ESIG-NARUC Training Series on Bulk Power System Issues: Integration of Utility-Scale Storage

Market Design Considerations for Battery Operation

June 8, 2023

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Agenda

Integration of Utility-Scale Storage

- FERC Order No. 841 Summary
- Electric Storage Resource
  - Participation Model
  - State-of-Charge (SoC) Management Options
- Storage Performance during Extreme Weather Conditions
  - California ISO September Heatwave

FERC Order No. 841: Summary

- ✓ ISOs must include a **participation model** for electric storage resources (ESRs) that allows them to participate in energy, ancillary service, and capacity markets when technically capable of doing so
- ✓ ESRs must be eligible to **set the wholesale price** as both a buyer and seller when the marginal resource
- ✓ ISOs must **account for physical parameters** of ESRs through bidding or otherwise
- ✓ ISOs must allow a minimum size requirement that is at most **100 kW**
- ✓ Sale of energy that is stored from purchases in the wholesale market must be **sold at wholesale nodal prices**
- ✓ ISOs must allow **self-management** of state of charge (SOC)

Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators, FERC Order 841, Final Rule, 162 FERC 61, 127 (February 15, 2018) ("Order No. 841").

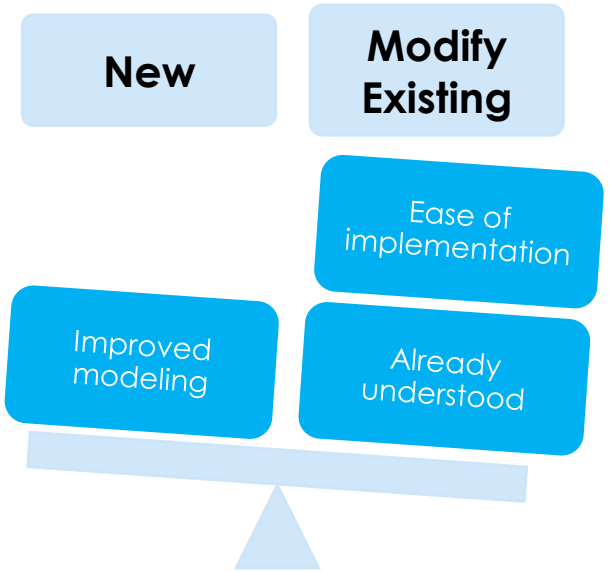
Participation Model: Introduction

What does it mean?

- **FERC NOPR:** Defined as "a set of **tariff provisions** that **accommodate the participation of resources with particular physical and operational characteristics** in the organized wholesale electric markets of the RTOs and ISOs."
- **FERC Order No. 841:** Tariff revisions that consist of **market rules** that, recognizing the **physical and operational characteristics** of the resource, **facilitates** their participation in RTO/ISO markets
- **ERPI**: Definition of a participation model also includes the **set of market clearing software provisions required to represent the physical and operational characteristics** of the resource.

Participation Model Characteristics

- Mathematical modeling in market software
- Bidding parameters
- Service eligibility
- Other participation rules



ESR Participation Model

O841: Requirement

- ISOs *must* include a participation model for ESRs that allows them to participate in energy, ancillary service, and capacity markets when technically capable of doing so. ISOs must account for physical parameters of ESRs through bidding or otherwise.

Energy Storage

Characteristics Include:

- Ability to inject power:
  - Min discharge
  - Max discharge
- Ability to withdraw power:
  - Min charge
  - Max charge
- Ability to store energy:
  - Min and max SoC
  - Roundtrip efficiency losses
  - Initial and end-of-horizon SoC
- Charge/discharge ramp rate

Order No. 841 Aspect	NYISO	PJM	SPP	ISO-NE	MISO	CAISO
Participation Model	1. Most entities are proposing two separate participation models: Continuous (e.g., batteries) and discontinuous (e.g., PSH) models 2. ESRs can participate in energy, ancillary services, and capacity markets (wherever applicable)					
	ESRs and **ELRs**; PSH cannot submit a charge and discharge offer in the same hour	**ESRs;** PSH plants can still use **pumped hydro optimizer**	**MSRs**; PSH plants cannot submit a charge and discharge offer in the same hour	**CSFs** and **BSFs**	**ESRs**	**NGRs** and **PSH model**

