

**Methodology for Implementing Operating Reserve Demand Curve (ORDC) to Calculate Real-Time Reserve Price Adder**

**Version \_1.8**

**Document Revisions**

| Date Approved | Version | Description | Author(s) | Approved By | Effective Date |
| --- | --- | --- | --- | --- | --- |
| 11/19/13 | 0.5 | ERCOT Board approved NPRR568, Real-Time Reserve Price Adder Based on Operating Reserve Demand Curve, and associated OBD, Methodology for Implementing Operating Reserve Demand Curve (ORDC) to Calculate Real-Time Reserve Price Adder | ERCOT | ERCOT Board | Upon system implementation of NPRR568 |
| 4/8/14 | 0.6 | Revisions proposed via NPRR598, Clarify Inputs to PRC and ORDC | ERCOT | ERCOT Board | Upon implementation of NPRR568 |
| 6/1/14 | 0.7 | Partial unboxing of NPRR568 due to system implementation of NPRR568 and NPRR555, Load Resource Participation in Security-Constrained Economic Dispatch | ERCOT |  | 6/1/14 |
| 8/11/15 | 0.8 | Synchronize the OBD with as built methodology, the removal of Phase 2, and the implementation of NPRR698 | ERCOT | ERCOT Board | 9/1/15 |
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| 12/11/18 | 1.7 | Revisions proposed by OBDRR006, Alignment of ORDC OBD with NPRR884, Adjustments to Pricing and Settlement for Reliability Unit Commitments (RUCs) of On-Line Combined Cycle Generation Resources, and OBDRR007, Revisions to the ORDC Methodology to Include Photo-Voltaic Generation Resources (PVGRs) | ERCOT | ERCOT Board | Upon implementation of OBDRR006 and OBDRR007 |
| 2/12/19 | 1.8 | Revisions proposed by OBDRR010, Related to NPRR910, Clarify Treatment of RUC Resource that has a Day-Ahead Market Three-Part Supply Award, and OBDRR011, ORDC OBD Revisions for PUCT Project 48551 | ERCOT | ERCOT Board | Upon implementation of OBDRR010 and OBDRR011 |

**PROTOCOL DISCLAIMER**

This document describes ERCOT systems and the response of these systems to Market Participant submissions incidental to the conduct of operations in the ERCOT Texas Nodal Market and is not intended to be a substitute for the ERCOT Protocols (available at <http://www.ercot.com/mktrules/nprotocols/current>), as amended from time to time. If any conflict exists between this document and the Protocols, the Protocols shall control in all respects.

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# 1. Purpose

For each Security-Constrained Economic Dispatch (SCED) process, ERCOT calculates a Real-Time On-Line Reserve Price Adder (RTORPA) and a Real-Time Off-Line Reserve Price Adder (RTOFFPA) based on the On-Line and Off-Line available reserves in the ERCOT System and the ORDC. The price after the addition of RTORPA to Locational Marginal Prices (LMPs) approximates the pricing outcome of Real-Time energy and Ancillary Service co-optimization since RTORPA captures the value of the opportunity cost of reserves based on the defined ORDC. Additionally, the Real-Time Off-Line Reserve Capacity (RTOFFCAP) shall be administratively set to zero when the SCED snapshot of the Physical Responsive Capability (PRC) is less than or equal to the PRC MW at which Energy Emergency Alert (EEA) Level 1 is initiated. An Ancillary Service imbalance Settlement is done based on Protocol Section 6.7.5, Real-Time Ancillary Service Imbalance Payment or Charge, to make Resources indifferent to the utilization of their capacity for energy or Ancillary Service reserves.

This document describes:

* The ERCOT Board-approved methodology that ERCOT uses for determining the Real-Time reserve price adders based on ORDC.
* The ERCOT Board-approved parameters for implementing ORDC.

# 2. Methodology for Implementing ORDC

For each execution of SCED, the System Lambda of the power balance constraint will be determined and the ORDC will be constructed as probability of reserves falling below the minimum contingency level (PBMCL) multiplied by the difference between Value of Lost Load (VOLL) and System Lambda. This approach is needed with the current rules in order to ensure that power balance is given the highest priority and can result in a reserve price that is near zero with an energy price near System-Wide Offer Cap (SWCAP) under scarcity conditions.

