# Storage Design and Modeling

*Outage Management, Uplift, & DEB*
*Distribution-Level & Paired Resources Working Group*

Stakeholder Meeting

February 20, 2025
9 am – 4 pm

# Reminders

- This call is being recorded for informational and convenience purposes only. Any related transcriptions should not be reprinted without ISO's permission.

- The meeting is structured to stimulate dialogue and engage different perspectives.

- Please keep comments professional and respectful.

- Please try to be brief and refrain from repeating what has already been said so that we can manage this time efficiently.

# Instructions for raising your hand to ask a question

- Open the Participant and Chat panels from the bottom right.

- If you are connected to audio through your computer or used the “call me” option, select the raise hand icon located on the bottom of your screen.
  - **Note**: *3 only works if you dialed into the meeting.

- Please remember to state your name and affiliation before making your comment.

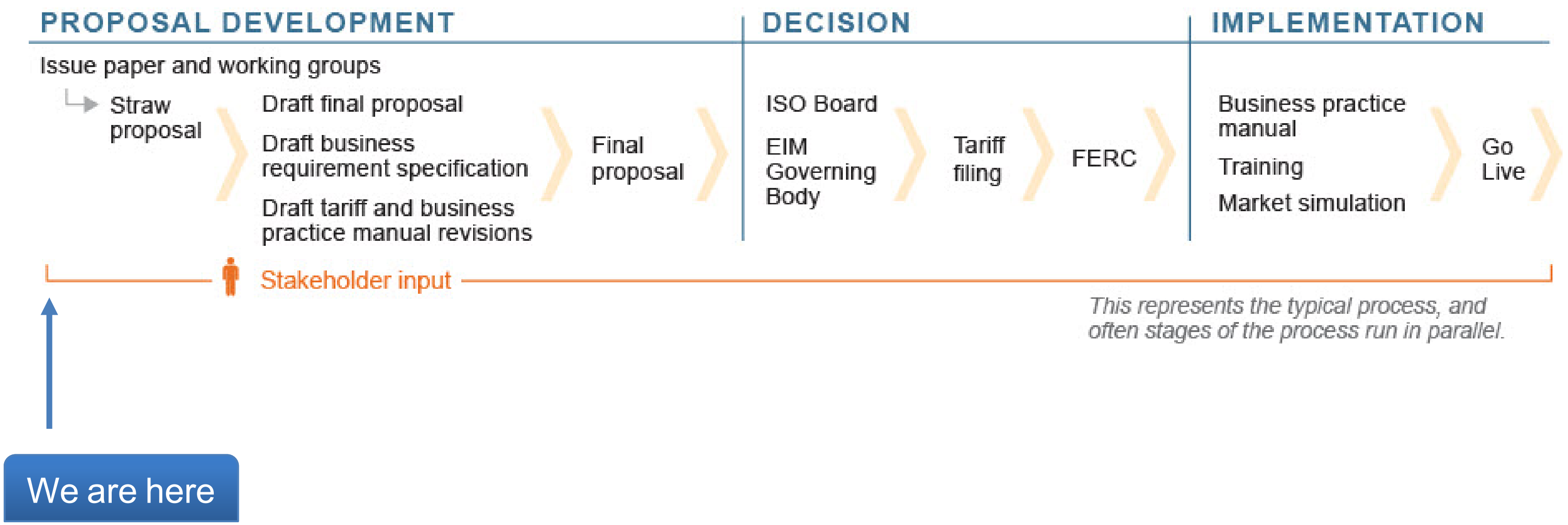
- You may also send your question via chat to either **Brenda Marquez** or to all panelists.

- If you need technical assistance during the meeting, please send a chat to the event producer.

# Agenda

| Time | Topic | Presenter |
|---|---|---|
| 9:00 – 9:05 | Welcome and today's agenda | Brenda Marquez |
| 9:05 – 9:20 | Overview of Topic Groups and Timeline | Sergio Dueñas Melendez |
| 9:20 – 10:10 | Overview of Planned Storage Constraints | Sergio Dueñas Melendez |
| 10:10 – 10:55 | Overview of SOC Definition & Calculation | Sergio Dueñas Melendez |
| 10:55 – 11:00 | Break | |
| 11:00 – 11:45 | Overview of the Use of Implied Bid Spreads | Dinesh Das Gupta |
| 11:45 – 12:00 | Open discussion | |
| 12:00 – 1:00 | Lunch Break | |
| 1:00 – 1:45 | Overview of Distribution-Level Storage Charging Constraints | Dinesh Das Gupta |
| 1:45 – 2:30 | Overview of DEBs for Hybrid Resources | Dinesh Das Gupta |
| 2:30 – 2:35 | Break | |
| 2:35 – 3:35 | Stakeholder presentations | Various stakeholders |
| 3:35 – 3:55 | Open discussion | |
| 3:55 – 4:00 | Next Steps | Brenda Marquez |

