Manual No. 002

Business Practices Manual

Energy and Operating Reserve Markets

Attachment D

Real-Time Energy and Operating Reserve Market Software Formulations and Business Logic

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List of Exhibits:

1. Introduction

This introduction to Attachment D to the Midcontinent Independent System Operator, Inc. (MISO) *Business Practices Manual (BPM) for Energy and Operating Reserve Markets* includes basic information about this BPM Attachment and the other MISO BPMs. The first section (Section 1.1) of this Introduction provides information about MISO's BPMs. The second section (Section 1.2) is an introduction to this BPM Attachment. The third section (Section 1.3) identifies other documents in addition to the BPMs, which can be used by the reader as references when reading this BPM.

1.1 Purpose of the MISO Business Practices Manuals

The BPMs developed by MISO provide background information, guidelines, business rules, and processes established by MISO for the operation and administration of the MISO markets, provisions of transmission reliability services, and compliance with MISO settlements, billing, and accounting requirements. A complete list of MISO BPMs is available for reference through MISO's website. All definitions in this document are as provided in the MISO Tariff, the NERC Glossary of Terms Used in Reliability Standards, or are as defined by this document.

1.2 Purpose of this Business Practices Manual Attachment

This Attachment D to the *BPM for Energy and Operating Reserve Markets* covers the software formulations and business logic used to implement the rules, design, and operational elements of MISO's Real-Time Energy and Operating Reserve Market.

This BPM Attachment conforms and complies with MISO's Open Access Transmission, Energy and Operating Reserve Markets Tariff (Tariff), the North American Electric Reliability Council (NERC), also known as the Electric Reliability Organization (ERO), operating policies, and the applicable Regional Reliability Organization (RRO) reliability principles, guidelines, and standards, and is designed to facilitate administration of efficient Energy and Operating Reserve Markets.

This BPM Attachment benefits readers who want answers to the following questions:

- What are the roles of MISO and the Market Participants (MPs) in the Real-Time Energy the Energy and Operating Reserve Markets?
- What are the basic concepts that one needs to know to interact with the Real-Time Energy and Operating Reserve Markets?
- What MP activities must be performed to engage in the Energy and Operating Reserve Markets?

1.3 References

Other reference information related to this BPM Attachment includes:

- Tariff of MISO, Inc.
- Agreement of Transmission Facilities Owners to Organize the Midcontinent Independent System Operator, Inc., a Delaware Non-Stock Corporation (referred to as “T.O. Agreement” or “TOA”)

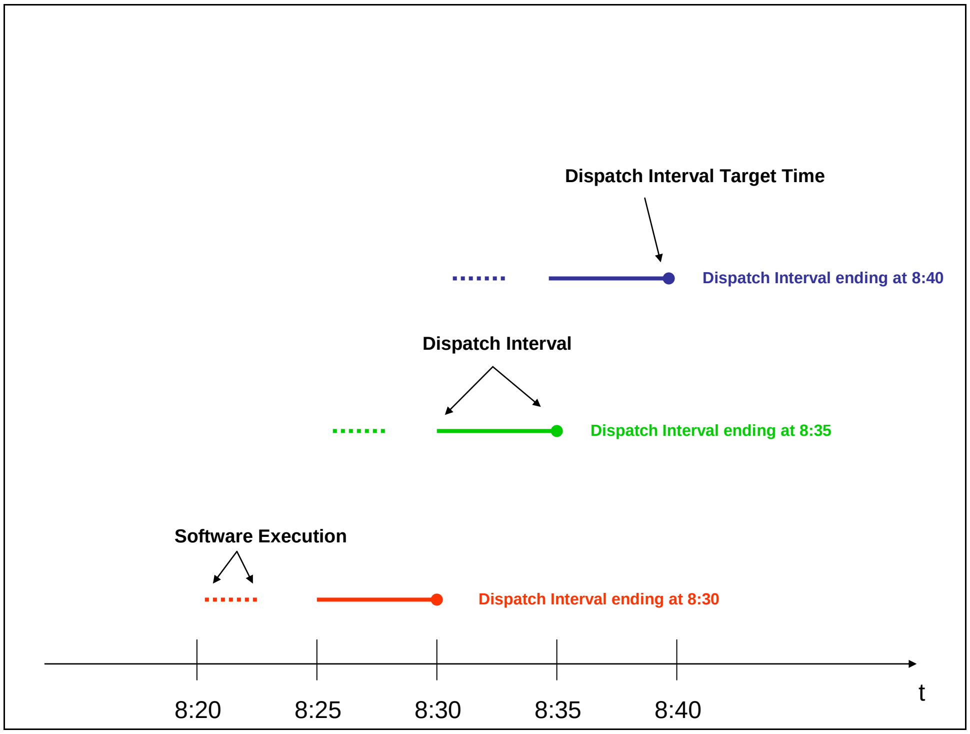
2. General Information

The Real-Time Energy and Operating Reserve Market software consists of the following processes:

- Pre-SCED Processing
- SCED Engine
- SCED-Pricing
- Post-SCED Processing

For a specific five-minute Dispatch Interval, the Real-Time Energy and Operating Reserve Market software begins executing approximately 9 minutes and 55 seconds prior to the end of the Dispatch Interval or approximately 4 minutes and 55 seconds prior to the beginning of the next Dispatch Interval. Therefore, all data used for the Real-Time Energy and Operating Reserve Market must be available approximately 10 minutes prior to the end of the Dispatch Interval or 5 minutes prior to the beginning of the next Dispatch Interval. The Real-Time Energy and Operating Reserve Market is cleared based on conditions projected for the Dispatch Interval Target Time, which is the time corresponding to the end of the Dispatch Interval. Exhibit 2-1 illustrates the Real-Time Energy and Operating Reserve Market software execution process:

Exhibit 2-1: Illustration of Real-Time Market Software Execution Process



Attachment D outlines the software formulation and business requirements for the Real-Time Energy and Operating Reserve Market.

3. Pre-SCED Processing

Pre-SCED processing includes the data calculations and data processing performed just prior to the execution of the SCED engine. The results of pre-SCED processing are used by the SCED algorithm. Pre-SCED processing establishes the following:

3.1 On-Line Flag

The on-line flag is determined for each Resource and Dispatch Interval prior to executing the SCED algorithm. A Resource must meet certain conditions in order to be considered on-line. The on-line flag is designated in the formulations as **OnLineFlag(r,di)** and will be set to 1 whenever a specific Resource is determined to be on-line for a specific Dispatch Interval.

3.1.1 On-Line Flag – Conventional Generation Resources and Demand Response Resources – Type II

Generation Resources (other than combined-cycle Generation Resources and Dispatchable Intermittent Resources) and Demand Response Resources – Type II will be considered on-line in the Real-Time Energy and Operating Reserve Market during a specific Dispatch Interval as long as the following conditions apply:

- The most recent State Estimator output for the Resource is greater than (or equal to) 0.5 MW or less than (or equal to) -0.5 MW.
- The most recent State Estimator breaker status for the Resource is closed.
- The Resource has not tripped off-line within the last 15 minutes based on data from active Contingency Reserve deployments.

  NOTE: The submitted ICCP Control Mode of a Resource does not impact the on-line flag due to time lag issues.

3.1.2 On-Line Flag – Aggregate Combined-Cycle Generation Resources

An aggregate combined-cycle Generation Resource will be considered on-line in the Real-Time Energy and Operating Reserve Market during a specific Dispatch Interval as long as the following conditions apply:

- The most recent State Estimator output for at least one of the individual Generation Resources that make up the aggregate Resource is greater than (or equal to) 0.5 MW or less than (or equal to) -0.5 MW.
- The most recent State Estimator breaker status for at least one of the individual Generation Resources that make up the aggregate Resource is closed.
- The Resource has not tripped off-line within the last 15 minutes based on data from active Contingency Reserve deployments.

- The Combined Cycle Status for the Resource is set to ***Aggregate*** for the day.
  NOTE: The submitted ICCP Control Modes of the individual generation Resources that make up the aggregate Resource do not impact the on-line flag due to time lag issues.

3.1.3 On-Line Flag – Individual Combined-Cycle Generation Resources

An individual Generation Resource that is part of an aggregate combined-cycle Resource will be considered on-line in the Real-Time Energy and Operating Reserve Market during a specific Dispatch Interval as long as the following conditions apply:

- The most recent State Estimator output for the individual Generation Resource is greater than (or equal to) 0.5 MW or less than (or equal to) -0.5 MW.
- The most recent State Estimator breaker status for the individual Generation Resource is closed.
- The individual Resource has not tripped off-line within the last 15 minutes based on data from active Contingency Reserve deployments.
- The Combined Cycle Status for the parent aggregate combined-cycle Generation Resource is set to ***Individual*** for the day.
  NOTE: The submitted ICCP Control Mode of the individual Generation Resource does not impact the on-line flag due to time lag issues.

3.1.4 On-Line Flag – Dispatchable Intermittent Resources

An individual Dispatchable Intermittent Resource will be considered on-line in the Real-Time Energy and Operating Reserve Market during a specific Dispatch Interval as long as the following conditions apply:

- The resource has been committed by a prior Day-Ahead or Real-Time process.
- The most recent State Estimator breaker status for the Resource is closed.
- The most recent State Estimator output for the individual Generation Resource is greater than 0 MW.

NOTE: The submitted ICCP Control Mode of a Resource does not impact the on-line flag due to time lag issues.

3.1.5 On-Line Flag – External Asynchronous Resources

An External Asynchronous Resource will be considered on-line in the Real-Time Energy and Operating Reserve Market during a specific Dispatch Interval as long as the following conditions apply:

- The resource Availability Status is set to ***Available***.

- The most recent State Estimator breaker status for the External Asynchronous Resource is closed.
- The External Asynchronous Resource has an active, non-zero Fixed Dynamic Interchange Schedule Import Schedule and/or Fixed Dynamic Interchange Schedule Export Schedule.

3.1.6 On-Line Flag – Electric Storage Resources

An Electric Storage Resource will be considered on-line in the Real-Time Energy and Operating Reserve Market during a specific Dispatch Interval as long as the following conditions apply:

- The Commitment Status is 'DC','CE' or 'CO' in normal condition and 'DE' or 'CE' in emergency condition.
- The most recent State Estimator output for the Resource is greater than (or equals to) 0.1 MW or less than (or equals to) -0.1 MW.
- The most recent State Estimator breaker status for the Resource is closed.
- The Resource has not tripped off-line within the last 15 minutes based on data from active Contingency Reserve deployments.
- **NOTE:** The submitted ICCP Control Mode of a Resource does not impact the on-line flag due to time lag issues.

3.2 Off-Line Supplemental Reserve Availability

The off-line Supplemental Reserve availability is determined for each Resource and Dispatch Interval prior to executing the SCED algorithm. A Resource must meet certain conditions in order to be considered available for off-line Supplemental Reserve in a specific Dispatch Interval. Dispatchable Intermittent Resources, Demand Response Resources - Type I and External Asynchronous Resources are not available to provide off-line Supplemental Reserve. A Resource must be available to provide off-line Supplemental Reserve in a specific Dispatch Interval in order to be cleared for off-line Supplemental Reserve by SCED for that Dispatch Interval. The off-line Supplemental Reserve availability is designated in the formulations as **OffLineSupAvailability(r,di)** and will be set to 1 whenever a specific Resource is available to clear off-line Supplemental Reserve in a specific Dispatch Interval.

3.2.1 Off-line Supplemental Reserve Availability – Conventional Generation Resources and Demand Response Resources – Type II

Generation Resources (other than combined-cycle Generation Resources) and Demand Response Resources – Type II will be available to provide off-line Supplemental Reserve in the

Real-Time Energy and Operating Reserve Market during a specific Dispatch Interval as long as the following conditions apply:

- The Off-Line Supplemental Reserve Dispatch Status for the Generation Resource or Demand Response Resource - Type II during the Dispatch Interval is not set to ***Not Participating***.
  NOTE: If a Resource was cleared for off-line Supplemental Reserve in the Day-Ahead Energy and Operating Reserve Market, the Off-Line Supplemental Reserve Dispatch Status in the Real-Time Energy and Operating Reserve Market cannot be set to ***Not Participating***.
- The Off-Line Supplemental Reserve Dispatch Status for the Generation Resource or Demand Response Resource - Type II during the Dispatch Interval is not set to **Emergency**.
  NOTE: This condition applies only when a shortage condition has not been declared.
- The Off-Line Supplemental Reserve Dispatch Status for the Generation Resource or Demand Response Resource- Type II during the Dispatch Interval is not set to **Not Qualified**.
- The Commitment Status for the Generation Resource or Demand Response Resource - Type II during the Dispatch Interval is not set to **Outage**.
- The Outage Scheduler outage type listed for the Generation Resource or Demand Response Resource - Type II is not set to Out of Service.
- The On-Line Flag of the Generation Resource or Demand Response Resource - Type II is set to 0 for the Dispatch Interval.The Generation Resource or Demand Response Resource- Type II is qualified during the asset registration process as a Quick-Start Resource capable of supplying off-line Supplemental Reserve.
- The Minimum Run Time of the Generation Resource or the Minimum Interruption Duration of the Demand Response Resource – Type II is set to 180 minutes or less.
- The Generation Resource or Demand Response Resource - Type II has been off-line for a period of time greater than or equal to the real-time minimum down time submitted for the Resource for the day.
- The Resource has not tripped off-line within the last 15 minutes based on data from active Contingency Reserve deployments.

3.2.2 Off-line Supplemental Reserve Availability – Aggregate Combined-Cycle Generation Resources

An aggregate combined-cycle Generation Resource will be available to provide off-line Supplemental Reserve in the Real-Time Energy and Operating Reserve Market during a specific Dispatch Interval as long as the following conditions apply:

- The Off-Line Supplemental Reserve Dispatch Status for the aggregate combined-cycle Generation Resource for the Dispatch Interval is not set to ***Not Participating***.
  NOTE: If a Resource was cleared for off-line Supplemental Reserve in the Day-Ahead Energy and Operating Reserve Market, the Off-Line Supplemental Reserve Dispatch Status in the Real-Time Energy and Operating Reserve Market cannot be set to ***Not Participating***.
- The Off-Line Supplemental Reserve Dispatch Status for the aggregate combined-cycle Generation Resource during the Dispatch Interval is not set to ***Emergency***.
  NOTE: This condition applies only when a shortage condition has not been declared.
- The Off-Line Supplemental Reserve Dispatch Status for the aggregate combined-cycle Generation Resource during the Dispatch Interval is not set to ***Not Qualified***.
- The Commitment Status for the aggregate combined-cycle Generation Resource during the Dispatch Interval is not set to ***Outag***e.
- The Outage Scheduler outage type listed for at least one of the individual Generation Resources that make up the aggregate combined-cycle Generation Resource during the Dispatch Interval is not set to ***Out of Service***.
- The On-Line Flag of the Generation aggregate combined-cycle Generation Resource is set to 0 for the Dispatch Interval.
- The aggregate combined-cycle Generation Resource is qualified during the asset registration process as a Quick-Start Resource capable of supplying off-line Supplemental Reserve.
- The Minimum Run Time of the Aggregate Combined Cycle Generation Resource is set to 180 minutes or less.
- The aggregate combined-cycle Generation Resource has been off-line for a period of time greater than or equal to the real-time minimum down time submitted for the Resource for the day.
- The Resource has not tripped off-line within the last 15 minutes based on data from active Contingency Reserve deployments.
- The Combined Cycle Status for the Resource is set to ***Aggregate*** for the day.

3.2.3 Off-line Supplemental Reserve Availability – Individual Combined-Cycle Generation Resources

An individual Generation Resource that is part of an aggregate combined-cycle Generation Resource will be available to provide off-line Supplemental Reserve in the Real-Time Energy and Operating Reserve Market as an individual Generation Resource during a specific Dispatch Interval as long as the following conditions apply:

- The Off-Line Supplemental Reserve Dispatch Status for the individual Generation Resource for the Dispatch Interval is not set to ***Not Participating***.
  NOTE: If a Resource was cleared for off-line Supplemental Reserve in the Day-Ahead Energy and Operating Reserve Market, the Off-Line Supplemental Reserve Dispatch Status in the Real-Time Energy and Operating Reserve Market cannot be set to ***Not Participating***.
- The Off-Line Supplemental Reserve Dispatch Status for the individual Generation Resource during the Dispatch Interval is not set to ***Emergency***.
  NOTE: This condition applies only when a shortage condition has not been declared.
- The Off-Line Supplemental Reserve Dispatch Status for the individual Generation Resource during the Dispatch Interval is not set to ***Not Qualified***.
- The Commitment Status for the individual Generation Resource during the Dispatch Interval is not set to ***Outage***.
- The Outage Scheduler outage type listed for the individual Generation Resource is not set to ***Out of Service***.
- The On-Line Flag of the individual Generation Resource is set to 0 for the Dispatch Interval.
- The individual Generation Resource is qualified during the asset registration process as a Quick-Start Resource capable of supplying off-line Supplemental Reserve.
- The Minimum Run Time of the individual Generation Resource is set to 180 minutes or less.
- The individual Generation Resource has been off-line for a period of time greater than or equal to the real-time minimum down time submitted for the Resource for the day.
- The Resource has not tripped off-line within the last 15 minutes based on data from active Contingency Reserve deployments.
- The Combined Cycle Status for the parent aggregate combined-cycle Generation Resource is set to ***Individual*** for the day.

3.2.4 Off-line Supplemental Reserve Availability – Electric Storage Resources

Electric Storage Resources will be available to provide off-line Supplemental Reserve in the Real-Time Energy and Operating Reserve Market during a specific Dispatch Interval as long as the Commitment Status is Available.

3.3 Regulating Reserve Availability

The Regulating Reserve availability is determined for each Resource and Dispatch Interval prior to executing the SCED algorithm. A Resource must meet certain conditions in order to be considered available to provide Regulating Reserve. Dispatchable Intermittent Resources and

Demand Response Resources - Type I are not available to provide Regulating Reserve. A Resource must be available to provide Regulating Reserve in a specific Dispatch Interval in order to be cleared for Regulating Reserve by SCED for that Dispatch Interval. The Regulating Reserve availability is designated in the formulations as **RegAvailability(r,di)** and will be set to 1 whenever a specific Resource is available to provide Regulating Reserve in a specific Dispatch Interval.

3.3.1 Regulating Reserve Availability – Generation Resources and Demand Response Resources – Type II

Generation Resources and Demand Response Resources - Type II will be available to provide Regulating Reserve in the Real-Time Energy and Operating Reserve Market during a specific Dispatch Interval as long as the following conditions apply:

- The Generation Resource or Demand Response Resource - Type II is on-line (i.e., the On-Line Flag for the Resource and Dispatch Interval is set to 1).
- The Generation Resource or Demand Response Resource - Type II is registered during the asset registration process as a Regulation Qualified Resource capable of supplying Regulating Reserve.
- The Regulating Reserve Dispatch Status for the Generation Resource or Demand Response Resource - Type II during the Dispatch Interval is not set to ***Not Participating***.

  NOTE: If a Resource was cleared for Regulating Reserve in the Day-Ahead Energy and Operating Reserve Market, the Regulating Reserve Dispatch Status in the Real-Time Energy and Operating Reserve Market cannot be set to ***Not Participating***.
- The Regulating Reserve Dispatch Status for the Generation Resource or Demand Response Resource - Type II during the Dispatch Interval is not set to ***Not Qualified***.

3.3.2 Regulating Reserve Availability – External Asynchronous Resources

External Asynchronous Resources will be available to provide Regulating Reserve in the Real-Time Energy and Operating Reserve Market during a specific Dispatch Interval as long as the following conditions apply:

- The External Asynchronous Resource is on-line (i.e., the On-Line Flag for the External Asynchronous Resource in the Dispatch Interval is set to 1) during the Dispatch Interval.
- The External Asynchronous Resource is registered during the asset registration process as a Regulation Qualified Resource capable of supplying Regulating Reserve.
- The Regulating Reserve Dispatch Status for the External Asynchronous Resource during the Dispatch Interval is not set to ***Not Participating***.

- The Regulating Reserve Dispatch Status for the External Asynchronous Resource during the Dispatch Interval is not set to ***Not Qualified***.

3.3.3 Regulating Reserve Availability – Electric Storage Resources

An Electric Storage Resource will be available to provide Regulating Reserve in the Real-Time Energy and Operating Reserve Market during a specific Dispatch Interval as long as the following conditions apply:

- The Electric Storage Resource is on-line (i.e., the On-Line Flag for the Resource and Dispatch Interval is set to 1) and Commitment Status is in 'DC', 'CH' or 'CO'.
- The Electric Storage Resource is registered during the asset registration process as a Regulation Qualified Resource capable of supplying Regulating Reserve.
- The Regulating Reserve Dispatch Status for the Electric Storage Resource during the Dispatch Interval is not set to ***Not Participating***.

  NOTE: If a Resource was cleared for Regulating Reserve in the Day-Ahead Energy and Operating Reserve Market, the Regulating Reserve Dispatch Status in the Real-Time Energy and Operating Reserve Market cannot be set to ***Not Participating***.
- The Regulating Reserve Dispatch Status for the Electric Storage Resource during the Dispatch Interval is not set to ***Not Qualified***.

3.4 Spinning Reserve Availability

The Spinning Reserve availability is determined for each Resource and Dispatch Interval prior to executing the SCED algorithm. A Resource must meet certain conditions in order to be considered available to provide Spinning Reserve. Dispatchable Intermittent Resources are not available to provide Spinning Reserve. A Resource must be available to provide Spinning Reserve in a specific Dispatch Interval in order to be cleared for Spinning Reserve by SCED for that Dispatch Interval. The Spinning Reserve availability is designated in the formulations as **SpinAvailability(r,di)** and will be set to 1 whenever a specific Resource is available to provide Spinning Reserve in a specific Dispatch Interval.

3.4.1 Spinning Reserve Availability – Generation Resources and Demand Response Resources – Type II

Generation Resources and Demand Response Resources - Type II will be available to provide Spinning Reserve in the Real-Time Energy and Operating Reserve Market during a specific Dispatch Interval as long as the following conditions apply:

- The Generation Resource or Demand Response Resource - Type II is on-line (i.e., the On-Line Flag for the Resource and Dispatch Interval is set to 1).

- The Generation Resource or Demand Response Resource - Type II is registered during the asset registration process as a Spin Qualified Resource capable of supplying Spinning Reserve.
- The Spinning Reserve Dispatch Status for the Generation Resource or Demand Response Resource - Type II during the Dispatch Interval is not set to ***Not Qualified***.

3.4.2 Spinning Reserve Availability – External Asynchronous Resources

External Asynchronous Resources will be available to provide Spinning Reserve in the Real-Time Energy and Operating Reserve Market during a specific Dispatch Interval as long as the following conditions apply:

- The External Asynchronous Resource on-line (i.e., the On-Line Flag for the External Asynchronous Resource in the Dispatch Interval is set to 1) during the Dispatch Interval.
- The External Asynchronous Resource is registered during the asset registration process as a Spin Qualified Resource capable of supplying Spinning Reserve.
- The Spinning Reserve Dispatch Status for the External Asynchronous Resource during the Dispatch Interval is not set to ***Not Qualified***.

3.4.3 Spinning Reserve Availability – Demand Response Resources – Type I

Demand Response Resources - Type I will be available to provide Spinning Reserve in the Real-Time Energy and Operating Reserve Market during a specific Dispatch Interval as long as the following conditions apply:

- The Demand Response Resource - Type I is not committed.
- The Demand Response Resource - Type I is registered during the asset registration process as a Spin Qualified Resource capable of supplying Spinning Reserve.
- The Spinning Reserve Dispatch Status for the Demand Response Resource - Type I during the Dispatch Interval is not set to ***Not Qualified***.
- The Spinning Reserve Dispatch Status for the Demand Response Resource - Type I during the Dispatch Interval is not set to ***Not Participating***.
- The Contingency Reserve Status for the Demand Response Resource – Type I during the day is set to “online”.
- The Spinning Reserve Dispatch Status for the Demand Response Resource - Type I during the Dispatch Interval is not set to ***Emergency***.
  NOTE: This condition applies only when a shortage condition has not been declared.

3.4.4 Spinning Reserve Availability – Electric Storage Resources

An Electric Storage Resource will be available to provide Spinning Reserve in the Real-Time Energy and Operating Reserve Market during a specific Dispatch Interval as long as the following conditions apply:

- The Electric Storage Resource is on-line (i.e., the On-Line Flag for the Resource and Dispatch Interval is set to 1).
- The Electric Storage Resource is registered during the asset registration process as a Spin Qualified Resource capable of supplying Spinning Reserve.
- The Spinning Reserve Dispatch Status for the Electric Storage Resource during the Dispatch Interval is not set to ***Not Qualified***.

3.5 Supplemental Reserve Availability

The Supplemental Reserve availability is determined for each Resource and Dispatch Interval prior to executing the SCED algorithm. A Resource must meet certain conditions in order to be considered available to provide Supplemental Reserve. Dispatchable Intermittent Resources are not available to provide Supplemental Reserve. A Resource must be available to provide Supplemental Reserve in a specific Dispatch Interval in order to be cleared for Supplemental Reserve by SCED for that Dispatch Interval. The Supplemental Reserve availability is designated in the formulations as **SupAvailability(r,di)** and will be set to 1 whenever a specific Resource is available to provide Supplemental Reserve in a specific Dispatch Interval.

3.5.1 Supplemental Reserve Availability – Generation Resources and Demand Response Resources - Type II

Generation Resources and Demand Response Resources - Type II will be available to provide Supplemental Reserve in the Real-Time Energy and Operating Reserve Market during a specific Dispatch Interval as long as the following conditions apply:

- The Generation Resource or Demand Response Resource - Type II is on-line (i.e., the On-Line Flag for the Resource and Dispatch Interval is set to 1).
- The Generation Resource or Demand Response Resource - Type II is registered during the asset registration process as a Supplemental Qualified Resource capable of supplying Supplemental Reserve.
- The On-Line Supplemental Reserve Dispatch Status for the Generation Resource or Demand Response Resource - Type II during the Dispatch Interval is not set to ***Not Qualified***.

3.5.2 Supplemental Reserve Availability – External Asynchronous Resources

External Asynchronous Resources will be available to provide Supplemental Reserve in the Real-Time Energy and Operating Reserve Market during a specific Dispatch Interval as long as the following conditions apply:

- The External Asynchronous Resource is on-line (i.e., the On-Line Flag for the External Asynchronous Resource in the Dispatch Interval is set to 1).during the Dispatch Interval.
- The External Asynchronous Resource is registered during the asset registration process as a Supplemental Qualified Resource capable of supplying Supplemental Reserve.
- The Supplemental Reserve Dispatch Status for the External Asynchronous Resource during the Dispatch Interval is not set to ***Not Qualified***.

3.5.3 Supplemental Reserve Availability – Demand Response Resources – Type I

Demand Response Resources - Type I will be available to provide Supplemental Reserve in the Real-Time Energy and Operating Reserve Market during a specific Dispatch Interval as long as the following conditions apply:

- The Demand Response Resource - Type I is not committed.
- The Demand Response Resource - Type I is registered during the asset registration process as a Supplemental Qualified Resource capable of supplying Supplemental Reserve.
- The Supplemental Reserve Dispatch Status for the Demand Response Resource - Type I during the Dispatch Interval is not set to ***Not Qualified***.
- The Supplemental Reserve Dispatch Status for the Demand Response Resource - Type I during the Dispatch Interval is not set to ***Not Participating***.
- The Contingency Reserve Status for the Demand Response Resource – Type I during the day is set to “offline”.
- The Contingency Reserve Status for the Demand Response Resource – Type I during the day is set to “online”, and the following is true: the Demand Response Resource – Type I is not registered as a Spin Qualified Resource, or its Spinning Reserve Dispatch Status is set to either Not Qualified or Not Participating.
- The Supplemental Reserve Dispatch Status for the Demand Response Resource - Type I during the Dispatch Interval is not set to ***Emergency***.
  NOTE: This condition applies only when a shortage condition has not been declared.

3.5.4 Supplemental Reserve Availability – Electric Storage Resources

An Electric Storage Resource will be available to provide Supplemental Reserve in the Real-Time Energy and Operating Reserve Market during a specific Dispatch Interval as long as the following conditions apply:

- The Electric Storage Resource is on-line (i.e., the On-Line Flag for the Resource and Dispatch Interval is set to 1).
- The Electric Storage Resource is registered during the asset registration process as a Supplemental Qualified Resource capable of supplying Supplemental Reserve.
- The On-Line Supplemental Reserve Dispatch Status for the Electric Storage Resource during the Dispatch Interval is not set to ***Not Qualified***.

3.6 On-Line Short Term Reserve Availability

The On-Line Short Term Reserve availability is determined for each resource and Dispatch Interval prior to executing the SCED algorithm. A resource must meet certain conditions in order to be considered available to provide On-Line Short Term Reserve. Demand Response Resources – Type I are not available to provide On-Line Short Term Reserve. A resource must be available to provide On-Line Short Term Reserve in a specific Dispatch Interval in order to be dispatched for On-Line Short Term Reserve by SCED. The on-line Short Term Reserve availability is designated in the formulations as **OnlineSupAvailability(r,di)** and will be set to 1 whenever a specific resource is available to provide on-line Short Term Reserve in a specific Dispatch Interval.

3.6.1 On-Line Short Term Reserve Availability – Generation Resources and Demand Response Resources – Type II

Generation Resources (other than Intermittent Resources and Dispatchable Intermittent Resources) and Demand Response Resources - Type II will be available to provide Short Term Reserve in SCED during a specific Dispatch Interval as long as the following conditions apply:

- The Generation Resource or Demand Response Resource - Type II is on-line (i.e., the On-Line Flag for the Resource and Dispatch Interval is set to 1).
- The On-Line Short Term Reserve Dispatch Status for the Generation Resource or Demand Response Resource - Type II during the dispatch interval must be set to ***Economic***

3.6.2 On-Line Short Term Reserve Availability – External Asynchronous Resources

External Asynchronous Resources will be available to provide On-Line Short Term Reserve in the SCED during a specific Dispatch Interval if the following conditions apply:

- The External Asynchronous Resource on-line (i.e., the On-Line Flag for the External Asynchronous Resource in the Dispatch Interval is set to 1) during the Dispatch Interval.
- The On-Line Short Term Reserve Dispatch Status for the External Asynchronous Resource during the Dispatch Interval must set to **Economic**.

3.6.3 On-Line Short Term Reserve Availability – Electric Storage Resources

An Electric Storage Resource will be available to provide On-Line Short Term Reserve in the SCED during a specific Dispatch Interval if the following conditions apply:

- The Electric Storage Resource is on-line (i.e., the On-Line Flag for the Electric Storage Resource in the Dispatch Interval is set to 1) during the Dispatch Interval.
- The On-Line Short Term Reserve Dispatch Status for the Electric Storage Resource during the Dispatch Interval must be set to **Economic**.

3.7 Off-Line Short Term Reserve Availability

The Off-Line Short Term Reserve availability is determined for each resource and Dispatch Interval prior to executing the SCED algorithm. A resource must meet certain conditions in order to be considered available to provide Off-Line Short Term Reserve. External Asynchronous Resources and Demand Response Resources – Type I are not available to provide Off-Line Short Term Reserve. A resource must be available to provide Off-Line Short Term Reserve in a specific Dispatch Interval cleared for Short Term Reserve by SCED for that Dispatch Interval. The off-line Short Term Reserve availability is designated in the formulations as **OfflineSTRAvailability(r,di)** and will be set to 1 whenever a specific resource is available to provide off-line Short Term Reserve in a specific Dispatch Interval

3.7.1 Off-Line Short Term Reserve Availability – Generation Resources and Demand Response Resources – Type II

Generation Resources (other than Intermittent Resources and Dispatchable Intermittent Resources) and Demand Response Resources - Type II will be available to provide Off-Line Short Term Reserve during a specific Dispatch Interval as long as the following conditions apply:

- The Generation Resource or Demand Response Resource - Type II is registered during the asset registration process as an Off-Line Short Term Qualified Resource capable of supplying Short Term Reserve.
  - The Commitment Status for the Generation Resource or Demand Response Resource - Type II during the Dispatch Interval is not set to ***Outag***e.
  - The Outage Scheduler outage type listed for the Generation Resource or Demand Response Resource - Type II is not set to ***Out of Service***.
  - The On-Line Flag of the Generation Resource or Demand Response Resource - Type II is set to 0 for the Dispatch Interval
  - The On-Line Flag of the Generation Resource or Demand Response Resource - Type II is set to 0 for the Dispatch Interval
- The Off-Line Short Term Reserve Dispatch Status for the Generation Resource or Demand Response Resource - Type II during the dispatch interval must be set to Economic.
- Minimum run time must be less than 4 hours
- Minimum down time constraint is met.

3.7.2 Off-Line Short Term Reserve Availability – Demand Response Resources – Type I

Demand Response Resources - Type I will be available to provide Off-Line Short Term Reserve in SCED during a specific Dispatch Interval if the following conditions apply:

- The Demand Response Resource - Type I is registered during the asset registration process as an Off-Line Short Term Reserve Qualified Resource capable of supplying Short Term Reserve.
- The Off-Line Short Term Reserve Dispatch Status for the Demand Response Resource - Type I during the Dispatch Interval must set to **Economic**.
- Minimum Non-Interruption Interval constraint is met.

3.8 Ramp Capability Availability

The Ramp Capability availability is determined for each Resource and Dispatch Interval prior to executing the SCED algorithm. A Resource must meet certain conditions in order to be considered available to provide Ramp Capability. Intermittent Resources and Demand Response Resources - Type I are not available to provide Ramp Capability. A Resource must be available to provide Energy in a specific Dispatch Interval in order to be cleared for Ramp Capability by SCED for that Dispatch Interval. The Ramp Capability availability is designated in the formulations as **RCAvailability(r,di)** and will be set to 1 whenever a specific Resource is available to provide Ramp Capability in a specific Dispatch Interval.

3.8.1 Ramp Capability Availability – Generation Resources and Demand Response Resources – Type II

A Generation Resource or Demand Response Resource - Type II which is not registered as an Intermittent Resource will be available to provide Ramp Capability in the Real-Time Energy and Operating Reserve Market during a specific Dispatch Interval as long as the following conditions apply:

- The Generation Resource or Demand Response Resource - Type II is on-line (i.e., the On-Line Flag for the Resource and Dispatch Interval is set to 1).
- The Ramp Capability Dispatch Status for the Generation Resource or Demand Response Resource - Type II during the Dispatch Interval is Economic

3.8.2 Ramp Capability Availability – External Asynchronous Resources

External Asynchronous Resources will be available to provide Ramp Capability in the Real-Time Energy and Operating Reserve Market during a specific Dispatch Interval as long as the following conditions apply:

- The External Asynchronous Resource is on-line (i.e., the On-Line Flag for the External Asynchronous Resource in the Dispatch Interval is set to 1) during the Dispatch Interval.

  The Ramp Capability Dispatch Status for the External Asynchronous Resource during the Dispatch Interval is set to Economic

3.8.3 Ramp Capability Availability – Electric Storage Resources

An Electric Storage Resource will be available to provide Ramp Capability in the Real-Time Energy and Operating Reserve Market during a specific Dispatch Interval as long as the following conditions apply:

- The Electric Storage Resource is on-line (i.e., the On-Line Flag for the External Asynchronous Resource in the Dispatch Interval is set to 1) during the Dispatch Interval.
- The Ramp Capability Dispatch Status for the Electric Storage Resource during the Dispatch Interval is set to Economic

3.9 Initial Energy Output

The Initial Energy Output, which is designated in the formulations as **InitialEnergyOutput(r,di)**, represents the projected Energy output of a Resource at the beginning of the Dispatch Interval. Since the Real-Time Energy and Operating Reserve Market software must begin executing 4 minutes and 55 seconds (+/-) prior to the beginning of the corresponding Dispatch Interval, the

Initial Energy Output must be projected based on 1) the Energy Dispatch Target associated with the previous Dispatch Interval, 2) on-going Contingency Reserve deployment instructions and 3) Resource output data from the most recent State Estimator solution. The Initial Energy Output is used in the ramp constraints to set the initial conditions of the Resource for the Dispatch Interval. The Initial Energy Output must be less than or equal to the Initial Energy Output Cap and greater than or equal to the Initial Energy Output Floor. No Initial Energy Output is calculated for Demand Response Resources - Type I.

3.9.1 Generation Resources, Electric Storage Resources and Demand Response Resources – Type II:

The Initial Energy Output Cap, designated as **InitialEnergyOutputCap(r,di)**, is calculated as follows for a specific Resource and Dispatch Interval:

InitialEnergyOutputCap(r,di)

= CurrentSEMW(r,di) + 5 * ActualRampUpRate(r,di-1)

The Initial Energy Output Floor, designated as **InitialEnergyOutputFloor(r,di)**, is calculated as follows for a specific Resource and Dispatch Interval:

InitialEnergyOutputFloor(r,di)
= CurrentSEMW(r,di) - 5 * ActualRampDownRate(r,di-1)

Note that for DRR-Type II Resources that are modelled without ICCP capability, CurrentSEMW(r,di) is determined to be equal to the Dispatch Target for Energy from the most recent Dispatch Interval; that is:

$$\text{CurrentSEMW(r,di)}^{\text{DRRIIw/oICCP}}\text{=EnergyDispatchTarget(r,di-1)}$$

Next, the Expected Contingency Reserve Deployment <u>at the beginning</u> of the Dispatch Interval, designated as **ExpectedContResDeploy(r,di)**, is calculated as follows for a specific Resource and Dispatch Interval.

ExpectedContResDeploy(r,di)

= Σ { ContResDeployMW(r,crd)
Crd * [BeginTime(di) - StartTime(crd)] / ContResDeployTime }

where

BeginTime(di) - 10 ≤ StartTime(crd) ≤ BeginTime(di)

Next the Initial Energy Dispatch, designated as **InitialEnergyDispatch(r,di)** is calculated as follows for a specific Resource and Dispatch Interval:

InitialEnergyDispatch(r,di)

= EnergyDispatchTarget(r,di-1) + ExpectedContResDeploy(r,di)

The Initial Energy Output is then calculated as follows for a specific resource and Dispatch Interval:

IF { InitialEnergyDispatch(r,di) > InitialEnergyOutputCap(r,di) **}**

InitialEnergyOutput(r,di) = InitialEnergyOutputCap(r,di)

ELSE IF { InitialEnergyDispatch(r,di) < InitialEnergyOutputFloor(r,di) **}**

InitialEnergyOutput(r,di) = InitialEnergyOutputFloor(r,di)

ELSE

InitialEnergyOutput(r,di) = InitialEnergyDispatch(r,di)

Exhibit 3-1through Exhibit 3-5 graphically illustrate how the Initial Energy Output of a Resource is determined for a Dispatch Interval under five different scenarios.

Exhibit 3-1: Illustration of Initial Energy Output Calculation - Example 1

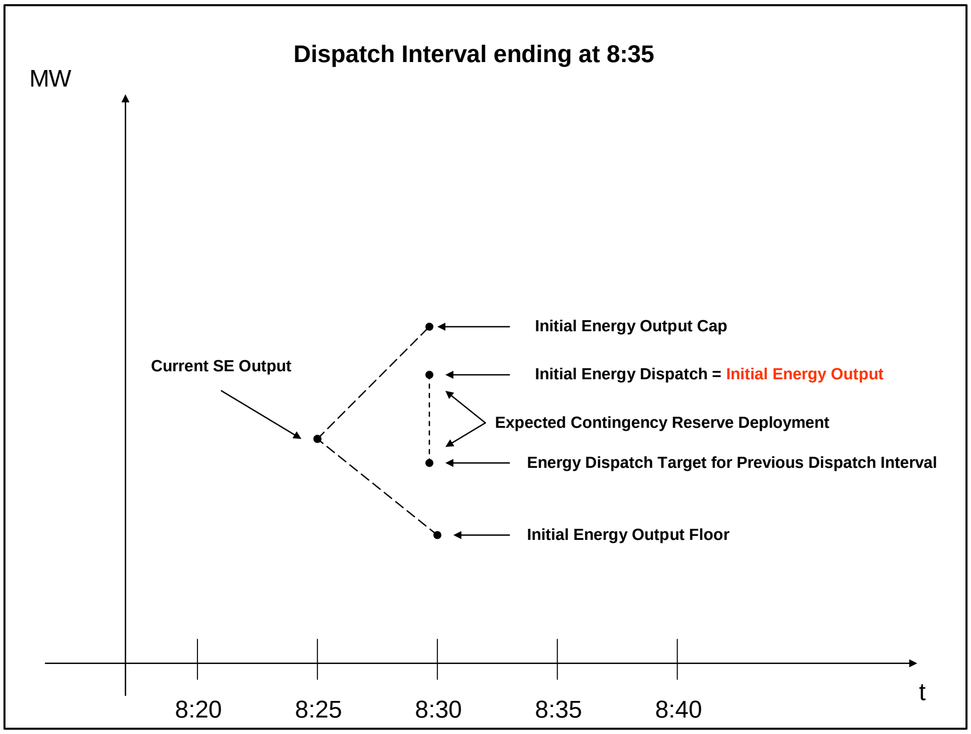


Exhibit 3-2: Illustration of Initial Energy Output Calculation - Example 2

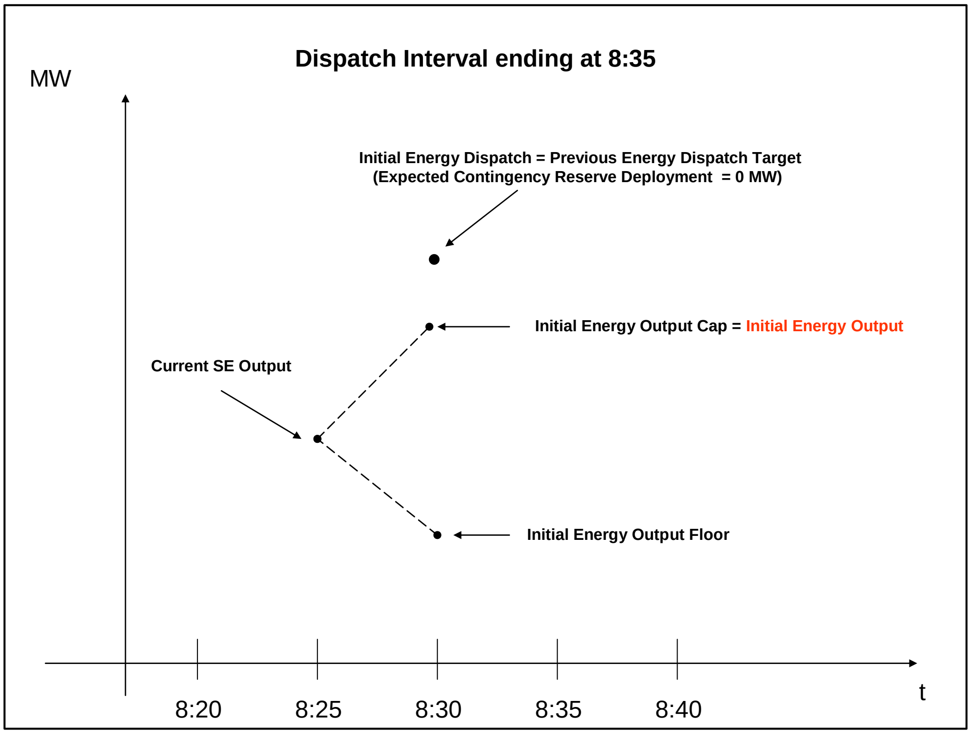


Exhibit 3-3: Illustration of Initial Energy Output Calculation - Example 3

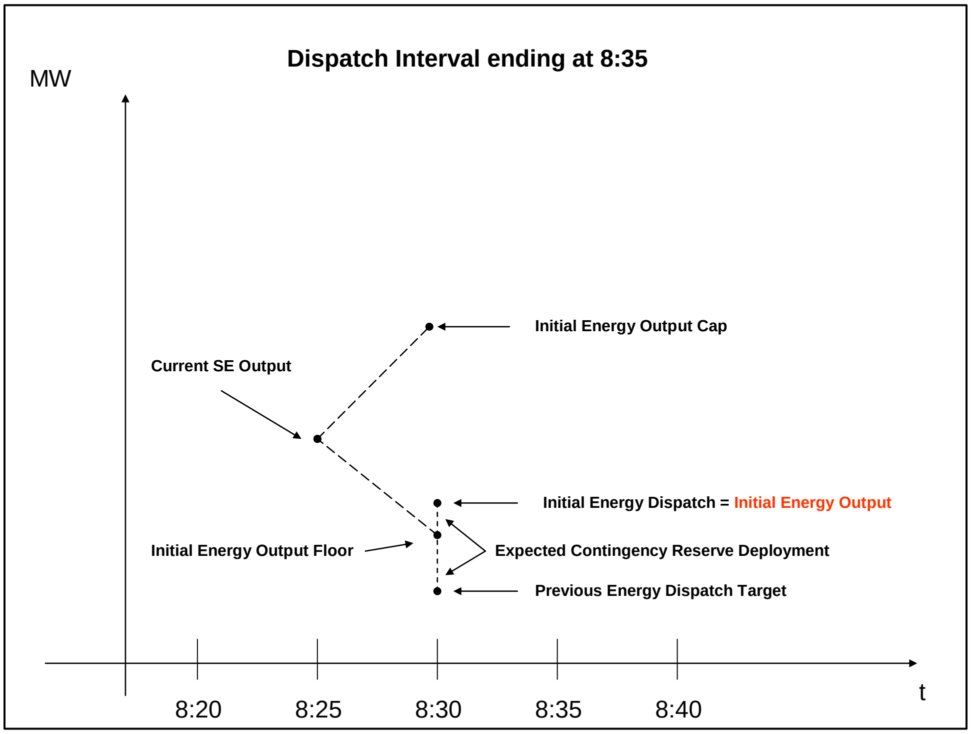


Exhibit 3-4: Illustration of Initial Energy Output Calculation - Example 4

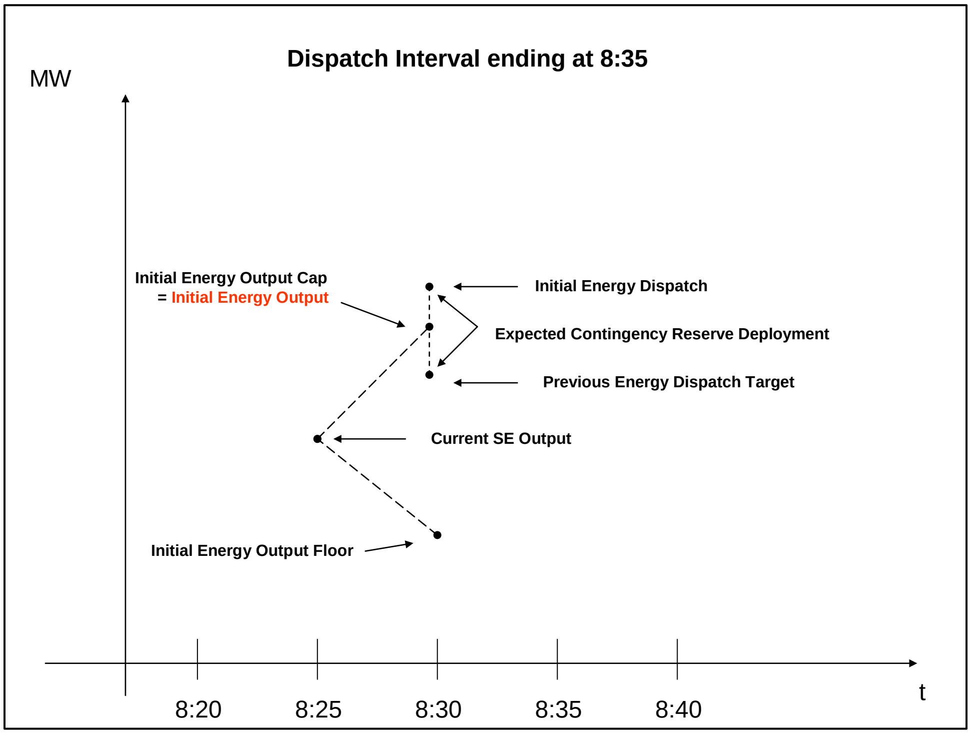
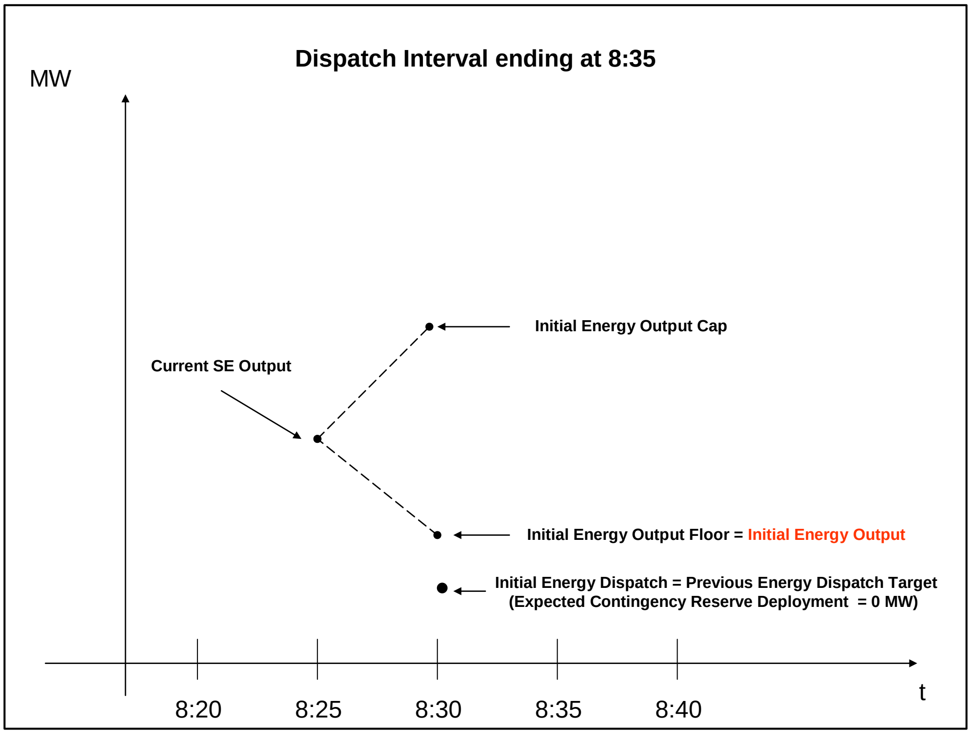


Exhibit 3-5: Illustration of Initial Energy Output Calculation - Example 5



3.9.2 External Asynchronous Resources:

The Expected Contingency Reserve Deployment <u>at the beginning</u> of the Dispatch Interval, designated as **ExpectedContResDeploy(r,di)**, is calculated as follows for a specific Resource and Dispatch Interval.

