Comments on Storage Enhancements
Issue Paper

Department of Market Monitoring

May 20, 2021

I. Summary

The Department of Market Monitoring (DMM) appreciates the opportunity to comment on the *Storage Enhancements Issue Paper*.[1] DMM provides the following comments:

- DMM suggests that the ISO prioritize enhancing processes for issuing exceptional dispatch instructions to battery resources in the near-term. Enhanced processes may have improved some inefficient outcomes from manual dispatches that DMM observed last year. Since exceptional dispatch functionality will continue to be used by ISO operators, enhancements to these processes for managing storage resources will be important as the storage fleet continues to grow significantly.
- Before considering significant changes to how storage resources are treated in the multi-interval optimization, DMM suggests that the ISO discuss with stakeholders various conditions under which batteries might be discharged uneconomically leading up to net load peak hours. DMM has observed some common cases where batteries have been discharged uneconomically in the binding interval in real-time, and believes that there are forthcoming and smaller-scale enhancements that could mitigate many of these occurrences.
- A longer real-time look ahead horizon could provide benefits in terms of positioning storage resources to be sufficiently charged to meet demand across net peak load hours. DMM has observed that during high load/high priced periods, resource adequacy storage resources often lack sufficient charge to provide 4-hour resource adequacy values. While a longer real-time horizon could better position storage resources to meet peak net load, resources should also be incentivized to be charged for peak net load hours when the ISO will rely on battery capacity the most.
- DMM supports the ISO re-examining bid cost recovery for storage resources, including whether the BCR calculation should consider total energy charged and discharged across the day or potentially within a cycle.
- DMM supports the ISO considering whether the battery participation model could be revised significantly from the current design, where hourly bids are offered to provide power, to a framework that is based more on valuing state of charge. However, it will be

[1] *Storage Enhancements Issue Paper*, California ISO, April 28, 2021: http://www.caiso.com/InitiativeDocuments/IssuePaper-EnergyStorageEnhancements.pdf

important that prices incentivize resources to follow dispatch instructions under any new framework.

DMM provides additional detail on these issues below.

II. Exceptional dispatch enhancements

DMM has observed that exceptional dispatch (ED) instructions sent to battery resources have sometimes resulted in inefficient outcomes on days where system conditions have been very tight. DMM recommends that the ISO prioritize enhancements to these processes for managing storage resources in the near-term.

Batteries have sometimes been sent ED instructions to charge significantly when resources are already at or near a full state of charge. In some of these cases, resources could not feasibly meet ED instructions to charge. In other cases, these ED instructions caused batteries to discharge uneconomically prior to the ED to charge, in order to reduce the resource's state of charge and create headroom so that the resource could meet the charge instruction.

Because EDs are often issued as fixed megawatt instructions today, when operators have issued EDs to batteries with existing ancillary service awards, ancillary service awards have become infeasible in real-time. Ancillary services must then be procured from other resources in real-time on short notice when the system may already be very constrained. Exceptional dispatch instructions that do not consider existing state of charge can also drive inefficient outcomes such as impacting prices in earlier intervals if resources are forced to discharge out of economic merit to meet the ED, and adding charging demand on the system when it is not needed.

