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| --- | --- | --- | --- |
| NPRR Number | [941](http://www.ercot.com/mktrules/issues/NPRR941) | NPRR Title | Create a Lower Rio Grande Valley Hub |
| Date of Decision | | November 20, 2019 | |
| Action | | Recommended Approval | |
| Timeline | | Normal | |
| Proposed Effective Date | | Upon system implementation | |
| Priority and Rank Assigned | | Priority – 2020; Rank – 2860 | |
| Nodal Protocol Sections Requiring Revision | | 3.5.2.6, Lower Rio Grande Valley 138/345 kV Hub (LRGV 138/345) (new)  3.5.2.6, ERCOT Hub Average 345 kV Hub (ERCOT 345)  3.5.2.7, ERCOT Bus Average 345 kV Hub (ERCOT 345 Bus) | |
| Related Documents Requiring Revision/Related Revision Requests | | None | |
| Revision Description | | This Nodal Protocol Revision Request (NPRR) creates a trading Hub “Lower Rio Grande Valley 138/345 kV Hub (LRGV 138/345)” in the ERCOT lower Rio Grande Valley. The NPRR also excludes this new Hub from the existing ERCOT-wide Hub average and Bus average calculations in Sections 3.5.2.6 and 3.5.2.7. | |
| Reason for Revision | | Addresses current operational issues.  Meets Strategic goals (tied to the [ERCOT Strategic Plan](http://www.ercot.com/content/news/presentations/2013/ERCOT%20Strat%20Plan%20FINAL%20112213.pdf) or directed by the ERCOT Board).  Market efficiencies or enhancements  Administrative  Regulatory requirements  Other: (explain)  *(please select all that apply)* | |
| Business Case | | The additional Hub will allow additional trading liquidity and forward price discovery for the lower Rio Grande Valley area. Hubs may also reduce risks to Market Participants, including reducing credit risks by increased ability to hedge congestion risks by having uniform delivery points. The cost of the project is related to removing constraints that exist in the original system design. Without removing these constraints it will impede any future Hub development. | |
| Credit Work Group Review | | ERCOT Credit Staff and the Credit Work Group (Credit WG) have reviewed NPRR941 and do not believe that it requires changes to credit monitoring activity or the calculation of liability. | |
| PRS Decision | | On 6/13/19, PRS unanimously voted to table NRR941 and refer the issue to WMS. All Market Segments were present for the vote.  On 8/15/19, PRS voted to recommend approval of NPRR941 as amended by the 8/6/19 DC Energy comments. There was one abstention from the Consumer (Occidental Chemical) Market Segment. All Market Segments were present for the vote.  On 9/12/19, PRS unanimously voted to table NPRR941 for one month. All Market Segments were present for the vote.  On 10/10/19, PRS unanimously voted to table NPRR941. All Market Segments were present for the vote.  On 11/13/19, PRS voted to endorse and forward to TAC the 8/15/19 PRS Report as amended by the 10/28/19 ERCOT comments and the Impact Analysis for NPRR941 with a recommended priority of 2020 and rank of 2860. There was one abstention from the Consumer (Occidental) Market Segment. The Independent Power Marketer (IPM) Market Segment was not present for the vote. | |
| Summary of PRS Discussion | | On 6/13/19, the sponsor reviewed the intent of NPRR941, and participants requested additional review by WMS, particularly the busses included in NPRR941, some of which overlap with other currently defined Hubs.  On 8/15/19, there was no discussion.  On 9/12/19, ERCOT Staff presented the Impact Analysis, noting differences between the underlying assumptions in place for NPRR817, Create a Panhandle Hub, and the changes proposed in NPRR941. Participants requested ERCOT conduct further analysis of other underlying restrictions within its system(s) which may similarly impact the cost to create future Hubs.  On 10/10/19, ERCOT Staff presented the requested analysis on restrictions within current system(s) which may impact the cost to create future Hubs, including several items which were included in the current Impact Analysis (items 1-3) and several more which could be considered (items 4-7). Participants requested ERCOT provide additional cost estimates for items 4-6 to assess which ones may be suitable for inclusion in a revised Impact Analysis in NPRR941.  On 11/13/19, ERCOT Staff reviewed the requested analysis on items 1-7 and the implementation options outlined in the 11/5/19 ERCOT comments, noting the need to revise the Impact Analysis for NPRR941. Participants expressed support for only pursuing items 1-3 as part of NPRR941 and requested ERCOT revise the Impact Analysis for consideration at TAC. | |
| TAC Decision | | On 11/20/19, TAC unanimously voted to recommend approval of NPRR941 as recommended by PRS in the 11/13/19 PRS Report as revised by TAC, and the Revised Impact Analysis. All Market Segments were present for the vote. | |
| Summary of TAC Discussion | | On 11/20/19, participants added verbiage to the Business Case noting the NPRR941 project’s impact on future trading Hub development. | |
| ERCOT Opinion | | ERCOT supports approval of NPRR941. | |

