Date: December 6, 2016
To: Board of Directors
From: Joel Mickey, Director Wholesale Market Design & Operations
Subject: Other Binding Document, Methodology for Implementing Operating Reserve Demand Curve (ORDC) to Calculate Real-Time Reserve Price Adder

Issue for the ERCOT Board of Directors

ERCOT Board of Directors Meeting Date: December 13, 2016
Item No.: 2.2

Issue:
Consideration of revisions to the Other Binding Document, Methodology for Implementing Operating Reserve Demand Curve (ORDC) to Calculate Real-Time Reserve Price Adder consistent with the Technical Advisory Committee's (TAC's) and ERCOT staff's recommendation.

Background/History:
The Protocols require ERCOT Board of Directors (Board) approval of the methodology for implementing the ORDC to calculate the Real-Time Reserve Price Adder in the Other Binding Document, Methodology for Implementing Operating Reserve Demand Curve (ORDC) to Calculate Real-Time Reserve Price Adder (Methodology).

On September 12, 2016, ERCOT staff proposed revisions to the Methodology to align with Nodal Protocol Revision Request (NPRR) 801, Non-Controllable Load Resource MW in PRC, which was unanimously endorsed by TAC and is expected to be approved by the Board at its December 13, 2016 meeting. On October 4, 2016 ERCOT filed clarifying comments to the Methodology. ERCOT staff requests that the clarification language in Section 2.2 of the Methodology be effective on January 1, 2017 and that the language changes in Section 2.2.1 of the Methodology be effective upon system implementation of NPRR801.

Key Factors Influencing Issue:
At its October 27, 2016 meeting, TAC unanimously voted to endorse the proposed revisions to the Methodology as amended by the October 4, 2016 ERCOT comments in conjunction with NPRR801, as set forth in Attachment A.

Conclusion/Recommendation:
ERCOT staff recommends that the Board approve revision of the Methodology as set forth in Attachment A, consistent with TAC's and ERCOT staff's recommendation, with an effective date of January 1, 2017 for changes in Section 2.2 and upon system implementation of NPRR801 for changes in Section 2.2.1.

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ELECTRIC RELIABILITY COUNCIL OF TEXAS, INC.
BOARD OF DIRECTORS RESOLUTION

WHEREAS, after due consideration of the alternatives, the Board of Directors (Board) of Electric Reliability Council of Texas, Inc. (ERCOT) deems it desirable and in the best interest of ERCOT to modify the Other Binding Document, Methodology for Implementing Operating Reserve Demand Curve (ORDC) to Calculate Real-Time Reserve Price Adder.

THEREFORE, BE IT RESOLVED, that the Other Binding Document, Methodology for Implementing Operating Reserve Demand Curve (ORDC) to Calculate Real-Time Reserve Price Adder, is hereby modified to reflect the changes set forth in Attachment A to this Resolution.

CORPORATE SECRETARY'S CERTIFICATE

I, Vickie G. Leady, Assistant Corporate Secretary of ERCOT, do hereby certify that, at its December 13, 2016 meeting, the ERCOT Board passed a motion approving the above Resolution by ______.

IN WITNESS WHEREOF, I have hereunto set my hand this ___ day of December, 2016.

____
Vickie G. Leady
Assistant Corporate Secretary

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

Version _1.~~1~~2

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
	0.9	Revisions proposed via NPRR710, Removal of ORDC Phase 2 Language and Modification to HASL Calculation	ERCOT	ERCOT Board	Upon implementation of NPRR710
	1.0	Unboxing of NPRR710 due to system implementation	ERCOT	ERCOT Board	10/22/15
6/14/16	1.1	Revisions proposed by NPRR766, Alignment of System-Wide Discount Factor Description with Operational Adjustments to RDF, to the system-wide discount factor determination	ERCOT	ERCOT Board	10/1/16
TBD	1.2	Revisions proposed by NPRR801, Non-Controllable Load Resource MW in PRC, to the Physical Responsive Capability (PRC) calculation and alignment with current implementation.	ERCOT		

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.

