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 for each resource to Market Participants. The least cost security-constrained economic dispatch is the least costly means of serving load and meeting reserve requirements at different locations in the PJM Region based on forecasted operating conditions 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 offers for energy and ancillary services at which Market Sellers have entered as described by the OA, Schedule 1, Section 1.10 and Section 2.4 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 ~~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~~.

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

(c~~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~~a~~ 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. ~~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.~~

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.

2.2   General.

The Office of the Interconnection calculates Locational Marginal Prices separately from and subsequent to the security-constrained unit commitment and security-constrained economic dispatch of the system, the latter of which is referred to as the dispatch run. The calculation of

Locational Marginal Prices, which occurs in a process referred to as the pricing run, is based on the same optimization problem as the security-constrained economic dispatch. The objective of both the dispatch run and the pricing run is to serve load and meet reserve requirements at the least cost while respecting transmission constraints. However, Integer Relaxation is applied only to Eligible Fast-Start Resources committed in the pricing run to provide energy.

In the dispatch run a commitment state of 1 represents a resource is committed and 0 represents a resource is not committed. In the pricing run Integer Relaxation allows the commitment state of a committed Eligible Fast-Start Resource to be lowered to any value between 0 and 1, inclusive of 0 and 1. This in turn allows the optimization problem in the pricing run to use any fraction of a committed Eligible Fast-Start Resource's output, including an amount less than the resource's offered Economic Minimum output, in the determination of Locational Marginal Prices.

The process for the determination of Locational Marginal Prices 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 Fast-Start Resource shall be an Eligible Fast-Start Resource when the following apply:

> (i) *A generation resource is committed on an offer with a notification time plus startup time of one hour or less and a Minimum Run Time of one hour or less.*
> (ii) *An Economic Load Response Participant resource is committed on an offer with a notification time of one hour or less and a Minimum Down Time of one hour or less.*
> (iii) *The resource shall not be any of the following:*
>> a. *Self-scheduled for Energy in a given interval*
>> b. *A pumped storage hydropower unit scheduled by the Office of the Interconnection pursuant to the hydro optimization tool in the Day-ahead Energy Market*
>> c. *A pseudo-tied resource that does not provide all of their output to PJM*
>> d. *A dynamically scheduled resource.*

Only Eligible Fast-Start Resources shall have Integer Relaxation applied in the calculation of Locational Marginal Prices.

2.3   Determination of System Conditions Using the State Estimator. Section Retired

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, 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 *using the offer schedule on which the resource is committed in the dispatch run.*

The Office of the Interconnection will determine *a resource's* applicable marginal energy offer, as described in the PJM Manuals, based on the latest approved real-time security constrained economic dispatch solution available for the target time and by comparing the megawatt output of the resource *from the pricing run* with the Market Seller's *Incremental Energy O*ffer curve *or, for Eligible Fast-Start Resources, the Market Seller's Composite Energy Offer in which the resource is evaluated in the Pricing Run.* For Eligible Fast-Start Resources, the amortized Start-Up Costs and amortized No-load Costs, expressed in dollars per megawatt-hour, are added to the resource's Incremental Energy Offer to determine a Composite Energy Offer, as described below:

(i)   *The amortized Start-Up Cost for a generation resource shall equal the resource's applicable Start-Up Cost, as determined in accordance with the PJM Manuals, amortized over (A) the resource's Economic Maximum or Emergency Maximum output, whichever is applicable, and (B) the resource's Minimum Run Time, rounded up to the nearest twelfth of an hour. The amortized Start-Up Cost is included in the resource's Composite Energy Offer in each five-minute interval in which the resource is pool-scheduled during the resource's Minimum Run Time. If the Minimum Run Time is less than 5 minutes, the Minimum Run Time used to calculate the amortized Start-Up Cost is 5 minutes and the amortized Start-Up Cost is added to the Incremental Energy Offer for the first five minute interval in which the resource runs. After the Minimum Run Time has been met, the*

amortized Start-Up Cost is not included in the Composite Energy Offer. To determine the amortized Start-Up Cost for Economic Load Response Participant resources, the Minimum Down Time is used in place of Minimum Run Time and shutdown cost is used in place of Start-Up Cost in the above equation.

The amortized Start-Up Cost, to the extent it is reviewed pursuant to Tariff, Attachment K-Appendix, section 6.4.3A, shall be adjusted if the resource's applicable Start-Up Cost exceeds the reasonably expected cost, as described in subsection (iii) below.

(ii)   The amortized No-load Cost shall equal the resource's applicable No-load Cost, amortized over the resource's Economic Maximum or Emergency Maximum output, whichever is applicable, and included in the Composite Energy Offer for each interval in which the resource is pool-scheduled.

