California ISO

Technical Appendix on the Persistent Uninstructed Energy Check

Renewable Integration: Market and Product Review
Phase 1

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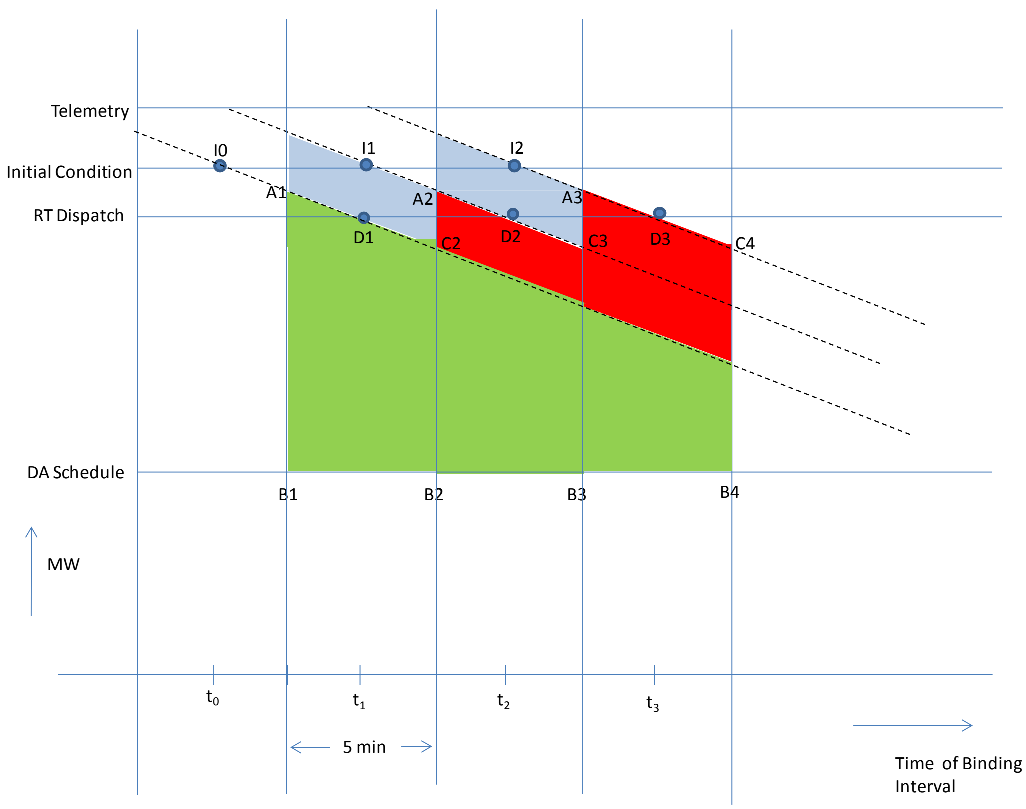
A high level description of the proposed methodology for the persistent uninstructed deviation check is presented in section 4.3.1 of the draft final proposal for Renewable Integration: Market and Product Review Phase 1.[1] This document follows up with an example to illustrate the calculations of Measures A and B for a given resource, as defined in the proposal for determining the qualification/disqualification of the resource's real-time energy in the real-time market bid cost recovery (BCR).

Figure 1 depicts different MW and MWh dispatch and deviation quantities of a generator over four successive binding intervals of the real-time dispatch (RTD). The mid-points of these binding intervals are respectively t_0, t_1, t_2 and t_3, the targeted time within the time intervals corresponding to the RTD dispatch levels or the so-called dispatch operating targets (DOTs). Each RTD time interval is 5-minute in length. For this example, let the check for persistent uninstructed deviation start at the intervals of t_1 and ended at the interval of t_3. The example considers the scenario that the generator generates at a MW level where its associated energy bid price is above the locational marginal price (LMP). RTD dispatches the generator downward subject to its ramp rate in the attempt to move the generator toward the MW level that its bid price is consistent with the LMP. However, the generator does not follow the dispatch instructions and its generation remains at the same high MW level.

