RTC+B: Modifications to RUC Capacity Short Calculations

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# Background

Under the RTC+B Project, the Reliability Unit Commitment (RUC) process is being modified to co-optimize energy and Ancillary Service (AS) procurements to meet the forecasted Load and AS requirements.

1. The binding outputs of the RUC process (including ERCOT Operator approval) are commitment instructions to Generation Resources (GRs). RUC committed GRs are eligible for Make-Whole payments.
2. A RUC committed GR is eligible to receive Make-Whole payment if the revenues (from energy and AS) is less than the approved costs (for details, please refer Section 5 of the Nodal Protocols).
3. Under the RTC+B Project, Make-Whole payments made to RUC committed GRs (cost of “RUCing” a GR), are recovered through Make-Whole Charges applied to QSEs in the following sequence:
   1. First: QSEs that are short on energy or AS for the RUC committed hours
   2. Then: If the charges collected from QSEs that are insufficient, then the remainder is collected from all QSEs on a Load Ratio Share (LRS) basis
   3. **If there are no RUC committed GRs for a particular hour, there is NO MAKE-WHOLE CHARGE to a QSE, even if that QSE is short on energy and/or AS for that hour. The QSE may receive energy and AS imbalance charges in Real-Time.**

# Reasons for modifications to the RUC Capacity Short Calculations

Currently approved RTC+B related protocols (NPRR1009, NPRR1014, NPRR1029, NPRR1032, and NPRR1139) has changes to incorporate QSE-level energy and AS shortage calculation.

After the RTC+B Project was restarted, the NPRRs approved while the project was on hold (e.g., NPRR1093) were reviewed to analyze any impact to the RTC+B Project. In this process the following items came up that impacted the RUC Capacity Short calculation:

1. Certain limitations in the approved RTC+B protocol changes:
   1. AS subtypes were not originally considered. For example, a QSE with RRS-PFR position could cover it with UFR or FFR, which should not be allowed.
   2. Logic for Reg-Down had a deficiency where it could be possible for the same Resource capacity to be used for Reg-Down as well as any other Up AS types/subtypes (Reg-Up, RRS-FFR,RRS-UFR,RRS-PFR, ECRSS, NSPINS).
   3. Logic for an Energy Storage Resource (ESR) providing AS when charging.
2. The need to incorporate ESR SOC considerations based on NPRR 1204.

This document describes the modifications to the calculation of potential QSE shortage of energy and/or AS to address the above issues.

An NPRR to modify the RUC Capacity Short calculations will be developed after discussions at RTCBTF.

# Description of modifications to RUC Capacity Short Calculation

The high-level changes are to modify QSE-level AS shortage calculation to:

1. Consider each AS subtype to prevent a limited AS subtype (such as RRS-UFR) from covering an unlimited AS subtype QSE position (RRS\_PFR).
2. Fix logic to prevent the same Resource’s capacity from being used for different AS types/subtypes (prevent double counting).
3. Fix logic to account for an ESR providing AS when charging.
4. Incorporate ESR SOC considerations based on NPRR 1204 and associated discussion with stakeholders.

## Overview of RUC Capacity Short Calculation

The RUC Capacity Short calculation process, in basic terms, is just an accounting procedure. It determines, for a particular hour using information from a “RUC Snapshot” and information from an “end of the Adjustment Period Snapshot”, if the Resources in the QSE’s portfolio can cover the QSE’s energy and AS position for that particular hour.

In summary, the structure of this section remains the same. However, some of the bill determinant calculations change.