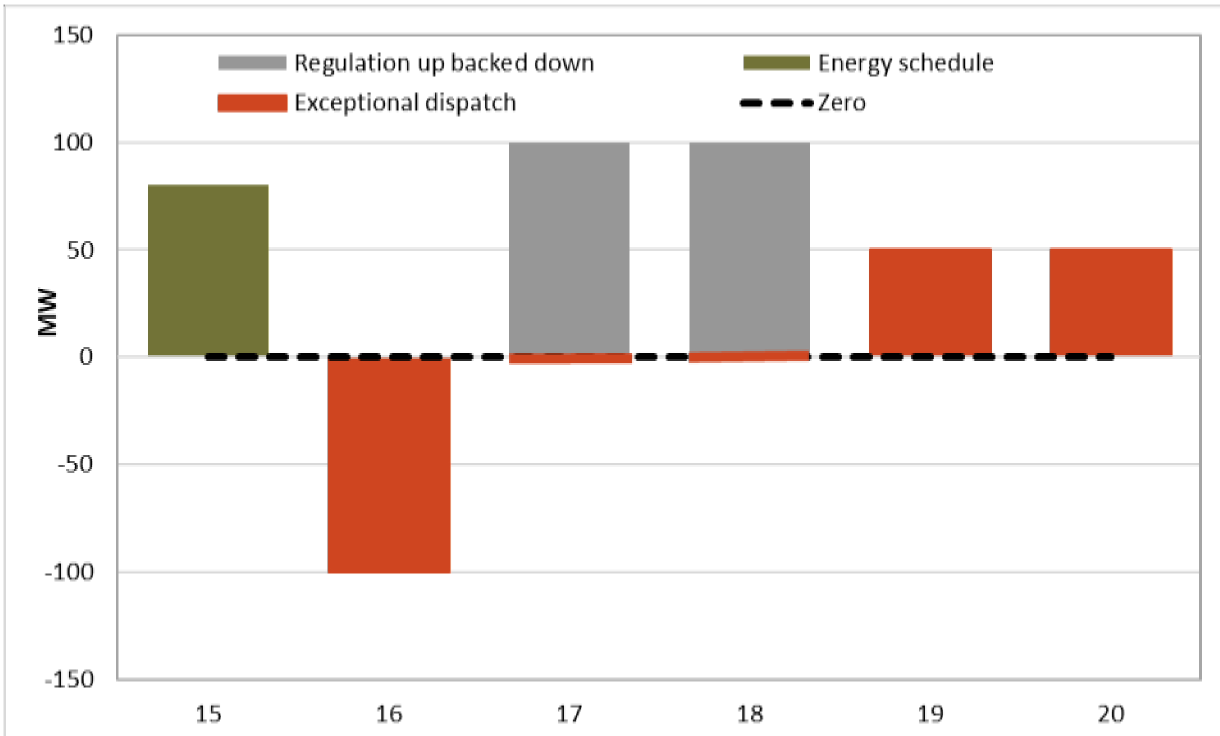
DMM believes that processes for issuing EDs to batteries could be significantly improved if EDs were issued as state of charge values instead of megawatt values. First, issuing EDs to batteries as state of charge values could help prevent ED instructions from being infeasible and could mitigate instances of resources being forced to either discharge or charge uneconomically to meet ED instructions. Issuing EDs as state of charge values could also allow batteries more flexibility to maintain existing ancillary service awards.

Figure 1 below illustrates some of the outcomes that DMM has observed when batteries have been issued exceptional dispatches. Consider a battery with a 100 MW Pmax, 100 MW Pmin, and 100 MWh state of charge. The ISO wants the battery to discharge 50 MW in hours 19 and 20 (100 MWh total). To effectuate this outcome, the ISO issues exceptional dispatches to this resource to fully charge at 100 MW in hour 16 and to discharge at 50 MW in hours 19 and 20 (100 MWh). The ISO also issues dispatch instructions in hours 17 and 18 for the resource to hold at 0 MW, in order to maintain 100 MWh of charge by the end of hour 18.

Now assume the resource was already 80% charged in hour 15. In order to meet the exceptional dispatch to charge at 100 MW in hour 16, the resource must discharge 80 MWh in hour 15. DMM has observed cases where this forced discharge is uneconomic for the resource.

Suppose the resource also had regulation up awards from the day-ahead market in hours 17 and 18. Because the ISO issues fixed 0 MW instructions to the resource in these hours, its regulation up awards are no longer feasible, and regulation up must be procured from other resources in real-time.