Figure 1 Real-Time Dispatch and Generation of a Generator Engaging in Persistent Uninstructed Deviations



[1] http://www.caiso.com/Documents/DraftFinalProposal-RenewableIntegrationMarket-ProductReviewPhase1.pdf.

In Figure 1, the horizontal line labeled "Telemetry" shows the actual MW level at which the generator is operating. The blue colored dots along the horizontal line labeled "Initial Condition" for different time intervals are the projected initial conditions used by RTD for performing optimization over the RTD horizon starting on the next interval following the interval of the initial condition. Further below is the line labeled "RT Dispatch" along which the blue dots are the binding real-time dispatch levels or DOTs for different time intervals. Despite the dispatch to instruct the generator to move downward in each interval, the generator deviates from such instructions and continues to operate at the same high MW level as indicated by the telemetry.

The projected initial condition of a given time interval t is used by the RTD process for which the optimization horizon begins at time interval t+1 with this interval as the binding interval. The projected initial condition of time interval t by design is projected from the most recent available telemetry toward the DOT of time interval t. The most recent telemetry is the one at measured at time interval t-1. Should the DOT for interval t be within reach from the telemetry of t-1 subject to ramp rate, initial condition of t is set to the DOT of t. Otherwise, the initial condition of t is set to the closest MW level to the DOT of t that can be achieved based on the ramp rate capability in 5-minutes from the telemetry of t-1.

The initial conditions of different time intervals as shown in Figure 1 are above the dispatch levels of the same intervals simply because the generator had an upward uninstructed deviation in the previous interval. Had the generator followed the previous dispatch instruction, the initial condition for the current time interval would have matched the dispatch level for that interval.

Figure 1 also shows three slanted, broken lines from upper left to lower right. The leftmost or lowest slanted line projects the dispatch and actual generation level of the generator over the time horizon had the generator exactly followed the instructions for interval t_1 and also projects what the dispatch would have been for subsequent intervals. This line reflects what the dispatch would have been had the resource never deviated from its instructions.

Similarly, the middle slanted line projects the dispatch based on the actual telemetered generation level at t_0 of the generator, had the generator exactly followed the instructions for interval t_2 and projects what the dispatch would have been in interval t_3. This line reflects what the dispatch would have been had the resource deviated from interval t_0 instruction but followed subsequent instructions.

Finally, the highest slanted line projects the dispatch level that can be achieved based on the actual telemetered generation level of the generator at t_1 given the resource's deviation from prior instructions in both interval t_0 and t_1

The horizontal line labeled "DA Schedule" shows the day-ahead schedule which is below the real-dispatch level. Therefore, the real-time instructed imbalance energy (IIE) is incremental for this example.

For the purpose of this example, the bid segment of the dispatch level with a bid price above the LMP extends from the dispatch level downward a MW level below the day-ahead schedule. For interval t_1, the instructed incremental energy represented by the area of $A_1B_1B_2C_2$ will incur an energy bid cost shortfall as revenue is less than bid cost and will be account for in the BCR calculation. Similarly are the energy represented by the area $A_2B_2B_3C_3$ of interval t_2 and the energy represented by the area $A_3B_3B_4C_4$ of interval t_3.

