California ISO

Energy Storage and Distributed Energy Resources –

Storage Default Energy Bid

Draft Final Proposal

September 15, 2020

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1. Executive summary

The fourth phase of the ESDER initiative advances ISO policy on storage resources and demand response resources, including development of a default energy bid for storage resources. A final proposal for the entire policy was publically posted on August 21, 2020 and discussed at a public teleconference the following week.[1] That proposal also discussed the formal written feedback of ISO's Market Surveillance Committee (MSC), which was published at about the same time.[2] The MSC's feedback was welcomed by the ISO and included several suggestions to improve the default energy bid formulation included in the final and draft final ESDER 4 proposals. At the public meeting the ISO made a commitment to carefully consider this feedback, and agreed to publish two papers (a draft final and final) for this purpose. Additional policy development on the ESDER 4 default energy bid proposal will include an opportunity for stakeholder feedback and public teleconference meetings where these refinements will be discussed.

The default energy bid for storage resources proposed by the ISO is more complex than most other default energy bids that the ISO currently employs. These default energy bids include three components: 1) the cost to purchase energy, 2) the variable costs to charge and discharge energy, and 3) the opportunity cost to ensure that the limited amount of energy stored in the resource is not discharged prior to the hours with the highest price potential.

The market surveillance committee made several suggestions for how a theoretical framework for a storage resource could work in an idealized market framework. The ISO agrees that these idealized frameworks are important concepts to understand while framing any default energy bid, but these frameworks also need to remain workable for scheduling coordinators that operate within the actual existing energy and ancillary service market framework. The MSC made two key suggestions on how the current default energy bid framework could be improved. First, they recommended that the day-ahead formulation of the default energy bid need not include the opportunity cost component. Second, they recommended that the ISO need not impose market power mitigation on very small storage resources. The ISO believes that both suggestion are worthy of further consideration and thus, have included these ideas in this proposal.

This proposal includes an abbreviated description of the previously proposed default energy bid and a detailed description of the small changes being proposed to the default energy bid formulation. These details provide the background and context necessary for complete discussion of the changes considered in this proposal. The changes discussed within this paper are a direct result of the MSC's opinion, and the remainder of this paper recaptures work that was completed and proposed in the final proposal of the ESDER 4 initiative. In following

[1] ESDER 4 stakeholder website: https://stakeholdercenter.caiso.com/StakeholderInitiatives/Energy-storage-and-distributed-energy-resources.
[2] MSC Opinion on ESDER 4: http://www.caiso.com/Documents/MSC-OpinionsonEnergyStorageandDistributedResourcesPhase4-Sep8_2020.pdf.

stakeholder discussions and comment periods, the ISO will focus on the proposed changes rather than the holistic default energy bid for storage resources.

This proposal also includes a description that certain small storage resources, less than 5 MW, that are not net-suppliers will be exempt from market power mitigation.

2. Stakeholder engagement plan

Date	Milestone
August 21	ESDER 4 Final proposal published
August 27	Stakeholder call for final proposal
September 9	MSC final opinion on ESDER 4 published
September 15	Publish ESDER – Storage DEB draft final proposal
September 22	Stakeholder call to discuss draft final proposal
Sept 30/Oct 1	**Board of Governors meeting for ESDER 4 (without storage DEB)**
October 6	Comments due on draft final proposal for the storage DEB
Mid-October	Publish ESDER – Storage DEB final proposal
December 16/17	**Board of Governors meeting for ESDER Storage DEB**
Fall 2021	Implement full ESDER 4 policy (including Storage DEB)

3. Storage resource default energy bid

To ensure that wholesale prices are just and reasonable, the CAISO and other organized markets have mitigation measures to minimize the exercise of market power and non-competitive outcomes.[3] The CAISO employs a tool called local market power mitigation (LMPM), which replaces market bids with marginal cost based default energy bids (DEBs) when it detects potential market power. The local market power mitigation tool helps to ensure that market prices are economic in uncompetitive situations. With the implementation of this proposal storage resources will be subject to local market power mitigation. They will also have a new option for default energy bids specifically designed for storage resources.

Today, there are about 550 MWs of grid-connected storage resources installed on the system. Further, the ISO anticipates that about 1,500 MW will be installed by the conclusion of 2021 and that similar amounts of new storage will be connected to the grid in subsequent years. This number does not include behind the meter storage resources installed in households or businesses not participating in the wholesale markets. None of these storage resources are currently subject to market power mitigation, and the CAISO believes that it is important to develop mitigation measures to manage market power given the rapidly growing number and influence of energy storage resources.