Figure 1. Example of exceptional dispatches issued to battery resources today



In the example above, suppose the ISO had the same goal – to discharge the resource 50 MWs in hours 19 and 20. If the ISO issued the exceptional dispatch as a target state of charge of 100 MWh by the end of hour 18, then the resource would only need to charge an additional 20 MWh between hour 15 and end of hour 18. The uneconomic discharge in hour 15 and significant charge in hour 16 could be avoided. The resource would also have been able to retain its regulation awards.

III. Uneconomic dispatches of storage resources in real-time

Before considering significant changes to how storage resources are treated in the multi-interval optimization, DMM suggests that the ISO engage in further discussion with stakeholders to better understand conditions under which battery resources might be discharged uneconomically leading up to net load peak hours. DMM has observed some common cases where batteries have been discharged uneconomically in the binding interval in real-time. DMM believes that there are forthcoming and potentially smaller-scale enhancements that could mitigate many of these occurrences.

Exceptional dispatches

DMM has observed that some uneconomic discharge activity has been driven by exceptional dispatches which did not consider existing state of charge, forcing resources to deplete to meet exceptional dispatch charging instructions. If exceptional dispatch processes for storage resources were improved as discussed above, these cases may be largely avoided.

Changing energy bids in real-time

DMM has observed that real-time battery bids have changed more significantly hour to hour starting in the third quarter of 2020. DMM has observed that when battery bids are changed significantly hour to hour in real-time, if charge bids in hour t+1 exceed discharge bids in hour t, then the market generally finds it economic to discharge the resource in hour t and recharge (buy) energy at a higher price in hour t+1. In many cases the discharge in hour t appears to be uneconomic, but the discharge/charge activity as a whole is economic.

DMM understands that SCs may increase charge bids across the net load ramp to reflect a higher willingness to charge in hours leading up to the net load peak, in order to ensure that resources are sufficiently charged to provide energy across net load peak hours. Because the real-time market horizon cannot see the net load peak in earlier real-time market runs, SCs must currently manage their state of charge before peak net load hours by modifying hourly energy bid prices.

DMM believes that the end-of-hour state of charge (EOH SOC) parameter developed under ESDER 4 could help SCs better manage real-time state of charge versus managing state of charge solely through hourly bids. DMM expects that the EOH SOC parameter could help mitigate cases where a resource may reflect a very high willingness to charge before net load peak hours, causing unexpected dispatches across hours.

Relatedly, while DMM supported the BCR rules developed under ESDER 4 which would apply to resources that opt to use the EOH SOC feature, DMM suggested that these BCR rules could be designed to be more precise.[2] DMM noted that the ISO's proposal could be overly conservative and could disqualify intervals from BCR eligibility that were not impacted by use of the EOH SOC constraint. DMM continues to recommend that the ISO consider refining BCR rules when EOH

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[2] *Comments on ESDER 4 Final Proposal*, DMM, September 16, 2020, pp. 4-5: http://www.caiso.com/Documents/DMMComments-EnergyStorageandDistributedEnergyResourcesPhase4-FinalProposal-Sep162020.pdf

SOC constraints are used, and potentially consider whether EOH SOC constraints were actually binding.

