SCHEDULE 29A

ELMP for Energy and Operating Reserve Market:

Ex-Post Pricing Formulations

I. INTRODUCTION

The Transmission Provider utilizes an extension of the simultaneously co-optimized Security Constrained Economic Dispatch (SCED) algorithm to calculate prices for Energy, Operating Reserves, Up Ramp Capability, Down Ramp Capability, and Short-Term Reserve. The SCED-Pricing algorithm utilizes a linear programming solver to minimize objective costs represented by a linear objective function subject to linear or linearized physical, reliability and Good Utility Practice constraints as in the simultaneously co-optimized SCED algorithm described in Schedule 29. The SCED-Pricing objective function includes total Energy costs, Regulating Reserve costs, Spinning Reserve costs, Supplemental Reserve costs, Short-Term Reserve costs, Market-Wide Operating Reserve value, Market-Wide Regulating and Spinning Reserve value, Market-Wide Regulating Reserve value, Up Ramp Capability value, and Down Ramp Capability value, and Market-Wide Short-Term Reserve value. The SCED-Pricing algorithm is solved on an Hourly basis for the Day-Ahead Energy and Operating Reserve Market and for each five (5) minute Dispatch Interval for the Real-Time Energy and Operating Reserve Market. The SCED-Pricing algorithm extends the concept of LMP and MCP by allowing the cost of committing Fast Start Resources and Emergency Operations Resources, the Energy cost of Fast Start Resources and Emergency Operations Resources dispatched at limits, and Emergency Demand Response Resources to set Energy, reserve, Up Ramp Capability, Down Ramp Capability, and Short-Term Reserve prices. This process is known as Extended LMP

(ELMP). The SCED-Pricing algorithm in Schedule 29A is the same as the SCED algorithm in Schedule 29 with the exception of its treatment of Fast Start Resources, Emergency Operations Resources and Emergency Demand Response Resources.

II. DAY-AHEAD PRICING FORMULATIONS

The Day-Ahead Pricing formulation considers the cost of Energy, Regulating Reserves and Spinning Reserves from Resources committed in the Hour. It also considers the costs of Supplemental Reserves and Short-Term Reserves from offline or uncommitted Resources. In addition, the Day-Ahead Pricing formulation considers the costs of committing and the costs of keeping online those Fast Start Resources that are committed by the Transmission Provider to be online in the Hour. It also considers the costs of committing and dispatching offline Fast Start Resources that are available for the Transmission Provider to commit in the Hour under conditions of Energy or Ancillary Service scarcity or that could alleviate transmission constraint violations, except for the Surplus Conditions in the Day-Ahead EORM described in section 39.2.11.c.

A. Online Resources

If an online Resource that is not a Fast Start Resource is committed by the Transmission Provider in the Day-Ahead Market processes described in Section 39.2.9, the costs in the objective function for the Resource and the constraints on the Resource's Energy, Ancillary Service, Up Ramp Capability, Down Ramp Capability, and Short-Term Reserve Schedules in the SCED-Pricing problem are the same as those for the Resource in the simultaneously co-optimized SCED algorithm described in Schedule 29.

For a Fast Start Resource committed by the Transmission Provider in the Day-Ahead market processes described in Section 39.2.9 to be online in the Hour, the SCED-Pricing algorithm considers the cost of committing and dispatching the Resource when setting prices. The SCED-Pricing algorithm considers the Resource eligible to set prices even if the Resource was scheduled to operate at its minimum or maximum limit. It also considers Start-Up Offer and No-Load Offer for Generation Resources and DRR – Type II which are Fast Start Resources, or Shut-Down Offer and Hourly Curtailment Offer for DRR – Type I which are Fast Start Resources when setting prices. To achieve this, the SCED-Pricing algorithm allows fractional commitment of a Fast Start Resource for purposes of setting prices, even though fractional commitment is not a physically achievable outcome. SCED-Pricing represents the fraction of the Fast Start Resource committed in the Hour by a continuous decision variable, on_{hour}. The SCED-Pricing algorithm requires that on_{hour} satisfy

$$0 \leq on_{hour} \leq 1$$

The SCED-Pricing algorithm allocates a share of the Start-Up Cost or Shut-Down-Cost for the Fast Start Resource to the Hour for which prices are being calculated. In the following N is the minimum run time for Generation Resources or DRR – Type II, or the Minimum Interruption Duration for DRR – Type I, offered by the Fast Start Resource in hours, rounded up to the nearest hour.

Generation Resources and DRR – Type II

$AllocatedShareStartUpCost_{hour}$ = *StartUpCost / N if hour is within N hours of the time the Resource was committed, or 0 if hour is later than N hours after the Generation Resource or DRR – Type II was committed.*

DRR – Type I

$AllocatedShareShutDownCost_t$ = ShutDownCost / N if hour is within N hours of the time the DRR - Type I was committed, or 0 if hour is later than N hours after the DRR - Type I was committed.

The SCED-Pricing algorithm allocates the No-Load Cost or Hourly Curtailment Cost for Fast Start Resources for the Hour to the Hour for which prices are being calculated.

If the Fast Start Resource was not committed to provide Regulation Reserves, the constraints for the Energy, Spinning Reserves, Up Ramp Capability, Down Ramp Capability, and Short-Term Reserve scheduled for the Fast Start Resource in SCED-Pricing will include the following. Let $DispatchSchedule_{hour}$ be the dispatch scheduled for the Resource in Hour *hour,* $SpinningReservesSchedule_{hour}$ be the Spinning Reserve Schedule for the Resource in Hour *hour,* $URCSchedule_{hour}$ be the Up Ramp Capability Schedule, $DRCSchedule_{hour}$ be the Down Ramp Capability Schedule for the Resource in Hour *hour* and $STRSchedule_{hour}$ be the Short-Term Reserve Schedule for the Resource in Hour *hour* in SCED-Pricing.

$$on_{hour} \times EconMin_{hour} \leq EnergyDispatchSchedule_{hour} - DRCSchedule_{hour}$$

$$0 \leq SpinningReservesSchedule_{hour}$$

$$0 \leq URCSchedule_{hour}$$

$$0 \leq DRCSchedule_{hour}$$

$$0 \leq STRSchedule_{hour}$$

$$EnergyDispatchSchedule_{hour} + SpinningReservesSchedule_{hour} + URCSchedule_{hour} \leq on_{hour} \times EconMax_{hour}$$

And

$$EnergyDispatchSchedule_{hour} + STRSchedule_{hour} \leq on_{hour} \times EconMax_{hour}$$

The ramping constraints affecting Energy, Spinning Reserve, Up Ramp Capability, Down Ramp Capability, and Short-Term Reserve schedules from the Fast Start Resource in the SCED-Pricing algorithm are the same as those in the SCED algorithm unless the Fast Start Resource is dispatched at its EconMin in the previous interval ($DispatchSchedule_{t-1} = EconMin_{t-1}$) in which case the down ramp constraint will be relaxed.

Generation Resources and DRR – Type II

The objective function elements for Generation Resource and DRR Type II which are Fast Start Resources include:

$$on_{hour} \times (AllocatedShareStartUpCost_{hour} + NoLoadCost_{hour})$$

$$+ \int_{0}^{EnergyDispatchSchedule_{hour}} IncrementalEnergyCost_{hour}(x)dx$$

$$+ SpinningOfferCost_{hour} \times SpinningReservesSchedule_{hour}$$

DRR Type I

The objective function elements for the DRR - Type I which are Fast Start Resources include:

$on_{hour} \times (AllocatedShareShutDownCost_{hour} + CurtailCost_{hour})$

$EnergyDispatchSchedule_{hour}$

$+ \int IncrementalEnergyCost_{hour}(x)dx$

0

If the Fast Start Resource was committed to provide Regulating Reserves, the constraints for the Energy, Spinning Reserves, Regulating Reserves, Up Ramp Capability, Down Ramp Capability, and Short-Term Reserve scheduled for the Fast Start Resource in SCED-Pricing include the following. Let $DispatchSchedule_{hour}$ be the dispatch scheduled for the Resource in Hour *hour*, $SpinningReservesSchedule_{hour}$ be the Spinning Reserve Schedule for the Resource in Hour *hour,* $RegulatingReservesSchedule_{hour}$ be the Regulating Reserve Schedule for the Resource in Hour *hour*, $URCSchedule_{hour}$ be the Up Ramp Capability Schedule, $DRCSchedule_{hour}$ be the Down Ramp Capability Schedule for the Resource in Hour *hour*, and $STRSchedule_{hour}$ be the Short-Term Reserve Schedule for the Resource in Hour *hour* in SCED-Pricing.

$0 \leq SpinningReservesSchedule_{hour}$

$0 \leq RegulatingReservesSchedule_{hour}$

$0 \leq URCSchedule_{hour}$

$0 \leq DRCSchedule_{hour}$

$0 \leq STRSchedule_{hour}$

$on_{hour} \times RegMin_{hour} \leq EnergyDispatchSchedule_{hour} - RegulatingReservesSchedule_{hour} - DRCSchedule_{hour}$

$$EnergyDispatchSchedule_{hour} + SpinningReservesSchedule_{hour} + RegulatingReservesSchedule_{hour} + URCSchedule_{hour} \leq on_{hour} \times RegMax_{hour}$$

$$EnergyDispatchSchedule_{hour} + STRSchedule_{hour} \leq on_{hour} \times RegMax_{hour}$$

The ramping constraints affecting Energy, Reserve, Up Ramp Capability, Down Ramp Capability, and Short-Term Reserve schedules from the Fast Start Resource in the SCED-Pricing algorithm are the same as those in the SCED algorithm unless the Fast Start Resource is dispatched at its RegMin in the previous interval ($DispatchSchedule_{t-1} = RegMin_{t-1}$) in which case the down ramp constraint will be relaxed.

