Study of the Operational Improvements and Other Benefits Associated with the Implementation of Real-Time Co-optimization of Energy and Ancillary Services

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1. Introduction

Electric Reliability Council of Texas, Inc. (ERCOT) provides this report in response to the October 27, 2017, Open Meeting discussion directing ERCOT and the Independent Market Monitor of Texas to study the expected benefits of the potential implementation of Real-Time Co-optimization (RTC) of energy and Ancillary Services (AS). This report addresses the implications of RTC on the actions of ERCOT's operators to manage system reliability and provides a quantitative analysis of the effects of RTC on historical Reliability Unit Commitment (RUC) and Supplemental Ancillary Service Market (SASM) activity. ERCOT has also provided support to the Independent Market Monitor (IMM) in its historical analysis of the impact of RTC on Security-Constrained Economic Dispatch (SCED), which is being submitted separately.

ERCOT's analysis has yielded several key findings. First, ERCOT anticipates significant operational benefits from the implementation of RTC, including more timely procurement of additional AS when necessary, more effective congestion management, a reduction in manual actions by operators, and an improved management of Resource-specific capabilities in assigning and deploying AS. Regarding RUC activity, a study of 165 historical RUC cases from 2016 indicates that co-optimization would have eliminated Resource commitments in at least 9 of the cases. Finally, ERCOT has executed 391 SASMs covering more than 2,200 operating hours since the beginning of the nodal market at clearing prices averaging approximately $100/MWh more than the corresponding Day-Ahead Market (DAM) price for the same operating day, hour, and AS product. The number of MW procured in these SASMs, when priced at the $100/MW premium, is a cost difference of approximately $11 million. RTC would eliminate the need for these SASMs. Also related to SASMs, the ability of Market Participants to buy back their AS in Real-Time under RTC and reduce their risk of a Day-Ahead AS obligation due to a SASM would likely increase the liquidity of the Day-Ahead AS market.

2. Operational Benefits of Co-optimization

Under the current market design, ERCOT procures required quantities of AS in the DAM to ensure grid reliability in Real-Time. AS procured in the DAM acts as insurance for system events ranging from forecast error to unit trips. ERCOT operators rely on SASMs to replace AS responsibilities that are declared infeasible due to congestion or that the responsible Qualified Scheduling Entity (QSE) fails to provide. The approximate two-hour period required to announce a SASM, allow Market Participants to update their offers, execute the SASM, post the results, and allow Market Participants to update their Current Operating Plans (COPs) reflecting awards, effectively prevents ERCOT from replacing the AS responsibility within the two hours following identification of the insufficiency, potentially extending AS shortages during that period. ERCOT operators have, in fact, experienced these shortages while awaiting procurement. By contrast, under RTC, SCED would dynamically assign AS responsibilities during its next execution and replace that responsibility. RTC thus resolves the reliability concerns associated with the delay in procuring infeasible or insufficient AS.

RTC would also improve ERCOT's ability to manage changing AS needs associated with the evolving Resource mix in the ERCOT region. As ERCOT's Resource mix continues to change, identifying risks associated with forecasted demand, wind, and solar will be key to ensuring reliable grid operations. ERCOT expects these changes will also result in more efficient and nimble unit commitments by Market Participants. The excess headroom capacity that the grid has enjoyed in Real-Time has often covered the historical risk associated with infeasible and insufficient AS and AS that QSEs fail to provide; but a decrease in this capacity could result in lower margins of error in both identifying AS requirements as well as replacing AS responsibilities. RTC would allow ERCOT to dynamically adjust AS quantities in Real-Time as uncertainties associated with demand, wind power, and solar power change. Without RTC, the changes to ERCOT's Resource mix would require ERCOT to be more conservative in estimating the needed AS quantities to ensure reliability, which may add costs to the market.[1]

The implementation of RTC would also allow ERCOT to more efficiently resolve congestion on the transmission system. RTC would enable SCED to recognize and act on the preference for having energy, as opposed to AS, at a given location on the transmission system, including during periods of non-scarcity. While locational pricing will indicate this preference under the current design, individual Market Participants cannot always respond to this preference in the near-term, especially those with small Resource portfolios. Additionally, the ability to act on this preference automatically and immediately will reduce the volatility of dispatch of Resources across the system.