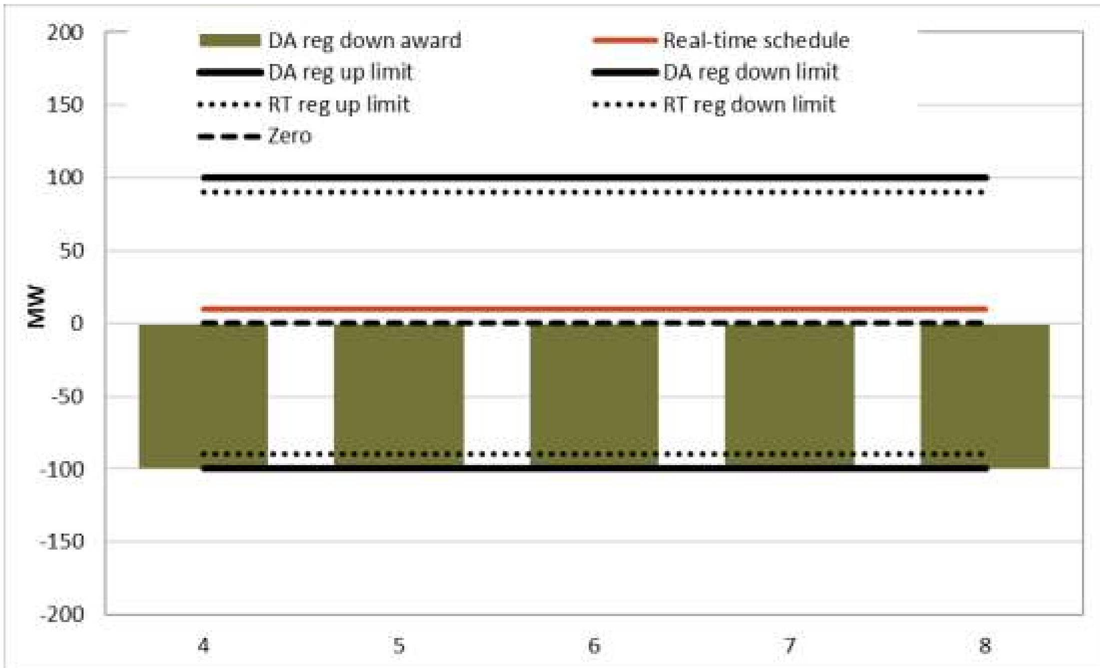
Regulation limits in real-time

DMM has observed that some uneconomic discharges of storage resources have been associated with resources with day-ahead regulation capacity awards having a more limited regulating range in real-time than values registered in the ISO master file. In the day-ahead market, resources are awarded regulation capacity based on upper and lower regulation limits registered in the ISO master file. However, DMM has observed that in real-time, resource regulating ranges are sometimes significantly more limited than regulating ranges registered with the ISO. When a battery has day-ahead regulation awards carried into real time, the narrower regulating ranges sometimes force batteries to operate at uneconomic discharge or charging operating points in order for regulation awards to remain feasible.

In Figure 2 below, suppose a battery received 100 MW of regulation down awards from the day-ahead market which are carried into real-time in hours ending 4 to 8. The resource’s regulation up limit registered with the ISO is 100 MW and its regulation down limit is -100 MW. However suppose the resource’s regulating range in real-time is actually between -90 MW and 90 MW (dotted lines). The real-time market recognizes these more narrow regulating ranges, and in order to ensure that the resource’s regulation down awards remain feasible in real-time, the market discharges the resource 10 MW (potentially out of the money) in these hours.

DMM suggests that if storage resource regulating ranges change frequently and if updated values are known in the day-ahead timeframe, then the ISO could allow storage resources to update regulating ranges daily. The daily updates could be reflected in the day-ahead market. This type of feature could help minimize instances where regulating ranges are narrower in real-time than modeled day-ahead, forcing resources to charge or discharge uneconomically.

Figure 2. Example of more limited regulating ranges in real-time



5-minute market state of charge constraints

When a battery resource's discharge energy bid range is less than upward ancillary service awards, or when a resource's charge energy bid range is less than downward ancillary service awards, then the following RTD constraints specified in the Market Operations BPM Section 7.8.2.5 are enforced.[3] :

$$SOC_{i,te} \geq \underline{SOC}_{i,te} + \max\left(0, SSEn_{i,te}, \underline{P}_{i,te} + SSRd_{i,te}\right)\frac{RM}{T}$$

$$SOC_{i,te} \leq \overline{SOC}_{i,te} + \eta_i \min\left(0, SSEn_{i,te}, \overline{P}_{i,te} - SSRu_{i,te} - SSSr_{i,te} - SSNr_{i,te}\right)\frac{RM}{T}$$

These constraints result in minimum state of charge and maximum state of charge constraints becoming more limiting than observed in the 15-minute market. While DMM understands that the intent of these constraints are to ensure that a battery has sufficient charge or headroom to charge to ensure that ancillary service awards or self-schedules are feasible for the rest of the hour in RTD, in practice these constraints have appeared to impact battery resource schedules in a way that is counter to their intent. DMM recommends that the ISO consider removing these constraints.