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| Sponsor | |
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| E-mail Address | [milberg@dc-energy.com](mailto:milberg@dc-energy.com) |
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| Market Segment | IPM |

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| --- | --- |
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| **Comments Received** | |
| Comment Author | **Comment Summary** |
| WMS 072219 | Requested PRS continue to table NPRR941 for further review by the Congestion Management Working Group (CMWG) |
| DC Energy 080619 | Modified the list of Hub Buses to only include those buses with at least three transmission connections |
| WMS 080819 | Endorsed NPRR941 as amended by the 8/6/19 DC Energy comments |
| ERCOT 102819 | Modified the Hub Bus names within Section 3.5.2.6 to ensure unique names for each |
| ERCOT 110519 | Provided the analysis requested at the October 10, 2019 PRS meeting regarding system limitations on creation of future Hub Buses and cost estimates to address them |

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| --- |
| **Market Rules Notes** |

Please note the baseline Protocol language in the following section(s) has been updated to reflect the incorporation of the following NPRR(s) into the Protocols:

* NPRR931, As Built Hub Average Calculation (incorporated 9/1/19)
  + Section 3.5.2.6

|  |
| --- |
| Proposed Protocol Language Revision |

**3.5.2.6 Lower Rio Grande Valley Hub (LRGV 138/345)**

(1) The Lower Rio Grande Valley Hub 138/345 kV Hub is composed of the following listed Hub Buses:

|  |  |  |  |
| --- | --- | --- | --- |
|  | ERCOT Operations |  |  |
| No. | Hub Bus | kV | Hub |
| 1 | AIRPORT | 138 | LRGV |
| 2 | ALBERTA | 138 | LRGV |
| 3 | BATES | 138 | LRGV |
| 4 | FRONTERA | 138 | LRGV |
| 5 | GARZA | 138 | LRGV |
| 6 | HARLNSW | 138 | LRGV |
| 7 | HEC | 138 | LRGV |
| 8 | KEY\_SW | 138 | LRGV |
| 9 | LA\_PALMA\_345 | 345 | LRGV |
| 10 | LA\_PALMA\_138 | 138 | LRGV |
| 11 | LASPULGA | 138 | LRGV |
| 12 | LISTON | 138 | LRGV |
| 13 | LOMA\_ALT | 138 | LRGV |
| 14 | MARCONI | 138 | LRGV |
| 15 | MILHWY | 138 | LRGV |
| 16 | MILITARY | 138 | LRGV |
| 17 | MV\_WEDN4 | 138 | LRGV |
| 18 | N\_MCALLN | 138 | LRGV |
| 19 | NEDIN\_345 | 345 | LRGV |
| 20 | NEDIN\_138 | 138 | LRGV |
| 21 | OLEANDER | 138 | LRGV |
| 22 | P\_ISABEL | 138 | LRGV |
| 23 | PALMHRTP | 138 | LRGV |
| 24 | PALMITO\_345 | 345 | LRGV |
| 25 | PALMITO\_138 | 138 | LRGV |
| 26 | PAREDES | 138 | LRGV |
| 27 | PHARMVEC | 138 | LRGV |
| 28 | PHARR | 138 | LRGV |
| 29 | PRICE\_RD | 138 | LRGV |
| 30 | RAILROAD | 138 | LRGV |
| 31 | RAYMND2 | 138 | LRGV |
| 32 | REDTAP | 138 | LRGV |
| 33 | RIO\_GRAN | 138 | LRGV |
| 34 | RIOHONDO\_345 | 345 | LRGV |
| 35 | RIOHONDO\_138 | 138 | LRGV |
| 36 | ROMA\_SW | 138 | LRGV |
| 37 | S\_MCALLN | 138 | LRGV |
| 38 | SCARBIDE | 138 | LRGV |
| 39 | SILASRAY | 138 | LRGV |
| 40 | STEWART | 138 | LRGV |
| 41 | WESLACO | 138 | LRGV |

