Energy Storage Enhancements: PG&E Proposal for Implementing Day-Ahead Attenuation Factors

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Agenda

1. Problems with Original Energy Storage Enhancements (ESE) Implementation
2. PG&E Proposal
3. Examples
4. Open Issues / Q&A

Problems with Original ESE Implementation

- "Spurious" Day-Ahead (DA) Energy Awards – Energy Awards that are contingent on increased SOC (i.e. charging) due to assumed regulation energy take

- Negative Ancillary Service Marginal Prices (ASMPs) – Arbitrage opportunity between regulation and energy demonstrated by the CAISO

Question: How can the CAISO implement DA attenuation factors while mitigating these adverse effects?

PG&E Proposal

- DA awards must satisfy original ESE constraint, but also must satisfy an energy only SOC constraint
- Energy awards to discharge must be supported by energy awards to charge, or by initial SOC
- Regulation awards are constrained by non-zero attenuation factors and by energy awards (more restrictive than original)

Outcomes:

1. Reduces risk of DA energy awards being reversed in real-time
2. Removes arbitrage opportunity between regulation and energy (thus reduces the likelihood of negative ASMPs)

PG&E Proposal

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

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

*Subject to existing Day-Ahead ASSOC constraints

Definitions:

$SOC_{i,t}^{AT}$ = SOC with attenuation factors $SOC_{i,t}^{EN}$ = SOC with energy only

$EN_{i,t}^{(+)}$ = Energy awards (discharge) $EN_{i,t}^{(-)}$= Energy awards (charge) η_i = charging eff.

$RU_{i,t}$ = Reg Up awards $ATRU_t$ = Reg Up attenuation factor

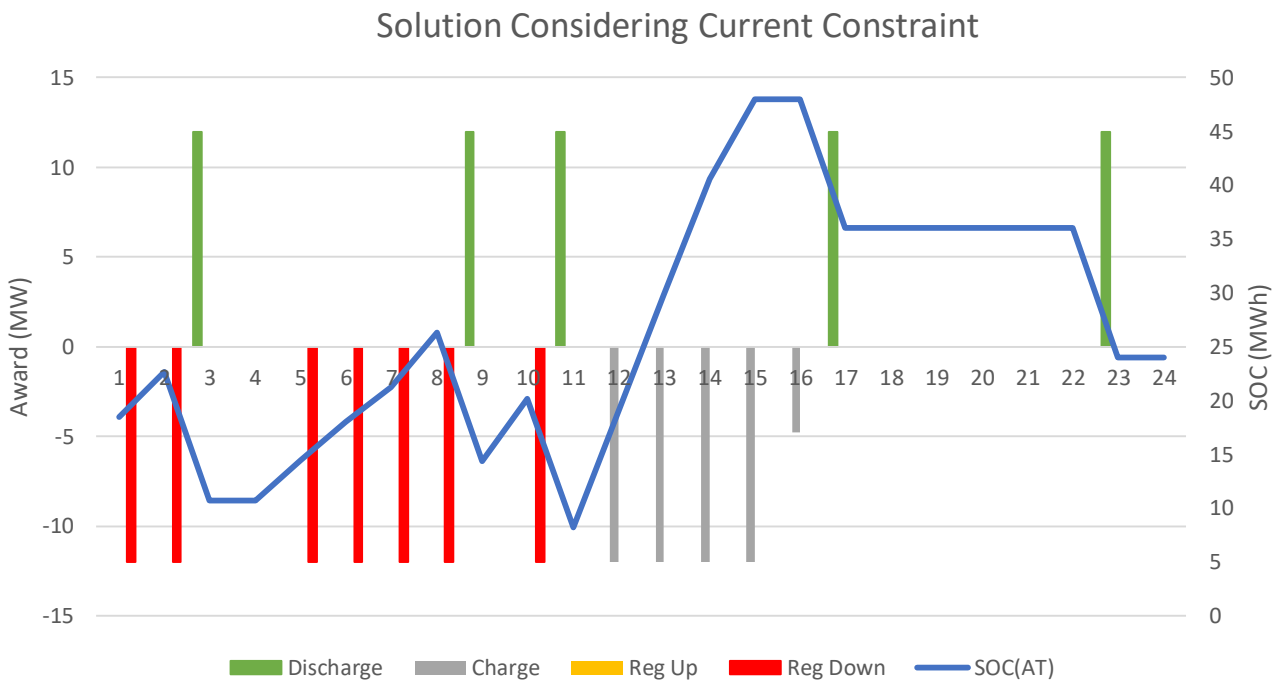
$RD_{i,t}$ = Reg Down awards $ATRD_t$ = Reg Down attenuation factor