[3] Market Operations BPM, Section 7.8.2.5.

For example, when a lower maximum state of charge is enforced in RTD to ensure that the resource maintains enough state of charge headroom to maintain feasible ancillary service awards or maintain charging self-schedules while operating at a charging state for the rest of the hour, the lower maximum state of charge constraint in RTD could result in the resource approaching its maximum state of charge sooner and more frequently. RTD will try to move the resource to its self-scheduled charging operating points, but the battery approaches the lower maximum state of charge constraint in doing so. The result is that RTD will eventually discharge the battery (often uneconomically) to create additional charging headroom in order for the resource to be moved back to a charging operating point in future intervals.

Counter to the intent of the constraint, the resource is discharged and backed off its charging operating point more frequently being subject to the lower maximum state of charge, and therefore its ancillary service awards or self-scheduled charging becomes infeasible more frequently. Because ancillary services are not procured in RTD, there is also no capacity procured to replace the reserves which become infeasible in RTD, which could pose potential reliability issues.

IV. Extending the real-time horizon

DMM believes that a longer real-time horizon could provide benefits in terms of positioning storage resources to be sufficiently charged to meet demand across net peak load hours. DMM has observed that during high load/high priced periods, resource adequacy storage resources have often lacked sufficient charge to provide 4-hour resource adequacy values. DMM has some concerns about battery resources remaining sufficiently charged to provide their resource adequacy values, particularly over several consecutive days.

To illustrate this issue, Figure 3 below shows the total state of charge of the resource adequacy standalone storage fleet from February 15 to February 18, 2021 when high natural gas prices contributed to very high sustained prices in the ISO market. The total state of charge of the battery fleet is capped by the 4-hour resource adequacy (energy) value of each individual resource. Storage resources were relied upon by the ISO to provide energy across this timeframe. As the week progressed, the total charge of the storage fleet began to decline.

Figure 4 shows the day-ahead and real-time schedules of the storage resource adequacy fleet. Schedules are capped by the resource adequacy value of each individual resource. This chart shows that resources were often backed off of day-ahead discharge awards in morning peak and evening net load peak hours. Resources were also backed off of some day-ahead charging awards in midday hours.

DMM observed that day-ahead discharge awards backed down in real-time were largely due to resources having insufficient state of charge to meet day-ahead awards. In late evening hours

(hours ending 21 through the end of the day) on February 17th for example, prices remained very high while some storage resources began to run out of charge. Resources generally bought back day ahead awards in these hours at a loss (prices were greater than real-time bids). These losses, however, were covered by real-time bid cost recovery.

These resources appeared to run out of charge in the late evening hours and could not meet day-ahead awards in these hours for a few reasons:

- Some resources reflected a much higher initial state of charge in the day-ahead market than actually materialized in real-time these days resulting in day-ahead discharge awards that could not be met with actual real-time charge levels.
- The day-ahead market scheduled some resources to charge midday based on charge/discharge activity being economic overall. However, the real-time market backed some resources off day-ahead charging awards in midday hours as charging appeared uneconomic in the limited real-time horizon.
- On February 17, some real-time energy schedules were shifted to earlier hours 17-19, leaving resources with less charge for hours 20-22.

The second two issues appear to be largely the result of the limited real-time look ahead horizon being unable to see higher priced hours later in the day, thereby opting to not charge resources midday or opting to discharge resources too early before the net load peak.

The first issue, however, also presents some concerns as there may be limited incentives for batteries to conservatively estimate their day-ahead initial state of charge. This is because they are protected from losses from real-time buybacks of day-ahead schedules through real-time BCR. Especially on constrained operating days, over-estimated state of charge levels in the day-ahead market could present issues in real-time if other resources must make up for battery capacity that is not actually available in real-time.