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| ***[OBDRR011: Replace the paragraph above with the following upon system implementation:]***  For each execution of SCED, the System Lambda of the power balance constraint will be determined and the ORDC will be based on analysis of the probability of reserves falling below the minimum contingency level (PBMCL) multiplied by the difference between Value of Lost Load (VOLL) and System Lambda. This approach is needed with the current rules in order to ensure that power balance is given the highest priority and can result in a reserve price that is near zero with an energy price near System-Wide Offer Cap (SWCAP) under scarcity conditions. |

Determining the following values is a major part of implementing ORDC to calculate Real-Time Reserve Price Adder:

1. VOLL
2. PBMCL
3. RTORPA and RTOFFPA

## 2.1 Determine VOLL

The VOLL is a parameter for implementing the ORDC and shall be approved by ERCOT Board.

## 2.2 Determine PBMCL

The key part of the concept is the determination of the PBMCL. PBMCL is derived from Loss of Load Probability curve (LOLP), which depends on many factors, including the probability of forced outages, probability of Load forecast error and probability of wind forecast error. LOLP at a given reserve level can be interpreted as the probability of the occurrence of an event with a magnitude greater than that reserve level. A minimum contingency level (X) is chosen in order to send an appropriate scarcity price signal to maintain reliability and stability of the system. The PBMCL is constructed by shifting the curve to the right by the minimum contingency level (X) amount and setting the value to one for reserve levels below the minimum contingency level (X). The PBMCL curve for a given reserve level (R) is given as follows:



LOLP is determined by analyzing historic events defined as the difference between the hour-ahead forecasted reserves with the reserves that were available in Real-Time during the Operating Hour. These events are split into twenty-four groups, comprising of four seasons and six time-of-day blocks per day. These groups are used to determine twenty-four distinct normal probability distributions of the events, which will determine the LOLP for the corresponding season and time block. The detailed logic for determining LOLP is described as below:

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| ***[OBDRR011: Replace the language above with the following upon system implementation:]***  Another key part of the ORDC concept is the determination of the PBMCL. PBMCL is derived by making certain adjustments to the Loss of Load Probability curve (LOLP). LOLP is the probability, at a given level of reserves, of the occurrence of a loss of reserves greater than the reserve level and is therefore determined by calculating the mean and standard deviation of differences between the hour-ahead forecasted reserves and the reserves that were available in Real-Time during the Operating Hour using historical data, as described in greater detail, below. The LOLP curve is defined as follows:  Where CDF is the Cumulative Distribution Function of the normal distribution with mean and standard deviation σ.  Once the LOLP curve is derived, ERCOT creates a Shifted Loss of Load Probability (SLOLP) curve. The SLOLP is the LOLP with mean shifted by the factor S \* σ, and for a given value reserve level R can be calculated as:  Where and CDF is the Cumulative Distribution Function of a normal distribution with mean μs and standard deviation σ.  The last step in determining PBMCL is shifting the SLOLP curve further to the right by a defined minimum contingency level, *X*, and setting the value of SLOLP to one for reserve levels below the minimum contingency level. The PBMCL curve for a given reserve level (R) is determined as follows:  The detailed logic for determining LOLP is described as below: |

1) For each Operating Hour in the study period, calculate the system-wide Hour-Ahead (HA) reserve using the snapshot of last Hourly Reliability Unit Commitment (HRUC) for the Operating Hour (at the end of Adjustment Period):

*HA Reserve = RUC On-Line Gen COP HSL - (RUC Load Forecast + RUC DCTIE Load)*

*+ RUC On-Line Load COP Non-Spin Responsibility + RUC On-Line Load COP Reg-Up Responsibility + RUC On-Line Load COP RRS Responsibility + RUC Off-Line Gen COP OFFNS HSL + RUC Off-Line Gen COP CST30HSL*

The calculation above excludes the following Generation Resources:

(a) Intermittent Renewable Resources (IRRs) other than Wind-powered Generation Resources (WGRs);

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| ***[OBDRR007: Delete item (a) above upon system implementation and renumber accordingly.]*** |

(b) Nuclear Resources; and

(c) Resources with ONTEST Current Operating Plan (COP) Status.

