Energy Storage Enhancements

Final Proposal

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Market & Infrastructure Policy

Table of Contents

1 Introduction

Storage developers are rapidly deploying new utility-scale resources onto the California grid to provide replacement capacity for retiring resources and to meet procurement mandates authorized by the California Public Utilities Commission. These storage resources will help the state meet its clean energy and climate goals. Ultimately, storage resources will be available to meet energy needs during most periods when renewable resources are not available to generate. Today, there is just over 3,500 MW of storage capacity available for dispatch in the market. These resources primarily charge during the lowest priced periods of the day (when solar is abundant) and discharging during the highest priced periods of the day. Today the grid relies on storage resources for the critical operation of one local capacity area. The state anticipates that storage resources will be necessary for the reliable operations in many other local capacity areas in the future. The ISO's annual local capacity area technical study proactively estimates the amount of energy storage that can be added to each local capacity area based on charging restrictions due to anticipated load and other local generation capability required to meet mandatory standards and transmission capability under applicable contingency conditions.[1]

The market models are evolving to address storage requirements. The fourth phase of the energy storage and distributed energy resources (ESDER) initiative, which was recently implemented, included development of market power mitigation for storage resources and tools to help scheduling coordinators manage state of charge.

The proposal addresses concerns regarding investment tax credits and property taxes and proposes changes to the existing co-located model that can be used by these resources for a limited period of time. These changes will completely prevent co-located resources from charging when beyond generation levels for on-site resources. These proposed changes are outlined in Section 4.2.

The proposal includes multiple updates and clarifications from the second revised straw proposal, but most of the content of the paper has remained the same. Notably, the proposal is moving the aspects of policy related to local reliability to the storage modeling enhancements initiative, with other improvements to the model. This will allow more time to discuss these changes with stakeholders and will allow ample time for implementation.

[1] These studies assume storage is fully charged exactly when needed based on area specific load profiles, and will operate precisely as required to meet those needs.

2 Policy Summary

As a quick reference and summary, this policy includes the following proposals:

- (4.1.1) State of charge will include expected impacts from regulation
- (4.1.1) Storage resources with AS awards must have RT energy bids in opposite direction *i.e.* Charging bids must accompany a reg up award
    - Day-ahead AS awards will only be for feasible quantities
    - Energy bids must be 50% of AS awards
- (4.1.2) Storage resources may be issued EDs to hold SOC in RT
    - Storage may receive a traditional ED or an SOC ED, but not both
- (4.1.3) Compensation will include lost opportunity from not generating
    - The market will calculate counterfactual energy revenues with and without the exceptional dispatch in place
    - Bids will determine counterfactual schedules
    - Actual LMPs, not counterfactuals, will be used in calculations
    - Time horizon will include the ED period through the end of the day
- (4.2.1) Develop an electable co-located functionality
    - This functionality will be available to all storage resources
    - This functionality will be electable on an hourly basis
    - Storage schedules will never exceed renewable schedules
    - Renewable forecasts used if schedules are unavailable in DA
    - Storage may deviate down to match renewables, when the renewable is producing less than the real-time schedule
    - Deviations will be subject to imbalance energy charges
    - Day-ahead forecasts will be used if schedules are absent
    - All resources are required to respond to operator and exceptional dispatch instructions within physical bounds of operation
    - The hybrid model will continue to be offered
- (4.2.2) Allow for co-located pseudo-tie resources to use an ACC
    - Resources under an ACC must be pseudo-tied from the same BAA
- (4.3) Include an opportunity cost term in the day-ahead storage DEB

3 Stakeholder Process

The proposal is at the "final proposal" stage in the energy storage enhancement (ESE) stakeholder process. Figure 1 below shows the status of the overall energy storage enhancements stakeholder process.

Figure 1: Stakeholder Process for ESE Stakeholder Initiative

4 Proposal

The non-generator resource (NGR) model was introduced in 2012 to allow for wholesale market participation of energy storage resources. The non-generator resource model may effectively integrate energy storage resources today, the increasing number and configuration needs of storage devices participating in the wholesale market warrants consideration of further market model enhancements to ensure storage resources are appropriately compensated and the market can accommodate the unique features of storage resources. Stakeholders identified a number of potential enhancements to consider to help better model storage resources. While the day-ahead market optimizes all resources over a 24-hour period, the real-time market has a shorter optimization horizon, which can make it more difficult to capture periods when it is critical that the storage resources have state of charge for several hours to meet system needs. The goal of this initiative is to explore enhancements that could help storage scheduling coordinators better manage resource state of charge and continue to ensure efficient market outcomes.

4.1 Reliability Enhancements

In comments some stakeholders requested additional information about the minimum state of charge requirement that was introduced as a component of the market enhancements for summer 2021 readiness.[2] That policy implemented a tool that could require storage resources to hold a minimum state of charge level to ensure that storage resources would be able to meet day-ahead discharge schedules. This tool is only triggered on days when market conditions are very tight, indicated by insufficient supply in the residual unit commitment market process. The policy called for this tool to be in place for a two year period, including summer 2021 and 2022, after which point it would retire. This final proposal does not extend use of the tool.

4.1.1 Ancillary Services

Today there is a requirement that all supply resources that provide ancillary services to generate or discharge energy if called upon by the market. Specifically, this requires that storage resources have a state of charge equal to 1 hour of regulation awards in the day-ahead market and 30 minutes in the real-time market. This means that a storage resource with a 10 MW award for regulation up, must have at least 10 MWh of state of charge in the day-ahead market during the hour with the award. In the real-time market, the same resource must carry at least 5 MWh of state of charge during each 15-minute and 5-minute interval during the hour that the resource receives the regulation award. This constraint is discussed further in the examples in this section.

A number of issues have been identified around the ability of storage resources to provide ancillary services to the market and the feasibility of day-ahead awards in real-time. Today, the real-time market requires a state of charge sufficient so that storage is capable of delivering at least 30 minutes of sustained energy for each ancillary service award. If a storage resource has insufficient state of charge, the real-time market will force a buy back of an ancillary service award and rescind the day-ahead ancillary service payment. This can result in incremental ancillary services procurement in the 15-minute market, which may create unnecessary operational challenges.