(2) The Lower Rio Grande Valley 138/345 kV Hub Price uses the aggregated Shift Factors of the Hub Buses for each hour of the Settlement Interval of the DAM in the Day-Ahead and is the simple average of the time weighted Hub Bus prices for each 15-minute Settlement Interval in Real-Time, for each Hub Bus included in this Hub.

(3) The Day-Ahead Settlement Point Price of the Hub for a given Operating Hour is calculated as follows:

**DASPP** *LRGV 138/345* **= DASL – (DAHUBSF***LRGV 138/345, c***\* DASP** *c***),**

**if HBBC***LRGV138/345***≠0**

**DASPP** *LRGV138/345* **= DASPP** *ERCOT345Bus***, if HBBC***LRGV138/345***=0**

Where:

DAHUBSF *LRGV138/345, c =* (HUBDF *hb, LRGV138/345, c* \* DAHBSF *hb, LRGV138/345, c*)

DAHBSF *hb, LRGV138/345, c =* (HBDF *pb, hb, LRGV138/345, c* \* DASF *pb, hb, LRGV138/345, c*)

HUBDF *hb, LRGV138/345, c =* IF(HB*LRGV138/345, c*=0, 0, 1 **/** HB *LRGV138/345, c*)

HBDF *pb, hb, LRGV138/345, c =* IF(PB*hb, LRGV138/345, c*=0, 0, 1 **/** PB *hb, LRGV138/345, c*)

The above variables are defined as follows:

| Variable | Unit | Definition |
| --- | --- | --- |
| DASPP *LRGV138/345* | $/MWh | *Day-Ahead Settlement Point Price*⎯The DAM Settlement Point Price at the Hub, for the hour. |
| DASL | $/MWh | *Day-Ahead System Lambda*⎯The DAM Shadow Price for the system power balance constraint for the hour. |
| DASP *c* | $/MWh | *Day-Ahead Shadow Price for a binding transmission constraint*⎯The DAM Shadow Price for the constraint *c* for the hour. |
| DAHUBSF *LRGV138/345,c* | none | *Day-Ahead Shift Factor of the Hub ⎯*The DAM aggregated Shift Factor of a Hub for the constraint *c* for the hour. |
| DAHBSF *hb, LRGV138/345,c* | none | *Day-Ahead Shift Factor of the Hub Bus⎯*The DAM aggregated Shift Factor of a Hub Bus *hb* for the constraint *c* for the hour. |
| DASF *pb,hb, LRGV138/345,c* | none | *Day-Ahead Shift Factor of the power flow bus⎯*The DAM Shift Factor of a power flow bus *pb* that is a component of Hub Bus *hb* for the constraint *c* for the hour. |
| HUBDF *hb, LRGV138/345,c* | none | *Hub Distribution Factor per Hub Bus in a constraint*⎯The distribution factor of Hub Bus *hb* for the constraint *c* for the hour. |
| HBDF *pb, hb, LRGV138/345,c* | none | *Hub Bus Distribution Factor per power flow bus of Hub Bus in a constraint*⎯The distribution factor of power flow bus *pb* that is a component of Hub Bus *hb* for the constraint *c* for the hour. |
| *pb* | none | An energized power flow bus that is a component of a Hub Bus for the constraint *c*. |
| PB *hb, LRGV138/345,c* | none | The total number of energized power flow buses in Hub Bus *hb* for the constraint *c*. |
| *hb* | none | A Hub Bus that is a component of the Hub with at least one energized power flow bus for the constraint *c*. |
| HBBC *LRGV138/345* | none | The total number of Hub Buses in the Hub with at least one energized component in each Hub Bus in base case. |
| HB *LRGV138/345,c* | none | The total number of Hub Buses in the Hub with at least one energized component in each Hub Bus for the constraint *c*. |
| *c* | none | A DAM binding transmission constraint for the hour caused by either base case or a contingency. |