BSF: Binary Storage Facility; **CSF**: Continuous Storage Facility; **ELR**: Energy Limited Resource; **ESR**: Electric Storage Resource; **MSR**: Market Storage Resource; **NGR**: Non-Generator Resource; **PSH**: Pumped Storage Hydro

SoC Management Options

Self-Schedule

- ESR self-dispatches its output and is insensitive to price.

Allowed by all ISOs/RTOs

Self-SOC-Management

- ESR provides an offer curve analogous to traditional resources.
- ESRs can set offers to ensure desired and feasible SOC.
- ISO schedules without SOC consideration

CAISO, NYISO ESR/PSH

SOC-Management-Lite

- ESR provides an offer curve.
- ISO does not schedule ESR if it would lead to infeasible SOC.
- Schedules are not optimized across time to optimize ESR schedules.

SPP, ISO-NE, MISO, PJM

ISO-SOC-Management

- ESR may or may not provide an offer curve.
- ISO ensures SOC feasibility and optimizes ESR schedules across time to minimize cost.

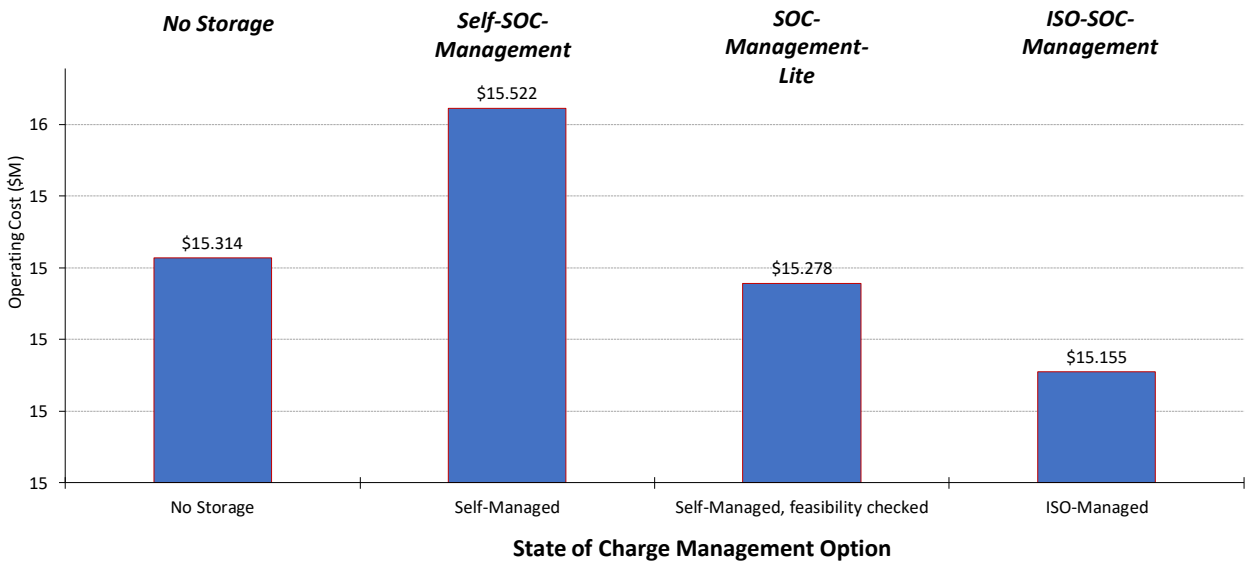
CAISO, NYISO ESR, PJM PSH

ISO scheduling responsibility / theoretical economic efficiency and reliability benefits / complexity