ExpectedContResDeploy(r,di)

= Σ { ContResDeployMW(r,crd)
Crd * [BeginTime(di) - StartTime(crd)] / ContResDeployTime }

where

BeginTime(di) - 10 ≤ StartTime(crd) ≤ BeginTime(di)

The Initial Energy Output is then calculated as follows for a specific Resource and Dispatch Interval:

InitialEnergyOutput(r,di)

= EnergyDispatchTarget(r,di-1) + ExpectedContResDeploy(r,di)

3.10 Ramp Rate Curve Flag

The ramp rate curve flag, designated in the formulations as **RampRateCurveFlag(r,di)**, is determined for each Resource and Dispatch Interval prior to executing the SCED algorithm. If the ramp rate curve flag is set to 1, then ramp rate curves will be utilized in the Real-Time Energy and Operating Reserve Market. If the ramp rate curve flag is set to 0, then ramp rate curves will not be utilized in the Real-Time Energy and Operating Reserve Market. The ramp rate curve flag will be set to 1 if the following conditions are satisfied:

- The Market Participant has enabled ramp rate curves for the Resource.
- The Market Participant has submitted valid bi-directional ramp rate, single-directional ramp-up rate and single-directional ramp-down rate curves (An Electric Storage Resource has Charge ramp rate curves and Discharge ramp rate curves).

If any of the conditions above are not satisfied for a specific resource and Dispatch Interval, the ramp rate flag will be set to 0 for that Resource and Dispatch Interval. Demand Response Resources - Type I do not utilize ramp rate curves and, thus, no Ramp Rate Curve Flag is calculated for these Resource types.

3.11 Emergency Maximum Release Flag

The emergency maximum release flag, designated in the formulations as **EmerMaxRelFlag(r,di)**, is determined for each Resource and Dispatch Interval prior to executing the SCED algorithm. If the emergency maximum release flag is set to 1, then the SCED algorithm may utilize the emergency maximum operating range of the Resource during the Dispatch Interval. If the emergency maximum release flag is set to 0, then the SCED algorithm will not utilize the emergency maximum operating range of the Resource during the Dispatch Interval. The emergency maximum release flag will be set to 1 if the following conditions are satisfied:

- MISO flags a shortage condition (but does not necessarily declare an EEA Level or minimum generation alert) indicating there is insufficient non-emergency capacity to satisfy the Energy and Operating Reserve requirement.
- In anticipation of a shortage condition, the RAC process has released the emergency maximum operating range on the Resource for the Dispatch Interval.
- The Resource is not scheduled to regulate for the Dispatch Interval (i.e., RF(r,di) = 0).
- An Electric Storage Resource has Commitment Status as “Emergency Discharge”

If any of the conditions above are not satisfied for a specific resource and Dispatch Interval, the emergency maximum release flag will be set to 0 for that Resource and Dispatch Interval. Dispatchable Intermittent Resources, Demand Response Resources - Type I do not contain emergency maximum limits, and, thus, no Emergency Maximum Release Flag is calculated for these Resource types.

3.12 Emergency Minimum Release Flag

The emergency minimum release flag, designated in the formulations as **EmerMinRelFlag(r,di)**, is determined for each Resource and Dispatch Interval prior to executing the SCED algorithm. If the emergency minimum release flag is set to 1, then the SCED algorithm may utilize the emergency minimum operating range of the Resource during the Dispatch Interval. If the emergency minimum release flag is set to 0, then the SCED algorithm will not utilize the emergency minimum operating range of the Resource during the Dispatch Interval. The emergency minimum release flag will be set to 1 if the following conditions are satisfied:

- MISO flags a surplus condition indicating there is insufficient loaded capacity above the non-emergency minimum limits to meet the energy and/or regulation-down requirements.
- In anticipation of a surplus condition, the RAC process has released the emergency minimum operating range on the Resource for the Dispatch Interval.
- The Resource is not scheduled to regulate for the Dispatch Interval (i.e., RF(r,di) = 0).
- An Electric Storage Resource has Commitment Status as “Emergency Charge”

If any of the conditions above are not satisfied for a specific resource and Dispatch Interval, the emergency minimum release flag will be set to 0 for that Resource and Dispatch Interval. External Asynchronous Resources and Demand Response Resources - Type I do not contain emergency minimum limits, and, thus, no Emergency Minimum Release Flag is calculated for these Resource types.

3.13 Overall Limits

For each Resource and Dispatch Interval, the overall emergency, economic and regulation limits are determined for each Resource and Dispatch Interval as follows:

3.13.1 Generation Resources and Demand Response Resources – Type II:

- The overall emergency maximum limit, designated in the formulations as **OverallEmerMaxLimit(r,di)**, is set equal to the Dispatch Interval emergency maximum limit for the Resource, unless no valid Dispatch Interval limit set has been specified, in which case the overall emergency maximum limit is set equal to the default emergency maximum limit for the Resource as specified during the asset registration process. The OverallEmerMaxLimit(r,di) does not exist for Dispatchable Intermittent Resources.

- The overall emergency minimum limit, designated in the formulations as **OverallEmerMinLimit(r,di)**, is set equal to the Dispatch Interval emergency minimum limit for the Resource, unless no valid Dispatch Interval limit set has been specified, in which case the overall emergency minimum limit is set equal to the default emergency minimum limit for the Resource as specified during the asset registration process.
- The overall economic maximum limit is designated in the formulations as **OverallEcoMaxLimit(r,di)**. For non-DIRs, it is set equal to the Dispatch Interval economic maximum limit for the Resource, unless no valid Dispatch Interval limit set has been specified, in which case the overall economic maximum limit is set equal to the default economic maximum limit for the Resource as specified during the asset registration process. For DIR Resources, it is set equal to the Forecast Maximum Limit, as described in the *Energy and Operating Reserves BPM* main document.
- The overall economic minimum limit, designated in the formulations as **OverallEcoMinLimit(r,di)**, is set equal to the Dispatch Interval economic minimum limit for the Resource, unless no valid Dispatch Interval limit set has been specified, in which case the overall economic minimum limit is set equal to the default economic minimum limit for the Resource as specified during the asset registration process.
- The overall regulation maximum limit, designated in the formulations as **OverallRegMaxLimit(r,di)**, is set equal to the Dispatch Interval regulation maximum limit for the Resource, unless no valid Dispatch Interval limit set has been specified, in which case the overall regulation maximum limit is set equal to the default regulation maximum limit for the Resource as specified during the asset registration process. The OverallRegMaxLimit(r,di) does not exist for Dispatchable Intermittent Resources.
- The overall regulation minimum limit, designated in the formulations as **OverallRegMinLimit(r,di)**, is set equal to the Dispatch Interval regulation minimum limit for the Resource, unless no valid Dispatch Interval limit set has been specified, in which case the overall regulation minimum limit is set equal to the default regulation minimum limit for the Resource as specified during the asset registration process. The OverallRegMinLimit(r,di) does not exist for Dispatchable Intermittent Resources.

3.13.2 External Asynchronous Resources:

- The overall emergency maximum limit, designated in the formulations as **OverallEmerMaxLimit(r,di)**, is set equal to the Dispatch Interval emergency maximum limit for the Resource, unless no valid Dispatch Interval limit set has been specified, in which case the overall emergency maximum limit is set equal to the default emergency maximum limit for the Resource as specified during the asset registration process.

- The overall emergency minimum limit, designated in the formulations as **OverallEmerMinLimit(r,di)**, is set equal to the 0.
- The overall economic maximum limit, designated in the formulations as **OverallEcoMaxLimit(r,di)**, is set equal to the Dispatch Interval economic maximum limit for the Resource, unless no valid Dispatch Interval limit set has been specified, in which case the overall economic maximum limit is set equal to the default economic maximum limit for the Resource as specified during the asset registration process.
- The overall economic minimum limit, designated in the formulations as **OverallEcoMinLimit(r,di)**, is set equal to 0.
- The overall regulation maximum limit, designated in the formulations as **OverallRegMaxLimit(r,di)**, is set equal to the Dispatch Interval regulation maximum limit for the Resource, unless no valid Dispatch Interval limit set has been specified, in which case the overall regulation maximum limit is set equal to the default regulation maximum limit for the Resource as specified during the asset registration process.
- The overall regulation minimum limit, designated in the formulations as **OverallRegMinLimit(r,di)**, is set equal to the Dispatch Interval regulation minimum limit for the Resource, unless no valid Dispatch Interval limit set has been specified, in which case the overall regulation minimum limit is set equal to the default regulation minimum limit for the Resource as specified during the asset registration process.

3.13.3 Electric Storage Resource:

- The overall charge emergency maximum limit, designated in the formulations as **OverallChargeEmerMaxLimit(r,di)**, is set equal to the Dispatch Interval charge emergency maximum limit for the Resource, unless no valid Dispatch Interval limit set has been specified, in which case the overall charge emergency maximum limit is set equal to the default charge emergency maximum limit for the Resource as specified during the asset registration process.
- The overall charge emergency minimum limit, designated in the formulations as **OverallChargeEmerMinLimit(r,di)**, is set equal to the Dispatch Interval charge emergency minimum limit for the Resource, unless no valid Dispatch Interval limit set has been specified, in which case the overall charge emergency minimum limit is set equal to the default charge emergency minimum limit for the Resource as specified during the asset registration process.
- The overall charge economic maximum limit is designated in the formulations as **OverallChargeEcoMaxLimit(r,di)**. It is set equal to the Dispatch Interval charge economic maximum limit for the Resource, unless no valid Dispatch Interval limit set has been specified,

in which case the overall charge economic maximum limit is set equal to the default economic maximum limit for the Resource as specified during the asset registration process.

- The overall charge economic minimum limit, designated in the formulations as **OverallChargeEcoMinLimit(r,di)**, is set equal to the Dispatch Interval charge economic minimum limit for the Resource, unless no valid Dispatch Interval limit set has been specified, in which case the overall charge economic minimum limit is set equal to the default charge economic minimum limit for the Resource as specified during the asset registration process.
- The overall charge regulation maximum limit, designated in the formulations as **OverallCharegeRegMaxLimit(r,di)**, is set equal to the Dispatch Interval charge regulation maximum limit for the Resource, unless no valid Dispatch Interval limit set has been specified, in which case the overall charge regulation maximum limit is set equal to the default charge regulation maximum limit for the Resource as specified during the asset registration process.
- The overall charge regulation minimum limit, designated in the formulations as **OverallChargeRegMinLimit(r,di)**, is set equal to the Dispatch Interval charge regulation minimum limit for the Resource, unless no valid Dispatch Interval limit set has been specified, in which case the overall charge regulation minimum limit is set equal to the default charge regulation minimum limit for the Resource as specified during the asset registration process.
- The overall charge emergency maximum limit, designated in the formulations as **OverallDischargeEmerMaxLimit(r,di)**, is set equal to the Dispatch Interval discharge emergency maximum limit for the Resource, unless no valid Dispatch Interval limit set has been specified, in which case the overall discharge emergency maximum limit is set equal to the default discharge emergency maximum limit for the Resource as specified during the asset registration process.
- The overall discharge emergency minimum limit, designated in the formulations as **OverallDischargeEmerMinLimit(r,di)**, is set equal to the Dispatch Interval discharge emergency minimum limit for the Resource, unless no valid Dispatch Interval limit set has been specified, in which case the overall discharge emergency minimum limit is set equal to the default discharge emergency minimum limit for the Resource as specified during the asset registration process.
- The overall discharge economic maximum limit is designated in the formulations as **OverallDischargeEcoMaxLimit(r,di)**. It is set equal to the Dispatch Interval discharge economic maximum limit for the Resource, unless no valid Dispatch Interval limit set has been specified, in which case the overall discharge economic maximum limit is set equal to the default economic maximum limit for the Resource as specified during the asset registration process.

- The overall discharge economic minimum limit, designated in the formulations as **OverallDischargeEcoMinLimit(r,di)**, is set equal to the Dispatch Interval discharge economic minimum limit for the Resource, unless no valid Dispatch Interval limit set has been specified, in which case the overall discharge economic minimum limit is set equal to the default discharge economic minimum limit for the Resource as specified during the asset registration process.
- The overall discharge regulation maximum limit, designated in the formulations as **OverallCharegeRegMaxLimit(r,di)**, is set equal to the Dispatch Interval discharge regulation maximum limit for the Resource, unless no valid Dispatch Interval limit set has been specified, in which case the overall discharge regulation maximum limit is set equal to the default discharge regulation maximum limit for the Resource as specified during the asset registration process.
- The overall discharge regulation minimum limit, designated in the formulations as **OverallDischargeRegMinLimit(r,di)**, is set equal to the Dispatch Interval discharge regulation minimum limit for the Resource, unless no valid Dispatch Interval limit set has been specified, in which case the overall discharge regulation minimum limit is set equal to the default discharge regulation minimum limit for the Resource as specified during the asset registration process.

3.14 Limit Processing

For each Resource and Dispatch Interval, a single maximum limit, designated in the formulations as **MaxLimit(r,di)**, and a single minimum limit, designated in the formulations as **MinLimit(r,di)**, is established as follows.

3.14.1 Maximum Limit – Generation Resources (other than DIRs) and Demand Response Resources – Type II:

The following logic is used to establish the maximum limit of a specific Generation Resource or Demand Response Resource - Type II for a specific Dispatch Interval:

IF { RegMaxLimitOverrideFlag(r) = 1 **}**
AND { RF(r,h) = 1 **}**

MaxLimit(r,di) = RegMaxLimitOverride(r)

NOTE: If a regulation minimum limit override has been entered for the Resource, the regulation maximum limit override must be greater than or equal to the regulation minimum limit override.

ELSE IF { MaxLimitOverrideFlag(r) = 1 **}**
AND { EmerMaxRelFlag(r,di)=0 **}**
AND { RF(r,h) = 0 **}**

MaxLimit(r,di) = MaxLimitOverride(r)

NOTE: If a minimum limit override has been entered for the Resource, the maximum limit override must be greater than or equal to the minimum limit override.

ELSE IF { EmerMaxLimitOverrideFlag(r) = 1 **}**
AND { EmerMaxRelFlag(r,di) = 1 **}**
AND { RF(r,h) = 0 **}**

MaxLimit(r,di) = EmerMaxLimitOverride(r)

NOTE: If an emergency minimum limit override has been entered for the Resource, the emergency maximum limit override must be greater than or equal to the emergency minimum limit override.

ELSE IF { RF(r,h) = 1 **}**

MaxLimit(r,di) = OverallRegMaxLimit(r,h)

ELSE IF { EmerMaxRelFlag(r,di) = 1 **}**

MaxLimit(r,di) = OverallEmerMaxLimit(r,h)

ELSE

MaxLimit(r,di) = OverallEcoMaxLimit(r,h)

3.14.2 Maximum Limit – Dispatchable Intermittent Resources:

The following logic is used to establish the maximum limit of a specific Dispatchable Intermittent Resource for a specific Dispatch Interval:

MaxLimit(r,di) = OverallEcoMaxLimit(r,h)

NOTE: The process for establishing the Forecast Maximum Limit, which is identical to the OverallEcoMaxLimit(r,h), is provided in the main document accompanying this appendix.

3.14.3 Maximum Limit – External Asynchronous Resources:

The following logic is used to establish the maximum limit of a specific External Asynchronous Resource for a specific Dispatch Interval:

IF { RegMaxLimitOverrideFlag(r) = 1 **}**
AND { RF(r,h) = 1 **}**

MaxLimit(r,di) = RegMaxLimitOverride(r)

NOTE: If a regulation minimum limit override has been entered for the Resource, the regulation maximum limit override must be greater than or equal to the regulation minimum limit override.

ELSE IF { MaxLimitOverrideFlag(r) = 1 **}**
AND { EmerMaxRelFlag(r,di)=0 **}**
AND { RF(r,h) = 0 **}**

MaxLimit(r,di) = MaxLimitOverride(r)

NOTE: If a minimum limit override has been entered for the Resource, the maximum limit override must be greater than or equal to the minimum limit override.

ELSE IF { EmerMaxLimitOverrideFlag(r) = 1 **}**

AND { EmerMaxRelFlag(r,di) = 1 **}**
AND { RF(r,h) = 0 **}**

MaxLimit(r,di) = EmerMaxLimitOverride(r)

NOTE: If an emergency minimum limit override has been entered for the Resource, the emergency maximum limit override must be greater than or equal to the emergency minimum limit override.

ELSE IF { RF(r,h) = 1 **}**
MaxLimit(r,di) = OverallRegMaxLimit(r,h)

ELSE IF { EmerMaxRelFlag(r,di) = 1 **}**
MaxLimit(r,di) = OverallEmerMaxLimit(r,h)

ELSE
MaxLimit(r,di) = OverallEcoMaxLimit(r,h)

3.14.4 Maximum Limit – Electric Storage Resources:

The following logic is used to establish the maximum limit of a specific Electric Storage Resource for a specific Dispatch Interval:

IF CommitStatus(r,h) = ‘DC’:
IF { RegMaxDischargeOverrideFlag(r) = 1 }
AND { RF(r,h) = 1 }

MaxLimit(r,di) = RegMaxDischargeOverride(r)

NOTE: If a regulation minimum discharge override has been entered for the Resource, the regulation maximum discharge override must be greater than or equal to the regulation minimum discharge override.

ELSE IF { EcoMaxDischargeOverrideFlag(r) = 1 }
AND { RF(r,h) = 0 }

MaxLimit(r,di) = EcoMaxDischargeOverride(r)

NOTE: If a minimum discharge override has been entered for the Resource, the maximum discharge override must be greater than or equal to the minimum discharge override.

ELSE IF { RF(r,h) = 1 }

MaxLimit(r,di) = RegMaxDischarge(r,h)

ELSE

MaxLimit(r,di) = EcoMaxDischarge(r,h)

ELSE IF CommitStatus(r,h) = ‘CH’ or ‘CO’ or ‘AV’:

IF { RegMaxChargeOverrideFlag(r) = 1 }
AND { RF(r,h) = 1 }

MaxLimit(r,di) = RegMaxChargeOverride(r)

NOTE: If a regulation minimum charge override has been entered for the Resource, the regulation maximum charge override must be greater than or equal to the regulation minimum charge override.

ELSE IF { EcoMaxChargeOverrideFlag(r) = 1 }
AND { RF(r,h) = 0 }

MaxLimit(r,di) = EcoMaxChargeOverride(r)

NOTE: If a minimum charge override has been entered for the Resource, the maximum charge override must be greater than or equal to the minimum charge override.

ELSE IF { RF(r,h) = 1 }

MaxLimit(r,di) = RegMaxCharge(r,h)

ELSE

MaxLimit(r,di) = EcoMaxCharge(r,h)

ELSE IF CommitStatus(r,h) = 'DE':

IF { EmerMaxDischargeOverrideFlag(r) = 1 }

MaxLimit(r,di) = EmerMaxDischargeOverride(r)

ELSE

MaxLimit(r,di) = EmerMaxDischarge(r,h)

ELSE IF CommitStatus(r,h) = 'CE':

IF { EmerMaxChargeOverrideFlag(r) = 1 }

MaxLimit(r,di) = EmerMaxChargeOverride(r)

ELSE

MaxLimit(r,di) = EmerMaxCharge(r,h)

3.14.5 Minimum Limit – Generation Resources and Demand Response Resources – Type II:

The following logic is used to establish the minimum limit of a specific Generation Resource or Demand Response Resource - Type II for a specific Dispatch Interval:

IF { RegMinLimitOverrideFlag(r) = 1 **}**

AND { RF(r,h) = 1 **}**

MinLimit(r,di) = RegMinLimitOverride(r)

NOTE: If a regulation maximum limit override has been entered for the Resource, the regulation minimum limit override must be less than or equal to the regulation maximum limit override.

ELSE IF { MinLimitOverrideFlag(r) = 1 **}**

AND { EmerMinRelFlag(r,di)=0 **}**

AND { RF(r,h) = 0 **}**

MinLimit(r,di) = MinLimitOverride(r)

NOTE: If a maximum limit override has been entered for the Resource, the minimum limit override must be less than or equal to the maximum limit override.

ELSE IF { EmerMinLimitOverrideFlag(r) = 1 **}**
AND { EmerMinRelFlag(r,di) = 1 **}**
AND { RF(r,h) = 0 **}**

MinLimit(r,di) = EmerMinLimitOverride(r)

NOTE: If an emergency maximum limit override has been entered for the Resource, the emergency minimum limit override must be less than or equal to the emergency maximum limit override.

ELSE IF { RF(r,h) = 1 **}**

MinLimit(r,di) = OverallRegMinLimit(r,h)

ELSE IF { EmerMinRelFlag(r,di) = 1 **}**

MinLimit(r,di) = OverallEmerMinLimit(r,h)

ELSE

MinLimit(r,di) = OverallEcoMinLimit(r,h)

3.14.6 Minimum Limit – External Asynchronous Resources:

The following logic is used to establish the minimum limit of a specific External Asynchronous Resource for a specific Dispatch Interval:

IF { RegMinLimitOverrideFlag(r) = 1 **}**
AND { RF(r,h) = 1 **}**

MinLimit(r,di) = RegMinLimitOverride(r)

NOTE: If a regulation maximum limit override has been entered for the Resource, the regulation minimum limit override must be less than or equal to the regulation maximum limit override.

ELSE IF { RF(r,h) = 1 **}**

MinLimit(r,di) = OverallRegMinLimit(r,h)

ELSE

MinLimit(r,di) = 0

3.14.7 Minimum Limit – Electric Storage Resources:

The following logic is used to establish the minimum limit of a specific Electric Storage Resource for a specific Dispatch Interval:

IF CommitStatus(r,h) = ‘DC’ or ‘CO’:

IF { RegMinDischargeOverrideFlag(r) = 1 }
AND { RF(r,h) = 1 }

MinLimit(r,di) = RegMinDischargeOverride(r)

NOTE: If a regulation maximum discharge override has been entered for the Resource, the regulation minimum discharge override must be less than or equal to the regulation maximum discharge override.

ELSE IF { EcoMinDischargeOverrideFlag(r) = 1 }
AND { RF(r,h) = 0 }

MinLimit(r,di) = EcoMinDischargeOverride(r)

NOTE: If a maximum discharge override has been entered for the Resource, the minimum discharge override must be less than or equal to the maximum discharge override.

ELSE IF { RF(r,h) = 1 }

MinLimit(r,di) = RegMinDischarge(r,h)

ELSE

MinLimit(r,di) = EcoMinDischarge(r,h)

ELSE IF CommitStatus(r,h) = ‘CH’ or ‘AV’:

IF { RegMinChargeOverrideFlag(r) = 1 }
AND { RF(r,h) = 1 }

MinLimit(r,di) = RegMinChargeOverride(r)

NOTE: If a regulation maximum charge override has been entered for the Resource, the regulation minimum charge override must be less than or equal to the regulation maximum charge override.

ELSE IF { EcoMinChargeOverrideFlag(r) = 1 }
AND { RF(r,h) = 0 }

MinLimit(r,di) = EcoMinChargeOverride(r)

NOTE: If a maximum charge override has been entered for the Resource, the minimum charge override must be less than or equal to the maximum charge override.

ELSE IF { RF(r,h) = 1 }

MinLimit(r,di) = RegMinCharge(r,h)

ELSE

MinLimit(r,di) = EcoMinCharge(r,h)

ELSE IF CommitStatus(r,h) = ‘DE’:

IF { EmerMinDischargeOverrideFlag(r) = 1 }

MinLimit(r,di) = EmerMinDischargeOverride(r)

ELSE

MinLimit(r,di) = EmerMinDischarge(r,h)

ELSE IF CommitStatus(r,h) = 'CE':

IF { EmerMinChargeOverrideFlag(r) = 1 }

MinLimit(r,di) = EmerMinChargeOverride(r)

ELSE

MinLimit(r,di) = EmerMinCharge(r,h)

3.15 Ramp Rate Processing

For each Resource and Dispatch Interval, a ramp-up rate, designated in the formulations as **RampUpRate(r,di)**, and a ramp-down rate, designated in the formulations as **RampDownRate(r,di)**, is established as follows.

3.15.1 Ramp-Up Rate – Generation Resources and Demand Response Resources – Type II:

The following logic is used to establish the ramp-up rate for each Generation Resource and Demand Response Resource - Type II for a specific Dispatch Interval:

IF { BiDirRampRateOverrideFlag(r) = 1 **}**
AND { RF(r,h) = 1 **}**

RampUpRate(r,di) = BiDirRampRateOverride(r)

ELSE IF { SingleDirRampUpRateOverrideFlag(r) = 1**}**
AND { RF(r,h) = 0 **}**

RampUpRate(r,di) = SingleDirRampUpRateOverride(r)

ELSE IF { RampRateCurveFlag(r) = 1 **}**
AND { RF(r,h) = 1 **}**

RampUpRate(r,di) = BiDirRampRateCurve(r,InitialEnergyOutput(r,di))

ELSE IF { RampRateCurveFlag(r) = 1 **}**
AND { RF(r,h) = 0 **}**

RampUpRate(r,di) = SingleDirRampUpRateCurve(r,InitialEnergyOutput(r,di))

ELSE IF { Dispatch IntervalBiDirRampRate(r,di) ≠ NULL **}**
AND { RF(r,h) = 1 **}**

RampUpRate(r,di) = Dispatch IntervalBiDirRampRate(r,di)

ELSE IF { Dispatch IntervalSingleDirRampUpRate(r) ≠ NULL **}**
AND { RF(r,h) = 0 **}**

RampUpRate(r,di) = Dispatch IntervalSingleDirRampUpRate(r,di)

ELSE IF { RF(r,h) = 1 **}**

RampUpRate(r,di) = DefaultBiDirRampRate(r,h)

ELSE

RampUpRate(r,di) = DefaultSingleDirRampUpRate(r,h)

3.15.2 Ramp-Up Rate – External Asynchronous Resources:

The following logic is used to establish the ramp-up rate for each External Asynchronous Resource for a specific Dispatch Interval:

IF { BiDirRampRateOverrideFlag(r) = 1 **}**
AND { RF(r,h) = 1 **}**

RampUpRate(r,di) = BiDirRampRateOverride(r)

ELSE IF { SingleDirRampUpRateOverrideFlag(r) = 1**}**
AND { RF(r,h) = 0 **}**

RampUpRate(r,di) = SingleDirRampUpRateOverride(r)

ELSE IF { Dispatch IntervalBiDirRampRate(r,di) ≠ NULL **}**
AND { RF(r,h) = 1 **}**

RampUpRate(r,di) = Dispatch IntervalBiDirRampRate(r,di)

ELSE IF { Dispatch IntervalSingleDirRampUpRate(r) ≠ NULL **}**
AND { RF(r,h) = 0 **}**

RampUpRate(r,di) = Dispatch IntervalSingleDirRampUpRate(r,di)

ELSE IF { RF(r,di) = 1 **}**

RampUpRate(r,di) = DefaultBiDirRampRate(r,di)

ELSE

RampUpRate(r,di) = DefaultSingleDirRampUpRate(r,h)

3.15.3 Ramp-Down Rate – Generation Resources and Demand Response Resources – Type II:

The following logic is used to establish the ramp-down rate for each Generation Resource and Demand Response Resource - Type II for a specific Dispatch Interval:

IF { BiDirRampRateOverrideFlag(r) = 1 **}**
AND { RF(r,h) = 1 **}**

RampDownRate(r,di) = BiDirRampRateOverride(r)

ELSE IF { SingleDirRampDownRateOverrideFlag(r) = 1**}**
AND { RF(r,h) = 0 **}**

RampDownRate(r,di) = SingleDirRampDownRateOverride(r)

ELSE IF { RampRateCurveFlag(r) = 1 **}**
AND { RF(r,h) = 1**}**

RampDownRate(r,di) = BiDirRampRateCurve(r,InitialEnergyOutput(r,di))

ELSE IF { RampRateCurveFlag(r) = 1**}**
AND { RF(r,h) = 0 **}**

RampDownRate(r,di)
= SingleDirRampDownRateCurve(r,InitialEnergyOutput(r,di))

ELSE IF { Dispatch IntervalBiDirRampRate(r,di) ≠ NULL **}**
AND { RF(r,h) = 1**}**

RampDownRate(r,di) = Dispatch IntervalBiDirRampRate(r,di)

ELSE IF { Dispatch IntervalSingleDirRampDownRate(r) ≠ NULL **}**
AND { RF(r,h) = 0 **}**

RampDownRate(r,di) = Dispatch IntervalSingleDirRampDownRate(r,h)

ELSE IF { RF(r,h) = 1**}**

RampDownRate(r,di) = DefaultBiDirRampRate(r,h)

ELSE

RampDownRate(r,di) = DefaultSingleDirRampDownRate(r,h)

3.15.4 Ramp-Down Rate – External Asynchronous Resources:

The following logic is used to establish the ramp-down rate for each External Asynchronous Resource for a specific Dispatch Interval:

IF { BiDirRampRateOverrideFlag(r) = 1**}**
AND { RF(r,h) = 1**}**

RampDownRate(r,di) = BiDirRampRateOverride(r)

ELSE IF { SingleDirRampDownRateOverrideFlag(r) = 1**}**

AND { RF(r,h) = 0 **}**

RampDownRate(r,di) = SingleDirRampDownRateOverride(r)

ELSE IF { Dispatch IntervalBiDirRampRate(r,di) ≠ NULL **}**
AND { RF(r,h) = 1**}**

RampDownRate(r,di) = Dispatch IntervalBiDirRampRate(r,di)

ELSE IF { Dispatch IntervalSingleDirRampDownRate(r) ≠ NULL **}**
AND { RF(r,h) = 0 **}**

RampUpRate(r,di) = Dispatch IntervalSingleDirRampDownRate(r,h)

ELSE IF { RF(r,h) = 1**}**

RampDownRate(r,di) = DefaultBiDirRampRate(r,h)

ELSE

RampDownRate(r,di) = DefaultSingleDirRampDownRate(r,h)

3.15.5 Ramp-Up Rate – Electric Storage Resources:

The following logic is used to establish the ramp-up rate for each Electric Storage Resource for a specific Dispatch Interval:
IF { CommitStatus(r,h) = 'DC' or 'DE' }:

IF { DischargeRampRateOverrideFlag(r) = 1 **}**

RampUpRate(r,di) = DischargeRampRateOverride(r)

ELSE IF { RampRateCurveFlag(r) = 1 **}**
AND{ DischargeRampRateCurve(r,InitialEnergyOutput(r,di)) is not NULL }

RampUpRate(r,di) = DischargeRampRateCurve(r,InitialEnergyOutput(r,di))

ELSE

RampUpRate(r,di) = DischargeRampRate(r,h)
ELSE IF { CommitStatus(r,h) = 'CH' or 'CE' }:

IF { ChargeRampRateOverrideFlag(r) = 1 **}**

RampUpRate(r,di) = ChargeRampRateOverride(r)

ELSE IF **{** RampRateCurveFlag(r) = 1 **}**
AND { DischargeRampRateCurve(r,InitialEnergyOutput(r,di)) is not NULL }

RampUpRate(r,di) = ChargeRampRateCurve(r,InitialEnergyOutput(r,di))

ELSE

RampUpRate(r,di) = ChargeRampRate(r,h)

ELSE IF { CommitStatus(r,h) = 'CO'}:

IF { ChargeRampRateOverrideFlag(r) = 1 **}**
AND { InitialEnergyOutput(r,di) < -0.1MW }

RampUpRate(r,di) = ChargeRampRateOverride(r)

ELSE IF **{** DishargeRampRateOverrideFlag(r) = 1 **}**
AND { InitialEnergyOutput(r,di) > 0.1MW }

RampUpRate(r,di) = DischargeRampRateOverride(r)

ELSE IF **{** RampRateCurveFlag(r) = 1 **}**
AND { InitialEnergyOutput(r,di) < -0.1MW }
AND { ChargeRampRateCurve(r,InitialEnergyOutput(r,di)) is not NULL }

RampUpRate(r,di) = ChargeRampRateCurve(r,InitialEnergyOutput(r,di))

ELSE IF { RampRateCurveFlag(r) = 1 **}**
AND { InitialEnergyOutput(r,di) > 0.1MW }
AND { DischargeRampRateCurve(r,InitialEnergyOutput(r,di)) is not NULL }

RampUpRate(r,di) = DischargeRampRateCurve(r,InitialEnergyOutput(r,di))

ELSE IF { InitialEnergyOutput(r,di) < -0.1MW }
AND { RampRateCurveFlag(r) = 1 **}**

RampUpRate(r,di) = ChargeRampRate(r,h)

ELSE IF { InitialEnergyOutput(r,di) > 0.1MW }

RampUpRate(r,di) = DischargeRampRate(r,h)

ELSE if { RampRateCurveFlag(r) = 1 **}**

RampUpRate(r,di)=Min{DischargeRampRateCurve(r,InitialEnergyOutput(r,di)), ChargeRampRateCurve(r,InitialEnergyOutput(r,di))}

ELSE

RampUpRate(r,di)= Min{ChargeRampRate(r,h), DischargeRampRate(r,h)}

3.15.6 Ramp-Down Rate – Electric Storage Resources:

The Ramp-Down Rate of each Electric Storage Resource is always the same as its Ramp-Up Rate.

3.16 Control Status

The Control Status, which is designated in the formulations as **ControlStatus(r,di)**, indicates the capabilities of a specific Resource during a specific Dispatch Interval. If the Control Status is set to 0 (Off-Line) for a specific resource for a specific Dispatch Interval, the Resource is off-line. If the Control Status is set to 1 (Load Following) for a specific resource for a specific Dispatch Interval, the Resource is capable of following load, and can be dispatched for Energy, Spinning Reserve and Supplemental Reserve, as qualified. If the Control Status is set to 2 (Regulating) for a specific resource for a specific Dispatch Interval, the Resource is capable of regulating, and can be dispatched for Energy, Regulating Reserve, Spinning Reserve and Supplemental Reserve, as qualified. If the Control Status is set to 3 (Non-Dispatchable) for a specific resource for a specific Dispatch Interval, the Resource is on-line but not dispatchable, and thus cannot supply Operating Reserve or set Energy LMPs. The Control Status does not apply to Demand Response Resources - Type I.

3.16.1 Control Status – Generation Resources and Demand Response Resources – Type II:

The Control Status will be set to 2 (Regulating) if the Resource meets the following conditions for the Dispatch Interval:

- The On-Line Flag is set to 1 for the Resource for the Dispatch Interval
- The Resource has been committed
- The Resource start-up / shut-down logic is not in a start-up or shut-down mode.
- The Resource does not utilize start-up/shut-down logic and the resource state-estimated output has been greater than the resource minimum limit at least once since the start of the commitment period
- The Resource is not being manually dispatched
- The Resource has not been made non-dispatchable
- The Resource is available to regulate for the Dispatch Interval
- The Resource has been scheduled to potentially provide regulation for the Dispatch Interval

If the Resource does not meet the conditions necessary for the Control Status to be set to 2 (Regulating) during the Dispatch Interval, then the Control Status will be set to 1 (Load Following) if the Resource meets the following conditions for the Dispatch Interval:

- The On-Line Flag is set to 1 for the Resource for the Dispatch Interval
- The Resource has been committed
- The Resource start-up / shut-down logic is not in a start-up or shut-down mode.
- The Resource does not utilize start-up/shut-down logic and the resource state-estimated output has been greater than the resource minimum limit at least once since the start of the commitment period
- The Resource is not registered as an Intermittent Resource
- The Resource is not being manually dispatched

- The Resource has not been made non-dispatchable

If the Resource does not meet the conditions necessary for the Control Status to be set to 1 (Load Following) or 2 (Regulating) during the Dispatch Interval, then the Control Status will be set to 3 (Non-Dispatchable) if the Resource meets any of the following conditions for the Dispatch Interval:

- The On-Line Flag is set to 1 for the Resource for the Dispatch Interval
- The Resource utilizes start/stop logic and is in start-up mode.

Otherwise, the Control Status is set to 0 (Off-Line).

3.16.2 Control Status – External Asynchronous Resources:

The Control Status will be set to 2 (Regulating) if the Resource meets the following conditions for the Dispatch Interval:

- The Resource is available
- The Resource is not being manually dispatched
- The Resource telemetry has good quality and is not being held
- The Resource is available to regulate for the Dispatch Interval
- The Resource has been scheduled to regulate for the Dispatch Interval
- The Resource has not been made non-dispatchable

If the Resource does not meet the conditions necessary for the Control Status to be set to 2 (Regulating) during the Dispatch Interval, then the Control Status will be set to 1 (Load Following) if the Resource meets the following conditions for the Dispatch Interval:

- The Resource is available
- The Resource is not being manually dispatched
- The Resource telemetry has good quality and is not being held
- The Resource has not been made non-dispatchable

If the Resource does not meet the conditions necessary for the Control Status to be set to 1 (Load Following) or 2 (Regulating) during the Dispatch Interval, then the Control Status will be set to 3 (Non-Dispatchable) if the Resource meets the following conditions for the Dispatch Interval:

- The Resource is available
- The Resource is being manually dispatched, is being held, or has been made non-dispatchable.

If the Resource is not available for the Dispatch Interval, the Control Status is set to 0 (Off-Line).

3.16.3 Control Status – Electric Storage Resources:

The Control Status will be set to 2 (Regulating) if the Resource meets the following conditions for the Dispatch Interval:

- The Commitment Status of the Resource for the Dispatch Interval is ‘DC’, ‘CH’ or ‘CO’
- The Resource has been committed
- The Resource is not being manually dispatched
- The Resource has not been made non-dispatchable
- The Resource is available to regulate for the Dispatch Interval

If the Resource does not meet the conditions necessary for the Control Status to be set to 2 (Regulating) during the Dispatch Interval, then the Control Status will be set to 1 (Load Following) if the Resource meets the following conditions for the Dispatch Interval:

- The Commitment Status of the Resource for the Dispatch Interval is ‘DC’, ‘CH’ or ‘CO’
- The Resource has been committed
- The Resource is not being manually dispatched
- The Resource has not been made non-dispatchable
- The Resource is not available to regulate for the Dispatch Interval

If the Resource does not meet the conditions necessary for the Control Status to be set to 1 (Load Following) or 2 (Regulating) during the Dispatch Interval, then the Control Status will be set to 3 (Non-Dispatchable) if the Resource meets the following conditions for the Dispatch Interval:

- The Resource is being manually dispatched, is being held, or has been made non-dispatchable.

Otherwise, the Control Status is set to 0 (Off-Line).

3.17 Fixed Dispatch

The fixed dispatch condition represents a conflict between the offers of a resource and the initial conditions of the resource in the Dispatch Interval. If outside of limits, the energy dispatch will be ramped toward the applicable limit and fixed at the resulting output. Fixed Dispatch applies to Generation Resources, External Asynchronous Resources and Demand Response Resources - Type II.

The Fixed Dispatch Flag, designated in the formulations as FixedDispFlag(r,di), indicates whether Resource r with Control Status 1 or 2 has a fixed dispatch, and is prohibited from being dispatched for reserves in Dispatch Interval di. The Fixed Dispatch Energy Level, designated in the formulations as FixedDispMW(r,di), indicates the energy level for a resource with FixedDispFlag(r,di)=1.

For a resource with Control Status equal to 2, the Fixed Dispatch Flag will be set to 1 if any of the following conditions are true:

- The Initial Energy Output calculated for the Resource and Dispatch Interval is greater than the regulation maximum limit plus five times the applicable bidirectional ramp rate for the Dispatch Interval. In this scenario, the Fixed Dispatch Energy Level is calculated by ramping the resource toward (but not past) its maximum limit at its applicable down ramp rate.
- The Initial Energy Output calculated for the Resource and Dispatch Interval is less than the regulation minimum limit less five times the applicable bidirectional ramp rate for the Dispatch Interval. In this scenario, the Fixed Dispatch Energy Level is calculated by ramping the resource toward (but not past) its minimum limit at its applicable up ramp rate.
- The MinLimit(r,di) and MaxLimit(r,di) for the Resource and Dispatch Interval are equal. In this scenario, the Fixed Dispatch Energy Level is calculated by ramping the resource toward (but not past) the limit at its applicable ramp rate,
- The applicable bidirectional ramp rate for the Resource and Dispatch Interval is zero. In this scenario, the Fixed Dispatch Energy Level is fixed at InitialEnergyOutput(r,di).

For a resource with Control Status equal to 1, the Fixed Dispatch Flag will be set to 1 if any of the following conditions are true:

- The Initial Energy Output calculated for the Resource and Dispatch Interval is greater than the maximum limit plus five times the ramp-down rate for the Dispatch Interval. In this scenario, the Fixed Dispatch Energy Level is calculated by ramping the resource toward (but not past) its maximum limit at its applicable down ramp rate.
- The Initial Energy Output calculated for the Resource and Dispatch Interval is less than the minimum limit less five times the ramp-up rate for the Dispatch Interval. In this scenario, the Fixed Dispatch Energy Level is calculated by ramping the resource toward (but not past) its minimum limit at its applicable up ramp rate.
- The MinLimit(r,di) and MaxLimit(r,di) for the Resource and Dispatch Interval are equal. In this scenario, the Fixed Dispatch Energy Level is calculated by ramping the resource toward (but not past) the limit at its applicable ramp rate,

- The ramp-up rate plus ramp-down rate for the Resource and Dispatch Interval is equal to zero. In this scenario, the Fixed Dispatch Energy Level is fixed at InitialEnergyOutput(r,di).

3.18 Regulation Mode Flag

The Regulation Mode Flag, which is designated in the formulations as **RegModeFlag(r,di)**, indicates whether or not Resource r will be scheduled to regulate for Dispatch Interval di. If the Control Status is set to 2 and the Fixed Dispatch Flag is set to 0 for a specific Resource in a specific Dispatch Interval, the Regulation Mode Flag will be set to 1 for that Resource and Dispatch Interval. If the Control Status is not set to 2 or the Fixed Dispatch Flag is set to 1 for a specific Resource in a specific Dispatch Interval, then the Regulation Mode Flag will be set to 0 for that Resource and Dispatch Interval.

3.19 Self-Scheduled Energy Status

The Self-Scheduled Energy Status, which is designated in the formulations as **SSEnergyStatus(r,di)**, is determined as follows for each Resource (except for Demand Response Resources - Type I) and Dispatch Interval based on the submitted Energy Dispatch Status for that Resource and Dispatch Interval:

- If the Energy Dispatch Status for a specific Resource and Dispatch Interval is set to ***Self Schedule***, then the Self-Scheduled Energy Status is set to 1 for that Resource and Dispatch Interval.
- If the Energy Dispatch Status for a specific Resource and Dispatch Interval is not set to ***Self Schedule***, then the Self-Scheduled Energy Status is set to 0 for that Resource and Dispatch Interval.

The Self-Scheduled Energy status is used in the self-schedule Energy constraints in the SCED algorithm.

3.20 Self-Scheduled Regulating Reserve Status

The Self-Scheduled Regulating Reserve Status, which is designated in the formulations as **SSRegResStatus(r,di)**, is determined as follows for each Resource (except Dispatchable Intermittent Resources, Demand Response Resources - Type I) and Dispatch Interval based on the submitted Regulating Reserve Dispatch Status for that Resource and Dispatch Interval:

- If the Regulating Reserve Dispatch Status for a specific Resource and Dispatch Interval is set to ***Self Schedule***, then the Self-Scheduled Regulating Reserve Status is set to 1 for that Resource and Dispatch Interval.

- If the Regulating Reserve Dispatch Status for a specific Resource and Dispatch Interval is not set to ***Self Schedule***, then the Self-Scheduled Regulating Reserve Status is set to 0 for that Resource and Dispatch Interval.

The Self-Scheduled Regulating Reserve Status is used in the self-schedule Regulating Reserve constraints in SCED.

3.21 Self-Scheduled Spinning Reserve Status

The Self-Scheduled Spinning Reserve Status, which is designated in the formulations as **SSSpinResStatus(r,di)**, is determined as follows for each Resource (except Dispatchable Intermittent Resources) and Dispatch Interval based on the submitted Spinning Reserve Dispatch Status for that Resource and Dispatch Interval:

- If the Spinning Reserve Dispatch Status for a specific Resource and Dispatch Interval is set to ***Self Schedule***, then the Self-Scheduled Spinning Reserve Status is set to 1 for that Resource and Dispatch Interval.
- If the Spinning Reserve Dispatch Status for a specific Resource and Dispatch Interval is not set to ***Self Schedule***, then the Self-Scheduled Spinning Reserve Status is set to 0 for that Resource and Dispatch Interval.

The Self-Scheduled Spinning Reserve Status is used in the self-schedule Contingency Reserve constraints in SCED.

3.22 Self-Scheduled Supplemental Reserve Status

The Self-Scheduled Supplemental Reserve Status, which is designated in the formulations as **SSSupResStatus(r,di)**, is determined as follows for each External Asynchronous Resource and Demand Response Resource - Type I and for each Dispatch Interval based on the submitted Supplemental Reserve Dispatch Status for that Resource and Dispatch Interval:

- If the Supplemental Reserve Dispatch Status for a specific Resource and Dispatch Interval is set to ***Self Schedule***, then the Self-Scheduled Supplemental Reserve Status is set to 1 for that Resource and Dispatch Interval.
- If the Supplemental Reserve Dispatch Status for a specific Resource and Dispatch Interval is not set to ***Self Schedule***, then the Self-Scheduled Supplemental Reserve Status is set to 0 for that Resource and Dispatch Interval.

The Self-Scheduled Supplemental Reserve Status is used in the self-schedule Contingency Reserve constraints in SCED.