The table below summarizes the changes to the grey box Section 5.7.4.1.1.

|  |  |
| --- | --- |
| Section | Description of Proposed Change |
| 5.7.4.1.1 (11) and (14) : Ancillary Service Shortfall:  @RUC snapshot and,  @ end of Adjustment Period. | These two sections describe how the Ancillary Service (AS) shortfall in MW for a QSE is calculated according to the RUC Snapshot and, again, at the end of the Adjustment Period.  Changes to section 5.7.4.1.1 (11) and (14):   * RUCASFSNAP, RUCASFADJ: The procedure by which the AS shortfall is calculated at the RUC Snapshot and at the end of the Adjustment Period will be revamped and is described in later sections. |
| 5.7.4.1.1 (10) and (13) : Overall Shortfall :  @RUC snapshot and,  @ end of Adjustment Period. | These two sections describe how the overall shortfall in MW for a QSE is calculated according to the RUC Snapshot and, again, at the end of the Adjustment Period.  Changes to section 5.7.4.1.1 (10) and (13):   * RUCCAPSNAP, RUCCAPADJ, each has two new terms ESRASSNAP, ESRASADJ (QSE AS MW Position covered by ESRs) and ESRMWSNAP, ESRMWADJ (MW discharge/charge to support QSE AS MW Position coverage as well as respect COP SOC values) at the RUC Snapshot and at the end of the Adjustment Period. The terms ESRASSNAP and ESRMWSNAP are described later. The terms ESRASADJ and ESRMWADJ are the same calculation but evaluated at the end of the Adjustment Period * In RCAPSNAP and RCAPADJ, the HSL of ESRs in the QSEs portfolio is removed. This is replaced by ESRMWSNAP and ESRMWADJ in RUCCAPSNAP and RUCCAPADJ, respectively. |

The text box below summarizes the RUC Capacity Short Calculations for the RUC Snapshot. Similar calculations are performed for the end of the Adjustment Period.

INPUTS: For each hour in the RUC Snapshot;

1. Day-Ahead posting of AS Deployment Factors
2. Resource Registered Qualified AS MW Amounts for each AS subtype.
3. QSE’s RTAML
4. QSE DAM energy and AS awards and QSE submitted data (energy & Capacity Trades, AS Trades, QSE’s Resource COP data, QSE’s Resource AS Offers, and DC Tie Imports)

PROCESSING/CALCULATIONS: For each hour in the RUC Snapshot;

1. Calculate for each Resource, per hour, the AS MW Capability, by AS subtype (ASMWCAPABILITY)
2. Perform calculations (using optimization technique) to determine:
3. ASMWCAPUSED : Calculated amount of a Resource capacity used to cover its QSE AS position, per hour.
4. ESRMWSNAP: Calculated total MW discharge/charge, per QSE, per hour, required to support hourly AS position considering deployment factors and difference in consecutive hours HBSOC.
5. ESRASSNAP: Calculated QSE’s AS MW position covered by the QSE’s ESR portfolio.
6. QSE AS MW shortage (RUCASFSNAP):

RUCASFSNAP *ruc, q,i* =QSE total AS position –

1. QSE Overall shortage (RUCOSFSNAP)

RUCOSFSNAP *ruc, q,i* = Max (0, ((RTAML *q, p,i* \* 4) + ASONPOSSNAP *ruc, q,i* – RUCCAPSNAP *ruc, q,I* ))

## Inputs

The RUC Capacity Short Calculation inputs for each hour (or Settlement Interval in that hour) in a particular RUC process are:

1. Day-Ahead posting of AS Deployment Factors (*Available to Market Participants as part of the Day- Ahead Posting in the morning. Values between 0 to 1 for each AS type)*
2. Resource Registered Qualified AS MW Amounts for each AS subtype (*Part of QSE qualification testing and maintained in ERCOT Registration system*)
3. QSE’s RTAML (*After the fact meter data that is available to QSEs. Units are MWh for each 15-minute Settlement Interval*)
4. QSE DAM energy and AS awards and QSE submitted data:
5. QSE’s DAM energy awards, energy and Capacity Trades, and DC Tie Imports. Used to calculate QSE’s hourly Net Energy Position for each hour.
6. QSE Submitted hourly data:
7. AS Trades by AS type/subtype: Used to calculate each QSE’s AS MW Positions based on DAM, and AS Trades for each hour.
8. Resource COP data:
   1. Res. Status,
   2. AS MW Capabilities,
   3. HSL/MPC,
   4. LSL/LPC,
   5. Min/Max SOC, HBSOC
9. AS Offers by type/subtype.

