Energy Storage Enhancements

Draft Final Proposal

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Market & Infrastructure Policy

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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 ISO market. The ISO observes these resources primarily charging during the lowest priced periods of the day (when solar is abundant) and discharging during the highest priced periods of the day. Today the ISO relies on storage resources for the critical operation of one local capacity area. The ISO anticipates that storage resources will be necessary for the reliable operations in many other local capacity areas in the future. In the ISO's annual local capacity area technical studies, the ISO 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 ISO 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 ISO acknowledges 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 ISO included multiple updates and clarifications from the second revised straw proposal, but most of the content of the paper has remained the same. Notably, the ISO is moving the aspects of policy related to local reliability to the storage modeling enhancements initiative, with other improvements to the model.

[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.

This will allow the ISO more time to discuss these changes with stakeholders and will allow ample time for implementation.

2 Policy Summary

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

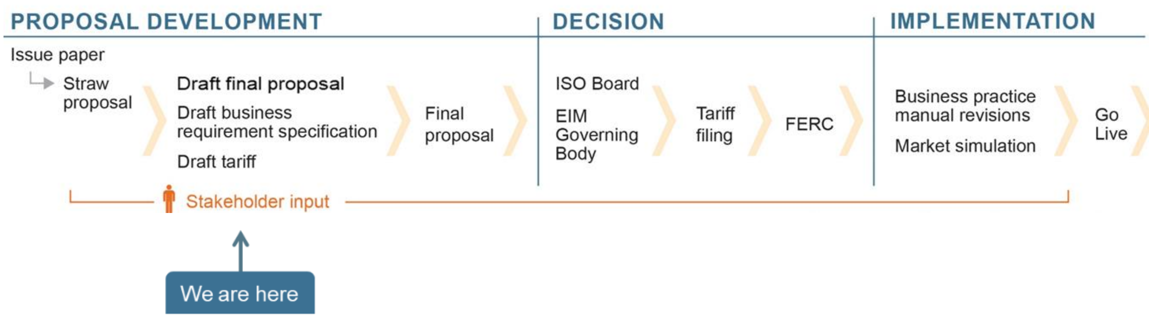
- (4.1.1) State of charge will include expected impacts from regulation
- (4.1.1) Storage must bid energy in the opposite direction of AS awards
  - A energy bids need only be 50% of AS bids
- (4.1.2) Storage resources may be issued EDs to hold SOC in RT
  - Storage may receive a traditional ED or an SOC ED, but not both
- (4.1.3) Compensation will include lost opportunity from not generating
  - ISO will calculate counterfactual energy revenues with and without the exceptional dispatch in place
  - ISO will use bids to 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 model
  - Available to all storage resources
  - Storage schedules will never exceed renewable schedules
  - 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
  - All resources are required to respond to operator and exceptional dispatch instructions within physical bounds of operation
  - ISO continues to offer the hybrid model
- (4.2.2) Allow for co-located pseudo-tie resources to apply 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 ISO is at the "straw proposal" stage in the energy storage enhancement (ESE) stakeholder process. Figure 1 below shows the status of the overall energy storage enhancements stakeholder process.

The purpose of the straw proposal is to include detailed solutions for resolving issues related to the integration, modeling, and participation of energy storage in the ISO market. The ISO will publish a number of straw proposals, and solicit stakeholder feedback after each iteration. The ISO will publish a draft final proposal, solicit stakeholder feedback and then conclude with a final proposal. As appropriate, the ISO may organize focused working groups to address complex issues or issues that have cross-jurisdictional concerns as we move through the initiative process.

Figure 1: Stakeholder Process for ESE Stakeholder Initiative



4 Proposal

The ISO introduced the non-generator resource (NGR) model in 2012 to allow for wholesale market participation of energy storage resources. Although the ISO believes the non-generator resource model effectively integrates 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 for the ISO to consider to help better model storage resources. While the ISO's 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 the tool would be retired.

This policy does not adapt the minimum state of charge requirement and does not extend the expiration of the tool. Although this policy addresses similar issues that arose during discussions for the minimum state of charge requirement, the changes proposed here are meant to function independently from the minimum state of charge requirement.