2) For each SCED interval in the study period, calculate the system-wide available SCED reserve using SCED telemetry and solution as:

*SCED Reserve = SCED On-Line Gen HSL – SCED Gen Base Point + SCED On-Line Load Telemetry RRS Schedule + SCED On-Line Load Telemetry Reg-Up Responsibility + SCED On-Line Load Telemetry Non-Spin Schedule + SCED Off-Line Gen OFFNS HSL + SCED Off-Line RTCST30HSL -* SCED under-generation Power Balance MW

The calculation above excludes the following Generation Resources:

(a) Intermittent Renewable Resources (IRRs) other than Wind-powered Generation Resources (WGRs);

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| ***[OBDRR007: Delete item (a) above upon system implementation and renumber accordingly.]*** |

(b) Nuclear Resources;

(c) Resources with telemetered net real power (in MW) less than 95% of their telemetered LSL; and

(d) Resources with a telemetered status of:

(i) ONTEST;

(ii) STARTUP (except Resources with Non-Spin Ancillary Service Resource Responsibility greater than zero); or

(iii) SHUTDOWN.

3) For each Operating Hour in the study period, calculate the hourly average system-wide SCED reserve by averaging the interval SCED reserve in step 2).

4) For each Operating Hour in the study period, calculate the system-wide Reserve Error as:

*Reserve Error = HA Reserve – SCED Reserve (Hourly Average) + Firm\_Load\_Shed (Hourly Average)*

5) For each Operating Hour in the study period, allocate it to the corresponding season and time block. All the hours will be split into 24 distribution groups based on the Season and the time of day:

* 4 Seasons of
  + Winter (Months 12, 1, 2),
  + Spring (Months 3, 4, 5),
  + Summer (Months 6, 7, 8)
  + Fall (Months 9, 10, 11)
* 6 time-of-day blocks each consisting of 4 hours

6) Calculate the mean () and standard deviation () for each of the twenty-four distinct LOLP distributions using the calculated Reserve Error in step 4). The current values can be found at ERCOT.com on the Real-Time Market page. This hourly error is normally distributed and hence LOLP for a given value reserve level R can be calculated:



Where CDF is the Cumulative Distribution Function of the normal distribution with mean  and standard deviation.

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| ***[OBDRR011: Replace paragraphs (5) and (6) above with the following upon system implementation:]***  5) Calculate the mean () and standard deviation () using the calculated Reserve Error in step 4) for the study period. This and are then used to determine the PBMCL curve as described above. |

## *2.2.1 Calculation of Rs and Rsns*

*Rs* is the reserves from Resources participating in SCED plus the Reg-Up and RRS from Load Resources and the additional available capacity from Load Resources other than Controllable Load Resources with a validated Real-Time RRS Schedule. *Rsns*is equal to *Rs* plus the reserves from Resources that are not currently available to SCED but could be available in 30 minutes.

1) *Rs* is calculated based on SCED telemetry and solution as:

*Rs = RTOLCAP = RTOLHSL – RTBP + RTCLRCAP + RTNCLRCAP – RTOLNSRS – RTPBPC*

*Where:*

*RTCLRCAP = RTCLRBP – RTCLRLPC – RTCLRNS + RTCLRREG*

*RTNCLRCAP = Min(Max(RTNCLRNPC – RTNCLRLPC,0.0), RTNCLRRRS \* 1.5)*

Where

* *RTOLCAP* is the system total Real-Time On-Line reserve capacity of all On-Line Resources for the SCED interval.
* *RTOLHSL* is the system total Real-Time telemetered High Sustained Limits (HSLs) for all Generation Resources (excluding non-Wind-powered Generation Resource (WGR) Intermittent Renewable Resources (IRRs), Nuclear Resources, Resources with a telemetered ONTEST, ONRUC (inclusive of On-Line Reliability Must-Run (RMR) Resources), STARTUP (except Resources with Non-Spin Ancillary Service Resource Responsibility greater than zero), or SHUTDOWN Resource Status and Resources with telemetered net real power (in MW) less than 95% of their telemetered LSL) available to SCED for the SCED interval discounted by the system-wide discount factor.

