3.1.3.2 Expected Energy Calculation Algorithm

The following notation is used in the algorithm:

- `:` For...
- `:` If...
- `i` Resource index.
- `h` Trading Hour index in the target Trading Day.
- `N` Number of Trading Hours in the target Trading Day.
- `k` Dispatch interval index from the start of a Trading Hour.
- `j` Exceptional Dispatch instruction index.
- `l` DOT sequence index from consecutive RTD, RTCD, or RTDD runs, as applicable.
- `p` Resource power output.
- `t` Time.
- `T` Time limit.
- `T_l` DOT timestamp for DOT sequence `l`. This is the mid-interval points (2.5 minutes middle point for 5-minute dispatch; 7.5 minutes middle point for 15-minute dispatch; or 5 minute middle point for 10-minute RTCD dispatch.
- `T_h,k` End time of dispatch interval `k` in Trading Hour `h`; `T_h,0` is the start of Trading Hour `h`.
- `T_0` Shorthand notation for `T_1,0`: the start of the target Trading Day.
- `TF_LOL` Forward overlapped lower operating limit extension time limit for Generating Resources.
- `TB_LOL` Backward overlapped lower operating limit extension time limit for Generating Resources.
- `TF_GLOL` Forward overlapped lower generating operating limit extension time limit for NGR.
- `TB_GLOL` Backward overlapped lower generating operating limit extension time limit for NGR.
- `TF_LLOL` Forward overlapped lower load operating limit extension time limit for NGR.
- `TB_LLOL` Backward overlapped lower load operating limit extension time limit for NGR.
- `TF_ED` Forward Exceptional Dispatch instruction extension time limit.
- `TB_ED` Backward Exceptional Dispatch instruction extension time limit.
- `TF_ref` Forward RIE terminating reference time.
- `TB_ref` Backward RIE terminating reference time.
- `NULL` No value.
- `S_GEN` Set of Generating Resources.
- `S_TIE` Set of Inter-Tie Resources.
- `S_IMP` Set of Import Resources; `S_IMP` is a subset of `S_TIE`.
- `S_EXP` Set of Export Resources; `S_EXP` is a subset of `S_TIE`.
- `S_HPD` Set of Hourly Pre-Dispatched Resources; `S_HPD` is a subset of `S_GEN` union `S_TIE`.
- `S_ECA` Set of ECA/ACA Resources; `S_ECA` is a subset of `S_GEN` union `S_TIE`.
- `S_RMR` Set of RMR Resources; `S_RMR` is a subset of `S_GEN` and `S_RMR` intersection `S_ECA` is empty.
- `S_PSH` Set of Pumped-Storage Hydro (PSH) Resources; `S_PSH` is a subset of `S_GEN` and `S_PSH` intersection `S_ECA` is empty.
- `S_PUMP` Set of Pump (Participating Load) Resources; `S_PUMP` is a subset of `S_GEN` and `S_PUMP` intersection `S_ECA` is empty.
- `S_MSS` Set of Load Following Resources; `S_MSS` is a subset of `S_GEN` union `S_IMP` and `S_MSS` intersection `S_ECA` is empty.

\((S_MSS \cap S_GEN) \cap S_HPD = \emptyset\).
Set of Inter-Tie Generating Resources (Generating Resources at Scheduling Points); 
\[ S_{TG} \subseteq S_{GEN} \]

Set of Non-Generating Resources; Resources explicitly identified as NGR resources.

Registered Minimum Load at Generating Side of NGR resources. This is a positive number. It is assumed 0 for NGR.

Registered Maximum Capacity at Generating Side of NGR resources. This is a positive number. It is assumed constant.

Registered Minimum Load at Load Side of NGR resources. This is a negative number. It is assumed 0 for NGR.

Registered Maximum Capacity at Load Side of NGR resources. This is a negative number. It is assumed constant.

Pumping Level for Pumped-Storage Hydro and Pump Resources.

Day-Ahead Lower Economic Limit; the bottom of the day-ahead energy bid. 
(MQS needs to derive this value from DA mitigated energy bid.)

Day-Ahead Upper Economic Limit; the top of the day-ahead energy bid. 
(MQS needs to derive this value from DA mitigated energy bid.)

Real-Time Lower Operating Limit; it reflects Minimum Load overrates. This does not apply to NGR resources.

Real-Time Upper Operating Limit; it reflects Maximum Capacity derates. This does not apply to NGR resources.

Real-Time Lower Operating Limit at Gen Side; it reflects \( G_{MIN} \) overrates. This applies to NGR resources only, and will be assumed as zero.

Real-Time Upper Operating Limit at Gen Side; it reflects \( G_{MAX} \) derates. This applies to NGR resources only.

Real-Time Lower Operating Limit at Load Side; it reflects \( L_{MIN} \) overrates. This applies to NGR resources only, and will be assumed as zero.

Real-Time Upper Operating Limit at Load Side; it reflects \( L_{MAX} \) derates. This applies to NGR resources only.

Real-Time Lower Economic Limit; the bottom of the real-time energy bid.

Real-Time Upper Economic Limit; the top of the real-time energy bid.

Real-Time Commitment Status (0: offline; 1: generating; –1: pumping; for Generating Resources; 1 for all others).

Real-Time mitigated energy bid function; bid price versus power output.

Day-Ahead Schedule.

Day-Ahead Base Schedule for ECA/ACA Resources; it is included in the DAS.

Day-Ahead Scheduled Energy.

Day-Ahead Base Energy.

Day-Ahead Minimum Generating Energy; the Day-Ahead Energy attributed to \( G_{MIN} \) for NGR.

Day-Ahead Minimum Load Energy; the Day-Ahead Energy attributed to \( P_{MIN} \) for Generating Resources or the Day-Ahead Energy attributed to \( L_{MIN} \) for NGR.

Day-Ahead Self-Scheduled Energy.

Day-Ahead Bid Awarded Energy.

Day-Ahead Net Energy.

Day-Ahead Pumping Energy.

Hour-Ahead Schedule for Hourly Pre-Dispatched Resources.
RTBS Real-Time Base Schedule for ECA/ACA Resources; it is included in the HAS for HPD Resources.
RTBD Real-Time Base Deviation.
DOT Dispatch Operating Target; resource dispatch including the RTBS.
DOP(t) Dispatch Operating Point function; expected resource power output, including the RTBS, versus time.
s(t) DOP Slope Direction function versus time.
SR(t) Standard Ramp function; expected resource scheduled power output, including the 20-min linear ramp across hourly boundaries, if applicable, versus time.
RTSS Real-Time Total Self-Schedule for Generating or Inter-Tie Resource.
RTTGSS Real-Time Total Generating Self-Schedule for NGR.
RTTLSS Real-Time Total Load Self-Schedule for NGR.
RTLMP Real-Time Locational Marginal Price. HPD resources will still have the real-time LMP (5-min) from RTM in addition to the HASP LMP (hourly shadow prices). MQS needs to make sure to get the real-time LMP to use as RTLMP, not the HASP LMP.
RTLED Real-Time Lower unconstrained Economic Dispatch based on the LMP and the energy bid.
RTUED Real-Time Upper unconstrained Economic Dispatch based on the LMP and the energy bid.
ED_MIN Minimum Exceptional Dispatch including the RTBS.
ED_MAX Maximum Exceptional Dispatch including the RTBS.
ED_FIX Fixed Exceptional Dispatch including the RTBS.
ED_BND Binding Exceptional Dispatch including the RTBS.
QLFI Qualified Load Following Instruction for non-HPD Load Following Resources.
RS Reference Schedule.
IIE Instructed Imbalance Energy.
BED Base Energy Deviation.
SRE Standard Ramping Energy.
EXME Extra-Marginal Energy.
RED Ramping Energy Deviation.
ORED Overlapping Ramping Energy Deviation.
NRED Non-overlapping Ramping Energy Deviation.
GNRED Non-overlapping Ramping Energy Deviation for NGR in generating mode.
LNRED Non-overlapping Ramping Energy Deviation for NGR in load mode.
RIE Residual Imbalance Energy.
TRIE Top of the hour RIE.
GTRIE Top of the hour RIE for NGR in generating mode.
LTRIE Top of the hour RIE for NGR in load mode.
BRIE Bottom of the hour RIE.
GBRIE Bottom of the hour RIE for NGR in generating mode.
LBRIE Bottom of the hour RIE for NGR in load mode.
RTMGE Real-Time Minimum Generating Energy; the Real-Time Energy attributed to G_MIN for NGR.
RTMLE Real-Time Minimum Load Energy; the Real-Time Energy attributed to Pmin for Generating Resources or the Real-Time Energy attributed to L_MIN for NGR.
RTPE  Real-Time Pumping Energy.
HASE  Hour-Ahead Scheduled Energy.
DRE   Derate Energy.
UDRE  Upper Derate Energy due to $P_{MAX}$ derates.
GUDRE Generating Upper Derate Energy due to $G_{MAX}$ derates.
LUDRE Load Upper Derate Energy due to $L_{MAX}$ derates.
LDRE  Lower Derate Energy due to $P_{MIN}$ overrates.
GLDRE Generating Lower Derate Energy due to $G_{MIN}$ overrates.
LLDRE Load Lower Derate Energy due to $L_{MIN}$ overrates.
LFE   Load Following Energy.
EDE   Exceptional Dispatch Energy.
OE    Optimal Energy.
OOE   Overlapping Optimal Energy.
GGOE  Overlapping Optimal Energy for NGR in generating mode.
LOOE  Overlapping Optimal Energy for NGR in load mode.
NOE   Non-overlapping Optimal Energy.
GNOE  Non-overlapping Optimal Energy for NGR in generating mode.
LNOE  Non-overlapping Optimal Energy for NGR in load mode.
TOL   Configurable tolerance used in integral termination time calculation; set by default to 0.005 MW.
RAMPT Ramping Tolerance expected energy.
TEE   Total Expected Energy (based on DOP).
TTEE  Total Target Expected Energy (based on RDOT).
RDOT(t) Ramping Dispatch Operating Target; a continuous piecewise linear curve connecting consecutive DOTs using their mid-interval points, from RTD, RTCD, or RTDD runs, as applicable.

