

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 forecasted operating conditions and the submitted energy offers as described in Operating Agreement, Schedule 1, section 2.4. The real-time 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 applicable reserve requirements. 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. 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 the latest approved real-time security constrained economic dispatch solution with a target time at the end of the current five-minute interval 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 corresponding to each reserve service~~Reserve Penalty Factors~~, and any monitored transmission constraints that may exist.

(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 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.

(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 Participanta Demand Resource; (2) Congestion Price, which is the effect on transmission congestion costs (whether positive or negative inclusive of Transmission Constraint Penalty Factors); ~~including Transmission Constraint Penalty Factors~~, associated with increasing

the output of a generation resource or decreasing the consumption by an Economic Load Response Participant-Demand-Resource, based on the effect of increased generation from the resource on transmission line loadings constraints, which may include the modeling of energy and/or reserves, as described in the PJM Manuals; 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 Demand 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 the applicable reserve requirements, unit resource constraints, transmission constraints, and marginal loss impact.

(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.

(e) The Office of the Interconnection shall use its Real-time Price software to calculate the cost of procuring an additional increment of Synchronized Reserve at each bus as the sum of the following components of the Synchronized Reserve Locational Clearing Price: (1) system Synchronized Reserve price, which is the price of supplying an additional increment of Synchronized Reserve in the system; and (2) Synchronized Reserve congestion price at the bus, which 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 an Economic Load Response Participant at that bus providing Synchronized Reserve, based on the effect of such a change on the applicable transmission constraints modeling energy and reserves that impact Synchronized Reserve, as described in the PJM Manuals.

(f) The Office of the Interconnection shall use its Real-time Price software to calculate the cost of procuring an additional increment of 10-minute Ramp and Uncertainty Reserve Up at each bus as the sum of the following components of the 10-minute Ramp and Uncertainty Reserve Up Locational Clearing Price: (1) system 10-minute Ramp and Uncertainty Reserve Up price, which is the price of supplying an additional increment of 10-minute Ramp and Uncertainty Reserve Up in the system; and (2) 10-minute Ramp and Uncertainty Reserve Up congestion price at the bus, which 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 an Economic Load Response Participant at that bus providing 10-minute Ramp and Uncertainty Reserve Up, based on the effect of such a change on the applicable transmission constraints modeling energy

and reserves that impact 10-minute Ramp and Uncertainty Reserve Up as described in the PJM Manuals.

(g) The Office of the Interconnection shall use its Real-time Price software to calculate the cost of procuring an additional increment of 10-minute Ramp and Uncertainty Reserve Down at each bus as the sum of the following components of the 10-minute Ramp and Uncertainty Reserve Down Locational Clearing Price: (1) system 10-minute Ramp and Uncertainty Reserve Down price, which is the price of supplying an additional increment of 10-minute Ramp and Uncertainty Reserve Down in the system; and (2) 10-minute Ramp and Uncertainty Reserve Down congestion price at the bus, which is the effect on transmission congestion costs (whether positive or negative) associated with decreasing the output of a generation resource or increasing the consumption by an Economic Load Response Participant at that bus, based on the effect of such a change on the applicable transmission constraints modeling energy and reserves that impact 10-minute Ramp and Uncertainty Reserve Down, as described in the PJM Manuals.

(h) The Office of the Interconnection shall use its Real-time Price software to calculate the cost of procuring an additional increment of 30-minute Ramp and Uncertainty Reserve at each bus as the sum of the following: (1) system 30-minute Ramp and Uncertainty Reserve price, which is the price of supplying an additional increment of 30-minute Ramp and Uncertainty Reserve in the system; and (2) 30-minute Reserve 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 the consumption by an Economic Load Response Participant at that bus, based on the effect of such a change on the applicable transmission constraints modeling energy and reserves that impact 30-minute Ramp and Uncertainty Reserve, as described in the PJM Manuals. The 30-minute Ramp and Uncertainty Reserve Locational Clearing Price for a given bus shall be the sum of the cost of supplying an additional increment of 30-minute Ramp and Uncertainty Reserve at the bus as described above and the system 30-minute Reserve price as discussed in Operating Agreement, Schedule 1, section 2.5(i).

(i) The Office of the Interconnection shall use its Real-time Price software to calculate the cost of procuring an additional increment of 30-minute Reserve at each bus as the sum of the following components of the Secondary Reserve Locational Clearing Price: (1) system 30-minute Reserve price, which is the price of supplying an additional increment of 30-minute Reserve in the system; and (2) 30-minute Reserve congestion price at the bus, which 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 an Economic Load Response Participant at that bus, based on the effect of such a change on the applicable transmission constraints modeling energy and reserves that impact 30-minute Reserve, as described in the PJM Manuals.

2.5.1 Prices During Emergency Actions ~~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 ~~30-minute Reserve shortage, 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 all reserve requirements in every modeled Reserve Zone and Reserve Sub-zone can be met at prices less than or equal to the~~

~~applicable Reserve Penalty Factor for those reserve requirements, Real-time Prices shall be calculated as described in Operating Agreement, Schedule 1, section 2.5 and no Reserve Penalty Factor(s) shall apply beyond the normal lost opportunity costs incurred by the reserve requirements. When the Real-time Price software determines that a 30-minute Reserve shortage, a Primary Reserve shortage and/or a Synchronized Reserve shortage exists, whereby 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 Reserve Sub-zone, the Office of Interconnection shall implement shortage pricing. During shortage pricing, the Real-time Prices 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 consistent with the determination of the clearing price for each reserve product, and the components of Locational Marginal Prices referenced in Operating Agreement, Schedule 1, section 2.5 above shall be calculated as described below. Shortage pricing shall exist until the Real-time Price software program is able to meet the specified reserve requirements and there is no Voltage Reduction Action or Manual Load Dump Action in effect.~~

(b) 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 ~~at the~~ Reserve Zone ~~or Reserve Sub-zone~~ is experiencing a ~~Primary Reserve shortage and/or a~~ Synchronized Reserve shortage.