To help prevent these concerns, the proposal includes two changes to rules currently in place. First, an enhancement to the equation that governs state of charge so that the market optimization will recognize the impact of regulation awards on storage resource's state of charge in the day-ahead and real-time markets. This is meant to help anticipate the energy that will be lost or gained by a storage resource that provides ancillary services. The second change requires

[2] Market Enhancements for Summer 2021 Readiness: https://stakeholdercenter.caiso.com/StakeholderInitiatives/Market-enhancements-for-summer-2021-readiness.

that scheduling coordinators for storage resources submit economic energy bids to charge when awarded upward ancillary services, or economic bids to discharge when providing regulation down.

Both changes are important for ensuring that storage resources are available to provide ancillary services to the market. The first change is important and will better align predicted state of charge with actual realized state of charge while storage resources are providing regulation up or regulation down. The second will ensure that if a resource is deviating from anticipated state of charge, it will still have the ability to charge or discharge if the resource is in danger of not meeting requirements for providing ancillary services. This rule is necessary because without it a storage resource could be in a situation where it is relied on to provide an ancillary service, but may not physically be able to provide that service because it has no state of charge.

The first measure will reduce the need and frequency of use for the second, but the first measure would never completely mitigate the need for the second. As stakeholders noted in the comments, the actual impact to state of charge from regulation awards can vary significantly from one hour to another. They also may vary from one day to another, even within the same hour. The proposed formulation will improve the modeling of a resource’s state of charge in the optimization. In practice, the actual state of charge for resources providing regulation will still deviate from these expectations. Because of these deviations tools are necessary to ensure that resources can meet and provide ancillary services. This can be achieved if there is a supporting energy bid and an ability for a resource to receive a dispatch award for energy.

Stakeholders provided significant feedback on this aspect of the policy and responses are included here:

- *Multiple stakeholders ask for more analysis on contributing factors to operational concerns around storage resources.* As more experience is gained, analysis will be provided in this initiative and via other avenues as it becomes available.
- *Multiple stakeholders ask the specific concerns leading to these proposal.* The solution to require bids addresses situations where a storage resource is physically unable to provide an ancillary service because of insufficient state of charge. By requiring an energy bid, the market can ensure that a resource will ensure will [have state of charge even if it is deviating from day-ahead schedules and in danger of not meeting requirements for providing ancillary services.

- *Multiple stakeholders ask for additional clarity on how the multipliers will be set and for reports on these values*. The proposal is to set the multipliers to best reflect the reality of how energy consumption is related to ancillary service awards. These values will be posted in the business practice manual and will be updated as necessary to reflect the realities of the system. This could be potentially completed on a monthly or seasonal basis. Details will be posted regarding how these values are derived when they are updated. At this point, a firm methodology has not been adopted for how to develop these values. The efficacy of the process of setting these values, along with the methodology employed will be evaluated in typical reporting. Additional stakeholder input on how this methodology may be enhanced in the future may also be sought.
- *Multiple stakeholders ask to expand multipliers to apply for specific months, hours, and resources.* Currently the proposal does not anticipating updating the requirements on a resource basis. This may be overly burdensome and may leave too few observations to generate robust values. This could be true for resources that have been on the system for a particularly long period of time, but are not often awarded regulating services. However, analysis will be conducted to ensure that these values accurately reflect reality.
- *Multiple stakeholders suggest that the amount of energy required to bid into the market is reevaluated*. The 50% energy bidding requirement will cover typical scenarios where storage is providing ancillary services. This is supported by the analysis presented in the appendix. The energy requirement will cover most cases where there is heavy demands on energy from resources providing ancillary services.
- *Multiple stakeholders ask to not impose new bidding requirements in the day-ahead market, but only impose these rules in the real-time market.* This was incorporated into the proposal.
- *Multiple stakeholders ask for numerical examples for how the updates to the state of charge formula and the new requirement would impact storage resources.* Some numerical examples were provided at the market surveillance committee meeting in September.[3] The proposal includes those examples, in this section.

[3] Energy Storage Enhancements Discussion, Market Surveillance Committee, September 19, 2022: http://www.caiso.com/Documents/EnergyStorageEnhancements-Presentation-September19_2022.pdf.

- *The Western Power Trading Forum asks how storage could ensure bids alongside ancillary service awards since the awards are unknown until after the optimization is complete.* The presentation at the market surveillance committee in September provided additional detail on this, and will ensure through a market constraint that any solution from the day-ahead optimization will allow storage resources to be able to include energy bids with ancillary service awards. Additionally, the proposal was refined to no longer require energy bids in the day-ahead market, only the real-time market.
- *The Western Power Trading Forum suggests that resources may have adequate state of charge to ensure ancillary service availability for multiple hours and should not be subject to restrictions during those times.* Because ancillary services are primarily procured in the day-ahead market and additional procurement in the real-time market is limited, there is no way to ensure that storage resources will have sufficient state of charge to provide ancillary service awards in the real-time market. The proposal addresses this concern within the existing market construct for ancillary services.
- *The California Energy Storage Alliance recommends that the new rules requiring energy bids have a sunset period.* This comment is appreciated, but at this time the proposal does not consider a sunset period. Reviewing market results and could trigger re-assessment of these bidding requirements based on whether a need continues to exist.
- *Calpine suggests implementing a constraint to ensure sufficient state of charge in real-time in lieu of changes to bidding requirements.* The market enforces the ancillary service state of charge constraint to ensure that storage resources have sufficient state of charge to provide regulating services. This constraint is ineffective if a resource has insufficient state of charge and has no energy bid in the market. Other constraints would may not ensure sufficient state of charge in real-time.
- *Calpine asks if this proposal includes changes to the automatic generator control logic.* The automatic generator control logic will not change as a result of this proposal.
- *Large-Scale Storage Association recommends that the proposal consider expanding the state of charge formulation to include operating reserves.* This proposal takes an incremental approach where the regulation values will be included in the state of charge equation first, then could be potentially expanded to operating reserves. Observation of market

behavior indicates regulation has a far more significant impact on state of charge than reserves.