Storage resources can be versatile and have various opportunities to earn potential revenues in the CAISO day-ahead and real-time market. Some of these opportunities include arbitraging energy market prices and potentially moving large amounts of energy from low priced periods to high priced periods in the day to help with renewable integration. These resources are also generally flexible and have fast ramping capabilities to offer ancillary services to the market. Balancing potential revenue streams, in addition to potential fixed payments through the resource adequacy framework, can be challenging for certain storage resource types given their cost structure. Understanding the economics of the underlying resources are important when considering the design of a default energy bid.

Default energy bid formulation

To apply local market power mitigation, the CAISO determined three cost components to include in the default energy bid for storage resources. Each of these specific components are described in detail below. These components include:

1. Energy Costs
2. Variable Operations Costs, including Cycling and Cell Degradation Costs
3. Opportunity Costs

[3] For example, a generator may have the ability to exercise market power when supplying energy within a transmission-constrained area if it is a pivotal supplier.

The ISO's proposed derivation for the default energy bid calculation is outlined in Equation 1 and Equation 2. The formula for the default energy bid in the day-ahead market simply considers the expected cost to buy energy and the expected cost for the variable costs associated with the resource operation, including cycling. The formulation in the real-time market has two components, the first is the same as the day-ahead formulation, while the second component captures expected opportunity costs for the resource to discharge energy. Each of the specific components are described in greater detail below.

In the final proposal for the energy storage and ESDER 4 initiative, the formulations in both the day-ahead and real-time markets were identical and matched the formula outlined in Equation 2. The ISO proposes to change the formulation for the default energy bid in the day-ahead market, as expressed, so that this formulation does not include the opportunity cost. The MSC noted that the previously proposed default energy bid need not include the opportunity cost in the day-ahead market, as this market already implicitly assumes opportunity costs. This stems directly from the way that the optimization of the day-ahead market works.

The ISO's day-ahead market software solves a constrained optimization problem for energy and ancillary service procurement from the fleet across a 24 hour time horizon. While solving this problem, the market software uses a minimization algorithm with aggregate system cost as the objective function. This means that the day-ahead market will schedule storage resources to charge during the lowest priced hours and to discharge during the highest priced hours, in order to minimize those costs.

Equation 1: Day-ahead storage default energy bid

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

Equation 2: Real-time storage default energy bid

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

Where:

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

The ISO proposes to mitigate the entire bid curve for a storage resource. Because a +/- 200 MW storage resource could back generation down from 200 MW to 100 MW or charge at -200 MW instead of -100 MW in an effort to increase prices in local areas, the CAISO proposes that the default energy bid be applied to the entire output of a storage resource, not just the discharging portion of the resource bid. Mitigation will be applied to the full range of output, including the entire charging and discharging range for storage resources.

The formulation for the default energy bid outlined above includes a variable 'ρ' to account for the variable costs that the resource incurs while producing energy. CAISO believes that for most storage resources, the bulk of these costs will include cell degradation costs, or the wear and tear the cells of the battery experience as the resources charges and discharges. However, other costs related to the storage resource charging or discharging may be included in this

component. This value will be assumed to be zero for the entire charging portion of the bid, when computing the default energy bid curve for the entire operating range of the resource. Therefore, for any market interval the default energy bid will always be a constant value for the entire charging portion of the resource's operating range. These assumptions will always ensure that the default energy bid is monotonically increasing with output, consistent with the current framework for our market solution.

Energy Costs

Storage resources are different from traditional resources on the CAISO system. For example, gas fired generators have an available fuel supply that is converted to energy, and the heat rate, which describes the efficiency of the resource, informs the resource's marginal cost. Storage resources "buy" energy from the grid and sell that energy back to the grid by discharging at a later point in time. Nevertheless, when a storage resource discharges, the impacts to the grid are identical to a traditional generator running.

It is critical that a value approximating the costs of energy purchased through the wholesale market be included in the default energy bid for storage resources. For example, if a storage resource buys energy at the lowest prices of the day at $10/MWh, it will have significantly lower costs than if it was buying energy at $50/MWh. Energy purchased at higher costs implies that sales need to be made at higher prices to maintain the same price spread.