The objective function elements for the Fast Start Resource include:

$$on_{hour} \times (AllocatedShareStartUpCost_{hour} + NoLoadCost_{hour})$$

$$+ \int_{0}^{EnergyDispatchSchedule_{hour}} IncrementalEnergyCost_{hour}(x)dx$$

$$+ SpinningOfferCost_{hour} \times SpinningReservesSchedule_{hour}$$

$$+ RegulatingOfferCost_{hour} \times RegulatingReservesSchedule_{hour}$$

B. Offline Resources

Offline Fast Start Resources that are available to be committed in the Day-Ahead Market by the Transmission Provider participate in SCED-Pricing if either or both of the following conditions hold:

The SCED algorithm finds a solution that does not meet energy and/or reserve requirements in the Hour except for the Surplus Conditions in the Day-Ahead EORM described in section 39.2.11.c; and/or

The SCED algorithm finds a solution that violates a transmission constraint for which the Transmission Provider is the monitoring entity and the Transmission Provider determines that commitment of the Fast Start Resource provides significant relief to the violation. For purposes of this provision, offline Resources with Generation Shift Factors either greater than or equal to 6% or less than or equal to – 6% are deemed to be providing significant relief to the transmission constraint violation.

In these scenarios, committing and dispatching offline Fast Start Resource is an action that the Transmission Provider could take to address the shortage or violation. Rather than set price using a shortage cost or a transmission penalty price, the SCED-Pricing algorithm determines prices based on the action that the Transmission Provider could take to address the problem. The constraints for the Energy and Reserves scheduled for the Fast Start Resource in SCED-Pricing include the following. Let $DispatchSchedule_{hour}$ be the dispatch scheduled for the Resource in Hour *hour,* let $OffLineSupplementalReservesSchedule_{hour}$ be the offline Supplemental Reserve Schedule, and let $STRSchedule_{hour}$ be the offline Short-Term Reserve Schedule for the Generation Resource or DRR - Type II in Hour *hour* in SCED-Pricing and let

$ContingencyReservesSchedule_{hour}$ be the Reserves, whether Supplemental Reserves or Spinning Reserves, and let $STRSchedule_{hour}$ be the offline Short-Term Reserve Schedule for a DRR - Type I.

The SCED-Pricing algorithm allocates a share of the Start-Up Cost or Shut-Down cost for the Fast Start Resource to the Hour for which prices are being calculated. In the following equation, N is the minimum run time for Generation Resources or DRR - Type II, or the Minimum Interruption Duration for DRR - Type I, offered by the Fast Start Resource in hours, where N is rounded up to the nearest hour.

Generation Resources and DRR - Type II

For Generation Resources and DRR - Type II:

$$AllocatedShareStartUpCost_{hour} = StartUpCost / N$$

$$on_{hour} \times EconMin_{hour} \leq EnergyDispatchSchedule_{hour} \leq on_{hour} \times EconMax_{hour}$$

$$0 \leq OffLineSupplementalReservesSchedule_{hour} \leq (1 - on_{hour}) \times min\{EconMax_{hour}, MaxOfflineResponseLimit_{hour}\}$$

$$0 \leq STRSchedule_{hour} \leq (1 - on_{hour}) \times min\{EconMax_{hour}, MaxOfflineSTRResponseLimit_{hour}\}$$

$$\leq (1 - on_{hour}) \times min\{EconMax_{hour}, MaxOfflineResponseLimit_{hour}\}$$

DRR - Type I

For DRR - Type I:

$$AllocatedShareShutDownCost_{hour} = ShutDownCost / N$$

$$on_{hour} \times EconMin_{hour} \leq EnergyDispatchSchedule_{hour} \leq on_{hour} \times TargetedDemandReduction_{hour}$$

$$0 \leq ContingencyReservesSchedule_{hour} \leq (1 - on_{hour}) \times TargetedDemandReduction_{hour}$$

$$0 \leq STRSchedule_{hour} \leq (1 - on_{hour}) \times TargetedDemandReduction_{hour}$$

Generation Resource and DRR - Type II

The objective function elements for a Fast Start Resource which is either a Generation Resource or DRR Type II include:

$$on_{hour} \times (AllocatedShareStartUpCost_{hour} + NoLoadCost_{hour})$$

$$+ \int_{0}^{EnergyDispatchSchedule_{hour}} IncrementalEnergyCost_{hour}(x)dx$$

$$+ OffLineSupplementalOfferCost_{hour} \times OffLineSupplementalReservesSchedule_{hour}$$

$$+ OffLineSTROfferCost_{hour} \times STRSchedule_{hour}$$

DRR - Type I

The objective function elements for a Fast Start Resource which is DRR Type I include:

$$on_{hour} \times (AllocatedShareShutDownCost_{hour} + CurtailCost_{hour})$$

$$+ \int_{0}^{EnergyDispatchSchedule_{hour}} IncrementalEnergyCost_{hour}(x)dx$$

$$+ ContingencyReservesOfferCost_{hour} \times ContingencyReservesSchedule_{hour}$$

$$+ OffLineSTROfferCost_{hour} \times STRSchedule_{hour}$$

where $ContingencyReservesOfferCost_{hour}$ the Spinning Reserve Offer if it is offering Spinning Reserve or Supplemental Reserves Availability Offer if it is offering Supplemental Reserves.

C. SCED-Pricing Algorithm

The SCED-Pricing algorithm is the same as the SCED algorithm, with the exceptions for treatment of Fast Start Resources described above.

Objective Function:

Minimize {Total Hourly Energy Costs

+ Total Hourly Commitment Costs for Fast Start Resources

+ Total Hourly Regulating Reserve Costs

+ Total Hourly Spinning Reserve Costs

+ Total Hourly Supplemental Reserve Costs

+ Total Hourly Short-Term Reserve Costs

- Total Hourly Market-Wide Operating Reserve Value

- Total Hourly Market-Wide Regulating and Spinning Reserve Value

- Total Hourly Market-Wide Regulating Reserve Value

- Total Dispatch Interval Market-Wide Up Ramp Capability Value

- Total Dispatch Interval Market-Wide Down Ramp Capability Value

- Total Dispatch Interval Market-Wide Short-Term Reserve Value}

Where:

Total Hourly Energy Costs

= The sum of the hourly Energy costs that would be incurred by all Resources supplying dispatchable Energy, based on their submitted Energy offer curves, if they were to operate according to the schedule produced by SCED-Pricing for the given Hour.

Total Hourly Commitment Costs for Fast Start Resources

= The sum of the hourly Start-Up Offer and No-Load Offer for Generation Resources and DRR – Type II, or Shut-Down Offer and Hourly Curtailment Offer for DRR – Type I that would be incurred by all Fast Start Resources available for commitment by the Transmission Provider,

based on their submitted Start-Up, No-Load Offer, Shut-Down Offer, and Hourly Curtailment Offer if they were to operate according to the commitment produced by SCED-Pricing for the given Hour.

Total Hourly Regulating Reserve Costs

= The sum of the hourly Regulating Reserve costs, based on the Regulating Capacity Offer and Regulating Mileage Offer prices, that would be incurred by all Resources supplying dispatchable Regulating Reserve, if they were to operate according to the schedule produced by SCED-Pricing algorithm for the given Hour.

Total Hourly Spinning Reserve Costs

= The sum of the hourly Spinning Reserve costs, based on the Spinning Reserve offer prices, that would be incurred by all Resources supplying dispatchable Spinning Reserve, if they were to operate according to the schedule produced by SCED-Pricing algorithm for the given Hour.

Total Hourly Supplemental Reserve Availability Costs

= The sum of the hourly Supplemental Reserve availability costs, based on the Supplemental Reserve offer prices, that would be incurred by all Resources supplying dispatchable Supplemental Reserve if they were to operate according to

the schedule produced by SCED-Pricing algorithm for the given Hour.

Total Hourly Short-Term Reserve Costs

= The sum of the hourly Short-Term Reserve costs, based on the Off-line Short-Term Reserve Offer prices that would be incurred by all Resources supplying dispatchable Short-Term Reserve if they were to operate according to the schedule produced by the SCED-Pricing algorithm for the given Hour.

Total Hourly Market-Wide Operating Reserve Value

= The hourly value of the Market-Wide Operating Reserve cleared by SCED-Pricing to the Load Serving Entities and Market Participant with Exports on whose behalf the Transmission Provider is procuring Operating Reserves based on the Market-Wide Operating Reserve Demand Curve.

Total Hourly Market-Wide Regulating and Spinning Reserve Value

= The hourly value of the Market-Wide Regulating and Spinning Reserve cleared by SCED-Pricing to the Load Serving Entities and Market Participant with Exports on whose behalf the Transmission Provider is procuring

Regulating and Spinning Reserves based on the Market-Wide Regulating and Spinning Reserve Demand Curve.

Total Hourly Market-Wide Regulating Reserve Value

= The hourly value of the Market-Wide Regulating Reserve cleared by SCED-Pricing to the Load Serving Entities on whose behalf the Transmission Provider is procuring Regulating Reserves based on the Market-Wide Regulating Reserve Demand Curve.