- *Pacific Gas and Electric notes that telemetered state of charge could be different than modeled state of charge.* This is true and the market uses telemetered state of charge as an input and a start condition to the modeled state of charge in the real-time markets. This is dissimilar from the day-ahead market, where modeled state of charge from the previous hour is used as the starting state of charge for the current hour and the starting condition is supplied to the market.

Modeling State of Charge

Today, state of charge for a storage resource is governed by the following formula:

$$SOC_{i,t} = SOC_{i,t-1} - \left(P_{i,t}^{(+)} + \eta_i P_{i,t}^{(-)}\right)$$

Where

$SOC_{i,t}$	State of charge for resource *i* at time *t*
$P_{i,t}^{()}$	Discharging (+) or charging (-) instruction for resource *i* at time *t*
η_i	Round trip efficiency for resource *i*

This equation states that state of charge changes as the resource receives dispatch instructions. For example, if the resource receives an award to discharge 60 MW during a specific hour in the day-ahead market, the state of charge for that resource will be 60 MWh less at the end of the hour compared to the start of the hour. Further, if the storage resource is awarded a charging schedule for 60 MW during a specific hour, that resource will have 60 MWh * η_i of additional state of charge at the end of the hour. A typical round trip efficiency might be around 85%, making the increase in state of charge 51 MWh, or 60 MWh * .85.

This equation does not consider ancillary service awards. For example, if a resource is awarded 60 MW of regulation up for a specific hour without an energy award, this equation assumes that the resource will have the same state of charge at the beginning and end of the hour. In practice this will not be true. In the real-time market, resources that receive regulation awards receive 4-second automatic generator control (AGC) instructions from the market. In aggregate in real-time, the resource will certainly have less state of charge than at the start of the hour. However, the exact amount of state of charge is uncertain and will depend on real-time system conditions.

The proposal will also help to ensure that charging or discharging schedules do not exceed physical limits of the storage resource while determining the state of charge during any particular interval.[4] The proposal is to update the model governing state of charge in the day-ahead and real-time markets to the following formula:

$$SOC_{i,t} = SOC_{i,t-1} - \left(P_{i,t}^{(+)} + \eta_i P_{i,t}^{(-)} + \mu_1 RU_{i,t} - \mu_2 \eta_i RD_{i,t}\right)$$

Where

$RU_{i,t}$	Regulation up awarded to resource *i* at time *t*
$RD_{i,t}$	Regulation down awarded to resource *i* at time *t*
μ	Multiplier, applicable for a specific hour

This formula denotes energy awards as *P*, where this value can be positive, representing discharge awards, or negative, representing charge awards. Discharge awards only impact the formula in the $P_{i,t}^{(+)}$ term, and the values for this term are positive and reduce the state of charge. Charge awards only impact the formula in the $P_{i,t}^{(-)}$ term, and the values for this term are negative and increase the state of charge. Values for both regulation up and regulation down awards are positive.

This formula illustrates that state of charge, in any interval, is a function of the state of charge in the previous interval, the energy dispatch instructions during the previous interval and a fraction of the regulation awards in the previous interval. The proposal notes that only the fraction μ of the full amount of regulation will factor into the state of charge for the next interval in the real-time or day-ahead market. This multiplier will be specified in a business practice manual and may be updated as analysis drives updates of actual regulation awards and impacts to state of charge. This multiplier may be different for each hour for regulation up and regulation down. Preliminary analysis on these values found values for μ_1 ranging from .02 to .16 across the hours of the day and μ_2 ranging between .10 and .37. A full summary of these values is provided in the Appendix.

[4] Business Practice Manual for Market Operations, p 353: https://bpmcm.caiso.com/Pages/BPMDetails.aspx?BPM=Market%20Operations.

Energy Bids

Day-ahead ancillary service awards over multiple consecutive hours may not be feasible in the real-time market because the state of charge could be depleted by use of the resource providing these services. There have been multi-week periods when large storage resources were completely committed for ancillary services for multiple consecutive hours. These conditions resulted in periods where the market had significantly less access to ancillary services than what was initially procured for reliable grid operation in the real-time market. Resources that provide ancillary services must be accessible to the market and must not be exposed to conditions that can lead to persistent resource unavailability.

To address this issue, the proposal asks that all ancillary service awards or qualified self-provisions for storage resources be accompanied with bids for energy.[5] Previously, the proposed was that a 10 MW award for upward ancillary services must be accompanied by a 10 MW bid to charge the resource. This would allow, for example, a +/- 12 MW resource to provide up to 6 MW of regulation up and 6 MW of regulation down at the same time, with accompanying bids for a 6 MW range of energy to charge and a 6 MW range of energy to discharge. If a resource did not bid energy in the day-ahead market, it would not receive any award for ancillary services. Likewise, failing to submit sufficient energy bids in the real-time market would result in no-pay for any ancillary service awards from the day-ahead market.

This final proposal, relaxes the prior requirement to only require energy bids in the real-time market equal to 50% of the ancillary service award from the day-ahead market. The proposal also relaxes the requirement for energy bids in the day-ahead market. Returning to the prior example, a +/- 12 MW storage resource with an ancillary service schedule of 12 MW of regulation up would be required to bid a 6 MW range of charging capability in the real-time market alongside the ancillary service award. This could be a bid from in the operating range of the resource from 0 MW to -6 MW. The same resource could be awarded up to 8 MW of regulation up and 8 MW of regulation down at the same time, as long as these awards were accompanied by bids of a 4 MW range to charge and a 4 MW range to discharge energy. However, this resource could not be awarded to provide 9 MW of regulation up and 9 MW of regulation down during the same hour. If this was awarded the resource could not provide the

[5] These bids may clear for energy awards or not. This is a requirement that bid submissions or self-scheduled energy accompany ancillary service awards.

required energy bids in real-time. This requirement is less burdensome than the previous 100% requirement, and will ensure the ability to charge or discharge when a storage resource is in jeopardy of not meeting availability requirements for providing ancillary services in most scenarios.

The proposed rules will not require bids in the day-ahead market from the storage resource, but ancillary services will not be awarded in the day-ahead market that cannot accommodate the required energy bids in the real-time market. Further, numerical examples are provided in the sub-section below.