# CAISO Policy Initiative Stakeholder Process



# Overview of Topic Groups and Timeline

# Revised overview of scope and topic groups

## Outage Management, Uplift, and DEB Topics

- Outage reporting and nonlinearity issues
- SOC definition and calculation
- Storage uplift redesign
- Storage DEB modifications

## SOC Management Topics

- SOC management for capacity awards
- System SOC mechanism
- Biddable SOC concepts

## Distribution-level & Paired Resources Topics

- Co-located resource settlement enhancements
- Distribution-level storage charging constraints
- DEB for hybrid resources
- Additional hybrid topics

# Revised timeline

| Date | Milestone |
|---|---|
| 02/20/25 | Stakeholder meeting on Topic Group 1 and Working Group on Topic Group 3 |
| 03/05/25 | Comments due |
| *03/24/25* | Topic Group 1 Straw Proposal Posting ***(Outage Reporting & Nonlinearity Issues, SOC Definition & Calculation)*** |
| *03/31/25* | Stakeholder meeting on Topic Group 1 and Working Group on Topic Group 2 |
| *04/23/25* | Stakeholder meeting on Topic Group 1 and Working Group on Topic Group 3 |
| 05/07/25 | Comments due |

**All dates are tentative until confirmed through a notice in the ISO's Daily Briefing.*

# Revised timeline

| Date | Milestone |
|---|---|
| 05/21/25 | Topic Group 1 Revised Straw Proposal Posting & Topic Groups 2 and 3 Issue Paper Posting |
| 05/28/25 | Stakeholder meeting on Topic Group 1 and Working Group on Topic Group 2 |
| 06/25/25 | Stakeholder meeting on Topic Group 1 and Working Group on Topic Group 3 |
| 07/16/25 | Comments due |

**All dates are tentative until confirmed through a notice in the ISO's Daily Briefing.*

# Discussion

# Overview of Planned Storage Constraints

# Background – Energy Storage Enhancements and Day-Ahead Market Enhancements Initiatives

- Within the Energy Storage Enhancements (ESE) initiative, the ISO considered changes to how the state of charge was modeled in both the day-ahead and real-time markets for regulation
- The proposal was an attempt to better reconcile the modeled state of charge with the reality of how state of charge changes for storage resources that receive energy and regulation awards through the use of attenuation factors
- This solution was originally intended to be implemented with the spring 2023 software release; however, when changes to the state of charge equation were made in the testing environment negative prices for regulation down were detected, an outcome that is not supported by rules specified in the tariff

# Background – Energy Storage Enhancements and Day-Ahead Market Enhancements Initiatives

- The ISO delayed implementation of this feature, published a workshop paper, and held a stakeholder meeting to discuss this result with market participants while collectively workshopping next steps
- This process resulted on a modified proposal, the two constraint solution, which employs two constraints to manage SOC in a manner that decouples the dispatch of energy and regulation awards
- While the ${SOC_{i,t}}^{AT}$ constraint will continue to ensure that regulation awards are supported in conjunction with energy awards through the day-ahead market optimization, the need to also satisfy the ${SOC_{i,t}}^{EN}$ constraint will ensure that energy discharge awards are supported absent the potential energy created by regulation awards

# Background – Energy Storage Enhancements and Day-Ahead Market Enhancements Initiatives

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- While the ${SOC_{i,t}}^{AT}$ constraint will continue to ensure that regulation awards are supported in conjunction with energy awards through the day-ahead market optimization, the need to also satisfy the ${SOC_{i,t}}^{EN}$ constraint will ensure that energy discharge awards are supported absent the potential energy created by regulation awards

$$SOC_{i,t}^{AT} = SOC_{i,t-1}^{AT} - (EN_{i,t}^{(+)} + \eta_i EN_{i,t}^{(-)} + ATRU_t RU_{i,t} - ATRD_t \eta_i RD_{i,t}) \frac{\Delta T}{T_{60}}$$

$$\underline{SOC_{i,t}} \leq SOC_{i,t}^{AT} \leq \overline{SOC_{i,t}}$$

$$SOC_{i,t}^{EN} = SOC_{i,t-1}^{EN} - (EN_{i,t}^{(+)} + \eta_i EN_{i,t}^{(-)}) \frac{\Delta T}{T_{60}}$$

$$\underline{SOC_{i,t}} \leq SOC_{i,t}^{EN} \leq \overline{SOC_{i,t}}$$

# Background – Energy Storage Enhancements and Day-Ahead Market Enhancements Initiatives

- While these solutions were being discussed in the ESE initiative, the Day-Ahead Market Enhancements (DAME) initiative was considering the development of envelope equations
  - Envelope equations seek to account for the impact of imbalance reserves on state-of-charge (SOC) by estimating a reasonable upper and lower bound for each hour
  - The imbalance reserves would impact the upper and lower limits, as would energy awards, but would not impact the state of charge equation for storage resources
  - Once the hypothetical SOC reaches the lower or upper limit of the resource, then the market will schedule the resource to charge or discharge prior to scheduling any additional imbalance reserves that could potentially cause the hypothetical value to exceed the limit