Total Hourly Market-Wide Up Ramp Capability Value

= The hourly value of the cleared Market-Wide Up Ramp Capability to the Load Serving Entities and Market Participant with Exports on whose behalf the Transmission Provider is procuring Up Ramp Capability based on the Market-Wide Up Ramp Capability Demand Curve.

Total Hourly Market-Wide Down Ramp Capability Value

= The hourly value of the cleared Market-Wide Down Ramp Capability to the Load Serving Entities and Market Participant with Exports on whose behalf the Transmission Provider is procuring Down Ramp Capability based on the Market-Wide Down Ramp Capability Demand Curve.

Total Hourly Market-Wide Short-Term Reserve Value

= The hourly value of the cleared Market-Wide Short-Term Reserve to the Load Serving Entities and Market Participants with Exports on whose behalf the Transmission Provider is procuring Short-Term Reserve based on the Market-Wide Short-Term Reserve Demand Curve.

Constraints:

Subject to

Nodal Power Balance Constraint

Market-Wide Operating Reserve Constraint

Market-Wide Regulating and Spinning Reserve Constraint

Market-Wide Regulating Reserve Constraint

Market-Wide Non-DRR1 Operating Reserve Constraint

Market-Wide Non-DRR 1 Regulating and Spinning Reserve Constraint

Market-Wide Up Ramp Capability Constraint

Ramp Procurement Minimum Reserve Zone Up Ramp Capability Requirement Constraint

Market-Wide Down Ramp Capability Constraint

Ramp Procurement Minimum Reserve Zone Down Ramp Capability Requirement Constraint

Market-Wide Short-Term Reserve Constraint

Resource Limit Constraints

Resource Ramping Constraints

Transmission Constraints

Sub-Regional Power Balance Constraints in the Second Planning Area

Post Reserve Deployment Constraints

Co-optimized Reserve Zone Operating Reserve constraints

Co-optimized Reserve Zone Regulating and Spinning Reserve constraints

Co-optimized Reserve Zone Regulating Reserve constraints

Co-optimized Reserve Zone Short-Term Reserve constraints

Electric Storage Resource Energy Storage Level constraints

Where:

The Nodal Power Balance Constraint ensures that the net Energy injected at an electrical Node to equal the net Energy flowing out of the same electrical Node on connected branches.

The Market-Wide Operating Reserve Constraint ensures the supply of Market-Wide Operating Reserve is greater than or equal to the Market-Wide Operating Reserve cleared by SCED-Pricing.

The Market-Wide Regulating and Spinning Reserve Constraint ensures that the supply of Market-Wide Regulating and Spinning Reserve is greater than or equal to the Market-Wide Regulating and Spinning Reserve requirement cleared by SCED-Pricing.

The Market-Wide Regulating Reserve Constraint ensures the supply of Market-Wide Regulating Reserve is greater than or equal to the Market-Wide Regulating Reserve cleared by SCED-Pricing.

The Market-Wide Non-DRR1 Operating Reserve Constraint ensures the percentage of Market-Wide Operating Reserve that is cleared by SCED-Pricing on Generation Resources, DRR – Type II, Electric Storage Resources, External Asynchronous Resources, and/or Distributed Energy Aggregated Resources complies with Applicable Reliability Standards.

The Market-Wide Non-DRR1 Regulating and Spinning Reserve Constraint ensures the percentage of Market-Wide Regulating and Spinning Reserve that is cleared by SCED-Pricing on Generation Resources, DRR – Type II, Electric Storage Resources, External Asynchronous Resources, and/or Distributed Energy Aggregated Resources complies with Applicable Reliability Standards.

The Market-Wide Up Ramp Capability Constraint ensures the supply of Market-Wide Up Ramp Capability is greater than or equal to the cleared demand for Market-Wide Up Ramp Capability.

The Ramp Procurement Minimum Reserve Zone Up Ramp Capability Requirement Constraint ensure that the cleared Up Ramp Capability in a zone can be converted to Energy when needed while respecting transmission constraints.

The Market-Wide Down Ramp Capability Constraint ensures the supply of Market-Wide Down Ramp Capability is greater than or equal to the cleared demand for Market-Wide Down Ramp Capability.

The Ramp Procurement Minimum Reserve Zone Down Ramp Capability Requirement Constraint ensure that the cleared Down Ramp Capability in a zone can be converted to Energy when needed while respecting transmission constraints.

The Market-Wide Short-Term Reserve Constraint ensures the supply of Market-Wide Short-Term Reserve is greater than or equal to the cleared demand for Market-Wide Short-Term Reserve.

The Resource Limit Constraints ensure that each Resource has the Capacity, based on submitted limits, to simultaneously supply cleared Energy, deploy one hundred percent (100%) of cleared Regulating Reserve in the upward direction, deploy one hundred percent (100%) of cleared Spinning Reserve, deploy one hundred percent (100%) of cleared Supplemental Reserve, and change output in the upward direction one hundred percent (100%) of cleared Up Ramp Capability. The Resource Limit Constraints ensure that each Resource has the Capacity, based on submitted limits, to simultaneously supply cleared Energy and deploy one hundred percent (100%) of cleared Short-Term Reserve. In addition, the Resource Limit Constraints ensure that each Resource has the ability to simultaneously supply cleared Energy, deploy one hundred percent (100%) of the cleared Regulating Reserve in the downward direction, and change output in the

downward direction one hundred percent (100%) of cleared Down Ramp Capability with no Spinning Reserve, Supplemental Reserve, or Short-Term Reserve deployment. For Fast Start Resources, the upper limits and lower limits on capacity available to provide energy, reserves, Up Ramp Capability, Down Ramp Capability, and Short-Term Reserve are adjusted by the fractional commitment level for the Resource determined by SCED-Pricing.

The Resource Ramping Constraints ensure that each Resource is cleared by SCED-Pricing in a manner to follow load based on cleared Energy levels in adjacent dispatch intervals, to deploy Regulating Reserve and Contingency Reserve in a manner that will comply with Applicable Reliability Standards, to support the cleared level of Up Ramp Capability and Down Ramp Capability, and to support the deployment of Short-Term Reserve.

The Transmission Constraints ensure that Energy is cleared by SCED-Pricing on Resources and Loads in such a way as to prevent flows on transmission flowgates and branches from exceeding normal operating limits under basecase conditions or Emergency operating limits under a first contingency loss of a Resource or transmission facility. In addition, the Transmission Constraints also ensure that Operating Reserves can be deployed, Up Ramp Capability and Down Ramp Capability can be supplied, and Short-Term Reserve can be supplied in such a way as to prevent flows on transmission flowgates and branches from exceeding normal operating limits under basecase conditions or Emergency operating limits under a first contingency loss of a Resource or transmission

facility. Moreover, the Transmission Constraints shall also ensure that Short-Term Reserves can be deployed in such a way as to prevent flows on transmission flowgates and branches from exceeding normal operating limits under basecase conditions or Emergency operating limits under a first contingency loss of a Resource or transmission facility.

The Sub-Regional Power Balance Constraints ensure that Energy flows within the Transmission Provider Region are managed consistent with applicable seams agreements, coordination agreements, transmission service agreements, or operating procedures. The Sub-Regional Power Balance Constraints also ensure that Operating Reserves can be deployed, Up Ramp Capability and Down Ramp Capability can be supplied, and Short-Term Reserve can be supplied in such a way as to prevent flows on Sub-Regional Power Balance Constraints from exceeding the appropriate limits.

The Post Reserve Deployment Constraints ensure that Operating Reserves and Short-Term Reserve can be deployed in such a way as to prevent flows on identified Transmission Constraints from exceeding the appropriate limits.

The Co-optimized Reserve Zone Operating Reserve constraints ensure the supply of Operating Reserve within a specific Reserve Zone is greater than or equal to the Co-optimized Zonal Operating Reserve Requirement.

The Co-optimized Reserve Zone Regulating and Spinning Reserve constraints ensure the supply of Regulating and Spinning Reserve within a specific Reserve Zone is greater than or equal to the Co-optimized Zonal Spinning

Reserve Requirement plus the Co-optimized Zonal Regulating Reserve Requirement.

The Co-optimized Reserve Zone Regulating Reserve constraints ensure the supply of Regulating Reserve within a specific Reserve Zone is greater than or equal to the Co-optimized Zonal Regulating Reserve Requirement.

The Co-optimized Reserve Zone Short-Term Reserve constraints ensure the supply of Short-Term Reserve within a specific Reserve Zone is greater than or equal to the Co-optimized Zonal Short-Term Reserve Requirement.

Electric Storage Resources Energy Storage Level constraints ensure the Electric Storage Resource units have sufficient Energy Storage Level to supply Energy, Operating Reserves, Up Ramp Capability, Down Ramp Capability, and Short-Term Reserve reliably.

D. Shortage and Surplus Conditions

Under shortage condition in the Day-Ahead EORM described in section 39.2.10, Hourly Emergency Maximum Limits are used in SCED-Pricing for Resources available to be dispatched up to Hourly Emergency Maximum Limits in SCED.