3.23 Self-Scheduled On-Line Supplemental Reserve Status

The Self-Scheduled On-Line Supplemental Reserve Status, which is designated in the formulations as **SSOnLineSupResStatus(r,di)**, is determined as follows for each Generation Resource (except Dispatchable Intermittent Resources) and Demand Response Resource - Type II and for each Dispatch Interval based on the submitted On-Line Supplemental Reserve Dispatch Status for that Resource and Dispatch Interval:

- If the On-Line Supplemental Reserve Dispatch Status for a specific Resource and Dispatch Interval is set to ***Self Schedule***, then the Self-Scheduled On-Line Supplemental Reserve Status is set to 1 for that Resource and Dispatch Interval.
- If the On-Line Supplemental Reserve Dispatch Status for a specific Resource and Dispatch Interval is not set to ***Self Schedule***, then the Self-Scheduled On-Line Supplemental Reserve Status is set to 0 for that Resource and Dispatch Interval.

The Self-Scheduled On-Line Supplemental Reserve Status is used in the self-schedule Contingency Reserve constraints in SCED.

3.24 Self-Scheduled Off-Line Supplemental Reserve Status

The Self-Scheduled Off-Line Supplemental Reserve Status, which is designated in the formulations as **SSOffLineSupResStatus(r,di)**, is determined as follows for each Generation Resource (except Dispatchable Intermittent Resources) and Demand Response Resource - Type II and for each Dispatch Interval based on the submitted Off-Line Supplemental Reserve Dispatch Status for that Resource and Dispatch Interval:

- If the Off-Line Supplemental Reserve Dispatch Status for a specific Resource and Dispatch Interval is set to ***Self Schedule***, then the Self-Scheduled Off-Line Supplemental Reserve Status is set to 1 for that Resource and Dispatch Interval.
- If the Off-Line Supplemental Reserve Dispatch Status for a specific Resource and Dispatch Interval is not set to ***Self Schedule***, then the Self-Scheduled Off-Line Supplemental Reserve Status is set to 0 for that Resource and Dispatch Interval.

The Self-Scheduled Off-Line Supplemental Reserve Status is used in the self-schedule Contingency Reserve constraints in SCED.

3.25 Deployed Contingency Reserve

Deployed Contingency Reserve, which is designated in the formulations as **DeployedContRes(r,di)**, is determined for each Resource (except for Dispatchable Intermittent Resources) and Dispatch Interval and represents the total amount of Contingency Reserve deployment that was initiated on the Resource during the previous Dispatch Interval and continues to be deployed on the Resource at the beginning of the current Dispatch Interval.

3.26 Contingency Reserve Clearing Cap

A Contingency Reserve clearing cap, designated in the formulations as **ClearedContResCap(r,di)**, is determined for each Resource (except for Dispatchable Intermittent Resources) and Dispatch Interval and represents the maximum amount of Contingency Reserve the Resource is allowed to clear in a Dispatch Interval based on actual Contingency Reserve deployments made earlier in the day. This cap is normally set equal to the Emergency Maximum Limit of the Resource, which in effect disables the cap. However, if Contingency Reserve was deployed on the Resource earlier in the day and the Resource or common bus where the Resource is located deployed less than the requested amount in the Contingency Reserve Deployment Period (i.e., did not pass any of the four Contingency Reserve Deployment Tests), then the Contingency Reserve cap for the rest of the day is set equal to the lowest amount of Contingency Reserve actually deployed for all deployments where the resource deployed less than the requested Contingency Reserve deployment amount.

3.27 Resource Regulating Reserve Total Offer Price

The Regulating Reserve total offer price, designated in the formulations as **RegResOfferPrice(r,h)** is determined for each Resource prior to executing the SCUC algorithm. The Regulating Reserve total offer price is equal to the sum of the Resource’s Regulation Capacity offer (in $/MWh), and the Resource’s Regulation Mileage Offer (in $/MW) multiplied by the Regulation Deployment Factor (in units of deployments/hour). The Regulation Deployment Factor is needed to convert the mileage offer per MW of movement into an hourly offer. The Regulation Deployment Factor is updated for each calendar Operating Month, based on analysis performed for a one month period ending on the fifteenth of the month prior to the Operating Month. The factor is determined by first calculating the average ratio of deployed Regulating Mileage to cleared Regulating Capacity, averaged across all Resources providing Regulation, for each Dispatch Interval. This average is then multiplied by 12 to convert from average deployments per interval to average deployments per hour.

3.28 Contingency Reserve Offer Price

The Contingency Reserve offer price is determined for each Resource (except for Dispatchable Intermittent Resources) and for each Dispatch Interval. The Contingency Reserve Offer Price is designated in the formulations as **ContResOfferPrice(r,di)**.

3.28.1 Contingency Reserve Offer Price – Generation Resources and Demand Response Resources – Type II

The following logic is used to set the Contingency Reserve offer price for Generation Resources (other than DIRs) and Demand Response Resources - Type II.

- If a Generation Resources or Demand Response Resources - Type II is available to provide Spinning Reserve and on-line, then the Contingency Reserve offer price is set equal to the Spinning Reserve offer price.
- If a Generation Resource or Demand Response Resource - Type II is available to provide Supplemental Reserve, not available to provide Spinning Reserve and on-line, then the Contingency Reserve offer price is set equal to the On-Line Supplemental Reserve offer price.
- If a Generation Resource or Demand Response Resource - Type II is available to provide Off-Line Supplemental Reserve and off-line, then the Contingency Reserve offer price is set equal to the Off-Line Supplemental Reserve offer price.

3.28.2 Contingency Reserve Offer Price – Demand Response Resources – Type I

The following logic is used to set the contingency reserve offer price for Demand Response Resources - Type I for use in the SCED algorithm.

- If a Demand Response Resource - Type I is available to provide Spinning Reserve, then the Contingency Reserve offer price is set equal to the Spinning Reserve offer price for the hour.
- If a Demand Response Resource - Type I is available to provide Supplemental Reserve but is not available to provide Spinning Reserve, then the Contingency Reserve offer price is set equal to the Supplemental Reserve offer price for the hour.

3.28.3 Contingency Reserve Offer Price – External Asynchronous Resources

The following logic is used to set the Contingency Reserve offer price for External Asynchronous Resources.

- If an External Asynchronous Resource is available to provide Spinning Reserve and on-line, then the Contingency Reserve offer price is set equal to the Spinning Reserve offer price.
- If an External Asynchronous Resource is available to provide Supplemental Reserve, not available to provide Spinning Reserve and on-line, then the Contingency Reserve offer price is set equal to the On-Line Supplemental Reserve offer price.

3.28.4 Contingency Reserve Offer Price – Electric Storage Resources

The following logic is used to set the Contingency Reserve offer price for Electric Storage Resources.

- If an Electric Storage Resource is available to provide Spinning Reserve and on-line, then the Contingency Reserve offer price is set equal to the Spinning Reserve offer price.
- If an Electric Storage Resource is available to provide Supplemental Reserve, not available to provide Spinning Reserve and on-line, then the Contingency Reserve offer price is set equal to the On-Line Supplemental Reserve offer price.
- If an Electric Storage Resource is available to provide Off-Line Supplemental Reserve and is off-line, then the Contingency Reserve offer price is set equal to the Off-Line Supplemental Reserve offer price.

3.29 Offline Short Term Reserve Offer Price

The Offline Short Term Reserve Offer price is determined for each resource prior to executing the SCED algorithm. The Off-line Short Term Reserve Offer price is designated in the formulations as **offlineSTRResOfferPrice(r,di)**.

3.29.1 Offline Short Term Reserve Offer Price – Generation Resources

The following logic is used to set the Offline Short Term Reserve Offer price for Generation Resources for use in the SCED algorithm.

- If a Generation Resource is available to provide offline Short Term Reserve per Section 3.7.1 and is offline, then the Off-Line Short Term Reserve Offer price is set equal to the Off-Line Short Term Reserve Offer price.

3.29.2 Offline Short Term Reserve Offer Curve – Demand Response Resources – Type I and Type II

The following logic is used to set the Off-Line Short Term Reserve Offer price curve for Demand Response Resources - Type I and II for use in the SCED algorithm.

If a Demand Response Resource - Type I and II is available to provide offline Short Term Reserve per Section 3.7.1 or Section 3.7.2, then the Off-Line Short Term Reserve Offer curve is set based upon participant-submitted values up to a three segment offer curve and “usebidslope” flag specified for the hour.

3.30 Market-Wide Contingency Reserve Requirement Adjustment

For the first fifteen (15) minutes following a Contingency Reserve deployment event (i.e., disturbance recovery period), the Contingency Reserve requirement will be adjusted to the greater of the maximum available Contingency Reserve or the pre-disturbance Contingency Reserve requirement less the Contingency Reserve deployment amount. For the ninety (90) minute period following the disturbance recovery period (i.e., Contingency Reserve replenishment period), the Contingency Reserve requirements will be adjusted to the greater of the maximum available Contingency Reserve or the pre-disturbance Contingency Reserve requirement less the Contingency Reserve deployment amount, unless the event is terminated prior to the end of the replenishment period. The Contingency Reserve Adjustment is equal to the pre-deployment Contingency Reserve Requirement less the post-deployment adjusted Contingency Reserve Requirement.

Should multiple Contingency Reserve deployments be effective at the same time, the Contingency Reserve requirements will be adjusted to the greater of the maximum available Contingency Reserve or the pre-disturbance Contingency Reserve requirement less the Contingency Reserve deployment amounts associated with each event. The Contingency Reserve Adjustment is equal to the pre-deployment Contingency Reserve Requirement less the post-deployment adjusted Contingency Reserve Requirement.

3.31 Market-Wide Operating Reserve Requirement

The Market-Wide Operating Reserve Requirement is calculated for each Dispatch Interval prior to executing the SCED algorithm. The Market-Wide Operating Reserve Requirement for a specific Dispatch Interval is set equal to the sum of the Market-Wide Regulating Reserve Requirement for that Dispatch Interval plus the Market-Wide Contingency Reserve Requirement for that Dispatch Interval less the Market-Wide Contingency Reserve Requirement Adjustment for the Dispatch Interval. The Market-Wide Operating Reserve Requirement for a specific Dispatch Interval is designated in the formulations as **MWORReq(di)**.

3.32 Market-Wide Regulating plus Spinning Reserve Requirement

The Market-Wide Regulating plus Spinning Reserve Requirement is calculated for each Dispatch Interval prior to executing the SCED algorithm. The Market-Wide Regulating plus Spinning Reserve Requirement for a specific Dispatch Interval is set equal to the sum of the Market-Wide Regulating Reserve Requirement for that Dispatch Interval plus the Market-Wide Spinning Reserve Requirement for that Dispatch Interval. The Market-Wide Regulating plus Spinning Reserve Requirement for a specific Dispatch Interval is designated in the formulations as **MWRegSpinReq(di)**.

3.33 Market-Wide Short Term Reserve Requirement

The Market-Wide Short Term Requirement is calculated for each Dispatch Interval prior to executing the SCED algorithm. The Market-Wide Short Term Reserve Requirement for a specific Dispatch Interval is designated in the formulations as **MWSTRReq(di)**.

3.34 Market-Wide Up Ramp Capability Requirement

The Market_Wide Up Ramp Capability Requirement is calculated for each Dispatch Interval prior to executing the SCED algorithm. The Market-Wide Up Ramp Capability Requirement for a specific Dispatch Interval is set to be the sum of Up Net Demand change and Uncertainty at the ramp deployment time. The Market-Wide Up Ramp Capability Requirement for a specific Dispatch Interval is designated in the formulations as **MWRCUpReq(di)**.

3.35 Market-Wide Down Ramp Capability Requirement

The Market_Wide Down Ramp Capability Requirement is calculated for each Dispatch Interval prior to executing the SCED algorithm. The Market-Wide Down Ramp Capability Requirement for a specific Dispatch Interval is set to be the sum of Down Net Demand Change and Uncertainty at the ramp deployment time. The Market-Wide Down Ramp Capability Requirement for a specific Dispatch Interval is designated in the formulations as **MWRCDownReq(di)**.

4. Method to Establish Minimum Co-Optimized Zonal Operating Reserve and other reserve Requirements

MISO identifies the minimum Co-Optimized Zonal Operating Reserve, Ramp Capability and Short Term Reserve Requirements as the minimum amount of Reserves needed within a Reserve Zone as determined by co-optimization with Post Reserve Deployment Constraints. The Post Reserve Deployment Constraints are the post zonal reserve deployment flows on the transmission constraints, used to determine the Co-optimized Zonal Regulating Reserve Requirement, Co-optimized Zonal Contingency Reserve Requirement, Co-optimized Zonal Spinning Reserve Requirement, Co-optimized Zonal Ramp Capability Requirement and Co-optimized Zonal Short Term Reserve Requirement for each Reserve Zone.

4.1 Generation-Based Operating Reserve Requirement Factor

The Generation-Based Operating Reserve Requirement Factor, designated in the formulations as **GenORReqFactor(di)**, represents the minimum percentage of the Market-Wide Operating Reserve Requirement that must be satisfied by Generation Resources, Demand Response Resources - Type II and External Asynchronous Resources based on reliability standards. Currently, the amount of Supplemental Reserve that may be supplied by interruptible load is 50%

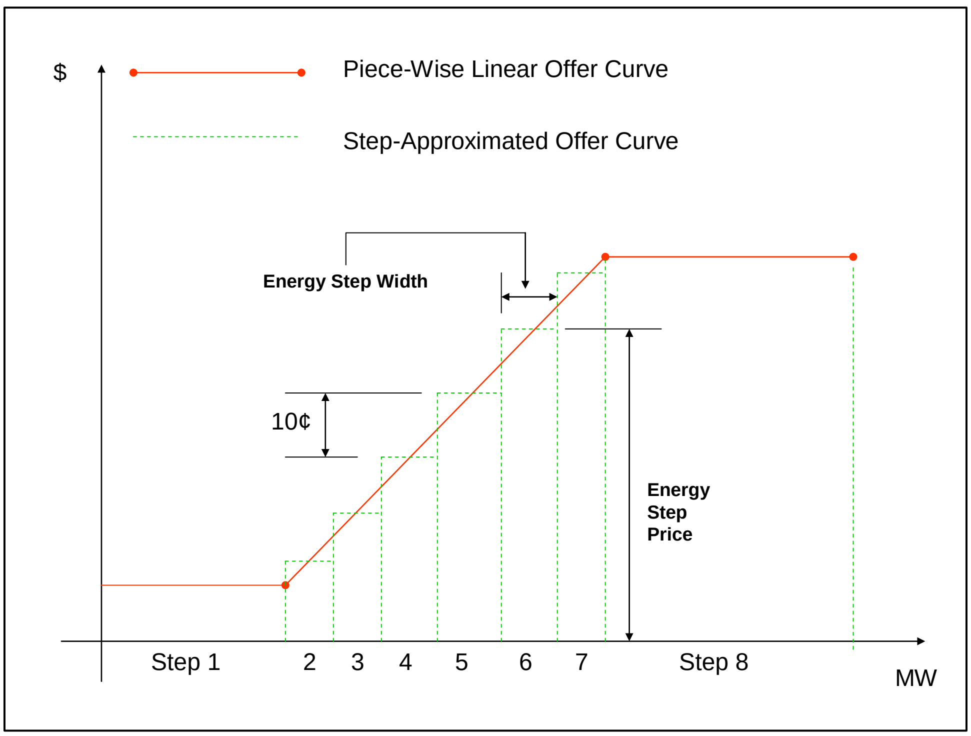
of the Supplemental Reserve requirement. The Generation-Based Operating Reserve Requirement Factor will be calculated for each Dispatch Interval as follows:

GenORReqFactor(di)
= MWRegSpinReq(di) / MWORReq(di)
+ 0.5 * [MWORReq(di) - MWRegSpinReq(di)] / MWORReq(di)

4.2 SCED Energy Offer Curve Linearization

For each Resource, if the Energy offer curve for the Dispatch Interval is modeled as a piece-wise linear curve, it is converted to an approximated step offer curve for use in the SCED algorithm. The SCED Energy offer curve linearization creates a new offer curve step for each ten cent ($0.10) increase in the offer curve price, up to a maximum of 100 offer curve steps. Exhibit 4-1 below provides a graphical illustration of the SCED offer curve linearization:

Exhibit 4-1: SCED Energy Offer Curve Linearization Illustration



The Energy step width and Energy step price of each approximated Energy offer curve step are designated in the formulations as **EnergyStepWidth(r,di,st)** and **EnergyStepPrice(r,di,st)** respectively.

4.3 Market-Wide Operating Reserve Demand Curve Construction

Prior to each SCED execution, the Market-Wide Operating Reserve Demand Curve is constructed for the Dispatch Interval based on the specification in the Tariff and the Market-Wide Operating Reserve Requirement calculated for the Dispatch Interval. The Market-Wide Operating Reserve Demand Curve includes a primal variable for each demand curve step, designated in the formulations as **MWOpResStepClearing(st,di)**, a MW step width for each demand curve step, designated in the formulations as **MWOpResStepWidth(st,di)** and a price for each demand curve step, designated in the formulations as **MWOpResStepPrice(st,di)**.

All other demand curves are either single step curves (Market-Wide Regulating Reserve Demand Curve and the Reserve Zone Regulating Reserve Demand Curves), two step curves (Reserve Zone Operating Reserve Demand Curves), or three-step curves (Market-Wide Regulating and Spinning Reserve Demand Curve, Reserve Zone Regulating and Spinning Reserve Demand Curves) that can be modeled directly in the SCED formulations.

4.4 Net Scheduled Interchange Calculations

The MISO Balancing Authority Net Scheduled Interchange, designated as **NSI(di)** in the formulations, is determined for the Dispatch Interval di based on scheduling data from webTrans and Contingency Reserve Deployment System. The Net Scheduled Interchange is calculated as the sum of the following:

- The total MW sum of all fixed export schedules less the total MW sum of all fixed import schedules.
- The total MW sum of all dynamic export schedules less the total MW sum of all dynamic import schedules. Dynamic schedule amounts may be determined based on either the estimated value from webTrans or a projected value telemetered in advance by the market participant.
- The total MW algebraic sum of all NSI adjustments resulting from active Contingency Reserve Sharing Group events.

4.5 System Loss Rate

The MISO system loss rate, designated in the formulations as **SystemLossRate(di)**, represents the ratio of system losses to total system demand and is calculated as follows based on State Estimator data:

SystemLossRate(di) = SEActualLosses(di) / SESystemDemand(di)

4.6 System Demand Calculation

The system demand for a specific Dispatch Interval, designated in the formulations as **SystemDemandMW(di)**, represents the projected demand of the MISO market load at the end of the Dispatch Interval. The system demand for a specific Dispatch Interval is estimated as follows:

SystemDemandMW(di) = Σ { STLF(lba,di) + STLFCorrectionFactor(lba,di) } * [1 - SystemLossRate(di)] lba + SystemLoadOffset(di)

Therefore, the projected demand of the MISO market load for the end of a Dispatch Interval is equal to the sum of the corrected short-term load forecast for each local balancing authority multiplied by one less the system loss rate and then adjusted by a system load offset factor. The system load offset factor is used to move Resource outputs early in anticipation of large changes in forecasted system demand and/or net scheduled interchange.

4.7 External Injection Calculation

The external injection MW, designated in the formulations as **ExternalInjectionMW(i,di)**, are calculated for each external generation bus for a Dispatch Interval to represent the impacts on losses and congestion of external generation serving external load as well as to model interchange into or out of the MISO Balancing Authority.

The external injection MWs for each external generation bus are initialized at the value determined by the most recent State Estimator solution available prior to executing the SCED algorithm. The positive external injection MWs are then scaled up or down until the sum of the negative external injection MWs less the positive external injection MWs is equal to the net scheduled interchange.

4.8 Loss Offset Factor Calculation

The loss offset factor for Dispatch Interval di, designated in the formulations as **LossOffsetFactor(di)**, is used in the modeled losses constraint to estimate actual series branch losses within the MISO market as a function of the SCED dispatch results. The loss offset factor is the ratio of the difference between marginal and actual series branch losses within the MISO market to the system demand of the MISO market. To estimate the loss offset factor, the marginal losses associated with the most recent State Estimator solution are calculated by applying the loss sensitivity factors associated with the State Estimator solution to all injections and withdrawals associated with the State Estimator solution, or:

SEMarginalLosses(di) = Σ { CurrentSEMW(i,di) * ∂Loss(di)/∂P(i,di) }

The loss offset factor is then calculated as follows:

LossOffsetFactor(di) = [SEActualLosses(di) - SEMarginalLosses(di)] / SESystemDemand(di)

The loss offset factor is negative since losses are a quadratic function of branch flows; thus, marginal losses will always exceed actual losses.

4.9 Contingency Analysis Constraint Activation

The Reliability Coordinators may activate any transmission flowgate constraints as necessary to manage transmission congestion based on the results of the State Estimator driven Real-Time Contingency Analysis application. The constraint shift factors and AC flows are passed to the Real-Time Security Constrained Economic Dispatch for modeling in the Real-Time Energy and Operating Reserve Market.

5. SCED Formulations

The Real-Time SCED algorithm is executed for each Dispatch Interval to:

- Clear Energy, Regulating Reserve, Spinning Reserve and Supplemental Reserve, Up Ramp, Down Ramp Capability and Short Term Reserve on Resources
- Calculate Ex Ante Locational Marginal Prices (LMPs) for Energy
- Calculate Market Clearing Prices (MCPs) for Regulating Reserve, Spinning Reserve , Supplemental Reserve, Up Ramp and Down Ramp Capability and Short Term Reserve

The Real-Time SCED algorithm uses a Linear Programming (LP) solver. In the formulations that follow, continuous primal variables are shown in a red font and constraint violation variables are shown in a blue font. See Attachment A on Market Optimization Techniques for background information on LP SCED formulations.

5.1 SCED Objective Function

The overall objective function of the SCED algorithm is to minimize the following cost function over a single Dispatch Interval:

MINIMIZE {Resource Energy Costs
+ Regulating Reserve Costs
+ Contingency Reserve Costs
+ Off-Line Short Term Reserve Costs
- Market-Wide Operating Reserve Value
- Market-Wide Regulating Reserve Value
-Market-Wide Regulating plus Spinning Reserve Value
-Market-Wide Up Ramp Capability Value
-Market-Wide Down Ramp Capability Value
- Market-Wide Short Term Reserve Value
+ Constraint Violation Penalty Costs**
+ Tie-Breaking Penalty Costs

**Note: Applies only when there are opposing constraints

The cost terms in the objective function above are described as follows.

5.1.1 Resource Energy Costs

Resource Energy costs apply only to Generation Resources, Demand Response Resources - Type II, External Asynchronous Resources and Electric Storage Resource. Energy costs are expressed mathematically in the SCED objective function as follows:

Resource Energy Costs

$$= \sum_{r} \left\{ \int_{0}^{EnergyDispatchTarget(r,di)} EnergyOfferCurve(r,di,MW)dMW \right\} / 12$$

NOTE: The Energy offer curve must be converted to an approximated stepped curve in order to linearize the SCED optimization problem. Each step of the approximated offer curve is then treated as a separate offer and the amount of dispatch within each step is treated as a separate continuous primal variable in the SCED optimization problem. Therefore, the following mathematical expression for Energy Costs is incorporated into the actual SCED objective function:

Energy Costs

$$= \sum_{r} \sum_{st} \{ EnergyStepPrice(r,di,st) * EnergyStepClearing(r,di,st) \} / 12$$

where

$$EnergyDispatchTarget(r,di) = \sum_{st} \{ EnergyStepClearing(r,di,st) \}$$

5.1.2 Regulating Reserve Costs

Regulating Reserve costs apply only to Generation Resources, Demand Response Resources - Type II and External Asynchronous Resources. Regulating Reserve costs are expressed mathematically in the SCED objective function as follows:

Regulating Reserve Costs

$$= \sum_{r} \{ RegResOfferPrice(r,di) * ClearedRegRes1(r,di) + RegCapOfferPrice(r,di)*ClearedRegRes2(r,di) \} / 12$$

NOTE: Regulation-qualified DRR-Type II resources may submit a Regulating Reserve offer curve. This curve would then be treated similar to an Energy offer curve as described in the Resource Energy Costs Section 5.1.1.

5.1.3 Contingency Reserve Costs

Contingency Reserve costs apply to all Resources. Contingency Reserve costs are expressed mathematically in the SCED objective function as follows:

Contingency Reserve Costs

$$= \sum_{r} \{ ContResOfferPrice(r,di) * ClearedContRes(r,di) \} / 12$$

NOTE: DRR-Type I and DRR-Type II resources may submit Contingency Reserve offer curves. These curves would then be treated similar to an Energy offer curve as described in the Resource Energy Costs Section 5.1.1.

5.1.4 Off-Line Short Term Reserve Costs

Off-Line Short Reserve costs apply to uncommitted Generation Resources (other than Intermittent Resources, Dispatchable Intermittent Resources and Demand Response Resource – Type I) and Demand Response Resources - Type I and II. Off-Line Short Term Reserve costs are expressed mathematically in the SCUC objective function as follows:

Off-Line Short Term Reserve Costs

$$= \sum_{r} \sum_{di} \{ OffLineSTROfferPrice(r,di) * ClearedOffLineSTR(r,di) \}$$

5.1.5 Market-Wide Operating Reserve Value

Market-Wide Operating Reserve Value is expressed mathematically in the SCED objective function as follows:

Market Wide Operating Reserve Value

$$= \int_{0}^{ClearedMWOpRes(di)} MWOpResDemandCurve(di,MW)dMW / 12$$

NOTE: The market-wide Operating Reserve demand curve is a stepped curve. Therefore, the following mathematical expression for market-wide Operating Reserve value is incorporated into the actual SCED objective function:

Market Wide Operating Reserve Value

$$= \sum_{st} \{ MWOpResStepPrice(st,di) * MWOpResStepClearing(st,di)\} / 12$$

5.1.6 Market-Wide Regulating Reserve Value

Market-Wide Regulating Reserve Value is expressed mathematically in the SCED objective function as follows:

Market Wide Regulating Reserve Value

$$= \int_{0}^{ClearedMWRegRes(di)} MWRegResDemandCurve(di,MW)dMW / 12$$

NOTE: The market-wide Regulating Reserve demand curve is a two-step curve RegResDemandPrice per MW and $0 per MW). Therefore, the following mathematical expression for market-wide Regulating Reserve value is incorporated into the actual SCED objective function:

Market-Wide Regulating Reserve Value

$$= RegResDemandPrice * MWRegResStep1Clearing(di) / 12$$

5.1.7 Market-Wide Regulating plus Spinning Reserve Value

Market-Wide Regulating plus Spinning Reserve Value is expressed mathematically in the SCED objective function as follows:

Market Wide Regulating plus Spinning Reserve Value

$$= \int_{0}^{ClearedMWRegRes(di)+ClearedMWSpinRes(di)} MWRegSpinResDemandCurve(di,MW)dMW$$

NOTE: The market-wide regulating plus spinning reserve demand curve is a three-step curve ($98 per MWhr, $65 per MWhr and $0 per MWhr). Therefore, the following mathematical expression for market-wide regulating plus spinning reserve value is incorporated into the actual SCED objective function:

Market-Wide Regulating plus Spinning Reserve Value

= {(98) * MWRegSpinResStep1Clearing(di)
+ 65 * MWRegSpinResStep2Clearing(di)+ 0 * MWRegSpinResStep3Clearing(di)}

r di

5.1.8 Market-Wide Short Term Reserve Value

Market-Wide Short Term Reserve Reserve Value is expressed mathematically in the SCED objective function as follows:

Market Wide Short Term Reserve Value

$$= \int_{0}^{ClearedMWSTRRes(di)} MWSTRResDemandCurve(di,MW)dMW$$

NOTE: The market-wide Short Term Reserve demand curve is a one-step curve ($100 per MWhr). Therefore, the following mathematical expression for market-wide Short-Term reserve value is incorporated into the actual SCED objective function:

Market-Wide Short Term Reserve Value

$$= \sum_{st} \{ MWSTRResStepPrice(st,h) * MWSTRResStepClearing(st,h)\}$$

5.1.9 Market Wide Up Ramp Capability value

The Market Wide Up Ramp Capability Value

$$= \int_{0}^{ClearedMWRCUp(di)} MWRCUpDemandCurve(di,MW)dMW$$

NOTE: The market-wide up ramp capability demand curve is a two-step curve ($5 per MWhr and $0 per MWhr). Therefore, the following mathematical expression for market-wide ramp up capability value is incorporated into the actual SCED objective function:

Market-Wide Up Ramp Capability Value

$$= \sum_{st} \{ MWRCUpResStepPrice(st,h) * MWRCUpResStepClearing(st,h)\}$$

5.1.10 Market Wide Down Ramp Capability value

The Market Wide Ramp Capability Value

$$= \int_{0}^{ClearedMWRCDown(di)} MWRCDownDemandCurve(di,MW)dMW$$

NOTE: The market-wide down ramp capability demand curve is a $0 penalty one-step curve (down ramp capability demand is not required). Therefore, the following mathematical expression for Down Market-Wide Ramp Capability Value is incorporated into the actual SCED objective function:

Market-Wide Down Ramp Capability Value

$$= 0 * MWRCDownStepClearing(di)$$

5.1.11 Opposing Constraint Violation Penalty Costs

Opposing constraint violation penalty costs are included in the SCED objective function to avoid an infeasible solution when opposing constraints exists (see Attachment A on Market Optimization Techniques for more information on addressing infeasible solutions). Constraint violation variables are introduced into the cost minimization objective function with penalty price coefficients. The opposing constraint violation penalty terms are used to ensure the solution satisfies all constraints if possible and/or to prioritize the constraints to determine which constraints are violated under an opposing constraint scenario. The following opposing constraint violation penalty terms are included in the cost minimization objective function of the SCED algorithm:

5.1.11.1 Resource Maximum Limit Violation Cost:

Applies to Generation Resources, Demand Response Resources - Type II and External Asynchronous Resources:

Resource Maximum Limit Violation Cost

$$= \sum_{r} \{ \text{LimitPenPrice} * \text{MaxLimitViolation}(r,di) \} / 12$$

5.1.11.2 Resource Minimum Limit Violation Cost:

Applies to Generation Resources, Demand Response Resources - Type II and External Asynchronous Resources:

Resource Minimum Limit Violation Cost

$$= \sum_{r} \{ \text{LimitPenPrice} * \text{MinLimitViolation}(r,di) \} / 12$$

5.1.11.3 Resource Ramp Rate Violation Cost:

Applies to Generation Resources, Demand Response Resources - Type II and External Asynchronous Resources:

Resource Ramp Rate Violation Cost

$$= \sum_{r} \{ \text{RampPenPrice} * \text{GeneralRampUpViolation}(r,di) \} / 12$$

$$+ \sum_{r} \{ \text{RampPenPrice} * \text{GeneralRampDownViolation}(r,di) \} / 12$$

$$+ \sum_{r} \{ \text{RampPenPrice} * \text{ContResRampViolation}(r,di) \} / 12$$

$$+ \sum_{r} \{ \text{RampPenPrice} * \text{RegRampViolation}(r,di) \} / 12$$

$$+ \sum_{r} \{ \text{RampPenPrice} * \text{RCUpRampViolation(r,di)} \} / 12$$

$$+ \sum_{r} \{ \text{RampPenPrice} * \text{RCDownRampViolation(r,di)} \} / 12$$

$$+ \sum_{r} \{ \text{RampPenPrice} * \text{STRRampViolation(r,di)} \} / 12$$

5.1.11.4 Global Power Balance Violation Cost:

Applies to the entire market.

Global Power Balance Violation Cost

= EnergyShortagePenPrice * GlobalEnergyShortage(di) / 12
+ EnergySurplusPenPrice * GlobalEnergySurplus(di) / 12

5.1.11.5 Generation-Based Regulating Reserve Violation Cost:

Applies to the entire market.

Generation Based Regulating Reserve Violation Cost

= GenRegShortagePenPrice * GenRegShortage(di) / 12

5.1.11.6 Generation-Based Regulating plus Spinning Reserve Violation Cost:

Applies to the entire market

Generation Based Regulating plus Spinning Reserve Violation Cost

= GenRegSpinShortagePenPrice * GenRegSpinShortage(di) / 12

5.1.11.7 Generation-Based Operating Reserve Violation Cost:

Applies to the entire market

Generation Based Operating Reserve Violation Cost

= GenOpResShortagePenPrice * GenOpResShortage(di) / 12

5.1.11.8 Transmission Demand Curve Violation Cost:

Applies to each transmission constraint. Each Transmission Constraint consists of a step curve with one or more steps.

Transmission Demand Curve Violation Cost

$$= \sum_{k} \{ \text{TransLimitPenPrice} * \text{TransLimitStepViolation(st,k,di)} \} / 12$$

5.1.11.9 Sub-Regional Demand Curve Violation Cost:

Applies to the Sub-Regional Demand Constraint. The Sub-Regional Demand Constraint consists of a step curve.

Sub-Regional Demand Curve Violation Cost

$$= \sum_{k} \{ \text{SubRegLimitPenPrice(st,k,h)} * \text{SubRegLimitStepViolation(st,k,di)} \} / 12$$

5.1.11.10 Reserve Procurement Transmission Limit Regulation Up Violation Cost:

Applies to each transmission constraint selected as a reserve procurement constraint.

Reserve Procurement Transmission Limit Regulation Up Violation Cost

$$= \sum_{k} \{ [\text{TransLimitRegUpPenPrice} * \text{TransLimitViolationRegUp(k)}] \}$$

5.1.11.11 Reserve Procurement Transmission Limit Regulation Down Violation Cost:

Applies to each transmission constraint selected as a reserve procurement constraint.

Reserve Procurement Transmission Limit Regulation Down Violation Cost

$$= \sum_{k} \{[\text{TransLimitRegDownPenPrice} * \text{TransLimitViolationRegDown(k)}]\}$$

5.1.11.12 Reserve Procurement Transmission Limit Contingency Reserve Event Violation Cost:

Applies to each transmission constraint selected as a reserve procurement constraint.

Reserve Procurement Transmission Limit Contingency Reserve Event Violation Cost

$$= \sum_{k} \sum_{z} \{[TransLimitCREventPenPrice * TransLimitViolationCREvent(k,z)]\}$$

5.1.11.13 Short Term Reserve Post-Deployment Power Balance Constraint Violation Cost:

Applies to each Reserve Zone.

Short Term Reserve Post-Deployment Power Balance Constraint Violation Cost

$$= \sum_{z} \sum_{di} \{[ZneedSTRPenPrice * (ZNeedViolSTRPos(z,di) + ZNeedViolSTRNeg(z,di))]\}$$

5.1.11.14 Reserve Procurement Transmission Limit Short Term Reserve Event Violation Cost:

Applies to each transmission constraint selected as a Short Term Reserve procurement constraint.

Short Term Reserve Procurement Transmission Limit Short Term Reserve Event Violation Cost

$$= \sum_{k} \sum_{di} TotalSTRPenaltyCost(k,di)$$

,where

$$TotalSTRPenaltyCost(k,di) >= TransLimitSTRPenPrice(k,di)*[TransLimitViolSTR(k,e,di) + TransLimitSurplusSTR(k,e,di)]$$

5.1.11.15 Ramp Procurement Transmission Limit Up Ramp Capability Violation Cost:

Applies to each transmission constraint selected as a ramp procurement constraint.

Ramp Procurement Up Ramp Capability post deployment transmission limit Violation Cost

= Σ {[TransLimitRCUpPenPrice * TransLimitViolationRCUp(k)]}

5.1.11.16 Ramp Procurement Transmission Limit Down Ramp Capability Violation Cost:

Applies to each transmission constraint selected as a ramp procurement constraint.

Ramp Procurement Down Ramp Capability post deployment transmission limit Violation Cost

= Σ {[TransLimitRCDownPenPrice * TransLimitViolationRCDown(k)]}

5.1.11.17 Maximum Resource Regulating Reserve Violation Cost:

Applies to each Resource.

Maximum Resource Regulating Reserve Violation Cost

$$= \sum_{r} \{ \text{Max ResourceRegPenPrice} * \text{MaxResourceRegViolation(r,di)} \} / 12$$

5.1.11.18 Maximum Resource Contingency Reserve Violation Cost:

Applies to each Resource.

Maximum Resource Contingency Reserve Violation Cost

$$= \sum_{r} \{ \text{Max ResourceContResPenPrice} * \text{Max ResourceContResViolation(r,di)} \} / 12$$

5.1.11.19 Maximum Resource Short Term Reserve Violation Cost:

Applies to each resource

Maximum Resource Short Term Reserve Violation Cost

$$= \sum_{r} \{ \text{MaxResourceSTRResPenPrice} * \text{MaxResourceSTRResViolation(r,di)} \} / 12$$

5.1.11.20 Maximum Resource Up Ramp Capability Violation Cost:

Applies to each Resource.

Maximum Resource Down Ramp Capability Violation Cost

$$= \sum_{r} \{ \text{MaxResourceRCUpPenPrice} * \text{MaxResourceRCUPViolation(r,di)} \} / 12$$

5.1.11.21 Maximum Resource Down Ramp Capability Violation Cost:

Applies to each Resource.

Maximum Resource Down Ramp Capability Violation Cost

$$= \sum_{r} \{ \text{MaxResourceRCDownPenPrice} * \text{MaxResourceRCDownViolation(r,di)} \} / 12$$

5.1.11.22 Resource Self-Scheduled Energy Violation Cost:

Applies to each Resource.

Resource Self-Scheduled Energy Violation Cost

$$= \sum_{r} \{ \text{SSEnergyPenPrice} * \text{SSEnergyDeficit(r,di)} \} / 12$$

5.1.11.23 Resource Self-Scheduled Regulating Reserve Violation Cost:

Applies to each Resource.

Resource Self-Scheduled Regulating Reserve Violation Cost

$$= \sum_{r} \{ \text{SSRegPenPrice} * \text{SSRegDeficit(r,di)} \} / 12$$

5.1.11.24 Resource Self-Scheduled Contingency Reserve Violation Cost:

Applies to each Resource.

Resource Self-Scheduled Contingency Reserve Violation Cost

$$= \sum_{r} \{ \text{SSContResPenPrice} * \text{SSContResDeficit(r,di)} \} / 12$$

5.1.11.25 Resource Contingency Reserve Deployment Constraint Violation Cost:

Applies to each Resource.

Resource Contingency Reserve Deployment Constraint Violation Cost

$$= \sum_{r} \{ \text{DeployedContResPenPrice} * \text{DeployedContResDeficit}(r,di) \} / 12$$

5.1.12 Tie-Breaking Penalty Costs

Tie-breaking penalty costs are included in the objective function to ensure fair and equitable clearing of Energy and Operating Reserve when there is more than one optimum solution (See Attachment A on Market Optimization Techniques for a discussion of tie-breaking constraints). The tie-breaking penalty prices are hard coded at $0.000001 to prevent any measurable impact on prices.

5.1.12.1 Energy Tie-Breaking Penalty Costs:

Energy Tie Breaking Penalty Costs

$$= \sum_{e1} \sum_{e2} \{ 0.000001 * \text{EnergyTieBreak1}(r1,r2,di) \} / 12$$

$$+ \sum_{e1} \sum_{e2} \{ 0.000001 * \text{EnergyTieBreak2}(r1,r2,di) \} / 12$$

5.1.12.2 Regulating Reserve Tie-Breaking Penalty Costs:

Regulating Reserve Tie Breaking Penalty Costs

$$= \sum_{r1} \sum_{r2} \{ 0.000001 * \text{RegResTieBreak1}(r1,r2,di) \} / 12$$

$$+ \sum_{r1} \sum_{r2} \{ 0.000001 * \text{RegResTieBreak2}(r1,r2,di) \} / 12$$

5.1.12.3 Contingency Reserve Tie-Breaking Penalty Costs:

Contingency Reserve Tie Breaking Penalty Costs

$$= \sum_{r1} \sum_{r2} \{ 0.000001 * ContResTieBreak1(r1,r2,di) \} / 12$$

$$+ \sum_{r1} \sum_{r2} \{ 0.000001 * ContResTieBreak2(r1,r2,di) \} / 12$$

5.1.12.4 Short Term Reserve Tie-Breaking Penalty Costs:

Short Term Reserve Tie Breaking Penalty Costs

$$= \sum_{r1} \sum_{r2} \{ 0.000001 * STRResTieBreak1(r1,r2) \}$$

$$+ \sum_{r1} \sum_{r2} \{ 0.000001 * STRResTieBreak2(r1,r2) \}$$

5.2 SCED Constraints

The overall objective function of the SCED algorithm is minimized subject to the following constraints:

NOTE: While the formal constraint representation includes all variables on the LHS and a single constant on the RHS, the SCED constraints below have been arranged in a format that provides the most clarity as to the purpose and function of the constraint.

5.2.1 Generation Resource and Demand Response Resource – Type II Constraints

5.2.1.1 Energy Step Clearing Constraints

Constraint Classification: Physical

Constraint Type: Hard LE

The following constraints ensure that the cleared Energy associated with a specific Energy offer curve step during a specific Dispatch Interval is less than or equal to the Energy step width of the Energy offer curve step for the Dispatch Interval or zero if the Resource is not on-line:

$$EnergyStepClearing(r,di,st) \leq OnLineFlag(r,di) * EnergyStepWidth(r,di,st)$$

If the Resource on-line flag for the Dispatch Interval is set to 0, then the cleared Energy for each Energy offer curve step associated with the Resource must be zero. If the Resource on-line flag for the Dispatch Interval is set to 1, then the cleared Energy for a specific Energy offer curve step must be less than or equal to the Energy step width of that Energy offer curve step.

5.2.1.2 Energy Dispatch Target Constraints

Constraint Classification: Physical

Constraint Type: Hard Equality

The following constraints establish the Energy dispatch target of a Resource during the Dispatch Interval:

IF {{ ControlStatus(r,di) = 1 **}**
OR { ControlStatus(r,di) = 2 **}}**
AND { FixedDispFlag(r,di) = 0 **}**

$$EnergyDispatchTarget(r,di) = \sum_{st} \{EnergyStepClearing(r,di,st)\}$$

ELSE IF {{ ControlStatus(r,di) = 1 **}**
OR { ControlStatus(r,di) = 2 **}}**
AND { FixedDispFlag(r,di) = 1 **}**

EnergyDispatchTarget(r,di) = FixedDispMW(r,di)

ELSE IF { Control Status(r,di) = 3 **}**
AND { ManualDispatchFlag(r,di) = 1 **}**

EnergyDispatchTarget(r,di) = ManualDispatchMW(r,di)

ELSE IF { Control Status(r,di) = 3 **}**
AND { StartStopModeFlag(r,di) = 1 **}**

EnergyDispatchTarget(r,di) = StartStopProfileMW(r,di)

ELSE IF { Control Status(r,di) = 3 **}**

EnergyDispatchTarget(r,di) = CurrentSEMW(r,di)

ELSE

EnergyDispatchTarget(r,di) = 0

If the Resource Control Status is set to 1 (Load Following) or 2 (Regulating) for the Dispatch Interval and the Fixed Dispatch Flag is set to 0, the Energy dispatch target for the Resource and Dispatch Interval is set equal to the sum of the Energy cleared for each of the offer curve steps. If the Resource Control Status is set to 1 (Load Following) or 2 (Regulating) for the Dispatch Interval, but the resource Fixed Dispatch Flag is set to 1, the Energy dispatch target for the Resource and Dispatch Interval is set equal to the Fixed Dispatch Energy Level. If the Resource Control Status is set to 3 (Non-Dispatchable) for the Dispatch Interval and the Resource is being manually dispatched, the Energy dispatch target for the Resource and Dispatch Interval is set equal to the operator-entered manual dispatch MW target. If the resource Control Status is set to 3 (Non-Dispatchable) for the Dispatch Interval and the resource is in a start-up or shut-down mode, the Energy dispatch target for the Resource and Dispatch Interval is set equal to the start-up or shut-down profile MW target. If the Resource Control Status is set to 3 (Non-Dispatchable) but the Resource is not being manually dispatched and is not in a start-up or shut-down mode, the Energy dispatch target for the Resource and Dispatch Interval is set equal to the actual Resource output as calculated by the State Estimator just prior to SCED execution. If the Resource Control Status is set to 0 (Off-Line) for the Dispatch Interval, the Energy dispatch target for the Resource and Dispatch Interval is set to 0.

5.2.1.3 Cleared Regulating Reserve Constraints

Constraint Classification: Physical

Constraint Type: Hard LE

The following constraints ensure that Regulating Reserve is only cleared on a Resource during the Dispatch Interval if the Regulation Mode Flag is set to 1, indicating a Control Status for the Dispatch Interval equal to 2 (Regulating). This constraint also limits the amount of Regulating Reserve that can be cleared on a Resource during the Dispatch Interval to fifty percent of the difference between the maximum limit and the minimum limit of the Resource for the Dispatch Interval.

IF { Resource is a DIR **}**

ClearedRegRes1(r,di) = 0

ClearedRegRes2(r,di) = 0

ELSE

ClearedRegRes1(r,di) + ClearedRegRes2(r,di)

≤

0.5 * RegModeFlag(r,di) * [MaxLimit(r,di) - MinLimit(r,di)]

If the Resource regulation mode flag is set to 1 for the Dispatch Interval, an amount of Regulating Reserve may be cleared on the Resource equal to 50% of the difference between the maximum limit and the minimum limit for the Resource during that Dispatch Interval. If the Resource regulation mode flag is set to 0 for the Dispatch Interval, no Regulating Reserve may be cleared on the Resource for the Dispatch Interval.

Further regulation clearing constraints ensure that both portions of regulating reserve cleared on a resource (the portion cleared considering the regulating reserve total offer cost, and the portion cleared considering the regulation capacity offer cost only), are greater than or equal to zero:

ClearedRegRes1(r,di) ≥ 0

and

ClearedRegRes2(r,di) ≥ 0

5.2.1.4 Cleared Contingency Reserve Constraints

Constraint Classification: Physical

Constraint Type: Hard LE

The following constraints require that a Resource either 1) be on-line and available for Spinning Reserve or Supplemental Reserve for the Dispatch Interval or 2) off-line and be available for off-line Supplemental Reserve for the Dispatch Interval in order for Contingency Reserve to be cleared on that Resource during the Dispatch Interval. In addition, these constraints limit the amount of Contingency Reserve that can be cleared on an on-line Resource to a value not more than the difference between the maximum limit of the Resource for the Dispatch Interval and the minimum limit of the Resource for the Dispatch Interval, or on an off-line Resource to a value not more than the maximum off-line response limit of the Resource for the Dispatch Interval.

IF { Resource is a DIR **}**

ClearedContRes(r,di) = 0

ELSE

ClearedContRes(r,di)

≤

[OnLineFlag(r,di)] * [MaxLimit(r,di) - MinLimit(r,di)] * SpinAvailability(r,di)

+ [OnLineFlag(r,di)] * [MaxLimit(r,di) - MinLimit(r,di)]
* [SupAvailability(r,di) - SpinAvailability(r,di)]

+ [1-OnLineFlag(r,di)] * [MaxOffLineResponse(r,di)]
* [OffLineSupResAvailability(r,di)]

If the Spinning Reserve availability and the Supplemental Reserve availability of a specific Resource are both 0 during the Dispatch Interval and the Resource is on-line, the Contingency Reserve cleared on that Resource for that Dispatch Interval must also be 0. If either the Spinning Reserve availability or the Supplemental Reserve availability of a specific Resource are 1 during a specific Dispatch Interval and the Resource is on-line for that Dispatch Interval, Contingency Reserve may be cleared on that Resource during the Dispatch Interval, based on economics and other constraints, up to the difference between the maximum limit and minimum limit of the Resource for the Dispatch Interval. If the off-line Supplemental Reserve availability of a specific

Resource is 0 during the Dispatch Interval and the Resource is not on-line, the Contingency Reserve cleared on that Resource for that Dispatch Interval must also be 0. If the off-line Supplemental Reserve availability of a specific Resource is 1 during the Dispatch Interval and the Resource is not on-line, Contingency Reserve may be cleared on that Resource during the Dispatch Interval, based on economic and other constraints, up to the maximum off-line response limit of the Resource for the Dispatch Interval.

5.2.1.5 Off-Line Short Term Reserve Availability and Dispatch Constraints

Constraint Classification: Physical

Constraint Type: Hard LE

The following constraints require that a resource be available for off-line Short Term Reserve during a specific Dispatch Interval in order to be dispatched for off-line Short Term Reserve during that Dispatch Interval.

ClearedOffLineSTR (r,di)

≤

{[1 – CF(r,di] * min[MaxOffLineSTR(r,di) , EcoMaxLimit (r,di)]}
* OffLineSTRAvailability(r,di)

5.2.1.6 On-Line Short Term Reserve Availability and Dispatch Constraints

Constraint Classification: Physical

Constraint Type: Hard LE

The following constraints require that a resource be available for on-line Short Term Reserve during a specific interval in order to be dispatched for on-line Short Term Reserve during that interval.