# Background – Energy Storage Enhancements and Day-Ahead Market Enhancements Initiatives

- In both initiatives, the ISO suggested, as an alternative, to expand the envelope equations to include regulation up and regulation down
  - As a result of the DAME initiative, the following changes and additional constraints were approved for storage resources:
    - The ancillary service state of charge constraint will be extended to include imbalance reserves
    - The day-ahead market will generate an upper and lower bound, or envelope, for state of charge
      - The envelope could constrain operation for storage resources and the initial upper and lower bounds will be set to the initial day-ahead state of charge
      - The initial multiplier attached to the imbalance reserves in the envelope equation will continue to be discussed, but will be set initially to 0.85

# Planned Storage Constraints – Updates to the Ancillary Service State of Charge Constraint

- Today the day-ahead market ensures that ancillary services awarded to storage resources will have sufficient state of charge to deliver those awards via the ancillary service state of charge constraint, shown below

$$SOC_{i,t-1} - RU_{i,t} - SR_{i,t} - NR_{i,t} \geq \underline{SOC}_{i,t}$$
$$SOC_{i,t-1} + \eta_i \, RD_{i,t} \leq \overline{SOC}_{i,t}$$

*Where:*

| | |
|---|---|
| $RU_{i,t}$ | *Regulation up award for resource i at time t* |
| $SR_{i,t}$ | *Spinning reserve award for resource i at time t* |
| $NR_{i,t}$ | *Non-spinning reserve award for resource i at time t* |
| $\underline{SOC}_{i,t}$ | *Minimum state of charge for resource i at time t* |
| $RD_{i,t}$ | *Regulation down award for resource i at time t* |
| $\overline{SOC}_{i,t}$ | *Maximum state of charge for resource i at time t* |

- These equations state that a storage resource must have sufficient state of charge to ensure that they provide awarded capacity for ancillary services for at least one hour

# Planned Storage Constraints – Updates to the Ancillary Service State of Charge Constraint

- The current constraint ensures that storage resources have sufficient state of charge to provide all four ancillary services including regulation up, regulation down, spinning reserve and non-spinning reserve
- With DAME, the constraint will be expanded to require sufficient state of charge to provide imbalance reserve up and imbalance reserve down in addition to the other ancillary services

$$SOC_{i,t-1} - RU_{i,t} - SR_{i,t} - NR_{i,t} - IRU_{i,t} \geq \underline{SOC}_{i,t}$$
$$SOC_{i,t-1} + \eta_i \left(RD_{i,t} + IRD_{i,t}\right) \leq \overline{SOC}_{i,t}$$

*Where:*

$IRU_{i,t}$ *Imbalance reserve up award for resource i at time t*

$IRD_{i,t}$ *Imbalance reserve down award for resource i at time t*

# Planned Storage Constraints – Updates to the Ancillary Service State of Charge Constraint

- Furthermore, these constraints would be expanded into the residual unit commitment process to require sufficient state of charge to provide reliability capacity up and reliability capacity down in addition to the other terms included in the constraint enforced in the day-ahead market

$$SOC_{i,t} - RU_{i,t} - SR_{i,t} - NR_{i,t} - IRU_{i,t} - RCU_{i,t} \geq \underline{SOC}_{i,t}$$

$$SOC_{i,t} + \eta_i \left(RD_{i,t} + IRD_{i,t} + RCD_{i,t}\right) \leq \overline{SOC}_{i,t}$$

*Where:*

| | |
|---|---|
| $RCU_{i,t}$ | *Reliability capacity up award for resource i at time t* |
| $RCD_{i,t}$ | *Reliability capacity down award for resource i at time t* |

# Planned Storage Constraints – Envelope Constraints

- Envelope constraints in the day-ahead market will ensure that storage resources have sufficient state of charge to provide imbalance reserves
  - These equations include an estimate of a hypothetical upper bound for storage resources and a hypothetical lower bound for storage resources, and tracks these values over time
  - These values create an envelope, or boundary, for state of charge
  - Once the hypothetical state of charge reaches the lower/upper limit of the resource, then the market will schedule the resource to charge prior to scheduling any additional imbalance reserves that could potentially cause the hypothetical value to exceed the limit