To appropriately value the emergency capacity that is designated as available during the shortage condition only, Proxy Offers will be established. The Proxy Offer is the maximum of the Emergency Tier I Offer Floor and the Energy Offer of the applicable capacity block, up to a maximum of the Energy Offer Hard Price Cap. The Emergency Tier I Offer Floor is established at the initiation of the shortage condition as the maximum of $500 and the highest available economic offer in the Energy Emergency Area with the costs of committing and dispatching Fast

Start Resources considered in the same way as that specified in Section II.A and Section II.B, up to a maximum of the Energy Offer Hard Price Cap. The Proxy Offer will be used in the SCED-Pricing algorithm specified in Section II.C for Resources' emergency dispatch range above the Hourly Economic Maximum Limit or the entire range for emergency commitments.

The Resource Limit Constraints of the SCED-Pricing algorithm specified in Section II.C are modified for emergency commitment of Resources that are not Fast Start Resources, to make such Resources eligible to set prices even if the Resources are scheduled to operate at their minimum limits. To achieve this, the SCED-Pricing algorithm allows fractional commitment of emergency committed Resources that are not Fast Start Resources for the purposes of setting prices, even though fractional commitment is not a physically achievable outcome. The SCED-Pricing algorithm represents the fraction of such a Resource that is committed in the Hour by a continuous decision variable, on_{hour}. The SCED-Pricing algorithm requires that on_{hour} satisfy

$$0 \leq on_{hour} \leq 1$$

If an emergency committed Resource that is not a Fast Start Resource is not committed to provide Regulation Reserves, the constraints for the Energy, Spinning Reserves, Up Ramp Capability, Down Ramp Capability, and Short-Term Reserve scheduled for such Resource in the SCED-Pricing algorithm will include the following. Let $EnergyDispatchSchedule_{hour}$ be the dispatch scheduled for the Resource in Hour *hour,* $SpinningReservesSchedule_{hour}$ be the Spinning Reserve Schedule for the Resource in Hour *hour,* $URCSchedule_{hour}$ be the Up Ramp Capability Schedule, $DRCSchedule_{hour}$ be the Down Ramp Capability Schedule, and $STRSchedule_{hour}$ be the

Short-Term Reserve Schedule for the Resource in Hour *hour* for the Resource in Hour *hour* in the SCED-Pricing algorithm.

$$on_{hour} \times EconMin_{hour} \leq EnergyDispatchSchedule_{hour} - DRCSchedule_{hour}$$

$$0 \leq SpinningReservesSchedule_{hour}$$

$$0 \leq URCSchedule_{hour}$$

$$0 \leq DRCSchedule_{hour}$$

$$0 \leq STRSchedule_{hour}$$

$$EnergyDispatchSchedule_{hour} + SpinningReservesSchedule_{hour} + URCSchedule_{hour} \leq on_{hour} \times EconMax_{hour}$$

$$EnergyDispatchSchedule_{hour} + STRSchedule_{hour} \leq on_{hour} \times EconMax_{hour}$$

If an emergency committed Resource that is not a Fast Start Resource is committed to provide Regulation Reserves, the constraints for the Energy, Spinning Reserves, Regulating Reserves, Up Ramp Capability, Down Ramp Capability, and Short-Term Reserve scheduled for such Resource in the SCED-Pricing algorithm include the following. Let $EnergyDispatchSchedule_{hour}$ be the dispatch scheduled for the Resource in Hour *hour*, $SpinningReservesSchedule_{hour}$ be the Spinning Reserve Schedule for the Resource in Hour *hour,* $RegulatingReservesSchedule_{hour}$ be the Regulating Reserve Schedule for the Resource in Hour *hour*, $URCSchedule_{hour}$ be the Up Ramp Capability Schedule, $DRCSchedule_{hour}$ be the Down Ramp Capability Schedule, and $STRSchedule_{hour}$ be the Short-Term Reserve Schedule for the Resource in Hour *hour* for the Resource in Hour *hour* in SCED-Pricing algorithm.

$$0 \leq SpinningReservesSchedule_{hour}$$

$$0 \leq RegulatingReservesSchedule_{hour}$$

$$0 \leq URCSchedule_{hour}$$

$$0 \leq DRCSchedule_{hour}$$

$$0 \leq STRSchedule_{hour}$$

$$on_{hour} \times RegMin_{hour} \leq EnergyDispatchSchedule_{hour} - RegulatingReservesSchedule_{hour} - DRCSchedule_{hour}$$

$$EnergyDispatchSchedule_{hour} + SpinningReservesSchedule_{hour} + RegulatingReservesSchedule_{hour} + URCSchedule_{hour} \leq on_{hour} \times RegMax_{hour}$$

$$EnergyDispatchSchedule_{hour} + STRSchedule_{hour} + \leq on_{hour} \times RegMax_{hour}$$

Although the SCED-Pricing algorithm allows the fractional commitment of emergency committed Resources that are not Fast Start Resources, the algorithm does not consider the costs of committing such Resources in price setting. As such, the objective function elements of emergency committed Resources that are not Fast Start Resources are the same in the SCED-Pricing algorithm as in the SCED algorithm.

Under Surplus Condition in the Day-Ahead EORM described in section 39.2.11, Emergency Minimum Limits are used in SCED-Pricing for Resources available to be dispatched down to Emergency Minimum Limits in SCED. In addition, during a Surplus Condition, the

commitment variable for all Fast Start Resource that were physically committed by the Transmission Provider are held at the value 1 in SCED-Pricing.

III. REAL-TIME FORMULATIONS

The Real-Time pricing formulation considers the cost of Energy, Regulating Reserves, Spinning Reserves, Up Ramp Capability, Down Ramp Capability, and Short-Term Reserves from Resources committed in the Dispatch Interval. It also considers the costs of Supplemental Reserves and Short-Term Reserves from offline or uncommitted Resources. In addition, the Real-Time Pricing formulation considers the costs of committing and the costs of keeping online those Fast Start Resources that the Transmission Provider committed either in the Day-Ahead Energy and Operating Reserve Market or in the RAC processes, to be on line in the Dispatch Interval. The Real-Time Pricing formulation also considers the costs of committing and the costs of keeping online those Emergency Operations Resources that the Transmission Provider committed in the RAC processes, to be on line in the Dispatch Interval. Emergency Operations Resources are only considered in Real-Time Pricing formulation when initiated by the Transmission Provider as specified in Emergency operating procedures. It also considers the costs of committing and dispatching offline Fast Start Resources that are available for the Transmission Provider to commit in the Dispatch Interval under conditions of Energy, Ancillary Service, or Short-Term Reserve scarcity or that could alleviate transmission constraint violations, except for the Capacity Surplus under Minimum Load Conditions in RT EORM described in section 40.2.21.b. If the Transmission Provider called upon Emergency Demand Response, the SCED-Pricing algorithm will also consider the cost of the Emergency Demand Response scheduled by the Transmission Provider.

Under capacity shortage conditions in RT EORM described in section 40.2.20, the SCED-Pricing algorithm will also consider the cost of resources that are scheduled by the Transmission Provider during Emergency operating procedures as specified by their Proxy Offers.

A. Online Resources

If an online Resource that is not a Fast Start Resource is committed by the Transmission Provider either in the Day-Ahead Energy and Operating Reserve Market or in the RAC processes to be online in the Dispatch Interval, the costs in the objective function for the Resource and the constraints on the Resource's Energy, Ancillary Service, Up Ramp Capability, Down Ramp Capability, and Short-Term Reserve Schedules in the SCED-Pricing problem are the same as those for the Resource in the simultaneously co-optimized SCED algorithm described in Schedule 29.

For a Fast Start Resource that was committed by the Transmission Provider either in the Day-Ahead Energy and Operating Reserve Market or in the RAC processes to be online in the Dispatch Interval, or an Emergency Operations Resource that was committed by the Transmission Provider in the RAC processes to be online in the Dispatch Interval, the SCED-Pricing algorithm considers the cost of committing and dispatching the Resource when setting prices. The SCED-Pricing algorithm considers the Resource eligible to set prices even if the Resource was scheduled to operate at its minimum or maximum limit. It also considers Start-Up Offer and No-Load Offer for Generation Resources and DRR– Type II which are Fast Start Resources, Emergency Operations Resources or Shut-Down Offer and Hourly Curtailment Offer for DRR – Type I which are Fast Start Resources or Emergency Operations Resources when

setting prices. To achieve this, the SCED-Pricing algorithm allows fractional commitment of a Fast Start Resource or an Emergency Operations Resource for purposes of setting prices, even though this is not a physically achievable outcome. SCED-Pricing represents the fraction of the Fast Start Resource or Emergency Operations Resource that is committed in the Dispatch Interval, *t*, for which prices are being calculated by the continuous decision variable on_t. The SCED-Pricing algorithm requires that on_t satisfy

$$0 \leq on_t \leq 1$$

The SCED-Pricing algorithm allocates a share of the Start-Up Cost or Shut-Down-Cost for the Fast Start Resource or Emergency Operations Resource to the interval for which prices are being calculated. In the following N is the minimum run time for Generation Resources or DRR – Type II, or the Minimum Interruption Duration for DRR – Type I, offered by the Fast Start Resource or Emergency Operations Resource in hours rounded up to the nearest five (5) minutes. The SCED-Pricing algorithm models the withdrawal associated with the Energy Dispatch Schedule of a DRR - Type I which is a Fast Start Resource at the Commercial Pricing Node specified for the DRR - Type I.