4.1.1 Ancillary Services

Today the ISO requires all supply resources that provide ancillary services to have sufficient energy if called upon by the market. Specifically, the ISO requires that storage resources retain energy 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 going into the hour with the award. In the real-time market, the same resource must carry at least 5 MWh of state of charge going into each 15-minute period during the hour that the resource receives the regulation award.

A number of issues have been identified around the ability of storage resources to provide ancillary services to the market and the feasibility of awards from the day-ahead market into the real-time market. 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 delivery 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 services award and rescind a day ahead ancillary

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

services 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 ISO proposes two changes to rules currently in place. First, the ISO proposes an enhancement to the equation that governs state of charge so that regulation awards will impact 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. This will be tracked by the market optimization and incorporated in state of charge. The second change requires that storage resources have economic energy bids available while providing regulation up or 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 regulating services. 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 the resource if the resource is in danger of not meeting ISO requirements for providing ancillary services.

The ISO agrees that the first measure will reduce the need and frequency of use for the second, but does not agree that the first measure would ever completely mitigate the need for the second. As stakeholders noted in the comments, actual state of charge changes related to regulation awards can change drastically from one hour to another. They also may change drastically from one day to another, even within the same hour. This means that on average the proposed formulation will be an improvement on the best guess for state of charge, but in practice the actual state of charge for regulating resources will deviate from these expectations. Because of these deviations the ISO still needs tools to ensure that resources can meet the criteria to 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.

In response to stakeholder comments the ISO is proposing that multipliers be specific to each hour of the day. The ISO also received comments that multiplier could be region specific or resource specific. Analysis on an individual resource basis may be challenging because there may be insufficient data to fully identify a solution. Developing these values on a regional level may be possible, and the ISO will consider this when presenting future analysis and data on regulation awards.

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 ISO. 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.[3] The ISO proposes to update the model governing state of charge in the day-ahead and real-time markets to the following formula:

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

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

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 ISO 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 the ISO updates analysis of actual regulation awards and impacts to state of charge. This multiplier may be different for each hour for regulation up and regulation down. The ISO performed some preliminary analysis on these values and 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.

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 potentially depleted by use of the resource providing these services. The ISO operations team observed multi-week periods when large storage resources were completely committed for ancillary services for multiple consecutive hours. During this period these conditions resulted in periods where the ISO 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 by the ISO and must not be exposed to conditions that can lead to persistent resource unavailability.

To address this issue, the ISO proposes that all ancillary service awards for storage resources be accompanied with bids for energy.[4] Previously the ISO proposed that a 10 MW award for ancillary services must be accompanied by a 10 MW of bids to charge the resource. The rules previously proposed would allow 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. Similarly, if a resource does not bid energy, it will not receive any award for ancillary services. Not submitting sufficient energy bids in the real-time market would result in no-pay for any ancillary service awards from the day-ahead market.

The ISO relaxed this proposal to only require energy bids equal to 50% of the ancillary service award. Under this proposal, a +/- 12 MW storage resource providing 12 MW of regulation up would be required to bid a 6 MW range of charging capability. This same resource would be permitted to provide up to 8 MW of regulation up and 8 MW of regulation down at the same time, while bidding a 4 MW range to charge and discharge energy. 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. These rules would be in place in the day-ahead and real-time markets.

The proposed rule is applicable to bids, and does not specify if a bid will clear or not. This will continue to be determined by the market software.

4.1.2 Exceptional Dispatch

ISO operators 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.

The ISO proposes new functionality that will allow the ISO operators to dispatch storage resources to hold a certain state of charge (MWh), in addition to the

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

traditional (MW) exceptional dispatch.[5] The ISO operators will have a tool that allows 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, operators may subsequently issue a dispatch for the resource to provide energy through a typical exceptional dispatch, or simply release the resource from the exceptional dispatch with a state of charge target so that they can discharge economically. The ISO always seeks to avoid exceptional dispatch, and only uses these tools when reliability or grid stability is threatened.

Because so much use-limited storage is interconnecting at the same time that the ISO is capacity constrained in peak hours, the ISO believes it is prudent to develop these tools. They can help ISO operators manage energy across the storage fleet as well as overall generating capability for critical times of the day. The ISO also notes 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 ISO operators want 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 from the ISO 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

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[5] 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.