(4) The Real-Time Settlement Point Price of the Hub for a given 15-minute Settlement Interval is calculated as follows:

**RTSPP** *LRGV138/345* **= Max [-$251, (RTRSVPOR + RTRDP +**

**(HUBDF** *hb, LRGV138/345* **\* ( (RTHBP** *hb, LRGV138/345, y* **\* TLMP** *y***) / (TLMP** *y***))))], if HB***LRGV138/345***≠0**

**RTSPP** *LRGV138/345* **= RTSPP** *ERCOT345Bus*, **if HB***LRGV138/345***=0**

Where:

RTRSVPOR = (RNWF *y* \* RTORPA *y*)

RTRDP = (RNWF *y* \* RTORDPA *y*)

RNWF *y* = TLMP *y* / TLMP *y*

RTHBP *hb, LRGV138/345, y* = (HBDF *b, hb, LRGV138/345* \* RTLMP *b, hb, LRGV138/345, y*)

HUBDF *hb, LRGV138/345* = IF(HB *LRGV138/345*=0, 0, 1 **/** HB*LRGV138/345*)

HBDF *b, hb, LRGV138/345* = IF(B*hb, LRGV138/345*=0, 0, 1 **/** B *hb, LRGV138/345*)

The above variables are defined as follows:

| **Variable** | **Unit** | **Description** |
| --- | --- | --- |
| RTSPP *LRGV138/345kV* | $/MWh | *Real-Time Settlement Point Price*⎯The Real-Time Settlement Point Price at the Hub for the 15-minute Settlement Interval. |
| RTRSVPOR | $/MWh | *Real-Time Reserve Price for On-Line Reserves*⎯The Real-Time Reserve Price for On-Line Reserves for the 15-minute Settlement Interval. |
| RTORPA*y* | $/MWh | *Real-Time On-Line Reserve Price Adder per interval*⎯The Real-Time On-Line Reserve Price Adder for the SCED interval *y*. |
| RTRDP | $/MWh | *Real-Time On-Line Reliability Deployment Price*⎯The Real-Time price for the 15-minute Settlement Interval, reflecting the impact of reliability deployments on energy prices that are calculated from the Real-Time On-Line Reliability Deployment Price Adder. |
| RTORDPA *y* | $/MWh | *Real-Time On-Line Reliability Deployment Price Adder*⎯The Real-Time price adder that captures the impact of reliability deployments on energy prices for the SCED interval *y.* |
| RNWF *y* | none | *Resource Node Weighting Factor per interval*⎯The weight used in the Resource Node Settlement Point Price calculation for the portion of the SCED interval *y* within the Settlement Interval. |
| RTHBP *hb, LRGV138/345kV, y* | $/MWh | *Real-Time Hub Bus Price at Hub Bus per SCED interval*⎯The Real-Time energy price at Hub Bus *hb* for the SCED interval *y*. |
| RTLMP *b, hb, LRGV138/345kV, y* | $/MWh | *Real-Time Locational Marginal Price at Electrical Bus of Hub Bus per interval*⎯The Real-Time LMP at Electrical Bus *b* that is a component of Hub Bus *hb* for the SCED interval *y*. |
| TLMP *y* | second | *Duration of SCED interval per interval*⎯The duration of the portion of the SCED interval *y* within the 15-minute Settlement Interval. |
| HUBDF *hb, LRGV138/345kV* | none | *Hub Distribution Factor per Hub Bus*⎯The distribution factor of Hub Bus *hb*. |
| HBDF *b, hb, LRGV138/345kV* | none | *Hub Bus Distribution Factor per Electrical Bus of Hub Bus*⎯The distribution factor of Electrical Bus *b* that is a component of Hub Bus *hb*. |
| *y* | none | A SCED interval in the 15-minute Settlement Interval. The summation is over the total number of SCED runs that cover the 15-minute Settlement Interval. |
| *b* | none | An energized Electrical Bus that is a component of a Hub Bus. |
| B *hb, LRGV138/345kV* | none | The total number of energized Electrical Buses in Hub Bus *hb*. |
| *hb* | none | A Hub Bus that is a component of the Hub. |
| HB*LRGV138/345kV* | none | The total number of Hub Buses in the Hub with at least one energized component in each Hub Bus. |