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| ***[OBDRR006, OBDRR007, and OBDRR010: Replace applicable portions of the variable “RTOLHSL” above with the following upon system implementation:]***   * *RTOLHSL* is the system total Real-Time telemetered High Sustained Limits (HSLs) for all Generation Resources available to SCED for the SCED interval, discounted by the system-wide discount factor, except for the following:   + Nuclear Resources;   + Resources with telemetered net real power (in MW) less than 95% of their telemetered LSL; and   + Resources with a telemetered Resource Status of:     - ONTEST;     - ONRUC (including On-Line Reliability Must-Run (RMR) Resources but excluding those Reliability Unit Commitment (RUC) Resources that have been awarded a Day-Ahead Market (DAM) Three-Part Supply Offer for the hour);       * For a Combined Cycle Generation Resource with a Resource Status of ONRUC that was RUC-committed from one On-Line configuration to a different configuration with additional capacity, the exclusion is equal to the maximum of zero and the telemetered HSL value minus the COP HSL of the Qualified Scheduling Entity (QSE)-committed configuration for the RUC hour at the snapshot time of the RUC instruction.     - STARTUP (except for Resources with Non-Spin Ancillary Service Resource Responsibility greater than zero); or     - SHUTDOWN. |

* *RTBP* is the system total SCED Base Points for all Generation Resources (excluding all IRRs other than WGRs, nuclear Resources, Resources with a telemetered ONTEST, STARTUP (except Resources with Non-Spin Ancillary Service Resource Responsibility greater than zero), or SHUTDOWN Resource Status and Resources with telemetered net real power (in MW) less than 95% of their telemetered LSL) for the SCED interval discounted by the system-wide discount factor.

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| ***[OBDRR007: Replace the variable “RTBP” above with the following upon system implementation:]***   * *RTBP* is the system total SCED Base Points for all Generation Resources (excluding nuclear Resources, Resources with a telemetered ONTEST, STARTUP (except Resources with Non-Spin Ancillary Service Resource Responsibility greater than zero), or SHUTDOWN Resource Status and Resources with telemetered net real power (in MW) less than 95% of their telemetered LSL) for the SCED interval discounted by the system-wide discount factor. |

* *RTCLRCAP* is the system total Real-Time capacity from Controllable Load Resources for the SCED interval. It is the sum of SCED Base Points less the telemetered CLR LSL and Non-Spin Schedule for all Controllable Load Resources.
* *RTNCLRCAP* is the system total Real-Time capacity for all Load Resources other than Controllable Load Resources that have a validated Real-Time RRS Ancillary Service Schedule for the SCED interval.
* *RTPBPC* is the system total SCED under-generation Power Balance MW violated for the SCED interval.
* *RTNCLRNPC* is the system total Real-Time net real power consumption from all Load Resources other than Controllable Load Resources that have a validated Real-Time RRS Ancillary Service Schedule for the SCED interval discounted by the system-wide discount factor.
* *RTNCLRLPC* is the system total Real-Time Low Power Consumption (LPC) from all Load Resources other than Controllable Load Resources that have a validated Real-Time RRS Ancillary Service Schedule for the SCED interval discounted by the system-wide discount factor.
* *RTNCLRRRS* is the system total Real-Time RRS Ancillary Service Responsibilities from all Load Resources other than Controllable Load Resources for the SCED interval discounted by the system-wide discount factor.
* *RTOLNSRS* is the system total Real-Time telemetered On-Line Non-Spin Ancillary Service Schedule for all On-Line Generation Resources for the SCED interval discounted by the system-wide discount factor.
* *RTCLRBP* is the system total SCED Base Points from Controllable Load Resources for the SCED interval discounted by the system-wide discount factor.
* *RTCLRLPC* is the system total Real-Time telemetered Low Power Consumption from Controllable Load Resources for the SCED interval discounted by the system-wide discount factor.
* *RTCLRREG* is the system total validated capacity from Controllable Load Resources with Primary Frequency Response (not SCED qualified) Regulation-Up Ancillary Service Schedule discounted by the system-wide discount factor.
* *RTCLRNS* is the system total validated Real-Time telemetered Non-Spin Ancillary Service Schedules from Controllable Load Resources for the SCED interval discounted by the system-wide discount factor.