Implementing RTC would also allow ERCOT operators to focus on other reliability issues. Significant operator attention is currently allocated to various activities associated with monitoring and addressing system AS needs. These activities include (1) identifying the conditions that will trigger the need to deploy AS and release additional capacity for economic dispatch, (2) tracking the ability of individual Resources to meet scheduled AS responsibilities, and (3) detecting cases in which the provision of AS is infeasible due to congestion on the transmission system. These manual activities would be automatically performed with the implementation of RTC and would be done without adversely impacting market pricing, which is a risk when using manual processes. Automating these activities through RTC would allow ERCOT operators to refocus their attention on various other concerns arising on the grid during Real-Time operations. RTC would also result in more consistent, predictable outcomes for Market Participants, due to the replacing current manual reliability actions with a market solution, and would allow Market Participants to better prepare for and respond to conditions on the grid.

Finally, the implementation of RTC would result in improved management of Resource-specific capabilities in assigning and deploying AS through continuous Real-Time adjustments of individual AS responsibilities. Today, the scenarios in which this does not occur can lead to degradation of the services. For example, in transitioning from one operating hour to another, Resources may take multiple SCED intervals to adjust to their updated AS responsibilities, which means the full amount of AS they are obligated to provide may not necessarily be available for deployment during this transition period. Similar concerns arise with the deployment of Regulation Service at the portfolio level where the system is not designed to consider individual Resource capabilities and the total

[1] The quantities of AS that are procured in the DAM are typically determined between 1 month and 13 months ahead of the operating period during which they will be in effect. With these values being determined far in advance, the amount of AS procured may not necessarily truly reflect the needs in Real-Time. The methodology for determining the minimum amount of AS can be found at http://www.ercot.com/content/wcm/key_documents_lists/89135/ERCOT_Methodologies_for_Determining_Minimum_Ancillary_Service_Requirements.zip.

expected output of the Resource cannot be fully attained. The continuous adjustments enabled through RTC would increase the likelihood that procured AS would be fully provided.

In a related manner, implementation of RTC would allow ERCOT to better utilize limited-duration Resources such as batteries and Controllable Load Resources. RTC would allow ERCOT to use system-wide information updated every five minutes to identify the optimal AS responsibility quantities for each Resource while considering and respecting the Resource's limits and status. This will remove unnecessary barriers to participation in the AS markets.

3. Reliability Unit Commitment (RUC) Analysis

3.1. Impact of RTC on the Need for RUC Commitments

If RTC were to be implemented in the ERCOT market, ERCOT presumes that the optimization engine for the RUC process would also be modified to co-optimize energy and AS. As a result, the RUC engine would have improved capability to resolve projected congestion on the transmission system with Resources that are already committed by their Qualified Scheduling Entity (QSE) to be on-line. Co-optimization would allow all on-line capacity from Resources, including capacity that is currently reserved by Market Participants to provide AS, to be used in the most effective way to meet all of the constraints of the system: balancing power needs, meeting AS requirements, and managing transmission constraints. This would lead to an overall reduction in the need for ERCOT to instruct additional Resources on-line.

Currently, each QSE decides which of its Resources will be responsible for satisfying the QSE's AS obligation in Real-Time. These obligations can result from DAM awards, SASM awards, self-schedules of AS, or trades with other Market Participants. The decisions are communicated to ERCOT through Resource COPs, and the COPs are used as inputs to the RUC optimization engine. The RUC optimization engine is unable to modify the AS assignments of Resources, even if the reserved capacity could help resolve transmission congestion and avoid out-of-market Resource commitments. Incorporating the co-optimization of energy and AS in the RUC process would provide the RUC optimization engine the flexibility to determine the most efficient way to make use of the Resources projected to be on-line and available.

Two conditions need to be met in order for co-optimization to reduce the need for RUC instructions by ERCOT. First, at least one Resource with an AS responsibility must be located at a point in the system where it could help manage transmission congestion that cannot be resolved through the re-dispatch of other on-line Resources. Second, there must be other Resources elsewhere in the system that are both qualified to provide the service and not currently needed to help resolve other constraints on the system. In cases where these conditions are not met, co-optimization will not affect the need for RUC instructions. In cases where these conditions are met, the magnitude of the benefit will depend on the amount of capacity being reserved on the Resource to provide AS, the sensitivity of the Resource in helping to resolve the transmission congestion, and the magnitude of the projected overloading of the transmission equipment prior to rearranging the AS responsibilities.