**Note: None of the inputs to the RUC Capacity Short Calculation are from the output of the RUC process executed by the ERCOT Operator.**

## QSE AS Portfolio Position by AS Subtype.

The calculation of any potential QSE-level AS position shortfall at the RUC Snapshot (5.7.4.1.1 (11)) and at the end of the Adjustment Period (5.7.4.1.1 (14)) will be modified to process the calculation by AS subtype.

The variables below are the QSE AS Positions by the AS subtypes; RegUp, RegDn, RRS-PFR, RRS-UFR, RRS-FFR, ECRSS (SCED dispatchable), ECRSM (Non-SCED dispatchable), NSPINS (SCED dispatchable), NSPINM (Non-SCED dispatchable); at the RUC Snapshot (used in 5.7.4.1.1 (11). Similar variables are defined for the end of the Adjustment Period (used in 5.7.4.1.1 (14).

|  |  |
| --- | --- |
| RUPOSSNAP *ruc, q, h* | *Regulation Up Position at Snapshot* ⎯The QSE *q’s* Real-Time Reg-Up Ancillary Service Position according to the RUC Snapshot for the RUC process *ruc* for the hour *h* that includes the 15-minute Settlement Interval. |
| RDPOSSNAP *ruc, q, h* | *Regulation Down Position at Snapshot* ⎯The QSE *q’s* Real-Time Reg-Down Ancillary Service Position according to the RUC Snapshot for the RUC process *ruc* for the hour *h* that includes the 15-minute Settlement Interval. |
| PFPOSSNAP *ruc, q, h* | *Responsive Reserve (Governor Response or Governor-Like Response) Position at Snapshot* ⎯The QSE *q’s* Real-Time RRS-PFR Ancillary Service Position according to the RUC Snapshot for the RUC process *ruc* for the hour *h* that includes the 15-minute Settlement Interval. |
| UFPOSSNAP *ruc, q, h* | *Responsive Reserve (Under Frequency trigger at 59.7 Hz.) Position at Snapshot* ⎯The QSE *q’s* Real-Time RRS-UFR Ancillary Service Position according to the RUC Snapshot for the RUC process *ruc* for the hour *h* that includes the 15-minute Settlement Interval. |
| FFPOSSNAP *ruc, q, h* | *Responsive Reserve (Fast Frequency Response) Position at Snapshot* ⎯The QSE *q’s* Real-Time RRS-FFR Ancillary Service Position according to the RUC Snapshot for the RUC process *ruc* for the hour *h* that includes the 15-minute Settlement |
| ESPOSSNAP *ruc, q, h* | *ERCOT Contingency Reserve Service (SCED Dispatchable) Position at End of Adjustment Period* ⎯The QSE *q’s* ECRS Ancillary Service Position that is SCED dispatchable according to the RUC Snapshot for the RUC process *ruc* for the hour *h* that includes the 15-minute Settlement Interval. |
| EMPOSSNAP *ruc, q, h* | *ERCOT Contingency Reserve Service (Non-SCED Dispatchable) Position at End of Adjustment Period* ⎯The QSE *q’s* ECRS Ancillary Service Position that is Non-SCED dispatchable according to the RUC Snapshot for the RUC process *ruc* for the hour *h* that includes the 15-minute Settlement Interval. |
| NSPOSSNAP *ruc, q, h* | *Non-Spin Reserve Service (SCED Dispatchable) Position at End of Adjustment Period* ⎯The QSE *q’s* Non-Spin Ancillary Service Position that is SCED dispatchable according to the RUC Snapshot for the RUC process *ruc* for the hour *h* that includes the 15-minute Settlement Interval. |
| NMPOSSNAP *ruc, q, h* | *Non-Spin Reserve Service (Non-SCED Dispatchable) Position at End of Adjustment Period* ⎯The QSE *q’s* Non-Spin Ancillary Service Position that is Non-SCED dispatchable according to the RUC Snapshot for the RUC process *ruc* for the hour *h* that includes the 15-minute Settlement Interval. |

## Resource Capacity Accounting and Variables

Load Resource (NCLR, CLR): NCLR, CLR has Upward AS capacity while consuming energy and Reg-Down (for CLR) capability if it can increase energy consumption when called upon.