ClearedOnLineSTR (r,di)
≤
{ - ClearedEnergy (r,di) - ClearedRegRes1(r,di)
+ CF(r,di)* EcoMaxLimit (r,di) - RF(r,di)*[EcoMaxLimit(r,di) – RegMaxLimit(r,di)]}
* OnLineSTRAvailability(r,di)

The following maximum limit constraints apply to resources during any interval of an emergency mode SCED execution when there was a shortage detected for that interval during the initial normal mode SCED iteration.

ClearedOnLineSTR (r,di)
≤
{ - ClearedEnergy (r,di) - ClearedRegRes1(r,di)
+ CF(r,di)* EcoMaxLimit (r,di) - RF(r,di)*[EcoMaxLimit(r,di) – RegMaxLimit(r,di)]
+ EmerMaxRelease(r,di) * [EmerMaxLimit(r,di) - EcoMaxLimit(r,di)] }
* OnLineSTRAvailbility(r,di)

5.2.1.7 Maximum Limit Constraints

Constraint Classification: Physical

Constraint Type: Penalized LE

The following maximum limit constraints apply to Resources during the Dispatch Interval.

EnergyDispatchTarget(r,di)

+ ClearedRegRes1(r,di) + ClearedRegRes2(r,di)

+ ClearedContRes(r,di) + ClearedRCUp(r,di)

≤

OnLineFlag(r,di) * MaxLimit(r,di)

+ [1 - OnLineFlag(r,di)] * MaxOffLineResponse(r,di)

+ MaxLimitViolation(r,di)

If the Resource on-line flag is set to 1 for the Dispatch Interval, the sum of the Energy dispatch target, cleared Regulating Reserve and cleared Contingency Reserve for the Resource and Dispatch Interval cannot exceed the maximum limit of the Resource for the Dispatch Interval. If the Resource on-line flag is set to 0 for the Dispatch Interval, the sum of the Energy dispatch target, cleared Regulating Reserve and cleared Contingency Reserve for the Resource and Dispatch Interval cannot exceed the maximum off-line response of the Resource for the Dispatch Interval (in this scenario the Energy dispatch target and cleared Regulating Reserve would be zero, and the cleared Contingency Reserve could only be non-zero if the Resource is available for off-line Supplemental Reserve).

5.2.1.8 Minimum Limit Constraints

Constraint Classification: Physical

Constraint Type: Penalized GE

The following minimum limit constraints apply to Resources during the Dispatch Interval.

EnergyDispatchTarget(r,di)

- ClearedRegRes1(r,di) - ClearedRCDown(r,di)

≥

OnLineFlag(r,di) * MinLimit(r,di)

- MinLimitViolation(r,di)

If the Resource on-line flag is set to 1 for the Dispatch Interval, the Energy dispatch target for the Resource and Dispatch Interval less the portion of cleared Regulating Reserve for the Resource and Dispatch Interval cleared based on total offer must be greater than or equal to the minimum limit of the Resource for the Dispatch Interval. If the Resource on-line flag is set to 0 for the Dispatch Interval, the Energy dispatch target for the Resource and Dispatch Interval less the portion of Regulating Reserve for the Resource and Dispatch Interval cleared based on total offer are not restricted by the minimum limit of the Resource for the Dispatch Interval (in this scenario the Energy dispatch target and cleared Regulating Reserve would be zero,)

5.2.1.9 General Ramp-Up Constraints

Constraint Classification: Physical

Constraint Type: Penalized LE

The following constraints are used to ensure the change in the Energy dispatch target can be accommodated by the ramp-up rate.

EnergyDispatchTarget(r,di)

≤

InitialEnergyOutput(r,di)

+ 5 * RampUpRate(r,di)

+ GeneralRampUpViolation(r,di)

5.2.1.10 General Ramp-Down Constraints

Constraint Classification: Physical

Constraint Type: Penalized GE

The following constraints are used to ensure the change in the Energy dispatch target can be accommodated by the ramp-down rate.

EnergyDispatchTarget(r,di)

≥

InitialEnergyOutput(r,di)

- 5 * RampDownRate(r,di)

- GeneralRampDownViolation(r,di)

5.2.1.11 Contingency Reserve Ramp Constraints

Constraint Classification: Physical

Constraint Type: Penalized LE

The following constraints are used to limit the Contingency Reserve cleared on a Resource during the Dispatch Interval based on ramp capability.

[ContResRampFact / ContResDeployTime] * ClearedContRes(r,di)

≤

RampUpRate(r,di)

+ ContResRampViolation(r,di)

The Contingency Reserve ramp factor is a tuning parameter that determines the percentage of cleared Contingency Reserve that should be deployable within the Contingency Reserve Deployment Time assuming no ramping for Energy or Regulating Reserve.

5.2.1.12 Regulating Reserve Ramp Constraints

Constraint Classification: Physical

Constraint Type: Penalized LE

The following constraints are used to limit the Regulating Reserve cleared on a Resource during the Dispatch Interval based on ramp capability.

[RegRampFactor/RegResponseTime]*[ClearedRegRes1(r,di)+ClearedRegRes2(r,di)]

≤

RampDownRate(r,di)

+ RegRampViolation(r,di)

The Regulating Reserve ramp multiplier is a tuning parameter that determines the percentage of cleared Regulating Reserve that should be deployable within the Regulation Response Time. It is important to note that while the ramp-down rate is specified in this constraint, the ramp-up and ramp-down rate are the same (i.e., equal to the bi-directional ramp rate) for any Resource that can clear Regulating Reserve, so the choice of using the ramp-down rate instead of the ramp-up rate is completely arbitrary.

5.2.1.13 Up Ramp Capability Ramp Constraints

Constraint Classification: Physical

Constraint Type: Penalized LE

The following constraints are used to limit the Up Ramp Capability cleared on a Resource during the Dispatch Interval based on ramp capability.

[RCupRampFactor/RCUpResponseTime]*[ClearedRCUp(r,di)]

≤

RampUpRate(r,di)

+ RCUpRampViolation(r,di)

The Up Ramp Capability Factor is a tuning parameter that determines the percentage of cleared Up Ramp Capability that should be deployable within the Ramp Up Response Time. It is important to note that while the ramp-up rate is specified in this constraint,

5.2.1.14 Down Ramp Capability Ramp Constraints

Constraint Classification: Physical

Constraint Type: Penalized LE

The following constraints are used to limit the Down Ramp Capability cleared on a Resource during the Dispatch Interval based on ramp capability.

[RCDownRampFactor/RCDownResponseTime]*[ClearedRCDown(r,di)]

≤

RampDownRate(r,di)

+ RCDownRampViolation(r,di)

The Down Ramp Capability Factor is a tuning parameter that determines the percentage of cleared Down Ramp Capability that should be deployable within the Ramp Down Response Time. It is important to note that while the ramp-down rate is specified in this constraint.

5.2.1.15 Short Term Reserve Ramp Constraints

Constraint Classification: Physical

Constraint Type: Penalized LE

The following constraints are used to limit the Down Ramp Capability cleared on a resource during the Dispatch Interval based on ramp capability.

[STRRampFactor/STRResponseTime]*[ClearedOnlineSTR (r,di)]
≤
RampUpRate(r,di)
+ STRRampViolation(r,di)

The STRRampFactor is a tuning parameter that determines the percentage of cleared Short Term Reserve that should be deployable within the Short Term Reserve Response Time. It is important to note that the ramp-up rate is used in this constraint.

5.2.1.16 Maximum Resource Regulating Reserve Constraints

Constraint Classification: Good Utility Practice

Constraint Type: Penalized LE

The following constraints are used to limit the Regulating Reserve that can be cleared on a single Resource during the Dispatch Interval to a maximum percentage of the market-wide Regulating Reserve requirement for the Dispatch.

ClearedRegRes1(r,di) + ClearedRegRes2(r,di)

≤

MaxRegResFactor * MWRegReq(di)

+ Max ResourceRegViolation(r,di)

5.2.1.17 Maximum Resource Daily Regulating Reserve Constraints

Constraint Classification: Good Utility Practice

Constraint Type: Penalized LE

The following constraints apply to DRR Type-II Resources and limit the maximum amount of Regulating Reserves that can be dispatched on a specific resource across all twenty-four hours in a specific calendar day.

$$\sum_{h \in d} \{ \text{RegResDispatchComp1(r,di)} + \text{RegResDispatchComp2(r,di)} \}$$

$$\leq$$

DRRMaxDailyReg(r,d)

5.2.1.18 Maximum Resource Contingency Reserve Constraints

Constraint Classification: Good Utility Practice

Constraint Type: Penalized LE

The following constraints are used to limit the Contingency Reserve that can be cleared on a single Resource during the Dispatch Interval to a maximum percentage of the market-wide Contingency Reserve requirement.

ClearedContRes(r,di)

≤

MaxContResFactor * MWContResReq(di)

+ Max ResourceContResViolation(r,di)

5.2.1.19 Maximum Resource Short Term Reserve Constraints

Constraint Classification: Good Utility Practice

Constraint Type: Penalized LE

The following constraints are used to limit the Short Term Reserve that can be dispatched on a single resource in a specific interval to a maximum percentage of the market-wide Contingency Reserve requirement.

ClearedOnlineSTR (r,di) + ClearedOfflineSTR (r,di)
≤
MaxSTRResFactor * MWSTRResReq(di)
+ MaxResourceSTRResViolation(r,di)

5.2.1.20 Maximum Resource Up Ramp Capability Constraints

Constraint Classification: Good Utility Practice

Constraint Type: Penalized LE

The following constraints are used to limit the Up Ramp Capability that can be cleared on a single Resource during the Dispatch Interval to a maximum percentage of the market-wide Up Ramp Capability requirement.

ClearedRCUp(r,di)

≤

MaxRCUpFactor * MWRCUpReq(di)

+ MaxResourceRCUpViolation(r,di)

5.2.1.21 Maximum Resource Down Ramp Capability Constraints

Constraint Classification: Good Utility Practice

Constraint Type: Penalized LE

The following constraints are used to limit the Down Ramp Capability that can be cleared on a single Resource during the Dispatch Interval to a maximum percentage of the market-wide Down Ramp Capability requirement.

ClearedRCDown(r,di)

≤

MaxRCDownFactor * MWRCDownReq(di)

+ MaxResourceRCDownViolation(r,di)

5.2.1.22 Maximum Resource Daily Contingency Reserve Constraints

Constraint Classification: Good Utility Practice

Constraint Type: Penalized LE

The following constraints apply to DRR Type-II Resources and limit the maximum amount of Regulating Reserves that can be dispatched on a specific resource across all twenty-four hours in a specific calendar day.

$$\sum_{h \in d} \{ \text{ClearedContRes}(r,di) \}$$

≤

DRRMaxDailyCR(r,d)

5.2.1.23 Self-Scheduled Energy Constraints

Constraint Classification: Good Utility Practice

Constraint Type: Penalized GE

The following constraints are used to ensure that the Energy dispatch target on a Resource is greater than or equal to the self-scheduled Energy on the Resource during the Dispatch Interval if the Resource is on-line and dispatchable and the Energy Dispatch Status is set to ***Self Schedule***.

IF { ControlStatus(r,di) ≠ 3 **} AND {** FixedDispFlag(r,di)=0 **}**

EnergyDispatchTarget(r,di)

≥

OnLineFlag(r,di) * SSEnergyStatus(r,di) * SSEnergyMW(r,di)

- SSEnergyDeficit(r,di)

END IF

This constraint does not restrict the clearing of Energy above the self-scheduled amount.

5.2.1.24 Self-Scheduled Regulating Reserve Constraints

Constraint Classification: Good Utility Practice

Constraint Type: Penalized GE

The following constraints are used to ensure the portion of Regulating Reserve cleared on a Resource based on total offer is greater than or equal to the self-scheduled Regulating Reserve on the Resource during the Dispatch Interval if the Resource is on-line, has been selected for regulation via the RAC process and the Regulating Reserve Dispatch Status is set to ***Self Schedule***.

ClearedRegRes1(r,di)

≥

OnLineFlag(r,di) * RegModeFlag(r,di) * SSRegResStatus(r,di)
* SSRegResMW(r,di)

- SSRegResDeficit(r,di)

This constraint does not restrict the clearing of Regulating Reserve above the self-scheduled amount.

5.2.1.25 Self-Scheduled Contingency Reserve Constraints

Constraint Classification: Good Utility Practice

Constraint Type: Penalized GE

The following constraints are used to ensure the Contingency Reserve cleared on an on-line Resource is greater than or equal to the self-scheduled Contingency Reserve on the Resource if 1) the Spinning Reserve Dispatch Status is set to ***Self Schedule*** and the Resource is available to provide Spinning Reserve or 2) the On-Line Supplemental Reserve Dispatch Status is set to ***Self Schedule***, the Resource is available to provide Supplemental Reserve but is not available to provide Spinning Reserve. In addition, the following constraints are used to ensure the Contingency Reserve cleared on a Resource that has not been committed for the Dispatch Interval by SCUC is greater than or equal to the self-scheduled Contingency Reserve on the Resource if 1) the Off-Line Supplemental Reserve Dispatch Status is set to ***Self Schedule*** and the Resource is available to provide Off-Line Supplemental Reserve.

IF { ControlStatus(r,di) ≠ 3 **} AND {** FixedDispFlag(r,di)=0 **}**

ClearedContRes(r,di)

≥

OnLineFlag(r,di) * SSSpinResStatus(r,di) * SSSpinResMW(r,di)
* SpinAvailability(r,di)
+ OnLineFlag(r,di) * SSOnLineSupResStatus(r,di) * SSOnLineSupResMW(r,di)
    * [SupAvailability(r,di) - SpinAvailability(r,di)]
+ [1 - OnLineFlag(r,di)] * SSOffLineSupResStatus(r,di)
    * SSOffLineSupResMW(r,di) * OffLineSupAvailability(r,di)
- SSContResDeficit(r,di)

END IF

Spinning Reserve self-schedules are enforced during the Dispatch Interval if the Resource is on-line, the Resource Control Status is not set to 3 for the Dispatch Interval, the Resource Fixed Dispatch Flag is set to 0 for the Dispatch Interval, the Resource Spinning Reserve Dispatch Status is set to ***Self Schedule*** for the Dispatch Interval and the Resource is available to supply Spinning

Reserve during the Dispatch Interval. On-Line Supplemental Reserve self-schedules are enforced during the Dispatch Interval if the Resource is on-line, the Resource Control Status is not set to 3 for the Dispatch Interval, the Resource Fixed Dispatch Flag is set to 0 for the Dispatch Interval, the Resource On-Line Supplemental Reserve Dispatch Status is set to ***Self Schedule*** for the Dispatch Interval, the Resource is available to supply Supplemental Reserve during the Dispatch Interval and the Resource is not available to supply Spinning Reserve during the Dispatch Interval. Off-Line Supplemental Reserve self-schedules are enforced during the Dispatch Interval if the Resource is not on-line, the Resource Off-Line Supplemental Reserve Dispatch Status is set to ***Self Schedule*** for the Dispatch Interval and the Resource is available to supply off-line Supplemental Reserve during the Dispatch Interval. This constraint does not restrict the clearing of Contingency Reserve above the self-schedule.

5.2.1.26 Contingency Reserve Deployment Constraint

Constraint Classification: Good Utility Practice

Constraint Type: Penalized GE

The following constraints are used to ensure the Contingency Reserve cleared on a Resource in a specific Dispatch Interval is greater than or equal to the Contingency Reserve deployed (not cleared) on the Resource prior to the Dispatch Interval.

ClearedContRes(r,di)

≥

DeployedContRes(r,di)

- DeployedContResDeficit(r,di)

This constraint will only be applicable in Dispatch Intervals where Contingency Reserve deployment is active on the Resource at the beginning of SCED execution for the Dispatch Interval.

5.2.1.27 Contingency Reserve Capping Constraint

Constraint Classification: Good Utility Practice

Constraint Type: Hard LE

The following constraints are used to ensure the Contingency Reserve cleared on a Resource in a specific Dispatch Interval is less than or equal to the Contingency Reserve cap on the Resource in place for the day.

ClearedContRes(r,di)

≤

ClearedContResCap(r,di)

5.2.2 Demand Response Resource – Type I Constraints

5.2.2.1 Cleared Energy Constraints

Constraint Classification: Physical

Constraint Type: Hard Equality

The following constraints ensure that the cleared Energy associated with a Resource during the Dispatch Interval is equal to the targeted demand reduction level if the Resource is committed during the Dispatch Interval or zero if the Resource is not committed during the Dispatch Interval.

ClearedEnergy(r,di)

=

CF(r,di) * TargetDemRedLevel(r,di)

If the commitment flag is set to 0 for a Resource for the Dispatch Interval, then the cleared Energy for the Resource must be zero for the Dispatch Interval. If the commitment flag is set to 1 for a Resource for the Dispatch Interval, then the cleared Energy for the Resource is set equal to the targeted demand reduction level for the Dispatch Interval.

5.2.2.2 Cleared Regulating Reserve Constraints

Constraint Classification: Physical

Constraint Type: Hard Equality

The following constraints prevent a Demand Response Resource - Type I from clearing Regulating Reserve during the Dispatch Interval.

ClearedRegRes1(r,di) = 0

ClearedRegRes2(r,di) = 0

5.2.2.3 Cleared Contingency Reserve Constraints

Constraint Classification: Physical

Constraint Type: Hard LE

The following constraints ensure that Contingency Reserve is only cleared on a Resource during the Dispatch Interval where the Resource is uncommitted and is available to supply Spinning Reserve and/or Supplemental Reserve. This constraint also limits the amount of Contingency Reserve that can be cleared on a Resource during the Dispatch Interval to the targeted demand reduction level of the Resource for the Dispatch Interval.

ClearedContRes(r,di)

≤

[1 - CF(r,di)] * TargetDemRedLeve(r,di) * SpinAvailability(r,di)

+ [1 - CF(r,di)] * TargetDemRedLeve(r,di) * [SupAvailability(r,di) - SpinAvailability(r,di)]

If the Spinning Reserve availability and the Supplemental Reserve availability of a specific Resource are both 0 during the Dispatch Interval or the Resource on-line flag has been set to 1 for the Dispatch Interval, the Contingency Reserve cleared on that Resource for the Dispatch Interval must also be 0. If either the Spinning Reserve availability or the Supplemental Reserve availability of a Resource is 1 for the Dispatch Interval and the Resource on-line flag has been set to 0 for the Dispatch Interval, Contingency Reserve may be cleared on that Resource during the Dispatch Interval, based on economic and other constraints, up to the targeted demand reduction level of the Resource for the Dispatch Interval.

5.2.2.4 Cleared Off-Line Short Term Reserve Constraints

Constraint Classification: Physical

Constraint Type: Hard LE

The following constraints ensure that Short Term Reserve is only dispatched on a resource during an hour where the resource is not committed (i.e., the commitment flag is 0). This constraint also limits the amount of Short Term Reserve that can be dispatched on a resource during an interval to the targeted demand reduction level of the resource during that interval.

ClearedOfflineSTR (r,di)
≤
[1 - CF(r,di)] * TargetDemRedLevel(r,di) * STROfflineAvailibality(r,di)

5.2.2.5 Maximum Resource Contingency Reserve Constraints

Constraint Classification: Good Utility Practice

Constraint Type: Penalized LE

The following constraints are used to limit the Contingency Reserve that can be cleared on a single Resource in a specific Dispatch Interval to a maximum percentage of the market-wide Contingency Reserve requirement.

ClearedContRes(r,di)

≤

MaxContResFactor * MWContResReq(di)

+ Max ResourceContResViolation(r,di)

5.2.2.6 Maximum Resource Short Term Reserve Constraints

Constraint Classification: Good Utility Practice

Constraint Type: Penalized LE

The following constraints are used to limit the Short Term Reserve that can be dispatched on a single resource in a specific interval to a maximum percentage of the market-wide Short Term Reserve requirement.

ClearedOfflineSTR (r,di)
≤
MaxSTRResFactor * MWSTRResReq(di)
+ MaxResourceSTRResViolation(r,di)

5.2.2.7 Maximum Resource Daily Contingency Reserve Constraint

Constraint Classification: Good Utility Practice

Constraint Type: Penalized LE

The following constraints are used to limit the total daily Contingency Reserve that can be cleared by a single Resource across all twenty-four hours in a specific calendar day.

$$\sum_{h \in d} \{ \text{ContResDispatch(r,di)} \}$$

≤

DRRMaxDailyCR(r,di)

5.2.2.8 Self-Scheduled Contingency Reserve Constraints

Constraint Classification: Good Utility Practice

Constraint Type: Penalized GE

The following constraints are used to ensure the Contingency Reserve cleared on a Resource is greater than or equal to the self-scheduled Contingency Reserve on the Resource if the Resource has not been committed by SCUC for the Dispatch Interval and 1) the Spinning Reserve Dispatch Status is set to ***Self Schedule*** and the Resource is available to provide Spinning Reserve or 2) the Supplemental Reserve Dispatch Status is set to ***Self Schedule***, the Resource is available to provide Supplemental Reserve but is not available to provide Spinning Reserve.

CleaaredContRes(r,di)

≥

[1 - CF(r,di)] * SSSpinResStatus(r,di) * SSSpinResMW(r,di)
* SpinAvailability(r,di)

+ [1 - CF(r,di)] * SSSupResStatus(r,di) * SSSupResMW(r,di)
* [SupAvailability(r,di) - SpinAvailability(r,di)]

- SSContResDeficit(r,di)

5.2.2.9 Contingency Reserve Capping Constraint

Constraint Classification: Good Utility Practice

Constraint Type: Hard LE

The following constraints are used to ensure the Contingency Reserve cleared on a Resource in a specific Dispatch Interval is less than or equal to the Contingency Reserve cap on the Resource in place for the day.

ClearedContRes(r,di)

≤

ClearedContResCap(r,di)

5.2.3 External Asynchronous Resource Constraints

5.2.3.1 Energy Step Clearing Constraints

Constraint Classification: Physical

Constraint Type: Hard LE

The following constraints ensure that the cleared Energy associated with a specific Energy offer curve step during a specific Dispatch Interval is less than or equal to the Energy step width of the Energy offer curve step for the Dispatch Interval or zero if the Resource is not on-line:

EnergyStepClearing(r,di,st)

≤

AvailableFlag(r,di) * EnergyStepWidth(r,di,st)

If the Resource availability flag for the Dispatch Interval is set to 0, then the cleared Energy for each Energy offer curve step associated with the Resource must be zero. If the Resource availability flag for the Dispatch Interval is set to 1, then the cleared Energy for a specific Energy offer curve step must be less than or equal to the Energy step width of that Energy offer curve step.

5.2.3.2 Energy Dispatch Target Constraints

Constraint Classification: Physical

Constraint Type: Hard Equality

The following constraints establish the Energy dispatch target of a Resource during the Dispatch Interval:

IF {{ ControlStatus(r,di) = 1 **}**
OR { ControlStatus(r,di) = 2 **}}**
AND { FixedDispFlag(r,di) = 0 **}**

EnergyDispatchTarget(r,di)

=

$\sum_{st}$ {EnergyStepClearing(r,di,st)}

ELSE IF {{ ControlStatus(r,di) = 1 **}**
OR { ControlStatus(r,di) = 2 **}}**
AND { FixedDispFlag(r,di) = 1 **}**

EnergyDispatchTarget(r,di)

=

FixedDispMW(r,di)

ELSE IF { Control Status(r,di) = 3 **}**
AND { ManualDispatchFlag(r,di) = 1 **}**
AND { EARHoldFlag(r,di) = 0 **}**

EnergyDispatchTarget(r,di)

=

ManualDispatchMW(r,di)

ELSE IF { Control Status(r,di) = 3 **}**
AND { EARHoldFlag(r,di) = 1 **}**

EnergyDispatchTarget(r,di)

=

EARHoldMW(r,di)

ELSE

EnergyDispatchTarget(r,di)

=

0

If the Resource Control Status is set to 1 (Load Following) or 2 (Regulating) for the Dispatch Interval and the Fixed Dispatch Flag is set to 0, the Energy dispatch target for the Resource and Dispatch Interval is set equal to the sum of the Energy cleared for each of the offer curve steps. If the Resource Control Status is set to 1 (Load Following) or 2 (Regulating) for the Dispatch Interval and the Fixed Dispatch Flag is set to 1, the Energy dispatch target for the Resource and

Dispatch Interval is set equal to the Fixed Dispatch Energy Level. If the Resource Control Status is set 3 (Non-Dispatchable) for the Dispatch Interval and the Resource is being manually dispatched and the Resource Hold Flag is set to 0, the Energy dispatch target for the Resource and Dispatch Interval is set equal to the operator entered manual dispatch MW target. If the Resource Control Status is set 3 (Non-Dispatchable) for the Dispatch Interval and the Resource and the Resource Hold Flag is set to 1, the Energy dispatch target for the Resource in the Dispatch Interval is set equal to the EAR Hold Energy Level. If the Resource Control Status is set to 0 (Off-Line) for the Dispatch Interval, the Energy dispatch target for the Resource and Dispatch Interval is set to 0.

5.2.3.3 Cleared Regulating Reserve Constraints

Constraint Classification: Physical

Constraint Type: Hard LE

The following constraints ensure that Regulating Reserve is only cleared on a Resource during the Dispatch Interval if the Regulation Mode Flag is set to 1, indicating a Control Status for the Dispatch Interval equal to 2 (Regulating). This constraint also limits the amount of Regulating Reserve that can be cleared on a Resource during the Dispatch Interval to fifty percent of the difference between the maximum limit and the minimum limit of the Resource for the Dispatch Interval.

$$\text{ClearedRegRes1}(r,di) + \text{ClearedRegRes2}(r,di)$$

$$\leq$$

$$0.5 * \text{RegModeFlag}(r,di) * [\text{MaxLimit}(r,di) - \text{MinLimit}(r,di)]$$

If the Resource regulation mode flag is set to 1 for the Dispatch Interval, an amount of Regulating Reserve may be cleared on the Resource equal to 50% of the difference between the maximum limit and the minimum limit for the Resource during that Dispatch Interval. If the Resource regulation mode flag is set to 0 for the Dispatch Interval, no Regulating Reserve may be cleared on the Resource for the Dispatch Interval.

Further regulation clearing constraints ensure that both portions of regulating reserve cleared on a resource (the portion cleared considering the regulating reserve total offer cost, and the portion cleared considering the regulation capacity offer cost only), are greater than or equal to zero:

ClearedRegRes1(r,di) ≥ 0

and

ClearedRegRes2(r,di) ≥ 0

5.2.3.4 Cleared Contingency Reserve Constraints

Constraint Classification: Physical

Constraint Type: Hard LE

The following constraints require that a Resource be available and available for Spinning Reserve or Supplemental Reserve for the Dispatch Interval in order for Contingency Reserve to be cleared on that Resource during the Dispatch Interval. In addition, these constraints limit the amount of Contingency Reserve that can be cleared on an available Resource to a value not more than the difference between the maximum limit of the Resource for the Dispatch Interval and the minimum limit of the Resource for the Dispatch Interval.

ClearedContRes(r,di)

≤

[AvailFlag(r,di)] * [MaxLimit(r,di) - MinLimit(r,di)] * SpinAvailability(r,di)

+ [AvailFlag(r,di)] * [MaxLimit(r,di) - MinLimit(r,di)]
* [SupAvailability(r,di) - SpinAvailability(r,di)]

If the Spinning Reserve availability and the Supplemental Reserve availability of a specific Resource are both 0 during the Dispatch Interval and/or the Resource is not available, the Contingency Reserve cleared on that Resource for that Dispatch Interval must also be 0. If either the Spinning Reserve availability or the Supplemental Reserve availability of a specific Resource are 1 during a specific Dispatch Interval and the Resource is available for that Dispatch Interval, Contingency Reserve may be cleared on that Resource during the Dispatch Interval, based on economics and other constraints, up to the difference between the maximum limit and minimum limit of the Resource for the Dispatch Interval

5.2.3.5 Cleared Off-Line Supplemental Reserve Constraints

Constraint Classification: Physical

Constraint Type: Hard Equality

The following constraints prevent an External Asynchronous Resource from dispatching off-line Supplemental Reserve during any Dispatch Interval.

OffLineSupResDispatch(r,di)

=

0

5.2.3.6 On-Line Short Term Reserve Availability and Dispatch Constraints

Constraint Classification: Physical

Constraint Type: Hard LE

The following constraints require that a resource be available for on-line Short Term Reserve during a specific hour in order to be dispatched for on-line Short Term Reserve during that interval.

OnLineSTRDispatch(r,di)
≤
{ - EnergyDispatch(r,di) - RegResDispatch1(r,di)
+ CF(r,di)* EcoMaxLimit (r,ci) - RF(r,di)*[EcoMaxLimit(r,ci) – RegMaxLimit(r,di)]}
* OnLineSTRAvailibity(r,di)

The following maximum limit constraints apply to resources during any interval of an emergency mode SCED execution when there was a shortage detected for that interval during the initial normal mode SCED iteration.

OnLineSTRDispatch(r,di)
≤
{ - EnergyDispatch(r,di) - RegResDispatch1(r,di)
+ CF(r,di)* EcoMaxLimit (r,di) - RF(r,di)*[EcoMaxLimit(r,di) – RegMaxLimit(r,di)]
+ EmerMaxRelease(r,di) * [EmerMaxLimit(r,di) - EcoMaxLimit(r,di)] }
* OnLineSTRAvailibity(r,di)

5.2.3.7 Maximum Limit Constraints

Constraint Classification: Physical

Constraint Type: Penalized LE

The following maximum limit constraints apply to Resources during the Dispatch Interval.

EnergyDispatchTarget(r,di)

+ ClearedRegRes1(r,di) + ClearedRegRes2(r,di)

+ ClearedContRes(r,di) + ClearedRCUp(r,di)

≤

AvailFlag(r,di) * MaxLimit(r,di)

+ MaxLimitViolation(r,di)

If the Resource availability flag is set to 1 for the Dispatch Interval, the sum of the Energy dispatch target, cleared Regulating Reserve and cleared Contingency Reserve for the Resource and Dispatch Interval cannot exceed the maximum limit of the Resource for the Dispatch Interval. If the Resource availability flag is set to 0 for the Dispatch Interval, the Energy dispatch target, cleared Regulating Reserve and cleared Contingency Reserve for the Resource and Dispatch Interval must be zero.

5.2.3.8 Minimum Limit Constraints

Constraint Classification: Physical

Constraint Type: Penalized GE

The following minimum limit constraints apply to Resources during the Dispatch Interval.

EnergyDispatchTarget(r,di)

- ClearedRegRes1(r,di) - ClearedRCDown(r,di)

≥

AvailFlag(r,di) * MinLimit(r,di)

- MinLimitViolation(r,di)

If the Resource availability flag is set to 1 for the Dispatch Interval, the Energy dispatch target for the Resource and Dispatch Interval less the portion of cleared Regulating Reserve for the Resource and Dispatch Interval based on total offer must be greater than or equal to the minimum limit of the Resource for the Dispatch Interval. If the Resource availability flag is set to 0 for the Dispatch Interval, the Energy dispatch target for the Resource and Dispatch Interval less the portion of Regulating Reserve for the Resource and Dispatch Interval based on total offer are not restricted by the minimum limit of the Resource for the Dispatch Interval.

5.2.3.9 General Ramp-Up Constraints

Constraint Classification: Physical

Constraint Type: Penalized LE

The following constraints are used to ensure the change in the Energy dispatch target can be accommodated by the ramp-up rate.

EnergyDispatchTarget(r,di)

≤

InitialEnergyOutput(r,di)

+ 5 * RampUpRate(r,di)

+ GeneralRampUpViolation(r,di)

5.2.3.10 General Ramp-Down Constraints

Constraint Classification: Physical

Constraint Type: Penalized GE

The following constraints are used to ensure the change in the Energy dispatch target can be accommodated by the ramp-down rate.

EnergyDispatchTarget(r,di)

≥

InitialEnergyOutput(r,di)

- 5 * RampDownRate(r,di)

- GeneralRampDownViolation(r,di)

5.2.3.11 Contingency Reserve Ramp Constraints

Constraint Classification: Physical

Constraint Type: Penalized LE

The following constraints are used to limit the Contingency Reserve cleared on a Resource during the Dispatch Interval based on ramp capability.

[ContResRampFact / ContResDeployTime] * ClearedContRes(r,di)

≤

RampUpRate(r,di)

+ ContResRampViolation(r,di)

The Contingency Reserve ramp factor is a tuning parameter that determines the percentage of cleared Contingency Reserve that should be deployable within the Contingency Reserve Deployment Time assuming no ramping for Energy or Regulating Reserve.

5.2.3.12 Regulating Reserve Ramp Constraints

Constraint Classification: Physical

Constraint Type: Penalized LE

The following constraints are used to limit the Regulating Reserve cleared on a Resource during the Dispatch Interval based on ramp capability.

[RegRampFactor/RegResponseTime]*[ClearedRegRes1(r,di)+ClearedRegRes2(r,di)]

≤

RampDownRate(r,di)

+ RegRampViolation(r,di)

The Regulating Reserve ramp multiplier is a tuning parameter that determines the percentage of cleared Regulating Reserve that should be deployable within the Regulation Response Time. It is important to note that while the ramp-down rate is specified in this constraint, the ramp-up and ramp-down rate are the same (i.e., equal to the bi-directional ramp rate) for any Resource that can clear Regulating Reserve, so the choice of using the ramp-down rate instead of the ramp-up rate is completely arbitrary.

5.2.3.13 Up Ramp Capability Ramp Constraints

Constraint Classification: Physical

Constraint Type: Penalized LE

The following constraints are used to limit the Up Ramp Capability cleared on a Resource during the Dispatch Interval based on Ramp Capability.

[RCupRampFactor/RCUpResponseTime]*[ClearedRCUp(r,di)]

≤

RampUpRate(r,di)

+ RCUpRampViolation(r,di)

The Up Ramp Capability Factor is a tuning parameter that determines the percentage of cleared Up Ramp Capability that should be deployable within the Ramp Up Response Time.

5.2.3.14 Down Ramp Capability Ramp Constraints

Constraint Classification: Physical

Constraint Type: Penalized LE

The following constraints are used to limit the Down Ramp Capability cleared on a Resource during the Dispatch Interval based on Ramp Capability.

[RCDownRampFactor/RCDownResponseTime]*[ClearedRCDown(r,di)]

≤

RampDownRate(r,di)

+ RCDownRampViolation(r,di)

The Down Ramp Capability Factor is a tuning parameter that determines the percentage of cleared Down Ramp Capability that should be deployable within the Ramp Down Response Time.

5.2.3.15 Short Term Reserve Ramp Constraints

Constraint Classification: Physical

Constraint Type: Penalized LE

The following constraints are used to limit the Down Ramp Capability cleared on a Resource during the Dispatch Interval based on ramp capability.

[STRRampFactor/STRResponseTime]*[ClearedOnlineSTR (r,di)]
≤
RampUpRate(r,di)
+ STRRampViolation(r,di)

The Short Term Reserve Ramp Factor is a tuning parameter that determines the percentage of cleared Short Term Reserve that should be deployable within the Short Term Reserve Response Time. It is important to note that the ramp-up rate is used in this constraint

5.2.3.16 Maximum Resource Regulating Reserve Constraints

Constraint Classification: Good Utility Practice

Constraint Type: Penalized LE

The following constraints are used to limit the Regulating Reserve that can be cleared on a single Resource during the Dispatch Interval to a maximum percentage of the market-wide Regulating Reserve requirement for the Dispatch.

ClearedRegRes1(r,di)+ClearedRegRes2(r,di)

≤

MaxRegResFactor * MWRegReq(di)

+ Max ResourceRegViolation(r,di)

5.2.3.17 Maximum Resource Contingency Reserve Constraints

Constraint Classification: Good Utility Practice

Constraint Type: Penalized LE

The following constraints are used to limit the Contingency Reserve that can be cleared on a single Resource during the Dispatch Interval to a maximum percentage of the market-wide Contingency Reserve requirement.

ClearedContRes(r,di)

≤

MaxContResFactor * MWContResReq(di)

+ MaxResourceContResViolation(r,di)

5.2.3.18 Maximum Resource Short Term Reserve Constraints

Constraint Classification: Good Utility Practice

Constraint Type: Penalized LE

The following constraints are used to limit the Short Term Reserve that can be dispatched on a single resource in a specific interval to a maximum percentage of the market-wide Short Term Reserve requirement.

ClearedOnlineSTR(r,di)

≤
MaxSTRResFactor * MWSTRResReq(di)
+ MaxResourceSTRResViolation(r,di)

5.2.3.19 Maximum Resource Up Ramp Capability Constraints

Constraint Classification: Good Utility Practice

Constraint Type: Penalized LE

The following constraints are used to limit the Up Ramp Capability that can be cleared on a single Resource during the Dispatch Interval to a maximum percentage of the market-wide Ramp Up Capability requirement.

ClearedRCUp(r,di)

≤

MaxRCUpFactor * MWRCUpReq(di)

+ MaxResourceRCUpViolation(r,di)

5.2.3.20 Maximum Resource Down Ramp Capability Constraints

Constraint Classification: Good Utility Practice

Constraint Type: Penalized LE

The following constraints are used to limit the Down Ramp Capability that can be cleared on a single Resource during the Dispatch Interval to a maximum percentage of the market-wide Ramp Down Capability requirement.

ClearedRCDown(r,di)

≤

MaxRCDownFactor * MWRCDownReq(di)

+ MaxResourceRCDownViolation(r,di)

5.2.3.21 Self-Scheduled Energy Constraints

Constraint Classification: Good Utility Practice

Constraint Type: Penalized GE

The following constraints are used to ensure that the Energy dispatch target on a Resource is greater than or equal to the self-scheduled Energy on the Resource during the Dispatch Interval if the Resource is available and dispatchable and the Energy Dispatch Status is set to ***Self Schedule***.

IF { ControlStatus(r,di) ≠ 3 **} AND {** FixedDispFlag(r,di)=0 **}**

EnergyDispatchTarget(r,di)

≥

AvailFlag(r,di) * SSEnergyStatus(r,di) * SSEnergyMW(r,di)

- SSEnergyDeficit(r,di)

END IF

This constraint does not restrict the clearing of Energy above the self-scheduled amount.

5.2.3.22 Self-Scheduled Regulating Reserve Constraints

Constraint Classification: Good Utility Practice

Constraint Type: Penalized GE

The following constraints are used to ensure the portion of Regulating Reserve cleared on a Resource based on total offer cost is greater than or equal to the self-scheduled Regulating Reserve on the Resource during the Dispatch Interval if the Resource is available, has been selected for regulation via the RAC process and the Regulating Reserve Dispatch Status is set to ***Self Schedule***.

ClearedRegRes1(r,di)

≥

AvailFlag(r,di) * RegModeFlag(r,di) * SSRegResStatus(r,di)
* SSRegResMW(r,di)

- SSRegResDeficit(r,di)

This constraint does not restrict the clearing of Regulating Reserve above the self-scheduled amount.

5.2.3.23 Self-Scheduled Contingency Reserve Constraints

Constraint Classification: Good Utility Practice

Constraint Type: Penalized GE

The following constraints are used to ensure the Contingency Reserve cleared on a Resource that is available is greater than or equal to the self-scheduled Contingency Reserve on the Resource if the Spinning Reserve Dispatch Status is set to ***Self Schedule*** and the Resource is available to provide Spinning Reserve.

IF { ControlStatus(r,di) ≠ 3 **} AND {** FixedDispFlag(r,di)=0 **}**

ClearedContRes(r,di)

≥

AvailFlag(r,di) * SSSpinResStatus(r,di) * SSSpinResMW(r,di)
* SpinAvailability(r,di)

+ AvailFlag(r,di) * SSOnLineSupResStatus(r,di)
* SSOnLineSupResMW(r,di)
* [SupAvailability(r,di) - SpinAvailability(r,di)]

- SSContResDeficit(r,di)

ELSE

ClearedContRes(r,di) = 0

END IF

Spinning Reserve self-schedules are enforced during the Dispatch Interval if the Resource is available, the Resource Spinning Reserve Dispatch Status is set to ***Self Schedule*** for the Dispatch Interval and the Resource is available to supply Spinning Reserve during the Dispatch Interval. Supplemental Reserve self-schedules are enforced during the Dispatch Interval if the Resource is available, the Resource On-Line Supplemental Reserve Dispatch Status is set to ***Self Schedule*** for the Dispatch Interval, the Resource is available to supply Supplemental Reserve during the Dispatch Interval and the Resource is not available to supply Spinning Reserve during the Dispatch Interval.

5.2.3.24 Contingency Reserve Deployment Constraint

Constraint Classification: Good Utility Practice

Constraint Type: Penalized GE

The following constraints are used to ensure the Contingency Reserve cleared on a Resource in a specific Dispatch Interval is greater than or equal to the Contingency Reserve deployed (not cleared) on the Resource prior to the Dispatch Interval.

ClearedContRes(r,di)

≥

DeployedContRes(r,di)

- DeployedContResDeficit(r,di)

This constraint will only be applicable in Dispatch Intervals where Contingency Reserve deployment is active on the Resource at the beginning of SCED execution for the Dispatch Interval.

5.2.3.25 Contingency Reserve Capping Constraint

Constraint Classification: Good Utility Practice

Constraint Type: Hard LE

The following constraints are used to ensure the Contingency Reserve cleared on a Resource in a specific Dispatch Interval is less than or equal to the Contingency Reserve cap on the Resource in place for the day.

ClearedContRes(r,di)

≤

ClearedContResCap(r,di)

5.2.4 Electric Storage Resource Constraints

5.2.4.1 Energy Step Clearing Constraints

Constraint Classification: Physical

Constraint Type: Hard LE

The following constraints ensure that the cleared positive energy associated with a specific energy positive offer curve step during a specific Dispatch Interval is less than or equal to the energy positive step width of the energy offer curve step for the Dispatch Interval or zero if the Resource is not on-line:

EnergyStepPositiveClearing(r,di,st) ≤ OnLineFlag(r,di) * EnergyStepPositiveWidth(r,di,st)

The following constraints ensure that the negative energy associated with a specific enery negative offer curve step during a specific Dispatch Interval is less than or equal to the negative energy step width of the energy offer curve step for the Dispatch Interval or zero if the Resource is not on-line:

EnergyStepNegativeClearing(r,di,st)≤ OnLineFlag(r,di)* nergyStepNegativeWidth(r,di,st)

If the Resource on-line flag for the Dispatch Interval is set to 0, then the cleared energy for each energy offer curve step associated with the Resource must be zero. If the Resource on-line flag for the Dispatch Interval is set to 1, then the cleared energy (positive/negative) for a specific energy offer curve step must be less than or equal to the (positive/negative) energy step width of that energy offer curve step.

5.2.4.2 Cleared Energy Constraints

Constraint Classification: Physical

Constraint Type: Hard Equality

The following constraints establish the Energy Dispatch Target of a Resource during the Dispatch Interval:

IF {{ ControlStatus(r,di) = 1 **}**
OR { ControlStatus(r,di) = 2 **}}**
AND { FixedDispFlag(r,di) = 0 **}**

EnergyDispatchTarget(r,di) = Σ {EnergyStepPositiveClearing(r,di,st)}

+ Σ {EnergyStepNegativeClearing(r,di,st)}

ELSE IF {{ ControlStatus(r,di) = 1 **}**
OR { ControlStatus(r,di) = 2 **}}**

AND { FixedDispFlag(r,di) = 1 **}**

EnergyDispatchTarget(r,di) = FixedDispMW(r,di)

ELSE IF { Control Status(r,di) = 3 **}**
AND { ManualDispatchFlag(r,di) = 1 **}**

EnergyDispatchTarget(r,di) = ManualDispatchMW(r,di)

ELSE IF { Control Status(r,di) = 3 **}**

EnergyDispatchTarget(r,di) = CurrentSEMW(r,di)

ELSE

EnergyDispatchTarget(r,di) = 0

If the Resource Control Status is set to 1 (Load Following) or 2 (Regulating) for the Dispatch Interval and the Fixed Dispatch Flag is set to 0, the Energy Dispatch Target for the Resource and Dispatch Interval is set equal to the sum of the Energy cleared for each of the offer curve steps. If the Resource Control Status is set to 1 (Load Following) or 2 (Regulating) for the Dispatch Interval, but the Resource Fixed Dispatch Flag is set to 1, the Energy Dispatch Target for the esource and Dispatch Interval is set equal to the Fixed Dispatch Energy Level. If the Resource Control Status is set to 3 (Non-Dispatchable) for the Dispatch Interval and the Resource is being manually dispatched, the Energy Dispatch Target for the Resource and Dispatch Interval is set equal to the operator-entered manual dispatch MW target. If the Resource Control Status is set to 3 (Non-Dispatchable) but the Resource is not being manually dispatched, the Energy dispatch target for the Resource and Dispatch Interval is set equal to the actual Resource output as calculated by the State Estimator just prior to SCED execution. If the Resource Control Status is set to 0 (Off-Line) for the Dispatch Interval, the Energy Dispatch Target for the Resource and Dispatch Interval is set to 0.

5.2.4.3 Cleared Regulating Reserve Constraints

Constraint Classification: Physical

Constraint Type: Hard LE

The following constraints ensure that Regulating Reserve is only cleared on a Resource during the Dispatch Interval if the regulation mode flag is set to 1, indicating a Control Status for the Dispatch Interval equal to 2 (Regulating). This constraint also limits the amount of Regulating Reserve that can be cleared on a Resource during the Dispatch Interval to fifty percent of the difference between the maximum limit and the minimum limit of the Resource for the Dispatch Interval.

$$\text{ClearedRegRes1}(r,di) + \text{ClearedRegRes2}(r,di) \le 0.5 * \text{RegModeFlag}(r,di) * [\text{MaxLimit}(r,di) - \text{MinLimit}(r,di)]$$

If the Resource regulation flag is set to 1 for the Dispatch Interval, an amount of Regulating Reserve may be cleared on the Resource equal to 50% of the difference between the maximum limit and the minimum limit for the Resource for the Dispatch Interval. If the Resource regulation flag is set to 0 for the Dispatch Interval, no Regulating Reserve may be cleared on the Resource for the Dispatch Interval.

Further regulation clearing constraints ensure that both portions of Regulating Reserve cleared on a Resource (the portion cleared considering the Regulating Reserve total offer cost, and the portion cleared considering the regulation capacity offer cost only), are greater than or equal to zero:

$$\text{ClearedRegRes1}(r,di) \ge 0$$

and

$$\text{ClearedRegRes2}(r,di) \ge 0$$

5.2.4.4 Cleared Contingency Reserve Constraints

Constraint Classification: Physical

Constraint Type: Hard LE

The following constraints require that a Resource either 1) be on-line and be available for Spinning Reserve or Supplemental Reserve for the Dispatch Interval or 2) be off-line and be available for off-line Supplemental Reserve for the Dispatch Interval in order for Contingency Reserve to be cleared on that Resource during the Dispatch Interval. In addition, these constraints limit the amount of Contingency Reserve that can be cleared on an on-line Resource to a value not more than the difference between the maximum limit of the Resource for the Dispatch Interval and the minimum limit of the Resource for the Dispatch Interval, or on an off-line Resource to a value not more than the maximum off-line response limit of the Resource for the Dispatch Interval.

ClearedContRes(r,di)
≤
[OnLineFlag(r,di)] * [MaxLimit(r,di) - MinLimit(r,di)] * SpinAvailability(r,di)
+ [OnLineFlag(r,di)] * [MaxLimit(r,di) – MinLimit(r,di)]
* [SupAvailability(r,di) - SpinAvailability(r,di)]
+ [1- OnLineFlag(r,di)] * [MaxOffLineResponse(r,di)]
* [OffLineSupAvailability(r,di)]

If the Spinning Reserve availability and the Supplemental Reserve availability of a specific Resource are both 0 during the Dispatch Interval and the Resource is on-line, the Contingency Reserve cleared on that Resource for that Dispatch Interval must also be 0. If either the Spinning Reserve availability or the Supplemental Reserve availability of a specific Resource are 1 during a specific Dispatch Interval and the Resource is on-line for that Dispatch Interval, Contingency Reserve may be cleared on that Resource during the Dispatch Interval, based on economics and other constraints, up to the difference between the maximum limit and minimum limit of the Resource for the Dispatch Interval. If the off-line Supplemental Reserve availability of a specific Resource is 0 during the Dispatch Interval and the Resource is off-line, the Contingency Reserve cleared on that Resource for that Dispatch Interval must also be 0. If the off-line Supplemental Reserve availability of a specific Resource is 1 during the Dispatch Interval and the Resource is off-line, Contingency Reserve may be cleared on that Resource during the Dispatch Interval, based on economic and other constraints, up to the maximum off-line response limit of the Resource for the Dispatch Interval.