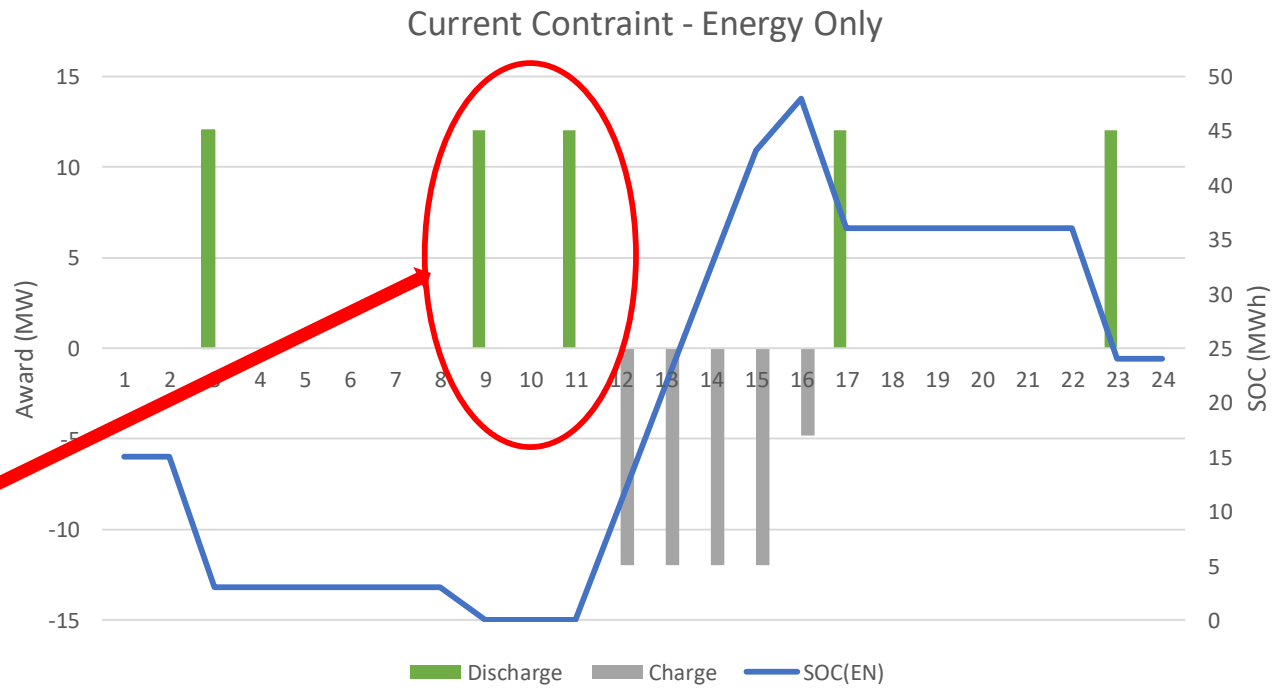
Example 1

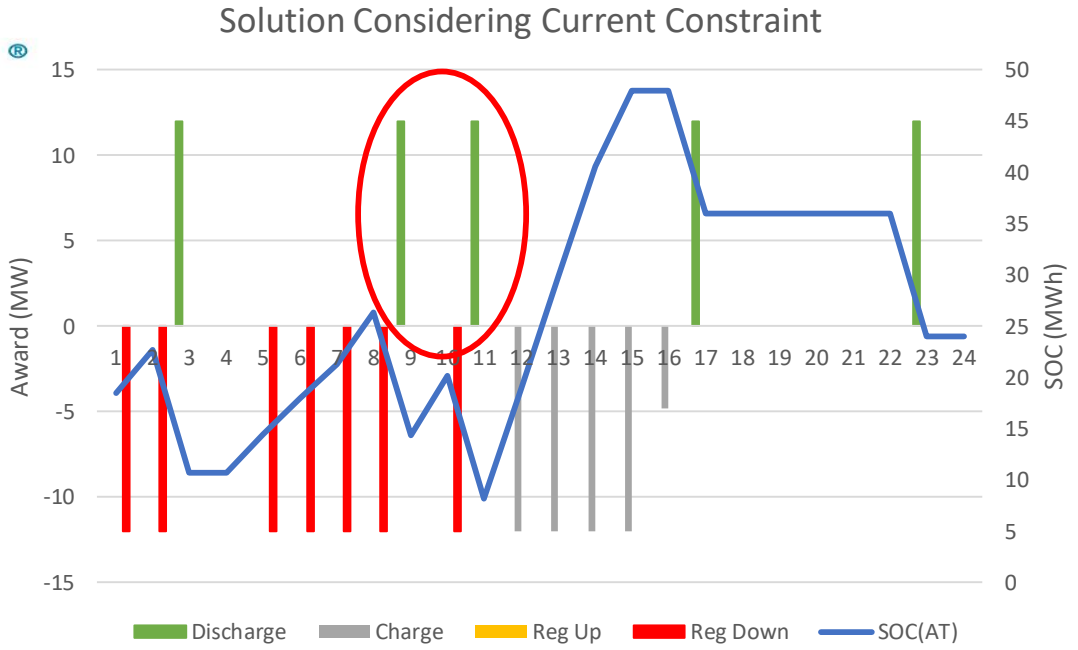
Assumptions:

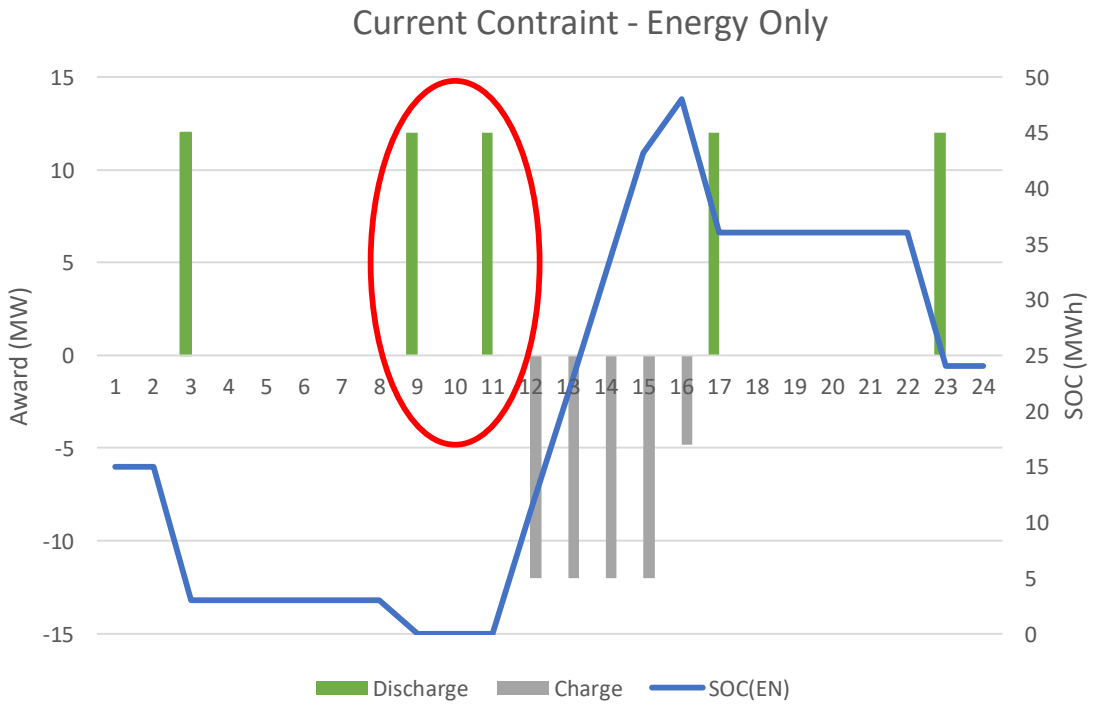
- Four-hour 12 MW battery (max SOC = 48 MWh)
- Current ESE attenuation factors
- Initial SOC = 15 MWh
- Charging efficiency = 0.9
- DA Reg Down and Energy awards