Generation Resources and DRR Type II

$AllocatedShareStartUpCost_t = StartUpCost / (N \times Intervals\ per\ Hour)$ *if t is within N hours of the time the Resource was committed, or 0 if t is later than N hours after the Generation Resource DRR – Type II was committed.*

DRR Type I

$AllocatedShareShutDownCost_{hour}$ = ShutDownCost / (N × Intervals per Hour) if hour is within N hours of the time the DRR - Type I was committed, or 0 if hour is later than N hours after the DRR - Type I was committed.

The SCED-Pricing algorithm allocates the No-Load Cost or Hourly Curtailment Cost for the Dispatch Interval to the Dispatch Interval for which prices are being calculated.

If the Fast Start Resource or Emergency Operations Resource was not committed to provide Regulation Reserves, the constraints for the Energy, Spinning Reserves, Up Ramp Capability, Down Ramp Capability, and Short-Term Reserves scheduled for the Fast Start Resource or Emergency Operations Resource in SCED-Pricing includes the following. Let $DispatchSchedule_t$ be the dispatch scheduled for the Resource in Dispatch Interval *t,* $URCSchedule_t$ be the Up Ramp Capability Schedule and $DRCSchedule_t$ be the Down Ramp Capability Schedule for the Resource in Dispatch Interval *t,* $SpinningReservesSchedule_t$ be the Spinning Reserve Schedule for the Resource in Dispatch Interval *t,* and $STRSchedule_t$ be the Short-Term Reserve Schedule for the Resource in Dispatch Interval *t* in SCED-Pricing.

$$on_t \times EconMin_t \leq EnergyDispatchSchedule_t - DRCSchedule_t$$

$$0 \leq SpinningReservesSchedule_t$$

$$0 \leq URCSchedule_t$$

$$0 \leq DRCSchedule_t$$

$$0 \leq STRSchedule_t$$

$$EnergyDispatchSchedule_t + SpinningReservesSchedule_t + URCSchedule_t \leq on_t \times EconMax_t$$

$$EnergyDispatchSchedule_t + STRSchedule_t \leq on_t \times EconMax_t$$

The ramping constraints affecting Energy, Spinning Reserve, Up Ramp Capability, Down Ramp Capability, and Short-Term Reserve schedules from the Fast Start Resource or Emergency Operations Resource in the SCED-Pricing algorithm are the same as those in the SCED algorithm unless the Fast Start Resource or Emergency Operations Resource is dispatched at its EconMin in the previous interval ($DispatchSchedule_{t-1} = EconMin_{t-1}$) in which case the down ramp constraint will be relaxed.

Generation Resource and DRR Type II

The objective function elements for the Fast Start Resource or Emergency Operations Resource for Generation Resource and DRR Type II include:

$$on_t \times (AllocatedShareStartUpCost_t + ({}^{NoLoadCost_t}/_{(Intervals\ per\ Hour)}))$$

$$+ \left(\int_0^{EnergyDispatchSchedule_t} IncrementalEnergyCost_t(x)dx\right) / (Intervals\ per\ Hour)$$

$$+ (SpinningOfferCost_t \times SpinningReservesSchedules_t) / (Intervals\ per\ Hour)$$

DRR Type I

The objective function elements for the DRR - Type I which is a Fast Start Resource or Emergency Operations Resource include:

$$On_t \times (AllocatedShareShutDownCost_t + (CurtailCost_t) / (Intervals\ per\ Hour))$$

$$+ \int_{0}^{EnergyDispatchSchedule_t} IncrementalEnergyCost_{hour}(x)dx / (Intervals\ per\ Hour)$$

If the Fast Start Resource or Emergency Operations Resource was committed to provide Regulation Reserves, the constraints for the Energy, Spinning Reserves, Regulating Reserves, Up Ramp Capability, Down Ramp Capability, and Short-Term Reserve scheduled for the Fast Start Resource in SCED-Pricing include the following. Let $DispatchSchedule_t$ be the dispatch level for the Resource in Dispatch Interval t, $SpinningReservesSchedule_t$ be the Spinning Reserve Schedule for the Resource in Dispatch Interval t, $RegulatingReservesSchedule_t$ be the Regulating Reserve Schedule for the Resource in Dispatch Interval t, $URCSchedule_t$ be the Up Ramp Capability Schedule, $DRCSchedule_t$ be the Down Ramp Capability Schedule for the Resource in Dispatch Interval t, and $STRSchedule_t$ be the Short-Term Reserve Schedule for the Resource in Dispatch Interval t in SCED-Pricing.

$$on_t \times RegMin_t \leq EnergyDispatchSchedule_t - RegulatingReservesSchedule_t - DRCSchedule_t$$

$$0 \leq SpinningReservesSchedule_t$$

$$0 \leq RegulatingReservesSchedule_t$$

$$0 \leq URCSchedule_t$$

$$0 \leq DRCSchedule_t$$

$0 \leq STRSchedule_t$

$Energy_t + SpinningReservesSchedule_t + RegulatingReservesSchedule_t + URCSchedule_t \leq on_t \times RegMax_t$

$Energy_t + STRSchedule_t \leq on_t \times RegMax_t$

The ramping constraints affecting Energy Reserve, Up Ramp Capability, Down Ramp Capability, and Short-Term Reserve schedules from the Fast Start Resource or Emergency Operations Resource in the SCED-Pricing algorithm are the same as those in the SCED algorithm unless the Fast Start Resource or Emergency Operations Resource is dispatched at its RegMin in the previous interval ($DispatchSchedule_{t-1} = RegMin_{t-1}$) in which case the down ramp constraint will be relaxed.

The objective function elements for the Fast Start Resource or Emergency Operations Resource include:

$on_t \times (AllocatedShareStartUpCost_t + (NoLoadCost_t / (Intervals\ per\ Hour)))$

$$+ \left(\int_0^{EnergyDispatchSchedule_t} IncrementalEnergyCost_t(x)dx\right) / (Intervals\ per\ Hour)$$

$$+ (SpinningOfferCost_t \times SpinningReservesSchedules_t) / (Intervals\ per\ Hour)$$

$$+ (RegulatingOfferCost_t \times RegulatingReservesSchedules_t) / (Intervals\ per\ Hour)$$

B. Offline Resources

Offline Fast Start Resources that are available to be committed by the Transmission Provider participate in SCED-Pricing if either or both of the following conditions hold:

a) The SCED algorithm finds a solution that does not meet energy and/or reserve requirements in the Dispatch Interval, except for the Capacity Surplus under Minimum Load Conditions in RT EORM described in section 40.2.21.b;

b) The SCED algorithm finds a solution that violates a transmission constraint for which the Transmission Provider is the monitoring entity and the Transmission Provider determines that commitment of the Fast Start Resource provides significant relief to the violation. For purposes of this provision, offline Resources with Generation Shift Factors either greater than or equal to 6% or less than or equal to – 6% are deemed to be providing significant relief to the transmission constraint violation.

In these scenarios, committing and dispatching an offline Fast Start Resource is an action that the Transmission Provider could take to address the shortage or violation. Rather than set price using a shortage cost or a transmission penalty price, the SCED-Pricing algorithm determines prices based on the action that the Transmission Provider could take to address the problem. The constraints for the Energy and Reserves scheduled for the Fast Start Resource in SCED-Pricing include the following. Let $DispatchSchedule_t$ be the dispatch scheduled for the Resource in Dispatch Interval *t,* $OffLineSupplementalReservesSchedule_t$ be the Off Line Supplemental Reserve Schedule, and $STRSchedule_t$ be the Short-Term Reserve Schedule for the

Generation Resource or DRR - Type II, and let $ContingencyReservesSchedule_t$ be the Reserves, whether Supplemental Reserves or Spinning Reserves, and $STRSchedule_t$ be the Short-Term Reserve Schedule for a DRR - Type I in Dispatch Interval *t* in SCED-Pricing**.**

The SCED-Pricing algorithm allocates a share of the commitment cost or curtailment cost for the Fast Start Resource to the Dispatch Interval(s) for which prices are being calculated. In the following equation, N is the minimum run time for Generation Resources or DRR - Type II, or the Minimum Interruption Duration for DRR - Type I, offered by the Fast Start Resource in hours, rounded up to the nearest five (5) minutes. M is the lesser of a predefined allocation time (the time to allocate commitment costs rounded up to the nearest five (5) minutes, in hours) and the minimum run time. The predefined allocation time will be set at four (4) Real-Time study intervals, i.e., 1/3 hour.

Generation Resources and DRR Type II

For Generation Resources and DRR - Type II:

$$on_t \times EconMin_t \leq EnergyDispatchSchedule_t \leq on_t \times EconMax_t$$

$$0 \leq OffLineSupplementalReservesSchedule_t$$

$$0 \leq STRSchedule_t$$

$$OffLineSupplementalReservesSchedule_t \leq (1 - on_t) \times min\{EconMax_t, MaxOfflineResponseLimit_t\}$$

$$STRSchedule_t \leq (1 - on_t) \times min\{EconMax_t, MaxOfflineSTRResponseLimit_t\}$$

$$N: Min\ run\ time_t\ (in\ hours);\ M: lesser\ \{Allocation\ time\ (in\ hours),\ Min\ run\ time_t\}$$

$$AllocatedShareCommitmentCost_t = (StartUpCost + NoLoadCost_t \times N + \max\{0, \int_0^{EconMin_t} IncrementalEnergyCost_t(x)dx - UDS\ SMP_t \times EconMin_t\} \times (N - M)) / (M \times Intervals\ per\ Hour)$$

Here $UDS\ SMP_t$ is the Marginal Energy Component from Economic Dispatch process at interval t.