1. The energy consumed by a Load Resource is assumed to be captured in the Load Forecast
2. A MW credit is given for the Upward AS capability (ASOFRLRSNAP term in equation defining RUCCAPSNAP)

Generation Resource (GR): GR provides Upward AS capacity with its unloaded remaining capacity and Reg-Down if it can decrease energy injection when called upon.

1. A MW credit is given for the GR HSL (RCAPSNAP term in equation defining RUCCAPSNAP)

Energy Storage Resources (ESRs): ESRs can provide AS while charging like a Load Resource (LR) providing AS while consuming energy (charging). Also, ESRs can provide AS while discharging, like a GR. In addition, with NPRR 1204, QSEs will self-schedule their ESRs to their submitted COP State of Charge (SOC) considering the AS Deployment Factors. To recognize the ability of ESR to provide AS while charging or discharging the following new terms are introduced for the ESRs in the QSE’s portfolio:

1. ESRASSNAP ruc, q, h = The QSE Upward AS MW position (RU,RRS,ECRS,NSPIN) covered by the QSEs ESR portfolio at RUC Snapshot. This is equivalent to the term ASOFRLRSNAP ruc, q, r, h in RUCCAPSNAP for Load Resources because ESRs can provide AS when charging.

ESRMWSNAP ruc, q, h = This is the equivalent counterpart of the GR HSL included in RCAPSNAL and RCAPADJ described above for a GR. The calculated net QSE ESR portfolio MW discharging or charging accounts for the:

* + 1. QSE AS MW positions covered by the QSEs ESR portfolio for a given hour,
    2. the MinSOC, MaxSOC, HBSOC for hour h (minSOC and maxSOC constraint satisfied) and;
    3. the difference between HBSOC for hour h and HBSOC for hour h+1 (difference of HBSOC is the net of energy dispatch and AS deployments using AS Deployment Factors) at the RUC Snapshot.

1. Similar terms ESRASADJ and ESRMWADJ are there for the calculations at the end of the Adjustment Period.

ASMWCAPABILITY= For each hour and for each Resource (NCLR, CLR, GR, ESR) in a QSE’s portfolio, the MW capability (ASMWCAPABILITY) of each AS subtype is determined.

Note 1: For Load Resources replace HSL with MPC and LSL with LPC,

Note 2: For GR with COP status of “OFF” and qualified to provide NSPIN, replace the term “HSL-LSL” with “HSL”, otherwise this GR with “OFF” status is considered equivalent to a GR with “OUT” status and is ignored.

ASMWCAPUSED=The amount of the Resource’s MW capability of a particular AS subtype (ASMWCAPABILITY) that is “used” (ASMWCAPUSED ) to cover the QSE portfolio level AS position. The ASMWCAPUSED is determined when performing the AS shortage calculation described later.

|  |  |
| --- | --- |
| ASMWCAPABILITY *ruc, q, h, AStype, rtype* | *MW Capability to provide AStype Ancillary Service at Snapshot –* The capacity represented by validated ‘AStype’ Ancillary Service Offers for Resource Type *rtype* represented by QSE *q* according to the RUC Snapshot for the RUC process *ruc* for the hour *h* that includes the 15-minute Settlement Interval. Where for a Combined Cycle Train, the Resource *r* is a Combined Cycle Generation Resource within the Combined Cycle Train. A Resource’s offered capacity is only included in the sum to the extent that the Resource’s COP Status and Ancillary Service Capability indicate it would be capable of providing the ‘AStype’ Ancillary Service during the hour *h*. |
| ASMWCAPUSED *ruc, q, h, AStype, rtype* | *MW Capacity used to cover the QSE’s ‘AStype’ Ancillary Service Position by the Resources of type ‘rtype’ in the QSE’s portfolio –* Calculated MW Capacity of a Resource used to cover its QSE’s “AStype” Ancillary Service Positionfor the RUC process *ruc* for the hour *h* that includes the 15-minute Settlement Interval. |

## Optimization Process: QSE AS Shortfall Calculation (RUCASFSNAP)

The description below replaces the calculation of RUCASFSNAP using data from the RUC Snapshot in grey box 5.7.4.1.1 (11). The same calculation is evaluated using data from the Snapshot at the end of the Adjustment Period to determine RUCASFADJ and replaces the grey box language in 5.7.4.1.1 (14).