# Planned Storage Constraints – Envelope Constraints

- Envelope constraints in the day-ahead market will ensure that storage resources have sufficient state of charge to provide imbalance reserves

$$SOC_{i,t}^{(u)} = SOC_{i,t-1}^{(u)} - EN_{i,t}^{(+)} - \eta_i \, EN_{i,t}^{(-)} + \eta_i \, AIRD_t \, IRD_{i,t} \leq \overline{SOC}_{i,t}$$

$$SOC_{i,t}^{(l)} = SOC_{i,t-1}^{(l)} - EN_{i,t}^{(+)} - \eta_i \, EN_{i,t}^{(-)} - AIRU_t \, IRU_{i,t} \geq \underline{SOC}_{i,t}$$

*Where:*

| | |
|---|---|
| $SOC_{i,t}^{(u)}$ | *Upper envelope for state of charge for resource i at time t* |
| $AIRD_t$ | *Adjustable multiplier applied to downward imbalance reserves to calculate the upper envelope for state of charge at time t* |
| $SOC_{i,t}^{(l)}$ | *Lower envelope for state of charge for resource i at time t* |
| $AIRU_t$ | *Adjustable multiplier applied to upward imbalance reserves to calculate the lower envelope for state of charge at time t* |

# Planned Storage Constraints – Envelope Constraints

- These constraints will also be included in the residual unit commitment market run, considering reliability capacity

$$SOC_{i,t}^{(u)} = SOC_{i,t-1}^{(u)} - EN_{i,t}^{(+)} - \eta_i \, EN_{i,t}^{(-)} + \eta_i \, AIRD_t \, IRD_{i,t} + \eta_i \, ARCD_t \, RCD_{i,t} \leq \overline{SOC}_{i,t}$$

$$SOC_{i,t}^{(l)} = SOC_{i,t-1}^{(l)} - EN_{i,t}^{(+)} - \eta_i \, EN_{i,t}^{(-)} - AIRU_t \, IRU_{i,t} - ARCU_t \, RCU_{i,t} \geq \underline{SOC}_{i,t}$$

*Where:*

$ARCD_t$ *Adjustable multiplier applied to downward reliability capacity at time t*

$ARCU_t$ *Adjustable multiplier applied to upward reliability capacity at time t*

# Planned Storage Constraints – Envelope Constraints

- Since the products introduced by the DAME initiative (reliability capacity [RC] and imbalance reserves [IR]) are new, there is no actual operational experience for how awards for these products typically impact storage resources or how storage may be relied on during stressed system conditions to provide these products
- In this context, market simulation will use initial multiplier values of 85%
- Market simulation will perform sensitivity analysis for this tunable parameter holding all the other configurable parameters constant
- After analysis, optimized values will be deployed in parallel operations and market participants will get have an opportunity to evaluate and provide suggestions for any changes
- The final optimized configurations will be used for parallel operations and go-live

# Discussion

# Overview of SOC Definition & Calculation

# Background – SOC Estimates and SOC Definition

- SOC is not an observable value, but rather a calculation or estimate that varies as a function of voltage
- There are many ways to estimate SOC and different assets may employ different methods to calculate the value that is conveyed to the ISO through telemetry
  - Regardless of the method used, the estimates should reflect a good faith judgement of the unit's capability
- Today, the definition of SOC within the ISO's Tariff can be found in Appendix A, which reads:
  - "State of Charge: The Energy available to CAISO Markets from a Non-Generator Resource or storage device."
    - The current definition does not further define the term "available", which may lead to operational ambiguity regarding whether all stored energy is accessible to the market

# Inaccessible Energy – Voltage Imbalance

- Voltage imbalance occurs when the voltages across the cells (or strings of cells) of a battery resource are no longer balanced
- When the voltage of the cells are no longer balanced, the lowest voltage cell will limit the discharge capability of the battery, and limit the available energy the resource is able to provide to the CAISO system
  - Voltage imbalance also affects the charging capability of the battery (the cell with the highest voltage limits the charging capability)
- The energy stored in the other cells in the battery will be represented in total the telemetered SOC for the resource, but this energy is inaccessible due to cell imbalance
- Imbalances can occur due to manufacturing impurity, cycling through the assets operational lifetime, and augmentation choices

# Inaccessible Energy – Low SOC

- The ISO has identified instances where storage resources submit outages which significantly derate their Pmax in periods where the resources have a low but non-zero state of charge and have received a dispatch operating target (DOT) greater than 0 MW