All capacity quantities are in MW, all energy quantities are in MWh, all prices are in $/MWh, and time is in sec.
**Expected Energy Calculation Algorithm**

Any absent variables are considered zero. For example, a missing DAS is considered zero. Energy quantities are zero by default when the relevant conditions in their formulae do not hold. One exception to this rule, given an interval and a resource, if the resource is not committed or within the startup/shutdown period in DA or RT, there should be no expected energy and allocation calculated. This is to avoid a lot of zero expected energy being calculated.

The Total Self-Schedule is the sum of all self-schedules except pumping self-schedules. The energy bid, and thus the Lower/Upper Economic Limits are relative to the Total Self-Schedule, which includes the Base Schedule. For Generating Resources, the Lower Economic Limit is equal to the higher of the Total Self-Schedule or the Minimum Load. The Upper Economic Limit is equal to the top of the energy bid. If there is no energy bid, the Upper Economic Limit is equal to the Lower Economic Limit. For NGR, if there is a Generating Self-Schedule, the Lower Economic limit is equal to the Total Generating Self-Schedule, and if there is a Load Self-Schedule, the Upper Economic limit is equal to the Total Load Self-Schedule.

The Lower Operating Limit is greater than or equal to the Minimum Load and it reflects Minimum Load overrates. The Minimum Load and the Lower Operating Limit for Inter-Tie Resources are both zero. The Upper Operating Limit is less than or equal to the Maximum Capacity and it reflects Maximum Capacity derates. The Maximum Capacity and the Upper Operating Limit for Inter-Tie Resources are both infinite.

\[
\begin{align*}
0 & \leq P_{MIN} \leq RTLE_{i,h} \leq RTUEL_{i,h} \leq P_{MAX} \quad \therefore i \in S_{GEN} \\
0 & \leq P_{MIN} \leq RTLOL_{i,h,k} \leq RTUOL_{i,h,k} \leq P_{MAX} \quad \therefore i \in S_{TIE} \\
P_{MIN} & = RTLOL_{i,h,k} = 0 \\
P_{MAX} & = RTUOL_{i,h,k} = \infty \\
L_{MAX} & \leq RTLE_{i,h} \leq RTUEL_{i,h} \leq G_{MAX} \\
G_{MIN} & \leq GRTLOL_{i,h,k} \leq GRTUOL_{i,h,k} \leq G_{MAX} \\
L_{MAX} & \leq LRTUOL_{i,h,k} \leq LRTLOL_{i,h,k} \leq L_{MIN} \quad \therefore i \in S_{NGR} \\
G_{MIN} & = 0 \\
L_{MIN} & = 0 \\
\therefore i \in S_{NGR}
\end{align*}
\]

*LRTLOL* and *GRTLOL* are always zero until we implement the non-zero *GMIN* and *LMIN*. 

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3.1.3.2.1 Day-Ahead Scheduled Energy
\[ \text{DASE}_{i,h} = DAS_{i,h} \times \text{hr} \]

3.1.3.2.2 Day-Ahead Base Energy
\[ \text{DABE}_{i,h} = DABS_{i,h} \times \text{hr} \]

3.1.3.2.3 Day-Ahead Minimum Generating and Load Energy
\[ \text{DAMLE}_{i,h} = \max \left( 0, \min \left( DAS_{i,h}, P_{\text{MIN}} \right) - DABS_{i,h} \right) \times \text{hr} \quad \because i \in S_{\text{GEN}} \cup S_{\text{TE}} \]
\[ \text{DAMGE}_{i,h} = \max \left( 0, \min \left( DAS_{i,h}, G_{\text{MIN}} \right) \right) \times \text{hr} \quad \because i \in S_{\text{NGR}} \]
\[ \text{DAMLE}_{i,h} = \min \left( 0, \max \left( DAS_{i,h}, L_{\text{MIN}} \right) \right) \times \text{hr} \quad \because i \in S_{\text{NGR}} \]

Note: For NGR resources: \( G_{\text{MIN}} = 0 \), and \( L_{\text{MIN}} = 0 \), thus \( \text{DAMGE}_{i,h} = \text{DAMLE}_{i,h} = 0 \).

3.1.3.2.4 Day-Ahead Self Scheduled Energy
\[ \text{DASE}_{i,h} = \max \left( 0, \min \left( DAS_{i,h}, \text{DAE}_{i,h} \right) - \max \left( P_{\text{MIN}}, DABS_{i,h} \right) \right) \times \text{hr} \quad \because i \in S_{\text{GEN}} \cup S_{\text{TE}} \]
\[ \text{DASE}_{i,h} = \begin{cases} \max \left( 0, \min \left( DAS_{i,h}, \text{DAE}_{i,h} \right) - G_{\text{MIN}} \right) \times \text{hr} & : DAS_{i,h} \geq 0 \\ \min \left( 0, \max \left( DAS_{i,h}, \text{DAE}_{i,h} \right) - L_{\text{MIN}} \right) \times \text{hr} & : DAS_{i,h} < 0 \end{cases} \quad \because i \in S_{\text{NGR}} \]

3.1.3.2.5 Day-Ahead Bid Awarded Energy
\[ \text{DABAE}_{i,h} = \max \left( 0, DAS_{i,h} - \text{DAE}_{i,h} \right) \times \text{hr} \quad \because i \in S_{\text{GEN}} \cup S_{\text{TE}} \]
\[ \text{DABAE}_{i,h} = \begin{cases} \max \left( 0, DAS_{i,h} - \max \left( 0, \text{DAE}_{i,h} \right) \right) \times \text{hr} & : DAS_{i,h} \geq 0 \\ \min \left( 0, DAS_{i,h} - \min \left( 0, \text{DAE}_{i,h} \right) \right) \times \text{hr} & : DAS_{i,h} < 0 \end{cases} \quad \because i \in S_{\text{NGR}} \]

3.1.3.2.6 Day-Ahead Net Energy
\[ \text{DANE}_{i,h} = \text{DAMLE}_{i,h} + \text{DASE}_{i,h} + \text{DABAE}_{i,h} \quad \because i \in S_{\text{GEN}} \cup S_{\text{TE}} \]
\[ DANE_{i,h} \equiv DAMGE_{i,h} + DAMLE_{i,h} + DASSE_{i,h} + DABAE_{i,h} \quad : \ i \in S_{NGR} \]

3.1.3.2.7 Day-Ahead Pumping Energy

\[ DAPE_{i,h} = \min (0, DAS_{i,h}) \times \text{Ihr} \quad : \ i \in S_{GEN} \cup S_{TIE} \]

3.1.3.2.8 Day-Ahead Energy Accounting Balance

\[ DASE_{i,h} \triangleq DAPE_{i,h} + DABE_{i,h} + DAMLE_{i,h} + DASSE_{i,h} + DABAE_{i,h} \quad : \ i \in S_{GEN} \cup S_{TIE} \]

\[ DASE_{i,h} \triangleq DABE_{i,h} + DAMGE_{i,h} + DAMLE_{i,h} + DASSE_{i,h} + DABAE_{i,h} \quad : \ i \in S_{NGR} \]

3.1.3.2.9 Block Energy Accounting Rules

The DOP of the following Resources is converted to a step function at the relevant DOTs for Expected Energy accounting as follows:

\[ DOP_{i,h}(t) = DOT_{i,h,k} \quad : T_{h,k-1} \leq t < T_{h,k}, \quad k = 1,2,\ldots,12 \quad \forall \ i \in S_{TIE} \cup S_{ECA} \cup (S_{TE} \cap S_{HPD}) \]

3.1.3.2.10 Instructed Imbalance Energy

\[ IIE_{i,h,k} = \int_{T_{h,k-1}}^{T_{h,k}} \frac{(DOP(t) - DAS_{i,h})}{3600} dt \]

For Generating, NGR, or Import Resources, positive Instructed Imbalance Energy is produced, whereas negative Instructed Imbalance Energy is consumed. The converse is true for Export Resources, i.e., positive Instructed Imbalance Energy is consumed, whereas negative Instructed Imbalance Energy is produced.