DRR Type I

For DRR - Type I:

$$AllocatedShareCurtailmentCost_t = (ShutDownCost + CurtailCost_t \times N + \max\{0, \int_0^{EconMin_t} IncrementalEnergyCost_t(x)dx - UDS\ SMP_t \times EconMin_t\} \times (N - M)) / (M \times Intervals\ per\ Hour)$$

$$On_t \times EconMin_t \leq EnergyDispatchSchedule_t \leq on_t \times TargetedDemandReduction_t$$

$$0 \leq ContingencyReservesSchedule_t \leq (1 - on_t) \times TargetedDemandReduction_t$$

$$0 \leq STRSchedule_t \leq (1 - on_t) \times TargetedDemandReduction_t$$

Generation Resources and DRR Type II

The objective function elements for a Fast Start Resource which is either a Generation Resource or DRR Type II includes:

$on_t \times AllocatedShareCommitmentCost_t$

$$+ \int_{0}^{EnergyDispatchSchedule_t} IncrementalEnergyCost_t(x)dx) / (Intervals\ per\ Hour)$$

$+ (OffLineSupplementalOfferCost_t \times OffLineSupplementalReservesSchedules_t) / (Intervals\ per\ Hour)$

$+ (OffLineSTROfferCost_t \times STRSchedules_t) / (Intervals\ per\ Hour)$

DRR Type I

The objective function elements for the DRR Type I Resource which is a Fast Start Resource includes:

$on_t \times AllocatedShareCurtailmentCost_t$

$$+ \int_{0}^{EnergyDispatchSchedule_t} IncrementalEnergyCost_t(x)dx) / (Intervals\ per\ Hour)$$

$+ (ContingencyReservesOfferCost_t \times ContingencyReservesSchedules_t) / (Intervals\ per\ Hour)$

$+ (OffLineSTROfferCost_t \times STRSchedules_t) / (Intervals\ per\ Hour)$

where $ContingencyReservesOfferCost_t$ is the Spinning Reserve Offer if the DRR - Type I Resource is offering Spinning Reserve or Supplemental Reserves Availability Offer if it is offering Supplemental Reserves.

Emergency Demand Response Resources

For an Emergency Demand Response Resource that was scheduled by the Transmission Provider to provide Energy by reduction in Load (or increase in behind the meter generation) in the Dispatch Interval, the SCED-Pricing algorithm will consider the cost of committing the Resource to reduce Energy consumption and the incremental cost of Energy reduction from the Resource when setting prices. To achieve this, the SCED-Pricing algorithm allows the reduction of Energy consumption by the Emergency Demand Response Resource to be adjusted for pricing purposes. The SCED-Pricing algorithm models the withdrawal associated with the maximum reduction in power consumption of an Emergency Demand Response Resource at the Commercial Pricing Node specified for the Emergency Demand Response Resource. SCED-Pricing represents the fraction of the Emergency Demand Response Resource that committed by the SCED-Pricing algorithm in the Dispatch Interval t by the continuous decision variable on_t. SCED-Pricing algorithm requires that on_t satisfy

$$0 \leq on_t \leq 1$$

The SCED-Pricing algorithm allocates a share of the Shut-Down Cost for the Emergency Demand Response Resource to the interval for which prices are being calculated. In the following, N is the period of time in Hours for which the Transmission Provider scheduled reduction in Energy consumption from the Emergency Demand Resource, $EconMax_t$ is the

maximum reduction in power consumption in Dispatch Interval *t* that can be scheduled from the Emergency Demand Response Resource if called upon to reduce consumption in Dispatch Interval t, and $EconMin_t$ is the minimum reduction in power consumption in Dispatch Interval *t* that can be scheduled from the Emergency Demand Response Resource if called upon to provide reduce consumption in Dispatch Interval *t*. The allocation of Shut-Down Cost is then given by the following:

$$AllocatedShareShutDownCost_t = ShutDownCost/(N \times Intervals\ per\ Hour)$$

The constraints for the scheduled reduction from the Emergency Demand Response Resource in SCED-Pricing include the following:

$$on_t \times EconMin_t \leq EnergyReduction_t \leq on_t \times EconMax_t$$

The objective function elements for the Emergency Demand Response Resource includes:

$$on_t \times AllocatedShareShutDownCost_t$$

$$EnergyDispatchSchedule_t$$

$$+ \left(\int_0 IncrementalEnergyCost_t(x)dx\right) / (Intervals\ per\ Hour)$$

C. SCED – Pricing Algorithm

The SCED-Pricing algorithm is the same as the SCED algorithm, with the exceptions for treatment of Fast Start Resources, Emergency Operations Resources and Emergency Demand Response Resources described above.

Objective Function:

Minimize {Total Dispatch Interval Energy Costs

+ Total Dispatch Interval Commitment Costs for Fast Start Resources

+ Total Dispatch Interval Commitment Costs for Emergency Operations Resources

+Total Dispatch Interval Commitment Costs and Energy Reduction Costs for Emergency Demand Response Resources

+ Total Dispatch Interval Regulating Reserve Costs

+ Total Dispatch Interval Spinning Reserve Costs

+ Total Dispatch Interval Supplemental Reserve Costs

+ Total Dispatch Interval Short-Term Reserve Costs

- Total Dispatch Interval Market-Wide Operating Reserve Value

- Total Dispatch Interval Market-Wide Regulating and Spinning Reserve Value

- Total Dispatch Interval Market-Wide Regulating Reserve Value

- Total Dispatch Interval Market-Wide Up Ramp Capability Value

- Total Dispatch Interval Market-Wide Down Ramp Capability Value

- Total Dispatch Interval Market-Wide Short-Term Reserve Value}

Where

Total Dispatch Interval Energy Costs

= The sum of the Dispatch Interval Energy costs that would be incurred by all Resources supplying dispatchable Energy, based on their submitted Energy offer curves, if they were to operate according to the schedule produced by SCED-Pricing for the given Dispatch Interval.

Total Dispatch Interval Commitment Costs for Fast Start Resources

= The sum of the Dispatch Interval Start-Up Offer and No-Load Offer for Generation Resources and DRR – Type II, or Shut-Down Offer and Hourly Curtailment Offer for DRR – Type I that would be incurred by all Fast Start Resources available for commitment by the Transmission Provider, based on their submitted Start-Up, No-Load Offer, Shut-Down Offer, and Hourly Curtailment Offer, if they were to operate according to the commitment produced by SCED-Pricing for the given Dispatch Interval.

Total Dispatch Interval Commitment Costs for Emergency Operations Resources

= The sum of the Dispatch Interval Start-Up Offer and No-Load Offer for Generation Resources and DRR – Type II, or Shut-Down Offer and Hourly Curtailment Offer for DRR – Type I that would be incurred by all Emergency Operations Resources available for commitment by the Transmission Provider, based on their

submitted Start-Up, No-Load Offer, Shut-Down Offer, and Hourly Curtailment Offer, if they were to operate according to the commitment produced by SCED-Pricing for the given Dispatch Interval.

Total Dispatch Interval Commitment Costs and Energy Reduction Costs for Emergency Demand Response Resources

= The sum of the Dispatch Interval Shut-Down Offer and Energy Reduction Costs that would be incurred by Emergency Demand Response Resources, based on their submitted Shut-Down and Incremental Energy Reduction Offer Costs, if they were to operate according to the schedule produced by SCED-Pricing for the given Dispatch Interval.

Total Dispatch Interval Regulating Reserve Costs

= The sum of the Dispatch Interval Regulating Reserve costs, based on the Regulating Capacity Offer and Regulating Mileage Offer prices, that would be incurred by all Resources supplying dispatchable Regulating Reserve if they were to operate according to the schedule produced by SCED-Pricing algorithm for the given Dispatch Interval.

Total Dispatch Interval Spinning Reserve Costs

= The sum of the Dispatch Interval Spinning Reserve costs, based on the Spinning Reserve offer prices, that would be incurred by all

Resources supplying dispatchable Spinning Reserve if they were to operate according to the schedule produced by SCED-Pricing algorithm for the given Dispatch Interval.

Total Dispatch Interval Supplemental Reserve Availability Costs

= The sum of the Dispatch Interval Supplemental Reserve availability costs, based on the Supplemental Reserve offer prices, that would be incurred by all Resources supplying dispatchable Supplemental Reserve if they were to operate according to the schedule produced by SCED-Pricing algorithm for the given Dispatch Interval.

Total Dispatch Interval Short-Term Reserve Availability Costs

= The sum of the Dispatch Interval Short-Term Reserve availability costs, based on the Off-Line Short-Term Reserve Offer prices, that would be incurred by all Resources supplying dispatchable Short-Term Reserve if they were to operate according to the schedule produced by the SCED-Pricing algorithm for the given Dispatch Interval.

Total Dispatch Interval Market-Wide Operating Reserve Value

= The Dispatch Interval value of the Market-Wide Operating Reserve cleared by SCED-Pricing to the Load Serving Entities and Market Participant with Exports on whose behalf the Transmission

Provider is procuring Operating Reserves based on the Market-Wide Operating Reserve Demand Curve.

Total Dispatch Interval Market-Wide Regulating and Spinning Reserve Value

= The Dispatch Interval value of the Market-Wide Regulating and Spinning Reserve cleared by SCED-Pricing to the Load Serving Entities and Market Participants with Exports on whose behalf the Transmission Provider is procuring Regulating and Spinning Reserve based on the Market-Wide Regulating and Spinning Reserve Demand Curve.

