Energy Storage Enhancements

State of Charge Formula

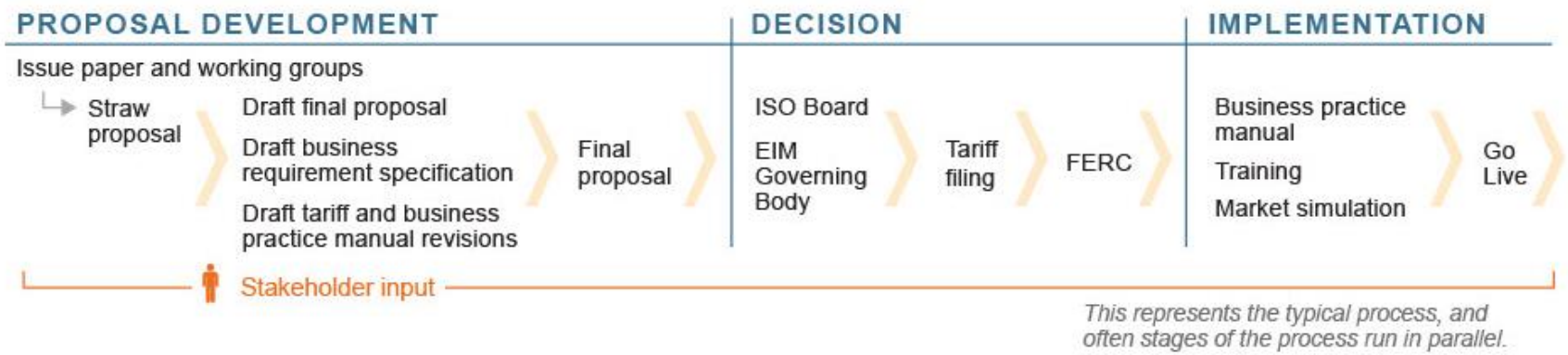
Workshop

August 3, 2022

Agenda

Time	Topic	Speaker
1:00-1:10	Introductions and Stakeholder Process	Brenda Corona
1:10-1:45	Current Proposal	Danny Johnson
1:45-2:30	Envelope Equations	Danny Johnson
2:30-3:00	PG&E Presentation	Michael Volpe, Alva Svoboda
3:00-3:55	Additional Discussion	Danny Johnson
3:55-4:00	Next Steps	Brenda Corona

Initiative Stakeholder Process



We are here

- Jul 31, 2023 Workshop paper posted
- Aug 03, 2023 Hybrid workshop
- Mar 15, 2023 Revised draft tariff language posted
- Oct 27, 2022 Final proposal posted

The energy storage enhancements policy on state of charge was developed to address two concerns

1. Better alignment between day-ahead state of charge and actual state of charge in real-time
   - When storage resources provide regulating service it does impact state of charge
   - Regulation down increases state of charge
   - Regulation up decreases state of charge
2. Address operational concerns observed from storage resources participating in the market
   - Operational experience shows that of storage resources not having state of charge and being unable to respond to automatic generator control instructions
   - Generally happens when resources receive multiple consecutive hours of regulation awards

ESE PROPOSAL

The energy storage enhancements policy included changes to the state of charge equation

- Today the formula that governs state of charge is:

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

- The ISO proposed to update the formula as follows:

$$SOC_{i,t} = SOC_{i,t-1} - \left(P_{i,t}^{(+)} + \eta_i P_{i,t}^{(-)} + \mu_{1,t} RU_{i,t} - \mu_{2,t}\eta_i RD_{i,t}\right)$$

$SOC_{i,t}$	State of charge for resource *i* at time *t*
$P_{i,t}^{()}$	Dis/Charge (+/-) instruction for resource *i* at time *t*
η_i	Round trip efficiency for resource *i*
$RU_{i,t}$	Regulation up awarded to resource *i* at time *t*
$RD_{i,t}$	Regulation down awarded to resource *i* at time *t*
μ	Multiplier for each product and hour

- Implementation of these changes was anticipated with the Spring 2023 software release