- Generally, the ISO has identified two drivers for energy inaccessibility at low SOC:
  – Non-linearity in rates of charging and discharging at low SOC (foldback)
  – Significant opportunity costs associated with fully discharging

# Inaccessible Energy – Low SOC

- Significant opportunity costs associated with fully discharging
  - Resources that face such constraints may have the capacity to be fully discharged, but doing so may impose significant costs on the resource due to the opportunity costs associated with the resulting outage and the costs of bringing the resource back online
  - Lithium based batteries may suffer irreversible damage not only when discharging near/at Pmax as they approach the SOC min, but also vice versa
  - These factors may lead resources to be effectively operated as if their minimum stored energy limit is greater than zero even though their master file characteristics indicate that the resource's minimum stored energy limit is equal to zero

# Inaccessible Energy – Low SOC

- Significant opportunity costs associated with fully discharging
  - The implicit higher minimum stored energy limit typically appears to be enforced through the use of outages that derate the storage resource's Pmax to prevent discharge instructions that would deplete the resource's SOC beyond that level
  - The minimum SOC constraints that some resources face are known by the resource operators and could be represented to the market through various means including the minimum stored energy limit master file characteristic and outages that up-rate the minimum state of charge parameter
  - If such constraints are not accurately communicated, infeasible energy schedules may be awarded in the real-time market because the actual lower limit of a resource's SOC may exceed the stored energy required to satisfy the energy award

# Potential Changes to SOC Estimates and SOC Definition

- Further discussion and consideration of best practices in the estimation of SOC for telemetry

- Further clarification that the SOC estimate conveyed to the ISO via telemetry should account for the energy that is accessible to the market

- Further discussion on whether outages or modification to the MF parameters are the best way to accurately represent stored energy parameters

# Discussion

# Overview of the Use of Implied Bid Spreads

## Stakeholders requested clarity on the use of implied bid spreads within the markets' optimization

- Use of the implied bid spread is a consequence of the markets' optimization to utilize stored energy in the most valuable intervals so as to find a cost-minimizing solution

- The following slides seek to illustrate how the implied bid spread may be used in the context of the real-time market (RTM) via the multi-interval optimization (MIO) process

- The ISO will continue to work to document examples of the use of the implied bid spread for a future knowledge article on the matter

# Background – Multi-interval Optimization (MIO)

- MIO allows the RTM to position resources to handle changes in the future horizon
- For storage resources, the MIO charges or discharges a storage asset due to projected conditions in the future, linking solutions over intervals to ensure the asset's limited SOC is utilized when it is most valuable
- MIO may charge or discharge a storage resource to prepare for a future energy award, to avoid hitting the resource's maximum SOC constraint, to adjust for future interval economic conditions stemming from supply, demand or net interchange forecasts, or to rebalance an exceptional dispatch
- As a result, MIO may dispatch a resource uneconomically in the binding interval due to actions taken by the SC, due to factors that inform the ISO's market optimization, or due to the optimization process itself

# Rationale – Implied Bid Spread and the MIO

- Assume a battery has initial SOC 0
- Charging Bid is $CB and Discharging bid is $DB
- Interval 1 LMP is $LMP1 and interval 2 LMP is $LMP2
- The optimization will charge the storage asset in the 1st interval and discharge it at the 2nd interval only if:

  ($CB – $LMP1) + ($LMP2 – $DB) >= 0; or,

  ($DB - $CB) <= ($LMP2 - $LMP1)
- As long as the bid spread [($DB - $CB)] is less than the LMP difference, the value of energy in the latter interval is higher

# Example – Implied Bid Spread and the MIO

- Consider a 5 MW, 4-hr storage resource with:
  - The resource is energy-limited, with SOC at 25% (5 MWh)
  - Bid to discharge = $100
  - Bid to charge = $50
  - LMP in the binding interval = $120
- The MIO look-ahead indicates that prices will remain at $120 for the binding interval and the next five advisory intervals, but then they will be at $750 for the remaining seven advisory intervals
- In this context, the MIO determines that uneconomic dispatch to charge to capture future prices would be optimal

# Without multi-interval optimization (MIO), resources may forgo future profits to dispatch economically in the binding interval