The proposed rule is applicable to bids, and does not specify if these energy bids will clear or not, and does not specify the price that a market participant must submit the bid at. Awards for energy will continue to be determined by the market software.

Numerical Examples

Some numerical examples were presented at the market surveillance meeting in September. Typically, details about how specific constraints might be formulated are worked out in the business requirement process. The examples presented to the market surveillance committee speculated that the following set of ***bidding requirement*** constraints could be enforced in the day-ahead market:

$$\overline{En_{i,t}^{(-)}} \geq \left(RU_{i,t} + SR_{i,t} + NR_{i,t}\right) * .5$$

$$\overline{En_{i,t}^{(+)}} \geq \left(RD_{i,t}\right) * .5$$

The first equation ensures that the upper end of the range of potential charging bids is greater than 50% of the summation of regulation up, spinning reserve, and non-spinning reserve awards for the resource. The second equation ensures that the upper end of the range of potential discharge bids is greater than 50% of the regulation down award for the resource. As noted, these constraints would not require energy bids be submitted in the day-ahead market, rather that the day-ahead ancillary service awards would allow for these bids in the real-time market.

As proposed above, ***state of charge*** will be modeled using the following formula:

$$SOC_{i,t} = SOC_{i,t-1} - \left(P_{i,t}^{(+)} + \eta_i P_{i,t}^{(-)} + \mu_1 RU_{i,t} - \mu_2 \eta_i RD_{i,t}\right)$$

Finally, the market already enforces a set of resource specific constraints called the ***ancillary service state of charge constraint*** in the real-time market:

$$SOC_{i,t} \geq \underline{SOC}_{i,t} + 0.5 * RU_{i,t} + 0.5 * SR_{i,t} + 0.5 * NR_{i,t}$$

$$SOC_{i,t} \leq \overline{SOC}_{i,t} - 0.5 * RD_{i,t}$$

These constraints ensure that storage resources have sufficient state of charge, above minimum or below maximum state of charge levels, respectively, to ensure support a full output of regulation energy for a 30 minute period in the real-time market. The same equations are enforced in the day-ahead market, but require 60 minutes of state of charge.

Suppose a resource has a +/- 100 MW operating range and can hold a state of charge between 0 MWh and 400 MWh. Also suppose that the model assumes the resource will have 200 MWh of energy going into hour ending 14, and that the resource has no losses between charging and discharging. In the following scenarios these dispatch awards are feasible in the day-ahead market:

- 0 MW of energy and 100 MW of regulation up

In this scenario the market calculates the state of charge for the resource at the end of hour ending 14 at 189 MWh (200 MWh – 100 MW * .11). This is sufficient state of charge to support the 100 MWh requirement for state of charge for the regulation up award. The resource would have the ability to bid up to 100 MW of charging energy in the real-time market, exceeding the proposed requirement to bid 50 MW of charging energy in the real-time market to support this regulation award.

- 50 MW of energy and 50 MW of regulation up

In this scenario the market calculates the state of charge for the resource at the end of hour ending 14 at 144.5 MWh (200 MWh – 50 MW – 50 MW * .11). This is sufficient state of charge to support the 50 MWh requirement for state of charge for the regulation up awarded. The resource would have the ability to bid up to 100 MW of charging energy in the real-time market, exceeding the proposed requirement to bid 25 MW of charging energy in the real-time market to support this regulation award.

- 100 MW of energy and 100 MW of regulation down

In this scenario the market calculates the state of charge for the resource at the end of hour ending 14 at 121 MWh (200 MWh – 100 MW + 100 MW * .21). This is sufficient state of charge to support the requirement to have no more than 300 MWh for state of charge for the regulation down awarded. The resource would have the ability to bid up to 100 MW of discharge energy in the real-time market, meeting the proposed requirement to bid 50 MW of discharge energy in the real-time market to support this regulation award.

Now assume the same resource is in a different scenario where the model assumes the resource will have 50 MWh of energy going into hour ending 14 in the day-ahead market. In the following scenarios the following dispatch awards are infeasible:

- 0 MW of energy and 100 MW of regulation up

In this scenario the market calculates the state of charge for the resource at the end of hour ending 14 at 39 MWh (50 MWh – 100 MW * .11). This is insufficient state of charge to support the 100 MWh requirement for state of charge for the regulation up awarded. The resource would have the ability to bid up to 100 MW of charging energy in the real-time market, exceeding the proposed requirement to bid 50 MW of charging energy in the real-time market to support this regulation award.

- 50 MW of energy and 50 MW of regulation up

In this scenario the market calculates the state of charge for the resource at the end of hour ending 14 at -5.5 MWh (50 MWh – 50 MW – 50 MW * .11). This is an infeasible award because the calculated state of charge is below the minimum state of charge of 0 MWh for the resource.

- 100 MW of regulation up and 100 MW of regulation down

In this scenario the market calculates the state of charge for the resource at the end of hour ending 14 at 60 MWh (50 MWh – 100 MW * .11 + 100 MW * .21). This is insufficient state of charge to support the 100 MWh requirement for state of charge for the regulation up awarded, but is sufficient to support the maximum state of charge of 300 MWh for the regulation down awarded. The resource would not have the ability to bid any charging or discharge energy in the real-time market and would not meet the proposed requirement to bid 50 MW of discharge energy and 50 MW of charging energy in the real-time market to support this regulation award.

4.1.2 Exceptional Dispatch

The market can exceptionally dispatch resources on the grid to ensure reliability. For storage resources, this includes dispatch instructions to discharge energy and dispatch instructions to charge. If a resource is dispatched to discharge energy to the grid, then the resource will receive compensation at the higher of their bid or the prevailing price for the dispatched (MW) amount.

Some feedback was provided on this aspect of the policy and some responses are supplied here:

- *Calpine asks how the new tool will interact with existing exceptional dispatch.* The proposed policy states that a resource will either be awarded a traditional exceptional dispatch (to a MW target) or an exceptional dispatch to hold state of charge (to a MWh target) but there will never be an instance where there is overlap. This proposal will implement controls to ensure that the resource is only ever receiving instructions for one or the other exceptional dispatch and operators will be alerted if they issue an exceptional dispatch that would invalidate an exceptional dispatch that is already in place.