3.1.3.2.11 Base Energy Deviation

The Real-Time Base Deviation is defined as follows:

\[ RTBD_{i,h,k} \equiv RTBS_{i,h,k} - DABS_{i,h} \quad : \ i \in S_{ECA} \]

The Base Energy Deviation is calculated as follows:

\[ BED_{i,h,k} = \int_{T_{h,k-1}}^{T_{h,k}} \frac{RTBD_{i,h,k}}{3600} dt \quad : \ i \in S_{ECA} \]
3.1.3.2.12 Standard Ramping Energy

The Standard Ramp function is defined as follows:

$$SR_{i,h}(t) = \begin{cases} 
DAS_{i,h} + \frac{DAS_{i,h+1} - DAS_{i,h}}{1200} (T_{h,2} - t) & : T_{h,0} \leq t \leq T_{h,2} \\
DAS_{i,h} & : T_{h,2} \leq t \leq T_{h,10} \\
DAS_{i,h} + \frac{DAS_{i,h+1} - DAS_{i,h}}{1200} (t - T_{h,10}) & : T_{h,10} \leq t \leq T_{h,12} \\
DAS_{i,h} & : i \in S_{HPD} \cup S_{TIE} \cup S_{ECA}
\end{cases}$$

The Standard Ramping Energy is calculated as follows:

$$SRE_{i,h,k} = \int_{T_{h,k-1}}^{T_{h,k}} \frac{(SR_{i,h}(t) - DAS_{i,h})}{3600} dt = \begin{cases} 
\frac{(DAS_{i,h-1} - DAS_{i,h})}{32} & : i \notin S_{HPD} \cup S_{TIE} \cup S_{ECA} \land k = 1 \\
\frac{(DAS_{i,h-1} - DAS_{i,h})}{96} & : i \notin S_{HPD} \cup S_{TIE} \cup S_{ECA} \land k = 2 \\
\frac{(DAS_{i,h+1} - DAS_{i,h})}{96} & : i \notin S_{HPD} \cup S_{TIE} \cup S_{ECA} \land k = 11 \\
\frac{(DAS_{i,h+1} - DAS_{i,h})}{32} & : i \notin S_{HPD} \cup S_{TIE} \cup S_{ECA} \land k = 12
\end{cases}$$

3.1.3.2.13 Load Following Energy

The Load Following Energy is calculated as follows:

$$LFE_{i,h,k} = \begin{cases} 
\int_{T_{h,k-1}}^{T_{h,k}} \frac{\min\left(0, DAS_{i,h} + QLFI_{i,h,k} - \min\left(DAS_{i,h}, SR_{i,h,k}(t)\right)\right)}{3600} dt & : QLFI_{i,h,k} < 0 \\
\int_{T_{h,k-1}}^{T_{h,k}} \frac{\max\left(0, DAS_{i,h} + QLFI_{i,h,k} - \max\left(DAS_{i,h}, SR_{i,h,k}(t)\right)\right)}{3600} dt & : QLFI_{i,h,k} > 0
\end{cases}$$

Note: Currently, NGR resources cannot be MSS Load Following Resources.

3.1.3.2.14 Reference Schedule

To combine the distinct effects of Load Following and Base Schedule Deviation in the formulae, it is convenient to define the following Reference Schedule function:

$$RS_{i,h}(t) = \begin{cases} 
RTBD_{i,h,k} + QLFI_{i,h,k} & : T_{h,k-1} \leq t < T_{h,k}, k = 1,2,\ldots,12
\end{cases}$$
3.1.3.2.15 Real-Time Pumping Energy

RTPE is the algebraic sum of negative IIE due to pumping increase and positive IIE due to pumping reduction, as follows:

\[
RTPE_{i,h,k} = \int_{\tau_{i,k-1}}^{\tau_{i,k}} \frac{\min\left(0, DOP(t) - \min\left(0, RS_{i,h,k}, DAS_{i,h}, SR_{i,h}(t)\right)\right)}{3600} dt + \int_{\tau_{i,k}}^{\tau_{i,k+1}} \frac{\max\left(0, \min\left(0, DOP(t)\right) - \max\left(0, RS_{i,h,k}, DAS_{i,h}, SR_{i,h}(t)\right)\right)}{3600} dt \quad : i \in S_{GEN} \cup S_{TIE}
\]

3.1.3.2.16 Real-Time Minimum Generating Energy and Minimum Load Energy

\[
RTMLE_{i,h,k} = \int_{\tau_{i,k-1}}^{\tau_{i,k}} \frac{\max\left(0, \min\left(DOP(t), P_{MIN}\right) - \min\left(0, RS_{i,h,k}, DAS_{i,h}, SR_{i,h}(t)\right)\right)}{3600} dt \quad : i \in S_{GEN} \cup S_{TIE}
\]

\[
RTMGEn_{i,h,k} = \int_{\tau_{i,k-1}}^{\tau_{i,k}} \frac{\max\left(0, \min\left(DOP(t), G_{MIN}\right) - \max\left(0, RS_{i,h,k}, DAS_{i,h}, SR_{i,h}(t)\right)\right)}{3600} dt \quad : i \in S_{NGR}
\]

\[
RTMLE_{i,h,k} = \int_{\tau_{i,k}}^{\tau_{i,k+1}} \frac{\min\left(0, \max\left(DOP(t), L_{MPL}\right) - \min\left(0, RS_{i,h,k}, DAS_{i,h}, SR_{i,h}(t)\right)\right)}{3600} dt \quad : i \in S_{NGR}
\]

3.1.3.2.17 Hour-Ahead Scheduled Energy

\[
HASE_{i,h} = \int_{\tau_{i,0}}^{\tau_{i,1}} \frac{\max\left(0, HAS_{i,h} - \max\left(P_{MIN}, RS_{i,h}\right)\right)}{3600} dt + \int_{\tau_{i,0}}^{\tau_{i,1}} \frac{\min\left(0, \max\left(0, HAS_{i,h}\right) - RS_{i,h}\right)}{3600} dt \quad : i \in S_{HPD}
\]

3.1.3.2.18 Extra-Marginal Energy

Extra-Marginal Energy is either produced Instructed Imbalance Energy at a higher bid price than the real-time LMP or consumed Instructed Imbalance Energy at a lower bid price than the real-time LMP, exclusive of Standard Ramping Energy. For Generating and Non-Generating Resources in generating mode and for Import Resources, Instructed Imbalance Energy without a bid price, i.e., below or above the energy bid, is considered to be bid at \(-\infty\) if it is lower than the Lower Economic Limit, and at \(+\infty\) if it is higher than the Upper Economic Limit. The converse is true for Export Resources, i.e., Instructed Imbalance Energy is considered to be bid at \(+\infty\) if it is lower than the Lower Economic Limit, and at \(-\infty\) if it is higher than the Upper Economic Limit. For Pumped-Storage Hydro and
Pump Resources in pumping mode, Instructed Imbalance Energy is considered to be bid at $+\infty$ if it is higher than the Pumping Level, and at $-\infty$ if it is lower than the Pumping Level.

To calculate Extra-Marginal Energy, the real-time LMP must be indexed against the relevant energy bid as follows:

$$
RTLED_{i,h,k} = \max \{ p : RTBP_{i,h}(p) < RTLMP_{i,h,k} \} \quad \therefore RTCS_{i,h,k} \geq 0
$$

$$
RTUED_{i,h,k} = \min \{ p : RTBP_{i,h}(p) > RTLMP_{i,h,k} \} \quad \therefore RTCS_{i,h,k} = -1
$$

$RTLED$ and $RTUED$ are either both equal to the energy bid breakpoint where the bid price jumps over the $RTLMP$, including the $RTLEL$ or $RTUEL$, or equal to the start and end, respectively, of the energy bid segment with a bid price equal to the $RTLMP$ when the resource is marginal. $RTLED$ and $RTUED$ are both equal to the Pumping Level for pumping mode. For NGR with a discontinuity across zero, it is assumed that a single Energy Bid segment will span the range from $L_{MIN}$ to $G_{MIN}$. If the $RTLMP$ matches the bid price of that segment: $RTLED = L_{MIN}$ and $RTUED = G_{MIN}$. Also it is important to note that, when there is no real-time energy bid:

$$
RTLED_{i,h,k} = RTUED_{i,h,k} = \max( RTSS_{i,h,k}, P_{MIN} ) \quad \therefore i \in S_{GEN} \cup S_{TIE}
$$

$$
RTLED_{i,h,k} = RTUED_{i,h,k} = \begin{cases} 
\max( RTTGSS_{i,h,k}, G_{MIN} ) & \because RTTGSS_{i,h,k} > 0 \\
\min( RTTLSS_{i,h,k}, L_{MIN} ) & \because RTTLSS_{i,h,k} < 0 \\
0 & \because RTTGSS_{i,h,k} = RTTLSS_{i,h,k} = 0 
\end{cases} \quad \therefore i \in S_{NGR}
$$

In general, $RTLED$ and $RTUED$ may differ in each dispatch interval. For the following sections, it is convenient to define the following functions:

$$
RTLED_{i,h,k}(t) = RTLED_{i,h,k} \\
RTUED_{i,h,k}(t) = RTUED_{i,h,k}
$$

$RTLED_{i,h,k}(t) = RTLED_{i,h,k}$ $\because T_{h,k-1} \leq t < T_{h,k}, \quad k = 1,2,...,12$

Extra-Marginal Energy is calculated separately for each relevant Instructed Imbalance Energy subtype, as shown in the following sections.