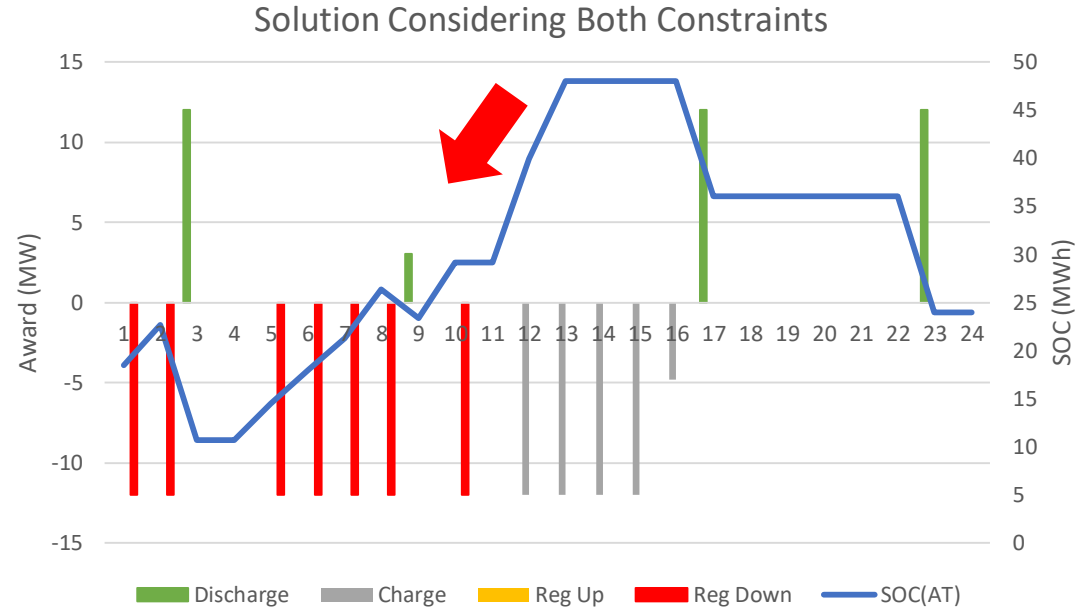
Note: in Energy Only scenario, energy awards in these hours cannot be delivered without additional SOC (from Reg Down charging)

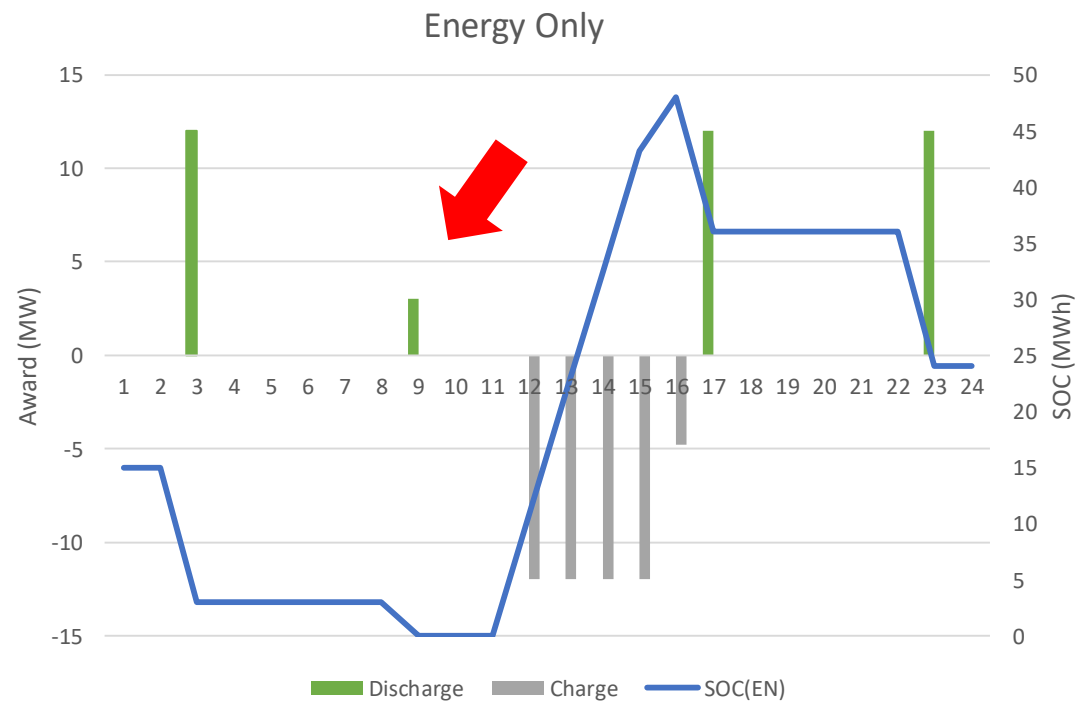





Solution Considering Current Constraint
Award (MW)
SOC (MWh)
Discharge
Charge
Reg Up
Reg Down
SOC(AT)


Current Contraint - Energy Only
Award (MW)
SOC (MWh)
Discharge
Charge
SOC(EN)