The amortized No-load Cost, to the extent it is reviewed pursuant to Tariff, Attachment K-Appendix, section 6.4.3A, shall be adjusted if the resource's applicable Incremental Energy Offer and No-load Cost exceed the reasonably expected cost, as described in subsection (iii) below.

(iii)   To the extent a Composite Energy Offer of a generation resource that is an Eligible Fast-Start Resource is less than $2,000/megawatt-hour and is reviewed pursuant to Operating Agreement, Schedule 1, 6.4.3A, pursuant to which the Office of the Interconnection evaluates the resource's submitted Start-Up Cost and No-load Cost against the resource's reasonably expected Start-Up Cost and No-load Cost, adjustments may be applied to yield a Composite Energy Offer no lower than $1,000/megawatt-hour at the Economic Maximum output as follows:

    1)   If the submitted Start-Up Cost and No-load Cost do not exceed the respective reasonably expected costs, no adjustments shall be made to the submitted Composite Energy Offer.

    2)   If the submitted Start-Up Cost does not exceed the resource's reasonably expected Start-Up Cost but the submitted No-load Cost does exceed the reasonably expected No-load Cost, then the Composite Energy offer shall equal the Incremental Energy Offer plus the amortized submitted Start-Up Cost; provided, however, if the resulting Composite Energy Offer at Economic Maximum yields a value less than $1,000/megawatt-hour, then the Composite Energy Offer shall include an amortized No-load Cost value sufficient to make the Composite Energy Offer equal to $1,000/megawatt-hour at Economic Maximum.

    3)   If the submitted Start-Up Cost exceeds the resource's reasonably expected Start-Up Cost but the submitted No-load Cost does not exceed the reasonably expected No-load Cost, then the Composite Energy Offer shall equal the Incremental Energy Offer plus the amortized No-load Cost;

provided, however, if the resulting Composite Energy Offer at Economic Maximum yields a value less than $1,000/megawatt-hour, then the Composite Energy Offer shall include an amortized Start-Up Cost value sufficient to make the Composite Energy Offer equal to $1,000/megawatt-hour at Economic Maximum.

4) *If both the submitted Start-Up Cost and No-load Cost exceed the respective reasonably expected costs and the Incremental Energy Offer is below $1,000 MWh, then the Composite Energy Offer shall equal $1,000/megawatt-hour and be composed of the resource's: (i) Incremental Energy Offer, (ii) a No-load Cost value equal to the lesser of the resource's amortized submitted No-load Cost or a value sufficient to make the Composite Energy Offer at Economic Maximum equal to $1,000/megawatt-hour, and (iii) to the extent the sum of the foregoing is less than $1,000/megawatt-hour, an amortized Start-Up Cost value sufficient to make the Composite Energy Offer equal to $1,000/megawatt-hour at Economic Maximum.*

(c)   *If a generation resource that is* an Eligible Fast-Start Resource submits a market-based offer that results in a Composite Energy Offer that exceeds $1,000/megawatt-hour *at the resource's Economic Maximum*:

(i)   If the Incremental Energy Offer of the market-based schedule exceeds the Incremental Energy Offer of the associated cost-based offer, *then the amortized Start-Up Cost and the amortized No-load Cost for the market-based schedule shall both be considered to exceed their respective reasonably expected cost, and the Composite Energy Offer shall be equal to $1,000/megawatt-hour and be composed of the resource's (i) Incremental Energy Offer, (ii) a No-load Cost value equal to the lesser of the resource's amortized submitted No-load Cost or a value sufficient to make the Composite Energy Offer at Economic Maximum equal to $1,000/megawatt-hour, and (iii) to the extent the sum of the foregoing is less than $1,000/megawatt-hour, an amortized Start-Up Cost value sufficient to make the Composite Energy Offer equal to $1,000/megawatt-hour at Economic Maximum.*

(ii)   *If the Incremental Energy Offer of the market-based schedule is not greater than the Incremental Energy Offer of the associated cost-based offer and:*

(1)   *If* the amortized No-load Cost for the market-based schedule *exceeds* the No-load Cost of the associated cost-based offer or, exceeds the reasonably expected cost *of such cost-based offer, then the amortized No-load Cost shall be adjusted in the matter set forth in subsections (b)(iii)(2) and (4) above, as applicable.*

(2)   *If the amortized Start-Up Cost for the market-based schedule exceeds the Start-Up Cost of the specified on the associated cost-based offer or*

exceeds the reasonably expected cost of the Start-Up Cost of such cost-based offer, then the amortized Start-Up Cost shall be adjusted in the manner set forth in subsections (b)(iii)(3) and (4), as applicable.

