Secondary Reserve Market Clearing Price, and Locational Marginal Price as applicable. The Reserve Penalty Factors for the Minimum 30-minute Reserve Requirement, the Minimum Primary Reserve Requirement and the Minimum Synchronized Reserve Requirement will continue to be used in the Synchronized Reserve Market Clearing Price, Non-Synchronized Reserve Market Clearing Price, Secondary Reserve Market Clearing Price, and Locational Marginal Price calculation, as applicable, until the Voltage Reduction Action has been terminated.

The purpose of the Manual Load Dump Warning is to warn members that dumping load may be necessary to maintain reliability. Following the Manual Load Dump Warning, the Office of the Interconnection may commence a Manual Load Dump Action during which it directs PJM Members to initiate a manual load dump pursuant to the procedures described in the PJM Manuals. If the Office of the Interconnection issues a Manual Load Dump Action for the Reserve Zone or Reserve Sub-Zone the Reserve Penalty Factors for the Minimum 30-minute Reserve Requirement, the Minimum Primary Reserve Requirement and the Minimum Synchronized Reserve Requirement are incorporated in the calculation of the Synchronized Reserve Market Clearing Price, Non-Synchronized Reserve Market Clearing Price, Secondary Reserve Market Clearing Price, and Locational Marginal Price as applicable. The Reserve Penalty Factors for the Minimum 30-minute Reserve Requirement, the Minimum Primary Reserve Requirement and the Minimum Synchronized Reserve Requirement will continue to be used in the Synchronized Reserve Market Clearing Price, Non-Synchronized Reserve Market Clearing Price, Secondary Reserve Market Clearing Price, and Locational Marginal Price calculation, as applicable, until the Manual Load Dump Action has been terminated.

~~Shortage pricing will be terminated in a Reserve Zone or Reserve Sub-Zone when demand and reserve requirements can be fully satisfied with generation and Economic Load Response~~

~~Participant resources and any Voltage Reduction Action and/or Manual Load Dump Action taken for that Reserve Zone or Reserve Sub Zone has also been terminated.~~

## 2.6 Calculation of Day-ahead Prices.

(a) ~~For the Day-ahead Energy Market, day-ahead Locational Marginal Prices shall be determined on the basis of the least-costly means of obtaining energy to serve the next increment of load and meet the day-ahead scheduling reserve requirements in the PJM Region, based on, security-constrained dispatch, model flows and system conditions resulting from the load specifications (including PRD Curves properly submitted by Load Serving Entities for the Price Responsive Demand loads that they serve), offers for generation, dispatchable load, Increment Offers, Decrement Bids, Up-to Congestion Transactions offers for demand reductions, Day-ahead Scheduling Reserve offers, and bilateral interchange transactions submitted to the Office of the Interconnection and scheduled in the Day-ahead Energy Market. Such prices shall be determined in accordance with the provisions of this section applicable to the Day-ahead Energy Market and shall be the basis for purchases and sales of energy and Transmission Congestion Charges resulting from the Day-ahead Energy Market. This calculation shall be made for each hour in the Day-ahead Energy Market by applying a linear optimization method to minimize energy and reserve costs, given scheduled system conditions, scheduled transmission outages, any transmission limitations that may exist, and a set of Operating Reserve Demand Curves. This calculation shall be made by applying a joint optimization of energy and reserves, given scheduled system conditions, a set of energy offers, a set of reserve offers, a set of Operating Reserve Demand Curves, and any binding transmission constraints that may exist.~~

The Day-ahead Energy Market uses a multistage solution. The first stage, Resource Scheduling and Commitment (RSC) solves for an initial unit commitment with a limited set of constraints. The second stage solves with a more complete set of constraints/contingencies and performs the Three Pivotal Supplier test. The third stage, Scheduling Pricing and Dispatch, optimizes the dispatch and calculates final Day Ahead Energy Market prices.

In performing this calculation, the Office of the Interconnection shall calculate the cost of serving an increment of load at each bus from each resource associated with an eligible energy 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, interchange transactions, and/or has offered to decrease consumption by an Economic Load Response Participant resource, Decrement Bid, 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 an *Economic Load Response Participant 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

an Economic Load Response Participant resource based on the effect of increased generation from or consumption by the resource on transmission line losses.

(b) The day-ahead Locational Marginal Prices at a bus shall be determined through the joint optimization program based on the lowest marginal cost to serve the next increment of load at the bus taking into account resource constraints, transmission constraints, marginal loss impact, and the impact of the applicable Operating Reserve Demand Curves. When the marginal energy megawatts is provided by converting a megawatts of reserves into a megawatts of energy, the resulting Locational Marginal Price takes into account the opportunity cost of that exchange.

### 3.2.3 Operating Reserves.

(o) Dispatchable pool-scheduled generation resources and dispatchable self-scheduled generation resources that follow dispatch shall not be assessed balancing Operating Reserve deviations. Pool-scheduled generation resources and dispatchable self-scheduled generation resources that do not follow dispatch shall be assessed balancing Operating Reserve deviations in accordance with the calculations described below and in the PJM Manuals.