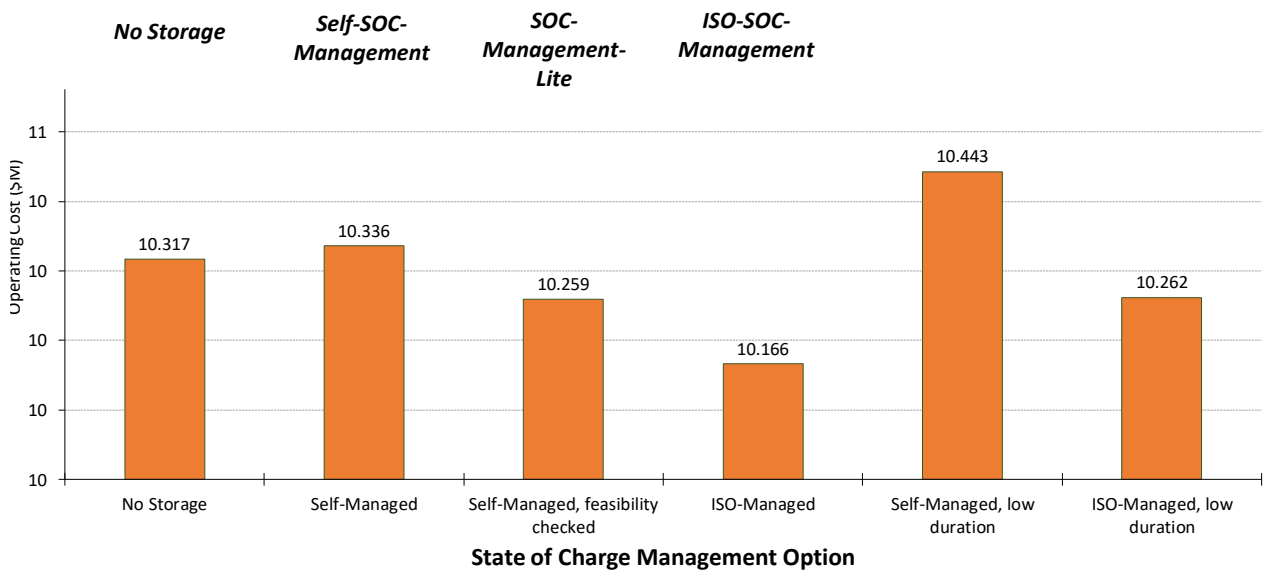
ESR asset owner participation responsibility and flexibility / computational efficiency