    (3)   To the extent the Composite Energy Offer resulting from subsections (c)(ii)(1) and (2) above would exceed $2,000/MWh, then the Composite Energy Offer shall equal $2,000/megawatt-hour and the submitted Start-Up Cost and No-load Cost shall be adjusted in the manner set forth in subsection (e) below.

    (d)   *For purposes of calculating Real-time Prices,* the applicable marginal *Incremental Energy O*ffer used in the calculation of Real-time Prices shall not exceed $2,000/megawatt-hour.

    (e)   *If a generation* resource that is an Eligible Fast-Start Resource submits an offer that results in a Composite Energy Offer with a maximum segment that exceeds $2,000/megawatt-hour *and such offer is reviewed pursuant to Operating Agreement, Schedule 1, 6.4.3A, pursuant to which the Office of the Interconnection evaluates the resource's submitted Start-Up Cost and No-load Cost against the resource's reasonably expected Start-Up Cost and No-load Cost, the following adjustments will be made to cap the offer at no higher than $2,000/megawatt-hour:*

    (i)   If the submitted Start-Up Cost and No-load Cost do not exceed the respective reasonably expected costs, the Composite Energy Offer shall equal $2,000/megawatt-hour and be composed of: (i) the resource's Incremental Energy Offer, (ii) to the extent the Incremental Energy Offer is less than $2,000/megawatt-hour, a No-load Cost value equal to the lesser of the resource's amortized submitted No-load Cost or a value sufficient to make the Composite Energy Offer at Economic Maximum equal to $2,000/megawatt-hour, and (iii) to the extent the sum of the foregoing is less than $2,000/megawatt-hour, a Start-Up Cost value an amortized Start-Up Cost value sufficient to make the Composite Energy Offer at Economic Maximum equal to $2,000/megawatt-hour.

    (ii)   If the submitted Start-Up Cost does not exceed the resource's reasonably expected Start-Up Cost but the submitted No-load Cost does exceed the reasonably expected No-load Cost, then the Composite Energy offer shall equal the Incremental Energy Offer plus the amortized submitted Start-Up Cost; provided, however, if the resulting Composite Energy Offer at Economic Maximum yields a value greater than $2,000/megawatt-hour, then the Composite Energy Offer shall include an amortized Start Up Cost value sufficient to make the Composite Energy Offer equal to $2,000/megawatt-hour.

    (iii)   If the submitted Start-Up Cost exceeds the resource's reasonably expected Start-Up Cost but the submitted No-load Cost does not exceed the reasonably expected No-load Cost, then the Composite Energy Offer shall equal the Incremental Energy Offer plus the amortized No-load Cost; provided, however, if the resulting

Composite Energy Offer at Economic Maximum yields a value greater than $2,000/megawatt-hour, then the Composite Energy Offer shall include an amortized No-load Cost value sufficient to make the Composite Energy Offer equal to $2,000/megawatt-hour.

(iv) *If the submitted Start-Up Cost and No-load Cost both exceed the respective reasonably expected costs, the Composite Energy Offer shall equal the lesser of the resource's Incremental Energy Offer or $2,000/megawatt-hour.*

(v) *To the extent any of the foregoing subsections (e)(ii) through (e)(iv) would result in a Composite Energy Offer less than $1,000/MWh at Economic Maximum, the Composite Energy Offer shall equal $1,000/megawatt-hour and be composed of the resource's: (i) Incremental Energy Offer, (ii) a No-load Cost value equal to the lesser of the resource's amortized submitted No-load Cost or a value sufficient to make the Composite Energy Offer equal to $1,000/megawatt-hour at Economic Maximum, and (iii) to the extent the sum of the foregoing is less than $1,000/megawatt-hour, an amortized Start-Up Cost value sufficient to make the Composite Energy Offer equal to $1,000/megawatt-hour at Economic Maximum.*

(f) To the extent an Economic Load Response Participant resource's Composite Energy Offer is reviewed pursuant to Operating Agreement, Schedule 1, 6.4.3A, pursuant to which the Office of the Interconnection evaluates the resource's submitted shutdown cost against the resource's reasonably expected shutdown costs, adjustments may be applied to yield a Composite Energy Offer, at Economic Maximum, no lower than $1,000/megawatt-hour and no greater than $2,000/megawatt-hour as follows:

(i) *If a Composite Energy Offer at Economic Maximum is greater than $1,000/megawatt-hour but does not exceed $2,000/megawatt-hour, and the amortized shutdown cost, to the extent that it is reviewed pursuant to Operating Agreement, Schedule 1, section 6.4.3A, does not exceed the resource's reasonably expected shutdown cost, then no adjustments shall be made to the submitted Composite Energy Offer.*