Total Dispatch Interval Market-Wide Regulating Reserve Value

= The Dispatch Interval value of the Market-Wide Regulating Reserve cleared by SCED-Pricing to the Load Serving Entities on whose behalf the Transmission Provider is procuring Regulating Reserve based on the Market-Wide Regulating Reserve Demand Curve.

Total Dispatch Interval Market-Wide Up Ramp Capability Value

= The Dispatch Interval value of the cleared Market-Wide Up Ramp Capability to the Load Serving Entities and Market Participant with Exports on whose behalf the Transmission Provider is procuring Up Ramp Capability based on the Market-Wide Up Ramp Capability Demand Curve.

Total Dispatch Interval Market-Wide Down Ramp Capability Value

= The Dispatch Interval value of the cleared Market-Wide Down Ramp Capability to the Load Serving Entities and Market Participant with Exports on whose behalf the Transmission Provider is procuring Down Ramp Capability based on the Market-Wide Down Ramp Capability Demand Curve.

Total Dispatch Interval Market-Wide Short-Term Reserve Value

= The Dispatch Interval value of the cleared Market-Wide Short-Term Reserve to the Load Serving Entities and Market Participants with Exports on whose behalf the Transmission Provider is procuring Short-Term Reserve based on the Market-Wide Short-Term Reserve Demand Curve.

Constraints:

Subject to

Global Power Balance Constraint

Market-Wide Operating Reserve Constraint

Market-Wide Regulating and Spinning Reserve Constraint

Market-Wide Regulating Reserve Constraint

Market-Wide Non-DRR1 Operating Reserve Constraint

Market-Wide Non-DRR 1 Regulating and Spinning Reserve Constraint

Market-Wide Up Ramp Capability Constraint

Ramp Procurement Minimum Reserve Zone Up Ramp Capability Requirement Constraint

Market-Wide Down Ramp Capability Constraint

Ramp Procurement Minimum Reserve Zone Down Ramp Capability Requirement Constraint

Market-Wide Short-Term Reserve Constraint

Resource Limit Constraints

Resource Ramping Constraints

Transmission Constraints

Sub-Regional Power Balance Constraints in the Second Planning Area

Post Reserve Deployment Constraints

Co-optimized Reserve Zone Operating Reserve constraints

Co-optimized Reserve Zone Regulating and Spinning Reserve constraints

Co-optimized Reserve Zone Regulating Reserve constraints

Co-optimized Reserve Zone Short-Term Reserve constraints

Electric Storage Resource Energy Storage Level constraints

Where

The Global Power Balance Constraint ensures that the net Energy injected into the Eastern Interconnection model equals the net Energy withdrawn from the Eastern Interconnection model plus losses.

The Market-Wide Operating Reserve Constraint ensures the supply of Market-Wide Operating Reserve is greater than or equal to the Market-Wide Operating Reserve cleared by SCED-Pricing.

The Market-Wide Regulating and Spinning Reserve Constraint ensures that the supply of Market-Wide Regulating and Spinning Reserve is greater than or equal to the Market-Wide Regulating and Spinning Reserve requirement cleared by SCED-Pricing.

The Market-Wide Regulating Reserve Constraint ensures the supply of Market-Wide Regulating Reserve is greater than or equal to the Market-Wide Regulating Reserve cleared by SCED-Pricing.

The Market-Wide Non-DRR1 Operating Reserve Constraint ensures the percentage of Market-Wide Operating Reserve that is cleared by SCED-Pricing on Generation Resources, DRR – Type II, Electric Storage Resources, External Asynchronous Resources, and/or Distributed Energy Aggregated Resources complies with Applicable Reliability Standards.

The Market-Wide Non-DRR1 Regulating and Spinning Reserve Constraint ensures the percentage of Market-Wide Regulating and Spinning Reserve that is cleared by SCED-Pricing on Generation Resources, DRR – Type II, Electric Storage Resources, External Asynchronous Resources, and/or Distributed Energy Aggregated Resources complies with Applicable Reliability Standards.

The Market-Wide Up Ramp Capability Constraint ensures the supply of Market-Wide Up Ramp Capability is greater than or equal to the cleared demand for Market-Wide Up Ramp Capability.

The Ramp Procurement Minimum Reserve Zone Up Ramp Capability Requirement Constraint ensure that the cleared Up Ramp Capability in a zone can be converted to Energy when needed while respecting transmission constraints.

The Market-Wide Down Ramp Capability Constraint ensures the supply of Market-Wide Down Ramp Capability is greater than or equal to the cleared demand for Market-Wide Down Ramp Capability.

The Ramp Procurement Minimum Reserve Zone Down Ramp Capability Requirement Constraint ensure that the cleared Down Ramp Capability in a zone can be converted to Energy when needed while respecting transmission constraints.

The Market-Wide Short-Term Reserve Constraint ensures the supply of Market-Wide Short-Term Reserve is greater than or equal to the cleared demand for Market-Wide Short-Term Reserve.

The Resource Limit Constraints ensure that each Resource has the Capacity, based on submitted limits, to simultaneously supply cleared Energy, deploy one hundred percent (100%) of cleared Regulating Reserve in the upward direction, deploy one hundred percent (100%) of cleared Spinning Reserve, deploy one hundred percent (100%) of cleared Supplemental Reserve, change output in the upward direction one hundred percent (100%) of cleared Up Ramp Capability. The Resource Limit Constraints ensure that each Resource has the Capacity, based on submitted limits, to simultaneously supply cleared Energy and deploy one hundred percent (100%) of cleared Short term Reserve. In addition,

the Resource Limit Constraints ensure that each Resource has the ability to simultaneously supply cleared Energy deploy one hundred percent (100%) of the cleared Regulating Reserve in the downward direction, and change output in the downward direction one hundred percent (100%) of cleared Down Ramp Capability with no Spinning Reserve, Supplemental Reserve, or Short-Term Reserve deployment. For Fast Start Resources and Emergency Operations Resources, the upper limits and lower limits on capacity available to provide energy, reserves, Up Ramp Capability, Down Ramp Capability, and Short-Term Reserve are adjusted by the partial commitment level for the Resource determined by SCED-Pricing. For Emergency Demand Resources, the upper and lower limits on energy reduction are adjusted by the partial commitment level for the Resource as determined by SCED-Pricing.

The Resource Ramping Constraints ensure that each Resource is cleared in a manner to follow load based on cleared Energy levels in adjacent Dispatch Intervals. to deploy Regulating Reserve and Contingency Reserve in a manner that will comply with Applicable Reliability Standards, to support the cleared level of Up Ramp Capability and Down Ramp Capability, and to support the deployment of Short-Term Reserve.

The Transmission Constraints ensure that Energy is cleared by SCED-Pricing on Resources and Loads in such a way as to prevent flows on transmission flowgates and branches from exceeding normal operating limits under basecase conditions or Emergency operating limits under a first contingency loss of a

Resource or transmission facility. In addition, the Transmission Constraints also ensure that Operating Reserves can be deployed, Up Ramp Capability and Down Ramp Capability can be supplied, and Short-Term Reserve can be supplied in such a way as to prevent flows on transmission flowgates and branches from exceeding normal operating limits under basecase conditions or Emergency operating limits under a first contingency loss of a Resource or transmission facility. Moreover, the Transmission Constraints shall also ensure that Short-Term Reserves can be deployed in such a way as to prevent flows on transmission flowgates and branches from exceeding normal operating limits under basecase conditions or Emergency operating limits under a first contingency loss of a Resource or transmission facility.

The Sub-Regional Power Balance Constraints ensure that Energy flows within the Transmission Provider Region are managed consistent with applicable seams agreements, coordination agreements, transmission service agreements, or operating procedures. The Sub-Regional Power Balance Constraints also ensure that Operating Reserves can be deployed, Up Ramp Capability and Down Ramp Capability can be supplied, and Short-Term Reserve can be supplied in such a way as to prevent flows on Sub-Regional Power Balance Constraints from exceeding the appropriate limits.

The Post Reserve Deployment Constraints ensure that Operating Reserves and Short-Term Reserves can be deployed in such a way as to prevent flows on identified Transmission Constraints from exceeding the appropriate limits.

The Co-optimized Reserve Zone Operating Reserve constraints ensure the supply of Operating Reserve within a specific Reserve Zone is greater than or equal to the Co-optimized Zonal Operating Reserve Requirement.

The Co-optimized Reserve Zone Regulating and Spinning Reserve constraints ensure the supply of Regulating and Spinning Reserve within a specific Reserve Zone is greater than or equal to the Co-optimized Zonal Spinning Reserve Requirement plus the Co-optimized Zonal Regulating Reserve Requirement.

The Co-optimized Reserve Zone Regulating Reserve constraints ensure the supply of Regulating Reserve within a specific Reserve Zone is greater than or equal to the Co-optimized Zonal Regulating Reserve Requirement.

The Co-optimized Reserve Zone Short-Term Reserve constraints ensure the supply of Short-Term Reserve within a specific Reserve Zone is greater than or equal to the Co-optimized Zonal Short-Term Reserve Requirement.

Electric Storage Resource Energy Storage Level constraints ensure the Electric Storage Resource units have sufficient Energy Storage Level to supply Energy, Operating Reserves, Up Ramp Capability, Down Ramp Capability, and Short-Term Reserve reliably.