Implied bid spread: 100 – 50 = $50

| SOC (MWh) | Interval | Discharge Bid | Charge Bid | LMP | Dispatch (MWh) | Revenue | Profit |
|---|---|---|---|---|---|---|---|
| 5.0 | 0 | $ 100.0 | $ 50.0 | $ 120.0 | 0.4 | $ 50.0 | $ 8.3 |
| 4.6 | 1 | $ 100.0 | $ 50.0 | $ 120.0 | 0.4 | $ 50.0 | $ 8.3 |
| 4.2 | 2 | $ 100.0 | $ 50.0 | $ 120.0 | 0.4 | $ 50.0 | $ 8.3 |
| 3.8 | 3 | $ 100.0 | $ 50.0 | $ 120.0 | 0.4 | $ 50.0 | $ 8.3 |
| 3.3 | 4 | $ 100.0 | $ 50.0 | $ 120.0 | 0.4 | $ 50.0 | $ 8.3 |
| 2.9 | 5 | $ 100.0 | $ 50.0 | $ 120.0 | 0.4 | $ 50.0 | $ 8.3 |
| 2.5 | 6 | $ 100.0 | $ 50.0 | $ 750.0 | 0.4 | $ 312.5 | $ 270.8 |
| 2.1 | 7 | $ 100.0 | $ 50.0 | $ 750.0 | 0.4 | $ 312.5 | $ 270.8 |
| 1.7 | 8 | $ 100.0 | $ 50.0 | $ 750.0 | 0.4 | $ 312.5 | $ 270.8 |
| 1.3 | 9 | $ 100.0 | $ 50.0 | $ 750.0 | 0.4 | $ 312.5 | $ 270.8 |
| 0.8 | 10 | $ 100.0 | $ 50.0 | $ 750.0 | 0.4 | $ 312.5 | $ 270.8 |
| 0.4 | 11 | $ 100.0 | $ 50.0 | $ 750.0 | 0.4 | $ 312.5 | $ 270.8 |
| 0.0 | 12 | $ 100.0 | $ 50.0 | $ 750.0 | 0.0 | $ - | $ - |
| **Total** | | | | | **5.0** | **$ 2,175.0** | **$ 1,675.0** |

LMP spread between binding and 12th advisory interval: $750 – $120 = $630

# MIO optimizes use of stored energy by comparing LMP spreads and implied cost spread

MIO dispatches resource uneconomically in the binding interval to ensure dispatch in 12th advisory interval, increasing total profit

| SOC (MWh) | Interval | Discharge Bid | Charge Bid | LMP | Dispatch (MWh) | Revenue | Profit |
|---|---|---|---|---|---|---|---|
| 5.0 | 0 | $ 100.0 | $ 50.0 | $ 120.0 | -0.4 | $ (50.0) | $ (8.3) |
| 5.4 | 1 | $ 100.0 | $ 50.0 | $ 120.0 | 0.4 | $ 50.0 | $ 8.3 |
| 5.0 | 2 | $ 100.0 | $ 50.0 | $ 120.0 | 0.4 | $ 50.0 | $ 8.3 |
| 4.6 | 3 | $ 100.0 | $ 50.0 | $ 120.0 | 0.4 | $ 50.0 | $ 8.3 |
| 4.2 | 4 | $ 100.0 | $ 50.0 | $ 120.0 | 0.4 | $ 50.0 | $ 8.3 |
| 3.8 | 5 | $ 100.0 | $ 50.0 | $ 120.0 | 0.4 | $ 50.0 | $ 8.3 |
| 3.3 | 6 | $ 100.0 | $ 50.0 | $ 750.0 | 0.4 | $ 312.5 | $ 270.8 |
| 2.9 | 7 | $ 100.0 | $ 50.0 | $ 750.0 | 0.4 | $ 312.5 | $ 270.8 |
| 2.5 | 8 | $ 100.0 | $ 50.0 | $ 750.0 | 0.4 | $ 312.5 | $ 270.8 |
| 2.1 | 9 | $ 100.0 | $ 50.0 | $ 750.0 | 0.4 | $ 312.5 | $ 270.8 |
| 1.7 | 10 | $ 100.0 | $ 50.0 | $ 750.0 | 0.4 | $ 312.5 | $ 270.8 |
| 1.3 | 11 | $ 100.0 | $ 50.0 | $ 750.0 | 0.4 | $ 312.5 | $ 270.8 |
| 0.8 | 12 | $ 100.0 | $ 50.0 | $ 750.0 | 0.4 | $ 312.5 | $ 270.8 |
| **Total** | | | | | **4.6** | **$ 2,387.5** | **$ 1,929.2** |