(ii) *If the amortized shutdown cost, to the extent that it is reviewed pursuant to Operating Agreement, Schedule 1, section 6.4.3A, exceeds the resource's reasonably expected shutdown cost, then the Composite Energy Offer shall equal: (i) the resource's Incremental Energy Offer, and (ii) to the extent the Incremental Energy Offer is less than $1,000/megawatt-hour, a shutdown value equal to the lesser of the resource's amortized submitted shutdown cost or a value sufficient to make the Composite Energy Offer at Economic Maximum equal to $1,000/megawatt-hour.*

(iii) *If the Composite Energy Offer at Economic Maximum exceeds $2,000/megawatt-hour and the amortized shutdown cost, to the extent that it is reviewed pursuant to Operating Agreement, Schedule 1, section 6.4.3A, does not exceed the resource's reasonably expected shutdown cost, then the Composite Energy Offer shall equal*

> *$2,000/megawatt-hour: (i) the resource's Incremental Energy Offer, and (ii) to the extent the Incremental Energy Offer is less than $2,000/megawatt-hour, a shutdown value sufficient to make the Composite Energy Offer equal to $2,000/megawatt-hour.*

(g)   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 forecasted *operating* conditions *and the submitted energy offers as described in Tariff, Attachment K-Appendix, section 2.4. 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 the latest approved real-time security constrained economic dispatch case 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 Reserve Penalty Factors, 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 Tariff, Attachment K Appendix, 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 Tariff, Attachment K Appendix, 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.

(b̲c̶)		*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 Tariff, Attachment K-Appendix, 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.*

(c̲d̶)		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 Tariff, Attachment K-Appendix, 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 a Demand 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 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 losses. The *R*eal-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.

(d̲e̶)		*During the Operating Day, the calculation set forth in Tariff, Attachment K-Appendix, 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 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, *R*eal-time Prices shall be calculated as described in *Tariff, Attachment K-Appendix, s*ection 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 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 *R*eal-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, and the components of Locational Marginal Prices referenced in *Tariff, Attachment K-Appendix,* 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 a 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 or Reserve Sub-Zone the Reserve Penalty Factor for the Primary Reserve Requirement and the Reserve Penalty Factor for the Synchronized Reserve Requirement are incorporated in the calculation of the Synchronized Reserve Market Clearing Price, Non-Synchronized Reserve Market Clearing Price and Locational Marginal Price as applicable. The Reserve Penalty Factor for the Primary Reserve Requirement and the Reserve Penalty Factor for the Synchronized Reserve Requirement will continue to be used in the Synchronized Reserve Market Clearing Price, Non-Synchronized 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 Factor for the Primary Reserve Requirement and the Reserve Penalty Factor for the Synchronized Reserve Requirement are incorporated in the calculation of the Synchronized Reserve Market Clearing Price, Non-Synchronized Reserve Market Clearing Price and Locational Marginal Price as applicable. The Reserve Penalty Factor for the Primary Reserve Requirement and the Reserve Penalty Factor for the Synchronized Reserve Requirement will continue to be used in the Synchronized Reserve Market Clearing Price, Non-Synchronized 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 demand response 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)   The Office of the Interconnection shall use day-ahead security constrained economic dispatch optimization software to determine the least-cost*ly means of obtaining energy to serve the next increment of load and meet day-ahead scheduling reserve requirements in the PJM Region,.- b-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 *as described in Tariff, Attachment K-Appendix, section 2.4A*, dispatchable load, Increment Offers, Decrement Bids, *Up-to Congestion Transactions,* offers for demand reductions, <u>Day-ahead Scheduling Reserve offers,</u> and *interchange* transactions submitted to the Office of the Interconnection and scheduled in the Day-ahead Energy Market. *Day-ahead economic dispatch is performed in the day-ahead security constrained economic dispatch software program, known as the dispatch run. Day-ahead Prices are calculated in a subsequent execution of the day-ahead security constrained economic dispatch optimization software program, known as the pricing run. The pricing run executes the same optimization as the dispatch run but additionally applies Integer Relaxation to Eligible Fast-Start Resources.*

<u>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.</u>

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 costs, given scheduled system conditions, scheduled transmission outages, and any transmission limitations that may exist. 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, 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 energy offer or 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.

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 <= 105% of day-ahead economic minimum or day-ahead economic minimum plus 5 MW, whichever is greater.

(ii)   real-time economic maximum >= 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:

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

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

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

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

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.   ~~UDS~~LAtime = ~~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 Basepoint~~ dispatch signal or the actual output and ramp-limited desired MW value for each Real-time Settlement Interval. If the dispatch signal ~~UDS Basepoint~~ 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 ~~dispatch signal~~UDS Basepoint, or if its % off dispatch is <= 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~~dispatch 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~~dispatch 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~~ dispatch LMP Desired MWh.

- 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 – 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~~dispatch 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.