5.2.4.5 On-Line Short Term Reserve Availability and Dispatch Constraints

Constraint Classification: Physical

Constraint Type: Hard LE

The following constraints require that a Resource be available for on-line Short Term Reserve during a specific Dispatch Interval in order to be dispatched for on-line Short Term Reserve during that Dispatch Interval.

ClearedOnLineSTR (r,di)

≤
{ - EnergyDispatchTarget (r,di) - ClearedRegRes1(r,di)
+ OnLineFlag(r,di)*EcoMaxLimit (r,di) - RegModeFlag(r,di)*[EcoMaxLimit(r,di) – RegMaxLimit(r,di)]}
* OnLineSTRAvailabity(r,di)

The following maximum limit constraints apply to Resources during any Dispatch Interval of an emergency mode when there was a shortage detected for that Dispatch Interval during the initial normal mode iteration.

ClearedOnLineSTR (r,di)
≤
{ - EnergyDispatchTarget (r,di) - ClearedRegRes1(r,di)
+ OnLineFlag(r,di)* EcoMaxLimit (r,di) - RegModeFlag(r,di)*[EcoMaxLimit(r,di) – RegMaxLimit(r,di)]
+ EmerMaxRelease(r,di) * [EmerMaxLimit(r,di) - EcoMaxLimit(r,di)] }
* OnLineSTRAvailabity(r,di)

5.2.4.6 Maximum Limit Constraints

Constraint Classification: Physical
Constraint Type: Penalized LE
The following maximum limit constraints apply to Resources during the Dispatch Interval.

EnergyDispatchTarget(r,di)
+ ClearedRegRes1(r,di) + ClearedRegRes2(r,di)
+ ClearedContRes(r,di)
≤
OnLineFlag(r,di) * MaxLimit(r,di)
+ [1 - OnLineFlag(r,di)] * MaxOffLineResponse(r,di)
+ MaxLimitViolation(r,di)

If the Resource is on-line for the Dispatch Interval, the sum of the energy, Regulating Reserve and Contingency Reserve cleared on the Resource during the Dispatch Interval cannot exceed the maximum limit of the Resource for the Dispatch Interval. If the Resource is off-line for the Dispatch Interval, the sum of the energy, Regulating Reserve and Contingency Reserve cleared on the Resource during the Dispatch Interval cannot exceed the maximum off-line response of the Resource for the Dispatch Interval (in this scenario the cleared energy and Regulating Reserve would be zero, and the cleared Contingency Reserve could only be non-zero if the Resource is available for off-line Supplemental Reserve).

5.2.4.7 Maximum Energy Storage Limit Constraints

Constraint Classification: Physical

Constraint Type: Penalized LE

The following Maximum Energy Storage limit constraints apply to Resources during the Dispatch Interval.

<u>Interval-to-Interval SOC</u>

SOC(r,di)

≤

SOCMax(r) + MaxEnergyStorageLimitViolation (r,di)

Where:

SOC(r,di) = SOC(r,di-1)_* - (interval t minute duration/60 minutes)

*[*EnergyDispatchTarget(r,di) ** {if* EnergyDispatchTarget(r,di) *>= 0 then 1 else ESR Efficiency Factor}*

+ ClearedRegRes1(r,di) ** RegStorageUseFactor]*

+ ClearedContRes(r,di)**(SpinStorageUseFactor / SuppStorageUseFactor)*

*+Max(0,*ClearedOnlineSTR(r,di) - ClearedContRes(r,di)) * STRStorage*Use*Factor*]*

AND = $SOC(r,1) = SOC_{initial}$

<u>Intra-Interval SOC</u>

SOC(r,di)

≤

SOCMAX(r,di) + MaxEnergyStorageLimitViolation (r,di)

Where:

SOC(r,di) = SOC(r,di-1)_* - (interval t minute duration/60 minutes)

*[*EnergyDispatchTarget(r,di) ** {if* EnergyDispatchTarget(r,di) *>= 0 then 1 else ESR Efficiency Factor}*

- ClearedRegRes1(r,di) * *RegStorageReliabilityFactor*

The cleared energy storage on Resource r during Dispatch Interval di must not exceed the maximum energy storage level limit for the Dispatch Interval of the Resource.

5.2.4.8 Minimum Energy Storage Limit Constraints

Constraint Classification: Physical

Constraint Type: Penalized GE

The following Minimum Energy Storage limit constraints apply to Resources during the Dispatch Interval.

Interval-to-Interval SOC

SOC(r,di)
≥
SOCMin(r) + MinEnergyStorageLimitViolation (r,di)
Where:

SOC(r,di) = SOC(r,di-1)_* - (interval t minute duration/60 minutes)

*[*EnergyDispatchTarget(r,di) ** {if* EnergyDispatchTarget(r,di) *>= 0 then 1 else ESR Efficiency Factor}*

+ ClearedRegRes1(r,di) * *RegStorageUseFactor*

+ ClearedContRes(r,di)**(SpinStorageUseFactor / SuppStorageUseFactor)*

*+Max(0,*ClearedOnlineSTR(r,di) - ClearedContRes(r,di)) * STRStorage*Use*Factor*]*

AND

SOC(r,1) = $SOC_{initial}$

- **Intra-Interval SOC**

SOC(r,di)
≥
SOCMin(r,di) + MinEnergyStorageLimitViolation (r,di)
Where:

SOC(r,di) = SOC(r,di-1)_* - (interval t minute duration/60 minutes)

*[EnergyDispatchTarget(r,di) * {if EnergyDispatchTarget(r,di) >= 0 then 1 else ESR Efficiency Factor}*
*+ ClearedRegRes1(r,di) * RegStorageReliabilityFactor*
+ ClearedContRes(r,di)(SpinStorageReliabilityFactor / SuppStorageReliabilityFactor)*
*+Max(0,ClearedOnlineSTR(r,di) - ClearedContRes(r,di)) * STRStorageReliabilityFactor]*

The cleared energy storage on Resource r during Dispatch Interval di must exceed the minimum energy storage level limit for the Dispatch Interval of the Resource.

5.2.4.9 Minimum Limit Constraints

Constraint Classification: Physical

Constraint Type: Penalized GE

The following minimum limit constraints apply to Resources during the Dispatch Interval.

EnergyDispatchTarget(r,di) - ClearedRegRes1(r,di) - ClearedRCDown(r,di)
≥
OnLineFlag(r,di) * MinLimit(r,di) * MinLimitScaleFactor(di)
- MinLimitViolation(r,di)

If the Resource on-line flag is set to 1 for the Dispatch Interval, the energy cleared on the Resource during the Dispatch Interval, less the portion of the Regulating Reserve cleared based on total offer on the Resource during the Dispatch Interval, must be greater than or equal to the minimum limit of the Resource for the Dispatch Interval. If the Resource on-line flag is set to 0 for the Dispatch Interval, the energy cleared on the Resource during the Dispatch Interval, less the Regulating Reserve cleared on the Resource during the Dispatch Interval, are not restricted by the minimum limit of the Resource for the Dispatch Interval.

5.2.4.10 General Ramp-Up Constraints

Constraint Classification: Physical

Constraint Type: Penalized LE

The following constraints are used to ensure the change in the Energy Dispatch Target can be accommodated by the ramp-up rate.

EnergyDispatchTarget(r,di)
≤ InitialEnergyOutput(r,di) + 5* RampUpRate(r,di)
+ GeneralRampUpViolation(r,di)

5.2.4.11 General Ramp-Down Constraints

Constraint Classification: Physical

Constraint Type: Penalized GE

The following constraints are used to ensure the change in the Energy Dispatch Target can be accommodated by the ramp-down rate.

.

EnergyDispatchTarget(r,di)
≥
InitialEnergyOutput(r,di)
- 5 * RampDownRate(r,di) - RampDownViolation(r,di)

5.2.4.12 Contingency Reserve Ramp Constraints

Constraint Classification: Physical

Constraint Type: Penalized LE

The following constraints are used to limit the Contingency Reserve cleared on a Resource during the Dispatch Interval based on ramp capability.

[ContResRampMult / ContResDeployTime] * ClearedContRes(r,di)
≤
RampRate(r,di)
+ ContResRampViolation(r,di)

The Contingency Reserve ramp multiplier is a tuning parameter that determines the percentage of cleared Contingency Reserve that should be deployable within the Contingency Reserve Deployment Time.

5.2.4.13 Regulating Reserve Ramp Constraints

Constraint Classification: Physical

Constraint Type: Penalized LE

The following constraints are used to limit the Regulating Reserve cleared on a Resource during the Dispatch Interval based on ramp capability.

[RegRampMult / RegResponseTime]* {ClearedRegRes1(r,di) + ClearedRegRes2(r,di)}
≤
RampRate(r,di) + RegRampViolation(r,di)

The Regulating Reserve ramp multiplier is a tuning parameter that determines the percentage of cleared Regulating Reserve that should be deployable within the Regulation Response Time.

5.2.4.14 Up Ramp Capability Ramp Constraints

Constraint Classification: Physical

Constraint Type: Penalized LE

The following constraints are used to limit the Up Ramp Capability cleared on a Resource during the Dispatch Interval based on ramp capability.

[RCupRampMult/RCUpResponseTime]*[ClearedRCUp(r,di)]

≤

RampRate(r,di) + RCUpRampViolation(r,di)

The Up Ramp Capability ramp multiplier is a tuning parameter that determines the percentage of cleared Up Ramp Capability that should be deployable within the Ramp Up Response Time.

5.2.4.15 Down Ramp Capability Ramp Constraints

Constraint Classification: Physical

Constraint Type: Penalized LE

The following constraints are used to limit the Down Ramp Capability cleared on a Resource during the Dispatch Interval based on ramp capability.

[RCDownRampMult/RCDownResponseTime]*[ClearedRCDown(r,di)]

≤

RampRate(r,di) + RCDownRampViolation(r,di)

The Down Ramp Capability Ramp Multiplier is a tuning parameter that determines the percentage of cleared Down Ramp Capability that should be deployable within the Ramp Down Response Time.

5.2.4.16 Short Term Reserve Ramp Constraints

Constraint Classification: Physical

Constraint Type: Penalized LE

The following constraints are used to limit the Down Ramp Capability cleared on a Resource during the Dispatch Interval based on ramp capability.

[STRRampMulti/STRResponseTime] * [ClearedOnlineSTR (r,di)]

≤ RampRate(r,di) + STRRampViolation(r,di)

The Short Term Reserve Ramp Multiplier is a tuning parameter that determines the percentage of cleared Short Term Reserve that should be deployable within the Short Term Reserve Response Time.

5.2.4.17 Maximum Resource Regulating Reserve Constraints

Constraint Classification: Good Utility Practice

Constraint Type: Penalized LE

The following constraints are used to limit the Regulating Reserve that can be cleared on a single Resource during the Dispatch Interval to a maximum percentage of the market-wide Regulating Reserve requirement for the Dispatch Interval.

ClearedRegRes1(r,di) + ClearedRegRes2(r,di)
≤ MaxRegResFactor * MWRegReq(di) + MaxResourceRegViolation(r,di)

5.2.4.18 Maximum Resource Contingency Reserve Constraints

Constraint Classification: Good Utility Practice

Constraint Type: Penalized LE

The following constraints are used to limit the Contingency Reserve that can be cleared on a single Resource during the Dispatch Interval to a maximum percentage of the market-wide Contingency Reserve requirement.

ClearedContRes(r,di)
≤
MaxContResFactor * MWContResReq(di)
+ MaxResourceContResViolation(r,di)

5.2.4.19 Maximum Resource Short Term Reserve Constraints

Constraint Classification: Good Utility Practice

Constraint Type: Penalized LE

The following constraints are used to limit the Short Term Reserve that can be cleared on a single Resource during the Dispatch Interval to a maximum percentage of the market-wide Short Term Reserve requirement.

ClearedOnlineSTR (r,di)
≤ MaxSTRFactor * MWSTRReq(di) + MaxResourceSTRResViolation(r,di)

5.2.4.20 Self-Scheduled Energy Constraints

Constraint Classification: Good Utility Practice

Constraint Type: Penalized GE

The following constraints are used to ensure that the energy cleared on a Resource is greater than or equal to the self-scheduled energy (or less than or equal to the self-scheduled energy if self-scheduled energy is less than 0) on the Resource during the Dispatch Interval if the Resource has been committed by SCUC and the Energy Dispatch Status is set to ***Self Schedule***.

IF { SSEnergyMW(r,di) > 0 MW }

EnergyDispatchTarget(r,di)

≥

OnLineFlag(r,di) * SSEnergyStatus(r,di) * SSEnergyMW(r,di)

- SSEnergyDeficit(r,di)

ELSE

EnergyDispatchTarget(r,di)

≤

OnLineFlag(r,di) * SSEnergyStatus(r,di) * SSEnergyMW(r,di)

+ SSEnergySuplus(r,di)

This constraint does not restrict the clearing of energy above the positive self-scheduled amount or the clearing of energy below the negative self-scheduled amount.

5.2.4.21 Self-Scheduled Regulating Reserve Constraints

Constraint Classification: Good Utility Practice

Constraint Type: Penalized GE

The following constraints are used to ensure the portion of Regulating Reserve based on total offer cleared on a Resource is greater than or equal to the self-scheduled Regulating Reserve on the Resource during the Dispatch Interval if the Resource is on-line, the Resource has been selected for regulation via the RAC process and the Regulating Reserve Dispatch Status is set to ***Self Schedule***.

ClearedRegRes1(r,di)

≥
OnLineFlag(r,di) * RegModeFlag(r,di) * SSRegResStatus(r,di) * SSRegResMW(r,di)
- SSRegResDeficit(r,di)

This constraint does not restrict the clearing of Regulating Reserve above the self-scheduled amount.

5.2.4.22 Self-Scheduled Contingency Reserve Constraints

Constraint Classification: Good Utility Practice

Constraint Type: Penalized GE

The following constraints are used to ensure the Contingency Reserve cleared on a Resource that is on-line for the Dispatch Interval is greater than or equal to the self-scheduled Contingency Reserve on the Resource if 1) the Spinning Reserve Dispatch Status is set to ***Self Schedule*** and the Resource is available to provide Spinning Reserve or 2) the On-Line Supplemental Reserve Dispatch Status is set to ***Self Schedule***, the Resource is available to provide Supplemental Reserve but is not available to provide Spinning Reserve. In addition, the following constraints are used to ensure the Contingency Reserve cleared on a Resource that is on-line for the Dispatch Interval is greater than or equal to the self-scheduled Contingency Reserve on the Resource if 1) the Off-Line Supplemental Reserve Dispatch Status is set to ***Self Schedule*** and the Resource is available to provide Off-Line Supplemental Reserve.

ClearedContRes(r,di)
≥
OnLineFlag(r,di) * SSSpinResStatus(r,di) * SSSpinResMW(r,di) * SpinAvailability(r,di)
+ OnLineFlag(r,di) * SSOnLineSupResStatus(r,di) * SSOnLineSupResMW(r,di)
* [SupAvailability(r,di) - SpinAvailability(r,di)]
+ [1 - OnLineFlag(r,di)] * SSOffLineSupResStatus(r,di) * SSOffLineSupResMW(r,di)
* OffLineSupAvailability(r,di)
- SSContResDeficit(r,di)

Spinning Reserve self-schedules are enforced during the Dispatch Interval if the Resource is on-line for the Dispatch Interval, the Resource Spinning Reserve Dispatch Status is set to ***Self Schedule*** for the Dispatch Interval and the Resource is available to supply Spinning Reserve during the Dispatch Interval. On-Line Supplemental Reserve self-schedules are enforced during the Dispatch Interval if the Resource is on-line for the Dispatch Interval, the Resource On-Line Supplemental Reserve Dispatch Status is set to ***Self Schedule*** for the Dispatch Interval, the Resource is available to supply Supplemental Reserve during the Dispatch Interval and the Resource is not available to supply Spinning Reserve during the Dispatch Interval. Off-Line Supplemental Reserve self-schedules are enforced during the Dispatch Interval if the Resource is off-line for the Dispatch Interval, the Resource Off-Line Supplemental Reserve Dispatch Status is set to ***Self Schedule*** for the Dispatch Interval and the Resource is available to supply off-line Supplemental Reserve during the Dispatch Interval. This constraint does not restrict the clearing of Contingency Reserve above the self-schedule.

5.2.5 Global Power Balance Constraints

The Real-Time SPD algorithm uses a Global Power Balance Constraint that requires the net Energy injected into the Network Model to equal the net Energy out of the Network Model plus losses.

5.2.5.1 Bus Energy Injection Constraints

Constraint Classification: Physical

Constraint Type: Hard Equality

The following constraints establish the Energy injected at each bus for the Dispatch Interval where net Energy injections include all injections.

PI(i,di)

=

$$\sum_{r} \{ DF(i,r) * EnergyDispatchTarget(r,di) \}$$

r

The net Energy injected at a bus is equal to the sum of all Resource Energy injected into the bus.

5.2.5.2 Bus Energy Withdrawal Constraints

Constraint Classification: Physical

Constraint Type: Hard Equality

The following constraints establish the Energy withdrawn at each bus for the Dispatch Interval where Energy withdrawals include all system demand:

$$PW(i,di)$$

$$=$$

$$RefBusDF(i,di) * SystemDemandMW(di)\}$$

The Energy withdrawn at a bus is equal to the sum of all system demand Energy withdrawn from the bus.

5.2.5.3 Modeled Losses Constraint

The modeled losses constraint is used to approximate series transmission losses in terms of net injections at all buses using linearized marginal loss sensitivity factors as follows.

$$ModeledLosses(di)$$

$$=$$

$$\sum_{i} \{ \partial Loss(i,di)/\partial P(i,di) * PI(i,di)\}$$

$$+ \sum_{i} \{ \partial Loss(i,di)/\partial P(i,di) * PW(i,di)\}$$

$$+ \sum_{i} \{ \partial Loss(i,di)/\partial P(i,di) * ExternalInjectionMW(i,di)\}$$

$$+ LossOffsetFactor(di) * SystemDemandMW(di)$$

Linearized marginal loss sensitivity factors are used to calculate marginal losses in terms of net injections at each bus. However, marginal losses are greater than actual losses since losses are non-linear (i.e., Branch Losses = 3 * I^2R). The loss offset term in this constraint corrects for the difference between marginal losses and actual losses, and is estimated based on the fixed system demand MW and the loss offset factor. Modeled losses are actually modeled at the load distributed reference bus in order to distribute losses through the system. Because losses are modeled at the load distributed reference bus, all injections and withdrawals at the load distributed reference bus (which include both system demand and actual losses) have no net impact on modeled losses.

5.2.5.4 Global Power Balance Constraint

Constraint Classification: Reliability

Constraint Type: Penalized Equality

The global power balance constraints ensure that all Energy injected into the Eastern Interconnection during the Dispatch Interval balances with all Energy withdrawn from the Eastern Interconnection during the Dispatch Interval.

The global power balance constraint is expressed as follows:

$$\Sigma \{ PI(i,di) \}$$

$$- NSI(di)$$

$$+ GlobalEnergyShortage(i,di)$$

$$=$$

$$\Sigma_i \{ PW(i,di) \}$$

$$+ ModeledLosses(di)$$

$$+ GlobalEnergySurplus(i,di)$$

5.2.6 Reliability Constraints

5.2.6.1 Market-Wide Operating Reserve Constraint

Constraint Classification: Reliability

Constraint Type: Logic-Based, Hard GE

The market-wide Operating Reserve constraints require that the total of the minimum zonal Operating Reserve Requirements (Regulating, Spinning, and Supplemental) in an Dispatch Interval be greater than or equal to the market-wide Operating Reserve requirement for that Dispatch Interval.

$$
\begin{aligned}
& MWRegReq(di) \\
& + \sum_{z} \{ ZminSpinReq(z,di) \} \\
& + \sum_{z} \{ ZMinSuppReq(z,di) \} \\
& \geq \\
& \sum_{st} \{ MWOpResStepClearing(st,di) \}
\end{aligned}
$$

5.2.6.2 Market-Wide Regulating plus Spinning Reserve Constraint

Constraint Classification: Reliability

Constraint Type: Logic Based, Hard GE

The market-wide Regulating plus Spinning Reserve constraint requires that the total supply of Regulating Reserve and Spinning Reserve during the Dispatch Interval be greater than or equal to the market-wide Regulating plus Spinning Reserve requirement for the Dispatch Interval.

$$MWRegReq(di) + \sum_{z} \{ ZMinSpinReq(z,di) \} \geq MWRegSpinResStep1Clearing(di) + MWRegSpinResStep2Clearing(di) + MWRegSpinResStep3Clearing(di)$$

5.2.6.3 Market-Wide Regulating Reserve Constraint

Constraint Classification: Reliability

Constraint Type: Hard GE

The market-wide Regulating Reserve constraints require that the sum of each Reserve Zone's minimum zonal regulating reserve requirement in an Dispatch Interval be greater than or equal to the market-wide Regulating Reserve requirement for that Dispatch Interval.

$$\sum_{z} \{ ZminRegReq(z,di) \} \geq MWRegResStep1Clearing(di) + MWRegResStep2Clearing(di)$$

5.2.6.4 Market-Wide Short Term Reserve Constraints

Constraint Classification: Reliability

Constraint Type: Hard GE

The market-wide Short Term Reserve constraints require that the total supply of Short Term Reserve from the sum of each Reserve Zone's minimum zonal Short Term reserve requirement in an hour be greater than or equal to the market-wide Short Term Reserve requirement for that interval.

$$\sum_{z} \{ ZminSTRReq(z,di) \} \geq MWSTRResClearing(di)$$

5.2.6.5 Market-Wide Up Ramp Capability Constraint

Constraint Classification: Good Utility Practice

Constraint Type: Hard GE

The market-wide Up Ramp Capability constraints require that the sum of Up Ramp Capability from each Reserve Zone's minimum zonal Up Ramp Capability requirement in a Dispatch Interval be greater than or equal to the market-wide Up Ramp Capability requirement for that Dispatch Interval.

$$\sum_{z} \{ ZminRCUpReq(z,di) \} \geq MWRCUpStep1Clearing(di) + MWRCUpStep2Clearing(di)$$

5.2.6.6 Market-Wide Down Ramp Capability Constraint

Constraint Classification: Good Utility Practice

Constraint Type: Hard GE

The market-wide Down Ramp Capability constraints require that the sum of Down Ramp Capability from each Reserve Zone's minimum zonal Down Ramp Capability requirement in a Dispatch Interval be greater than or equal to the market-wide Down Ramp Capability requirement for that Dispatch Interval.

$$\sum_{z} \{ ZminRCDownReq(z,di) \}$$

$$\geq$$

$$MWRCDownStep1Clearing(di)$$

$$+$$

$$MWRCDownStep2Clearing(di)$$

5.2.6.7 Reserve Procurement Minimum Reserve Zone Regulating Reserve Requirement

Constraint Classification: Reliability

Constraint Type: Hard GE

The Reserve Procurement Regulating Reserve constraints require that the total supply of Regulating Reserve within a reserve zone in a Dispatch Interval be greater than or equal to the minimum reserve zone Regulating Reserve requirement for that reserve zone.

$$\sum_{r \in z} \{ClearedRegRes1(r,h)\}$$

$$\geq$$

$$ZMinRegReq(z,di)$$

These constraints require that sum of the Regulating Reserve dispatched on all resourceswithin a specific reserve zone during the Dispatch Interval is greater than or equal to the minimum zonal regulating reserve requirement for that reserve zone. The reserve procurement minimum reserve requirements ensure that cleared reserves are deliverable as needed.

5.2.6.8 Reserve Procurement Minimum Reserve Zone Regulating plus Spinning Reserve Requirement

Constraint Classification: Reliability

Constraint Type: Hard GE

The Reserve Procurement Regulating plus Spinning Reserve constraints require that the total supply of Regulating plus Contingency Reserve within a reserve zone in an Dispatch Interval be greater than or equal to the minimum reserve zone Regulating plus Spinning Reserve requirement for that reserve zone.

$$\sum_{r \in z} \{ \text{ClearedRegRes1}(r,di) + \text{ClearedRegRes2}(r,di) \}$$

$$+$$

$$\sum_{r \in z} \{\text{ClearedContRes}(r,di)\}$$

$$\geq$$

$$\text{ZMinRegReq}(z,di)$$

$$+$$

$$\text{ZMinSpinReq}(z,di)$$

These constraints require that sum of the Regulating Reserve and Contingency Reserves dispatched on all resources within a specific reserve zone during the Dispatch Interval is greater than or equal to the minimum zonal regulating plus spinning reserve requirement for that reserve zone. The reserve procurement minimum reserve requirements ensure that cleared reserves are deliverable as needed.

5.2.6.9 Reserve Procurement Minimum Reserve Zone Operating Reserve Requirement

Constraint Classification: Reliability

Constraint Type: Hard GE

The Reserve Procurement Operating Reserve constraints require that the total supply of Operating Reserves within a reserve zone in a Dispatch Interval be greater than or equal to the sum of the minimum reserve zone Regulating Reserve requirement and the minimum reserve zone Regulating plus Spinning Reserve requirement for that reserve zone and that Dispatch Interval.

$$\sum_{r \in z} \{ClearedRegRes1(r,di) + ClearedRegRes2(r,di)\}$$

$$+$$

$$\sum_{\substack{r \in z \\ r \neq SER}} \{ClearedContRes(r,di)\}$$

$$\geq$$

$$ZMinRegReq(z,di)$$

$$+$$

$$ZMinSpinReq(z,di)$$

$$+$$

$$ZMinSuppReq(z,di)$$

These constraints require that sum of the Regulating Reserve and Contingency Reserves dispatched on all resources within a specific reserve zone during the Dispatch Interval is greater than or equal to the sum of the minimum zonal regulating reserve requirement and the minimum zonal regulating plus spinning reserve requirement for that reserve zone. The reserve procurement minimum reserve requirements ensure that cleared reserves are deliverable as needed.

5.2.6.10 Reserve Procurement Minimum Reserve Zone Short Term Reserve Requirement

Constraint Classification: Reliability

Constraint Type: Hard GE

The Reserve Procurement Short Term Reserve constraints require that the total supply of Short Term Reserves within a Reserve Zone in an interval be greater than or equal to the sum of the minimum Reserve Zone Short Term Reserve requirement for that Reserve Zone and that interval.

$$\sum_{r \in z} \{ ClearedOnlineSTR(r,di) + ClearedOfflineSTR(r,di) \} \geq ZMinSTRReq(z,di)$$

These constraints require that sum of the Short Term Reserve on all resources within a specific Reserve Zone during the hour is greater than or equal to the sum of the minimum zonal Short Term Reserve requirement. The reserve procurement minimum reserve requirements ensure that cleared reserves are deliverable as needed.

5.2.6.11 Ramp Procurement Minimum Reserve Zone Up Ramp Capability Requirement

Constraint Classification: Good Utility Practice

Constraint Type: Hard GE

The ramp procurement minimum Reserve Zone Up Ramp Capability constraints require that the total supply of Up Ramp Capability within a Reserve Zone in an Dispatch Interval be greater than or equal to the minimum Reserve Zone Up Ramp Capability requirement for that Reserve Zone.

$$\sum_{r \in z} \{ ClearedRCUp(r,di) \} \geq ZMinRCUpReq(z,di)$$

These constraints require that sum of Up Ramp Capability dispatched on all resources within a specific Reserve Zone during the Dispatch Interval is greater than or equal to the minimum zonal Up Ramp Capability requirement for that Reserve Zone. The Ramp procurement minimum reserve zone Up Ramp Capability requirements ensure that cleared Up Ramp Capability are deliverable as needed.

5.2.6.12 Ramp Procurement Minimum Reserve Zone Down Ramp Capability Requirement

Constraint Classification: Good Utility Practice

Constraint Type: Hard GE

The ramp procurement minimum Reserve Zone Down Ramp Capability constraints require that the total supply of Down Ramp Capability within a Reserve Zone in an Dispatch Interval be greater than or equal to the minimum Reserve Zone Down Ramp Capability requirement for that Reserve Zone.

$$\sum_{r \in z} \{ \text{ClearedRCDown}(r,di) \}$$

$$\geq$$

$$\text{ZMinRCDownReq}(z,di)$$

These constraints require that sum of Down Ramp Capability dispatched on all resources within a specific Reserve Zone during the Dispatch Interval is greater than or equal to the minimum zonal Down Ramp Capability requirement for that Reserve Zone. The Ramp procurement minimum Reserve Zone Down Ramp Capability requirements ensure that cleared Down Ramp Capability are deliverable as needed.

5.2.6.13 Generation-Based Operating Reserve Constraints

Constraint Classification: Reliability

Constraint Type: Penalized GE

The generation-based Operating Reserve constraints are used to comply with reliability standards that limit the amount of Operating Reserve that can be carried on Demand Response Resources - Type I.

$$\sum_{r \notin DRR1} \{ \text{ClearedRegRes1}(r,di) + \text{ClearedRegRes2}(r,di) \}$$

$$+ \sum_{r \notin DRR1} \{ ClearedContRes(r,di) \}$$

$$\geq$$

$$MWORReq(di) * GenORReqFactor(di)$$

$$- GenOpResShortage(di)$$

These constraints require that the amount of Regulating Reserve and Contingency Reserve cleared on all Resources other than Demand Response Resources - Type I must be greater than or equal to the market-wide Operating Reserve requirement multiplied by a generation-based Operating Reserve requirement factor.

5.2.6.14 Generation-Based Regulating plus Spinning Reserve Constraints

Constraint Classification: Reliability

Constraint Type: Penalized GE

The generation-based Regulating plus Spinning Reserve constraints are used to limit the amount of Regulating and/or Spinning Reserve that can be carried on Demand Response Resources - Type I.

$$\sum_{r \notin DRR1} \{ ClearedRegRes1(r,di) + ClearedRegRes2(r,di) \}$$

$$+ \sum_{r \notin DRR1} \{ ClearedContRes(r,di) * SpinAvailability(r,di) \}$$

$$\geq$$

$$MWRegSpinReq(di) * GenRegSpinReqFactor$$

$$- GenRegSpinResShortage(di)$$

These constraints require that the amount of Regulating Reserve and Contingency Reserve cleared on all Resources that are 1) qualified to provide Spinning Reserve and 2) are not Demand Response Resources - Type I, must be greater than or equal to the market-wide Regulating plus Spinning Reserve requirement multiplied by a generation-based Regulating plus Spinning Reserve requirement factor.

The Cleared Regulating Reserve Constraints for Demand Response Resources – Type I (see Section 5.2.2.2) prevent Demand Response Resources – Type I from clearing Regulating Reserves. Currently, GenRegSpinReqFactor is set such that the Spinning Reserve cleared on qualified Resources other than Demand Response Resources – Type I is greater than or equal to 60%.

5.2.6.15 Generation-Based Regulating Reserve Constraints

Constraint Classification: Reliability

Constraint Type: Penalized GE

The generation-based Regulating Reserve constraints are used to comply with reliability standards that limit the amount of Regulating Reserve that can be carried on demand Response Resources – Type I.

$$\sum_{r \notin DRR1} \{ ClearedRegRes1(r,di) \}$$

$$\geq$$

$$MWRegReq(di) * GenRegReqFactor$$

$$- GenRegResShortage(di)$$

These constraints require that the amount of Regulating Reserve cleared on all Resources that are not Demand Response Resources - Type I to be greater than or equal to the market-wide Regulating Reserve requirement multiplied by a generation-based Regulating Reserve requirement factor.

Since pre-SCED processing already prohibits Demand Response Resources - Type 1 from supplying Regulating Reserve based on the Tariff rules, **these constraints are unnecessary and have been disabled** in the SCED algorithm.

As reliability standards continue to be developed and modified, these constraints may need to re-enabled and/or modified accordingly. For example, if a reliability standard were developed restricting the percentage of Regulating Reserve that could be cleared on "controllable load" to some value less than 100% but greater than 0% of the market-wide Regulating Reserve requirement, this constraint would be needed.

5.2.6.16 Transmission Contingency Analysis Constraints

Constraint Classification: Reliability

Constraint Type: Penalized LE

Transmission contingency analysis transmission flowgate constraints represent the set of transmission constraints identified in the Reliability Coordination process as potential problems based on the results of routine State Estimator contingency analysis. The Reliability Coordinator will activate these constraints in the Real-Time Energy and Operating Reserve Market for enforcement when the State Estimator contingency analysis results indicate an existing or potential constraint violation. When these constraints are activated, contingency analysis data are automatically transferred to the Real-Time Energy and Operating Reserve Market systems for pre-SCED processing.

$$\sum_{r} \{[\text{EnergyDispatchTarget}(r,di) - \text{CAMW}(r,di)|_{\text{Last CA Execution}}] * [\partial\text{Flow}(k,di)/\partial P(r)]|_{\text{Last CA Execution}}\}$$

$$+ \sum_{i} \{[\text{ExternalInjectionMW}(i,di) - \text{CAMW}(i,di)|_{\text{Last CA Execution}}] * [\partial\text{Flow}(k,di)/\partial P(i,di)]|_{\text{Last CA Execution}}\}$$

$$+ \sum \{[\text{PW}(i,di) - \text{CAMW}(i,di)|_{\text{Last CA Execution}}] \mid * [\partial\text{Flow}(k,di)/\partial P(i,di)]|_{\text{Last CA Execution}}\}$$

$$+ \text{CAFlow}(k,di)|_{\text{Last CA Execution}}$$

$$\leq$$

FGLimit(k,di)

+ TransLimitStepViolation(st,k,di)

Together, the left hand side of this constraint is defined as "Flow_SystemEnergySCED(k,di)", a useful expression which is used again in the constraints that follow.

5.2.6.17 Sub-Regional Power Balance Constraints Analysis

Constraint Classification: Reliability

Constraint Type: Penalized LE

The sub-regional power balance constraint analysis represents the net Energy injection and withdrawal established to manage intra-regional flows in accordance with applicable seams agreements, coordination agreements, transmission service agreements, or operating procedures.

$$\sum_{r} \{[\text{EnergyDispatchTarget}(r,di) - \text{CAMW}(r,di)|_{\text{Last CA Execution}}] * [\text{InyC}(k,r,di)]\}$$

$$+ \sum_{I} \{[\text{PW}(i,di) - \text{CAMW}(i,di)|_{\text{Last CA Execution}}] * [\text{InyC}(k,i,di)]\}$$

$$+ \text{DisFlow}(k,di)|_{\text{Last CA Execution}}$$

$$\leq$$

FGLimit(k,di)

+ SubRegLimitStepViolation(st,k,di)

5.2.6.18 Reserve Procurement Regulation-Up Constraints

Constraint Classification: Reliability

Constraint Type: Penalized LE

Reserve Procurement Regulation-Up constraints are used to ensure that for a specific subset of transmission constraints, the flow across the transmission constraint will be within limits under circumstances when all cleared Regulating Reserves are deployed in the upward direction.

$$\text{FG\_SystemEnergySCED}(k,di) + \sum_{z} \text{ZMinRegReq}(z,di) * \text{ZonalRegDepSens}(k,z,di) \le \text{FGLimit}(k,di) + \text{TransLimitViolationRegUp}(k,di)$$

One Reserve Procurement Regulation-Up constraint exists for each transmission constraint that is selected to be a reserve procurement regulation constraint prior to the market processes. The constraint ensures that the total flow on the flowgate as a result of the system cleared energy, as defined in Section 5.2.6.16, plus the sum of the minimum zonal regulating reserve requirements multiplied by the zonal regulation deployment sensitivities, is less than or equal to the flowgate limit. The zonal regulation deployment sensitivity is a ramp-rate weighted average of the sensitivities of either 1) the regulation-qualified resources in the zone, or 2) the resources scheduled to potentially provide regulating reserves in the zone.

5.2.6.19 Reserve Procurement Regulation-Down Constraints

Constraint Classification: Reliability

Constraint Type: Penalized LE

Reserve Procurement Regulation-Down constraints are used to ensure that for a specific subset of transmission constraints, the flow across the transmission constraint will be within limits under circumstances when all cleared Regulating Reserves are deployed in the downward direction.

$$\text{Flow\_SystemEnergySCED}(k,di) - \sum_{z} \text{ZMinRegReq}(z,di) * \text{ZonalRegDepSens}(k,z,di)$$

≤

FGLimit(k,di)

+ TransLimitViolationRegDown(k,di)

One Reserve Procurement Regulation-Down constraint exists for each transmission constraint that is selected to be a reserve procurement regulation constraint prior to the market processes. The constraint ensures that the total flow on the flowgate as a result of the system cleared energy, as defined in Section 5.2.6.16, minus the sum of the minimum zonal regulating reserve requirements multiplied by the zonal regulation deployment sensitivities, is less than or equal to the flowgate limit. The zonal regulation deployment sensitivity is a ramp-rate weighted average of the sensitivities of either 1) the regulation-qualified resources in the zone, or 2) the resources scheduled to potentially provide regulating reserves in the zone.

5.2.6.20 Reserve Procurement Contingency Reserve Event Constraints

Constraint Classification: Reliability

Constraint Type: Logic-Based Penalized LE

Reserve Procurement Contingency Reserve Event constraints are used to ensure that for a specific subset of transmission constraints, the flow across the transmission constraint will be within limits under circumstances when a contingency reserve event takes place for the loss of the largest resource in the zone.

IF { PMaxEvent(z,di) ≥PmaxThreshold }

IF { (1/SpinImpact) * PMaxEvent(z,di) ≤MWRegSpinReq(di)-MWRegReq(di)**}**

Flow_SystemEnergySCED(k,di)

-

PMaxEvent(zdi)* ZonalTripSens(k,z,di)

+

$$\text{RegImpact} * \{ \sum_{z1} \text{ZMinRegReq}(z1,di) * \text{ZonalRegDepSens}(k,z1,di) \}$$

+

{(1/SpinImpact) * PMaxEvent(z, di)

÷ [MWRegSpinReq(di)-MWRegReq(di)] } *

$$\{ \sum_{z1} \text{ZMinSpinReq}(z1, di) * \text{ZonalSpinDepSens}(k,z1, di) \} * \text{SpinImpact}$$

≤

FGLimit_CREvent(k,di)

+ TransLimitViolationCREvent(k,z,di)

ELSE

Flow_SystemEnergySCED(k,di)

-

PMaxEvent(z,di)* ZonalTripSens(k,z,di)

+

$$\text{RegImpact} * \{ \sum_{z1} \text{ZMinRegReq}(z1,di) * \text{ZonalRegDepSens}(k,z1,di) \}$$

+

$$\text{SpinImpact} * \{ \sum_{z1} \text{ZMinSpinReq}(z1,di) * \text{ZonalSpinDepSens}(k,z1,di) \}$$

+

{ { PMaxEvent(z,di) - SpinImpact * [MWRegSpinReq(di)-MWRegReq(di)] }

÷ { [MWOpResReq(di)-MWRegSpinReq(di)] } }

* { SuppImpact * $\sum_{z1}$ ZminSuppReq(z1,di) * ZonalSuppDepSens(k,z1,di)}

≤

FGLimit_CREvent(k,di)

+ TransLimitViolationCREvent(k,z,di)

END IF

ELSE

No constraint is modeled for that transmission constraint and that zone.

END IF

WHERE

PMaxEvent(z,di) is the size of the largest resource in zone z;

PmaxThreshold is a tuning parameter, a threshold on the size of the largest resource in a zone that triggers the modeling of a Reserve Procurement Contingency Reserve constraint for transmission constraints in the zone;

ZonalTripSens(k,z,di), or the zonal trip sensitivity, is a capacity-weighted average of the sensitivities of the resources available for commitment in the zone during Dispatch Interval di;

ZonalSpinDepSens(k,z,di), or the zonal spin deployment sensitivity, is a ramp-rate weighted average of either 1) the sensitivities of the regulation or spin qualified resources in the zone, or 2) the sensitivities of the committed, spin qualified resources in the zone and the resources scheduled to potentially provide regulating reserves in the zone during Dispatch Interval di;

ZonalSuppDepSens(k,z,di), or the zonal supplemental deployment sensitivity, is a weighted average of either 1) the sensitivities of resources in the zone that are qualified to provied off-line supplemental reserves, weighted by the ramp rate and the offline response capabilities of each resource, or 2) the weighted sensitivities just described, except applied to resources in the zone based on their actual commitment status (scheduled to potentially provide regulating reserves, committed but not scheduled to potentially provide regulating reserves, uncomitted but available for offline supplemental reserves) during Dispatch Interval di;

RegImpact is a tuning parameter that adjusts the impact on the constraint from regulating reserves;

SpinImpact is a tuning parameter that adjusts the impact on the constraint from spinning reserves;

SuppImpact is a tuning parameter that adjusts the impact on the constraint from supplemental reserves;

FGLimit_CREvent(k,di) is the flow limit on the transmission constraint given the post-contingency system topology.

One Reserve Procurement Contingency Reserve Event constraint exists for each transmission constraint and each reserve zone, provided that the size of the largest contingent event in the zone is greater than a threshold, and only for transmission constraints that have been selected to be reserve procurement contingency constraints prior to the market processes (this statement is represented by the outer “IF” statement in the logic above). The constraints ensure that reserves are deliverable during a contingency reserve event by enforcing that the pre-contingency system flow on the constraint, modified by several terms representing the impacts of regulating reserves, spinning reserves, and supplemental reserves, is less than the limit of the transmission constraint. The modifying terms are slightly different, depending on whether the size of the largest contingent event in the zone is greater than the amount of spinning reserves required for the zone (this statement is represented by the inner “IF” statement in the logic above.

5.2.6.21 Reserve Procurement Short Term Reserve Event Constraints

Constraint Classification: Reliability

Constraint Type: Logic-Based Penalized LE

Reserve Procurement Short Term Reserve Event constraints are used to ensure that for a specific subset of transmission constraints, the flow across the transmission constraint will be within limits under circumstances when a Short Term Reserve event takes place for the loss of the largest resource in the zone.

Flow_SystenEnergy(k,e,di)
=
Flow_SystemEnergySCED (k,di)
-
ZonalSTRNeed (e,di)* ZonalTripSens(k,e,di)
+
$\sum_{z}$ STRResponse(z,e,di) * ZonalSTRDepSens(k,z,di)
≤
STRTransLimit (k,di)
+ TransLimitViolationSTREvent(k,z,di)

WHERE

ZonalSTRNeed (e,di), the possible deployment MW for STR if event e happens at interval ci . Event e is defined as the largest generation contingency MW for a Reserve Zone. e is the collection for max events for each zone.

ZonalTripSens(k,e,di), zonal STR trip sensitivity, the sensitivity of the largest generation which is tripped in event e for transmission constraint k in hour h.

STRResponse(z,e,di), STR response provided by resources for constraint *k* in zone *z* at interval di . STR Response is less than sum of all cleared STR in zone z excluding cleared STR on the event contingency generation.

ZonalSTRDepSens(k,z,di), Zonal STR response sensitivity from zone z to constraint k at interval di , calculated as a weighted average of the constraint flow sensitivities of resources in the zone that are qualified to provide STR, weighted by the up ramp rate of online resources and maximum offline STR response of offline resources.

STRTransLimit (k,di), STR transmission constraint maximum flow allowed after STR response for constraint k at interval di .

One Reserve Procurement Short Term Reserve Event constraint exists for each transmission constraint and each Reserve Zone, provided that the size of the largest Short Term Reserve event in the zone is greater than a threshold, and only for transmission constraints that have been selected to be reserve procurement Short Term Reserve constraints prior to the market processes. The constraints ensure that reserves are deliverable during a Short Term Reserve event by enforcing the limitation that the pre-contingency system flow on the constraint, modified by several terms representing the impacts of Short Term Reserves, is less than the limit of the transmission constraint.

5.2.6.22 Short Term Reserve Post-Deployment Power Balance Constraint

Constraint Classification: Reliability

Constraint Type: Penalized LE

Post-event power balance constraints maintain power balance with the consideration of STR deployment and zonal events. The post-event power balance will be enforced for each STR event.

$$\sum_{z} \mathrm{STRResponse}(\mathrm{z,e,di}) + \mathrm{ZNeedViolSTRPos}(\mathrm{e,di}) - \mathrm{ZNeedViolSTRNeg}(\mathrm{e,di})$$

$$= \mathrm{ZonalSTRNeed}\ (\mathrm{e,di})\ \forall e$$

$$\mathrm{ZNeedViolSTRPos}(\mathrm{e,di}), \mathrm{ZNeedViolSTRNeg}(\mathrm{e,di}) \geq 0$$

5.2.6.23 Maximum Zonal Short Term Reserve deployment constraint

Constraint Classification: Reliability

Constraint Type: Hard LE

STR response provided by resources in zone *z* for contingency event at time h has to be less than the dynamically calculated zonal requirement.

$$STRResponse_{z,e,di} \leq ZminSTR_{z,di}$$

5.2.6.24 Ramp Procurement Up Ramp Capability post deployment transmission Constraints

Constraint Classification: Reliability

Constraint Type: Penalized LE

Ramp Procurement Up Ramp Capability constraints are used to ensure that for a specific subset of transmission constraints, the flow across the transmission constraint will be within limits under circumstances when all cleared Up Ramp Capability are deployed in the upward direction.

FG_SystemEnergySCED(k,di)

+ $\sum_{z}$ ZMinRCUpReq(z,di) * ZonalRCUpDepSens(k,z,di)

≤

FGLimit(k,di)

+ TransLimitViolationRCUp(k,di)

One Ramp Procurement Up Ramp Capability post deployment transmission constraint exists for each transmission constraint that is selected to be a ramp procurement ramp capability constraint prior to the market processes. The constraint ensures that the total flow on the flowgate as a result of the system cleared energy, as defined in Section 5.2.6.16, plus the sum of the minimum zonal up ramp capability requirements multiplied by the zonal up ramp capability deployment sensitivities, is less than or equal to the flowgate limit. The zonal up ramp capability deployment sensitivity is a ramp-rate weighted average of the sensitivities of the ramp capability qualified resources in the zone.

5.2.6.25 Ramp Procurement Down Ramp Capability Post deployment transmission Constraints

Constraint Classification: Reliability

Constraint Type: Penalized LE

Ramp Procurement Down Ramp Capability post deployment transmission constraints are used to ensure that for a specific subset of transmission constraints, the flow across the transmission constraint will be within limits under circumstances when all cleared Ramp Capability are deployed in the downward direction.

$$FG\_SystemEnergySCED(k,di)$$

$$- \sum_{z} ZMinRCDownReq(z,di) * ZonalRCDownDepSens(k,z,di)$$

$$\leq$$

$$FGLimit(k,di)$$

$$+ TransLimitViolationRCDown(k,di)$$

One Ramp Procurement Down Ramp Capability constraint exists for each transmission constraint that is selected to be a ramp procurement ramp capability constraint prior to the market processes. The constraint ensures that the total flow on the flowgate as a result of the system cleared energy, as defined in Section 5.2.6.16, plus the sum of the minimum zonal down ramp capability requirements multiplied by the zonal down ramp capability deployment sensitivities, is less than or equal to the flowgate limit. The zonal down ramp capability deployment sensitivity is a ramp-rate weighted average of the sensitivities of the Ramp Capability qualified resources in the zone.

5.2.7 Tie-Breaking Constraints

5.2.7.1 Cleared Energy Tie-Breaking Constraints

Constraint Classification: Good Utility Practice

Constraint Type: Hard Equality

The cleared Energy tie-breaking constraints ensure equitable clearing of Energy between two or more Resources / transactions when there are multiple optimum solutions.

EnergyTieBreak1(r1,r2,di)

– EnergyTieBreak2(r1,r2,di)

=

MaxLimit(r1,di) * ClearedEnergy(r2,di)

- MaxLimit(e2, di)* ClearedEnergy(r1,di)

The cleared Energy tie-breaking constraints distribute the clearing of Energy among price-tied Resources and/or transactions in proportion to the maximum limit offered by those Resources or transactions for the Dispatch Interval.