This proposal includes new functionality that will allow dispatch to storage resources to hold a certain state of charge (MWh), in addition to the traditional (MW) exceptional dispatch.[6] A tool will allow for dispatch of storage resources to charge to and hold a specific level of state of charge for a specific duration of time in the real-time market. For example, a specific exceptional dispatch may require a storage resource to charge to 75 MWh and hold that state of charge through the end of hour ending 20. When that energy may be needed later in the day, a dispatch for the resource to provide energy through a typical exceptional dispatch, or more simply the resource may be allowed to release energy economically through market dispatch.

Because so much use-limited storage is interconnecting at the same time that the market is capacity constrained in peak hours, and it is prudent to develop these tools. They can help manage energy across the storage fleet as well as overall generating capability for critical times of the day. This tool is consistent with current functionality to issue exceptional dispatches today, but has included a discussion here for transparency, and introduction of unique settlement for storage resources.

Compensation for traditional exceptional dispatch is based on the 'bid or better' paradigm where resources receive compensation for energy delivered in response to exceptional dispatch instructions at the higher of bid prices or prevailing market prices. This ensures that resources receive compensation at least as great as marginal costs to provide energy. Today, if the operators want

[6] Actual signals for exceptional dispatch to resources will continue to be transmitted to storage scheduling coordinators via a dispatch instruction in terms of MW. While exceptional dispatches are issued to storage resources to hold state of charge, these instructions will likely be for storage resources to not exceed 0 MW of output, if the resource has just met the target MWh. Actual details for instructions will be developed with the business requirements for this initiative.

a resource to hold state of charge, they could issue an exceptional dispatch at or near 0 MW, but this would result in almost no compensation for the exceptional dispatch. At the same time, the storage could potentially miss opportunities to participate in the real-time market during these periods and potentially earn significant market revenues.

Resources below target state of charge levels, when exceptionally dispatched to a certain state of charge, will be required to charge up to the target levels. These exceptional dispatch instructions will be issued similar to traditional exceptional dispatch instructions today. For example, if a storage resource is exceptionally dispatched to hold 75 MWh of state of charge, but is currently only at 50 MWh, the resource will receive traditional exceptional dispatch instructions to charge while moving from 50 MWh to 75 MWh. Once at 75 MWh the resource will receive exceptional dispatch instructions to hold that state of charge.

4.1.3 Compensation for Exceptional Dispatch to Hold State of Charge

Storage resources receiving exceptional dispatch instructions to hold state of charge will be compensated using a different methodology than traditional exceptional dispatch. This compensation will be based on an opportunity cost methodology and will capture the revenues that the resource would have received had it been optimally participating in the market, during the exceptional dispatch and for a period of time after the exceptional dispatch.

- *Some comments expressed concerns about the hypothetical calculations, including intervals of hypothetical instances when energy awards were not consistent with bids from resources.* The proposal augments the counterfactual dispatch instructions so that they only occur when they are economic. The proposal has not expanded the example to include this, but will implement this as a component of the logic for compensation.

Compensation Calculation

For each exceptional dispatch issued to a storage resource to hold state of charge, the market will compute two counterfactual values. The first will be the revenue maximizing energy dispatch the resource would have received if there was no exceptional dispatch in place, and the second is the revenue maximizing energy dispatch that the resource would have received if the exceptional dispatch was still in place.[7]

As noted above, the proposal recognizes that storage resources that are issued exceptional dispatch instructions to hold state of charge can impact prices, particularly in local areas where there is little other generation that can serve load. However, the proposal is unable to update these values and will use realized locational marginal prices to complete this analysis.

The time horizon for these counterfactuals will start from the first interval where the exceptional dispatch to hold state of charge is in place. The time horizon will include the entire horizon of the exceptional dispatch and will include additional periods through the end of the operating day. For example, if the exceptional dispatch began at 18:30 and was in place for 1.5 hours – through 8pm - then both counterfactuals would include intervals between 18:30 through midnight.

After calculation of both counterfactual values, the market will compare them. If the resource would have been able to make additional revenue if the exceptional dispatch was not in place, then the resource would be awarded the difference between the counterfactual revenue earned without the exceptional dispatch in place and with the exceptional dispatch in place, as an additional uplift payment for the day. Counterfactuals in the real-time market will be based on imbalances from day-ahead schedules, similar to typical real-time settlement practices.

Example

This highly simplified example illustrates how this calculation could be completed. It uses the same hypothetical resource discussed above with a -25 MW lower operating limit, +25 MW upper operating limit, 0 MWh minimum state of charge, and a 100 MWh maximum state of charge. At 18:30 the resource is issued a dispatch instruction to hold state of charge at or above 75 MWh and this exceptional dispatch is in place through 20:00. Further, for simplicity, we assume that the resource does not have any cycling costs associated with operating. These values will be included in the revenue calculations, when provided.

For simplicity, this example does not include 5-minute prices, but instead includes prices during half hour blocks. These are meant to represent segments of 6 5-minute prices. For this example, we assume that each of the 5-minute

[7] This methodology will only include counterfactual schedules for energy when storage resources have bids that economic.

prices within the illustrated interval results in an identical price, specified in Table 1.

Table 1: Exceptional Dispatch Compensation

		No Exceptional Dispatch				Exceptional Dispatch			
Hour	**Prices**	**SOC**	**Ideal MW**	**SOC_T+1**	**Rev**	**SOC**	**Const MW**	**SOC_T+1**	**Rev**
18:30	95	80	25	67.5	$ 1,188	80	0	80	$ -
19:00	**300**	67.5	25	55	$ 3,750	80	10	75	$1,500
19:30	**300**	55	25	42.5	$ 3,750	75	0	75	$ -
20:00	75	42.5	-25	55	$ (938)	75	0	75	$ -
20:30	85	55	25	42.5	$ 1,063	75	25	62.5	$1,063
21:00	100	42.5	25	30	$ 1,250	62.5	25	50	$1,250
21:30	125	30	25	17.5	$ 1,563	50	25	37.5	$1,563
22:00	150	17.5	25	5	$ 1,875	37.5	25	25	$1,875
22:30	45	5	-25	17.5	$ (563)	25	0	25	$ -
23:00	90	17.5	25	5	$ 1,125	25	25	12.5	$1,125
23:30	82	5	10	0	$ 410	12.5	25	0	$1,025
					$14,473				$9,400

The first column of this sheet represents the times with specific intervals, in half hour increments. The second column represents actual realized locational marginal prices. For simplicity, we assume that the storage resource bids to discharge anytime prices are greater than $50/MWh. Columns 3-6 and columns 7-10 represent the counterfactual ideal dispatch instructions for profit maximization if no exceptional dispatch is in place and the ideal dispatch instructions with the exceptional dispatch in place, respectively. Specifically, these sets of columns include information on current state of charge, counterfactual energy dispatch instruction, state of charge resulting from the dispatch instruction and the total revenue realized from the dispatch instruction.