D. Shortage and Surplus Conditions

Under capacity shortage conditions in the Real-Time EORM described in section 40.2.20, Hourly Emergency Maximum Limits are used in SCED-Pricing for Resources available to be dispatched up to Hourly Emergency Maximum Limits in SCED.

Planning Resources and Emergency Demand Response resources scheduled by the Transmission Provider during Emergency operating procedures are also included in SCED-Pricing. To appropriately value the emergency resources that are designated as available during the capacity shortage conditions only, Proxy Offers will be established.

Under capacity shortage conditions specified in 40.2.20 (a)(i), the Proxy Offer for a Resource's emergency capacity is the maximum of the Emergency Tier I Offer Floor and the Energy Offer of the applicable capacity block, up to a maximum of the Energy Offer Hard Price Cap. The Proxy Offer for an External Resource that qualified as a Planning Resource equals the Emergency Tier I Offer Floor. The Emergency Tier I Offer Floor is established as the maximum of $500 and the highest available economic offer in the Energy Emergency Area, up to a maximum of the Energy Offer Hard Price Cap. The costs of committing and dispatching online and offline Fast Start Resources and online Emergency Operations Resources are considered when determining the Emergency Tier I offer Floor, in the same way as that specified in Section III.A. As such, for the purpose of determining the Emergency Tier I Offer Floor, the cost of committing offline Fast Start Resources are spread over minimum run time or Minimum Interruption Duration (as applicable), rather than as specified in Section III.B. The Proxy Offer specified above will be used in the SCED-Pricing algorithm specified in the Section III.C.

Under capacity shortage conditions specified in 40.2.20 (a)(ii), the Proxy Offer for a Load Modifying Resource not cross-registered as an Emergency Demand Response resource equals the Emergency Tier II Offer Floor. The Proxy Offer for an Emergency Demand Response resource is the maximum of the Emergency Tier II Offer Floor and the EDR Offer. The Proxy Offer for an Emergency Energy Purchase equals the Emergency Tier II Offer Floor. The

Emergency Tier II Offer Floor is established as the maximum of the immediately preceding Emergency Tier I Offer Floor (if applicable), $1000 and the highest available economic or emergency offer in the Energy Emergency Area, up to a maximum of the Energy Offer Hard Price Cap. The costs of committing and dispatching online and offline Fast Start Resources and online Emergency Operations Resources are considered when determining the Emergency Tier II Offer Floor, in the same way as that specified in Section III.A. As such, for the purpose of determining the Emergency Tier II Offer Floor, the cost of committing offline Fast Start Resources are spread over minimum run time or Minimum Interruption Duration (as applicable), rather than as specified in Section III.B.

With the establishment of Emergency Tier II Offer Floor, the Proxy Offer for a Resource's emergency capacity will be the maximum of the Emergency Tier II Offer Floor and the Energy Offer of the applicable capacity block, up to a maximum of the Energy Offer Hard Price Cap, and the Proxy Offer for an External Resource that qualified as a Planning Resource will equal the Emergency Tier II Offer Floor.

The Proxy Offers established above will be used in the SCED-Pricing algorithm specified in Section III.C.

The Resource Limit Constraints of the SCED-Pricing algorithm are modified for emergency commitment of Resources that are not Fast Start Resources or Emergency Operations Resources, to make such Resources eligible to set prices even if the Resources are scheduled to operate at their minimum limits. To achieve this, the SCED-Pricing algorithm allows fractional commitment of emergency committed Resources that are not Fast Start Resources or Emergency Operations Resources for the purposes of setting prices, even though fractional commitment is

not a physically achievable outcome. The SCED-Pricing algorithm represents the fraction of an emergency committed Resource that is not Fast Start Resource or Emergency Operations Resource in the Dispatch Interval, *t*, for which prices are being calculated by the continuous decision variable on_t. The SCED-Pricing algorithm requires that on_t satisfy

$$0 \leq on_t \leq 1$$

If an emergency committed Resource that is not a Fast Start Resource or Emergency Operations Resource is not committed to provide Regulation Reserves, the constraints for the Energy, Spinning Reserves, Up Ramp Capability, Down Ramp Capability, and Short-Term Reserve scheduled for such Resource in the SCED-Pricing algorithm includes the following. Let $EnergyDispatchSchedule_t$ be the dispatch scheduled for the Resource in Dispatch Interval *t,* $SpinningReservesSchedule_t$ be the Spinning Reserve Schedule for the Resource in Dispatch Interval *t,* $URCSchedule_t$ be the Up Ramp Capability Schedule, $DRCSchedule_t$ be the Down Ramp Capability Schedule for the Resource in Dispatch Interval *t, and* $STRSchedule_t$ be the Short-Term Reserve Schedule for the Resource in Dispatch Interval *t* in SCED-Pricing algorithm.

$$on_t \times EconMin_t \leq EnergyDispatchSchedule_t - DRCSchedule_t$$

$$0 \leq SpinningReservesSchedule_t$$

$$0 \leq URCSchedule_t$$

$$0 \leq DRCSchedule_t$$

$$0 \leq STRSchedule_t$$

$$EnergyDispatchSchedule_t + SpinningReservesSchedule_t + URCSchedule_t \leq on_t \times EconMax_t$$

$$EnergyDispatchSchedule_t + STRSchedule_t \leq on_t \times EconMax_t$$

If an emergency committed Resource that is not a Fast Start Resource or Emergency Operations Resource is committed to provide Regulation Reserves, the constraints for the Energy, Spinning Reserves, Regulating Reserves, Up Ramp Capability, Down Ramp Capability, and Short-Term Reserve scheduled for such Resource in the SCED-Pricing algorithm include the following. Let $EnergyDispatchSchedule_t$ be the dispatch level for the Resource in Dispatch Interval *t*, $SpinningReservesSchedule_t$ be the Spinning Reserve Schedule for the Resource in Dispatch Interval *t,* $RegulatingReservesSchedule_t$ be the Regulating Reserve Schedule for the Resource in Dispatch Interval *t,* $URCSchedule_t$ be the Up Ramp Capability Schedule, $DRCSchedule_t$ be the Down Ramp Capability Schedule for the Resource in Dispatch Interval *t,* $STRSchedule_t$ be the Short-Term Reserve Schedule for the Resource in Dispatch Interval *t* in SCED-Pricing algorithm.

$$on_t \times RegMin_t \leq EnergyDispatchSchedule_t - RegulatingReservesSchedule_t - DRCSchedule_t$$

$$0 \leq SpinningReservesSchedule_t$$

$$0 \leq RegulatingReservesSchedule_t$$

$$0 \leq URCSchedule_t$$

$$0 \leq DRCSchedule_t$$

$$0 \leq STRSchedule_t$$

$$EnergyDispatchSchedule_t + SpinningReservesSchedule_t + RegulatingReservesSchedule_t + URCSchedule_t \leq on_t \times RegMax_t$$

$$EnergyDispatchSchedule_t + STRSchedule_t \leq on_t \times RegMax_t$$

Although the SCED-Pricing algorithm allows the fractional commitment of emergency committed Resources that are not Fast Start Resources or Emergency Operations Resources, the algorithm does not consider the costs of committing such Resources in price setting. As such, the objective function elements of emergency committed Resources that are not Fast Start Resources or Emergency Operations Resources are the same in the SCED-Pricing algorithm as in the SCED algorithm.

To consider the Proxy Offers of External Resources that qualified as Planning Resources, Load Modifying Resources and Emergency Energy Purchases, the SCED-Pricing algorithm allows their schedule to be adjusted for pricing purposes. The SCED-Pricing algorithm models the withdrawal associated with the maximum reduction in power consumption of a Load Modifying Resource at the Commercial Pricing Node specified for the Load Modifying Resource. SCED-Pricing represents the fraction of External Resources that qualified as Planning Resources, Load Modifying Resources and Emergency Energy Purchases that are committed in

the Dispatch Interval *t* by the continuous decision variable on_t. SCED-Pricing algorithm requires that on_t satisfy

$$0 \leq on_t \leq 1$$

In the following, $EconMax_t$ and $EconMin_t$ are defined as the level of power supply in Dispatch Interval *t* scheduled by the Transmission Provider from an External Resource that qualified as a Planning Resource or an Emergency Energy Purchase if called upon to provide energy in Dispatch Interval *t*, or the reduction in power consumption in Dispatch Interval *t* scheduled by the Transmission Provider from a Load Modifying Resource if called upon to reduce consumption in Dispatch Interval *t*.

The constraints for the scheduled External Resource that qualified as a Planning Resource, Load Modifying Resource or Emergency Energy Purchase in SCED-Pricing include the following:

$$on_t \times EconMint \leq EnergyDispatchSchedule_t \leq on_t \times EconMax_t$$

The objective function element for the scheduled External Resource that qualified as a Planning Resource, Load Modifying Resource or Emergency Energy Purchase includes:

$EnergyDispatchSchedule_t$

$(\int ProxyOffer_t(x)dx) / (Intervals\ per\ Hour)$

0

Under Capacity Surplus Condition under Minimum Load Conditions in RT EORM described in section 40.2.21.b, Emergency Minimum Limits are used in SCED-Pricing for

Resources available to be dispatched down to Emergency Minimum Limits in SCED. In addition, during a Capacity Surplus Condition, the commitment variable for all Fast Start Resource that were physically committed by the Transmission Provider are held at the value 1 in SCED-Pricing.