Operation and Market Design

Low Renewable Scenario



High Renewable Scenario

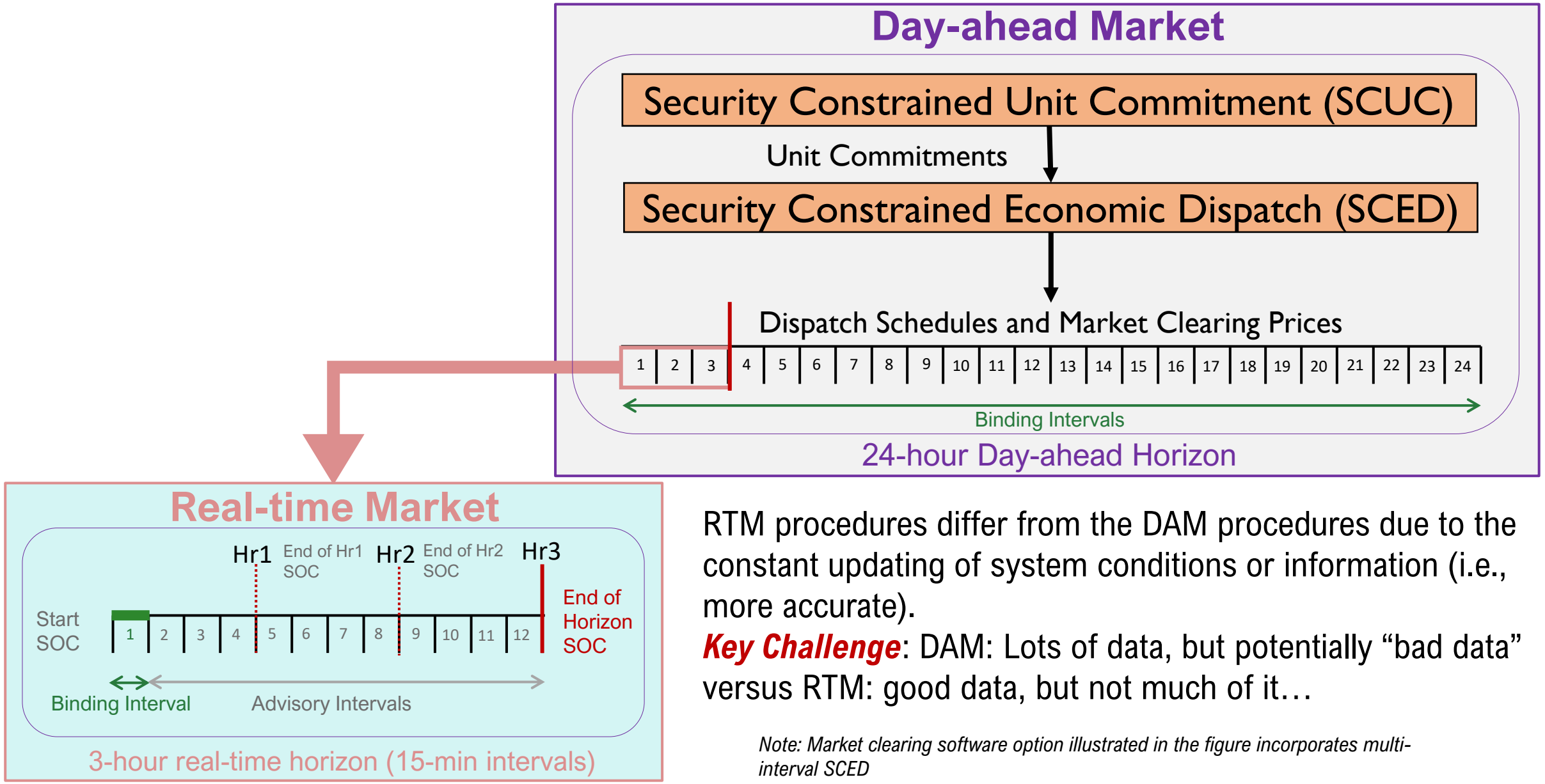


- ✓ Self-management found to *increase* costs when storage deployed
- ✓ *Greatest* cost reduction and profits observed when ISO manages state of charge and optimizes to lower costs
- ✓ Self-management still benefits efficiency if feasibility checked, allowing *greater flexibility* for participant
- ✓ Challenges may be *exacerbated* by duration of storage, amount of storage, and amount of renewables

The way electric storage is operated and how it participates within the market may have a substantial impact on the magnitude of benefits it provides to the system.

Ela, Singhal, *Integrating Electric Storage Resources into Electricity Market Operations: Evaluation of State of Charge Management Options,* EPRI, Palo Alto, CA: 2019. 3002013868.

The Forecast Dilemma



RTM procedures differ from the DAM procedures due to the constant updating of system conditions or information (i.e., more accurate).

Key Challenge: DAM: Lots of data, but potentially "bad data" versus RTM: good data, but not much of it…

Note: Market clearing software option illustrated in the figure incorporates multi-interval SCED

Storage Performance during Extreme Weather Conditions

Insights on recent experiences with utility-scale storage operation during the September heatwave in California

California ISO

Storage Resource Performance in Summer 2022

By end of 2022, about 60% of the new batteries in the US markets were in the CAISO footprint, including just over 3 GW of new standalone lithium-ion battery storage and just under 2 GW of batteries in hybrid projects (almost all solar)