3.2. Impact of RTC on Historical RUC Activity

ERCOT performed an analysis to quantify the effect of co-optimization on historical RUC cases. In this analysis, 165 historical RUC cases from 2016, during which a RUC instruction occurred, were executed with the inputs modified to determine whether there was a reduction in commitment recommendations from the RUC engine if it were able to co-optimize energy and AS. These 165 cases account for all cases in 2016 where the RUC engine recommended the commitment of the Resource that was instructed on-line by ERCOT. In the cases where a RUC instruction was not recommended by the RUC engine (e.g., a Verbal Dispatch Instruction (VDI) or a manual selection by the operator), a change to the commitment recommendation from the RUC engine would not clearly indicate a change in the decision to commit the Resource. It should also be noted that not all recommendations from the RUC engine are accepted and issued as instructions by ERCOT. For example, a recommendation is typically deferred if there is ample time to commit the Resource during a later RUC study.

To simulate the effects of co-optimization for this study, ERCOT modified the RUC cases to remove all AS responsibilities from on-line Generation Resources in order to provide the optimization engine flexibility to resolve transmission constraints with all on-line capacity. After executing the RUC optimization with these modified cases, the results were analyzed to determine whether there was still sufficient qualified on-line capacity available to which the AS responsibility could be reallocated. If sufficient capacity was identified in the solution, the analysis concluded that a RUC engine with co-optimization would have reached that solution while still honoring on-line AS requirements.[2] This approach is conservative and will not identify all cases in which co-optimization would have reduced the need for a RUC instruction. Even in a case where the solution did not have sufficient on-line capacity to meet the AS requirements, it is possible that a co-optimized solution could have found an alternative solution meeting both transmission and AS requirements by shifting dispatch from AS-qualified capacity elsewhere in the system to unused capacity on Resources not qualified to provide AS.

[2] RUC with co-optimization would not ensure that there is a specific amount of on-line capacity providing Non-Spinning Reserve but would instead ensure that there is a sufficient combination of on-line and off-line capacity available. For this reason, this analysis did not require that the Non-Spinning Reserve be provided by on-line Resources.

The results from this analysis can be found in the following table:

Result	Expected Co-optimization Impact	Number of Cases
All originally committed Resources would still be recommended.	The RUC-committed Resource would still have been committed.	109
At least one originally committed Resource was no longer recommended, and the decision to commit one or more of the Resources in the new set of recommendations could not be deferred.	A different Resource would have been committed instead of the RUC-committed Resource.	20
At least one originally committed Resource was no longer recommended, and the decision to commit all Resources in the new set of recommendations could be deferred.	The RUC-committed Resource would not have been committed, and the decision to commit an alternative Resource would have been deferred. No Resources would have been RUC-committed in some of these cases.	27
The committed Resources were no longer recommended, and no alternative Resources were recommended. There was sufficient remaining capacity for AS.	No Resource would have been RUC-committed.	9
Total		165

Table 1. 2016 RUC re-run results comparing recommended resources

These results show that, in 109 of the 165 cases, removing AS responsibilities did not change the Resource commitment recommendations, suggesting that RTC would not likely have impacted the decision to commit the Resource. There are two likely reasons that the commitment recommendations did not change in these cases: either the case had few or no Resources that were carrying AS and that also had the ability to reduce flow on the constrained element, or the initial constraint violations were so large that the capacity reserved for AS would be insufficient to resolve the constraint.

In 47 of the 165 cases, the analysis recommended commitment of a new Resource in place of one or more originally recommended Resources. In 20 of these 47 cases, the recommendation could not be deferred due to Resources' startup times. In these cases it is likely that co-optimization would not have impacted the decision to commit a Resource. However, in 27 of the 47 cases, the decision to commit all of the recommended Resources could be deferred for at least one hour, indicating that the operator could wait until closer to Real-Time to see if system conditions changed or there were self-commitments that obviated the need for a RUC instruction. It is likely that in some of these 27 cases, co-optimization would have eliminated the need for the RUC instruction.