In this proposal, the CAISO proposes an updated methodology to what was included in the revised straw proposal. This updated proposal includes using the actual results from the day-ahead market process to compute expected costs for a resource to purchase energy. Today, the day-ahead market process initially performs a market power mitigation (MPM) run, with unmitigated bids, then it performs a test to determine specific resource/hours that fail a dynamic competitive test assessment (DCPA), finally it performs the integrated forward market (IFM) run that includes mitigated bids for all resource/hours that fail dynamic competitive test assessment. The premise of this default energy bid is that storage resources will include energy prices from the market power mitigation run, which will inform the energy cost component of any default energy bid that may be applied in the successive integrated forward market run.[4]

Expected costs will be calculated for resources, as if they were performing one cycle per day, and charging during the least expensive continuous block of time during the day. The CAISO anticipates that most resources will have a 4-hours of storage duration, which implies that the amount of energy necessary to charge the resource will be just longer than 4-hours to include round trip efficiencies. This value should represent a conservative estimate of cost (on a $/MWh basis, for the duration of the discharge period) to charge a specific resource, particularly if the resource is performing less than one cycle per day. If a sub-set of storage resources routinely perform more than one cycle per day and require adjustment to the default energy bid, this update may be accommodated by a consultation with the CAISO.

[4] Additional information about the day-ahead market process is available in the market operations business practice manual here: https://bpmcm.caiso.com/Pages/BPMDetails.aspx?BPM=Market%20Operations.

This process will hold true for all storage resources in the day-ahead market. The real-time market will perform differently. Here actual locational marginal pricing (LMP) results from the integrated forward market run for a specific day will be used to determine energy costs for storage resource default energy bids in the real-time market.

Variable Costs (Including Cycling Costs)

The revised straw proposal included a complex modelling approach for cycling costs for storage resources. The second revised straw proposal outlined a significantly simplified approach to model cycling cost in a more general way, which is maintained in this final proposal. This proposal aligns with expectations for operating costs anticipated by battery developers with resources coming online in response to requests for offers (RFOs) to meet energy capacity needs on the California system in the next few years and in response to CPUC procurement.

From the workshop hosted in December, the CAISO learned that the actual operating costs for many of the resources that will or could potentially be built and interconnected to the system are designed specifically to optimally accomplish a particular operating behavior on a daily basis. This behavior may be configurable, however, it generally must be specified prior to the battery being developed. Many of the batteries are being built to optimally perform one cycle per day, which includes charging the battery once for four hours and discharging the battery for four hours later in the day.[5] Procurement of resources with these capabilities is a direct result of the CPUC RA counting rules that state that resources are only able to count for resource adequacy for the amount of energy they are able to provide consistently during a minimum four hour period.

Because most storage resources are designed to these minimum specifications, they generally experience a relatively consistent cost while operating within their design criteria, say 1 cycle per day, and significantly higher costs when operating at higher levels, say while operating beyond 1 cycle per day. Although these costs are impacted by the factors described in earlier versions of this proposal, which may include cycle depth, ambient temperature, current rate, and average state-of-charge, the impact may only be appreciable when the resource is operating within the bounds of where it was designed to operate. Specifically, the impact of each of these factors may be relatively small compared to the cost to operate a typical storage resource that may be built on the CAISO system beyond one cycle per day.

Many of these factors and how they impact cycling costs were explored in great detail in earlier versions of the paper. Although this work was useful, the approaches to model the specifics of these costs can be very complicated and may exceed the CAISO's current computational capabilities.

In this proposal, the ISO updates the proposed calculation for variable costs, including cycling costs, to correspond to a value that represents operating a storage resource beyond the specified range of performance that the resource was designed for. This value will be submitted

[5] Some resources may be designed with the purpose of delivering just over 1 cycle per day to allow for some additional flexibility. These resources may be designed to deliver 1.1 or 1.25 cycles per day.

by market participants to the CAISO and vetted. For example, this might be the cost to operate a resource beyond one cycle for most of the new storage resources that may likely be built on the system over the next few years.

There will be significantly more storage resources developed and integrated onto the CAISO system in the next few years. In discussions with battery manufacturers and experts in developing batteries, the CAISO learned that many anticipate costs related to cycling and operating, to generally be less than $30/MWh for most new lithium-ion based resources. The ISO notes that several developers have declared large differences between marginal cycling costs for different storage projects with different chemistries, even within the lithium-ion technology. This number may be applicable while the battery operates within its design specification, i.e. the first cycle per day. Conversations with a variety of battery manufacturers have been informative as to the costs of storage resources operating beyond their design specification, which may be between 2 to 3 times larger than those costs when operating within them.