LMP spread – implied cost spread = $630 - $50 = $580

# If future prices differ from MIO prediction, the LMP spread may be less than the implied cost spread

Potential outcome if resource is dispatched uneconomically in the binding interval and future prices differ from those forecasted by MIO

| SOC (MWh) | Interval | Discharge Bid | Charge Bid | LMP | Dispatch (MWh) | Revenue | Profit |
|---|---|---|---|---|---|---|---|
| 5.0 | 0 | $ 100.0 | $ 50.0 | $ 120.0 | -0.4 | $ (50.0) | $ (8.3) |
| 5.4 | 1 | $ 100.0 | $ 50.0 | $ 120.0 | 0.4 | $ 50.0 | $ 8.3 |
| 5.0 | 2 | $ 100.0 | $ 50.0 | $ 120.0 | 0.4 | $ 50.0 | $ 8.3 |
| 4.6 | 3 | $ 100.0 | $ 50.0 | $ 120.0 | 0.4 | $ 50.0 | $ 8.3 |
| 4.2 | 4 | $ 100.0 | $ 50.0 | $ 120.0 | 0.4 | $ 50.0 | $ 8.3 |
| 3.8 | 5 | $ 100.0 | $ 50.0 | $ 120.0 | 0.4 | $ 50.0 | $ 8.3 |
| 3.3 | 6 | $ 100.0 | $ 50.0 | $ 750.0 | 0.4 | $ 312.5 | $ 270.8 |
| 2.9 | 7 | $ 100.0 | $ 50.0 | $ 750.0 | 0.4 | $ 312.5 | $ 270.8 |
| 2.5 | 8 | $ 100.0 | $ 50.0 | $ 750.0 | 0.4 | $ 312.5 | $ 270.8 |
| 2.1 | 9 | $ 100.0 | $ 50.0 | $ 150.0 | 0.4 | $ 62.5 | $ 20.8 |
| 1.7 | 10 | $ 100.0 | $ 50.0 | $ 150.0 | 0.4 | $ 62.5 | $ 20.8 |
| 1.3 | 11 | $ 100.0 | $ 50.0 | $ 150.0 | 0.4 | $ 62.5 | $ 20.8 |
| 0.8 | 12 | $ 100.0 | $ 50.0 | $ 150.0 | 0.4 | $ 62.5 | $ 20.8 |
| **Total** | | | | | **4.6** | **$ 1,387.5** | **$ 929.2** |

LMP spread – implied cost spread = $30 - $50 = -$20

# Implied Bid Spread, MIO, and Bid Cost Recovery

- The implied bid spread use is a consequence of how the market optimization works since it seeks to use energy in the most valuable intervals so as to minimize the cost of the market solution
- Use of the implied bid spread in MIO can result in seemingly uneconomic dispatch in the binding interval given expected conditions and prices in the advisory intervals
- The dispatch decisions made in the binding interval feed into the surplus/shortfall calculations used for bid cost recovery (BCR)
- The ISO will continue to work to document examples of the use of the implied bid spread and its relationship to MIO and BCR for a future knowledge article on the matter

# Discussion

# Lunch Break

# Overview of Distribution-Level Storage Charging Constraints

# Distribution-Level Resources

- Resources that are interconnected via the distribution system, rather than the bulk transmission system

- Must follow distribution system operator's (DSO) wholesale distribution open access tariff (WDAT/WDT) in addition to the ISO's tariff

- Supply-side resources that participate under the Non-Generator Resource (NGR) pathway
  - Not DR/behind-the-meter resources

# Charging Constraints for Distribution-Level Resources

- The WDAT may include limitations on resources to minimize congestion or loss-of-load in the DSO's territory

- Due to charging limitations, assets may be unavailable to charge in certain hours or discharge per ISO dispatch

- DSO limitations are not explicitly represented in the ISO's systems (i.e., the Master File)
  - Conveyed to the ISO through the use of outage cards
  - May be static or dynamic

# Communication of Charging Constraints to the ISO

- 06/2024: the ISO allowed distribution-level assets to use OMS to reflect DSO level constraints
  - Challenging for dynamic limits, to discuss further here
- The ISO is considering identifying these resources in Master File
  - Gives operators insight into potential operational limitations these assets may experience

# Discussion

# Overview of DEBs for Hybrid Resources

# Background – Default Energy Bids

- Default energy bids (DEBs) are intended to ensure competitive outcomes in conditions where participants might have market power
- DEBs are intended to reflect a resource's marginal costs in the market absent perfect information
- DEBs seek to serve as a reasonable benchmark for a resource's specific short run marginal costs
- The DEB is only used for Market Power Mitigation in the incremental direction, there is no decremental mitigation
- DEBs are calculated daily for both the DA and RTM
- With the exception of the LMP-based DEB, the DEB does not vary by peak/off-peak period

# Background – Default Energy Bids

- A Default Energy Bid or DEB is a monotonically increasing staircase function consisting of a maximum of 10 economic bid segments, or 10 ($/MW, MW) pairs and an End MW value
- DEBs are unique to each Resource ID and are calculated separately for the Day-Ahead and Real-Time markets
- Each segment of the Default Energy Bid is associated with a field that indicates which methodology has been used to determine the segment
- The CAISO offers multiple methodologies that may be used to calculate DEBs
  - Variable Cost, Hydro, Storage, LMP, Negotiated