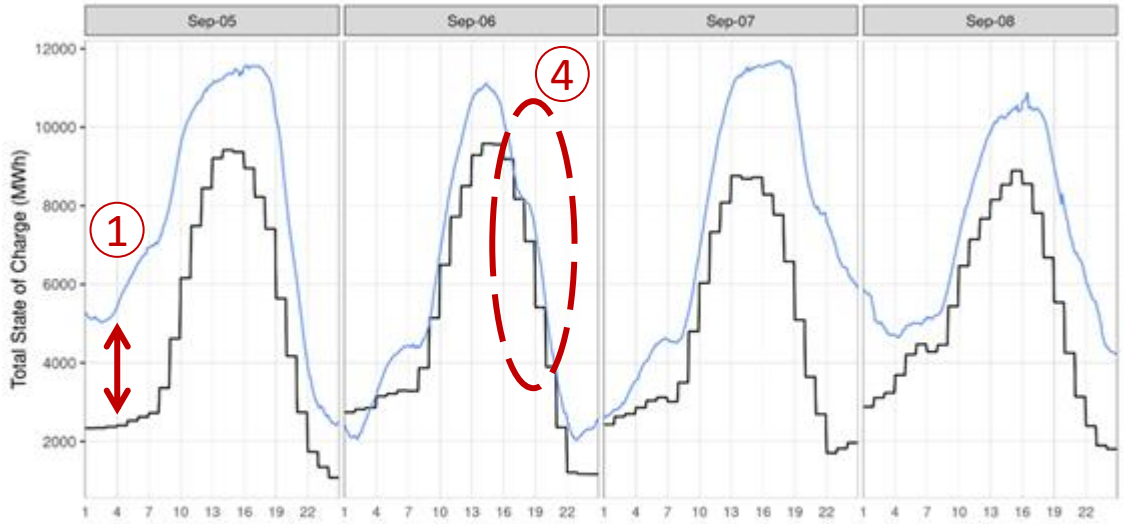
- CAISO experienced record-breaking summer weather conditions from Aug 31st through Sep 9th, 2022
  - Several cities saw their century-old temperature records broken
- CAISO usually operates with peak demand during the summer reaching around 50,000 MW
  - Encountered a significant deviation from historical norms on Sep 6th, setting a new load record of 52,061 MW
- Despite this challenge, the ISO managed to avert the need for rotating outages
  - Demand response initiatives
  - Flex alerts
  - Energy conservation efforts promoted through government emergency notifications that collectively reduced demand by about 1,500 MW
  - Use of storage resources that played a crucial role in maintaining system reliability

CAISO, *Summer Market Performance Report September 2022*, Published Nov. 2, 2022. [Online]. Available: http://www.caiso.com/Documents/SummerMarketPerformanceReportforSeptember2022.pdf

Storage Performance in Summer 2022

RUC: Reliability Unit Commitment; **RTD**: Real-time Dispatch

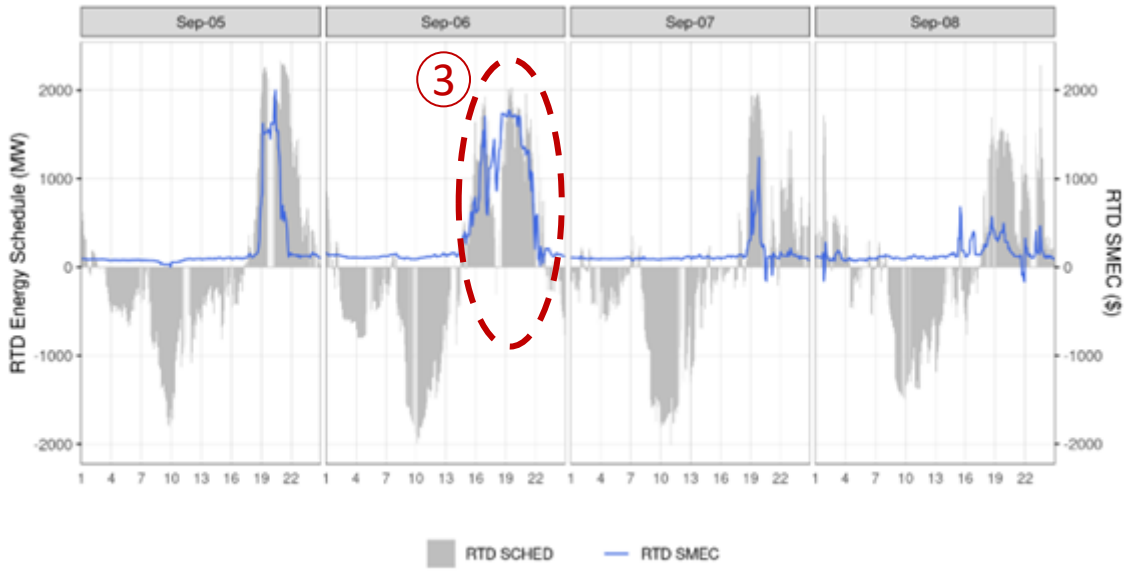
Impact of Min SoC requirement on real-time SoC