5.2.7.2 Cleared Regulating Reserve Tie-Breaking Constraints

Constraint Classification: Good Utility Practice

Constraint Type: Hard Equality

The cleared Regulating Reserve tie-breaking constraints ensure equitable clearing of Regulating Reserve between two or more Resources when there are multiple optimum solutions.

RegResTieBreak1(r1,r2,di)

– RegResTieBreak2(r1,r2,di)

=

InputRampRate(r1,di) * {ClearedRegRes1(r2,di) + ClearedRegRes2(r2,di)}

- InputRampRate (r2, di) * {ClearedRegRes1(r2,di) + ClearedRegRes2(r2,di)}

The cleared Regulating Reserve tie-breaking constraints distribute the clearing of Regulating Reserve amount price-tied Resources in proportion to the ramp rate offered by those Resources for the Dispatch Interval.

5.2.7.3 Cleared Contingency Reserve Tie-Breaking Constraints – On-Line Resources

Constraint Classification: Good Utility Practice

Constraint Type: Hard Equality

The cleared Contingency Reserve tie-breaking constraints ensure equitable clearing of Contingency Reserve between two or more committed Resources when there are multiple optimum solutions.

ContResTieBreak1(r1,r2,di)

– ContResTieBreak2(r1,r2,di)

=

RampUpRate(r1,di) * ClearedContRes(r2,di)

- RampUpRate (r2, di)* ClearedContRes(r1,di)

The cleared Contingency Reserve tie-breaking constraints distribute the clearing of Contingency Reserve amount price-tied Resources in proportion to the ramp rate offered by those Resources for the Dispatch Interval.

5.2.7.4 Cleared Contingency Reserve Tie-Breaking Constraints – Off-Line Resources

Constraint Classification: Good Utility Practice

Constraint Type: Hard Equality

The cleared Contingency Reserve tie-breaking constraints ensure equitable clearing of Contingency Reserve between two or more uncommitted Resources when there are multiple optimum solutions.

ContResTieBreak1(r1,r2,di)

– ContResTieBreak2(r1,r2,di)

=

MaxOffLineResponse(r1,di) * ClearedContRes(r2,di)

- MaxOffLine Reponse(r2,di)* ClearedContRes(r1,di)

NOTE: The maximum off-line response limit is replaced by the targeted demand reduction level if the off-line Resource is a Demand Response Resource - Type I.

The cleared Contingency Reserve tie-breaking constraints distribute the clearing of Contingency Reserve amount price-tied Resources in proportion to the ramp rate offered by those Resources for the Dispatch Interval.

5.2.7.5 Cleared Offline Short Term Reserve Tie-Breaking Constraints – Not Committed Resources

Constraint Classification: Good Utility Practice

Constraint Type: Hard Equality

The cleared Offline Short Term Reserve tie-breaking constraints ensure equitable clearing of Short Term Reserve between two or more non-committed resources when there are multiple optimal solutions.

STRResTieBreak1(r1,r2,di)
– STRResTieBreak2(r1,r2,di)
=
MaxOfflineSTR (r1,di) * ClearedOfflineSTR(r2,di)
- MaxOfflineSTR(r2, di)* ClearedOfflineSTR (r1,di)

The cleared Offline short term Reserve tie-breaking constraints distribute the clearing of Short Term Reserve among price-tied resources in proportion to the Short Term Offline max limit offered by those resources for the hour.

5.3 SCED Constraint Relaxation Logic

There are instances when opposing constraints cause a non-zero value for one or more violation variables. When this occurs, LMPs and MCPs become impacted by arbitrary penalty prices. Unless these penalty prices have been specified in the Tariff in the form of a demand curve (which is the case for Operating Reserve, Regulating Reserve, and Regulating plus Spinning Reserve constraints), it is necessary to employ constraint relaxation techniques and re-execute the SCED algorithm with the goal of generating the same primal solution (i.e., same clearing results), but removing the impacts of penalty pricing and instead relying on the maximum value of the supply curve to set prices.

After SCED executes, automatic constraint relaxation logic identifies constraints that have violation variable values greater than zero (i.e., violated constraints with penalty pricing impacts). The constraint limits are then adjusted (up for LE constraints and down for GE constraints) by an amount equal to the violation amount plus a small percentage (the percentage is configurable) and SCED is re-executed with the adjusted limits. The idea is that the second SCED execution will generate the same primal solution (i.e., cleared Energy, cleared Regulating Reserve and cleared Contingency Reserve should be the same or very close to the same as the first SCED iteration). However, with the adjusted limits, constraints that violated in the first SCED iteration will not violate in the second SCED iteration. LMPs and MCPs will no longer be impacted by arbitrary penalty prices. Instead prices will be based on the maximum supply curve price, where the supply curve is a function of both offers and opportunity costs.

It is important to note that while the LP solvers used to implement the SCED algorithm are very accurate, relaxation of a constraint by an amount exactly equal to the violation may not totally eliminate the constraint violation. Therefore, it is generally necessary to over-relax the violated constraint by a small over-relaxation percentage (generally 1% of the violation amount). The automatic constraint relaxation logic contains user configurable over-relaxation percentage settings to accomplish this.

The following constraints can be automatically relaxed by the Real-Time SCED algorithm, and the relaxation is prioritized based on the magnitude of the penalty price:

- Generation-Based Operating Reserve Constraint
- Generation-Based Regulating plus Spinning Reserve Constraint*
- Generation-Based Regulating Reserve Constraint*
- Maximum Resource Regulating Reserve Constraints
- Maximum Resource Contingency Reserve Constraints
- Maximum Resource Short Term Reserve Constraints

- Maximum Resource Up Ramp Capability Constraints
- Maximum Resource Down Ramp Capability Constraints
- Self-Scheduled Energy Constraints
- Self-Scheduled Regulating Reserve Constraints
- Self-Scheduled Contingency Reserve Constraints
- Contingency Reserve Deployment Constraints
- Activated M2M Transmission Constraints

5.4 SCED Output

The following output is generated by the SCED algorithm:

- Energy Dispatch Target for Resources
- Cleared Dispatch Interval Regulating Reserve volumes for Resources
- Cleared Dispatch Interval Spinning Reserve volumes for Resources
- Cleared Dispatch Interval Supplemental Reserve volumes for Resources
- Cleared Dispatch Interval Up Ramp Capability volumes for Resources
- Cleared Dispatch Interval Down Ramp Capability volumes for Resources
- Cleared Dispatch Interval Short Term Reserve volumes for resources
- Global power balance constraint Shadow Prices or **Globalλ(di)**
- Transmission constraint Shadow Prices
- Sub-Regional Power Balance constraint Shadow Prices
- Market-wide Operating Reserve constraint Shadow Prices
- Market-wide Regulating plus Spinning Reserve constraint Shadow Prices
- Market-wide Regulating Reserve constraint Shadow Prices
- Market-Wide Non-Sustainable Regulating Reserve constraint Shadow Prices
- Market-wide Up Ramp Capability constraint Shadow Prices
- Market-wide Down Ramp Capability constraint Shadow Prices
- Market-wide Short Term Reserve constraint shadow prices
- Generation-based Operating Reserve constraint Shadow Prices
- Ramp Procurement Minimum Reserve Zone Up Ramp Capability Requirement Constraint Shadow Prices
- Ramp Procurement Minimum Reserve Zone Down Ramp Capability Requirement Constraint Shadow Prices
  - Reserve Procurement Minimum Reserve Zone Operating Reserve constraint Dispatch Interval Shadow Price
  - Reserve Procurement Minimum Reserve Zone Regulating plus Spinning Reserve constraint Dispatch Interval Shadow Price

- Reserve Procurement Minimum Reserve Zone Regulating Reserve constraint Dispatch Interval Shadow Price
- Reserve Procurement Minimum Reserve Zone Short Term Reserve constraint Dispatch Interval Shadow Price

6. SCED-Pricing Formulations

The Real-Time SCED-Pricing algorithm is executed for each Dispatch Interval to:

- Calculate Ex Post Locational Marginal Prices (LMPs) for Energy
- Calculate Ex Post Market Clearing Prices (MCPs) for Regulating Reserve, Spinning Reserve Supplemental Reserve, Up Ramp Capability and Down Ramp Capability and Short Term Reserve

The Real-Time SCED-Pricing algorithm uses a Linear Programming (LP) solver. 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 and reserve prices. This process is known as the Extended LMP (ELMP). The SCED-Pricing is the same as the SCED algorithm in Section 4 of this Attachment with the exception of its treatment of Fast Start Resources, Emergency Operations Resources and Emergency Demand Response Resources. Fast Start Resources are online Generation Resources that are started, synchronized and inject Energy, or Demand Response Resources that reduce Energy consumption, within sixty (60) minutes of being notified and that each has a minimum run time of one hour or less or, an offline Generation Resource that can be started, synchronized and inject Energy, or a Demand Response Resource that can reduce its Energy consumption, within ten (10) minutes of being notified and that has a minimum run time of one hour or less and is not a fuel limited resource. Emergency Operations Resources are online Generation Resources that are not online Fast Start Resources and are started, synchronized and inject Energy, or Demand Response Resources that reduce Energy consumption, within two hundred forty (240) minutes of being notified and that each has a minimum run time of less than four hours. Emergency Operations Resources are only considered in Real-Time SCED-Pricing when initiated by the Transmission Provider as specified in Emergency operating procedures. When initiated, Emergency Operations Resources commitment costs are treated in the same manner as that of Fast Start Resources. Under Capacity Shortage Conditions, the SCED-Pricing algorithm will also consider the cost of Resources that are scheduled by MISO during Emergency operating procedures as specified by their Proxy Offers.

In the formulations that follow, continuous primal variables are shown in a red font and constraint violation variables are shown in a blue font. See Attachment A on Market Optimization Techniques for background information on LP SCED formulations.

6.1 SCED-Pricing Objective Function

The overall objective function of the SCED-Pricing algorithm is to minimize the following cost function over a single Dispatch Interval:

MINIMIZE { Resource Energy Costs
+ Fast Start Resources Commitment Cost
+ Emergency Demand Response Resource Energy Reduction and Shutdown Costs
+ Proxy Offer Costs of External Resource that Qualifies as Planning Resource, Load Modifying Resource or Emergency Energy Purchase
+ Regulating Reserve Costs
+ Contingency Reserve Costs
+ Off-Line Short Term Reserve Costs

- Market-Wide Operating Reserve Value
- Market-Wide Regulating Reserve Value
- Market-Wide Regulating plus Spinning Reserve Value
- Market-Wide Short Term Reserve Value
- Mark-Wide Up Ramp Capability Value
- Market-Wide Down Ramp Capability Value
+ Constraint Violation Penalty Costs**
+ Tie-Breaking Penalty Costs **}**

*Note: Under Capacity Shortage Conditions, a Proxy Offer will be used for Resources' emergency dispatch range above the maximum economic limit or the entire range for emergency commitments
**Note: Applies only when there are opposing constraints

The cost terms in the objective function above are described as follows.

6.1.1 SCED-Pricing Objective Function Cost Terms Shared with SCED Objective Function

A number of the cost terms of the SCED-Pricing objective function are calculated identically to cost term in the SCED objective function that can be found in section 5.1 of this Attachment. Those cost terms are:

- Resource Energy Costs,
- Regulation Reserve Costs,
- Contingency Reserve Costs,

- Off-Line Short Term Reserve Costs,
- Market-Wide Operating Reserve Value,
- Market-Wide Regulating Reserve Value,
- Market-Wide Regulating plus Spinning Reserve Value,
- Market-Wide Up Ramp Capability Value,
- Market-Wide Down Ramp Capability Value,
- Market-Wide Short Term Reserve Value,
- Reserve Zone Operating Reserve Value,
- Reserve Zone Regulating Reserve Value,
- Reserve Zone Regulating plus Spinning Reserve Value,
- Reserve Zone Short Term Reserve Value,
- Opposing Constraint Violation Penalty Costs,
- Tie-Breaking Penalty Costs
- Emergency Purchases Proxy Offer Cost*
- External Resources that are Planning Resources' Proxy Offer Cost*
- LMR Proxy Offer Cost*

* Under Capacity Shortage Conditions, the Proxy Offer Cost for a Resource's emergency capacity is the maximum of the Emergency Tier I or Tier II Offer Floor and the Energy Offer of the applicable capacity block. The Emergency Tier I Offer Floor is established at the declaration of Maximum Generation Emergency warning as the maximum of $500 and thehighest available economic offer in the Energy Emergency Areas with the costs of committing and dispatching Fast Start Resources considered in the same way as that specified in Section 5.1.2. The Emergency Tier II Offer Floor is established at the declaration of a maximum generation event, step 2 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 Areas. As such, a Proxy Offer is allowed to exceed the Energy Offer Price Cap which is for Incremental Energy Cost only.

6.1.2 Fast Start Resources Commitment Costs

Fast Start Resources Commitment Costs are 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 MISO based on their submitted Start-Up, No-Load Offer Costs, Shut-down offer and hourly curtailment offer if SCED-Pricing determines their possible commitment best meets the objective function.

The Real-Time SCED-Pricing considers the costs of committing and the costs of keeping on-line those Fast-Start Resources that are committed by MISO in Real Time to be on line in the Dispatch Interval. The Real-Time SCED-Pricing 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 SCED-Pricing when initiated by the Transmission Provider as specified in Emergency operating procedures. When initiated, Emergency Operations Resources commitment costs are treated in the same manner as that of Fast Start Resources. Real-Time SCED-Pricing also considers the costs of committing and dispatching off-line Fast Start Resources 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;
b) The SCED algorithm finds a solution that violates a transmission constraint for which MISO is the monitoring entity and MISO 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.

6.1.2.1 On-Line Resources

The SCED-Pricing algorithm allocates a share of the Start-Up Cost or Shut-Down-Cost of the Fast Start Resource to the interval for which prices are being calculated. The following costs are different than those in the SCED algorithm and 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.

On-line Fast Start Resources Commitment Costs are expressed mathematically in the SCED-Pricing objective function as follows:
Generation Resources and DRR type II

$$= \sum_{r} \{On(r, di) * \{AllocatedShareStartUpCost(r, di) + NoLoadCost(r, di) / 12\}\}$$

where AllocatedShareStartUpCost(r, di) = StartUpCost(r) / (N * 12) if di is within N hours of the time the Generation or DRR type II Resource was committed, or 0 if di is later than N hours after the Resource was committed

DRR type I

$$= \sum_{r1} \{On(r1, di) * \{(AllocatedShareShutdownCost(r1, di) + HourlyCurtailmentOffer(r1, di) / 12\}\},$$

Where AllocatedShareShutDownCost(r1, di) = ShutDownCost(r1) / (N * 12) if di is within N hours of the time the DRR - Type I was committed, or 0 if di is later than N hours after the DRR - Type I was committed

6.1.2.2 Off-line Resources

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 initially be set at four (4) Real-Time study intervals, i.e., 1/3 hour.

Off-line Fast Start Resources Commitment Costs are expressed mathematically in the SCED-Pricing objective function as follows:
Generation resources and DRR type II

$$= \sum_{r} \{On(r, di) * (StartUpCost(r) + NoLoadCost(r, di) * N + \max\{0, \int_{0}^{EconMin(r, di)} IncrementalEnergyCost(r, di, MW)dMW – UDS\ SMP(di) * EconMin(r, di)\} * (N - M)) / (M * 12)\}$$

DRR - Type I:

$$= \sum_{r1} \{On(r1, di) * (ShutDownCost(r1) + CurtailCost(r1, di) * N$$

$$+ \max\{0, \int_{0}^{TargetDemRedLevel(r1,\ di)} IncrementalEnergyCost(r1, di, MW)dMW - UDS\ SMP(di)$$

$$* TargetDemRedLevel(r1, di)\} * (N - M)) / (M * 12)\}$$

Here UDS SMP (di) is the Marginal Energy Component from Economic Dispatch process at interval di.

6.1.3 Emergency Demand Response Resource Energy Reduction and Shutdown Costs

In the following, N is the period time in Hours for which Emergency Demand Response Resource is called upon to provide reduce consumption. Emergency Demand Response Resource Energy Reduction and Shutdown Costs are expressed mathematically in the SCED-Pricing objective function as follows:

Emergency Demand Response Resource Energy Reduction and Shutdown Costs:

$$= \sum_{edr} \{On(edr, di) * \{(ShutDownCost(edr, di) / (N * 12)\}$$

$$+ \sum_{edr} \{ClearedEnergy(edr, di) * CostEnergy(edr, di) / 12\}$$

In the above, a Proxy Offer will be used for the Emergency Demand Response resource. The Proxy Offer is the maximum of the Emergency Tier II Offer Floor as established in Section 5.1.1 and the Emergency Demand Response Offer.

6.1.4 Proxy Offer Costs of External Resource that Qualifies as Planning Resource, Load Modifying Resource or Emergency Energy Purchase

Under Capacity Shortage Conditions, the Proxy Offer for an External Resource that qualifies as a Planning Resource equals the Emergency Tier I or Tier II Offer Floor as established in Section 5.1.1. 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 Energy Purchase equals the Emergency Tier II Offer Floor. Proxy Offer Costs of the scheduled External Resource that qualifies as a Planning Resource, Load Modifying Resource or Emergency Energy Purchase are expressed mathematically in the SCED-Pricing objective function as follows:

$$\left(\int_{0}^{EnergyDispatchSchedule_t} ProxyOffer_t(x)dx\right) / (Intervals\ per\ Hour)$$

6.2 SCED-Pricing Constraints

The overall objective function of the SCED-Pricing algorithm is minimized subject to the following constraints:

NOTE: While the formal constraint representation includes all variables on the LHS and a single constant on the RHS, the SCED constraints below have been arranged in a format that provides the most clarity as to the purpose and function of the constraint.

6.2.1 Generation Resource and Demand Response Resource – Type II Constraints

The constraints of the SCED-Pricing objective function related to non-fast start Generation Resource and Demand Response Resource Type II are calculated identically to constraints in the SCED objective function that can be found in section 5.2.1 of this Attachment. For fast start Generation Resource and Demand Response Resource Type II, a number of the constraints of the SCED-Pricing objective function are calculated identically to constraints in the SCED constraints that can be found in section 5.2.1 of this Attachment. Those constraints are:

- Energy Step Clearing Constraints,
- Energy Dispatch Target Constraints,
- Cleared Regulating Reserve Constraints,
- Cleared Contingency Reserve Constraints,
- Cleared Short Term Reserve Constraints,
- General Ramp-Up Constraints,
- General Ramp-Down Constraints,
- Contingency Reserve Ramp Constraints,
- Regulating Reserve Ramp Constraints,
- Up Ramp Capability Ramp Constraints,
- Down Ramp Capability Ramp Constraints
- Short Term Reserve Ramp Constraints
- Maximum Resource Regulating Reserve Constraints,
- Maximum Resource Daily Regulating Constraints,
- Maximum Resource Contingency Reserve Constraints,
- Maximum Resource Short Term Reserve Constraints,

- Maximum Resource Up Ramp Capability Constraints,
- Maximum Resource Down Ramp Capability Constraints,
- Maximum Resource Daily Contingency Constraints,
- Self-Scheduled Energy Constraints,
- Self-Scheduled Regulating Reserve Constraints,
- Self-Scheduled Contingency Reserve Constraints,
- Contingency Reserve Deployment Constraint,
- Contingency Reserve Capping Constraint

The additional constraints for fast start Generation Resource and Demand Response Resource Type II are described in the sections below.

6.2.1.1 Partial commitment constraint

To allow Fast Start Resource set price, SCED-Pricing represents the fraction of the Fast Start Resource committed by the SCED-Pricing algorithm in the Dispatch Interval *di* by the continuous decision variable *on(r,di)*. SCED-Pricing algorithm requires that *on(r,di)* satisfy $0 \leq on(r,di) \leq 1$.

At the declaration of Maximum Generation Emergency warning/Maximum Generation Emergency, to allow non-Fast Start Emergency Resource set price, SCED-Pricing represents the fraction of the non-Fast Start Emergency Resource committed by the SCED-Pricing algorithm in the Dispatch Interval *di* by the continuous decision variable *on(r,di)*. SCED-Pricing algorithm requires that *on(r,di)* satisfy $0 \leq on(r,di) \leq 1$.

6.2.1.2 Maximum Limit Constraints

Constraint Classification: Physical

Constraint Type: Penalized LE

Maximum Limit Constraints in the SCED-Pricing algorithm for non-Fast Start Resources follow the SCED algorithm and can be found in section 5.2.1 of this Attachment.

The following maximum limit constraints apply to on line Fast Start Resources r for Dispatch Interval di.

ClearedEnergy(r, di) + ContResCleared(r, di) + ClearedRegRes1(r,di) + ClearedRegRes2(r,di) + ClearedRCUp(r,di)
≤

On(r, di)*MaxLimit(r, di) + MaxLimitViolation(r,di)

6.2.1.3 Maximum Short Term Reserve Limit Constraints

Constraint Classification: Physical

Constraint Type: Penalized LE

Maximum Limit Constraints in the SCED-Pricing algorithm for non-Fast Start Resources follow the SCED algorithm and can be found in section 5.2.1 of this Attachment.

The following maximum short term reserve limit constraints apply to on line Fast Start Resources r for Dispatch Interval di.

ClearedEnergy(r, di) + ClearedRegRes1(r,di) + ClearedOnlineSTR(r,di)
≤
On(r, di)*MaxLimit(r, di) + MaxLimitViolation(r,di)

6.2.1.4 Minimum Limit Constraints

Constraint Classification: Physical

Constraint Type: Penalized LE

Minimum Limit Constraints in the SCED-Pricing algorithm for non-Fast Start Resources follow the SCED algorithm and can be found in section 5.2.1 of this Attachment.

The following minimum limit constraints apply to on line Fast Start Resources r for Dispatch Interval di

ClearedEnergy(r, di) − ClearedRegRes1(r,di) - ClearedRCDown(r,di)

≥

On(r, di)*MinLimit(r, di) - MinLimitViolation(r,di)

6.2.1.5 General Ramp-Down Constraints

Constraint Classification: Physical

Constraint Type: Penalized GE

The following constraints are used to ensure the change in the Energy Dispatch Target can be accommodated by the ramp-down rate.

EnergyDispatchTarget(r,di)

≥

InitialEnergyOutput(r,di)

- 5 * RampDownRate(r,di)

- GeneralRampDownViolation(r,di)

Under both normal condition and emergency condition, online Fast Start Resources, which are dispatched at their Economic Minimum (EcoMin) in the previous interval in the Real-Time Market, will be allowed to back down to 0 by not enforcing Ramp-Down constraint. This also applies to External Asynchonous Resources.

6.2.1.6 Offline Fast Start Resource Maximum Limit Constraint

Constraint Classification: Physical

Constraint Type: Penalized LE

The following offline fast start resource maximum limit constraints apply to Fast Start Resources while a scarcity condition exists or a constraint is in violation.

ClearedEnergy(r,di)

<

On(r, di)*MaxLimit(r, di) + MaxLimitViolation(r,di)

6.2.1.7 Offline Fast Start Resource Contingency Reserve Constraint

Constraint Classification: Physical

Constraint Type: Penalized LE

The following offline fast start resource contingency reserve constraints apply to Fast Start Resources while a scarcity condition exists or a constraint is in violation.

ConResCleared(r, di)

≤

{1− On(r, di)}

* Min[MaxOffLineResponse(r,di), Maxlimt(r,di)]+MaxLimitViolation(r,di)]

6.2.1.8 Offline Fast Start Resource Short Term Reserve Constraint

Constraint Classification: Physical

Constraint Type: Penalized LE

The following offline Fast Start Resource maximum limit constraints apply to Fast Start Resources while a scarcity condition exists or a transmission constraint is in violation.

ClearedOffLineSTR (r,di)

<

(1-On(r,h))*min(MaxLimit(r,di), MaxOffLineSTR(r,di))

6.2.2 Demand Response Resource – Type I Constraints

The constraints of the SCED-Pricing objective function related to non-fast start Demand Response Resource Type I are calculated identically to constraints in the SCED objective function that can be found in section 5.2.2 of this Attachment. For fast start Demand Response Resource Type I, a number of the constraints of the SCED-Pricing objective function related to Demand Response Resource Type I are calculated identically to constraints in the SCED constraints function that can be found in section 5.2.2 of this Attachment. Those constraints are:

- Cleared Regulating Reserve Constraints,
- Maximum Resource Contingency Reserve Constraints,
- Maximum Resource Short Term Reserve Constraints,
- Maximum Resource Daily Regulating Constraints,
- Self-Scheduled Contingency Reserve Constraints,
- Contingency Reserve Capping Constraints

The additional constraints for fast start Demand Response Resource Type I are described in the sections below.

6.2.2.1 Partial commitment constraint

To allow DRR type I to set price, SCED-Pricing represents the fraction of the DRR type I committed by the SCED-Pricing algorithm in the Dispatch Interval *di* by the continuous decision variable *on(r,di)*. SCED-Pricing algorithm requires that *on(r,di)* satisfy $0 \leq on(r,di) \leq 1$.

At the declaration of Maximum Generation Emergency warning/Maximum Generation Emergency, to allow non-Fast Start Emergency DRR type I Resource set price, SCED-Pricing represents the fraction of the non-Fast Start Emergency DRR type I Resource committed by the SCED-Pricing algorithm in the Dispatch Interval *di* by the continuous decision variable *on(r,di)*. SCED-Pricing algorithm requires that *on(r,di)* satisfy $0 \leq on(r,di) \leq 1$.

6.2.2.2 Cleared Energy Constraints

Constraint Classification: Physical

Constraint Type: Hard Equality

Cleared Energy Constraints in the SCED-Pricing algorithm follow the SCED algorithm for non-fast start DRR type I resources and can be found in section 5.2.2 of this Attachment.

The following constraints apply to Fast Start DRR type I Resources

ClearedEnergy(r,di) =

On(r, di)* TargetDemRedLevel (r, di)

6.2.2.3 Cleared Contingency Reserve Constraints

Constraint Classification: Physical

Constraint Type: Hard LE

Cleared Contingency Reserve Constraints in the SCED-Pricing algorithm is the same as the SCED algorithm for non-fast start DRR type I resources and can be found in section 5.2.2 of this Attachment. For fast start DRR type I resources

ClearedContRes(r,di)

≤

[1 - CF(r,di)] *[1- On(r,di)]*TargetDemRedLeve(r,di) * SpinAvailability(r,di)

+ [1 - CF(r,di)] *[1-On(r,di)]* TargetDemRedLeve(r,di) * [SupAvailability(r,di) - SpinAvailability(r,di)]

6.2.2.4 Cleared Offline Short Term Reserve Constraints

Constraint Classification: Physical

Constraint Type: Hard LE

The following constraints ensure that Short Term Reserve is only dispatched on a resource during a Dispatch Interval where the resource is not committed (i.e., the commitment flag is 0). This constraint also limits the amount of Short Term Reserve that can be dispatched on a resource during a Dispatch Interval to the targeted demand reduction level of the resource during that Dispatch Interval.

ClearedOfflineSTR (r,ci)
≤
[1 - CF(r,di)] *[1- On(r,di)]* TargetDemRedLevel(r,di) * STROfflineAvailability(r,di)

If the commitment flag is set to 0 for a resource during a specific Dispatch Interval, an amount of Short Term Reserve may be dispatched on the resource up to the targeted demand reduction level of the resource during that Dispatch Interval. If the commitment flag is set to 1 for a resource during a specific Dispatch Interval, no Short Term Reserve may be dispatched on that resource during that Dispatch Interval.

6.2.3 External Asynchronous Resource Constraints

The constraints of the SCED-Pricing objective function related to External Asynchronous Resource constraints are calculated identically to constraints in the SCED objective function that can be found in section 5.2.3 of this Attachment.

6.2.4 Emergency Demand Response Resource Constraints

6.2.4.1 Partial commitment constraint

To allow Emergency Demand Response Resource to set price, SCED-Pricing represents the fraction of the Emergency Demand Response Resource committed by the SCED-Pricing algorithm in the Dispatch Interval *di* by the continuous decision variable *on(r,di)*. SCED-Pricing algorithm requires that *on(r,di)* satisfy $0 \le on(r,di) \le 1$.

6.2.4.2 Energy Dispatch Target Constraints

Constraint Classification: Physical

Constraint Type: Hard Equality

ClearedEnergy(r,di) =
On(r, di)*EnergyScheduleMW (r, di)

6.2.5 External Resource that qualifies as Planning Resource, Load Modifying Resource or Emergency Energy Purchase

6.2.5.1 Partial Commitment Constraint

To allow an External Resource that qualifies as a Planning Resource, Load Modifying Resource or Emergency Energy Purchase to set price when deployed under declared emergency events the SCED-Pricing algorithm allows their schedule to be adjusted for pricing purposes. SCED-Pricing represents the fraction of these resources scheduled in the Dispatch Interval *di* by the continuous decision variable *on(r,di)*. SCED-Pricing algorithm requires that *on(r,di)* satisfy $0 \le on(r,di) \le 1$.

6.2.5.2 Energy Dispatch Target Constraints

Constraint Classification: Physical

Constraint Type: Hard Equality

EmergencyResourceClearedEnergy(r,di) =
On(r, di)*EnergyScheduleMW (r, di)

6.2.6 Global Power Balance Constraints

A number of the constraints of the SCED-Pricing objective function related to Global Power Balance constraints are calculated identically to constraints in the SCED objective function that can be found in section 5.2.5 of this Attachment. Those constraints are:

- Modeled Losses Constraints,
- Global Power Balance Constraints

The additional constraints for fast start Global Power Balance are described in the sections below.

6.2.6.1 Bus Energy Injection Constraints

Constraint Classification: Physical

Constraint Type: Hard Equality

Bus Energy Injection Constraints in the SCED-Pricing algorithm use the SCED algorithm found in section 5.2.5 this Attachment with the addition of fast start DRRI and EDRs energy clearing which are added into bus energy injections.

$$PI(i,di) = \sum_{r} \{ DF(i,r) * EnergyDispatchTarget(r,di) \} + \sum_{r} \{ DF(i,r) * FastStartDRRIEnergyDispatchTarget(r,di) \} + \sum_{r} \{ DF(i,r) * EDREnergyDispatchTarget(r,di) \} + \sum_{r} \{ DF(i,r) * EmergencyResourceClearedEnergy(r,di) \}$$

6.2.6.2 Bus Energy Withdrawal Constraints

Constraint Classification: Physical

Constraint Type: Hard Equality

Bus Energy Withdrawal Constraints in the SCED-Pricing algorithm use the SCED algorithm found in section 5.2.5 this Attachment with the addition of fast start DRR1, EDR and LMR added into system demand

$$PW(i,di) =$$

RefBusDF(i,di) * (SystemDemandMW(di) + FastStartDRR1energyMW(di) + EDRreductionMW(di) + LMRreductionMW(di))

6.2.7 Reliability Constraints

The constraints of the SCED-Pricing objective function related to Reliability constraints are calculated identically to constraints in the SCED objective function that can be found in section 5.2.6 of this Attachment.

6.2.8 Tie-Breaking Constraints

The constraints of the SCED-Pricing objective function related to Tie-Breaking constraints are calculated identically to constraints in the SCED objective function that can be found in section 5.2.7 of this Attachment.

6.3 SCED-Pricing Constraint Relaxation Logic

The SCED-Pricing Constraint Relaxation Logic is identical to the SCED Constraint Relaxation Logic which can be found in section 5.3 of this Attachment.

6.4 SCED-Pricing Output

The following output is generated by the SCED-Pricing algorithm:

- Energy Dispatch Target for Resources
- Cleared Dispatch Interval Regulating Reserve volumes for Resources
- Cleared Dispatch Interval Spinning Reserve volumes for Resources
- Cleared Dispatch Interval Supplemental Reserve volumes for Resources
- Cleared Dispatch Interval Short Term Reserve volumes for Resources
- Cleared Dispatch Interval Up Ramp Capability volumes for Resources
- Cleared Dispatch Interval Down Ramp Capability volumes for Resources
- Global power balance constraint Shadow Prices or **Global λ(di)**
- Transmission constraint Shadow Prices
- Market-wide Operating Reserve constraint Shadow Prices
- Market-wide Regulating plus Spinning Reserve constraint Shadow Prices
- Market-wide Regulating Reserve constraint Shadow Prices
- Market-wide Short Term Reserve constraint Shadow Prices
- Market-Wide Non-Sustainable Regulating Reserve constraint Shadow Prices
- Market-wide Up Ramp Capability constraint Shadow Prices
- Market-wide Down Ramp Capability constraint Shadow Prices
- Generation-based Operating Reserve constraint Shadow Prices

- Fast Start Resource Partial Commitment
- Marginal Resources for Energy Clearing
    - Reserve Procurement Minimum Reserve Zone Ramp Capability Up Reserve Requirement shadow prices
    - Reserve Procurement Minimum Reserve Zone Ramp Capability Down Reserve Requirement shadow prices
- Reserve Procurement Minimum Reserve Zone Operating Reserve constraint Dispatch Interval Shadow Price
- Reserve Procurement Minimum Reserve Zone Regulating plus Spinning Reserve constraint Dispatch Interval Shadow Price
- Reserve Procurement Minimum Reserve Zone Short Term Reserve constraint Dispatch Interval Shadow Price
- Reserve Procurement Minimum Reserve Zone Regulating Reserve constraint Dispatch Interval Shadow Price
- Under Maximum Generation Emergency, LMR, EDR, Emergency Purchases, External Resources that qualify as Planning ResourcesPartialCommitment

7. Post-SCED Processing

Post SCED processing includes product substitution calculations and the calculation of Locational Marginal Prices (LMPs) for Energy and Market Clearing Prices (MCPs) for Operating Reserves.

7.1 Product Substitution Calculations

Product substitution calculations determine dispatch quantities from cleared quantities. With regard to Operating Reserve in the Real-Time Energy and Operating Reserve Market, cleared quantities are the actual quantities that are procured and settled on. Cleared quantities are pre-substitution. Dispatch quantities represent how the cleared quantities are utilized. Dispatch quantities are post substitution. For example, assume in a hypothetical Dispatch Interval that the Regulating Reserve requirement is 500 MW, the Spinning Reserve requirement is 600 MW and the Supplemental Reserve requirement is 900 MW. This equates to an Operating Reserve requirement of 2,000 MW. Assume also the lowest cost means of meeting the entire Operating Reserve requirement of 2,000 MW is through Regulating Reserve provided by Resources (i.e., Regulating Reserve offers are lower than Spinning Reserve and/or Supplemental Reserve offers). The Real-Time Energy and Operating Reserve Market would clear, procure and settle 2,000 MW of Regulating Reserve and no Spinning or Supplemental Reserve. However, to operate the system, it is necessary to dispatch 600 MW of the Regulating Reserve as Spinning Reserve and 900 MW of the Regulating Reserve as Supplemental Reserve. That is, cleared reserve and dispatched reserve are two different quantities. Cleared reserve is a financial quantity whereas dispatched reserve is an operational quantity. The calculations used to determine dispatched quantities from cleared quantities (i.e., how one product substitutes for another) are detailed below

7.1.1 Resource Regulating Reserve Dispatched – Total

The next step is to determine the Resource Regulating Reserve Dispatched - Total for each Resource r during the Dispatch Interval di. This represents the total Regulating Reserve dispatched (but not necessarily cleared) on Resource r during Dispatch Interval di. The Resource Regulating Reserve Dispatched - Total, which is designated as **RegResDispatch(r,di)** in the formulations, is calculated as follows:

RegResDispatch(r,di)=ClearedRegRes1(r,di) + RegResDispatchComp2(r,di)

7.1.2 Dispatched Reserve Zone Regulating Reserve

The next step is to determine the Dispatched Reserve Zone Regulating Reserve for each Reserve Zone z during the Dispatch Interval di. The Dispatched Reserve Zone Regulating Reserve, which is designated as **RZRegResDispatch(z,di)** in the formulations, is calculated as follows:

$$RZRegResDispatch(z,di) = \sum_{r \in z} \{ RegResDisipatch(r,di) \}$$

7.1.3 Dispatched Market-Wide Regulating Reserve

The next step is to determine the Dispatched Market-Wide Regulating Reserve during the Dispatch Interval di. The Dispatched Market-Wide Regulating Reserve, which is designated as **MWRegResDispatch(di)** in the formulations, is calculated as follows:

$$MWRegResDispatch(di) = \sum \{ RegResDispatch(r,di) \}$$

7.1.4 Undispatched Reserve Zone Regulating Reserve

The next step is to determine the Undispatched Reserve Zone Regulating Reserve for each Reserve Zone z during the Dispatch Interval di. This represents the cleared Regulating Reserve in Reserve Zone z that has not been dispatched as Regulating Reserve, and thus will be substituted for Contingency Reserve. The Undispatched Reserve Zone Regulating Reserve, which is designated as **RZRegResUnDispatch(z,di)** in the formulations, is calculated as follows:

$$RZRegResUnDispatch(z,di) = \sum_{r \in z} \{ ClearedRegRes2(r,di) \}$$

7.1.5 Undispatched Resource Regulating Reserve

The next step is to determine the Undispatched Resource Regulating Reserve for each Resource r during the Dispatch Interval di. This represents the cleared Regulating Reserve on Resource r that has not been dispatched as Regulating Reserve, and thus will be substituted for Contingency Reserve. The Undispatched Resource Regulating Reserve, which is designated as **RegResUnDispatch(r,di)** in the formulations, is calculated as follows:

$$RegResUnDispatch(r,di) = ClearedRegRes2(r,di)$$

7.1.6 Reserve Zone Spinning Reserve Dispatch Requirement

The next step is to determine the Reserve Zone Spinning Reserve Dispatch Requirement for each Reserve Zone z during the Dispatch Interval di. The Reserve Zone Spinning Reserve Dispatch Requirement, which is designated as **RZSpinResDispatchReq(z,di)** in the formulations, is calculated as follows:

$$RZSpinResDispatchReq(z,di) = \mathbf{MAX\{} \; 0, RZRegSpinReq(z,di) - RZRegResDispatch(z,di) \mathbf{\}}$$

7.1.7 Market-Wide Spinning Reserve Dispatch Requirement

The next step is to determine the Market-Wide Spinning Reserve Dispatch Requirement during the Dispatch Interval di. The Market-Wide Spinning Reserve Dispatch Requirement, which is designated as **MWSpinResDispatchReq(di)** in the formulations, is calculated as follows:

MWSpinResDispatchReq(di)

= **MAX{** 0, MWRegSpinReq(di) - MWRegResDispatch(di)**}**

7.1.8 Available Resource Spinning Reserve

The next step is to determine the Available Resource Spinning Reserve during the Dispatch Interval di. The Available Resource Spinning Reserve, which is designated as **AvailSpinRes(r,di)** in the formulations, is calculated as follows:

AvailSpinRes(r,di)

= SpinAvailability(r,di) * [ClearedContRes(r,di) + RegResUnDispatch(r,di)]

7.1.9 Available Reserve Zone Spinning Reserve

The next step is to determine the Available Reserve Zone Spinning Reserve during the Dispatch Interval di. The Available Reserve Zone Spinning Reserve, which is designated as **AvailRZSpinRes(z,di)** in the formulations, is calculated as follows:

$$\text{AvailRZSpinRes(z,di)} = \sum_{r \in z} \{ \text{AvailSpinRes(r,di)} \}$$

7.1.10 Available Market-Wide Spinning Reserve

The next step is to determine the Available Market-Wide Spinning Reserve during the Dispatch Interval di. The Available Market-Wide Spinning Reserve, which is designated as **AvailMWSpinRes(di)** in the formulations, is calculated as follows:

$$\text{AvailMWSpinRes(di)} = \sum_{r} \{ \text{AvailSpinRes(r,di)} \}$$

7.1.11 Resource Spinning Reserve Dispatched – Component 1

The next step is to determine the Resource Spinning Reserve Dispatched - Component 1 for each specific Resource, which could be equal to or less than the amount of Spinning Reserve cleared on the Resource. The Resource Spinning Reserve Dispatched - Component 1 for Resource r during Dispatch Interval di, which is designated as **SpinResDispatchComp1(r,di)** in the formulations, is calculated as follows:

If the Available Reserve Zone Spinning Reserve in parent Reserve Zone z of Resource r exceeds the Reserve Zone Spinning Reserve Dispatch Requirement in parent Reserve Zone z of Resource r during Dispatch Interval di, the Resource Spinning Reserve Dispatched - Component 1 on Resource r is calculated as follows:

SpinResDispatchComp1(r,di)
= [RZSpinResDispatchReq(z,di) / AvailRZSpinRes(z,di)] * AvailSpinRes(r,di)

If the Available Reserve Zone Spinning Reserve in parent Reserve Zone z of Resource r is less than or equal to the Reserve Zone Spinning Reserve Dispatch Requirement in parent Reserve Zone z of Resource r during Dispatch Interval di, the Resource Spinning Reserve Dispatched - Component 1 on Resource r is calculated as follows:

SpinResDispatchComp1(r,di) = AvailSpinRes(r,di)

7.1.12 Reserve Zone Spinning Reserve Dispatched – Component 1

The next step is to determine the Reserve Zone Spinning Reserve Dispatched - Component 1 for each specific Reserve Zone. The Reserve Zone Spinning Reserve Dispatched - Component 1 during Dispatch Interval di, which is designated as **RZSpinResDispatchComp1(z,di)** in the formulations, is calculated as follows:

RZSpinResDispatchComp1(z,di)

$$= \sum_{r \in z} \{ \text{SpinResDispatchComp1}(r,di) \}$$

7.1.13 Market-Wide Spinning Reserve Dispatched – Component 1

The next step is to determine the Market-Wide Spinning Reserve Dispatched - Component 1. The Market-Wide Spinning Reserve Dispatched - Component 1, which is designated as **MWSpinResDispatchComp1(di)** in the formulations, is calculated as follows:

MWSpinResDispatchComp1(di)

$$= \sum_{z} \{ \text{RZSpinResDispatchComp1}(z,di) \}$$

7.1.14 Targeted Market-Wide Spinning Reserve Dispatch – Component 2

The next step is to determine the Targeted Market-Wide Spinning Reserve Dispatch - Component 2 for Dispatch Interval di, which is the additional market-wide Spinning Reserve required above and beyond the Market-Wide Spinning Reserve Dispatched - Component 1 to balance the total Market-Wide Spinning Reserve dispatch with the Market-Wide Spinning Reserve requirement. The Targeted Market-Wide Spinning Reserve Dispatch - Component 2 in Dispatch Interval di, which is designated as **TMWSpinResDispatchComp2(di)** in the formulations, is calculated as follows:

TMWSpinResDispatchComp2(di)

= **MAX{** 0, MWRegSpinReq(di) - MWRegReq(di)
- MWSpinResDispatchedComp1(di)**}**

7.1.15 Undispatched Market-Wide Spinning Reserve

The next step is to determine the Undispatched Market-Wide Spinning Reserve during the Dispatch Interval di. This represents the available Spinning Reserve that has not yet been dispatched as Contingency Reserve. The Undispatched Market-Wide Spinning Reserve, which is designated as **MWSpinResUnDispatch(di)** in the formulations, is calculated as follows:

MWSpinResUnDispatch(di)

= **MAX{** 0, AvailMWSpinRes(di) - MWSpinResDispatchedComp1(di)**}**

7.1.16 Resource Spinning Reserve Dispatched – Component 2

The next step is to determine the Resource Spinning Reserve Dispatched - Component 2 for each specific Resource. The Resource Spinning Reserve Dispatched - Component 2 for Resource r during Dispatch Interval di, which is designated as **SpinResDispatchComp2(r,di)** in the formulations, is calculated as follows:

If the Targeted Market-Wide Spinning Reserve Dispatch - Component 2 is less than or equal to the Undispatched Market-Wide Spinning Reserve **and** the Undispatched Market-Wide Spinning Reserve is greater than 0 MW during Dispatch Interval di, the Resource Spinning Reserve Dispatched - Component 2 on Resource r during Dispatch Interval di is calculated as follows:

SpinResDispatchComp2(r,di)

= [TMWSpinResDispatchComp2(di) / MWSpinResUnDispatch(di)]
* [AvailSpinRes(r,di) - SpinResDispatchComp1(r,di)]

If the Targeted Market-Wide Spinning Reserve Dispatch - Component 2 is greater than the Undispatched Market-Wide Spinning Reserve Dispatched - Component 2 **and** the Undispatched Market-Wide Spinning Reserve Dispatched - Component 2 is greater than 0 MW during Dispatch Interval di, the Resource Spinning Reserve Dispatched - Component 2 on Resource r during Dispatch Interval di is calculated as follows:

SpinResDispatchComp2(r,di) = AvailSpinRes(r,di) - SpinResDispatchComp1(r,di)

If the Undispatched Market-Wide Spinning Reserve Dispatched - Component 2 is equal to 0 MW during Dispatch Interval di, the Resource Spinning Reserve Dispatched - Component 2 on Resource r during Dispatch Interval di is calculated as follows:

SpinResDispatchComp2(r,di) = 0

7.1.17 Resource Spinning Reserve Dispatched – Total

The next step is to determine the Resource Spinning Reserve Dispatched - Total for each Resource r during the Dispatch Interval di. This represents the total Spinning Reserve dispatched (but not necessarily cleared) on Resource r during Dispatch Interval di. The Resource Spinning Reserve Dispatched - Total, which is designated as **SpinResDispatch(r,di)** in the formulations, is calculated as follows:

SpinResDispatch(r,di) = SpinResDispatchComp1(r,di) + SpinResDispatchComp2(r,di)

7.1.18 Resource Supplemental Reserve Dispatched – Total

The next step is to determine the Resource Supplemental Reserve Dispatched - Total for each Resource r during the Dispatch Interval di. This represents the total Supplemental Reserve dispatched (but not necessarily cleared) on Resource r during Dispatch Interval di. The Resource Supplemental Reserve Dispatched - Total, which is designated as **SupResDispatch(r,di)** in the formulations, is calculated as follows:

SupResDispatch(r,di)
= **MAX{** 0, RegResCleared(r,di) + ContResCleared(r,di)
- RegResDispatch(r,di) - Spin Res Dispatch(r,di)**}**

7.1.19 Dispatch Targets forwarded to MISO's AGC system and Resources:

The following dispatch targets are sent to MISO's AGC system and forwarded to the Resources via ICCP and/or XML:

- Energy Dispatch Target = EnergyDispatchTarget(r,di)
- Regulating Reserve Dispatch Quantity = RegResDispatch(r,di)
- Spinning Reserve Dispatch Quantity = SpinResDispatch(r,di)
- Supplemental Reserve Dispatch Quantity = SupResDispatch(r,di)

7.2 Contingency Reserve Cleared Calculations

The RT SCED algorithm clears Contingency Reserve on each Resource. The Contingency Reserve must then be classified as either Spinning Reserve or Supplemental Reserve. Should price separation exist between Spinning Reserve and Supplemental Reserve, the classification is simply based on whether the Resource is a Spin Qualified Resource (in which case the Contingency Reserve is classified as Spinning Reserve) or a Supplemental Qualified Resource only (in which case the Contingency Reserve is classified as Supplemental Reserve). If there is no price separation between Spinning Reserve and Supplemental Reserve, the classification is performed as outlined in this section.