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.

The ISO received some stakeholder comments expressing concerns about the hypothetical calculations including intervals of hypothetical instances for charging when prices are below bids from resources. The ISO proposes to augment the counterfactual dispatch instructions so that they only occur when they are economic.

The ISO also received comments about the duration of the timeframe considered for the counterfactuals. The concern was raised about the potential window considered being too short. The ISO updates this proposal to include a window that extends through the end of the operating day of the exceptional dispatch, instead of a window equal to the duration of the storage resource. The ISO is not proposing a longer timeframe, as extending this into another operational day may be more burdensome in the settlements process, because of additional needs to include data across multiple days.

Comments also asked about compensation for lost opportunities to provide ancillary services resulting from ISO issued exceptional dispatch instructions. Today, when an exceptional dispatch instruction prevents any resource from being able to provide scheduled ancillary service awards, that resource is compensated for losing that opportunity. This same functionality will be applied to storage resources that may be dispatched to hold state of charge, and because of those dispatches lose the ability to provide ancillary services.

Compensation Calculation

For each exceptional dispatch issued to a storage resource to hold state of charge, the ISO 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.[6]

As noted above, the ISO 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 ISO 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 ISO 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

[6] This methodology will only include counterfactual schedules to discharge energy when storage resources have bids that are below actual locational marginal prices.

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 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 ISO 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 ISO workshop stakeholders suggested that the ISO introduce 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, the ISO proposes enhancements to ensure any co-located storage resource can avoid grid charging. These changes, discussed further below, will be optional functionality that may be elected by co-located storage resources and will prevent dispatched above scheduled output from on-site renewable resources. As with all policy, the ISO may review behaviors of resources using this functionality and may choose to adapt or remove these provisions in the future. The ISO will monitor for problematic situations that arise from this functionality, particularly those that threaten reliability.

Finally, the ISO notes that any resource interconnected to the grid is subject to exceptional dispatch from the ISO operations team. These exceptional dispatches may be anywhere within the registered operational limits of the resource. The ISO 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 the ISO will continue to offer the hybrid model, which can have a lower operational bound for a resource at 0 MW.

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 ISO tariff to follow dispatch instructions that result from market awards.[7]

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.

The ISO proposes new functionality for storage resources to help address some of the concerns voiced by stakeholders. The ISO proposes 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.[8] This functionality will be electable 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

[7] 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.

[8] 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.

renewable generation schedules, and 2) allowances that ensure that actual real-time charging does not exceed actual real-time co-located renewable generation.

At this time the ISO is not proposing accommodations to provide 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 ISO will implement 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

The ISO proposes that storage resources be allowed 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 ISO is not proposing 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, the ISO allows co-located resources 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 ISO relax this requirement for co-located pseudo-tie resources, 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 ISO could then use the aggregate capability constraint (ACC) 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 ISO proposes 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.

The ISO also proposes that these resources have access to all features proposed in Section 4.2.1 for enhanced co-located functionality.

4.3 Default Energy Bid

The ISO developed the default energy bid for storage resources in the energy storage and distributed energy resources (ESDER) initiative.[9] 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.

The ISO proposed 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 ISO proposed that these values also incorporate 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 ISO 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.

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

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

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

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

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. The ISO and market participants have now had time to observe actual performance of these formulas in the market.

Operational Experience

A specific case was flagged and brought to the attention of the ISO by a storage scheduling coordinator, where the day-ahead dispatch schedule did not meet the third principle outlined by the ISO 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 situations where storage resources are dispatched in a similar manner to the case outlined above.

In response to this operational feedback the ISO 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 ISO 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 ISO proposes that the default energy bids be updated, 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 ISO proposes updating 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 by the ISO.

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. CAISO staff believes that 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

The ISO requests additional feedback from stakeholders on the solutions included in this revised straw proposal. The ISO will host a stakeholder call on August 25, 2022 to review the second revised straw proposal, and encourages all stakeholders to submit comments on the issue paper. Comments are due on September 09, 2022.

7 Appendix

The ISO reviewed 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. The ISO then conducted a simple linear regression where regulation up and regulation down were descriptive variables for the associated change in state of charge. 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. At this point the ISO is proposing to include 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%