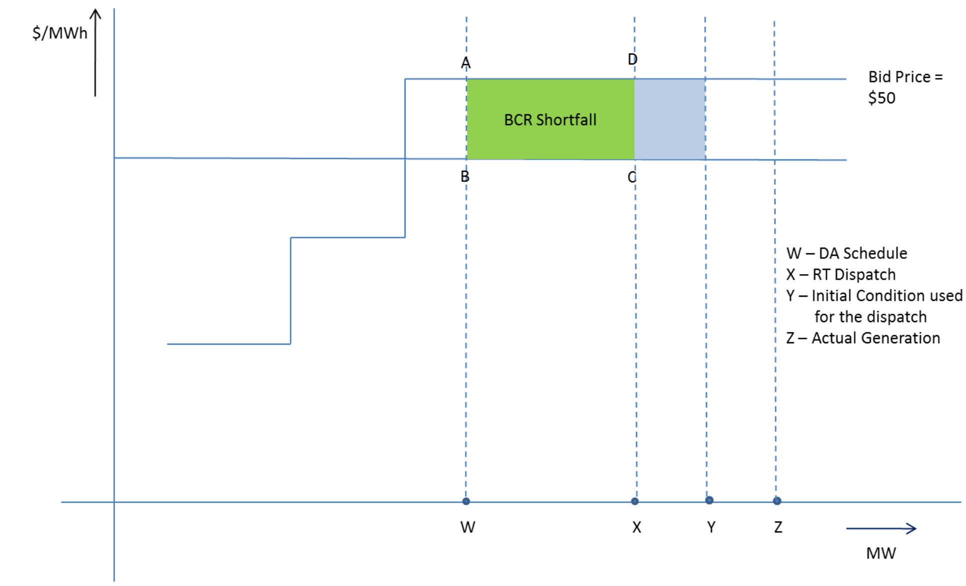
Consider interval t_1. The initial condition deviating above dispatch level of the interval is the result of upward uninstructed deviation of energy in the interval of t_0. The effect of upward uninstructed deviation of energy in interval of t_0 is manifested through the upward deviation of initial condition from dispatch level of interval t_1 that in turn causes the addition BCR shortfall of instructed imbalance energy of intervals t_2 and t_3. In fact, had the initial condition and dispatch level be the same for interval t_1, the dispatch level of interval t_2 would have followed the path of the lowest slanted line. The resultant instructed incremental energy having energy bid cost shortfall had the resource followed its dispatch instruction and not deviated is given by the green color area in Figure 1. The 5-minute energy amount of the initial condition in exceeding the dispatch level is the blue color area of interval t_1. This amount of energy causes the same amount of increased energy subject bid cost shortfall (uneconomical) energy in each of intervals t_2 and t_3. Similarly, the upward deviation of initial condition from dispatch level of interval t_2 causes an additional amount of energy subject to bid cost shortfall (uneconomical) instructed imbalance energy of interval t_3. This effect on interval t_3 is on top of those caused by the deviation of interval t_1 initial condition from dispatch level.

The two red color areas of intervals t_2 and t_3 of Figure 1 show the additional amount of energy subject to bid cost shortfall (uneconomical) instructed energy caused by the deviation of the initial condition from the dispatch level of each interval over the time period subject to the persistent uninstructed deviation check.

Based on the above discussion, an algorithm is developed where state variable indexed by the interval t is defined to accumulate the energy associated with the deviation of initial condition from the dispatch level in previous dispatch intervals. Such accumulated amount of energy as given by the state variable is the increase of the energy bid cost shortfall (uneconomical) instructed energy due to the deviation of initial condition from dispatch level which is the red colored area in Figure 1. In brevity without elaborating the details of the general algorithm, the state variable is updated for each interval where the value of the state variable of time t is set to the value of state variable of time t-1 plus the energy associated with the deviation of the initial condition from the dispatch level for interval t-1. Moreover, this energy accumulation by the state variable of a given interval is limited by the energy amount that is not economical based on the comparison of the LMP and the energy bid price based on the dispatch level of the given interval.