**3.5.2.7 ERCOT Hub Average 345 kV Hub (ERCOT 345)**

(1) The ERCOT Hub Average 345 kV Hub price for Day-Ahead is calculated for each hour using the aggregated Shift Factors of four Hubs: the North 345 kV Hub, the South 345 kV Hub, the Houston 345 kV Hub, and the West 345 kV Hub. The ERCOT Hub Average 345 kV Hub price for Real-Time is the simple average of four prices from the applicable time period: the North 345 kV Hub price, the South 345 kV Hub price, the Houston 345 kV Hub price, and the West 345 kV Hub price. The Panhandle 345 kV Hub and the Lower Rio Grande Valley 138/345 kV Hub are not included in either the Day-Ahead or Real-Time ERCOT Hub Average 345 kV Hub price.

(2) The Day-Ahead Settlement Point Price for the Hub “ERCOT 345” for a given Operating Hour is calculated as follows:

**DASPP *ERCOT345* = DASL – (DAHUBSF*ERCOT345, c* \* DASP *c*),**

**if HBBC*ERCOT345Bus*≠0**

**DASPP *ERCOT345* = DASPP *ERCOT345Bus*, if HBBC *ERCOT345Bus*=0**

Where:

DAHUBSF *ERCOT345, c =* (DAHUBSF *North345, c* + DAHUBSF *South345, c* +

DAHUBSF *Houston345, c* + DAHUBSF *West345, c*) / 4

The above variables are defined as follows:

| Variable | Unit | Definition |
| --- | --- | --- |
| DASPP *ERCOT345* | $/MWh | *Day-Ahead Settlement Point Price at ERCOT 345*⎯The DAM Settlement Point Price at ERCOT 345 Hub for the hour. |
| DASL | $/MWh | *Day-Ahead System Lambda*⎯The DAM Shadow Price for the system power balance constraint for the hour. |
| DASP *c* | $/MWh | *Day-Ahead Shadow Price for a binding transmission constraint*⎯The DAM Shadow Price for the constraint *c* for the hour. |
| DAHUBSF *ERCOT345,c* | none | *Day-Ahead Shift Factor of ERCOT 345 ⎯*The DAM aggregated Shift Factor of ERCOT 345 Hub for the constraint *c* for the hour. |
| DAHUBSF *North345,c* | none | *Day-Ahead Shift Factor of North 345⎯*The DAM aggregated Shift Factor of the North 345 Hub for the constraint *c* for the hour. |
| DAHUBSF *South345,c* | none | *Day-Ahead Shift Factor of South 345⎯*The DAM aggregated Shift Factor of the South 345 Hub for the constraint *c* for the hour. |
| DAHUBSF *Houston345,c* | none | *Day-Ahead Shift Factor of Houston 345⎯*The DAM aggregated Shift Factor of the Houston 345 Hub for the constraint *c* for the hour. |
| DAHUBSF *West345,c* | none | *Day-Ahead Shift Factor of West 345⎯*The DAM aggregated Shift Factor of the West 345 Hub for the constraint *c* for the hour. |
| HBBC *ERCOT345Bus* | none | The total number of Hub Buses in the ERCOT Bus Average 345 kV Hub (ERCOT 345 Bus) with at least one energized component in each Hub Bus in base case. The Hub “ERCOT 345 Bus” includes any Hub Bus defined in the Hub “North 345”, “South 345”, “Houston 345” and “West 345”. |
| *c* | none | A DAM binding transmission constraint for the hour caused by either base case or a contingency. |