3.1.3.2.19 Dispatch Operating Point Slope Direction

The Slope Direction of the Dispatch Operating Point function is the sign of its first derivative as follows:
s(t) = \text{signum}\left( \frac{d\text{DOP}(t)}{dt} \right) = \begin{cases} 
-1 & \text{decreasing} \\
0 & \text{flat} \\
1 & \text{increasing} 
\end{cases}

The Dispatch Operating Point may be discontinuous at the midpoint of each Dispatch Interval because of “vertical” corrections due to the “projected” State Estimator solution. The Slope Direction may change at these points, however, it remains constant for the first half and the second half of the Dispatch Interval. Note that the slope itself may change within these halves because of ramp rate changes; however, the slope direction does not change. Therefore, the Dispatch Operating Point Slope Direction can also be determined as follows:

\begin{align*}
-1 & : \text{DOP}(t_{h,k-1}) > \text{DOP}\left( \frac{T_{h,k-1} + T_{h,k}}{2} \right) \\
0 & : \text{DOP}(t_{h,k-1}) = \text{DOP}\left( \frac{T_{h,k-1} + T_{h,k}}{2} \right) \\
1 & : \text{DOP}(t_{h,k-1}) < \text{DOP}\left( \frac{T_{h,k-1} + T_{h,k}}{2} \right)
\end{align*}

3.1.3.2.20 Operating Limits

For the following sections, it is convenient to define the following operating limit functions:

\begin{align*}
RTUOL_{i,k}(t) & = RTUOL_{i,h,k} & : T_{h,k-1} \leq t < T_{h,k}, & k = 1,2,\ldots,12, & i \in \mathcal{S}_{\text{GEN}} \cup \mathcal{S}_{\text{TH}} \\
RTLOL_{i,k}(t) & = RTLOL_{i,h,k} & : T_{h,k-1} \leq t < T_{h,k}, & k = 1,2,\ldots,12, & i \in \mathcal{S}_{\text{GEN}} \cup \mathcal{S}_{\text{TH}}
\end{align*}
An overrated operating limit in a given Dispatch Interval is extended to subsequent and previous Dispatch Intervals while the Dispatch Operating Point ramps from/to that overrated operating limit to/from RTUED/RTLED, as follows:

\[
\begin{align*}
GR\text{TUOL}_{i,k}(t) & \equiv GR\text{TUOL}_{i,k,k} \\
GR\text{TLOL}_{i,k}(t) & \equiv GR\text{TLOL}_{i,k,k} \\
LR\text{TUOL}_{i,k}(t) & \equiv LR\text{TUOL}_{i,k,k} \\
LR\text{TLOL}_{i,k}(t) & \equiv LR\text{TLOL}_{i,k,k}
\end{align*}
\]

\[
\begin{align*}
: T_{h,k-1} \leq t < T_{h,k}, & \quad k = 1,2,\ldots,12, i \in S_{NGR}
\end{align*}
\]

Where the forward and backward overrated lower operating limit extension time limits are calculated as follows:

\[
\begin{align*}
TF_{LOL} & = \max T \quad : \begin{cases} RTLOL_{h,k} > P_{MIN} \\ s_i(t) = -1 \\ DOP(t) > RTUED_{i,k}(t) + TOL \end{cases} \quad : T_{h,k} \leq t \leq T_N \\
TB_{LOL} & = \min T \quad : \begin{cases} RTLOL_{h,k} > P_{MIN} \\ s_i(t) = 1 \\ DOP(t) > RTUED_{i,k}(t) + TOL \end{cases} \quad : T_{h,k-1} \geq t \geq T_0
\end{align*}
\]
If the search reaches the end or start of the target Trading Day, it shall continue into subsequent or previous Trading Days as needed.

### 3.1.3.2.21 Binding Exceptional Dispatch

There could be multiple Exceptional Dispatch instructions active in a given Dispatch Interval. Nevertheless, only one at most can be binding, determined as follows:

\[
TF_{GLOK} = \max T \quad : \quad \begin{cases} 
  GRTLOL_{t,k,h} > G_{MIN} \\
  s_i(t) = -1 \\
  DOP(t) > RTUED_{t,k,h}(t) + TOL
  
\end{cases} \quad : \quad T_{k,h} \leq t \leq T_N
\]

\[
TB_{GLOK} = \min T \quad : \quad \begin{cases} 
  GRTLOL_{t,k,h} > G_{MIN} \\
  s_i(t) = 1 \\
  DOP(t) > RTUED_{t,k,h}(t) + TOL
  
\end{cases} \quad : \quad T_{k,h-1} \geq t \geq T_0
\]

\[
TF_{LLOK} = \max T \quad : \quad \begin{cases} 
  LRTLOL_{t,k,h} < L_{MIN} \\
  s_i(t) = 1 \\
  DOP(t) < RTLED_{t,k,h}(t) - TOL
  
\end{cases} \quad : \quad T_{k,h} \leq t \leq T_N
\]

\[
TB_{LLOK} = \min T \quad : \quad \begin{cases} 
  LRTLOL_{t,k,h} < L_{MIN} \\
  s_i(t) = -1 \\
  DOP(t) < RTLED_{t,k,h}(t) - TOL
  
\end{cases} \quad : \quad T_{k,h-1} \geq t \geq T_0
\]

It is assumed that Exceptional Dispatch instructions cannot conflict; therefore, a Fixed Exceptional Dispatch cannot coexist with other Fixed Exceptional Dispatches, a higher Min Exceptional Dispatch, or a lower Max Exceptional Dispatch; moreover, a Min Exceptional Dispatch cannot be higher than a Max Exceptional Dispatch.

In general, the binding Exceptional Dispatch may differ in each Dispatch Interval. For the following sections, it is convenient to define the following function:

\[ ED_{BIND,k,h} = \begin{cases} 
  \max(ED_{FIX,k,h}, ED_{MIN,k,h,k}) & : ED_{FIX,k,h}, ED_{MIN,k,h,k} > RTUED_{t,k,h} \\
  \min(ED_{FIX,k,h}, ED_{MAX,k,h,k}) & : ED_{FIX,k,h}, ED_{MAX,k,h,k} < RTLED_{t,k,h} \\
  NULL & : \text{otherwise}
\end{cases} \]
The binding Exceptional Dispatch instruction in a given Dispatch Interval is extended to subsequent and previous Dispatch Intervals without a binding Exceptional Dispatch instruction while the Dispatch Operating Point ramps from/to the binding Exceptional Dispatch instruction to/from \( RTUED/RTLED \), as follows:

\[
ED_{BIND,h,k}(t) = ED_{BIND,h,k} \quad \vdash T_{h,k-1} \leq t < T_{h,k}, \quad k = 1, 2, \ldots, 12
\]

Where the forward and backward Exceptional Dispatch instruction extension time limits are calculated as follows:

\[
TF_{ED} = \max \left\{ \begin{array}{ll}
T & : \begin{array}{l}
ED_{BIND,h}(t) = NULL \\
s_i(t) = -1 \\
DOP_i(t) > RTUED_{i,h}(t) + TOL
\end{array}
\end{array} \right\}
\]

\[
TB_{ED} = \min \left\{ \begin{array}{ll}
T & : \begin{array}{l}
ED_{BIND,h}(t) = NULL \\
s_i(t) = 1 \\
DOP_i(t) > RTUED_{i,h}(t) + TOL
\end{array}
\end{array} \right\}
\]

\[
DF_{ED} = \max \left\{ \begin{array}{ll}
T & : \begin{array}{l}
ED_{BIND,h}(t) = NULL \\
s_i(t) = 1 \\
DOP_i(t) < RTLED_{i,h}(t) - TOL
\end{array}
\end{array} \right\}
\]

\[
TB_{ED} = \min \left\{ \begin{array}{ll}
T & : \begin{array}{l}
ED_{BIND,h}(t) = NULL \\
s_i(t) = -1 \\
DOP_i(t) < RTLED_{i,h}(t) - TOL
\end{array}
\end{array} \right\}
\]

If the search reaches the end or start of the target Trading Day, it shall continue into subsequent or previous Trading Days as needed.

To complete the Exceptional Dispatch function, any remaining NULL sections are replaced after extensions as follows:

\[
ED_{BIND,h,k}(t) \leftarrow \frac{RTLED_{i,h}(t) + RTUED_{i,h}(t)}{2} \quad \vdash ED_{BIND,h}(t) = NULL
\]

Considering any point in the unconstrained economic dispatch range as the binding Exceptional Dispatch by default when one does not exist, is an algorithmic mechanism to render it irrelevant in the equations without checking for its existence.