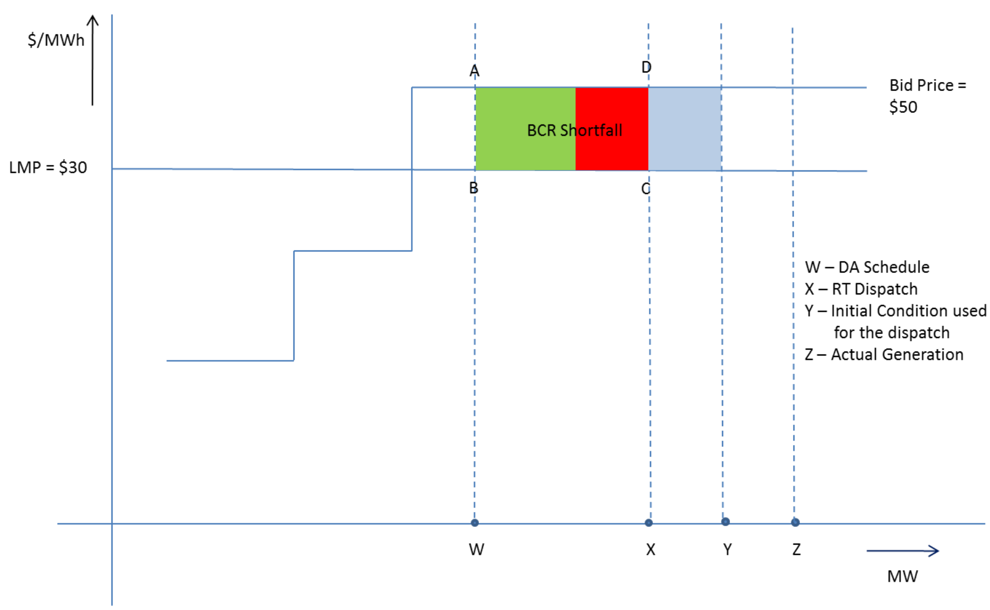
The next three figures, Figures 2, 3 and 4, show the financial consequence of persistent deviation from the perspective of the energy bid, one for each of the three intervals t_1, t_2 and t_3. Figure 2 for interval t_1 shows the day-ahead schedule (point W), initial condition (point Y) and real-time dispatch (point X) of interval t_1. In these figures, the actual generation or the telemetry as given by point Z is from the previous interval which is t_0. Initial condition Y is used for determining the dispatch for time interval t_2. The bid price at dispatch level exceeds the LMP and the bid segment of the dispatch level extends downward below the DA schedule. Since telemetry is above the dispatch level, the initial condition Y is projected downward toward dispatch level X. However, due to ramp rate limitation, Y is above X. The blue colored area is the energy between X and Y times the $ of bid price in exceeding the LMP. The area of ABCD covered entirely by green color is the shortfall amount of the instructed energy.

Figure 2 Financial Analysis of Persistent Uninstructed Deviation: Interval t_1



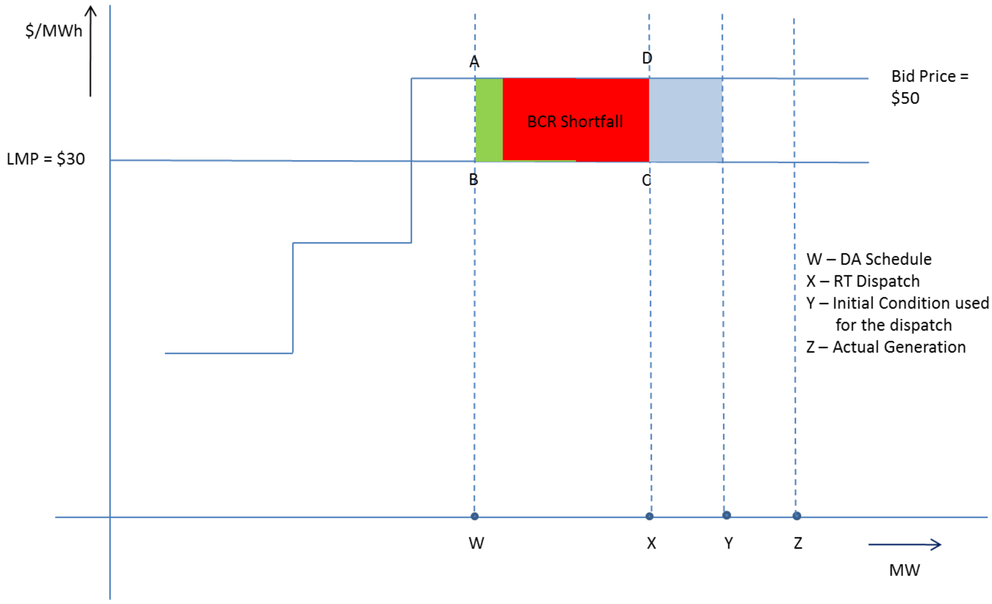
As the generator does not follow the dispatch instruction in interval t_1, Figure 3 for interval t_1 is essentially the same as Figure 2 except that area ABCD is partially covered with red color. This red color area is from the blue color area of Figure 2 representing the shortfall of interval t_2 caused by the deviation of initial condition from dispatch in interval t_1.