For ESRs, the COP MinSOC, COP MaxSOC and the COP SOC values across hours are considered along with the AS Deployment Factors. An ESR is assumed to have a 100% Round Trip Efficiency.

The concept adopted here is to first solve an optimization problem that performs the accounting/checks in a way that minimizes any potential RUC AS shortfall for the QSE.

Clarifications on “optimization”

1. The optimization used to determine AS Shortfall calculations is separate/distinct from the RUC engine optimization and is NOT about finding the cheapest solution that meets energy and Ancillary Service needs.
2. The RUC AS Shortfall “optimization” is about finding the AS coverage by a QSE of its AS portfolio to minimize any AS Shortfall.

Given below is the mathematical description of how optimization is used to minimize the QSE’s potential RUC AS shortfall calculation by maximizing coverage by the QSE’s resources of the QSE’s AS positions:

1. Objective: Minimize AS Shortage
2. QSE level Constraints:

For each QSE AS Position coverage (Use QSE portfolio qualified Resource capacity to cover QSE AS position by AS type:

1. Resource level constraints for each Resource (rtype = NCLR,CLR,GR,ESR, COP Resource Status = ON, OFFQS or OFF):
2. For all *ASType*:
3. Constraint to ensure that any particular AS credited capacity does not exceed Resource capability for that AS type, *ASType*=RU,RD,FFR,UFR,PFR,ECRSM,ECRSS,NPSINM,NSPINS and COP Resource Status = “ON”, “OFFQS”, “OFF”.

For GR with “OFF” COP Resource status and qualified to provide NSPIN, set LSL=0 for the equation below, otherwise this “OFF” GR is considered equivalent to a GR with “OUT” status and is ignored.

Where,

1. Constraint to ensure sum of AS credited capacity on a Resource does not exceed that Resources capability
2. *rtype* = NCLR, *ASType*= FFR,UFR, ECRSM, NPSINM and COP Resource status = “ON”:
3. *rtype* = CLR or GR, *ASType*=RU,RD,PFR,ECRSS,NSPINS and COP Resource status = “ON” for GR and CLR, COP Resource Status = “OFFQS”, “OFF” for GR:

For GR with “OFF” COP Resource status and qualified to provide NSPIN, set LSL=0 for the equation below, otherwise this “OFF” GR is considered equivalent to a GR with “OUT” status and is ignored.

1. *rtype* = ESR, *ASType*=RU,RD,FFR,PFR,ECRSS,NSPINS and COP Resource status = “ON”:
2. Constraints to respect the HSL, LSL and the three ESR SOC constraints (COP Resource status = “ON”)
3. HSL Constraint:
4. LSL Constraint:
5. MinSOC Constraint:
6. MaxSOC Constraint:
7. DiffHBSOC Constraint:
8. **QSE AS Shortage (RUCASFSNAP)**
9. QSE portfolio ESR net MW discharging or charging MW (ESRMWSNAP*ruc,q,h* ):

The third ESR SOC constraint is used to calculate the QSE portfolio ESR net discharging or charging MW based on the discharging or charging MW of individual ESRs in the QSE portfolio used to cover the QSE’s AS positions.