3.1.3.22  Instructed Imbalance Energy Stack

\[
\text{Figure 4.1-b. Instructed Imbalance Energy Stack for a NGR (DOP<\text{DAS at Gen Side})}
\]

\[
\text{Figure 4 illustrates how the various Instructed Imbalance Energy subtypes stack for a Generating Resource.}
\]

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Figures 4.x-a/b illustrate how the various Instructed Imbalance Energy subtypes stack for a NGR.
Figure 4.1-a. Instructed Imbalance Energy Stack for a NGR (DOP>DAS at Gen Side)
Figure 4.1-b. Instructed Imbalance Energy Stack for a NGR (DOP<DAS at Gen Side)
Figure 4.2-a. Instructed Imbalance Energy Stack for a NGR (DOP>DAS at Load Side)
Figure 4.2-b. Instructed Imbalance Energy Stack for a NGR (DOP<DAS at Load Side)
Figure 4.3-a. Instructed Imbalance Energy Stack for a NGR (DOP at Gen Side > DAS at Load Side)
Figure 4.3-b. Instructed Imbalance Energy Stack for a NGR (DOP at Load Side < DAS at Gen Side)
Figure 4.4-a. Instructed Imbalance Energy Stack for a NGR (DOP at Gen Side > DAS at Load Side)
3.1.3.2.23 Ramping Energy Deviation

The Ramping Energy Deviation is the sum of the Overlapping Ramping Energy Deviation that overlaps (and cancels) with Standard Ramping Energy and the Non-overlapping Ramping Energy Deviation:

\[ \text{RED}_{i,h,k} = \text{ORED}_{i,h,k} + \text{NRED}_{i,h,k} \quad : i \in S_{\text{GEN}} \]
\[ RED_{i,h,k} = ORED_{i,h,k} + GNRED_{i,h,k} + LNRED_{i,h,k} \quad \because i \in S_{NGR} \]

The Overlapping Ramping Energy Deviation is calculated as follows:

\[
ORED_{i,h,k} = \begin{cases} 
\int_{\tau_{h-1}}^{\tau_h} \frac{\min(0, \max(DOP(t), DAS_{i,h}) - SR_{i,h}(t))}{3600} dt & \because SR_{i,h}(t) > DAS_{i,h} \\
\int_{\tau_{h-1}}^{\tau_h} \frac{\max(0, \min(DOP(t), DAS_{i,h}) - SR_{i,h}(t))}{3600} dt & \because SR_{i,h}(t) < DAS_{i,h} 
\end{cases} \quad \therefore i \notin S_{HPD} \cup S_{TE} \cup S_{ECA} \land k = 1, 2, 11, 12
\]

The Non-overlapping Ramping Energy Deviation may occur at the start and/or end of the Trading Hour, and only for as long as the Dispatch Operating Point Slope Direction remains increasing or decreasing, as the relevant case may be. The Non-overlapping Ramping Energy Deviation can be determined by searching forward from the start of the Trading Hour and backward from the end of the Trading Hour as follows:

\[
NRED_{i,h} = \begin{cases} 
\int_{\tau_{h-1}}^{\tau_h} \frac{\min(0, \max(DOP_t, DAS_{i,h-1}) - \min(\{RTUOL_{i,h-1}(t), \ ED_{BND,h}(t), \ RTLED_{i,h}(t), \ RS_{i,h}(t), \ SR_{i,h}(t)\})}{3600} dt & \because DAS_{i,h-1} < DAS_{i,h} \\
\int_{\tau_{h-1}}^{\tau_h} \frac{\max(0, \min(DOP_t, DAS_{i,h-1}) - \max(\{RTLOL_{i,h-1}(t), \ ED_{BND,h}(t), \ RTUED_{i,h}(t), \ RS_{i,h}(t), \ SR_{i,h}(t)\})}{3600} dt & \because DAS_{i,h-1} > DAS_{i,h} \\
\int_{\tau_{h-1}}^{\tau_h} \frac{\min(0, \max(DOP_t, DAS_{i,h+1}) - \min(\{RTUOL_{i,h+1}(t), \ ED_{BND,h}(t), \ RTLED_{i,h}(t), \ RS_{i,h}(t), \ SR_{i,h}(t)\})}{3600} dt & \because DAS_{i,h+1} < DAS_{i,h} \\
\int_{\tau_{h-1}}^{\tau_h} \frac{\max(0, \min(DOP_t, DAS_{i,h+1}) - \max(\{RTLOL_{i,h+1}(t), \ ED_{BND,h}(t), \ RTUED_{i,h}(t), \ RS_{i,h}(t), \ SR_{i,h}(t)\})}{3600} dt & \because DAS_{i,h+1} > DAS_{i,h} 
\end{cases} \quad \therefore i \notin S_{NGR} \cup S_{HPD} \cup S_{TE} \cup S_{ECA}
\]
\[
\text{GNRED}_{i,h} = \begin{cases} 
\frac{\int_{t_{i-1}}^{t_i} \min\left(0, \max\left(0, DOP(t), DAS_{i,h-1}\right) - \min\left(GRTUOL_{i,h}(t), ED_{\text{BND},h}(t), RTLED_{i,h}(t), RS_{i,h}(t), SR_{i,h}(t)\right)\right) \, dt}{3600} & \text{if } DAS_{i,h-1} < DAS_{i,h} \\
\frac{\int_{t_{i-1}}^{t_i} \max\left(0, \min\left(DOP(t), DAS_{i,h-1}\right) - \max\left(GRTUOL_{i,h}(t), ED_{\text{BND},h}(t), RTLED_{i,h}(t), RS_{i,h}(t), SR_{i,h}(t)\right)\right) \, dt}{3600} & \text{if } DAS_{i,h-1} > DAS_{i,h} 
\end{cases}
\]

\[
\text{LNRED}_{i,h} = \begin{cases} 
\frac{\int_{t_{i-1}}^{t_i} \min\left(0, \max\left(0, DOP(t), DAS_{i,h-1}\right) - \min\left(LRTUOL_{i,h}(t), ED_{\text{BND},h}(t), RTLED_{i,h}(t), RS_{i,h}(t), SR_{i,h}(t)\right)\right) \, dt}{3600} & \text{if } DAS_{i,h-1} < DAS_{i,h} \\
\frac{\int_{t_{i-1}}^{t_i} \max\left(0, \min\left(DOP(t), DAS_{i,h-1}\right) - \max\left(LRTUOL_{i,h}(t), ED_{\text{BND},h}(t), RTLED_{i,h}(t), RS_{i,h}(t), SR_{i,h}(t)\right)\right) \, dt}{3600} & \text{if } DAS_{i,h-1} > DAS_{i,h} 
\end{cases}
\]

\[
\vdots \quad i \in S_{\text{NGR}}
\]

Where the integration terminating times are determined as follows:
\[ T_1 = \max T \quad \therefore \quad DOP(t) < \min \{ ED_{BND, b}(t), RTLED_{i, b}(t), SR_{i, b}(t) \} - TOL \quad \therefore \quad T_{b, 0} \leq t \leq T_{b+1, 0} \]

\[ T_2 = \max T \quad \therefore \quad DOP(t) > \max \{ ED_{BND, b}(t), RTUED_{i, b}(t), SR_{i, b}(t) \} + TOL \quad \therefore \quad T_{b, 0} \leq t \leq T_{b+1, 0} \]

\[ T_3 = \min T \quad \therefore \quad DOP(t) < \min \{ ED_{BND, b}(t), RTLED_{i, b}(t), SR_{i, b}(t) \} - TOL \quad \therefore \quad T_{b+1, 0} \geq t \geq T_{b, 0} \]

\[ T_4 = \min T \quad \therefore \quad DOP(t) > \max \{ ED_{BND, b}(t), RTUED_{i, b}(t), SR_{i, b}(t) \} + TOL \quad \therefore \quad T_{b+1, 0} \geq t \geq T_{b, 0} \]

### 3.1.3.2.24 Residual Imbalance Energy

The Residual Imbalance Energy may occur at the start and/or end of the Trading Hour, and only for as long as the Dispatch Operating Point Slope Direction remains increasing or decreasing, as the relevant case may be. The Residual Imbalance Energy at the top and bottom of the Trading Hour can be determined by searching forward from the start of the Trading Hour and backward from the end of the Trading Hour as follows:

\[
\begin{align*}
\text{RIE}_{i, b} &= \text{TRIE}_{i, b} + \text{BRIE}_{i, b} \\
\therefore i &\notin S_{\text{NGR}} \cup S_{\text{HPD}} \cup S_{\text{TE}} \cup S_{\text{ECA}} \\
\text{TRIE}_{i, b} &= \begin{cases} 
\frac{1}{3600} \int_{T_{b, 0}}^{T_{b+1, 0}} \min \{ 0, DOP(t) - \min \{ DAS_{i, b+1}, DAS_{i, b}, RTUOL_{i, b}(t), ED_{BND, b}(t), RTLED_{i, b}(t), SR_{i, b}(t), SR_{i, b}(t) \} \} dt & \therefore DOP(T_{b+1, 0}) < DAS_{i, b} \\
\frac{1}{3600} \int_{T_{b, 0}}^{T_{b+1, 0}} \max \{ 0, DOP(t) - \max \{ DAS_{i, b}, DAS_{i, b}, RTLOL_{i, b}(t), ED_{BND, b}(t), RTUED_{i, b}(t), SR_{i, b}(t), SR_{i, b}(t) \} \} dt & \therefore DOP(T_{b+1, 0}) > DAS_{i, b} 
\end{cases} \\
\therefore i &\notin S_{\text{NGR}} \cup S_{\text{HPD}} \cup S_{\text{TE}} \cup S_{\text{ECA}} \\
\text{BRIE}_{i, b} &= \begin{cases} 
\frac{1}{3600} \int_{T_{b, 0}}^{T_{b+1, 0}} \min \{ 0, DOP(t) - \min \{ DAS_{i, b+1}, DAS_{i, b}, RTUOL_{i, b}(t), ED_{BND, b}(t), RTLED_{i, b}(t), SR_{i, b}(t), SR_{i, b}(t) \} \} dt & \therefore DOP(T_{b+1, 0}) < DAS_{i, b} \\
\frac{1}{3600} \int_{T_{b, 0}}^{T_{b+1, 0}} \max \{ 0, DOP(t) - \max \{ DAS_{i, b}, DAS_{i, b}, RTLOL_{i, b}(t), ED_{BND, b}(t), RTUED_{i, b}(t), SR_{i, b}(t), SR_{i, b}(t) \} \} dt & \therefore DOP(T_{b+1, 0}) > DAS_{i, b} 
\end{cases} \\
\therefore i &\notin S_{\text{NGR}} \cup S_{\text{HPD}} \cup S_{\text{TE}} \cup S_{\text{ECA}}
\end{align*}
\]
Where the integration terminating times are determined as follows:

\[
RIE_{i,h} = GTRIE_{i,h} + LTRIE_{i,h} + GBRIE_{i,h} + LBRIE_{i,h} \quad : i \in S_{NGR}
\]

\[
GTRIE_{i,h} = \begin{cases} 
\int_{T_{i,a}}^{T_{i,b}} \min\left(0, \max\left(0, DOP(t) - \min\left(DAS_{i,h}, LRTLOI_{i,h}(t), ED_{BND_{i,h}}(t), RTLED_{i,h}(t), RS_{i,h}(t)\right)\right)\right) dt \\
\frac{3600}{T_{i,b} - T_{i,a}} \\
\end{cases} \quad \therefore DOP(T_{i,b}) < DAS_{i,h}
\]

\[
LTRIE_{i,h} = \begin{cases} 
\int_{T_{i,a}}^{T_{i,b}} \min\left(0, \max\left(0, DOP(t) - \min\left(DAS_{i,h}, LRTLOI_{i,h}(t), ED_{BND_{i,h}}(t), RTLED_{i,h}(t), RS_{i,h}(t)\right)\right)\right) dt \\
\frac{3600}{T_{i,b} - T_{i,a}} \\
\end{cases} \quad \therefore DOP(T_{i,b}) > DAS_{i,h}
\]

\[
GBRIE_{i,h} = \begin{cases} 
\int_{T_{i,a}}^{T_{i,b}} \min\left(0, \max\left(0, DOP(t) - \min\left(DAS_{i,h}, LRTLOI_{i,h}(t), ED_{BND_{i,h}}(t), RTLED_{i,h}(t), RS_{i,h}(t)\right)\right)\right) dt \\
\frac{3600}{T_{i,b} - T_{i,a}} \\
\end{cases} \quad \therefore DOP(T_{i,b}) < DAS_{i,h}
\]

\[
LBRIE_{i,h} = \begin{cases} 
\int_{T_{i,a}}^{T_{i,b}} \min\left(0, \max\left(0, DOP(t) - \min\left(DAS_{i,h}, LRTLOI_{i,h}(t), ED_{BND_{i,h}}(t), RTLED_{i,h}(t), RS_{i,h}(t)\right)\right)\right) dt \\
\frac{3600}{T_{i,b} - T_{i,a}} \\
\end{cases} \quad \therefore DOP(T_{i,b}) > DAS_{i,h}
\]
\[ T_3 = \text{max } T \quad : \quad \begin{cases} s_i(t) = 1 \\ \text{DOP}(t) < \min \{ \text{DAS}_{i,h-1}, \text{DAS}_{i,h}, \text{ED}_{\text{BND}i,h}(t), \text{RTLED}_{i,h}(t) \} - TOL \end{cases} \quad : \quad T_{h,0} \leq t \leq T \leq T_{h+1,0} \]

\[ T_6 = \text{max } T \quad : \quad \begin{cases} s_i(t) = -1 \\ \text{DOP}(t) > \max \{ \text{DAS}_{i,h-1}, \text{DAS}_{i,h}, \text{ED}_{\text{BND}i,h}(t), \text{RTLED}_{i,h}(t) \} + TOL \end{cases} \quad : \quad T_{h,0} \leq t \leq T \leq T_{h+1,0} \]

\[ T_7 = \text{min } T \quad : \quad \begin{cases} s_i(t) = -1 \\ \text{DOP}(t) < \min \{ \text{DAS}_{i,h+1}, \text{DAS}_{i,h}, \text{ED}_{\text{BND}i,h}(t), \text{RTLED}_{i,h}(t) \} - TOL \end{cases} \quad : \quad T_{h+1,0} \geq t \geq T \geq T_{h,0} \]

\[ T_8 = \text{min } T \quad : \quad \begin{cases} s_i(t) = 1 \\ \text{DOP}(t) > \min \{ \text{DAS}_{i,h+1}, \text{DAS}_{i,h}, \text{ED}_{\text{BND}i,h}(t), \text{RTLED}_{i,h}(t) \} + TOL \end{cases} \quad : \quad T_{h+1,0} \geq t \geq T \geq T_{h,0} \]

The 15-minute Trading Interval Reference for \text{TRIE}, \text{GTRIE}, and \text{LTRIE} is the one that includes or ends at the backward terminating time going beyond hourly boundaries, calculated as follows:

\[ \text{TB}_{\text{ref}} \text{ min } T \quad : \quad \begin{cases} s_i(t) = 1 \\ \text{DOP}(t) < \min \{ \text{DAS}_{i,h-1}, \text{DAS}_{i,h}, \text{ED}_{\text{BND}i,h}(t), \text{RTLED}_{i,h}(t) \} - TOL \end{cases} \quad : \quad T_{h,0} \geq t \geq T \]

The 15-minute Trading Interval Reference for \text{BRIE}, \text{GBRIE}, and \text{LBRIE} is the one that includes or starts at the forward terminating time going beyond hourly boundaries, calculated as follows:

\[ \text{TF}_{\text{ref}} \text{ max } T \quad : \quad \begin{cases} s_i(t) = -1 \\ \text{DOP}(t) < \min \{ \text{DAS}_{i,h+1}, \text{DAS}_{i,h}, \text{ED}_{\text{BND}i,h}(t), \text{RTLED}_{i,h}(t) \} - TOL \end{cases} \quad : \quad T_{h+1,0} \leq t \leq T \]

If the search reaches the end or start of the target Trading Day, it shall continue into subsequent or previous Trading Days as needed.

Note: In the above \text{TB}_{\text{ref}} and \text{TF}_{\text{ref}} formulae, \( h \) is the current hour where the conditions for the search are evaluated and it shall be decremented or incremented accordingly as the search proceeds to previous or subsequent hours.
The 15-minute mitigated Energy Bid of the 15-minute Trading Interval Reference shall be used in the settlement of Residual Imbalance Energy.

3.1.3.2.25 Derate Energy

The Derate Energy for Generating Resources is the sum of the Lower Derate Energy due to Minimum Load overrates and the Upper Derate Energy due to Maximum Capacity derates:

\[
DRE_{i,h,k} = LDRE_{i,h,k} + UDRE_{i,h,k} \quad : i \in S_{GEN}
\]

The Lower Derate Energy, including any overlap with LFE or BED, but excluding SRE, is calculated as follows:

\[
LDRE_{i,h,k} = \begin{cases} 
\frac{1}{3600} \int_{T_{i,k-1}}^{T_{i,k}} \left( \max \left(0, \min \left(DOP_i(t), RTLOL_{i,h,k}(t)\right) - \max \left(ED_{BNDL,0}(t), RTUED_{i,h,k}, HAS_{i,h}\right) \right) \right) dt \\
+ \frac{1}{3600} \int_{T_{i,k-1}}^{T_{i,k}} \left( \max \left(0, \min \left(DOP_i(t), RTLOL_{i,h,k}(t)\right) - \max \left(ED_{BNDL,0}(t), RTUED_{i,h,k}, RS_{i,h,k}, DAS_{i,h}, SR_{i,h}(t)\right) \right) \right) dt \\
\end{cases} 
\quad : i \in S_{GEN} \cup S_{HPD}
\]

The Upper Derate Energy, including any overlap with LFE or BED, but excluding SRE, is calculated as follows:

\[
UDRE_{i,h,k} = \begin{cases} 
\frac{1}{3600} \int_{T_{i,k-1}}^{T_{i,k}} \left( \min \left(0, \max \left(DOP_i(t), RTUOL_{i,h,k}\right) - \min \left(ED_{BNDL,0}(t), RTLED_{i,h,k}, HAS_{i,h}\right) \right) \right) dt \\
+ \frac{1}{3600} \int_{T_{i,k-1}}^{T_{i,k}} \left( \min \left(0, \max \left(DOP_i(t), RTUOL_{i,h,k}\right) - \min \left(ED_{BNDL,0}(t), RTLED_{i,h,k}, RS_{i,h,k}, DAS_{i,h}, SR_{i,h}(t)\right) \right) \right) dt \\
\end{cases} 
\quad : i \in S_{GEN} \setminus S_{HPD}
\]