Solution Considering Both Constraints
Award (MW)
SOC (MWh)
Discharge
Charge
Reg Up
Reg Down
SOC(AT)


Energy Only
Award (MW)
SOC (MWh)
Discharge
Charge
SOC(EN)

Example 2

	RegDN			ATRD	SOC	Delta SOC	Energy		
Interval End	MW	Bid Price	ASMP				MW	Bid Price	LMP
17	165.66	10.54	-5.27	0.25	**211.69**	**36.4**	0		89.7
18	0		6.72	0.35	**3.64**	**-208.05**	208.05	Discharge @20.09	92.07

Cost of providing 1 more MW of RD @10.54

Cost of procuring the resulting 0.22 MWh during peak hours @20.09

Cost of providing 0.22 MWh during the peak hours if procuring @ Market price (LMP = 92.07)

0

10.54

$$RD\ price = 10.54 \times 1 + (20.09 \times \overbrace{1 \times 0.25 \times 0.879}^{0.22}) - (92.07 \times \overbrace{1 \times 0.25 \times 0.879}^{0.22}) = -5.27$$

RD bid price

RD award

EN discharge bid price

Energy obtained from RD award

ATRD (attenuation factor for RD)

Charging Efficiency

LMP during peak hours

Energy now displaced by that obtained from RD award

Market would save $5.27 per additional MW of RD provided. This is by exchanging expensive energy @LMP for cheap energy obtained from RD award.

http://www.caiso.com/Documents/Presentation-MarketSimulation-20230615.pdf

Open Issues / Q&A

1. What is the magnitude of the software change?
2. Is the energy only constraint also needed in the real-time market?
3. Negative ASMPs may still occur; is that a problem?

Appendix

Appendix

ASSOC constraints:

$$SOC_{i,t-1} - RU_{i,t} - SR_{i,t} - NR_{i,t} \geq \underline{SOC}_{i,t}$$

$$SOC_{i,t-1} + \eta_i(RD_{i,t}) \leq \overline{SOC}_{i,t}$$

Attenuation factors:

Hour	Reg Up (mRU)	Reg Down (mRD)
1	11%	32%
2	4%	39%
3	4%	36%
4	2%	38%
5	3%	35%
6	4%	33%
7	7%	30%
8	4%	47%
9	4%	51%
10	5%	54%
11	5%	50%
12	6%	44%
13	5%	44%
14	6%	39%
15	6%	40%
16	6%	43%
17	6%	51%
18	8%	50%
19	11%	43%
20	8%	58%
21	5%	63%
22	8%	41%
23	8%	40%
24	3%	43%

Appendix

CAISO Tariff Section 27.1.2.1:

ASMPs are determined by first calculating Shadow Prices of Ancillary Services for each Ancillary Service type and the applicable Ancillary Services Regions. The Ancillary Services Shadow Prices are produced as a result of the co-optimization of Energy and Ancillary Services through the IFM and the Real-Time Market, subject to resource, network, and requirement constraints. The Ancillary Services Shadow Prices represent the marginal cost of the relevant binding regional constraints at the optimal solution, or the reduction of the combined Energy and Ancillary Service procurement cost associated with a marginal relaxation of that constraint. If the constraint for an Ancillary Services Region is not binding, the corresponding Ancillary Services Shadow Price in the Ancillary Services Region is zero (0).

Appendix

CAISO Tariff Section 27.1.2.2:

The ASMPs determined by the IFM or FMM optimization process for each resource whose Ancillary Service Bid is accepted will be no lower than the sum of (i) the Ancillary Service capacity Bid price submitted for that resource, and (ii) the foregone opportunity cost of Energy in the IFM or FMM for that resource. The foregone opportunity cost of Energy for this purpose is measured as the positive difference between the IFM or FMM LMP at the resource's Pricing Node and the resource's Energy Bid price. If the resource's Energy Bid price is higher than the LMP, the opportunity cost measured for this calculation is $0.

Market Operations BPM Section 4.4:

ASMPs can be described more precisely in terms of Regional Ancillary Service Shadow Prices (RASSPs). RASSPs are produced as a result of the co-optimization of Energy and AS for each AS Region, and represent the cost sensitivity of the relevant binding regional constraint at the optimal solution, i.e., the marginal reduction of the combined Energy-AS procurement cost associated with a marginal relaxation of that constraint. The opportunity cost for a resource which is awarded AS rather than energy when the energy bid is otherwise competitive is not computed explicitly, rather it is implicit in RASSP for that AS Region.