(3) The Real-Time Settlement Point Price for the Hub “ERCOT 345” for a given 15-minute Settlement Interval is calculated as follows:

RTSPP *ERCOT345* = (RTSPP *North345* + RTSPP *South345* + RTSPP *Houston345* + RTSPP *West345*) / 4

The above variables are defined as follows:

|  |  |  |
| --- | --- | --- |
| Variable | Unit | Definition |
| RTSPP *ERCOT345* | $/MWh | *Real-Time Settlement Point Price at ERCOT 345*⎯The Real-TimeSettlement Point Price at ERCOT 345 Hub for the 15-minute Settlement Interval. |
| RTSPP *North345* | $/MWh | *Real-Time Settlement Point Price at North 345*⎯The Real-Time Settlement Point Price at the North345 Hub for the 15-minute Settlement Interval. |
| RTSPP *South345* | $/MWh | *Real-Time Settlement Point Price at South 345*⎯The Real-Time Settlement Point Price at the South 345 Hub for the 15-minute Settlement Interval. |
| RTSPP *Houston345* | $/MWh | *Real-Time Settlement Point Price at Houston 345*⎯The Real-Time Settlement Point Price at the Houston 345 Hub for the 15-minute Settlement Interval. |
| RTSPP *West345* | $/MWh | *Real-Time Settlement Point Price at West 345*⎯The Real-Time Settlement Point Price at the West 345 Hub for the 15-minute Settlement Interval. |

**3.5.2.8 ERCOT Bus Average 345 kV Hub (ERCOT 345 Bus)**

(1) The ERCOT Bus Average 345 kV Hub is composed of the Hub Buses listed in Section 3.5.2.1, North 345 kV Hub (North 345); Section 3.5.2.2, South 345 kV Hub (South 345); Section 3.5.2.3, Houston 345 kV Hub (Houston 345); and Section 3.5.2.4, West 345 kV Hub (West 345). The Panhandle 345 kV Hub and the Lower Rio Grande Valley 138/345 kV Hub are not included in the ERCOT Bus Average 345 kV Hub price.

(2) The ERCOT Bus Average 345 kV Hub uses the aggregated Shift Factors of the Hub Buses for each hour of the Settlement Interval of the DAM in the Day-Ahead and is the simple average of the time weighted Hub Bus prices for each 15-minute Settlement Interval in Real-Time, for each Hub Bus included in this Hub.

(3) The Day-Ahead Settlement Point Price of the Hub for a given Operating Hour is calculated as follows:

**DASPP** *ERCOT345Bus* **= DASL – (DAHUBSF***ERCOT345Bus, c***\* DASP** *c***),**

**if HBBC***ERCOT345Bus***≠0**

**DASPP** *ERCOT345Bus* **= 0, if HBBC***ERCOT345Bus***=0**

Where:

DAHUBSF *ERCOT345Bus, c =* (HUBDF *hb, ERCOT345Bus, c* \* DAHBSF *hb, ERCOT345Bus, c*)

DAHBSF *hb, ERCOT345Bus, c  =* (HBDF *pb, hb, ERCOT345Bus, c* \* DASF *pb, hb, ERCOT345Bus, c*)

HUBDF *hb, ERCOT345Bus, c =* IF(HB*ERCOT345Bus, c*=0, 0, 1 **/** HB *ERCOT345Bus, c*)

HBDF *pb, hb, ERCOT345Bus, c =* IF(PB*hb, ERCOT345Bus, c*=0, 0, 1 **/** PB *hb, ERCOT345Bus, c*)