2) *Rsns* is calculated based on SCED telemetry and solution as

*Rsns* = *RTOLCAP + RTOFFCAP*

*RTOFFCAP = RTCST30HSL + RTOFFNSHSL +RTCLRNS + RTOLNSRS +*

*RTRUCCST30HSL*

Where

* *RTOLCAP* is the system total Real-Time On-Line reserve capacity of all On-Line Resources for the SCED interval.
* *RTOFFCAP* is the system total Real-Time Off-Line reserve capacity for the SCED interval.
* *RTCST30HSL* is the system total Real-Time telemetered HSLs of Generation Resources, excluding IRRs, that have telemetered an OFF Resource Status and can be started from a cold temperature state in 30 minutes and discounted by the system-wide discount factor.
* *RTCLRNS* is the system total validated Real-Time telemetered Non-Spin Ancillary Service Schedules from Controllable Load Resources for the SCED interval discounted by the system-wide discount factor.
* *RTOLNSRS* is the system total validated Real-Time telemetered On-Line Non-Spin Ancillary Service Schedule for all On-Line Generation Resources for the SCED interval discounted by the system-wide discount factor.
* *RTOFFNSHSL* is the system total telemetered HSLs of Generation Resources that have telemetered an OFFNS Resource Status and discounted by the system-wide discount factor.
* *RTRUCCST30HSL* is the system total Real-Time On-Line telemetered HSLs of ONRUC Resources that are qualified for RTCST30HSL for the SCED interval.

The system-wide discount factor used to discount inputs used in the calculation of reserves Rs and Rsns is calculated as the average of the currently approved Reserve Discount Factors (RDFs) applied to the temperatures from the current Season from the prior year.

## *2.2.2 Calculation of and*

 and  are functions that describe the PBMCL at various reserve levels.

1) Calculation of Curve :

 is a function of the Real-Time reserves that should be available in the first 30 minutes of the hour and is intended to capture the PBMCL for that level of reserves. The general equation for  is:



Where

* *X in this equation is the minimum contingency level*
* *LOLPS is the LOLP function for the spinning reserve.*

*LOLPS* is different from the 60 minutes *LOLP* in Table 1, which is calculated based on the hourly error analysis. The reserves are classified into two categories; those that are being provided by Resources in SCED and Load Resources providing Reg-Up and RRS and those that are being provided by Resources that are not currently available to SCED but could be made available in 30 minutes. Since the first reserve type is available immediately, those reserves are the only ones considered to be available to respond to any event that happens in the first 30 minutes of the hour. All reserve types are then considered to be available to respond to events that happen in the second 30 minutes of the hour. From the hourly error analysis, a mean () and standard deviation () for the 60 minute *LOLP* is determined for each of the different seasons and time blocks. Because the error analysis is hourly, to capture the events within the first 30 minutes for , the  and  needs to be scaled to reflect the 30 minute timeframe, with  hour:





So the *LOLPS* can be calculated based on the 60 minute *LOLP* as follows:



24  curves are developed based on the season and the time of day.

2) Calculation of Curve :

 is a function of all the Real-Time reserves that can be expected to be available within the hour and is intended to capture the PBMCL for that level of reserves. The general equation for  is:



This is similar to  but the key differences here are the types of reserves considered and the  and  that are used in calculating LOLP

* *The total On-Line and Off-Line applies for the full change in net Load over the hour and there is no scaling adjustments needed for*  and *in the  calculations*
* *X in this equation is the minimum contingency level*

24  curves are developed based on the season and the time of day.