Negative prices for regulation down were observed in the testing environment

- The market software understands the intertemporal relationship between regulation and state of charge
  - For Example: The market internalizes that a regulation award will increase state of charge for a storage resource
  - This energy has value and can be sold in the energy market
  - This value can impact the price of regulation, and in the case of regulation down, push down prices

- Negative regulation prices are not supported by the tariff today

The ISO has identified three potential paths forward, for policy related to state of charge

1. Retain previously proposed definition for state of charge
   - This would require edits to the tariff for ancillary service pricing
2. Develop envelope equations to account for regulation awards
   - This concept was originally developed as a component of the day-ahead market enhancements initiative
     - The objective of these new calculations help to ensure that ensure that storage resources will have energy to potentially deliver imbalance reserve awards in the real-time market
   - The same concept could apply to storage resources with regulation awards
3. Continue to discuss alternatives that address problem within future policy discussions

ENVELOPE EQUATIONS

Envelope equations were developed as a tool to limit the imbalance reserves awarded to storage resources

- The envelope equations do not impact state of charge, but instead construct a hypothetical upper and lower state of charge limit
- These limits must be within the boundaries of physical state of charge limits for the storage resource
- Once one of the limits reaches a boundary, the resource must be scheduled to charge or discharge energy before any further schedules in that direction
- Once a resource has a schedule that causes the envelopes to meet both boundaries no further schedules are possible
  - The day-ahead market still optimized over the 24 hour period

The envelope equations are meant to model a hypothetical upper and lower bound for storage

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

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

- The upper envelope is impacted by downward imbalance reserves, which can increase state of charge
- The lower envelope is impacted by upward imbalance reserves, which can decrease state of charge
- Both values must stay with the operating limits of the resource
- Adjustable multipliers are attached to each of the imbalance terms, initially to be set at .85

The envelope equations could be expanded to accommodate regulation awards

$$SOC_{i,t}^{(u)} = SOC_{i,t-1}^{(u)} - EN_{i,t}^{(+)} - \eta_i \, EN_{i,t}^{(-)} + \eta_i \, AIRD_t \, IRD_{i,t} + \eta_i \, ARD_t \, RD_{i,t}$$

$$SOC_{i,t}^{(l)} = SOC_{i,t-1}^{(l)} - EN_{i,t}^{(+)} - \eta_i \, EN_{i,t}^{(-)} - AIRU_t \, IRU_{i,t} - ARU_t \, RU_{i,t}$$

- The components in red would not be implemented until the release of the day-ahead market enhancements
- The terms on the right include of regulation up and regulation down with an adjustable multiplier applied
  - Multipliers would have to be established and applied to regulation up and regulation down
- These would be enforced alongside other constraints, including the ancillary service state of charge constraint

Example Assumption: A storage resource and calculated state of charge values

Assume that a storage resource can:

- Operate between -100 MW (charging) to +100 MW (discharge)
- Provide four hours of service
  - Energy limits from 0 MWh to 400 MWh
- Has 100% round trip efficiencies
- Begins the day half charged, at 200 MWh

Assume we are using values of 1.0 for the multipliers in the state of charge envelope equation

Example: Example resource with a 1.0 multiplier applied to regulation up and regulation down

	Hour	1	2	3	4	5	6
EN		100			-100		0
RU			100			100	0
RD				100		100	0
SOC_U	200	100	100	200	300	400	400
SOC	200	100	100	100	200	200	200
SOC_L	200	100	0	0	100	0	0

- Storage resources still must have 1 hour of energy to provide regulation in the day-ahead market (ASSOC)
- With envelope equations storage resources are limited to providing a certain amount of regulation up and/or down

Low multipliers may result in unfettered ability for storage resources to provide regulation

The ISO provided the following table in the day-ahead market enhancements stakeholder process:

Multiplier / SOC	400 MWh	200 MWh	100 MWh
1.0	4	2	1
.5	8	4	2
.25	16	8	4
.2	20	10	5
.1	24	20	10

- A multiplier of 0.1, a resource starting the day at 100 MWh may provide 10 hours of regulation up @ 100 MW
  - This may not ensure that a resource is available over in real-time
  - This may be worrisome, as the conversion of regulation to energy may be correlated

Setting multipliers is critical if implementing a solution using envelope equations

- Multipliers should be set in such a way that they ensure that resources will be available to deliver awards with a relatively high confidence
  - Ensuring that a solution is reliable 90-95% of the time may be a good starting place
  - This objective is **unlikely** be achieved if average values for multipliers are used
  - This could be difficult to determine and computationally burdensome

- Using a 90th or 95th percentile of actual conversion of regulation to energy may be a conservative place to start?