The above variables are defined as follows:

| **Variable** | **Unit** | **Definition** |
| --- | --- | --- |
| DASPP *ERCOT345Bus* | $/MWh | *Day-Ahead Settlement Point Price*⎯The DAM Settlement Point Price at the Hub, for the hour. |
| DASL | $/MWh | *Day-Ahead System Lambda*⎯The DAM Shadow Price for the system power balance constraint for the hour. |
| DASP *c* | $/MWh | *Day-Ahead Shadow Price for a binding transmission constraint*⎯The DAM Shadow Price for the constraint *c* for the hour. |
| DAHUBSF *ERCOT345Bus,c* | none | *Day-Ahead Shift Factor of the Hub ⎯*The DAM aggregated Shift Factor of a Hub for the constraint *c* for the hour. |
| DAHBSF *hb,ERCOT345Bus,c* | none | *Day-Ahead Shift Factor of the Hub Bus⎯*The DAM aggregated Shift Factor of a Hub Bus *hb* for the constraint *c* for the hour. |
| DASF *pb,hb,ERCOT345Bus,c* | none | *Day-Ahead Shift Factor of the power flow bus⎯*The DAM Shift Factor of a power flow bus *pb* that is a component of Hub Bus *hb* for the constraint *c* for the hour. |
| HUBDF *hb,ERCOT345Bus,c* | none | *Hub Distribution Factor per Hub Bus in a constraint*⎯The distribution factor of Hub Bus *hb* for the constraint *c* for the hour. |
| HBDF *pb, hb, ERCOT345Bus,c* | none | *Hub Bus Distribution Factor per power flow bus of Hub Bus in a constraint*⎯The distribution factor of power flow bus *pb* that is a component of Hub Bus *hb* for the constraint *c* for the hour. |
| *pb* | none | An energized power flow bus that is a component of a Hub Bus for the constraint *c*. |
| PB *hb, ERCOT345Bus,c* | none | The total number of energized power flow buses in Hub Bus *hb* for the constraint *c*. |
| *hb* | none | A Hub Bus that is a component of the ERCOT Bus Average 345 kV Hub (ERCOT 345 Bus) with at least one energized power flow bus for the constraint *c*. The Hub “ERCOT 345 Bus” includes any Hub Bus defined in the Hub “North 345”, “South 345”, “Houston 345” and “West 345”. |
| HBBC *ERCOT345Bus* | none | The total number of Hub Buses in the ERCOT Bus Average 345 kV Hub (ERCOT 345 Bus) with at least one energized component in each Hub Bus in base case. The Hub “ERCOT 345 Bus” includes any Hub Bus defined in the Hub “North 345”, “South 345”, “Houston 345” and “West 345”. |
| HB *ERCOT345Bus,c* | none | The total number of Hub Buses in the ERCOT Bus Average 345 kV Hub (ERCOT 345 Bus) with at least one energized component in each Hub Bus for the constraint *c*. The Hub “ERCOT 345 Bus” includes any Hub Bus defined in the Hub “North 345”, “South 345”, “Houston 345” and “West 345”. |
| *c* | none | A DAM binding transmission constraint for the hour caused by either base case or a contingency. |

(4) The Real-Time Settlement Point Price of the Hub for a given 15-minute Settlement Interval is calculated as follows:

**RTSPP** *ERCOT345Bus* **= Max [-$251, (RTRSVPOR + RTRDP +**

**(HUBDF** *hb, ERCOT345Bus* **\* ((RTHBP** *hb, ERCOT345Bus, y* **\* TLMP** *y***) / (TLMP** *y***))))], if HB** *ERCOT345Bus* **≠0**

**RTSPP** *ERCOT345Bus* **= 0, if HB***ERCOT345Bus* **=0**

Where:

RTRSVPOR = (RNWF *y* \* RTORPA *y*)

RTRDP = (RNWF *y* \* RTORDPA *y*)

RNWF *y* = TLMP *y* / TLMP *y*

RTHBP *hb, ERCOT345Bus, y* = (HBDF *b, hb, ERCOT345Bus* \* RTLMP *b, hb, ERCOT345Bus, y*)

HUBDF *hb, ERCOT345Bus* = 1 **/** (HB*North345* + HB*South345* + HB*Houston345* + HB*West345*)

If Electrical Bus *b* is a component of “North 345”

HBDF *b, hb, ERCOT345Bus* = IF(B *hb, North345*=0, 0, 1 **/** B *hb, North345*)

Otherwise

If Electrical Bus *b* is a component of “South 345”