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| ***[OBDRR011: Replace Section 2.2.2 above with the following upon system implementation:]*** 2.2.2 Calculation of  and  and  are functions that describe the PBMCL at various reserve levels.  1) Calculation of Curve :  is a function of the Real-Time reserves that should be available in the first 30 minutes of the hour and is intended to capture the PBMCL for that level of reserves. The general equation for  is:  Where   * *X in this equation is the minimum contingency level* * *SLOLPS is the Shifted LOLP function for the spinning reserve.*   *SLOLPS* is different from the 60 minutes *SLOLP*, which is calculated based on the hourly error analysis. The reserves are classified into two categories; those that are being provided by Resources in SCED and Load Resources providing Reg-Up and RRS and those that are being provided by Resources that are not currently available to SCED but could be made available in 30 minutes. Since the first reserve type is available immediately, those reserves are the only ones considered to be available to respond to any event that happens in the first 30 minutes of the hour. All reserve types are then considered to be available to respond to events that happen in the second 30 minutes of the hour. Because the error analysis is hourly, to capture the events within the first 30 minutes for , the distribution parameters need to be scaled to reflect the 30 minute timeframe, with  hour:    So the *SLOLPS* can be calculated based on the 60 minute *SLOLP* as follows:  2) Calculation of Curve :  is a function of all the Real-Time reserves that can be expected to be available within the hour and is intended to capture the PBMCL for that level of reserves. The general equation for  is:  This is similar to but the key differences here are the types of reserves considered and the  and  that are used in calculating SLOLP   * *The total On-Line and Off-Line applies for the full change in net Load over the hour and there is no scaling adjustments needed for μs* and *in the  calculations to account for timeframe differences* * *X in this equation is the minimum contingency level* |

## 2.3 Determination of Price Adders (RTORPA and RTOFFPA)

Once PBMCL is determined, the Real-Time On-Line Reserve Price Adder (RTORPA) and Real-Time Off-Line Reserve Price Adder (RTOFFPA) for each SCED interval can be calculated. RTORPA (a.k.a. *PS*) and RTOFFPA (a.k.a. *PNS*) are functions of the PBMCL at various levels of Real-Time reserves, the net value of Load curtailment, and time duration during which the reserves are available. RTORPA and RTOFFPA are determined as follows:





Where *v* represents the net value of Load curtailment and is calculated as the VOLL minus the SCED System Lambda. System Lambda is subtracted from VOLL to reflect the scarcity value of the marginal dispatch capacity and to ensure that the final cost of energy does not go above the VOLL. The Off-Line Available Reserves (RTOFFCAP) will be set to zero when the SCED snapshot of the PRC is equal to or below the PRC MW at which EEA Level 1 is initiated.

# 3. Methodology Revision Process

Revisions to this document, and the parameters to be used in the methodology, shall be made according to the approval process as prescribed in Protocol Section 6.5.7.3, Security Constrained Economic Dispatch, which requires TAC review and ERCOT Board approval.

# 4. Parameters for Implementing ORDC

The definition and values of the parameters used in implementing ORDC are as follows:

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| Parameter | Definition | Unit | Value |
| VOLL | Value of Lost Load | $/MWh | 9000 |
| X | Minimum contingency reserve level | MW | 2000 |

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| ***[OBDRR011: Replace Section 4 above with the following upon system implementation:]*** 4. Parameters for Implementing ORDC The definition and values of the parameters used in implementing ORDC are as follows:   |  |  |  |  | | --- | --- | --- | --- | | Parameter | Definition | Unit | Value | | VOLL | Value of Lost Load | $/MWh | 9000 | | X | Minimum contingency reserve level | MW | 2000 | | S | SLOLP distribution shift parameter | none | 0.25 |  |  |  |  |  |  | | --- | --- | --- | --- | --- | | ***[OBDRR011: Replace parameter “S” in the table above with the following on March 1, 2020:]***   |  |  |  |  | | --- | --- | --- | --- | | S | SLOLP distribution shift parameter | none | 0.5 | | |