Table of Contents

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 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 6.7.4, 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 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:

$$\pi(R) = \begin{cases} LOLP(R - X), & R - X > 0 \\ 1, & R - X \leq 0 \end{cases}$$

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:

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 On-Line Non-Controllable Load COP Additional Available Capacity~~ + 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);
   (b) Nuclear Resources; and
   (c) Resources with ONTEST 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 Non-Controllable Load Additional Available Capacity~~ + 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);
   (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 (μ) and standard deviation (σ) 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:

$$LOLP(\mu, \sigma, R) = 1 - CDF(\mu, \sigma, R)$$

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

2.2.1. Calculation of R_s and R_{sns}

R_s 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. R_{sns} is equal to R_s plus the reserves from Resources that are not currently available to SCED but could be available in 30 minutes.

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

R_s = *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, 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.
- *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.
- *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.

The Resource reserve discount factors are the seasonal system level parameters calculated based on average seasonal temperature and can be different for different Resource type reserves.

[Delete the sentence above on October 1, 2016.]

2) R_{sns} is calculated based on SCED telemetry and solution as

R_{sns} = *RTOLCAP* + *RTOFFCAP*

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

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.

The system-wide discount factor used to discount inputs is calculated for each Season based on the average of the Reserve Discount Factors (RDFs) for that Season from the year prior.

[Replace the sentence above with the following on October 1, 2016:]

The system-wide discount factor used to discount inputs used in the calculation of reserves R_s and R_{sns} 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 $\pi_S(R_S)$ and $\pi_{NS}(R_{SNS})$

$\pi_S(R_S)$ and $\pi_{NS}(R_{SNS})$ are functions that describe the PBMCL at various reserve levels.

1) Calculation of Curve $\pi_S(R_S)$:

$\pi_S(R_S)$ 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 $\pi_S(R_S)$ is:

$$\pi_S(R_S) = \begin{cases} LOLP_S(R_S - X), & R_S - X > 0 \\ 1, & R_S - X \le 0 \end{cases}$$

Where

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

$LOLP_S$ 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 (μ) and standard deviation (σ) 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 $\pi_S(R_S)$, the μ and σ needs to be scaled to reflect the 30 minute timeframe, with $\delta = 0.5$ hour:

$$\mu' = \delta * \mu = 0.5\mu$$

$$\sigma' = \frac{\delta}{\sqrt{\delta^2 + (1-\delta)^2}} * \sigma = 0.707\sigma$$

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

$$LOLP_S(\mu', \sigma', R) = LOLP(0.5\mu, 0.707\sigma, R) = 1 - CDF(0.5\mu, 0.707\sigma, R)$$

24 $\pi_S(R_S)$ curves are developed based on the season and the time of day.

2) Calculation of Curve $\pi_{NS}(R_{SNS})$:

$\pi_{NS}(R_{SNS})$ 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 $\pi_{NS}(R_{SNS})$ is:

$$\pi_{NS}(R_{SNS}) = \begin{cases} LOLP(R_{SNS} - X), & R_{SNS} - X > 0 \\ 1, & R_{SNS} - X \le 0 \end{cases}$$

This is similar to $\pi_S(R_S)$ but the key differences here are the types of reserves considered and the μ and σ 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* μ and σ *in the* $\pi_{NS}(R_{SNS})$ *calculations*
- *X in this equation is the minimum contingency level*

24 $\pi_{NS}(R_{SNS})$ curves are developed based on the season and the time of day.

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. P_S) and RTOFFPA (a.k.a. P_{NS}) 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:

$$RTORPA = P_S = v * 0.5 * \pi_S(R_S) + P_{NS}$$
$$RTOFFPA = P_{NS} = v * (1 - 0.5) * \pi_{NS}(R_{SNS})$$

where

$v = \max(0, VOLL - SystemLambda)$

$R_S = RTOLCAP$

$R_{SNS} = RTOLCAP + RTOFFCAP$

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:

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