In the 9 remaining cases, removing the AS responsibilities from the RUC cases resulted in the elimination of all RUC recommendations. In each of these cases, there was sufficient qualified capacity remaining to fulfill AS requirements, indicating that co-optimization would have eliminated the need for the RUC instruction. Thus, in total, ERCOT's analysis suggests that RTC would have eliminated the need for RUC instructions in at least 9 of the 165 cases studied; but, as noted above, it might also have eliminated the need for RUC instructions in some of the 27 cases in which the decision to commit could be deferred.

As part of this analysis, ERCOT also considered the impact of RTC on the total amount of capacity recommended for commitment by the RUC engine. For example, if co-optimization allowed a 50 MW HSL Resource needed for one hour to replace a 100 MW Resource needed for two hours, the out-of-market capacity would decrease from 200 MW-hours to 50 MW-hours (i.e., a reduction of 150 MW-hours).

The results from this additional analysis are shown in the following two tables:

Result	Number of Cases
Cases with fewer recommended HSL MW-hours	103
Cases with equal recommended HSL MW-hours	32
Cases with more recommended HSL MW-hours	30
Total	165

Table 2. 2016 RUC re-run results comparing recommended HSL MW-hours

Result	Number of Cases
Cases with fewer recommended LSL MW-hours	103
Cases with equal recommended LSL MW-hours	33
Cases with more recommended LSL MW-hours	29
Total	165

Table 3. 2016 RUC re-run results comparing recommended LSL MW-hours

The above tables illustrate that, out of 165 RUC cases studied, 103 of the cases (62%) recommended fewer HSL MW-hours in total after releasing AS responsibilities, 32 of the cases (19%) recommended the same number of HSL MW-hours, indicating that co-optimization had no effect on the need to issue RUC commitments, and 30 of the cases (18%) had more HSL MW-hours recommended. The impact to LSL MW-hour recommendations is nearly the same. In the cases where RUC recommended more HSL or LSL MW-hours, the RUC engine was able to resolve more transmission violations with the individual Resource AS responsibilities relaxed. While resulting in more MW-hours, this result illustrates that co-optimization would increase the reliability of the system by providing the dispatch engine more options to resolve transmission constraints. In total, the analysis reduced the total HSL MW-hours recommended in the 165 cases from approximately 712 GW-hours to 577 GW-hours, a reduction of 19%, and reduced the total LSL MW-hours from approximately 207 GW-hours to 164 GW-hours, a reduction of 21%.

An example illustrates how co-optimization can eliminate the need for a RUC commitment. On May 31, 2016, ERCOT issued a RUC instruction to commit Capitol Cogen, a Combined-Cycle Generation Resource in the Houston area, for three hours to relieve congestion on the Singleton-Zenith lines that carry power into Houston. In this particular case, co-optimization would have allowed RUC to access approximately 1,500 MW of capacity that could have helped relieve the constraint, but was reserved for AS. The Resources with this capacity had varying sensitivities to the projected congestion, but in aggregate could have provided up to 136 MW of relief on the congested transmission line and removed the need to commit Capitol Cogen. In fact, there was one on-line Resource alone that had 120 MW of capacity reserved for AS that could have otherwise resolved the transmission constraint on its own, without needing to reassign AS from any of the other Resources in the system.

This analysis only studied the RUC commitments that occurred in 2016, and the number and impact of RUC instructions can vary and are hard to predict. While this analysis is only an indication of the impact of co-optimization on future RUC instructions, the results show that co-optimization would have reduced the need for RUC instructions by at least 9 of the 165 cases studied. To the extent that changes in market conditions or system complexity and uncertainty increase the need for ERCOT to issue RUC instructions, co-optimization would likely further mitigate the impact of those commitments.

4. Impacts of Co-optimization on the Supplementary Ancillary Service Market

SASMs are one mechanism ERCOT uses to reassign AS obligations when one or more QSEs are unable to provide their AS obligation in Real-Time. SASMs are often less liquid than the DAM, resulting in clearing prices that are significantly higher than DAM and not reflective of either the DAM or RTM conditions. With RTC, the RUC process would ensure that sufficient AS-qualified capacity is available and AS responsibilities would be dynamically assigned to the optimal set of on-line qualified Resources in Real-Time by RTC. As a result, the liquidity for reassigning AS responsibility would be increased in Real-Time. ERCOT expects that SASM would not be necessary with RTC, particularly for the cases in which a SASM is being used to reassign AS for a QSE that is unable to meet its AS obligations.