7.2.1 Reserve Zone Spinning Reserve Cleared:

The Reserve Zone Spinning Reserve Cleared in each Reserve Zone z during Dispatch Interval di, which is designated as **RZClearedSpinRes(z,di)** in the formulations, is calculated as follows:

$$\text{RZClearedSpinRes(z,di)} = \sum_{r \in z} \{ \text{SpinAvailability(r,di)} * \text{ClearedContRes(r,di)} \}$$

7.2.2 Resource Spinning Reserve Cleared – Component 1:

The Resource Spinning Reserve Cleared - Component 1 on each Resource r during Dispatch Interval di, which is designated as **SpinResClearedComp1(r,di)** in the formulations, is calculated as follows:

If the Reserve Zone Spinning Reserve Cleared is greater than the Reserve Zone Regulating Reserve plus Spinning Reserve Requirement less the Reserve Zone Regulating Reserve Cleared, the Resource Spinning Reserve Cleared - Component 1 is calculated as follows:

$$\begin{aligned} &\text{SpinResClearedComp1(r,di)} \\ &\quad = \text{SpinAvailability(r,di)} * \mathbf{MAX\{}\ 0, \\ &\qquad [\text{RZRegSpinReq(z,di)} - \text{RZRegCleared(z,di)}] \\ &\qquad * [\text{ClearedConRes(r,di)} / \text{RZClearedSpinRes(z,di)}]\ \mathbf{\}} \end{aligned}$$

If the Reserve Zone Spinning Reserve Cleared is less than or equal to the Reserve Zone Regulating Reserve plus Spinning Reserve Requirement less the Reserve Zone Regulating Reserve Cleared, the Resource Spinning Reserve Cleared - Component 1 is calculated as follows:

SpinResClearedComp1(r,di) = SpinAvailability(r,di) * ClearedConRes(r,di)

7.2.3 Reserve Zone Spinning Reserve Cleared – Component 1

The next step is to determine the Reserve Zone Spinning Reserve Cleared - Component 1 for each specific Reserve Zone. The Reserve Zone Spinning Reserve Cleared - Component 1 during Dispatch Interval di, which is designated as **RZSpinResClearedhComp1(z,di)** in the formulations, is calculated as follows:

$$RZSpinResClearedComp1(z,di) = \sum_{r \in z} \{ SpinResClearedComp1(r,di)\}$$

7.2.4 Market-Wide Spinning Reserve Cleared – Component 1

The next step is to determine the Market-Wide Spinning Reserve Cleared - Component 1. The Market-Wide Spinning Reserve Cleared - Component 1, which is designated as **MWSpinResClearedComp1(di)** in the formulations, is calculated as follows:

$$MWSpinResClearedComp1(di) = \sum_{z} \{ RZSpinResClearedComp1(z,di)\}$$

7.2.5 Market-Wide Spinning Reserve Cleared

The next step is to determine the Market-Wide Spinning Reserve Cleared. The Market-Wide Spinning Reserve Cleared, which is designated as **MWSpinResCleared(di)** in the formulations, is calculated as follows:

$$MWSpinResCleared(di) = \sum_{r} \{ SpinAvailability(r,di) * ClearedContRes(r,di)\}$$

7.2.6 Targeted Market-Wide Spinning Reserve Cleared – Component 2

The next step is to determine the Targeted Market-Wide Spinning Reserve Cleared - Component 2 for Dispatch Interval di, which is the additional market-wide Spinning Reserve required above and beyond the Market-Wide Spinning Reserve Cleared - Component 1 to balance the total Market-Wide Regulating plus Spinning Reserve cleared with the Market-Wide Regulating plus Spinning Reserve requirement. The Targeted Market-Wide Spinning Reserve Cleared - Component 2 in Dispatch Interval di, which is designated as **TMWSpinResClearedComp2(di)** in the formulations, is calculated as follows:

TMWSpinResClearedComp2(di)

= **MAX{** 0, MWRegSpinResReq(di) - MWSubRegCleared(di) - MWSpinResClearedComp1(di)**}**

7.2.7 Available Market-Wide Spinning Reserve Cleared – Component 2

The next step is to determine the Available Market-Wide Spinning Reserve Cleared - Component 2 for Dispatch Interval di, which is the difference between the available Market-Wide Spinning Reserve that cleared and the Market-Wide Spinning Reserve Cleared - Component 1. The Available Market-Wide Spinning Reserve Cleared - Component 2 in Dispatch Interval di, which is designated as **AMWSpinResClearedComp2(di)** in the formulations, is calculated as follows:

AMWSpinResClearedComp2(di)

= **MAX{** 0, MWSpinResCleared(di) - MWSpinResClearedComp1(di)**}**

7.2.8 Resource Spinning Reserve Cleared – Component 2

The next step is to determine the Resource Spinning Reserve Cleared - Component 2 for each specific Resource. The Resource Spinning Reserve Cleared - Component 2 for Resource r during Dispatch Interval di, which is designated as **SpinResClearedComp2(r,di)** in the formulations, is calculated as follows:

If the Targeted Market-Wide Spinning Reserve Cleared - Component 2 is less than or equal to the Available Market-Wide Spinning Reserve Cleared - Component 2 **and** the Available Market-Wide Spinning Reserve Cleared - Component 2 is greater than 0 MW during Dispatch Interval di, the Resource Spinning Reserve Cleared - Component 2 on Resource r during Dispatch Interval di is calculated as follows:

SpinResClearedComp2(r,di)
= SpinAvailability(r,di)
* [TMWSpinResClearedComp2(di) / AMWSpinResCleared(di)]
* [ContResCleared(r,di) - SpinResClearedComp1(r,di)]

If the Targeted Market-Wide Spinning Reserve Cleared - Component 2 is greater than the Available Market-Wide Spinning Reserve Cleared - Component 2 **and** the Available Market-Wide Spinning Reserve Cleared - Component 2 is greater than 0 MW during Dispatch Interval di, the Resource Spinning Reserve Cleared - Component 2 on Resource r during Dispatch Interval di is calculated as follows:

SpinResDispatchComp2(r,di) = SpinAvailability(r,di)
* [ContResCleared(r,di) - SpinResClearedComp1(r,di)]

If the Available Market-Wide Spinning Reserve Cleared - Component 2 is equal to 0 MW during Dispatch Interval di, the Resource Spinning Reserve Cleared - Component 2 on Resource r during Dispatch Interval di is calculated as follows:

SpinResClearedComp2(r,di) = 0

7.2.9 Resource Spinning Reserve Cleared – Total

The next step is to determine the Resource Spinning Reserve Cleared - Total for each Resource r during the Dispatch Interval di. This represents the total Spinning Reserve cleared on Resource r during Dispatch Interval di. The Resource Spinning Reserve Cleared - Total, which is designated as **SpinResCleared(r,di)** in the formulations, is calculated as follows:

SpinResCleared(r,di) = SpinResClearedComp1(r,di) + SpinResClearedComp2(r,di)

7.2.10 Resource Supplemental Reserve Cleared – Total

The next step is to determine the Resource Supplemental Reserve Cleared - Total for each Resource r during the Dispatch Interval di. This represents the total Supplemental Reserve cleared on Resource r during Dispatch Interval di. The Resource Supplemental Reserve Cleared - Total, which is designated as **SupResCleared(r,di)** in the formulations, is calculated as follows:

SupResCleared(r,di) = ContResCleared(r,di) - SpinResCleared(r,di)

7.2.11 Cleared Contingency Reserve used in Settlements:

The following Cleared Contingency Reserve values are used for Settlements and represent what was actually procured from Resources in the Real-Time Energy and Operating Reserve Market:

- Cleared Spinning Reserve = SpinResCleared(r,di)
- Cleared Supplemental Reserve = SupResCleared(r,di)

7.3 LMP Calculations

The LMPs for a specific node and Dispatch Interval are equal to the sum of three components. In the Real-Time Energy and Operating Reserve Market, each of the three LMP components is determined individually and then summed together to form the nodal LMP. The nodal LMP components are then used to determine the commercial pricing node LMPs, as discussed in the Energy and Operating Reserve Market Business Practices Manual as well as in the Tariff.

Mathematically, the nodal LMP is calculated as follows for a specific node and Dispatch Interval;

$$LMP(i,di) = MECr(di) + MLC(i,di) + MCC(i,di)$$

Additional reserve procurement constraints have been added which place new limits on resource energy and operating reserve clearings, to ensure that cleared reserves are deliverable as needed. The shadow prices of these constraints are additive to the marginal congestion component of LMPs. Thus, the nodal LMP is expressed as follows for a specific node and Dispatch Interval:

$$\begin{aligned} LMP(i,di) = {} & MECr(di) + MLC(i,di) + MCC(i,di) \\ & + \sum_{k \notin \text{basecase constraints}} \{[\partial Flow(k,di)/\partial P(i,di)] * RPRegUp\lambda(i,di) \\ & + \sum_{k \notin \text{basecase constraints}} \{[\partial Flow(k,di)/\partial P(i,di)] * RPRegDown\lambda(i,di) \\ & + \sum_{z,\, k \notin \text{basecase constraints}} \{[\partial Flow(k,di)/\partial P(i,di)] * RPCRDep\lambda(i,z,di) \\ & + \sum_{z,\, k \notin \text{basecase constraints}} \{[\partial Flow(k,di)/\partial P(i,di)] * RPSTRDep\lambda(i,z,di) \end{aligned}$$

7.3.1 Calculation of the LMP at the Reference Bus (MECr)

The marginal Energy component of the LMP at the reference bus, designated as **$MEC_r(di)$**, is one of the three components of LMP and is the same for all LMPs in a specific Dispatch Interval. The marginal Energy component of LMP at the reference bus is equal to the shadow price of the global power balance constraint for a Dispatch Interval:

$$MEC_r(di) = Global\lambda(i,di)$$

7.3.2 Calculation of the Marginal Loss Component of Nodal LMPs (MLCs)

The marginal loss component of the LMP at a specific node, designated as **MLC(i, di)**, is one of the three components of the LMP and is calculated as follows for each node for a Dispatch Interval:

$$MLC(i,di) = -\,\partial Loss(di)/\partial P(i,di) * MEC_r(di)$$

7.3.3 Calculation of the Marginal Congestion Component of Nodal LMPs (MCCs)

The marginal congestion component of the LMP at a specific node, designated as **MCC(i, di)**, is one of the three components of the LMP and is calculated as follows for each node for a Dispatch Interval:

$$MCC(i,di) = -\sum_k \partial Flow(k,di)/\partial P(i,di) * MEC_r(di)$$

7.3.4 Calculation of Commercial Pricing Node LMPs

The LMP at a specific commercial pricing node, including LMPs at Resources, load zones, hubs and interfaces, is calculated as follows for each commercial pricing node for a Dispatch Interval:

$$LMP(cpn,di) = \sum_i \{ WF(i,cpn) * LMP(i,di)$$

7.3.5 Calculation of Commercial Pricing Node Marginal Loss Component of LMP (MLCs)

The marginal loss component of the LMP at a specific commercial pricing node (MLCs), including MLCs at Resource, load zones, hubs and interfaces, are calculated as follows for each commercial pricing node for a Dispatch Interval:

$$MLC(cpn,di) = \sum_i \{ WF(i,cpn) * MLC(i,di)$$

7.3.6 Calculation of Commercial Pricing Node Marginal Congestion Component of LMP (MCCs)

The commercial pricing node Marginal Congestion Component of LMP (MCCs), including MCCs at Resources, load zones, hubs and interfaces, are calculated as follows for each commercial pricing node for a Dispatch Interval:

$$MCC(cpn,di) = LMP(cpn,di) - MEC_r(di) - MLC(cpn,di)$$

7.3.7 LMP Capping Logic

Per the Tariff, LMPs must be capped at the Value of Lost Load (VOLL), which is currently set at $3,500 per MWh. The following capping logic is incorporated into the LMP calculations:

7.3.7.1 Global Energy Deficit or EEA3

In the unlikely event of a global Energy deficit or declared EEA3 event, all commercial node LMPs for the Dispatch Interval will be set equal to the VOLL. In addition, the MECr will be set equal to the VOLL and the marginal loss component and marginal congestion component of all LMPs will be set to zero.

7.3.7.2 MEC_r Exceeds VOLL

When $MEC_r(di)$ exceeds VOLL but there is no global Energy deficit, $MEC_r(di)$ is adjusted to VOLL and MCC(cpn,di) is adjusted as necessary to maintain the LMP(cpn,di) at the lesser of VOLL or the value calculated above.

7.3.7.3 MEC_r Does Not Exceed VOLL

When $MEC_r(di)$ does not exceed VOLL, MCC(cpn,di) is adjusted as necessary to maintain the LMP(cpn,di) at the lesser of VOLL or the value calculated above.

7.4 MCP Calculations

Regulating Reserve MCPs, Spinning Reserve MCPs, and Supplemental Reserve MCPs are calculated for each reserve zone and Dispatch Interval. Regulation Mileage MCPs are calculated in the Real-Time Market only, and hence, are not included below.

7.4.1 Regulating Reserve MCPs for Generation Resources, Demand Response Resources – Type II and External Asynchronous Resources

The Regulating Reserve MCPs for Generation Resources, Demand Response Resources - Type II and External Asynchronous Resources in a specific Dispatch Interval and reserve zone are calculated as the sum of the following, but capped at VOLL:

- Applicable off-line studies Reserve zone operating reserve constraint Dispatch Interval shadow price
- Applicable off-line studies Reserve zone regulating plus spinning reserve constraint Dispatch Interval shadow price
- Applicable off-line studies Reserve zone regulating reserve constraint Dispatch Interval shadow price
- Reserve Procurement Minimum Reserve zone operating reserve constraint Dispatch Interval shadow price
- Reserve Procurement Minimum Reserve zone regulating plus spinning reserve constraint Dispatch Interval shadow price
- Reserve Procurement Minimum Reserve zone regulating reserve constraint Dispatch Interval shadow price
- Generation-based operating reserve constraint Dispatch Interval shadow price
- Generation-based regulating plus spinning reserve constraint Dispatch Interval shadow price

7.4.2 Spinning Reserve MCPs for Generation Resources, Demand Response Resources v Type II and External Asynchronous Resources

The Spinning Reserve MCPs for Generation Resources, Demand Response Resources - Type II and External Asynchronous Resources in a specific Dispatch Interval and Reserve Zone are calculated as the sum of the following, but capped at VOLL:

- Applicable off-line studies Reserve Zone Operating Reserve constraint Dispatch Interval Shadow Price
- Applicable off-line studies Reserve Zone Regulating plus Spinning Reserve constraint Dispatch Interval Shadow Price
- Reserve Procurement Minimum Reserve Zone Operating Reserve constraint Dispatch Interval Shadow Price
- Reserve Procurement Minimum Reserve Zone Regulating plus Spinning Reserve constraint Dispatch Interval Shadow Price
- Generation-based operating reserve constraint Dispatch Interval Shadow Price
- Generation-based Regulating plus Spinning Reserve constraint Dispatch Interval Shadow Price

7.4.3 Spinning Reserve MCPs Demand Response Resources – Type I

The Spinning Reserve MCPs for Demand Response Resources – Type I in a specific Dispatch Interval and Reserve Zone are calculated as the sum of the following, but capped at VOLL:

- Applicable off-line studies Reserve Zone Operating Reserve constraint Dispatch Interval Shadow Price
- Applicable off-line studies Reserve Zone Regulating plus Spinning Reserve constraint Dispatch Interval Shadow Price
- Reserve Procurement Minimum Reserve Zone Operating Reserve constraint Dispatch Interval Shadow Price
- Reserve Procurement Minimum Reserve Zone Regulating plus Spinning Reserve constraint Dispatch Interval Shadow Price

7.4.4 Supplemental Reserve MCPs for Generation Resources, Demand Response Resources – Type II and External Asynchronous Resources

The Supplemental Reserve MCPs for Generation Resources, Demand Response Resources - Type II and External Asynchronous Resources in a specific Dispatch Interval and Reserve Zone are calculated as the sum of the following, but capped at VOLL:

- Applicable off-line studies Reserve Zone Operating Reserve constraint Dispatch Interval Shadow Price
- Reserve Procurement Minimum Reserve Zone Operating Reserve constraint Dispatch Interval Shadow Price
- Generation-based Operating Reserve constraint Dispatch Interval Shadow Price

7.4.5 Supplemental Reserve MCPs for Demand Response Resources – Type I

The Supplemental Reserve MCPs for Demand Response Resources in a specific Dispatch Interval and Reserve Zone are equal to the sum of the following, but capped at VOLL:

- Applicable off-line studies Reserve Zone Operating Reserve constraint Dispatch Interval Shadow Price
- Reserve Procurement Minimum Reserve Zone Operating Reserve constraint Dispatch Interval Shadow Price

7.4.6 Short Term Reserve MCPs for Generation Resources, Demand Response Resources – Type II and External Asynchronous Resources

The Short Term Reserve MCPs for Generation Resources, Demand Response Resources - Type II and External Asynchronous Resources in a specific Dispatch Interval and Reserve Zone are calculated as the sum of the following, but capped at VOLL:

- Reserve Procurement Minimum Reserve Zone Operating Reserve constraint Dispatch Interval Shadow Price

7.4.7 Short Term Reserve MCPs for Demand Response Resources – Type I

The Short Term Reserve MCPs for Demand Response Resources in a specific Dispatch Interval and Reserve Zone are equal to the sum of the following, but capped at VOLL:

- Reserve Procurement Minimum Reserve Zone Operating Reserve constraint Dispatch Interval Shadow Price

7.4.8 Up Ramp Capability Product MCPs for Generation Resources, Demand Response Resources Type II and External Asynchronous Resources

The Up Ramp Capability Product MCPs for qualified Generation Resources, Demand Response Resources - Type II and External Asynchronous Resources in a specific Dispatch Interval and Reserve Zone are calculated as below but capped at VOLL:

- Ramp Procurement Minimum Reserve Zone Up Ramp Capability constraint Dispatch Interval Shadow Price

7.4.9 Down Ramp Capability Product MCPs for Generation Resources, Demand Response Resources v Type II and External Asynchronous Resources

The Down Ramp Capability Product MCPs for qualified Generation Resources, Demand Response Resources - Type II and External Asynchronous Resources in a specific Dispatch Interval and Reserve Zone are calculated as below, but capped at VOLL:

- Ramp Procurement Minimum Reserve Zone Ramp Capability Down constraint Dispatch Interval Shadow Price

8. Current Tuning Parameter Settings

Listed below are the current tuning parameter settings for the Real-Time SCED algorithm:

- ContResRampFact = 1.0
- ContResDeployTime = 10 Minutes
- MaxContResFactor = 0.2
- MaxRegResFactor = 0.2
- RegRampFactor = 1.0
- RegResponseTime = 5 Minutes
- MaxRCUpFactor = 0.2
- MaxRCDownFactor = 0.2
- RCUpResponseTime = 10 Minutes
- RCDownResponseTime = 10 Minutes
- RCUpRampFactor = 1.0
- RCDownRampFactor = 1.0
- STRResponseTime = 30 Minutes
- MaxSTRResFactor = 1.0
- STRRampFactor = 1.0

9. Glossary of Variables, Arrays and Parameters

9.1 Array Indices

- **cpn:** Index of commercial pricing nodes
- **crd:** Index of non-Cancelled Contingency Reserve deployment events
- **di:** Index of Dispatch Intervals
- **i:** Index of buses or electrical nodes
- **k:** Index of transmission branches, constraints or flowgates
- **lba:** Index of local balancing authorities
- **r, r1, r2:** Index of Resources
- **st:** Index of offer curve or demand curve steps
- **z:** Index of reserve zones

9.2 MISO Input Data

- **ActualRampDownRate(r,di-1):** A floating point array. The actual ramp-down rate used by the RT-SCED algorithm for Resource r during the previous Dispatch Interval. Expressed in MW per Minute.
- **ActualRampUpRate(r,di-1):** A floating point array. The actual ramp-up rate used by the RT-SCED algorithm for Resource r during the previous Dispatch Interval. Expressed in MW per Minute.
- **BeginTime(di):** An integer array. The time at the beginning of Dispatch Interval di. Expressed in Minutes.
- **BiDirRampRateOverride(r):** A floating point array. The Bi-Directional Ramp Rate Override for Resource r. Expressed in MW per Minute.
- **BiDirRampRateOverrideFlag(r):** A Boolean array. The Bi-Directional Ramp Rate Override Flag for Resource r. If set to 1, the bi-directional ramp rate for Resource r is overridden with the Bi-Directional Ramp Rate Override. If set to 0, the bi-directional ramp rate for Resource r is not overridden with the Bi-Directional Ramp Rate Override.
- **CAFlow(k,di):** A floating point array. The most recent flow calculated for transmission constraint k by the State Estimator based transmission contingency analysis algorithm just prior to execution of RT-SCED for Dispatch Interval di. Expressed in MW.

- **CAMW(i,di):** A floating point array. The most recent net MW injection calculated for Bus i by the State Estimator based transmission contingency analysis algorithm just prior to execution of RT-SCED for Dispatch Interval di. If i is replaced with r, the net MW injection applies to resource r. Expressed in MW.
- **∂Flow(k,di)/∂P(i,di):** A floating point array. The shift factor for transmission contingency analysis constraint k and bus i during Dispatch Interval di, which represents the incremental flow on transmission contingency analysis constraint k for an incremental injection at Bus i coupled with an incremental withdrawal at the load distributed reference Bus. This shift factor is provided by the most recent State Estimator based transmission contingency analysis solution just prior to executing RT-SCED for Dispatch Interval di. If i is replaced with r, then this variable represents the shift factor for transmission contingency analysis constraint k and Resource r during Dispatch Interval di. Expressed in MW.
- **CF(r,di):** A Boolean array. The Commitment Flag for Resource r during Dispatch Interval di. If set to 1, Resource r is committed for Dispatch Interval di. If set to 0, Resource r is not committed for Dispatch Interval di.
- **ContResDeployMW(r,crd)**: A floating point array. The Contingency Reserve deployed on resource r due to Contingency Reserve deployment event crd. Expressed in MW.
- **CurrentSEMW(r,di)**: A floating point array. The most recent state estimated output of Resource r just prior to the execution of the RT-SCED algorithm for Dispatch Interval di. Expressed in MW.
- **DF(i,r):** A floating point array. The percent of Resource r output allocated to Bus i, or the normalized distribution factor for Bus i and Resource r.
- **DisFlow(di):** A floating point array. The most recent dispatch flow calculated for the Sub-Regional Power Balance Constraint by the system operations just prior to execution of RT-SCED for Dispatch Interval di. Expressed in MW.
- **EmerMaxLimitOverrideFlag(r):** A floating point array. The Emergency Maximum Limit Override for Resource r. Expressed in MW.
- **EmerMinLimitOverrideFlag(r):** A floating point array. The Emergency Maximum Limit Override for Resource r. Expressed in MW.
- **FGLimit(k,di):** A floating point array. The limit of flowgate constraint k in Dispatch Interval di. Expressed in MW.
- **FGLimit_CREvent(k,di):** A floating point array. The limit of flowgate constraint k in Dispatch Interval di used for Reserve Procurement Contingency Reserve Event Constraints. Expressed in MW.
- **InyC(k,r,h)**: A floating point array. Injection Coefficient for resource r over Sub-Regional Power Balance Constraint k during hour h. Expressed in MW.
- **∂Loss(di)/∂P(i,di):** A floating point array. The marginal loss sensitivity factor for injections at bus i during Dispatch Interval di calculated with respect to the load distributed reference Bus. Based on the most recent State Estimator solution available when RT-SCED is executed for Dispatch Interval di.

- **ManualDispatchFlag(r,di):** A Boolean array. The Manual Dispatch Flag for Resource r during Dispatch Interval di. If set to 1, Resource r is being manually dispatched during Dispatch Interval di. If set to 0, Resource r is not being manually dispatched during Dispatch Interval di.
- **ManualDispatchMW(r,di):** A floating point array. The Manual Dispatch MW amount for Resource r during Dispatch Interval di. This values is applicable only during manual dispatch conditions. Expressed in MW.
- **MaxChargeRateOverride(r):** A floating point array. The Maximum Energy Charge Rate Override for Resource r. Expressed in MWhr/min.
- **MaxChargeRateOverrideFlag(r):** A Boolean array. The Maximum Energy Charge Rate Override Flag for Resource r. If set to 1, the maximum energy charge rate for Resource r is overridden with the Maximum Energy Charge Rate Override. If set to 0, the maximum energy charge rate for Resource r is not overridden with the Maximum Energy Charge Rate Override.
- **MaxDischargeRateOverride(r):** A floating point array. The Maximum Energy Discharge Rate Override for Resource r. Expressed in MWhr/min.
- **MaxDischargeRateOverrideFlag(r):** A Boolean array. The Maximum Energy Discharge Rate Override Flag for Resource r. If set to 1, the maximum energy discharge rate for Resource r is overridden with the Maximum Energy Discharge Rate Override. If set to 0, the maximum energy discharge rate for Resource r is not overridden with the Maximum Energy discharge Rate Override.
- **MaxLimitOverride(r):** A floating point array. The Maximum Limit Override for Resource r. Expressed in MW.
- **MaxLimitOverrideFlag(r):** A Boolean array. The Maximum Limit Override Flag for Resource r. If set to 1, the emergency maximum and economic maximum limits for Resource r are overridden with the Maximum Limit Override. If set to 0, the emergency maximum and economic maximum limits for Resource r are not overridden with the Maximum Limit Override.
- **MinLimitOverride(r):** A floating point array. The Minimum Limit Override for Resource r. Expressed in MW.
- **MinLimitOverrideFlag(r):** A Boolean array. The Minimum Limit Override Flag for Resource r. If set to 1, the emergency minimum and economic minimum limits for Resource r are overridden with the Minimum Limit Override. If set to 0, the emergency minimum and economic minimum limits for Resource r are not overridden with the Minimum Limit Override.
- **MWContResReq(di):** A floating point array. The Market-Wide Contingency Reserve requirement for Dispatch Interval di. Expressed in MW.
- **MWOpResDemandCurve(di,MW):** A floating point array. The market-wide Operating Reserve demand curve for Dispatch Interval di. Expressed in $ per MW.
- **MWRegReq(di):** A floating point array. The Market-Wide Regulating Reserve requirement for Dispatch Interval di. Expressed in MW.
- **MWRegResDemandCurve(di,MW):** A floating point array. The market-wide Regulating Reserve demand curve for Dispatch Interval di. Expressed in $ per MW.
- **NSI(di):** A floating point array. The Net Scheduled Interchange for Dispatch Interval di. Expressed in MW.

- **RefBusDF(i,di):** A floating point array. The percent of the load distributed reference Bus allocated to bus i, or the normalized reference Bus distribution factor for Bus i.
- **RegMaxLimitOverride(r):** A floating point array. The Regulation Maximum Limit Override for Resource r. Expressed in MW.
- **RegMaxLimitOverrideFlag(r):** A Boolean array. The Regulation Maximum Limit Override Flag for Resource r. If set to 1, the regulation maximum limit for Resource r is overridden with the Regulation Maximum Limit Override. If set to 0, the regulation maximum limit for Resource r is not overridden with the Regulation Maximum Limit Override.
- **RegMinLimitOverride(r):** A floating point array. The Regulation Minimum Limit Override for Resource r. Expressed in MW.
- **RegMaxLimitOverrideFlag(r):** A Boolean array. The Regulation Minimum Limit Override Flag for Resource r. If set to 1, the regulation minimum limit for Resource r is overridden with the Regulation Minimum Limit Override. If set to 0, the regulation minimum limit for Resource r is not overridden with the Regulation Minimum Limit Override.
- **RegResDemandPrice:** A floating point variable. The regulating reserve demand curve price updated monthly by MISO in accordance with the tariff.
- **RF(r,di):** A Boolean array. The Regulation Flag for Resource r during Dispatch Interval di. If set to 1, Resource r is requested to regulate for Dispatch Interval di. If set to 0, Resource r is not requested to regulate for Dispatch Interval di.
- **SEActualLosses(di)**: A floating point array. The most recent state estimated actual system losses for the MISO market footprint just prior to the execution of the RT-SCED algorithm for Dispatch Interval di. Expressed in MW.
- **SESystemDemand(di)**: A floating point array. The most recent state estimated system demand for the MISO market footprint just prior to the execution of the RT-SCED algorithm for Dispatch Interval di. Expressed in MW.
- **SingleDirRampDownRateOverride(r):** A floating point array. The Single-Directional Ramp-Down Rate Override for Resource r. Expressed in MW per Minute.
- **SingleDirRampUpRateOverride(r):** A floating point array. The Single-Directional Ramp-Up Rate Override for Resource r. Expressed in MW per Minute.
- **SingleDirRampDownRateOverrideFlag(r):** A Boolean array. The Single-Directional Ramp-Down Rate Override Flag for Resource r. If set to 1, the single-directional ramp-down rate for Resource r is overridden with the Single-Directional Ramp-Down Rate Override. If set to 0, the single-directional ramp-down rate for Resource r is not overridden with the Single-Directional Ramp-Down Rate Override.
- **SingleDirRampUpRateOverrideFlag(r):** A Boolean array. The Single-Directional Ramp-Up Rate Override Flag for Resource r. If set to 1, the single-directional ramp-up rate for Resource r is overridden with the Single-Directional Ramp-Up Rate Override. If set to 0, the single-directional ramp-up rate for Resource r is not overridden with the Single-Directional Ramp-Up Rate Override.

- **StartStopModeFlag(r,di):** A Boolean array. The Start / Stop Mode Flag for Resource r during Dispatch Interval di. If set to 1, Resource r is in startup or shut-down during Dispatch Interval di. If set to 0, Resource r is not in startup or shut-down during Dispatch Interval di.
- **StartStopProfileMW(r,di):** A floating point array. The Start / Stop Profile MW value for Resource r during Dispatch Interval di. This value is applicable only during startup and shut-down conditions. The profile is based on offer data for a resource that utilizes start/stop logic, or ramped toward MinLimit(r,di) based on CurrentSEMW(r,di). Expressed in MW.
- **StartTime(crd):** An integer array. The start time of Contingency Reserve deployment event crd. Expressed in Minutes.
- **STLF(lba,di):** A floating point array. The short-term load forecast for Local Balancing Authority lba for the end of Dispatch Interval di. Expressed in MW.
- **STLFCorrectionFactor(lba,di):** A floating point array. The short-term load forecast correction factor for Local Balancing Authority lba for the end of Dispatch Interval di. Expressed in MW.
- **SystemLoadOffset(di):** A floating point array. The system load offset for the end of Dispatch Interval di. Expressed in MW.
- **MWSTRReq(di):** A floating point array. The Market-Wide Short Term Reserve requirement for hour h. Expressed in MW.
- **STRDCPriceStep(st,di)** : Price of system (market-wide) STR demand curve for price step st at hour h
- **STRDCMaxStep(st,di)** : MW width of the demand curve step which is the maximum market-wide STR cleared at the associated demand curve step price at hour h.

9.3 Market Participant Input Data

- **AvailFlag(r,di):** A Boolean array. The availability flag of Resource r during Dispatch Interval di. Set to 1 if Resource r is available during Dispatch Interval di. Set to 0 if Resource r is not available during Dispatch Interval di. Applies only to External Asynchronous Resources.
- **BandBiDirRampRate(r,di):** A floating point array. The dispatch band bi-directional ramp rate for Resource r during Dispatch Interval di. Expressed in MW per Minute.
- **BandMaxLimit(r,di):** A floating point array. The dispatch band maximum limit for Resource r during Dispatch Interval di. Expressed in MW.
- **BandMinLimit(r,di):** A floating point array. The dispatch band minimum limit for Resource r during Dispatch Interval di. Expressed in MW.
- **BandRegMaxLimit(r,di):** A floating point array. The dispatch band regulation maximum limit for Resource r during Dispatch Interval di. Expressed in MW.
- **BandRegMinLimit(r,di):** A floating point array. The dispatch band regulation minimum limit for Resource r during Dispatch Interval di. Expressed in MW.
- **BandSingleDirRampDownRate(r,di):** A floating point array. The dispatch band single-directional ramp-down rate for Resource r during Dispatch Interval di. Expressed in MW per Minute.

- **BandSingleDirRampUpRate(r,di):** A floating point array. The dispatch band single-directional ramp-up rate for Resource r during Dispatch Interval di. Expressed in MW per Minute.
- **BiDirRampRateCurve(r,MW):** A floating point array. The bi-directional ramp rate curve for Resource r. Expressed in MW per Minute.
- **DefaultBiDirRampRate(r):** A floating point array. The default bi-directional ramp rate for Resource r. Expressed in MW per Minute
- **DefaultSingleDirRampDownRate(r):** A floating point array. The default single-directional ramp-down rate for Resource r. Expressed in MW per Minute.
- **DefaultSingleDirRampUpRate(r,di):** A floating point array. The default single-directional ramp-up rate for Resource r. Expressed in MW per Minute.
- **DRRMaxDailyCR(d):** The maximum amount of Contingency Reserve that a DRR can produce in a day, d. Expressed in MW.
- **DRRMaxDailyReg(d):** The maximum amount of Regulating Reserve that a DRR can produce in a day, d. Expressed in MW.
- **EnergyOfferCurve(r,di,MW):** A floating point array. The Energy offer curve, piece-wise linear or stepped, submitted for Resource r for Dispatch Interval di. Expressed in $ per MWh.
- **EnergyStorageLossRate(r,di):** A floating point array. The energy storage loss rate for resource r. Expressed in MWh/min.
- **Dispatch intervalBiDirRampRate(r,di):** A floating point array. The Dispatch Interval bi-directional ramp rate for Resource r during Dispatch Interval di. Expressed in MW per Minute.
- **Dispatch intervalSingleDirRampDownRate(r,di):** A floating point array. The Dispatch Interval single-directional ramp-down rate for Resource r during Dispatch Interval di. Expressed in MW per Minute.
- **Dispatch intervalSingleDirRampUpRate(r,di):** A floating point array. The Dispatch Interval single-directional ramp-up rate for Resource r during Dispatch Interval di. Expressed in MW per Minute.
- **MaxEnergyStorageLevel(r,di):** A floating point array. The maximum energy storage level for resource r, in Dispatch Interval di. Expressed in MWh.
- **MaxOffLineResponse(r,di):** A floating point array. The maximum off-line response limit of Resource r during Dispatch Interval di. Expressed in MW.
- **OffLineSupResOfferPrice(r,di):** A floating point array. The off-line Supplemental Reserve offer price for Resource r for Dispatch Interval di. Expressed in $ per MW per Dispatch interval.
- **RegCapOfferPrice(r,di):** A floating point array. The Regulating Reserve capacity offer price for Resource r for Dispatch Interval di. Expressed in $ per MWh.
- **RegMileOfferPrice(r,h):** A floating point array. The Regulating Reserve mileage offer price for Resource r for Dispatch Interval di. Expressed in $ per MW.
- **RegResOfferPrice(r,di):** A floating point array. The Regulating Reserve offer price for Resource r for Dispatch Interval di. Expressed in $ per MWh.
- **SingleDirRampDownRateCurve(r,MW):** A floating point array. The single-directional ramp-down rate curve for Resource r. Expressed in MW per Minute.

- **SingleDirRampUpRateCurve(r,MW):** A floating point array. The single-directional ramp-up rate curve for Resource r. Expressed in MW per Minute.
- **SSEnergyMW(r,di):** A floating point array. The Energy self-schedule for Resource r during Dispatch Interval di. Expressed in MW.
- **SSRegResMW(r,di):** A floating point array. The Regulating Reserve self-schedule for Resource r during Dispatch Interval di. Expressed in MW.
- **SSSpinResMW(r,di):** A floating point array. The Spinning Reserve self-schedule for Resource r during Dispatch Interval di. Expressed in MW.
- **SSSupResMW(r,di):** A floating point array. The Supplemental Reserve self-schedule for Resource r during Dispatch Interval di. Expressed in MW. Applies only to Demand Response Resources - Type I and External Asynchronous Resources.
- **SSOffLineSupResMW(r,di):** A floating point array. The off-line Supplemental Reserve self-schedule for Resource r during Dispatch Interval di. Expressed in MW. Applies only to Generation Resource and Demand Response Resources - Type II.
- **SSOnLineSupResMW(r,h):** A floating point array. The on-line Supplemental Reserve self-schedule for Resource r during Dispatch Interval di. Expressed in MW. Applies only to Generation Resource and Demand Response Resources - Type II.
- **TargetDemRedLevel(r,h):** A floating point array. The targeted demand reduction level for Resource r during Dispatch Interval di. Expressed in MW. Applies only to Demand Resource Resources - Type I.
- **OfflineSTRMaxMinRunTimeHours(r,di):** A GEN or DRR2 resource MinimumRunTime must be less than this many hours in order to be offline STR qualified.
- **OfflineSTRDRR1MaxMinInterruptTimeHours(r,di):** A DRR1 resource MinimumInterruptTime must be less than this many hours in order to be offline STR qualified.
- **MaxOfflineSTR(r,di):** Maximum offline STR response of resource *r* at hour h within the STR response time
- **OfflineSTROfferPrice(r,di)**: Offline STR offer Price for resource r at hour di

9.4 Pre-SCED Processing Variables

- **ContResOfferPrice(r,di):** A floating point array. The Contingency Reserve offer price used in the SCED algorithm to dispatch Contingency Reserve on Resource r during Dispatch Interval di. Expressed in $ per MW.
- **ClearedContResCap(r,di):** A floating point array. The Contingency Reserve Clearing Cap for Resource r during Dispatch Interval di. Expressed in MW.
- **ControlStatus(r,di):** An integer array. The Control Status for Resource d during Dispatch Interval di. If set to 0, Resource r is off-line during Dispatch Interval di. If set to 1, Resource r is capable of following load during Dispatch Interval di. If set to 2, Resource r is capable of regulating and following load during Dispatch Interval di. If set to 3, Resource r is on-line, but not capable of following load or regulating during Dispatch Interval di.
- **DeployedContRes(r,di):** A floating point array. Deployed Contingency Reserve for Resource r during Dispatch Interval di. Expressed in MW.

- **EARHoldFlag(r,di):** A binary array. External Asynchronous Resource Hold flag. This flag is set when the Resource telemetry does not have good quality.
- **EARHoldMW(r,di):** A floating point array. External Asynchronous Resource Hold Energy Level. The manually-entered energy level for the Resource when the EAR Hold flag is set to 1. Expressed in MW.
- **EmerMaxRelFlag(r,di):** A Boolean array. The Emergency Maximum Release Flag for Resource r during Dispatch Interval di. If set to 1, the emergency maximum operating range is released for Resource r during Dispatch Interval di. If set to 0, the emergency maximum operating range is not released for Resource r during Dispatch Interval di.
- **EmerMinRelFlag(r,di):** A Boolean array. The Emergency Minimum Release Flag for Resource r during Dispatch Interval di. If set to 1, the emergency minimum operating range is released for Resource r during Dispatch Interval di. If set to 0, the emergency minimum operating range is not released for Resource r during Dispatch Interval di.
- **EnergyStepPrice(r,di,st):** A floating point array. The Energy offer curve step price for Resource r and offer curve step st during Dispatch Interval di. Expressed in $ per MWh.
- **EnergyStepWidth(r,di,st):** A floating point array. The Energy offer curve step width for Resource r and offer curve step st during Dispatch Interval di. Expressed in MW.
- **ExpectedContResDeploy(r,di):** A floating point array. The projected Contingency Reserve deployment on Resource r at the beginning of Dispatch Interval di. Expressed in MW.
- **ExternalInjectionMW(i,di):** A floating point array. The net injected power into the system modeled at external node i during Dispatch Interval di. Expressed in MW.
- **FixedDispFlag(r,di):** A binary array. The Fixed Dispatch Status for Resource r during Dispatch Interval di. This flag represents a conflict between the offers of a resource and the initial conditions of the resource in the Dispatch Interval. If set to 1, the Resource is prohibited from being dispatched for reserves. If outside of limits, the energy dispatch will be ramped toward the applicable limit and fixed at the resulting output.
- **FixedDispMW(r,di):** A floating point array. The Fixed Dispatch Energy Level for Resource r during Dispatch Interval di. This value represents the energy level for a resource that has FixedDispFlag(r,di)=1.
- **GenORReqFactor(di):** A floating point array. The percentage of Operating Reserve that must be supplied by Generation Resources, Demand Response Resources - Type II and External Asynchronous Resources for Dispatch Interval di based on reliability standards.
- **InitialEnergyDispatch(r,di):** A floating point array. The projected Energy dispatch of Resource r at the end of the last Dispatch Interval based on the Energy Dispatch Target for the previous Dispatch Interval adjusted for Contingency Reserve deployment at the end of the previous Dispatch Interval. Expressed in MW.
- **InitialEnergyOutput(r,di):** A floating point array. The projected initial Energy output of Resource r at the beginning of Dispatch Interval di. Expressed in MW.
- **InitialEnergyOutputCap(r,di):** A floating point array. The maximum projected initial Energy output of Resource r at the beginning of Dispatch Interval di based on State Estimator data and submitted ramp rates. Expressed in MW.

- **InitialEnergyOutputFloor(r,di):** A floating point array. The minimum projected initial Energy output of Resource r at the beginning of Dispatch Interval di based on State Estimator data and submitted ramp rates. Expressed in MW.
- **InitialStorageCeiling(r,di):** A floating point array. The maximum possible energy storage level on resource r, at the beginning of Dispatch Interval di.
- **InitialStorageFloor(r,di):** A floating point array. The minimum possible energy storage level on resource r, at the beginning of Dispatch Interval di.
- **LossOffsetFactor(di):** A floating point array. The loss offset factor for Dispatch Interval di. Expressed in per unit.
- **MaxLimit(r,di):** A floating point array. The maximum limit for Resource r during Dispatch Interval di.
- **MinLimit(r,di):** A floating point array. The minimum limit for Resource r during Dispatch Interval di.
- **MWOpResStepPrice(st,di):** A floating point array. The market-wide Operating Reserve demand curve step price for step st and Dispatch Interval di. Expressed in $ per MW.
- **MWOpResStepWidth(st,di):** A floating point array. The market-wide Operating Reserve demand curve step width for step st and Dispatch Interval di. Expressed in MW.
- **MWORReq(di):** A floating point array. The Market-Wide Operating Reserve requirement for Dispatch Interval di. Expressed in MW.
- **MWRegSpinReq(di):** A floating point array. The Market-Wide Regulating plus Spinning Reserve requirement for Dispatch Interval di. Expressed in MW.
- **MWRCUpReq(di):** A floating point array. The Market-Wide Up Ramp Capability requirement for Dispatch Interval di. Expressed in MW.
- **MWRCDownReq(di):** A floating point array. The Market-Wide Down Ramp Capability requirement for Dispatch Interval di. Expressed in MW.
- **MWSTRReq(di):** A floating point array. The Market-Wide Short Term Reserve requirement for Dispatch Interval di. Expressed in MW.
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- **OffLineSupAvailability(r,di):** A Boolean array. The off-line Supplemental Reserve availability of Resource r during Dispatch Interval di. Set to 1 if Resource r is available to provide off-line Supplemental Reserve during Dispatch Interval di. Set to 0 if Resource r is not available to provide off-line Supplemental Reserve during Dispatch Interval di.
- **OnLineFlag(r,di):** A Boolean array. The on-line flag for Resource r during Dispatch Interval di. Set to 1 if Resource r is on-line during Dispatch Interval di. Set to 0 if Resource r is off-line during Dispatch Interval di.
- **OverallEcoMaxLimit(r,di):** A floating point array. The overall economic maximum limit for Resource r during Dispatch Interval di. Expressed in MW.
- **OverallEcoMinLimit(r,di):** A floating point array. The overall economic minimum limit for Resource r during Dispatch Interval di. Expressed in MW.
- **OverallEmerMaxLimit(r,di):** A floating point array. The overall emergency maximum limit for Resource r during Dispatch Interval di. Expressed in MW.

- **OverallEmerMinLimit(r,di):** A floating point array. The overall emergency minimum limit for Resource r during Dispatch Interval di. Expressed in MW.
- **OverallMaxChargeRate(r,di):** A floating point array. The overall maximum energy charge rate for Resource r, during Dispatch Interval di. Expressed in MW.
- **OverallMaxDischargeRate(r,di):** A floating point array. The overall maximum energy discharge rate for Resource r, during Dispatch Interval di. Expressed in MW.
- **OverallRegMaxLimit(r,di):** A floating point array. The overall regulation maximum limit for Resource r during Dispatch Interval di. Expressed in MW.
- **OverallRegMinLimit(r,di):** A floating point array. The overall regulation minimum limit for Resource r during Dispatch Interval di. Expressed in MW.
- **RampDownAdjFact(r,di):** A floating point array. The Ramp-Down Adjustment Factor for Resource r during Dispatch Interval di. Expressed in MW per Minute.
- **RampDownRate(r,di):** A floating point array. The Ramp-Down Rate used for Resource r during Dispatch Interval di. Expressed in MW per Minute.
- **RampRateCurveFlag(r,di):** A Boolean array. The Ramp Rate Curve Flag for Resource r during Dispatch Interval di. If set to 1, ramp rates curves will be utilized for Resource r during Dispatch Interval di unless overrides are in place or dispatch bands are enabled for the Resource. If set to 0, ramp rate curves will not be utilized for Resource r during Dispatch Interval di.
- **RampUpAdjFact(r,di):** A floating point array. The Ramp-Up Adjustment Factor for Resource r during Dispatch Interval di. Expressed in MW per Minute.
- **RampUpRate(r,di):** A floating point array. The Ramp-Up Rate used for Resource r during Dispatch Interval di. Expressed in MW per Minute.
- **RegAvailability(r,di):** A Boolean array. The Regulating Reserve availability of Resource r during Dispatch Interval di. Set to 1 if Resource r is available to provide Regulating Reserve during Dispatch Interval di. Set to 0 if Resource r is not available to provide Regulating Reserve during Dispatch Interval di.
- **RCAvailability(r,di):** A Boolean array. The Ramp Capability availability of Resource r during Dispatch Interval di. Set to 1 if Resource r is available to provide Ramp Capability during Dispatch Interval di. Set to 0 if Resource r is not available to provide Ramp Capability during Dispatch Interval di.
- **RegModeFlag(r,di):** A Boolean array. The Regulation Mode Flag for Resource r during Dispatch Interval di. If set to 1, Resource r is scheduled to regulate for Dispatch Interval di. If set to 0, Resource r is not scheduled to regulate for Dispatch Interval di.
- **SEMarginalLosses(di):** A floating point array. The marginal State Estimator losses for the most recent State Estimator solution available when RT-SCED is executed for Dispatch Interval di. Expressed in MW.
- **SpinAvailability(r,di):** A Boolean array. The Spinning Reserve availability of Resource r during Dispatch Interval di. Set to 1 if Resource r is available to provide Spinning Reserve during Dispatch Interval di. Set to 0 if Resource r is not available to provide Spinning Reserve during Dispatch Interval di.

- **SSEnergyStatus(r,di):** A Boolean array. The Energy self-schedule status of Resource r during Dispatch Interval di. Set to 1 if Energy is being self-scheduled on Resource r during Dispatch Interval di. Set to 0 if Energy is not being self-scheduled on Resource r during Dispatch Interval di.
- **SSOffLineSupResStatus(r,di):** A Boolean array. The off-line Supplemental Reserve self-schedule status of Resource r during Dispatch Interval di. Set to 1 if off-line Supplemental Reserve is being self-scheduled on Resource r during Dispatch Interval di. Set to 0 if off-line Supplemental Reserve is not being self-scheduled on Resource r during Dispatch Interval di.
- **SSOnLineSupResStatus(r,di):** A Boolean array. The on-line Supplemental Reserve self-schedule status of Resource r during Dispatch Interval di. Set to 1 if on-line Supplemental Reserve is being self-scheduled on Resource r during Dispatch Interval di. Set to 0 if on-line Supplemental Reserve is not being self-scheduled on Resource r during Dispatch Interval di.
- **SSRegResStatus(r,di):** A Boolean array. The Regulating Reserve self-schedule status of Resource r during Dispatch Interval di. Set to 1 if Regulating Reserve is being self-scheduled on Resource r during Dispatch Interval di. Set to 0 if Regulating Reserve is not being self-scheduled on Resource r during Dispatch Interval di.
- **SSSpinResStatus(r,di):** A Boolean array. The Spinning Reserve self-schedule status of Resource r during Dispatch Interval di. Set to 1 if Spinning Reserve is being self-scheduled on Resource r during Dispatch Interval di. Set to 0 if Spinning Reserve is not being self-scheduled on Resource r during Dispatch Interval di.
- **SSSupResStatus(r,di):** A Boolean array. The Supplemental Reserve self-schedule status of Resource r during Dispatch Interval di. Set to 1 if Supplemental Reserve is being self-scheduled on Resource r during Dispatch Interval di. Set to 0 if Supplemental Reserve is not being self-scheduled on Resource r during Dispatch Interval di.
- **SupAvailability(r,di):** A Boolean array. The Supplemental Reserve availability of Resource r during Dispatch Interval di. Set to 1 if Resource r is available to provide Supplemental Reserve during Dispatch Interval di. Set to 0 if Resource r is not available to provide Supplemental Reserve during Dispatch Interval di.
- **SystemDemandMW(di):** A floating point array. The projected system demand at the end of Dispatch Interval di. Expressed in MW.
- **SystemLossRate(di):** A floating point array. The system loss rate based on the most recent State Estimator solution just prior to execution of RT-SCED for Dispatch Interval di. Expressed in per unit.
- **OnlineSTRAvailability(r,ci):** A Boolean array. The Short Term Reserve availability of resource r during interval ci. set to 1 if resource r is available to provide Short Term Reserve during hour h. Set to 0 if resource r is not available to provide Short Term Reserve during interval ci.
- **OfflineSTRAvailability(r,ci):** A Boolean array. The Short Term Reserve availability of resource r during interval ci. set to 1 if resource r is available to provide Short Term Reserve during interval ci. Set to 0 if resource r is not available to provide Short Term Reserve during interval ci.