1. QSE Portfolio Upward AS MW credit due to QSE’s ESRs: QSE UP AS position covered by its ESRs (ESRASSNAP*ruc,q,h*)

**ESRASSNAP*ruc,q,h* =**

**where ASType excludes RD (only considers Upward AS types)**

SOC related parameters:

: Time duration required to sustain MW energy dispatch (analogous to Real-Time Base Point)

: Time duration required to sustain MW Regulation Up/Down dispatch (analogous to Real-Time Regulation Up/Down MW award )

: Time duration required to sustain MW RRS-PFR dispatch (analogous to Real-Time RRS-PFR MW award )

: Time duration required to sustain MW RRS-FFR dispatch (analogous to Real-Time RRS-FFR MW award )

: Time duration required to sustain MW ECRS dispatch (analogous to Real-Time ECRS MW award )

: Time duration required to sustain MW Non-Spin dispatch (analogous to Real-Time Non-Spin MW award )

: Deployment Factor for Regulation Up in hour *h*

: Deployment Factor for Regulation Down in hour *h*

: Deployment Factor for RRS-PFR in hour *h*

: Deployment Factor for RRS-FFR in hour *h*

: Deployment Factor for ECRS in hour *h*

: Deployment Factor for Non-Spin in hour *h*

: Time duration required to sustain MW energy dispatch (analogous to Real-Time Base Point)

: Deployment Factor Time duration for energy dispatch

: Deployment Factor Time duration for Regulation Up/Down dispatch

: Deployment Factor Time duration for RRS-PFR dispatch

: Deployment Factor Time duration for RRS-FFR dispatch

: Deployment Factor Time duration for ECRS dispatch

: Deployment Factor Time duration for Non-Spin dispatch

## QSE AS Shortfall (RUCASFSNAP)

This is a recap of RUCASFSNAP from the previous section. It is shown here again for the sake of completeness.

The modifications to the equation to determine overall shortage at RUC Snapshot (5.7.4.1.1 (11)) is shown below using the results of the optimization described above. Similar modifications are made for the QSE AS shortfall calculation at the end of the Adjustment Period (5.7.4.1.1 (14)).

## Modifications to Billing Determinants RUCCAPSNAP *ruc, q, i* , RUCCAPADJ *q, i* , RCAPSNAP *ruc, q, r, h* , and RCAPADJ *q, r, i*

The changes to RUCCAPSNAP equation are highlighted in yellow below. The changes to RUCCAPADJ (5.7.4.1.1 (13)) equation are the same but using terms that are calculated at the end of the Adjustment Period.

**RUCCAPSNAP *ruc, q, i* =RCAPSNAP *ruc, q , r, h* + (RUCCPSNAP *ruc, q, h* – RUCCSSNAP *ruc, q, h*) + (DAEP *q, p, h* –DAES *q, p, h*) +**

**(RTQQEPSNAP *ruc, q, p, i* – RTQQESSNAP *ruc, q, p, i*)**

**+  DCIMPSNAP *ruc, q, p, i* + ASOFRLRSNAP *ruc, q, r, h***

**+ ESRMWSNAP *ruc, q,h* + ESRASSNAP *ruc, q, h***

**ESRASSNAP ruc, q, h** = The QSE Upward AS MW position (RU,RRS,ECRS,NSPIN) covered by the QSEs ESR portfolio at RUC Snapshot. This is equivalent to the term ASOFRLRSNAP ruc, q, r, h in RUCCAPSNAP for Load Resources because ESRs can provide AS when charging.

**ESRMWSNAP ruc, q, h** = This is the equivalent counterpart of the GR HSL included in RCAPSNAL and RCAPADJ described above for a GR. The calculated net QSE ESR portfolio MW discharging or charging accounts for the:

* + 1. QSE AS MW positions covered by the QSEs ESR portfolio for a given hour,
    2. the MinSOC, MaxSOC, HBSOC for hour h (minSOC and maxSOC constraint satisfied) and;
    3. the difference between HBSOC for hour h and HBSOC for hour h+1 (difference of HBSOC is the net of energy dispatch and AS deployment using AS Deployment Factors) at RUC Snapshot.

Similar terms ESRASADJ and ESRMWADJ are there for the calculations at the end of the Adjustment Period.

* Remove ESR HSL from RCAPSNAP and RCAPADJ

With the introduction of ESRMWSNAP and ESRMWADJ in RUCCAPSNAP and RUCCAPADJ respectively; ESR HSL is removed from RCAPSNAP and RCAPADJ.