Figure 3 Financial Analysis of Persistent Uninstructed Deviation: Interval t_2



In Figure 4 for interval t_3, the red colored area grows larger. It is the sum of red colored area and blue colored area of Figure 3, representing the energy of the deviation of initial condition from real-time dispatch accumulated over all previous time intervals within the period that the persistent check is activated.

Figure 4 Financial Analysis of Persistent Uninstructed Deviation: Interval t_3



Numerical values are used next to demonstrate the calculation of Measures A and B. Before arriving at the final results, several intermediate per interval quantities and their time aggregations are calculated. They are

- UIEeffect_i(MWh) – For a given interval, this energy quantity, calculated through the use of state variable is the amount of uneconomical energy caused by the previous interval deviations of the initial conditions from the real-time dispatches. This is the red colored area of Figure 1
- UIEbcr_i($) – For a given interval, this dollar quantity is real-time energy bid cost recovery shortfall $ amount caused by the previous interval deviations accounted for by UIEeffect_i. This is the red colored regions of Figure 3 and 4.
- UNENbcr_i($) – For a given interval, this dollar quantity is the total amount of real-time energy bid shortfall $ amount of the uneconomical energy. This is the regions ABCD of Figure 2, 3 and 4.

UIEeffect, UIEbcr and UNENbcr are the time aggregations of UIEeffect_i, UIEbcr_i and UNENbcr_i respectively for multiple set of intervals.

In this numerical example, let

- DA schedule = 200 MW
- Initial condition = 400 MW for intervals t_1, t_2 and t_3
- Real-time dispatch level = 350 MW for t_1, t_2 and t_3
- Bid price at dispatch level = $50/MWh
- LMP = $30/MWh t_1, t_2 and t_3

Then the 5-minute energy for MW between dispatch level and initial condition is 4.1667 MWh.

Interval	UIEeffect_i	UIEbcr_i	UNENbcr_i	Measure A (UIEbcr_i/UNENbc_i)	Measure B (UIEbcr_i/UIEeffect_i)
t_1	0 MWh	0	$250	0	0
t_2	4.1667 MWh	$83.33	$250	.333	$20/MWh
t_3	8.3333 MWh	$166.67	$250	.667	$20/MWh

UIEeffect = 12.5 MWh

UIEbcr = $250

UNENbcr = $750

Finally, two measures A and B are formulated using these three aggregated quantities.

1. Measure A is the ratio between the aggregated shortfall of uneconomical energy caused by the uninstructed deviation in real-time, i.e. the state variable value, and the aggregate shortfall of the actual uneconomical energy (UIEbcr($)/UNENbcr($)). The measure captures the persistency of the uninstructed deviation behavior that results in shortfall in BCR calculation.
2. Measure B is a $/MWh rate of the shortfall per MWh of uneconomical energy by uninstructed deviation which is the ratio between UIEbcr($) and UIEeffect,(MWh). This measure captures the per-MWh impact on BCR from the UIE cumulative effect.

Measure A = UIEbcr / UNENbcr = 0.333

Measure B = UIEbcr / UIEeffect = $20/MWh

The demonstration presented here is applicable to generators with fixed ramp rate for explanation simplicity. The concept can be extended to generators with dynamic ramp rate but the algorithm is more elaborate.