9.5 SCED Parameters

- **ClearedContResCapPenPrice:** The cleared Contingency Reserve cap constraint penalty price. Expressed in $ per MW.
- **ContResDeployTime:** The maximum amount of time in which Contingency Reserve must be deployed after notification. Expressed in Minutes.
- **ContResRampFact:** The amount of cleared Contingency Reserve a Resource must be able to deploy within the Contingency Reserve Deployment Time ignoring the ramping requirements of Energy and Regulating Reserve.
- **DeployedContResPenPrice:** The deployed Contingency Reserve constraint penalty price. Expressed in $ per MW.
- **EnergyShortagePenPrice:** The global power balance constraint deficit penalty price. Expressed in $ per MW.
- **EnergySurplusPenPrice:** The global power balance constraint surplus penalty price. Expressed in $ per MW.
- **GenOpResShortagePenPrice:** The generation-based Operating Reserve constraint penalty price. Expressed in $ per MW.
- **GenRegReqFactor:** The percentage of Regulating Reserve that must be supplied by Generation Resources, Demand Response Resources - Type II and External Asynchronous Resources based on applicable reliability standards.
- **GenRegShortagePenPrice:** The generation-based Regulating Reserve constraint penalty price. Expressed in $ per MW.
- **GenRegSpinReqFactor:** The percentage of Regulating plus Spinning Reserve that must be supplied by Generation Resources, Demand Response Resources - Type II and External Asynchronous Resources based on applicable reliability standards.
- **GenRegSpinShortagePenPrice:** The generation-based regulating plus Spinning Reserve constraint penalty price. Expressed in $ per MW.
- **LimitPenPrice:** The limit constraint penalty price. Expressed in $ per MW.
- **MaxConResFactor:** The maximum percentage of the market-wide Contingency Reserve requirement that can be supplied by a single Resource.
- **MaxRegResFactor:** The maximum percentage of the market-wide Regulating Reserve requirement that can be supplied by a single Resource.
- **MaxRCUpFactor:** The maximum percentage of the market-wide Up Ramp Capability requirement that can be supplied by a single Resource.
- **MaxRegDownFactor:** The maximum percentage of the market-wide Down Ramp Capability requirement that can be supplied by a single Resource.
- **MaxResourceContResPenPrice:** The maximum Resource Contingency Reserve constraint penalty price. Expressed in $ per MW.
- **MaxResourceRegPenPrice:** The maximum Resource Regulating Reserve constraint penalty price. Expressed in $ per MW.
- **MaxResourceRCUpPrice:** The maximum Resource Up Ramp Capability constraint penalty price. Expressed in $ per MW.

- **MaxResourceRCDownPrice:** The maximum Resource Down Ramp Capability constraint penalty price. Expressed in $ per MW.
- **PmaxEvent(z,di):** The size of the largest resource in zone z during Dispatch Interval di.
- **PMaxThreshold**: A tuning parameter. A threshold on the size of the largest resource in a zone that triggers the modeling of a Reserve Procurement Contingency Reserve constraint for transmission constraints.
- **RampPenPrice:** The ramp constraint penalty price. Expressed in $ per MW.
- **RegImpact:** A tuning parameter that adjusts the impact from regulating reserves on Reserve Procurement Contingency Reserve Event constraints.
- **RegRampFact:** The amount of cleared Regulating Reserve a Resource must be able to deploy within the Regulation Response Time ignoring the ramping requirements of Energy and Contingency Reserve.
- **RegResponseTime:** The maximum amount of time allowed for a resource to deploy cleared Regulating Reserve in either direction. Expressed in Minutes.
- **RCUpRampFactor:** The amount of cleared up ramp capability a Resource must be able to deploy within the Ramp Capability Response Time ignoring the ramping requirements of Energy, Regulation and Contingency Reserve.
- **RCUpResponseTime:** The maximum amount of time allowed for a resource to deploy cleared Up Ramp Capability. Expressed in Minutes.
- **RCDownRampFactor:** The amount of cleared down ramp capability a Resource must be able to deploy within the Down Ramp Capability Response Time ignoring the ramping requirements of Energy, Regulation and Contingency Reserve.
- **RCDownResponseTime:** The maximum amount of time allowed for a resource to deploy cleared Down Ramp Capability. Expressed in Minutes.
- **RegResDispatchComp1(r,di):** A floating point array. Regulating Reserve Dispatch - Component 1. The first of the two components of Regulating Reserve dispatched on resource r during Dispatch Interval di. Expressed in MW.
- **RegResDispatchComp2(r,di):** A floating point array. Regulating Reserve Dispatch - Component 2. The second of the two components of Regulating Reserve dispatched on resource r during Dispatch Interval di. Expressed in MW.
- **RegSpinShortagePenPrice:** The regulating plus Spinning Reserve constraint penalty price. Expressed in $ per MW.
- **SpinImpact:** A tuning parameter that adjusts the impact from spinning reserves on Reserve Procurement Contingency Reserve Event constraints.
- **SSContResPenPrice:** The self-scheduled Contingency Reserve constraint penalty price. Expressed in $ per MW.
- **SSEnergyPenPrice:** The self-scheduled Energy constraint penalty price. Expressed in $ per MW.
- **SSRegPenPrice:** The self-scheduled Regulating Reserve constraint penalty price. Expressed in $ per MW.

- **SubRegLimitPenPrice:** The Sub-Regional Power Balance constraint penalty price. Expressed in $ per MW.
- **SuppImpact:** A tuning parameter that adjusts the impact from supplemental reserves on Reserve Procurement Contingency Reserve Event constraints.
- **TransLimitCREventPenPrice:** The reserve procurement transmission constraint Contingency Reserve event penalty price. Expressed in $ per MW.
- **TransLimitRegDownPenPrice:** The reserve procurement transmission constraint regulation down penalty price. Expressed in $ per MW.
- **TransLimitRegUpPenPrice:** The reserve procurement transmission constraint regulation up penalty price. Expressed in $ per MW.
- **TransLimitRCDownPenPrice:** The ramp procurement down ramp capability post deployment transmission constraint penalty price. Expressed in $ per MW.
- **TransLimitRCUpPenPrice:** The ramp procurement up ramp capability post deployment transmission constraint penalty price. Expressed in $ per MW.
- **TransLimitPenPrice:** The transmission constraint penalty price. Expressed in $ per MW.
- **ZonalRegDepSens(k,z,di):** The zonal regulation deployment sensitivity for transmission constraint k and reserve zone z during Dispatch Interval di is the average sensitivity to the constraint for all resources qualified to provide Regulating Reserves in the zone, weighted by the ramp rate of each resource. ZonalRegDepSens(k,z,di) is described further in Section 5.2.6.18.
- **ZonalSpinDepSens(k,z,di):** The zonal spin deployment sensitivity for transmission constraint k and reserve zone z during Dispatch Interval di is a ramp-rate weighted average of the sensitivities of the regulation or spin qualified resources in the zone.
- **ZonalSuppDepSens(k,z,di):** The zonal supplemental deployment sensitivity for transmission constraint k and reserve zone z during Dispatch Interval di is a weighted average of the sensitivities of resources in the zone that are qualified to provied off-line Supplemental Reserves, weighted by the ramp rate and the offline response capabilities of each resource.
- **ZonalTripSens(k,z,di):** The zonal trip sensitivity for transmission constraint k and reserve zone z during Dispatch Interval di is a capacity-weighted average of the sensitivities of the resources available for commitment in the zone.
- **ZonalRCUpDepSens(k,z,di):** The zonal up ramp capability deployment sensitivity for transmission constraint k and reserve zone z during Dispatch Interval di is the average sensitivity to the constraint for all resources qualified to provide Up Ramp Capability in the zone, weighted by the ramp rate of each resource. ZonalRCUPDepSens(k,z,di) is described further in Section 4.2.6.19
- **ZonalRCDownDepSens(k,z,di):** The zonal Down Ramp Capability deployment sensitivity for transmission constraint k and Reserve Zone z during Dispatch Interval di is the average sensitivity to the constraint for all resources qualified to provide Down Ramp Capability in the zone, weighted by the ramp rate of each resource. ZonalRCUPDepSens(k,z,di) is described further in Section 4.2.6.20

- **ZonalSTRDepSens(k,z,di):** The zonal Short Term Reserve deployment sensitivity for transmission constraint k and Reserve Zone z during dispatch interval di is a weighted average of the sensitivities of resources in the zone that are qualified to provide off-line Supplemental Reserves, weighted by the ramp rate and the offline response capabilities of each resource.
- **ZonalTripSens(k,z,di):** The zonal trip sensitivity for transmission constraint k and Reserve Zone z during interval di is a capacity-weighted average of the sensitivities of the resources available for commitment in the zone.
- **MaxResourceSTRPenPrice**: Maximum single resource STR clearing constraint violation penalty price
- **STRResponseTime** : STR deployment time. This is a configurable option.
- **STRRampFactor** : STR ramp factor, a tuning parameter that determines the percentage of cleared STR that should be deployable within the STR response period.
- **TransLimitSTRPenPrice** : STR post-deployment transmission constraint violation penalty price.
- **ZNeedSTRPenPrice** : Zonal STR deployment power balance constraint violation penalty price.

9.6 SCED Primal Variables and Output Data

- **ClearedContRes(r,di):** A floating point array. The Contingency Reserve cleared by SCED on Resource r during Dispatch Interval di. Expressed in MW.
- **ClearedContResCapDeficit(r,di):** A floating point array. The Contingency Reserve cap constraint violation variable for Resource r during Dispatch Interval di. Expressed in MW.
- **ClearedMWOpRes(di):** A floating point array. The market-wide Operating Reserve cleared by SCED for Dispatch Interval di. Expressed in MW.
- **ClearedMWRegRes(di):** A floating point array. The market-wide Regulating Reserve cleared by SCED for Dispatch Interval di. Expressed in MW.
- **ClearedRegRes1(r,di):** A floating point array. The Regulating Reserve cleared by SCED on Resource r during Dispatch Interval di, considering the resource's total Regulating Reserve offer cost. Expressed in MW.
- **ClearedRegRes2(r,di):** A floating point array. The Regulating Reserve cleared by SCED on Resource r during Dispatch Interval di, considering the resource's regulation capacity offer cost. Expressed in MW.
- **ClearedRCUp(r,di):** A floating point array. The Up Ramp Capability cleared by SCED on Resource r during Dispatch Interval di, Expressed in MW.
- **ClearedRCDown(r,di):** A floating point array. The Down Ramp Capability cleared by SCED on Resource r during Dispatch Interval di, Expressed in MW.
- **ClearedRZOpRes(z,di):** A floating point array. The Reserve Zone Operating Reserve cleared by SCED for reserve zone z during Dispatch Interval di. Expressed in MW.
- **ClearedRZRegRes(z,di):** A floating point array. The Reserve Zone Regulating Reserve cleared by SCED for reserve zone z during Dispatch Interval di. Expressed in MW.

- **ContResRampViolation(r,di):** A floating point array. The Contingency Reserve ramp constraint violation variable for Resource r during Dispatch Interval di. Expressed in MW.
- **ContResTieBreak1(r1,r2,di):** A floating point array. The Contingency Reserve tie-breaking variable 1 between Resource r1 and Resource r2 for Dispatch Interval di.
- **ContResTieBreak2(r1,r2,h):** A floating point array. The Contingency Reserve tie-breaking variable 2 between Resource r1 and Resource r2 for Dispatch Interval di.
- **DeployedContResDeficit(r,di):** A floating point array. The deployed Contingency Reserve deficit constraint violation variable for Resource r during Dispatch Interval di. Expressed in MW.
- **ClearedMWRCUp(di):** A floating point array. The market-wide Up Ramp Capability cleared by SCED for Dispatch Interval di. Expressed in MW.
- **ClearedMWRCDown(di):** A floating point array. The market-wide Down Ramp Capability cleared by SCED for Dispatch Interval di. Expressed in MW.
- **EnergyDispatchTarget(r,di):** A floating point array. The Energy Dispatch Target for Resource r at the end of Dispatch Interval di. Expressed in MW.
- **EnergyScheduleMW (r,di):** The deployed MW assigned to the Emergency Demand Response, Load Modifying Resource, Emergency Energy purchases, external Planning Resources in the Dispatch Interval.
- **EnergyStepClearing(r,di,st):** A floating point array. The Energy cleared by SCED on offer curve step st for Resource r during Dispatch Interval di. Expressed in MW.
- **EnergyTieBreak1(r1,r2,di):** A floating point array. The Energy tie-breaking variable 1 between Resource 1 and Resource 2 for Dispatch Interval di.
- **EnergyTieBreak2(r1,r2,h):** A floating point array. The Energy tie-breaking variable 2 between Resource r1 and Resource or r2 for Dispatch Interval di.
- **Flow_SystemEnergySCED(k,di):** A floating point array. The transmission flow on transmission constraint k during Dispatch Interval di from entire set of system energy clearings across all market activities, both injections and withdrawals. Flow_**SystemEnergySCED(k,di)** is not a variable in itself, but is the sum of several variables, and is defined for ease of explanation of Reserve Procurement constraints. The definition of Flow_**SystemEnergySCED(k,di)** is given in Section5.2.6.16.
- **GeneralRampDownViolation(r,di):** A floating point array. The general ramp-down constraint violation variable for Resource r during Dispatch Interval di. Expressed in MW.
- **GeneralRampUpViolation(r,di):** A floating point array. The general ramp-up constraint violation variable for Resource r during Dispatch Interval di. Expressed in MW.
- **GenOpResShortage(di):** A floating point array. The generation-based Operating Reserve constraint deficit violation variable during Dispatch Interval di. Expressed in MW.
- **GenRegShortage(di):** A floating point array. The generation-based Regulating Reserve constraint deficit violation variable during Dispatch Interval di. Expressed in MW.
- **GenRegSpinShortage(di):** A floating point array. The generation-based regulating plus Spinning Reserve constraint deficit violation variable during Dispatch Interval di. Expressed in MW.

- **GlobalEnergyShortage(di):** A floating point array. The global power balance constraint deficit violation variable for Bus i during Dispatch Interval di. Expressed in MW.
- **GlobalEnergySurplus(di):** A floating point array. The global power balance constraint surplus violation variable for Bus i during Dispatch Interval di. Expressed in MW.
- **Globalλ(di):** A floating point array. The Shadow Price (i.e., dual variable) of the global power balance constraint during Dispatch Interval di. Expressed in $ per MW.
- **MaxLimitViolation(r,di):** A floating point array. The maximum limit constraint violation variable for Resource r during Dispatch Interval di. Expressed in MW.
- **Max ResourceContResViolation(r,di):** A floating point array. The maximum Resource Contingency Reserve constraint violation variable for Resource r during Dispatch Interval di. Expressed in MW.
- **Max ResourceRegViolation(r,di):** A floating point array. The maximum Resource Regulating Reserve constraint violation variable for Resource r during Dispatch Interval di. Expressed in MW.
- **MaxResourceRCUpViolation(r,di):** A floating point array. The maximum Resource Up Ramp Capability constraint violation variable for Resource r during Dispatch Interval di. Expressed in MW.
- **MaxResourceRCDownViolation(r,di):** A floating point array. The maximum Resource Down Ramp Capability constraint violation variable for Resource r during Dispatch Interval di. Expressed in MW.
- **ModeledLosses(di):** A floating point array. Actual losses modeled during Dispatch Interval di in the RT-SCED algorithm. Expressed in MW.
- **MinLimitViolation(r,di):** A floating point array. The minimum limit constraint violation variable for Resource r during Dispatch Interval di. Expressed in MW.
- **MWOpResStepClearing(st,di):** A floating point array. The market-wide Operating Reserve cleared by SCED for step st of the market-wide Operating Reserve Demand Curve during Dispatch Interval di. Expressed in MW.
- **MWRegSpinShortage(di):** A floating point array. The market-wide regulating plus Spinning Reserve constraint violation variable for Dispatch Interval di. Expressed in MW.
- **MWRegResStep1Clearing(di):** A floating point array. The market-wide Regulating Reserve cleared by SCED for step 1 of the market-wide Regulating Reserve Demand Curve during Dispatch Interval di. Expressed in MW.
- **MWRegResStep2Clearing(di):** A floating point array. The market-wide Regulating Reserve cleared by SCED for step 2 of the market-wide Regulating Reserve Demand Curve during Dispatch Interval di. Expressed in MW.
- **MWRegSpinResStep1Clearing(di):** A floating point array. The market-wide Regulating plus Spinning Reserve cleared by SCED for step 1 of the market-wide Regulating plus Spinning Reserve Demand Curve during Dispatch Interval di . Expressed in MW.
- **MWRegSpinResStep2Clearing(di):**A floating point array. The market-wide Regulating plus Spinning Reserve cleared by SCED for step 2 of the market-wide Regulating plus Spinning Reserve Demand Curve during Dispatch Interval di . Expressed in MW.

- **MWRegSpinResStep3Clearing(di):** A floating point array. The market-wide Regulating plus Spinning Reserve cleared by SCED for step 3 of the market-wide Regulating plus Spinning Reserve Demand Curve during Dispatch Interval di . Expressed in MW.
- **MWRCUpStep1Clearing(di):** A floating point array. The market-wide Up Ramp Capability cleared by SCED for step 1 of the market-wide Up Ramp Capability Demand Curve during Dispatch Interval di. Expressed in MW.
- **MWRCUpStep2Clearing(di):** A floating point array. The market-wide Up Ramp Capability cleared by SCED for step 2 of the market-wide Up Ramp Capability Demand Curve during Dispatch Interval di. Expressed in MW.
- **MWRCDownStep1Clearing(di):** A floating point array. The market-wide Down Ramp Capability cleared by SCED for step 1 of the market-wide Down Ramp Capability Demand Curve during Dispatch Interval di. Expressed in MW.
- **MWRCDownStep2Clearing(di):** A floating point array. The market-wide Down Ramp Capability cleared by SCED for step 2 of the market-wide Down Ramp Capability Demand Curve during Dispatch Interval di. Expressed in MW.
- **MWSTRResClearing(di):** A floating point array. The market-wide Short Term Reserve cleared by SCED of the market-wide Short Term Reserve Demand Curve during Dispatch Interval di. Expressed in MW.**PI(i,di):** A floating point array. Net Energy injections at bus i during Dispatch Interval di from Resources, imports and exports. Expressed in MW.
- **PW(i,di):** A floating point array. Energy withdrawals at Bus i during Dispatch Interval di due to system demand and modeled losses (i.e., Energy withdrawals modeled at the load distributed reference Bus). Expressed in MW.
- **RegRampViolation(r,di):** A floating point array. The Regulating Reserve ramp constraint violation variable for Resource r during Dispatch Interval di. Expressed in MW.
- **RCUpRampViolation(r,di):** A floating point array. The Up Ramp Capability ramp constraint violation variable for Resource r during Dispatch Interval di. Expressed in MW.
- **RCDownRampViolation(r,di):** A floating point array. The Down Ramp Capability ramp constraint violation variable for Resource r during Dispatch Interval di. Expressed in MW.
- **RegResTieBreak1(r1,r2,di):** A floating point array. The Regulating Reserve tie-breaking variable 1 between Resource r1 and Resource r2 for Dispatch Interval di.
- **RegResTieBreak2(r1,r2,di):** A floating point array. The Regulating Reserve tie-breaking variable 2 between Resource r1 and Resource r2 for Dispatch Interval di.
- **STRResTieBreak1(r1,r2,di):** A floating point array. The Short Term Reserve tie-breaking variable 1 between Resource r1 and Resource r2 for Dispatch Interval di.
- **STRResTieBreak2(r1,r2,di):** A floating point array. The Short Term Reserve tie-breaking variable 2 between Resource r1 and Resource r2 for Dispatch Interval di.
- **RPRegUpλ(k,di):** A floating point array. The Shadow Price (i.e., dual variable) of the reserve procurement regulation up constraint for transmission constraint k during Dispatch Interval di. Expressed in $ per MW.

- **RPRegDownλ(k,di):** A floating point array. The shadow price (i.e., dual variable) of the reserve procurement regulation down constraint for transmission constraint k during Dispatch Interval di. Expressed in $ per MW.
- **RPCRDepλ(k,z,di):** A floating point array. The Shadow Price (i.e., dual variable) of the reserve procurement Contingency Reserve deployment constraint for transmission constraint k during Dispatch Interval di. Expressed in $ per MW.
- **SSContResDeficit(r,di):** A floating point array. The self-scheduled Contingency Reserve constraint violation variable for Resource r during Dispatch Interval di. Expressed in MW.
- **SSEnergyDeficit(r,di):** A floating point array. The self-scheduled Energy constraint violation variable for Resource r during Dispatch Interval di. Expressed in MW.
- **SSRegDeficit(r,di):** A floating point array. The self-scheduled Regulating Reserve constraint violation variable for Resource r during Dispatch Interval di. Expressed in MW.
- **SubRegLimitStepViolation(st,k,h):** A floating point array. The Sub-Regional Power Balance constraint violation variable for constraint k during hour h. Expressed in MW.
- **TransLimitStepViolation(st,k,di):** A floating point array. The transmission limit constraint violation variable for transmission constraint k during Dispatch Interval di. Expressed in MW.
- **TransLimitViolationCREvent(k,z,di):** A floating point array. The reserve procurement transmission constraint Contingency Reserve event violation variable for constraint k under the event of loss the largest resource in zone z during Dispatch Interval di. Expressed in MW.
- **TransLimitViolationRegDown(k,di):** A floating point array. The reserve procurement transmission constraint regulation down violation variable for constraint k during Dispatch Interval di. Expressed in MW.
- **TransLimitViolationRegUp(k,di):** A floating point array. The reserve procurement transmission constraint regulation up violation variable for constraint k during Dispatch Interval di. Expressed in MW.
- **TransLimitViolationRCDown(k,di):** A floating point array. The ramp procurement Down Ramp Capability post deployment transmission constraint violation variable for constraint k during Dispatch Interval di. Expressed in MW.
- **TransLimitViolationRCUp(k,di):** A floating point array. The ramp procurement Up Ramp Capability post deployment transmission constraint violation variable for constraint k during Dispatch Interval di. Expressed in MW.
- **ZMinRegReq(z,di):** A floating point array. The solved minimum zonal Regulating Reserve requirement for zone z during Dispatch Interval di, expressed in MW. Together, the inclusion of the minimum zonal reserve requirements (regulation, spinning, and supplemental) ensure the deliverability of procured reserves intra-zonally, as needed.
- **ZMinSpinReq(z,di):** A floating point array. The solved minimum zonal Spinning Reserve requirement for zone z during Dispatch Interval di, expressed in MW. Together, the inclusion of the minimum zonal reserve requirements (regulation, spinning, and supplemental) ensure the deliverability of procured reserves intra-zonally, as needed.
- **ZMinSuppReq(z,di):** A floating point array. The solved minimum zonal supplemental reserve requirement for zone z during Dispatch Interval di, expressed in MW. Together, the inclusion

of the minimum zonal reserve requirements (regulation, spinning, and supplemental) ensure the deliverability of procured reserves intra-zonally, as needed.

- **ZMinRCUpReq(z,di):** A floating point array. The solved minimum zonal Up Ramp Capability requirement for zone z during Dispatch Interval di, expressed in MW. The inclusion of the minimum zonal Ramp Capability requirements ensure the deliverability of procured Up Ramp Capability intra-zonally, as needed.
- **ZMinRCDownReq(z,di):** A floating point array. The solved minimum zonal Down Ramp Capability requirement for zone z during Dispatch Interval di, expressed in MW. The inclusion of the minimum zonal ramp capability requirements ensure the deliverability of procured down ramp capability intra-zonally, as needed.
- **ZMinSTRReq(z,di):** A floating point array. The solved minimum zonal Short Term Reserve requirement for zone z during Dispatch Interval di, expressed in MW. The inclusion of the minimum zonal Short Term Reserve requirements ensures the deliverability of procured down ramp capability intra-zonally, as needed.
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9.7 SCED-Pricing Primal Variables and Output Data

- **ClearedContRes(r,di):** A floating point array. The Contingency Reserve cleared by SCED on Resource r during Dispatch Interval di. Expressed in MW.
- **ClearedContResCapDeficit(r,di):** A floating point array. The Contingency Reserve cap constraint violation variable for Resource r during Dispatch Interval di. Expressed in MW.
- **ClearedMWOpRes(di):** A floating point array. The market-wide Operating Reserve cleared by SCED for Dispatch Interval di. Expressed in MW.
- **ClearedMWRegRes(di):** A floating point array. The market-wide Regulating Reserve cleared by SCED for Dispatch Interval di. Expressed in MW.
- **ClearedRegRes1(r,di):** A floating point array. The Regulating Reserve cleared by SCED on Resource r during Dispatch Interval di, considering the resource’s total Regulating Reserve offer cost. Expressed in MW.
- **ClearedRegRes2(r,di):** A floating point array. The Regulating Reserve cleared by SCED on Resource r during Dispatch Interval di, considering the resource’s regulation capacity offer cost. Expressed in MW.
- **ClearedRCUp(r,di):** A floating point array. The Up Ramp Capability cleared by SCED on Resource r during Dispatch Interval di, Expressed in MW.
- **ClearedRCDown(r,di):** A floating point array. The Down Ramp Capability cleared by SCED on Resource r during Dispatch Interval di, Expressed in MW.
- **ClearedRZOpRes(z,di):** A floating point array. The Reserve Zone Operating Reserve cleared by SCED for Reserve Zone z during Dispatch Interval di. Expressed in MW.
- **ClearedRZRegRes(z,di):** A floating point array. The Reserve Zone Regulating Reserve cleared by SCED for Reserve Zone z during Dispatch Interval di. Expressed in MW.
- **ContResRampViolation(r,di):** A floating point array. The Contingency Reserve ramp constraint violation variable for Resource r during Dispatch Interval di. Expressed in MW.

- **ContResTieBreak1(r1,r2,di):** A floating point array. The Contingency Reserve tie-breaking variable 1 between Resource r1 and Resource r2 for Dispatch Interval di.
- **ContResTieBreak2(r1,r2,di):** A floating point array. The Contingency Reserve tie-breaking variable 2 between Resource r1 and Resource r2 for Dispatch Interval di.
- **DeployedContResDeficit(r,di):** A floating point array. The deployed Contingency Reserve deficit constraint violation variable for Resource r during Dispatch Interval di. Expressed in MW.
- **ClearedMWRCUp(di):** A floating point array. The market-wide Up Ramp Capability cleared by SCED for Dispatch Interval di. Expressed in MW.
- **ClearedMWRCDown(di):** A floating point array. The market-wide Down Ramp Capability cleared by SCED for Dispatch Interval di. Expressed in MW.
- **EnergyDispatchTarget(r,di):** A floating point array. The Energy Dispatch Target for Resource r at the end of Dispatch Interval di. Expressed in MW.
- **EnergyStepClearing(r,di,st):** A floating point array. The Energy cleared by SCED on offer curve step st for Resource r during Dispatch Interval di. Expressed in MW.
- **EnergyTieBreak1(r1,r2,di):** A floating point array. The Energy tie-breaking variable 1 between Resource 1 and Resource 2 for Dispatch Interval di.
- **EnergyTieBreak2(r1,r2,di):** A floating point array. The Energy tie-breaking variable 2 between Resource r1 and Resource or r2 for Dispatch Interval di.
- **Flow_SystemEnergySCED(k,di):** A floating point array. The transmission flow on transmission constraint k during Dispatch Interval di from entire set of system energy clearings across all market activities, both injections and withdrawals. Flow_**SystemEnergySCED(k,di)** is not a variable in itself, but is the sum of several variables, and is defined for ease of explanation of Reserve Procurement constraints. The definition of Flow_**SystemEnergySCED(k,di)** is given in Section5.2.6.16.
- **GeneralRampDownViolation(r,di):** A floating point array. The general ramp-down constraint violation variable for Resource r during Dispatch Interval di. Expressed in MW.
- **GeneralRampUpViolation(r,di):** A floating point array. The general ramp-up constraint violation variable for Resource r during Dispatch Interval di. Expressed in MW.
- **GenOpResShortage(di):** A floating point array. The generation-based Operating Reserve constraint deficit violation variable during Dispatch Interval di. Expressed in MW.
- **GenRegShortage(di):** A floating point array. The generation-based Regulating Reserve constraint deficit violation variable during Dispatch Interval di. Expressed in MW.
- **GenRegSpinShortage(di):** A floating point array. The generation-based Regulating plus Spinning Reserve constraint deficit violation variable during Dispatch Interval di. Expressed in MW.
- **GlobalEnergyShortage(di):** A floating point array. The global power balance constraint deficit violation variable for bus i during Dispatch Interval di. Expressed in MW.
- **GlobalEnergySurplus(di):** A floating point array. The global power balance constraint surplus violation variable for Bus i during Dispatch Interval di. Expressed in MW.

- **Globalλ(di):** A floating point array. The shadow price (i.e., dual variable) of the global power balance constraint during Dispatch Interval di. Expressed in $ per MW.
- **MaxLimitViolation(r,di):** A floating point array. The maximum limit constraint violation variable for Resource r during Dispatch Interval di. Expressed in MW.
- **MaxResourceContResViolation(r,di):** A floating point array. The maximum Resource Contingency Reserve constraint violation variable for Resource r during Dispatch Interval di. Expressed in MW.
- **MaxResourceRegViolation(r,di):** A floating point array. The maximum Resource Regulating Reserve constraint violation variable for Resource r during Dispatch Interval di. Expressed in MW.
- **MaxResourceRCUpViolation(r,di):** A floating point array. The maximum Resource Up Ramp Capability constraint violation variable for Resource r during Dispatch Interval di. Expressed in MW.
- **DaxResourceRCDownViolation(r,di):** A floating point array. The maximum Resource Down Ramp Capability constraint violation variable for Resource r during Dispatch Interval di. Expressed in MW.
- **ModeledLosses(di):** A floating point array. Actual losses modeled during Dispatch Interval di in the RT-SCED algorithm. Expressed in MW.
- **MinLimitViolation(r,di):** A floating point array. The minimum limit constraint violation variable for Resource r during Dispatch Interval di. Expressed in MW.
- **MWOpResStepClearing(st,di):** A floating point array. The market-wide Operating Reserve cleared by SCED for step st of the market-wide Operating Reserve Demand Curve during Dispatch Interval di. Expressed in MW.
- **MWRegSpinShortage(di):** A floating point array. The market-wide Regulating plus Spinning Reserve constraint violation variable for Dispatch Interval di. Expressed in MW.
- **MWRegResStep1Clearing(di):** A floating point array. The market-wide Regulating Reserve cleared by SCED for step 1 of the market-wide Regulating Reserve Demand Curve during Dispatch Interval di. Expressed in MW.
- **MWRegResStep2Clearing(di):** A floating point array. The market-wide Regulating Reserve cleared by SCED for step 2 of the market-wide Regulating Reserve Demand Curve during Dispatch Interval di. Expressed in MW.
- **MWRegSpinResStep1Clearing(di):** A floating point array. The market-wide Regulating plus Spinning Reserve cleared by SCED for step 1 of the market-wide Regulating plus Spinning Reserve Demand Curve during hour h. Expressed in MW.
- **MWRegSpinResStep2Clearing(di):**A floating point array. The market-wide Regulating plus Spinning Reserve cleared by SCED for step 2 of the market-wide Regulating plus Spinning Reserve Demand Curve during hour h. Expressed in MW.
- **MWRegSpinResStep3Clearing(di):** A floating point array. The market-wide Regulating plus Spinning Reserve cleared by SCED for step 3 of the market-wide Regulating Spinning Reserve Demand Curve during hour h. Expressed in MW.

- **MWRCUpStep1Clearing(di):** A floating point array. The market-wide Up Ramp Capability cleared by SCED for step 1 of the market-wide Up Ramp Capability Demand Curve during Dispatch Interval di. Expressed in MW.
- **MWRCUpStep2Clearing(di):** A floating point array. The market-wide Up Ramp Capability cleared by SCED for step 2 of the market-wide Up Ramp Capability Demand Curve during Dispatch Interval di. Expressed in MW.
- **MWRCDownStep1Clearing(di):** A floating point array. The market-wide Down Ramp Capability cleared by SCED for step 1 of the market-wide Down Ramp Capability Demand Curve during Dispatch Interval di. Expressed in MW.
- **MWRCDownStep2Clearing(di):** A floating point array. The market-wide Down Ramp Capability cleared by SCED for step 2 of the market-wide Down Ramp Capability Demand Curve during Dispatch Interval di. Expressed in MW.
- **NoLoadCost(r)**: A floating point array. The cost of a resource to produce energy or reserves when on line without load. Expressed in $.
- **PI(i,di):** A floating point array. Net Energy injections at bus i during Dispatch Interval di from Resources, imports and exports. Expressed in MW.
- **PW(i,di):** A floating point array. Energy withdrawals at Bus i during Dispatch Interval di due to system demand and modeled losses (i.e., Energy withdrawals modeled at the load distributed reference Bus). Expressed in MW.
- **RegRampViolation(r,di):** A floating point array. The Regulating Reserve ramp constraint violation variable for Resource r during Dispatch Interval di. Expressed in MW.
- **RCUpRampViolation(r,di):** A floating point array. The Up Ramp Capability ramp constraint violation variable for Resource r during Dispatch Interval di. Expressed in MW.
- **RCDownRampViolation(r,di):** A floating point array. The Down Ramp Capability ramp constraint violation variable for Resource r during Dispatch Interval di. Expressed in MW.
- **RegResTieBreak1(r1,r2,di):** A floating point array. The Regulating Reserve tie-breaking variable 1 between Resource r1 and Resource r2 for Dispatch Interval di.
- **RegResTieBreak2(r1,r2,di):** A floating point array. The Regulating Reserve tie-breaking variable 2 between Resource r1 and Resource r2 for Dispatch Interval di.
- **RPRegUpλ(k,di):** A floating point array. The Shadow Price (i.e., dual variable) of the reserve procurement regulation up constraint for transmission constraint k during Dispatch Interval di. Expressed in $ per MW.
- **RPRegDownλ(k,di):** A floating point array. The Shadow Price (i.e., dual variable) of the reserve procurement regulation down constraint for transmission constraint k during Dispatch Interval di. Expressed in $ per MW.
- **RPCRDepλ(k,z,di):** A floating point array. The Shadow Price (i.e., dual variable) of the reserve procurement Contingency Reserve deployment constraint for transmission constraint k during Dispatch Interval di. Expressed in $ per MW.
- **ShutDownCost(r)**: A floating point array. The cost of a Resource to shut down. Expressed in $.

- **SSContResDeficit(r,di):** A floating point array. The self-scheduled Contingency Reserve constraint violation variable for Resource r during Dispatch Interval di. Expressed in MW.
- **SSEnergyDeficit(r,di):** A floating point array. The self-scheduled Energy constraint violation variable for Resource r during Dispatch Interval di. Expressed in MW.
- **SSRegDeficit(r,di):** A floating point array. The self-scheduled Regulating Reserve constraint violation variable for Resource r during Dispatch Interval di. Expressed in MW.
- **StartUpCost(r)**: A floating point array. The cost of the resource to start up. Expressed in $.
- **TransLimitStepViolation(st,k,di):** A floating point array. The transmission limit constraint violation variable for transmission constraint k during Dispatch Interval di. Expressed in MW.
- **EmergencyResourceClearedEnergy(r,di):** A floating point array. The Energy Dispatch Target for LMR, Emergency Purchases and External Resources that qualify as Planning Resources at the end of Dispatch Interval di under Maximum Generation Emergency, expressed in MW.
- **TransLimitViolationCREvent(k,z,di):** A floating point array. The reserve procurement transmission constraint Contingency Reserve event violation variable for constraint k under the event of loss the largest resource in zone z during Dispatch Interval di. Expressed in MW.
- **TransLimitViolationRegDown(k,di):** A floating point array. The reserve procurement transmission constraint regulation down violation variable for constraint k during Dispatch Interval di. Expressed in MW.
- **TransLimitViolationRegUp(k,di):** A floating point array. The reserve procurement transmission constraint regulation up violation variable for constraint k during Dispatch Interval di. Expressed in MW.
- **ZMinRegReq(z,di):** A floating point array. The solved minimum zonal regulating reserve requirement for zone z during Dispatch Interval di, expressed in MW. Together, the inclusion of the minimum zonal reserve requirements (regulation, spinning, and supplemental) ensure the deliverability of procured reserves intra-zonally, as needed.
- **ZMinSpinReq(z,di):** A floating point array. The solved minimum zonal Spinning Reserve requirement for zone z during Dispatch Interval di, expressed in MW. Together, the inclusion of the minimum zonal reserve requirements (regulation, spinning, and supplemental) ensure the deliverability of procured reserves intra-zonally, as needed.
- **ZMinSuppReq(z,di):** A floating point array. The solved minimum zonal supplemental reserve requirement for zone z during Dispatch Interval di, expressed in MW. Together, the inclusion of the minimum zonal reserve requirements (regulation, spinning, and supplemental) ensure the deliverability of procured reserves intra-zonally, as needed.
- **ZMinRCUpReq(z,di):** A floating point array. The solved minimum zonal Up Ramp Capability requirement for zone z during Dispatch Interval di, expressed in MW. The inclusion of the minimum zonal Up Ramp Capability requirements ensure the deliverability of procured Up Ramp Capability intra-zonally, as needed.
- **ZMinRCDownReq(z,di):** A floating point array. The solved minimum zonal Down Ramp Capability requirement for zone z during Dispatch Interval di, expressed in MW. The inclusion

of the minimum zonal Down Ramp Capability requirements ensure the deliverability of procured Down Ramp Capability intra-zonally, as needed.

- **MaxResourceSTRViol(r,di):** Maximum single resource STR clearing constraint for resource at location r and interval di
- **ClearedOfflineSTR (r,di):** Cleared offline STR MW value for resource r at interval di
- **ClearedOnlineSTR (r,di):** STRonlineMW(r,h): Cleared online STR MW value for resource r at interval di
- **STRResDispatch (r,di)** : Cleared STR MW value for resource r at interval di
- **STRTransLimit(k,di) :** STR transmission constraint maximum flow allowed after STR response for constraint k at interval di
- **STRResponse(z,e,di)** : STR response provided by resources for constraint k in zone z at interval di.

9.8 Post-SCED Product Substitution Variables

- **AMWRegResDispatchComp2(di):** A floating point array. Actual Market-Wide Regulating Reserve Dispatch - Component 2. The total amount of "Component 2" Regulating Reserve that must be dispatched across the market to ensure the total dispatch of Regulating Reserve across the market balances the Market-Wide Regulating Reserve that actually cleared during Dispatch Interval di. Expressed in MW.
- **AvailMWSpinRes(di):** A floating point array. Available Market-Wide Spinning Reserve. The sum of the Available Spinning Reserve on all Resources across the market footprint during Dispatch Interval di. Expressed in MW.
- **AvailRZSpinRes(z,di):** A floating point array. Available Reserve Zone Spinning Reserve. The sum of the Available Spinning Reserve on all Resources within Reserve Zone z during Dispatch Interval di. Expressed in MW.
- **AvailSpinRes(r,di):** A floating point array. Available Spinning Reserve. The amount of cleared Spinning Reserve plus the amount of cleared Regulating Reserve not dispatched as Regulating Reserve on Resource r during Dispatch Interval di. Expressed in MW.
- **MWRegResDispatch(z,di):** A floating point array. Market-Wide Regulating Reserve Dispatch. The total Regulating Reserve dispatched across the market footprint during Dispatch Interval di. Expressed in MW.
- **MWSpinResDispatchComp1(di):** A floating point array. Market-Wide Spinning Reserve Dispatch - Component 1. The sum of the Spinning Reserve Dispatch - Component 1 associated with all resources across the market during Dispatch Interval di. Expressed in MW.
- **MWSpinResDispatchComp2(di):** A floating point array. Targeted Market-Wide Spinning Reserve Dispatch - Component 2. The total amount of "Component 2" Spinning Reserve that must be dispatched across the market to ensure the total dispatch of Regulating plus Spinning Reserve across the market balances the Market-Wide Regulating plus Spinning Reserve requirement during Dispatch Interval di. Expressed in MW.
- **MWSpinResDispatchReq(di):** A floating point array. Market-Wide Spinning Reserve Dispatch Requirement. The amount of Spinning Reserve that must be dispatched across the

market footprint during Dispatch Interval di to balance the Market-Wide Regulating plus Spinning Reserve dispatch with the Market-Wide Regulating plus Spinning Reserve requirement. Expressed in MW.

- **MWSpinResUnDispatch(di):** A floating point array. Undispatched Market-Wide Spinning Reserve. The total amount of cleared Spinning Reserve across the market footprint that has not been dispatched as Spinning Reserve Dispatch - Component 1 during Dispatch Interval di. Expressed in MW.
- **MWSubRegCleared(di):** A floating point array. Market-Wide Regulation Cleared capable of substitution. The total amount of Regulating Reserve cleared on resources across the market during Dispatch Interval di. Expressed in MW.
- **RegResDispatch(r,di):** A floating point array. Regulating Reserve Dispatch. The total Regulating Reserve dispatched on resource r during Dispatch Interval di (i.e., the sum of the component 1 and component 2 Regulating Reserve dispatch). Expressed in MW.
- **RegResDispatchComp1(r,di):** A floating point array. Regulating Reserve Dispatch - Component 1. The first of the two components of Regulating Reserve dispatched on resource r during Dispatch Interval di. Expressed in MW.
- **RegResDispatchComp2(r,di):** A floating point array. Regulating Reserve Dispatch - Component 2. The second of the two components of Regulating Reserve dispatched on resource r during Dispatch Interval di. Expressed in MW.
- **RZRegCleared(z,di):** A floating point array. Reserve Zone Regulation Cleared. The total amount of Regulating Reserve cleared in Reserve Zone z during Dispatch Interval di. Expressed in MW.
- **RZRegResDispatch(z,di):** A floating point array. Reserve Zone Regulating Reserve Dispatch. The total Regulating Reserve dispatched in Reserve Zone z during Dispatch Interval di. Expressed in MW.
- **RZRegResDispatchComp1(z,di):** A floating point array. Reserve Zone Regulating Reserve Dispatch - Component 1. The sum of the Regulating Reserve Dispatch - Component 1 associated with all resources in Reserve Zone z during Dispatch Interval di. Expressed in MW.
- **RZSpinResDispatchComp1(z,di):** A floating point array. Reserve Zone Spinning Reserve Dispatch - Component 1. The sum of the Spinning Reserve Dispatch - Component 1 associated with all resources in Reserve Zone z during Dispatch Interval di. Expressed in MW.
  RZSpinResDispatchReq(z,di): A floating point array. Reserve Zone Spinning Reserve Dispatch Requirement. The amount of Spinning Reserve that must be dispatched within Reserve Zone z during Dispatch Interval di to balance the Reserve Zone Regulating plus Spinning Reserve dispatch with the Reserve Zone Regulating plus Spinning Reserve requirement. Expressed in MW.
- **SpinResDispatch(r,di):** A floating point array. Spinning Reserve Dispatch. The total Spinning Reserve dispatched on resource r during Dispatch Interval di (i.e., the sum of the component 1 and component 2 Spinning Reserve dispatch). Expressed in MW.

- **SpinResDispatchComp1(r,di):** A floating point array. Spinning Reserve Dispatch - Component 1. The first of the two components of Spinning Reserve dispatched on resource r during Dispatch Interval di. Expressed in MW.
- **SpinResDispatchComp2(r,di):** A floating point array. Spinning Reserve Dispatch - Component 2. The second of the two components of Spinning Reserve dispatched on resource r during Dispatch Interval di. Expressed in MW.
- **SupResDispatch(r,di):** A floating point array. Supplemental Reserve Dispatch. The total Supplemental Reserve dispatched on resource r during Dispatch Interval di. Expressed in MW.
- **TMWRegResDispatchComp1(di):** A floating point array. Market-Wide Regulating Reserve Dispatch - Component 1. The sum of the Regulating Reserve Dispatch - Component 1 associated with all resources across the market during Dispatch Interval di. Expressed in MW.
- **TMWRegResDispatchComp2(di):** A floating point array. Targeted Market-Wide Regulating Reserve Dispatch - Component 2. The total amount of "Component 2" Regulating Reserve that must be dispatched across the market to ensure the total dispatch of Regulating Reserve across the market balances the Market-Wide Regulating Reserve requirement during Dispatch Interval di. Expressed in MW.

9.9 Post-SCED Contingency Reserve Clearing Calculation Variables

- **AMWSpinResClearedComp2(di):** A floating point array. Available Market-Wide Spinning Reserve Cleared - Component 2. The total amount of "Component 2" Spinning Reserve that must be cleared across the market to ensure the total cleared Regulating plus Spinning Reserve across the market does not exceed the cleared Market-Wide Regulating Reserve plus the cleared Contingency Reserve on Resources available to provide Spinning Reserve during Dispatch Interval di. Expressed in MW.
- **MWSpinResCleared(di):** A floating point array. Market-Wide Spinning Reserve Cleared. The total Spinning Reserve Cleared across the market during Dispatch Interval di. Expressed in MW.
- **MWSpinResClearedComp1(di):** A floating point array. Market-Wide Spinning Reserve Cleared - Component 1. The sum of the Spinning Reserve Cleared - Component 1 associated with all resources across the market during Dispatch Interval di. Expressed in MW.
- **RZClearedSpinRes(z,di):** A floating point array. Reserve Zone Spinning Reserve Cleared. The total amount of Spinning Reserve cleared in Reserve Zone z during Dispatch Interval di. Expressed in MW.
- **RZSpinResClearedComp1(z,di):** A floating point array. Reserve Zone Spinning Reserve Cleared - Component 1. The sum of the Spinning Reserve Cleared - Component 1 associated with all resources in Reserve Zone z during Dispatch Interval di. Expressed in MW.
- **SpinResCleared(r,di):** A floating point array. Spinning Reserve Cleared. The total Spinning Reserve cleared on resource r during Dispatch Interval di (i.e., the sum of the component 1 and component 2 Spinning Reserve cleared). Expressed in MW.

- **SpinResClearedComp1(r,di):** A floating point array. Spinning Reserve Cleared - Component 1. The first of the two components of Spinning Reserve cleared on resource r during Dispatch Interval di. Expressed in MW.
- **SpinResClearedComp2(r,di):** A floating point array. Spinning Reserve Cleared - Component 2. The second of the two components of Spinning Reserve cleared on resource r during Dispatch Interval di. Expressed in MW.
- **SupResCleared(r,di):** A floating point array. Supplemental Reserve Cleared. The total Supplemental Reserve cleared on resource r during Dispatch Interval di. Expressed in MW.
- **TMWSpinResClearedComp2(di):** A floating point array. Targeted Market-Wide Spinning Reserve Cleared - Component 2. The total amount of "Component 2" Spinning Reserve that must be cleared across the market to ensure the total cleared Regulating plus Spinning Reserve across the market balances the Market-Wide Regulating plus Spinning Reserve requirement during Dispatch Interval di. Expressed in MW.

9.10 Post-SCED Processing Pricing Variables

- **LMP(cpn,di):** A floating point array. The LMP for Commercial Pricing Node cpn during Dispatch Interval di.
- **LMP(i,di):** A floating point array. The LMP for Bus i during Dispatch Interval di.
- **MCC(cpn,di):** A floating point array. The marginal congestion component of the LMP at Commercial Pricing Node cpn during Dispatch Interval di.
- **MCC(i,di):** A floating point array. The Marginal Congestion Component of the LMP at Bus i during Dispatch Interval di.
- **MEC_r(di):** A floating point array. The marginal Energy component of the LMP at the load-distributed reference Bus during Dispatch Interval di.
- **MLC(cpn,di):** A floating point array. The Marginal Losses Component of the LMP at Commercial Pricing Node cpn during Dispatch Interval di.
- **MLC(i,di):** A floating point array. The Marginal Losses Component of the LMP at Bus i during Dispatch Interval di.
- **WF(i,cpn):** A floating point array. The weight factor for Bus i and Commercial Pricing Node cpn.