Figure 3. Resource adequacy standalone storage fleet state of charge

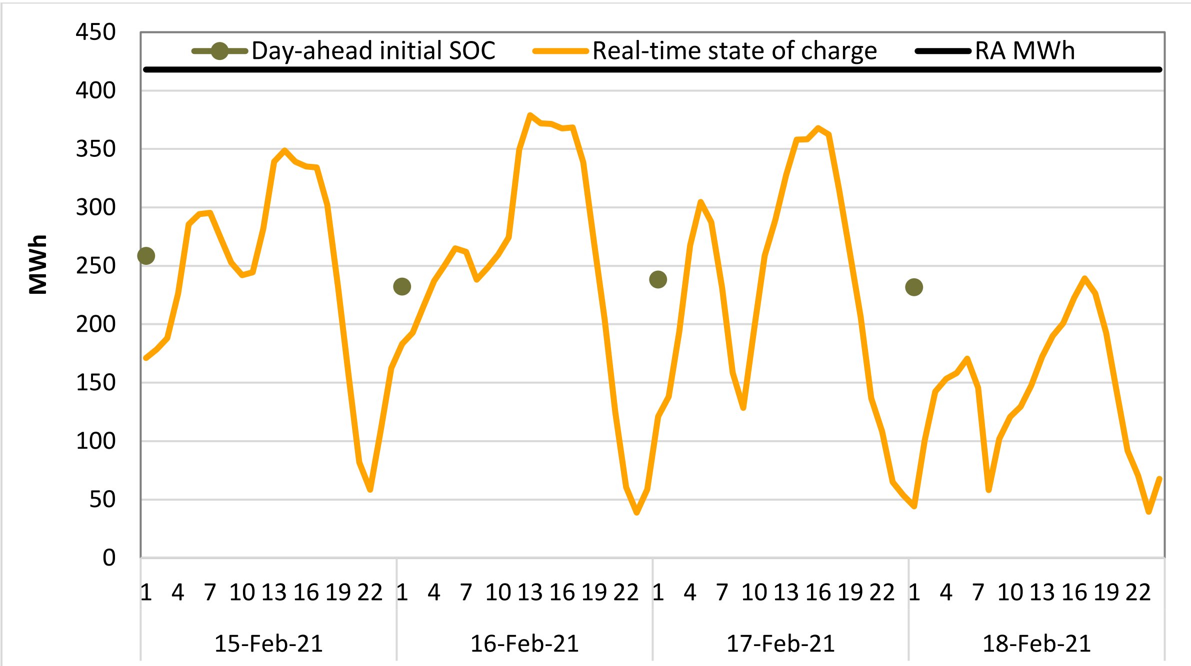
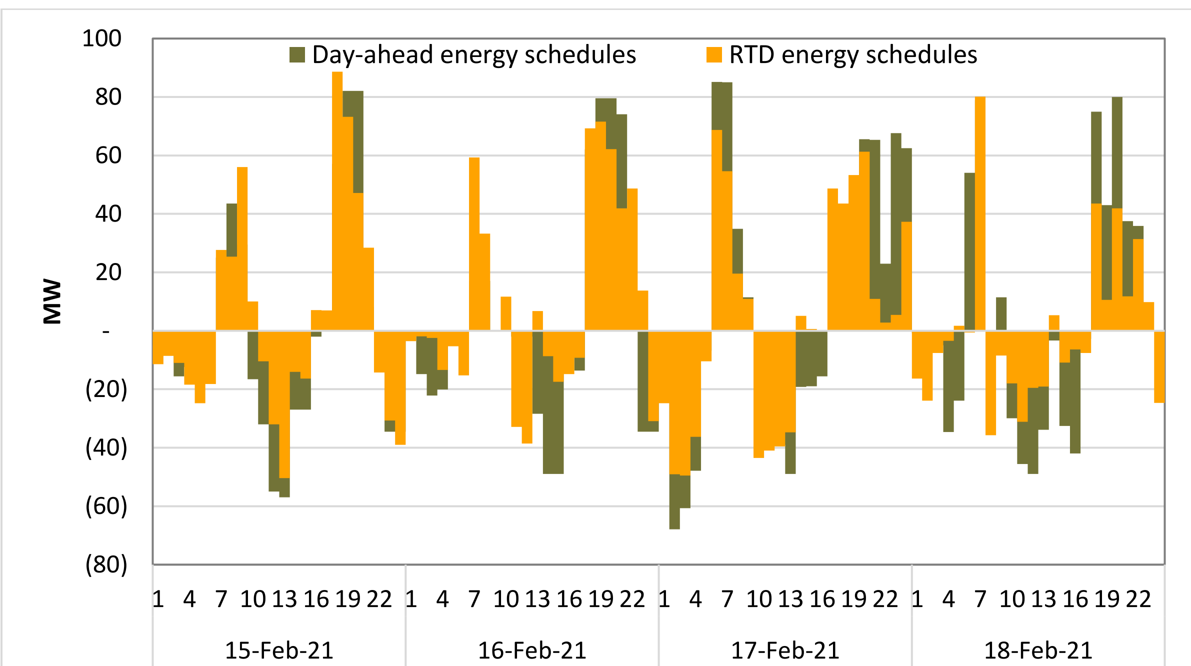