First, note that the time frame included in this example includes 5.5 hours of data. This corresponds to the initial exceptional dispatch, between 18:30 and 20:00, followed by 4 additional hours of data through midnight. Second, prices between 19:00 and 19:30 actually materialized at $300/MWh. Third, for this analysis the market does not generate counterfactual prices for intervals after the exceptional dispatch is in place.

Columns 3-6 represent the revenue maximizing, or ideal, dispatch for the resource had there been no exceptional dispatch, with corresponding state of charge values and revenues. In this scenario, the resource would have discharged energy during the high priced periods when the exceptional dispatch was in place (hours 18:30 through 20:00), then recharged for one half hour (hour 20:00 through 20:30), then discharged for most of the remainder of the period, excluding hour 22:30 when prices were low. This would have resulted in a hypothetical revenue of $14,473.

Columns 7-10 represent the revenue maximizing, or ideal, dispatch for the resource while observing the exceptional dispatch. In this scenario, the resource would have been limited by how much energy could have been discharged before 20:00. This allows for a relatively full state of charge at the conclusion of the exceptional dispatch, and results in discharging the resource anytime prices are above $50/MWh later in the day. Operating following this pattern would have resulted in a hypothetical revenue of $9,400.

In this instance the resource would be made an additional payment of $5,073 ($14,473 - $9,400) as an opportunity cost payment for incurring this specific exceptional dispatch instruction.

4.2 Co-located Enhancements

Many stakeholders commented that current investment tax credit (ITC) rules impact the financial incentives for storage resources. The investment tax credit rules also can impact contracting for storage resources. Some contracts expressly prohibit ‘grid charging’ for storage resources because grid charging can reduce the revenue stream for a storage or co-located projects. At the July 26 workshop stakeholders suggested a new mechanism for co-located resources that ensures revenue recovery if a storage resource seeking the investment tax credit were to incur costs due to grid charging. Such a mechanism may reduce qualifications in future contracts that prohibit grid charging and may allow storage resources seeking to bid charging capacity into the market to do so more freely.

In response to these requests, this proposal ensures any co-located storage resource can avoid grid charging by preventing dispatches above scheduled output from on-site renewable resources. These changes, discussed further below, will be optional functionality that scheduling coordinators for co-located storage resources may elect to use.

Any resource interconnected to the grid is subject to exceptional dispatch from the operations team. These exceptional dispatches may be anywhere within the registered operational limits of the resource. The operations team only uses exceptional dispatch authority when reliability is threatened and actions are often time sensitive, which is why compliance with these instructions is critical. To completely avoid situations where energy flows from the grid to a generating facility this proposal will continue to offer the hybrid model, which can have a lower operational bound for a resource at 0 MW.

Stakeholder submitted comments on this aspect of the policy and responses are provided here:

- *Several stakeholders comment that the proposal could present challenges for co-located facilities that do not schedule renewables in the day-ahead market.* In response, the proposal is changed to use forecast renewable values if schedules are not available.
- *Large-scale Storage Association asks if co-located pseudo-tie resources will have the enhanced co-located functionality option available.* Pseudo-tie resources will have the functionality proposed through this stakeholder initiative available to them.

4.2.1 Enhanced Co-Located Functionality

Co-located storage resources are able to and – when shown for resource adequacy – may be required to bid economically or self-schedule into the market. Either could result in a certain schedule to charge during a real-time interval. Storage resources, like all non-variable resources, are obligated by the tariff to follow dispatch instructions that result from market awards.[8]

Even if a storage resource is scheduled to charge at a level commensurate with forecasted production by a co-located renewable resource, if the co-located renewable resource is unable to generate at its schedule, then an onsite storage resource may be required to charge from the grid. This could occur for a variety of reasons, such as renewable resource intermittency or the renewable resource being backed down economically by market dispatch.

This proposal includes new functionality for storage resources to help address some of the concerns voiced by stakeholders. The proposal includes an electable functionality to limit dispatch instructions for co-located storage resources to charge to be no greater than the dispatch operating target of their co-located renewable resources in both the day-ahead and real-time markets.[9] This functionality will be electable on an hour by hour basis and offered to any co-located storage resource and will prevent ‘grid charging.’ This functionality will include two components: 1) market rules that ensures that storage charging schedules do not exceed renewable generation schedules, and 2) allowances that ensure that actual real-time charging does not exceed actual real-time co-

[8] Phase 4 for the energy storage and distributed energy resource policy implemented an exception to this rule when on-site renewables are generating above forecast levels.

[9] This functionality could allow for the maximum charging rate for a single storage resource to be determined by the output of a single or multiple renewable resources.

located renewable generation. Further, in the event that the co-located renewable resource is not scheduled in the day-ahead market, the market will use forecasts in lieu of market energy awards to limit dispatch for storage resources.

At this time the proposal does not accommodate this functionality to resources that are providing regulation. The premise of regulating energy is that the automatic generator control can dispatch the resource anywhere within the capacity range awarded for this service. This premise is inconsistent with limitations that could result from a resource not being fully or partially available because of output from on-site renewable generation.

Charging Schedules will not Exceed Renewable Schedules

The proposal includes functionality that will prevent storage resources from receiving instructions to charge in excess of the dispatch operating target of the co-located renewable resource(s). Generally, the dispatch operating target of a renewable resource equals its forecasted output. This functionality will apply whether the renewable-resource output was limited by fuel limitations or a supplemental negative dispatch instruction to operate below forecast.