HBDF *b, hb, ERCOT345Bus* = IF(B *hb, South345*=0, 0, 1 **/** B *hb, South345*)

Otherwise

If Electrical Bus *b* is a component of “Houston 345”

HBDF *b, hb, ERCOT345Bus* = IF(B *hb, Houston345*=0, 0, 1 **/** B *hb, Houston345*)

Otherwise

HBDF *b, hb, ERCOT345Bus* = IF(B *hb, West345*=0, 0, 1 **/** B *hb, West345*)

The above variables are defined as follows:

| **Variable** | **Unit** | **Description** |
| --- | --- | --- |
| RTSPP *ERCOT345Bus* | $/MWh | *Real-Time Settlement Point Price*⎯The Real-Time Settlement Point Price at the Hub, for the 15-minute Settlement Interval. |
| RTRSVPOR | $/MWh | *Real-Time Reserve Price for On-Line Reserves*⎯The Real-Time Reserve Price for On-Line Reserves for the 15-minute Settlement Interval. |
| RTORPA*y* | $/MWh | *Real-Time On-Line Reserve Price Adder per interval*⎯The Real-Time On-Line Reserve Price Adder for the SCED interval *y*. |
| RTRDP | $/MWh | *Real-Time On-Line Reliability Deployment Price*⎯The Real-Time price for the 15-minute Settlement Interval, reflecting the impact of reliability deployments on energy prices that are calculated from the Real-Time On-Line Reliability Deployment Price Adder. |
| RTORDPA *y* | $/MWh | *Real-Time On-Line Reliability Deployment Price Adder*⎯The Real-Time price adder that captures the impact of reliability deployments on energy prices for the SCED interval *y.* |
| RNWF *y* | none | *Resource Node Weighting Factor per interval*⎯The weight used in the Resource Node Settlement Point Price calculation for the portion of the SCED interval *y* within the Settlement Interval. |
| RTHBP *hb, ERCOT345Bus, y* | $/MWh | *Real-Time Hub Bus Price at Hub Bus per SCED interval*⎯The Real-Time energy price at Hub Bus *hb* for the SCED interval *y*. |
| RTLMP *b, hb, ERCOT345Bus, y* | $/MWh | *Real-Time Locational Marginal Price at Electrical Bus of Hub Bus per interval*⎯The Real-Time LMP at Electrical Bus *b* that is a component of Hub Bus *hb*, for the SCED interval *y*. |
| TLMP *y* | second | *Duration of SCED interval per interval*⎯The duration of the portion of the SCED interval *y* within the 15-minute Settlement Interval. |
| HUBDF *hb, ERCOT345Bus* | none | *Hub Distribution Factor per Hub Bus*⎯The distribution factor of Hub Bus *hb*. |
| HBDF *b, hb, ERCOT345Bus* | none | *Hub Bus Distribution Factor per Electrical Bus of Hub Bus*⎯The distribution factor of Electrical Bus *b* that is a component of Hub Bus *hb*. |
| *y* | none | A SCED interval in the 15-minute Settlement Interval. The summation is over the total number of SCED runs that cover the 15-minute Settlement Interval. |
| *b* | none | An energized Electrical Bus that is a component of a Hub Bus. |
| B *hb, North345* | none | The total number of energized Electrical Buses in Hub Bus *hb* that is a component of “North 345.” |
| B *hb, South345* | none | The total number of energized Electrical Buses in Hub Bus *hb* that is a component of “South 345.” |
| B *hb, Houston345* | none | The total number of energized Electrical Buses in Hub Bus *hb* that is a component of “Houston 345.” |
| B *hb, West345* | none | The total number of energized Electrical Buses in Hub Bus *hb* that is a component of “West 345.” |
| *hb* | none | A Hub Bus that is a component of the Hub. |
| HB*North345* | none | The total number of Hub Buses in “North 345.” |
| HB*South345* | none | The total number of Hub Buses in “South 345.” |
| HB*Houston345* | none | The total number of Hub Buses in “Houston 345.” |
| HB*West345* | none | The total number of Hub Buses in “West 345.” |