The Derate Energy for NGR is the sum of the Lower Derate Energy due to \(G_{MIN}/L_{MIN}\) overrates and the Upper Derate Energy due to \(G_{MAX}/L_{MAX}\) derates:
\[ DRE_{i,h,k} = GLDRE_{i,h,k} + GUDRE_{i,h,k} + LLDR_{i,h,k} + LUDRE_{i,h,k} \quad : i \in S_{NGR} \]

The Lower and Upper Derate Energy, including any overlap with LFE or BED, but excluding SRE, are calculated as follows:

\[
GLDRE_{i,h,k} = \left\{ \begin{array}{l}
\int_{t_{s,i,k-1}}^{t_{u,i,k}} \frac{\max \left( 0, \min \left( DOP_{i}(t), GRTLOL_{i,h,k}(t) \right) - \max \left( G_{MIN}, ED_{BNDI,h}(t), RTUED_{i,h,k}, DAS_{i,h}, SR_{i,h}(t) \right) \right)}{3600} dt + \\
\int_{t_{s,i,k}}^{t_{u,i,k-1}} \frac{\max \left( 0, \min \left( DOP_{i}(t), GRTLOL_{i,h,k}(t) \right), DAS_{i,h}, SR_{i,h}(t) \right) - \max \left( G_{MIN}, ED_{BNDI,h}(t), RTUED_{i,h,k}, DAS_{i,h}, SR_{i,h}(t) \right)}{3600} dt \\
\end{array} \right. 
\quad : i \in S_{NGR}
\]

\[
LLDRE_{i,h,k} = \left\{ \begin{array}{l}
\int_{t_{s,i,k-1}}^{t_{u,i,k}} \frac{\min \left( 0, \max \left( DOP_{i}(t), \Delta LRTLOL_{i,h,k}(t) \right) - \min \left( L_{MIN}, ED_{BNDI,h}(t), RTLED_{i,h,k}, DAS_{i,h}, SR_{i,h}(t) \right) \right)}{3600} dt + \\
\int_{t_{s,i,k}}^{t_{u,i,k-1}} \frac{\min \left( 0, \max \left( DOP_{i}(t), \Delta LRTLOL_{i,h,k}(t) \right), DAS_{i,h}, SR_{i,h}(t) \right) - \min \left( L_{MIN}, ED_{BNDI,h}(t), RTLED_{i,h,k}, DAS_{i,h}, SR_{i,h}(t) \right)}{3600} dt \\
\end{array} \right. 
\quad : i \in S_{NGR}
\]

\[
GUDRE_{i,h,k} = \left\{ \begin{array}{l}
\int_{t_{s,i,k-1}}^{t_{u,i,k}} \frac{\min \left( 0, \max \left( DOP_{i}(t), GRTUOL_{i,h,k} \right) - \min \left( ED_{BNDI,h}(t), RTLED_{i,h,k}, DAS_{i,h}, SR_{i,h}(t) \right) \right)}{3600} dt + \\
\int_{t_{s,i,k}}^{t_{u,i,k-1}} \frac{\min \left( 0, \max \left( DOP_{i}(t), GRTUOL_{i,h,k} \right), DAS_{i,h}, SR_{i,h}(t) \right) - \min \left( ED_{BNDI,h}(t), RTLED_{i,h,k}, DAS_{i,h}, SR_{i,h}(t) \right)}{3600} dt \\
\end{array} \right. 
\quad : i \in S_{NGR}
\]

\[
LUDRE_{i,h,k} = \left\{ \begin{array}{l}
\int_{t_{s,i,k-1}}^{t_{u,i,k}} \frac{\max \left( 0, \min \left( DOP_{i}(t), \Delta LRTUOL_{i,h,k} \right) - \max \left( ED_{BNDI,h}(t), RTUED_{i,h,k}, DAS_{i,h}, SR_{i,h}(t) \right) \right)}{3600} dt + \\
\int_{t_{s,i,k}}^{t_{u,i,k-1}} \frac{\max \left( 0, \min \left( DOP_{i}(t), \Delta LRTUOL_{i,h,k} \right), DAS_{i,h}, SR_{i,h}(t) \right) - \max \left( ED_{BNDI,h}(t), RTUED_{i,h,k}, DAS_{i,h}, SR_{i,h}(t) \right)}{3600} dt \\
\end{array} \right. 
\quad : i \in S_{NGR}
\]
3.1.3.2.26 Exceptional Dispatch Energy

The Exceptional Dispatch Energy for Generating and Inter-Tie Resources, including any overlap with LFE or BED, but excluding SRE and RTPE, is calculated as follows:

\[
EDE_{i,h,k} = \begin{cases} 
\int_{T_{i,h,k}}^{T_{i+1,h,k}} \frac{\max(0, \min(DOP(t), ED_{BND,i,h,k}(t)) - \max(0, RTUED_{i,h,k} - HAS_{i,h,k}))}{3600} dt &: ED_{BND,i,h,k}(t) > HAS_{i,h,k} \\
\int_{T_{i,h,k}}^{T_{i+1,h,k}} \frac{\min(0, \max(DOP(t), ED_{BND,i,h,k}(t)) - \min(0, RTUED_{i,h,k} - HAS_{i,h,k}))}{3600} dt &: ED_{BND,i,h,k}(t) < HAS_{i,h,k} 
\end{cases}
\]

\[
EDE_{i,h,k} = \begin{cases} 
\int_{T_{i,h,k}}^{T_{i+1,h,k}} \frac{\max(0, \min(DOP(t), ED_{BND,i,h,k}(t)) - \max(0, RTUED_{i,h,k} - RS_{i,h,k} + DAS_{i,h,k} - SR_{i,h,k}))}{3600} dt + \\
\int_{T_{i,h,k}}^{T_{i+1,h,k}} \frac{\min(0, \max(DOP(t), ED_{BND,i,h,k}(t)) - \min(0, RTUED_{i,h,k} - RS_{i,h,k} + DAS_{i,h,k} - SR_{i,h,k}))}{3600} dt 
\end{cases}
\]

\[
EDE_{i,h,k} = \begin{cases} 
\int_{T_{i,h,k}}^{T_{i+1,h,k}} \frac{\max(0, \min(DOP(t), ED_{BND,i,h,k}(t)) - \max(0, RTLED_{i,h,k} - RS_{i,h,k} + DAS_{i,h,k} - SR_{i,h,k}))}{3600} dt + \\
\int_{T_{i,h,k}}^{T_{i+1,h,k}} \frac{\min(0, \max(DOP(t), ED_{BND,i,h,k}(t)) - \min(0, RTLED_{i,h,k} - RS_{i,h,k} + DAS_{i,h,k} - SR_{i,h,k}))}{3600} dt 
\end{cases}
\]

The Exceptional Dispatch Energy for NGR, including any overlap with LFE or BED, but excluding SRE, is calculated as follows:
Any Instructed Imbalance Energy that remains unaccounted is Optimal Energy:

\[
OE_{i,h,k} = II_i \cdot BED_{i,h,k} - SRE_{i,h,k} - LFE_{i,h,k} - RTPE_{i,h,k} - RTMLE_{i,h,k} - HASE_{i,h,k} - RED_{i,h,k} - RIE_{i,h,k} - DRE_{i,h,k} - EDE_{i,h,k} \quad \text{:: } i \notin S_{NGR}
\]

\[
OE_{i,h,k} = II_i \cdot BED_{i,h,k} - SRE_{i,h,k} - LFE_{i,h,k} - RTMGE_{i,h,k} - RTMLE_{i,h,k} - HASE_{i,h,k} - RED_{i,h,k} - RIE_{i,h,k} - DRE_{i,h,k} - EDE_{i,h,k} \quad \text{:: } i \in S_{NGR}
\]

For Hourly Pre-Dispatched Resources, the Optimal Energy is calculated as the sum of the extra-marginal and infra-marginal portions as follows:
For non-Hourly Pre-Dispatched Inter-Tie or ECA/ACA Resources, for which no SRE/RED/RIE exists, the Optimal Energy is calculated as the sum of the extra-marginal and infra-marginal portions that may overlap with BED or not, as follows:

\[
OE_{i,h,k} = \int_{
\tau_{h-1}}^{\tau_h} \frac{\max(0, DOP_i(t) - \max(0, RTOLL_{r,h,k}(t), ED_{BNDL,h}(t), RTUED_{i,h,k}, HAS_{i,h}))}{3600} dt + \\
\int_{
\tau_{h-1}}^{\tau_h} \frac{\max(0, \min(DOP_i(t), RTUED_{i,h,k}) - \max(P_{MIN}, HAS_{i,h}))}{3600} dt + \\
\int_{
\tau_{h-1}}^{\tau_h} \frac{\min(0, \max(DOP_i(t), RTOLL_{r,h,k}, ED_{BNDL,h}(t), RTLED_{i,h,k}, HAS_{i,h}))}{3600} dt + \\
\int_{
\tau_{h-1}}^{\tau_h} \frac{\min(0, \max(DOP_i(t), RTLED_{i,h,k}) - HAS_{i,h}))}{3600} dt \\
\therefore i \in S_{HPD}
\]