(c) 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 Emergency Generation 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.

(d) 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 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 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, the system Synchronized Reserve price referenced in Operating Agreement, Schedule 1, section 2.5(e) shall be equal to or Reserve Sub-Zone the maximum price on the Operating Reserve Demand Curve ~~Penalty Factors for the 30-minute Reserve Requirement, the Primary Reserve Requirement, and the Synchronized Reserve service Requirement are incorporated in the calculation of the Synchronized Reserve Market Clearing Price, Non-Synchronized Reserve Market Clearing Price, the Secondary Reserve Market Clearing Price, and the Real-time System Energy Price shall be equal to the sum of (i) the maximum price on the Operating Reserve Demand Curve for the Synchronized Reserve service and (ii) \$2,000/MWh~~ Locational Marginal Price, as applicable and consistent with the provisions for determining those prices. The system Synchronized Reserve price and Real-time System Energy Price ~~Reserve Penalty Factors for the 30-minute Reserve Requirement, the Primary Reserve Requirement, and the Synchronized Reserve Requirement~~ will continue to be used in the Synchronized Reserve Market Locational ~~Clearing Price, Non-Synchronized Reserve Market Clearing Price, Secondary Reserve Market Clearing Price, and the~~ Locational Marginal Price calculations, as applicable and consistent with the provisions for determining those prices, 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, the system Synchronized Reserve price referenced in Operating Agreement, Schedule 1, section 2.5(e) shall be equal to or Reserve Sub-Zone the maximum price on the Operating Reserve Demand Curve ~~Penalty Factors~~ for the 30-minute Reserve Requirement, the Primary Reserve Requirement, and the Synchronized Reserve service 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 the Real-time System Energy ~~Locational Marginal Price shall be equal to the sum of (i) , as applicable and consistent with the provisions for determining those prices. The maximum price on the Operating Reserve Demand Curve for the 30-minute Reserve Requirement, the Primary Reserve Requirement, and the Synchronized Reserve Requirement service and (ii) \$2,000/MWh.~~ The system Synchronized Reserve price and Real-time System Energy Price will continue to be used in the Synchronized Reserve Market Locational ~~Clearing Price, Non-Synchronized Reserve Market Clearing Price and the~~ Locational Marginal Price calculations, as applicable and consistent with the provisions for determining those prices, until the Manual Load Dump Action has been terminated.

2.5.2 Declaration of Market Suspension

If the Office of the Interconnection declares a Market Suspension, per Operating Agreement, Section 1.11.6, resources will be paid for their energy output and Real-time Prices shall be determined on an hourly basis and applied to each Real-time Settlement Interval in the following manner:

- i) If the Market Suspension is less than or equal to six (6) consecutive hours, then the Real-time Prices associated with such Market Suspension shall be the average of Real-time Prices for each individual pricing node for all Real-time Settlement Intervals of the preceding and subsequent clock hours (from XX:00 to XX:59) adjacent to such Market Suspension.
- ii) If the Market Suspension is greater than six (6) consecutive hours but less than or equal to twenty-four (24) consecutive hours and there are cleared Day-ahead Prices for the affected Operating Day, then the Real-time Prices associated with such Market Suspension shall be the Day-ahead Prices for each corresponding hour. If no such Day-ahead Prices exist, then the Real-time Prices shall be the average of the Real-time Prices for each individual pricing node for all Real-time Settlement Intervals of the preceding and subsequent clock hours (from XX:00 to XX:59) adjacent to such Market Suspension.
- iii) If the Market Suspension is greater than twenty-four (24) consecutive hours, then the Real-time Prices associated with such Market Suspension shall be determined based on the construction of an aggregate supply curve.

The aggregate supply curve shall be established as follows:

For online resources operating on a cost-based offer at the time of the Market Suspension, that cost-based offer will be used in the construction of the aggregate supply curve and for all market clearing and compensation.

For online resources operating on a price-based offer at the time of the Market Suspension, the Office of the Interconnection shall use the cheapest available cost-based offer based on the dispatch cost formula as defined in Operating Agreement, Schedule 1, section 6.4.1(g) using the available cost-based offers in the Office of the Interconnection system at the time of the Market Suspension. The selected cost-based offer will be used in the construction of the aggregate supply curve and for all market clearing and compensation.

For available offline resources, the Office of the Interconnection shall use the cheapest available cost-based offer based on the dispatch cost formula as defined in Operating Agreement, Schedule 1, section 6.4.1(g) using the available cost-based offers in the Office of the Interconnection system at the time of the Market Suspension for the construction of the aggregate supply curve.

The summation of the actual generation MWs for on-line resources will be used as a proxy for demand. The energy component of Locational Marginal Price will be determined hourly from the supply curve at the intersection of supply and demand where the impact of constraints is not considered. The loss and congestion component of Locational Marginal Price will be set to zero dollars per megawatt-hour.

Self-scheduled resources will be included in the supply stack but with a zero dollar per megawatt-hour offer price, and will not be eligible to set price. Off-line resources and resources directed to lower their output to Economic Minimum will not be eligible to set price. Generation resources that may be dispatched out of economic merit order to maintain system reliability as a result of limits on transmission capability will not be eligible to set price.