If a co-located storage resource would like to elect this functionality, or has this functionality elected and would like it removed, they must go through the generator resource data template update process.

Allow Storage to Charge at Output from Renewables

This proposal allows storage resources to deviate down from their real-time dispatch instructions for charging during intervals when co-located renewables are unable to produce the forecast energy. For example, assume a solar resource is forecast and dispatched at 30 MW during one interval in real-time, and the associated co-located storage resource is scheduled to charge at -30 MW. While actually operating during the period, the solar resource is only able to produce 25 MW. In this case, the storage resource would be allowed to simultaneously only charge at -25 MW, even though the dispatch instruction to the resource was for -30 MW.

This prevents the storage resource from charging from the grid when it receives a charging schedule that exceeds the total energy awarded to the solar resource, during intervals when the solar resource is unable to generate at that award. The storage resource may not deviate beyond the difference in scheduled and actual energy from the variable resource and is required to charge at the level of output from the solar resource when deviating from dispatch instructions.

The proposal does not include any changes to the settlement system to accommodate these proposed rule changes. Storage resources that elect this alternate co-located model, and do not fully meet dispatch awards to charge will be subject to associated imbalance energy charges for those differences.

4.2.2 Pseudo-Tie Resource Functionality

During the stakeholder meetings on July 26, stakeholders requested enhanced functionality for modeling pseudo-tie resources. They suggested it would be beneficial for additional participation of resources outside of the ISO footprint. Today, co-located resources are allowed to have interconnection limits below the aggregate maximum output of on-site generation. This functionality is useful for facilities with renewable and storage resources, as the two generally are not producing at full output during the same time.

Today pseudo-tie resources are required to show firm capacity from the resource interconnection to a delivery point on the ISO transmission grid for their full generating capability. Stakeholders requested that the this requirement for co-located pseudo-tie resources be relaxed, and that the firm transmission need only be demonstrated for the amount of interconnection capacity that the co-located resources have, rather than the maximum generating capability of the entire facility. With these requirements in place the aggregate capability constraint (ACC), or a similar constraint, could be used to ensure that dispatch for the combination of the resources under the constraint does not exceed the interconnection limits and firm transmission dedicated to the project.

The proposal includes implementing this change, but only for co-located resources that can be modeled by an aggregate capability constraint and where all resources are pseudo-tied from the same balancing authority area to the ISO. Also, the host balancing authority must agree that firm transmission for the maximum capability is not required. Co-located resources pseudo-tied to the ISO seeking to utilize an aggregate capability constraint would need the prior written approval of their host balancing authority to utilize this functionality and verify that they have physical controls in place that prevent the co-located resources' exceeding the interconnection service capacity at their point of interconnection to the host balancing authority. This arrangement also may require modifications to agreements underlying the resource's pseudo-tie arrangement.

This proposal allows access for pseudo tie resources to all features proposed in Section 4.2.1 for enhanced co-located functionality.

4.3 Default Energy Bid

The proposal developed the default energy bid for storage resources in the energy storage and distributed energy resources (ESDER) initiative.[10] The default energy bid was discussed at great length with stakeholders and the market surveillance committee during public meetings and written materials posted to the initiative website.

That ESDER proposal included a default energy bid for storage resources that would accomplish three key principles. First, values for default energy bids should incorporate estimates of energy prices paid by storage resources to procure energy. Second, values should incorporate wear and tear due to the storage resource cycling to provide energy to the grid. This principle is most similar to those in place for traditional gas resources. Third, the proposal also incorporated an opportunity cost to avoid discharging the resource prior to the profit maximizing periods of the day. This aspect of the default energy bid captures that storage resources have a limited duration of discharge capability.

While the policy was developing the formulation for the default energy bids, one suggestion for improvement, made by the market surveillance committee, was that a term in the day-ahead default energy bid to account for opportunity costs was unnecessary. The idea was that if a storage resource was dispatched by the day-ahead market, because the market considers all 24 hours when optimizing, it will automatically select the hours with the highest prices. This logic is valid in scenarios when a scheduling coordinator for a storage resource is bidding the same cost through all 24 hours and those costs match the default energy bid of the resource.

[10] Energy storage and distributed energy resource initiative webpage: https://stakeholdercenter.caiso.com/StakeholderInitiatives/Energy-storage-and-distributed-energy-resources.

In light of this feedback and deep discussion with stakeholders this proposal includes the following default energy bids in the energy storage and distributed energy resource initiative:

$$\boldsymbol{DA\ Storage\ DEB = \left(MAX\left(En_{\delta/\eta}, 0\right) + \rho\right) * 1.1}$$

$$RT\ Storage\ DEB = Max\left[\left(MAX\left(En_{\delta/\eta}, 0\right) + \rho\right), OC_{\delta}\right] * 1.1$$

Where:

- *En*: Estimated cost for resource to buy energy
- δ: Energy duration
- η: Round-trip efficiency
- ρ: Variable cost
- *OC*: Opportunity Cost

These default energy bids were approved by FERC and introduced into the ISO market, alongside market power mitigation for storage, with the Fall 2021 software release. Market participants have now had time to observe actual performance of these formulas in the market.

Comments on this aspect of the policy and responses are included here:

- *Several stakeholders request that market results from the previous day-ahead market be used to inform opportunity cost adders.* An alternative method to developing opportunity costs could be to use the results from the previous day-ahead market run instead of the results from the market power mitigation pass from the same day. Although this is an alternative, in alignment with these comments, the proposal contends that results from the market power mitigation pass of the day-ahead market will more closely reflect actual prices in the day-ahead market relative to the final result of the day-ahead market run from the previous day. The proposal also acknowledges other comments that suggest that the market power mitigation prices may inherently not reflect final prices, because the market power mitigation run has not yet been applied to the results of the market outcomes with mitigated bids. However, these are likely the closest estimates available to calculate opportunity costs for storage resources using this model, when these calculations need to occur.
- *Several stakeholders suggest that the default energy bid should not mitigate the entire bid curve to the same price.* This aspect of the policy is attempting to maintain a very limited scope and not intend to reopen changing this part of the default energy bid here in this initiative.