What other venues should this be considered in

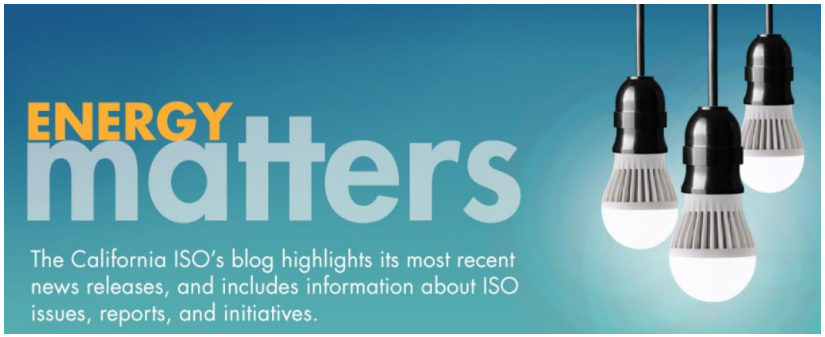
- Upcoming ASSOC initiative?
  - Significant expansion of scope

- Storage Modeling Enhancements?
  - Not scheduled for kick off until Spring 2024

NEXT STEPS

Next Steps

- This policy encourages stakeholder feedback on possible avenues for next steps. Stakeholders may submit comments in the commenting tool located on the Stakeholder Initiatives landing page (click on the “commenting tool” icon): https://stakeholdercenter.caiso.com/StakeholderInitiatives/Energy-storage-enhancements
- Please submit stakeholder written comments on today’s discussion and the accompanying paper by August 17, 2023, through the ISO’s commenting tool linked above.



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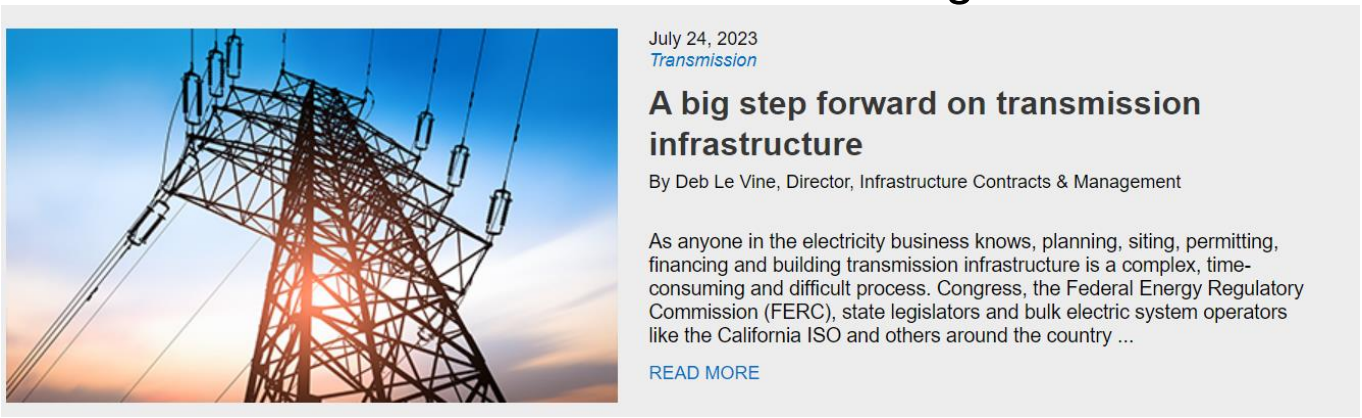

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- More information: California ISO - Extended Day-Ahead Market Forum (caiso.com)
- Register today!