# Default Energy Bid Options

| | Default Energy Bids | DEB Multiplier |
|---|---|---|
| **Variable Cost (Gas)** | (Heat rate * Fuel Cost + VO&M + misc. adders) * **DEB multiplier** | **110% DEB multiplier** based on observations of aggregate gas price data– day-over-day variation and price dispersion– targeting ~95% of costs covered |
| **Hydro** | Max(gas floor, short term opportunity costs, long-term opportunity costs) * **DEB multipliers** | **110%,140% DEB multipliers** based on analysis determining the number of intervals a resource would run given different scalars, targeting 95-99% efficiency |
| **Storage** | Max(cost to charge, LMP-based opportunity cost) * **DEB multiplier** | **110% DEB multiplier** covers variation between day-ahead and real-time prices |

# Default Energy Bid Options

| | Description |
|---|---|
| **LMP** | • A weighted average LMP based on the lowest 25% of validated and/or corrected LMPs set at the Generating Unit location during Trading Hours in the last 90 days when the Unit was dispatched.<br>• Generating Units must pass a competitiveness screen to qualify for this option in which 50% of their MWh dispatches over the prior 90-days must have been dispatched competitively.<br>• The LMP DEB will be calculated separately for on- and off-peak periods within the corresponding trade date and market |
| **Negotiated** | • An amount negotiated with the CAISO. |

# Default Energy Bid Options

$$\text{Storage DEB} = \text{Max}\left\{\left[\text{Max}\left(\text{En}_{\delta/\eta}, 0\right) + \rho\right], \text{PB\_OC}_{\gamma}\right\} * \text{DEB Multiplier}$$

| | | |
|---|---|---|
| **En** | Energy Cost | Estimates the average cost of energy needed to charge the storage resource, using LMP prices from the relevant PNode |
| $\eta$ | Round-Trip Efficiency | A resource-specific static value |
| $\delta$ | Energy Charging Duration | Time the resource is capable of charging, based on a resource's registered max/min continuous energy limit and Pmin, adjusted for round trip efficiency |
| $\gamma$ | Energy Discharge Duration | Time the resource is capable of discharging, based on a resource's registered max/min continuous energy limit and Pmin, adjusted for round trip efficiency |
| $\rho$ | Variable Storage Operations Cost | A resource-specific registered value representing costs associated with variable operation of the resource, including cycling and cell degradation costs |
| **PB_OC** | Price-based Opportunity Cost | Estimates the market opportunity cost corresponding to the nth highest LMP, where n corresponds to the discharge duration of the resource (e.g. 4th highest hour for a 4 hour discharge duration) |
| **DEB Multiplier** | 110% Multiplier (1.1) | Multiplier to cover any potential variability between the storage DEB calculation and resource's actual marginal costs; consistent with other DEB calculations |

# Hybrid resources lack a default energy bid

- Defining a hybrid DEB allows:
  - Inclusion in the local market power mitigation framework
  - Bidding up to the soft-offer cap
    - As set last year in Price Formation Enhancements

- The hybrid DEB should be congruent with the hybrid resource's underlying technologies and whether the hybrid is able to withdraw energy from the grid or not

# Stakeholder Perspectives (initiative comments)

- Terra-Gen strongly recommends expansion of the intended scope of hybrid resource issues beyond simply the hybrid resource DEB topic
- Other design elements that Terra-Gen has identified specific to hybrids, particularly the dynamic limit concept, should be discussed in coordination with any effort to develop a hybrid resource DEB formulation or applying LMPM for hybrid resources

# Stakeholder Perspectives (initiative comments)

- DMM believes hybrid resource DEB development should be a high priority for the ISO

- DMM commented one potential approach is to use the maximum of the DEBs that would apply to each of the generation components that make up the hybrid resource
  - While this type of approach may overestimate the marginal costs of hybrid resources in some hours, a simplified approach that is easy to implement would be preferable to a continued total lack of mitigation of hybrid resources

- Prior to hybrid resource DEB implementation, the ISO should complete refinements to the enhanced storage DEB to more accurately consider changing intraday opportunity costs

# Discussion

# Working Group Topic Group #3

# Stakeholder Presentations

# Discussion

# Next Steps

# Next steps

- Upcoming milestones:*
  - 03/05: Stakeholder comments due

**All dates are tentative until confirmed through a notice in the ISO's Daily Briefing.*

# For reference

- Visit initiative webpage for more information: https://stakeholdercenter.caiso.com/StakeholderInitiatives/Storage-design-modeling

- If you have any questions, please contact ISOStakeholderaffairs@caiso.com


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