Clearing prices are higher in SASMs than in the DAM for several reasons. First, SASMs typically have much less liquidity than the DAM, which is primarily attributable to the infrequent and unpredictable nature of SASMs. Market Participants do not set aside capacity from DAM to offer into a SASM, and capacity that was cleared in the DAM is also no longer available in a SASM. Liquidity is also limited because Market Participants may not have the fuel arrangements necessary to provide AS. The second reason SASM clearing prices are higher is that offer prices are higher. SASM offers are generally higher than DAM offers because the more economic AS capacity already cleared in the DAM and because there is no make-whole guarantee, so QSEs have to include any applicable startup and minimum generation costs in their SASM offer without knowing what volume of AS they will be awarded. All these factors tend to result in higher clearing prices, potentially significantly higher, in a SASM, relative to the DAM.

These higher prices can result in disproportionate impacts on QSEs with fewer Resources in their portfolios. If a QSE fails to meet its AS obligation, it is required to pay a financial penalty, which may be based on the SASM clearing price. A QSE with a larger fleet is more insulated from the risk of paying this penalty as it is more likely to be able to shift the AS responsibility to another Resource within its portfolio. This asymmetry in risk for Market Participants is present in both energy and AS products, but is of greater significance in the AS market because the financial penalties are often higher for AS than for energy. RTC would reduce this asymmetry and would create an opportunity for increased participation in the DAM AS market.

To quantify the risk of high penalties due to failing to meet an AS obligation, ERCOT studied historical SASM and DAM AS prices from Nodal Go-Live through January 2018 to determine the price spread between the two markets. During this period, ERCOT executed 391 SASMs to replace approximately 130,000 MWh of AS covering more than 2,200 operating hours. Table 4 below contains statistics for the differences between each SASM clearing price and the DAM clearing price for the same operating day, delivery hour, and AS product. The average difference is $99.78/MWh, which is a substantial risk for products that normally clear between $1/MWh and $20/MWh in the DAM. The total difference in cost of these SASMs was approximately $11 million. RTC would eliminate SASMs and their associated risk and would also likely increase the liquidity of the DAM AS market as a consequence.

Statistic	SASM Price Minus the DAM Price for the Same Hour and AS Type
Min	-$491.14
10%	-$8.40
25%	-$2.23
Median	$2.05
75%	$15.90
90%	$253.45
Max	$6,969.49
Mean	$99.78

Table 4. Statistics on differences between SASM prices vs. corresponding DAM prices (Dec. 2010 - Jan. 2018). Positive values indicate SASM price cleared higher than the corresponding DAM price for the same operating day, hour, and AS product.

5. Conclusions

ERCOT's analysis of the impacts of RTC on operations and on RUC and SASM procurement identified a number of potential benefits.

The study of historical RUC cases suggests that co-optimization would have reduced the need for a RUC instruction in at least 9 of the 165 cases studied, due to the optimization engine having the flexibility to use all of the on-line capacity to meet the energy and AS requirements of the system.

ERCOT's analysis of 391 historical SASMs found that SASM clearing prices averaged nearly $100/MW higher than the corresponding DAM price for the same operating day, hour, and AS product. The number of MW procured in the 391 historical SASMs priced at the approximate $100/MW premium is a cost difference of approximately $11 million. RTC would eliminate the need for these SASMs and the associated risk. This, combined with the ability of Market Participants to buy back their AS obligation in Real-Time through the clearing of AS awards under RTC, will increase the liquidity of the DAM AS market.

ERCOT believes that implementation of RTC would provide significant operational and reliability benefits as the complexities of managing a changing resource mix continue to grow through more timely procurement of AS when additional AS is required or Resources are unable to provide those services, more effective congestion management, and a reduction in manual actions by operators.

Finally, RTC will also provide a framework that will provide a mechanism for improved management of Resource-specific capabilities in assigning and deploying AS.