The Office of the Interconnection shall calculate a ramp-limited desired MW value for generation resources where the economic minimum and economic maximum are at least as far apart in real-time as they are in day-ahead according to the following parameters:

- (i) real-time economic minimum  $\leq$  105% of day-ahead economic minimum or day-ahead economic minimum plus 5 MW, whichever is greater.
- (ii) real-time economic maximum  $\geq$  95% day-ahead economic maximum or day-ahead economic maximum minus 5 MW, whichever is lower.

The ramp-limited desired MW value for a generation resource shall be equal to:

$$Ramp\_Request_t = \frac{(Dispatchtarget_{t-1} - AOutput_{t-1})}{(LAtime_{t-1})}$$

$$RL\_Desired_t = AOutput_{t-1} + (Ramp\_Request_t * Case\_Eff\_time_{t-1})$$

Formatted: Centered

$$Ramp\_Request_t = \frac{(UDStarget_{t-1} - AOutput_{t-1})}{(UDSLAtime_{t-1})}$$

$$RL\_Desired_t = AOutput_{t-1} + (Ramp\_Request_t * Case\_Eff\_time_{t-1})$$

Commented [A10]: This equation below is replaced with the above diagram.

where:

1.  $UDStarget - Dispatchtarget = UDS\_basepoint - Dispatch\ Signal$  for the previous UDS-approved Dispatch case

2. AOutput = Unit's [output-achievable target MW](#) at case solution time [as defined in the PJM Manuals](#)
3. [UDSLA](#)time = [UDS-Dispatch](#) look ahead time
4. Case\_Eff\_time = Time between [base-point](#)[signal](#) changes
5. RL\_Desired = Ramp-limited desired MW

To determine if a generation resource is following dispatch the Office of the Interconnection shall determine the unit's MW off dispatch and % off dispatch by using the lesser of the difference between the actual output and the [UDS-dispatch signal Basepoint](#) or the actual output and ramp-limited desired MW value for each Real-time Settlement Interval. If the [UDS Basepoint](#)[dispatch signal](#) and the ramp-limited desired MW for the resource are unavailable, the Office of the Interconnection will determine the unit's MW off dispatch and % off dispatch by calculating the lesser of the difference between the actual output and the [UDS-dispatch](#) LMP Desired MW for each Real-time Settlement Interval.

A pool-scheduled or dispatchable self-scheduled resource is considered to be following dispatch if its actual output is between its ramp-limited desired MW value and UDS Basepoint, or if its % off dispatch is  $\leq 10$ , or its Real-time Settlement Interval MWh is within 5% of the Real-time Settlement Interval ramp-limited desired MW. A self-scheduled generator must also be dispatched above economic minimum. The degree of deviations for resources that are not following dispatch shall be determined for each Real-time Settlement Interval in accordance with the following provisions:

- A dispatchable self-scheduled resource that is not dispatched above economic minimum shall be assessed balancing Operating Reserve deviations according to the following formula: Real-time Settlement Interval MWh – Day-Ahead MWh.
- A resource that is dispatchable day-ahead but is Fixed Gen in real-time shall be assessed balancing Operating Reserve deviations according to the following formula: Real-time Settlement Interval MWh – UDS LMP Desired MW.
- Pool-scheduled generators that are not following dispatch shall be assessed balancing Operating Reserve deviations according to the following formula: Real-time Settlement Interval MWh – Ramp-Limited Desired MW.
- If a resource's real-time economic minimum is greater than its day-ahead economic minimum by 5% or 5 MW, whichever is greater, or its real-time economic maximum is less than its Day Ahead economic maximum by 5% or 5 MW, whichever is lower, and UDS LMP Desired MWh for the Real-time Settlement Interval is either below the real time economic minimum or above the real time economic maximum, then balancing Operating Reserve deviations for the resource shall be assessed according to the following formula: Real time Settlement Interval MWh – UDS LMP Desired MWh.
- If a resource is not following dispatch and its % Off Dispatch is  $\leq 20\%$ , balancing Operating Reserve deviations shall be assessed according to the following formula:

Real-time Settlement Interval MWh – Ramp-Limited Desired MW. If deviation value is within 5% of Ramp-Limited Desired MW, balancing Operating Reserve deviations shall not be assessed.

- If a resource is not following dispatch and its % off Dispatch is > 20%, balancing Operating Reserve deviations shall be assessed according to the following formula: Real-time Settlement Interval MWh – UDS LMP Desired MWh.
- If a resource is not following dispatch, and the resource has tripped, for the Real-time Settlement Interval the resource tripped and the Real-time Settlement Intervals it remains offline throughout its day-ahead schedule balancing Operating Reserve deviations shall be assessed according to the following formula: Real-time Settlement Interval MWh – Day-Ahead MWh.
- For resources that are not dispatchable in both the *Day-Ahead* and Real-time Energy Markets balancing Operating Reserve deviations shall be assessed according to the following formula: Real-time Settlement Interval MWh - Day-Ahead MWh.

If a resource has a sum of the absolute value of generator deviations for an hour that is less than 5 MWh, then the resource shall not be assessed balancing Operating Reserve deviations for that hour.