- *Vistra asks to consider using the single highest hour to estimate the opportunity cost instead of using the duration of the resource.* This policy is attempting to maintain a very limited scope and does not consider an existing term to the day-ahead formulation. Re-evaluating the premise for generating terms in the default energy bid formulation is out of scope. There is a negotiated default energy bid available for situations where the existing default energy bid framework is insufficient. Finally, on days with extreme circumstances, such as September 6, a different formulation for default energy bids may be prudent, but it is unclear what that formulation would be at this time. This is something that may be considered in future initiatives.
- *Rev Renewables asks to create dispatch based on the current and proposed default energy bids.* Currently, the policy does not develop nor present that analysis at this time. The market results will be observed and may help to enhance default energy bids or the optimization if warranted.

Operational Experience

A specific case was flagged by a storage scheduling coordinator, where the day-ahead dispatch schedule did not meet the third principle outlined for storage default energy bids. Despite the scheduling coordinator bidding at a consistent price throughout the day, the resource was scheduled to discharge during the late afternoon hours and not during the highest priced hours in the evening. This happened because bids were higher than the default energy bids and market power mitigation triggered during the earlier hours of the day and not the later hours of the day. In this case, the market optimization chose to schedule the resources for discharge energy during periods when the resource appeared less expensive because of the mitigated bids.

A unique aspect of the storage default energy bid, is that it is computed from outputs of the market power mitigation pass of the day-ahead market, which are unknown to scheduling coordinators when they are submitting bids. This could lead to additional situations, and indeed stakeholders have noted additional situations, where storage resources are dispatched in a similar manner to the case outlined above.

In response to this operational feedback the proposal agrees that the outcome for this particular day is contrary to the principle expectations for how market power mitigation should be applied to storage resources. The proposal also acknowledges that even though this case was only for a specific day, this could be a routine occurrence under typical bidding circumstances. In light of these observations, the proposal includes and updated default energy bid, so that the day-ahead formulation includes an opportunity cost. This will result in the same formulation for default energy bids for storage resources in the day-ahead and real-time markets. Specifically, the proposal updates the existing formulations to the following equations:

$$\boldsymbol{DA\ Storage\ DEB = Max\left[\left(MAX\left(En_{\delta/\eta}, 0\right) + \rho\right), OC_{\delta}\right] * 1.1}$$

$$RT\ Storage\ DEB = Max\left[\left(MAX\left(En_{\delta/\eta}, 0\right) + \rho\right), OC_{\delta}\right] * 1.1$$

Where:

En: Estimated cost for resource to buy energy
δ: Energy duration
η: Round-trip efficiency
ρ: Variable cost
OC: Opportunity Cost

These proposed formulations should ensure that storage resources will be dispatched during the highest priced hours in the day-ahead market, in accordance with the principles initially outlined.

5 WEIM Classification

This initiative proposes to introduce a new market model, the energy storage resource model, for use by storage resources in the real-time market, as well as other changes to the existing non-generator resource model that will be applied to the markets. The WEIM Governing Body has joint authority with the Board of Governors over the changes proposed in this paper.

The role of the WEIM Governing Body with respect to policy initiatives changed on September 23, 2021, when the Board of Governors adopted revisions to the corporate bylaws and the Charter for EIM Governance to implement the Governance Review Committee's Part Two Proposal. Under the new rules, the Board and the EIM Governing Body have joint authority over any, "proposal to change or establish any CAISO tariff rule(s) applicable to the EIM Entity balancing authority areas, EIM Entities, or other market participants within the EIM Entity balancing authority areas, in their capacity as participants in EIM. This scope excludes from joint authority, without limitation, any proposals to change or establish tariff rule(s) applicable only to the CAISO balancing authority area or to the CAISO-controlled grid." Charter for EIM Governance § 2.2.1.

The tariff changes to implement this initiative would be "applicable to EIM Entity balancing authority areas, EIM Entities, or other market participants within EIM

Entity balancing authority areas, in their capacity as participants in EIM." If established, EIM balancing authority areas may use the energy storage resource model. Accordingly, the proposed changes outlined in this proposal fall within the scope of joint authority.

This proposed classification reflects the current state the initiative and could change as the stakeholder process moves ahead.

6 Next Steps

There will be a stakeholder call on October 31, 2022 to review the final proposal. This proposal will be presented to the WEIM Governing Body and the ISO Board of Governors for approval at the December meetings.

Appendix

This proposal reviews hourly records from three months of data for specific storage resources in the fleet from March 1, 2022 to May 31, 2022. This resulted in about 35,000 records where storage received either regulation up or regulation down awards. This data was paired with observed real-time information on changes in state of charge between the beginning of the award to the end of the award. These state of charge values were modified to remove any impact from energy schedules during the same time period. Then a simple linear regression where regulation up and regulation down were descriptive variables for the associated change in state of charge was performed. This analysis was performed on the entire set of data and subsets of data for each hour. From the results, it is clear that regulation awards in different hours have different impacts on state of charge. The proposal includes differences in each hour as an aspect of the state of charge formulation.

The table below shows the coefficients attached to the descriptive variables regulation up and regulation down and how they relate to state of charge. The first row indicates that typically an award of 100 MW of regulation up will result in a reduction of state of charge of about 8 MWh. It also indicates that an award 100 MW of regulation down will typically result in a 19 MWh increase in state of charge. Further, we might expect that a typical resource with an award of 100 MW of regulation up and 100 MW of regulation down would typically charge about 11 MWh (19 MWh – 8 MWh) without knowing what specific hour the award occurs.

	Reg Up	Reg Down
ALL	8%	19%
Hour	**Reg Up**	**Reg Down**
1	6%	12%
2	2%	10%
3	2%	13%
4	7%	18%
5	6%	11%
6	8%	13%
7	12%	24%
8	6%	22%
9	3%	13%
10	8%	13%
11	4%	13%
12	6%	18%
13	7%	20%
14	11%	21%
15	8%	21%
16	9%	21%
17	16%	25%
18	16%	35%
19	12%	21%
20	7%	35%
21	6%	37%
22	8%	23%
23	3%	26%
24	5%	25%