Although CAISO plans to allow the higher of these values to be included in the default energy bid for the storage resource, all values will need to be validated by CAISO staff before they may be used in default energy bids. Validation, in the form of estimates from storage manufactures may suffice for CAISO review. In the future, as more storage resources are connected to the grid, CAISO may develop guidelines for acceptable values, similar to guidelines for other values currently reviewed by the CAISO.[6] CAISO envisions that these values will be submitted once and will likely be set for longer periods of time, but will always have the potential of being updated when needed. CAISO does not expect that the costs associated with cycling cost will change much on a day-to-day basis. CAISO also acknowledges that these costs capture operations and maintenance costs for storage resources, which may adjust seasonally and may be changed to account for costs when resources are operating during hot weather in the summer or cooler weather during the remainder of the year.

Opportunity Costs

The market power mitigation tool can replace submitted bids with CAISO calculated default energy bids in the day-ahead and real-time market process. In the event that these bids are lower than the true cost to operate a resource, the tool may force an inefficient dispatch. Storage resources can only generate until stored energy is depleted before needing to be recharged. To avoid being discharged before the optimal time, a resource with limited availability should have an opportunity cost included in its default energy bid. These opportunity costs include the value to the resource owner from not running during a particular interval and saving stored energy until a later time when prices are higher.

If the resource is fully charged and has a default energy bid of $60/MWh, and the current market price is $75/MWh, it would be profitable for the resource to discharge and receive this revenue.

[6] These may include other values collected and verified by the ISO, such as major maintenance costs for specific resources.

However, this may be sub-optimal as prices in the successive four hours rise to $100/MWh. In this example, the resource would optimally wait to discharge stored energy, until the later hours when prices are higher.

This example is highly simplified, but illustrates the need for inclusion of an opportunity cost component in the default energy bid for storage resources in the real-time market. In this simple example, an opportunity cost increasing the total default energy bid to $100/MWh is appropriate for this resource. The inclusion of opportunity costs in the default energy bid is further complicated when a resource is capable of buying and selling energy for multiple hours, and buys or sells energy in the real-time market and experiences economic losses.

CAISO proposes including the highest price, corresponding to the storage duration of the resource in the default energy bids for storage resources. For example, if a specific storage resource is capable of storing 4 hours of energy, the opportunity cost included in the real-time default energy bid will be equal to estimated prices in the 4th highest hours of the day form the day-ahead market.[7]

Alternative Default Energy Bids

Although CAISO is striving to develop a functional default energy bid that will reasonably approximate costs for most storage resources, it may not be feasible to develop a methodology that will work for all storage resources and technology types. Therefore, resources always have the ability to apply for a negotiated default energy bid if the proposed methodology outlined is insufficient. Although the CAISO started a stakeholder initiative to update allowable operations and maintenance values because there are so few of these resources operating today, there is little reliable data for what these values will be for participating storage resources.[8] In the future, the ISO may update the default values allowable for all storage resources. These values will apply to variable cost default energy bids and may also be sufficient for some storage resources. Further, the operations and maintenance adders can be negotiated with the CAISO at a resource specific level, at a justifiable cost.

[7] For example, if prices are $45, $35, $32, $30, $27, $31, $40; the fourth highest hour would be $32.
[8] Variable operations and maintenance cost review initiative: http://www.caiso.com/StakeholderProcesses/Variable-operations-maintenance-cost-review.

4. Exemptions from mitigation for small resources

The market surveillance committee opinion also noted that it may not make sense to expose all storage resources to market power mitigation. They specifically noted that small resources may not have the ability to exercise market power, and that an inaccurate default energy bid could potentially be harmful to those resources. In light of this recommendation, the ISO proposes that storage resources less than 5 MW and whose ultimate parent company is not a net-supplier in the ISO market will not be subject to market power mitigation. On the other hand, resources that have a parent company that is a net-supplier in the ISO market will still be subject to market power mitigation, regardless of size.

5. Next steps

The ISO will discuss this draft final proposal for the storage default energy bid during a stakeholder web conference on September 22, 2020. Stakeholders are asked to submit written comments by October 6, 2020 through the ISO's new commenting tool. Stakeholders can begin using the tool after completing a simple one-time registration. The ISO conducted training on the use of the tool and how to register. A recording of that training is available at http://www.caiso.com/participate/Pages/LearningCenter/default.aspx.