For the remaining non-Hourly Pre-Dispatched Resources, for which SRE/RED/RIE may exist, the Optimal Energy is calculated as the sum of the extra-marginal and infra-marginal portions that may overlap with LFE or not, but excluding SRE/RED/RIE and RTPE. The Non-overlapping OE is calculated as follows:

\[
OE_{i,h,k} = \int_{
\tau_{h-1}}^{\tau_h} \frac{\max(0, DOP_i(t) - \max(0, RTOLL_{r,h,k}(t), ED_{BNDL,h}(t), RTUED_{i,h,k}, RS_{i,h,k}))}{3600} dt + \\
\int_{
\tau_{h-1}}^{\tau_h} \frac{\max(0, \min(DOP_i(t), RTUED_{i,h,k}) - \max(P_{MIN}, RS_{i,h,k}))}{3600} dt + \\
\int_{
\tau_{h-1}}^{\tau_h} \frac{\min(0, \max(DOP_i(t), RTOLL_{r,h,k}, ED_{BNDL,h}(t), RTLED_{i,h,k}, RS_{i,h,k}))}{3600} dt + \\
\int_{
\tau_{h-1}}^{\tau_h} \frac{\min(0, \max(DOP_i(t), RTLED_{i,h,k}) - RS_{i,h,k}))}{3600} dt \\
\therefore i \not\in S_{HPD} \land i \in S_{TE} \cup S_{ECA}
\]
\[ NOE_{i,h,k} = \min_{(\tau_{i,k-1}, \tau_k)} \int_{\tau_k}^{\tau_{i,k-1}} \max \left( 0, DOP_t(t) - \max \left( 0, RTLOL_{i,h,k}(t), ED_{BERD_{i,h,k}}(t), RTUED_{i,h,k}, RS_{i,h,k}, DAS_{i,h,k}, SR_{i,h,k}(t) \right) \right) d\tau + \frac{\tau_k - \tau_{i,k-1}}{3600} \]

\[ GNOE_{i,h,k} = \min_{(\tau_{i,k-1}, \tau_k)} \int_{\tau_k}^{\tau_{i,k-1}} \max \left( 0, DOP_t(t) - \max \left( 0, RTLOL_{i,h,k}(t), ED_{BERD_{i,h,k}}(t), RTUED_{i,h,k}, RS_{i,h,k}, DAS_{i,h,k}, SR_{i,h,k}(t) \right) \right) d\tau + \frac{\tau_k - \tau_{i,k-1}}{3600} \]

\[ \therefore \quad i \not\in S_{NGR} \cup S_{HFO} \cup S_{TIE} \cup S_{ECA} \]
The Overlapping Optimal Energy, which may exist only for Load Following Resources, is calculated as follows:

\[
LNOE_{i,h,k} = \max(t_{i,k}, t_{i}, t_{h}) \frac{\min(0, DOP_{i}(t) - \min\left(LRTLOL_{i,h,k}(t), ED_{RND\text{-}h,k}(t), RTLED_{i,h,k}, RS_{i,h,k}, DAS_{i,h,k}, SR_{i,h,k}(t)\right))}{3600} dt + \int_{\max(t_{i,k}, t_{i}, t_{h})}^{t_{h,k}} \frac{\min(0, \max(DOP_{i}(t), RTLED_{i,h,k}) - \min\left(L_{MIN}, RS_{i,h,k}, DAS_{i,h,k}, SR_{i,h,k}(t)\right))}{3600} dt + \int_{\max(t_{i,k}, t_{i}, t_{h})}^{t_{h,k}} \frac{\max(0, \min(L_{MIN}, DOP_{i}(t)) - \max\left(LRTUOL_{i,h,k}, ED_{RND\text{-}h,k}(t), RTUED_{i,h,k}, RS_{i,h,k}, DAS_{i,h,k}, SR_{i,h,k}(t)\right))}{3600} dt + \int_{\max(t_{i,k}, t_{i}, t_{h})}^{t_{h,k}} \frac{\max(0, \min\left(L_{MIN}, DOP_{i}(t), RTUED_{i,h,k}\right) - \max\left(RS_{i,h,k}, DAS_{i,h,k}, SR_{i,h,k}(t)\right))}{3600} dt
\]

\[\therefore i \in S_{NGR}\]

The Overlapping Optimal Energy, which may exist only for Load Following Resources, is calculated as follows:

\[
OOE_{i,h,k} = \max(t_{i,k}, t_{i}, t_{h}) \frac{\min(0, DOP_{i}(t), DAS_{i,h,k}, SR_{i,h,k}(t)) - \max(0, LRTLOL_{i,h,k}(t), ED_{RND\text{-}h,k}(t), RTLED_{i,h,k}, RS_{i,h,k}, DAS_{i,h,k}, SR_{i,h,k}(t))}{3600} dt + \int_{\max(t_{i,k}, t_{i}, t_{h})}^{t_{h,k}} \frac{\max(0, \min(DOP_{i}(t), RTUED_{i,h,k}, DAS_{i,h,k}, SR_{i,h,k}(t)) - \max\left(P_{MIN}, RS_{i,h,k}\right))}{3600} dt + \int_{\max(t_{i,k}, t_{i}, t_{h})}^{t_{h,k}} \frac{\min(0, \max(DOP_{i}(t), DAS_{i,h,k}, SR_{i,h,k}(t)) - \min\left(RTULOL_{i,h,k}, ED_{RND\text{-}h,k}(t), RTLED_{i,h,k}, RS_{i,h,k}, DAS_{i,h,k}, SR_{i,h,k}(t)\right))}{3600} dt + \int_{\max(t_{i,k}, t_{i}, t_{h})}^{t_{h,k}} \frac{\min(0, \max(DOP_{i}(t), RTLED_{i,h,k}, DAS_{i,h,k}, SR_{i,h,k}(t)) - RS_{i,h,k}}{3600} dt
\]

\[\therefore i \in S_{MSS} - S_{NGR}\]
The Optimal Energy is the sum of Overlapping and Non-overlapping Optimal Energy as follows:

\[ OE_{i,h,k} = OOE_{i,h,k} + NOE_{i,h,k} \quad \therefore i \notin S_{NGR} \cup S_{HPD} \cup S_{TR} \cup S_{KEA} \]

Note: Currently, NGR resources cannot be Load Following Resources.
\[ \text{OE}_{i,k} = \text{GOOE}_{i,k} + \text{LOOE}_{i,k} + \text{GNOE}_{i,k} + \text{LNOE}_{i,k} \quad : i \in S_{NGR} \]

3.1.3.2.28 **Real-time Self-Schedule Energy**

RTSSE, RTGSS, or RTLSS is NOT determined in the Expected Energy calculation. It is separated out from Optimal Energy in the Expected Energy allocation by carving out the OE portion that corresponds to RTSSE, RTGSS, or RTLSS. Section 3.1.3.3 further explains this logic.

3.1.3.2.29 **RMR Energy**

The calculation of RMR energy is not dependent and/or related to any other expected energy calculation. It is calculated to fulfill the RMR contractual settlement requirement. Detail explanation and formula comes from “Appendix 2: SRS Appendix 2 – MRTU_Expected Energy_Requirements.doc” Chapter 12.

3.1.3.3.1.3.2.30 **Total Expected Energy**

\[ TEE_{i,k} = \int_{T_{i-1}}^{T_i} \frac{DOP(t)}{3600} dt \]

3.1.3.3.1.3.2.31 **Ramping Dispatch Operating Target**

\[ RDOT(t) = DOT_{i-1} + \frac{DOT_{i-1}^T}{T_i - T_{i-1}} (t - T_{i-1}) \quad : T_{i-1} \leq t \leq T_i \]

3.1.3.3.1.3.2.32 **Total Target Expected Energy**

\[ TTEE_{i,k} = \int_{T_{i-1}}^{T_i} \frac{RDOT(t)}{3600} dt \]

3.1.3.3.1.3.2.33 **Ramping Tolerance**

\[ \text{RAMPT}_{i,k} = TTEE_{i,k} - TEE_{i,k} \]

3.1.3.3 **Exceptional Dispatch Energy and Its Pricing**

In expected energy allocation, the bid prices used for exceptional dispatch energy will be based on exceptional dispatch pricing rules documented in ISO SRS for RIMPR1.
Furthermore, after the appropriate energy bid prices are allocated, the exceptional dispatch energy determined by the extended exceptional instruction (not the original exceptional dispatch instruction) as described in section 3.1.3.2.21 will be re-classified as optimal energy with its bid prices determined by exceptional dispatch pricing rules.

The detection of the exception dispatch energy outside of an original exceptional dispatch instruction will be based on comparison between the interval of the EDE and the time frame of original exceptional dispatch instruction.