Figure 4. Resource adequacy standalone storage fleet energy schedules



V. Ensuring availability of storage resources

While a longer real-time look ahead horizon could help position storage resources to be able to meet demand in peak net load hours, resources should also be incentivized to be charged for peak net load hours when the ISO will rely on storage capacity the most.

DMM supports the ISO re-examining bid cost recovery for storage resources, including whether the BCR calculation should consider total energy charged and discharged across the day or potentially within a cycle. Under this type of approach, the ISO could also consider how to treat losses from real-time buybacks of day-ahead schedules when a resource's assumed state of charge in the day-ahead market far exceeds actual charge levels in real-time.

DMM suggests that the ISO also consider resource adequacy batteries' use of the following parameters in RAAIM or UCAP calculations. The ISO previously considered these types of parameters in its UCAP proposal in the RA Enhancements initiative. DMM has observed that use of some of these parameters have limited resources' ability to reach a state of charge to be able to provide 4-hour RA values across net peak load hours. Today, storage resources can avoid exposure to RAAIM if discharge bids are in place up to resource adequacy values in RAAIM hours. However, there are other means by which storage resources may limit availability in peak net load hours:

- De-rates to maximum SOC in Masterfile, SIBR, or OMS below a resource's 4 hour resource adequacy value
- De-rates to minimum SOC such that (maximum SOC – minimum SOC) is less than a resource's 4 hour resource adequacy value
- De-rates to Pmin or not offering charging bid range such that resources are unable to charge sufficiently for later hours.
- De-rates to Pmin or limiting charging bid range may require that a resource be economic to charge across a longer period of time in order to reach an SOC needed to provide 4 hours of resource adequacy. This scenario may not be an issue if a resource starts the day with a high level of charge. However, DMM has observed cases where resources start the day with a low state of charge and limit charging bid ranges such that it would take 8 or more hours charging at Pmin for a resource to be fully charged by hour ending 17.

VI. Alternative bid structures for storage resources

DMM supports the ISO considering more broadly whether the battery participation model could be revised significantly from the current design where hourly bids are offered to provide power, to a framework that is based more on valuing state of charge. Today, SCs must manage state of charge in hourly bids by changing discharge or charge bid prices each hour, sometimes resulting in unexpected cross-hour effects when bids vary significantly between hours.

A bid structure that centers more on state of charge may allow SCs to better reflect their costs, and could potentially better align day-ahead and real-time state of charge levels. However, it will be important that prices continue to incentivize resources to follow dispatch instructions under any new framework.