Shown below are the description of the Billing Determinants. Changes/New are highlighted in yellow.

|  |  |  |
| --- | --- | --- |
| ESRASSNAP ***ruc, q, h*** | MW | *Calculated AS MW Capacity Provided By QSE’s ESR Portfolio based on data from the RUC Snapshot –* The total ESR MW capacity used to cover the QSE *q’s* Upward AS position for Reg-Up, RRS,ECRS,and NSPIN in the RUC Snapshot for the RUC process *ruc*, for the hour *h* that includes the 15-minute Settlement Interval. |
| ESRMWSNAP ***ruc, q, h*** | MW | *Calculated QSE Total ESR MW Discharging or Charging Required To Support AS based on data from the RUC Snapshot* – The total net ESR MW discharging or charging required to cover the QSE *q’s* AS position provided by the QSE ESR portfolio in the RUC Snapshot for the RUC process *ruc*, for the hour *h* that includes the 15-minute Settlement Interval, taking into account the COP SOC values from COP. |
| ESRASADJ ***q, h*** | MW | *Calculated AS MW Capacity Provided By QSE’s ESR Portfolio at the end of the Adjustment Period –* The total ESR MW capacity used to cover the QSE *q’s* Upward AS position for Reg-Up, RRS,ECRS,and NSPIN during the hour *h* that includes the 15-minute Settlement Interval |
| ESRMWADJ ***q, h*** | MW | *Calculated QSE Total ESR MW Discharging or Charging Required To Support AS at the end of the Adjustment Period* – The total ESR MW discharging or charging required to cover the QSE *q’s* AS position provided by the QSE ESR portfolio during the hour h that includes the 15-minute Settlement Interval, taking into account the COP SOC values from COP. |
| RUCCAPSNAP *ruc, q, i* | MW | *RUC Capacity Snapshot at time of RUC*—The amount of the QSE *q*’s calculated capacity in the RUC Snapshot for the RUC process *ruc* for a 15-minute Settlement Interval *i*. |
| RUCCAPADJ q, i | MW | *RUC Capacity at End of Adjustment Period—The amount of the QSE q’s calculated capacity, excluding capacity for IRRs, at the end of the Adjustment Period for a 15-minute Settlement Interval i.* |
| RCAPSNAP ruc, q, r, h | MW | *Resource Capacity at Snapshot—*The available capacity of Generation Resource ~~or ESR~~ r represented by the QSE q, according to the RUC Snapshot for the RUC process ruc for the hour h that includes the 15-minute Settlement Interval. For ~~ESRs and~~ Generation Resources that are not IRRs, the available capacity shall be equal to HSL. For WGRs and PVGRs, the available capacity shall be equal to the WGRPP and the PVGRPP, respectively. Where for a Combined Cycle Train, the Resource r is a Combined Cycle Generation Resource within the Combined Cycle Train. |
| RCAPADJ q, r, h | MW | *Resource Capacity at End of Adjustment Period—*The HSL of a non-IRR Generation Resource ~~or ESR~~ r represented by the QSE q at the end of the Adjustment Period, for the hour h that includes the 15-minute Settlement Interval. Where for a Combined Cycle Train, the Resource r is a Combined Cycle Generation Resource within the Combined Cycle Train. |

## QSE Overall Shortage (RUCOSFSNAP)

There are no modifications to the equation to determine overall shortage at RUC Snapshot or at the end of the Adjustment Period. It is provided here for the sake of completeness. Below is the equation to calculate overall shortage at RUC Snapshot. The overall shortage equation at the end of the Adjustment Period is similar.

RUCOSFSNAP *ruc, q,i* = Max (0, ((RTAML *q, p,i* \* 4) + ASONPOSSNAP *ruc, q,i* – RUCCAPSNAP *ruc, q,I* ))

## QSE Final Shortage (RUCSFSNAP)

There are no modifications to the equation to determine final shortage at RUC Snapshot or at the end of the Adjustment Period. It is provided here for the sake of completeness. Below is the equation to calculate final shortage at RUC Snapshot. The final shortage equation at the end of the Adjustment Period is similar.

RUCSFSNAP *ruc, q, i* = Max(RUCOSFSNAP *ruc, q, i* , RUCASFSNAP *ruc, q, i* )