Impact of an inaccurate estimation of initial SoC parameter

RTD is limited in its ability to forecast conditions that may arise more than an hour in the future due to its short-sightedness

Impact of high scarcity pricing and congestion-related challenges

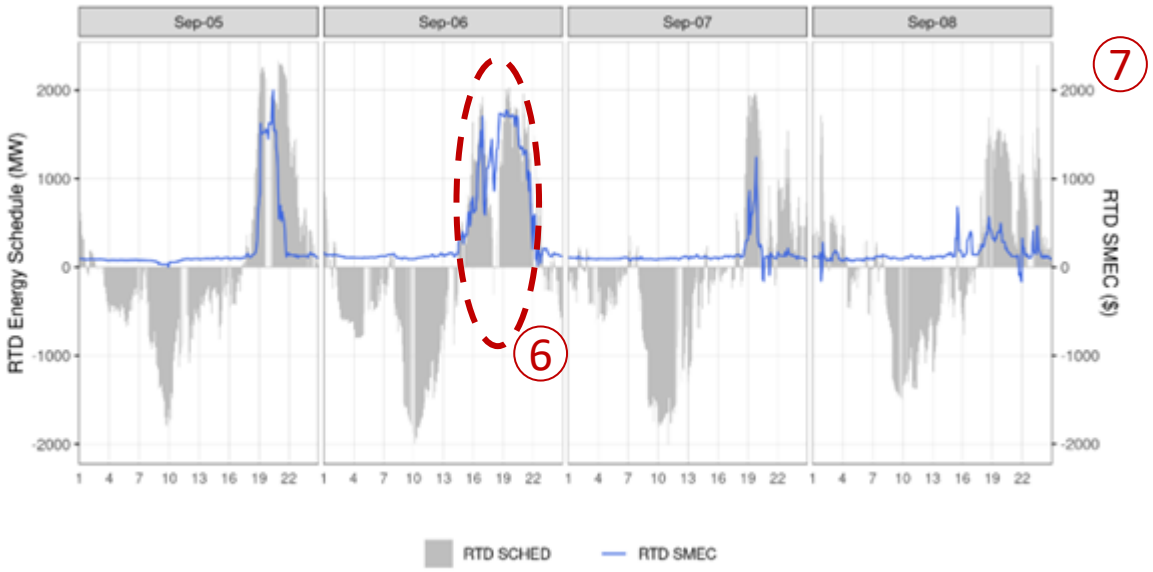


1. Initial SoC parameter in the day-ahead market
2. Challenges with real-time SoC management
3. Impact of merit order dispatch and market power mitigation
4. Minimum SoC requirement tool for resource adequacy storage resources
5. Dynamic horizon length of the Real-time Dispatch (RTD) market
6. Out-of-merit exceptional dispatch instructions by operators
7. Adjusted bid cap as per FERC O831
8. Impact of ancillary services on SoC management

CAISO, *Summer Market Performance Report September 2022*, Published Nov. 2, 2022. [Online]. Available: http://www.caiso.com/Documents/SummerMarketPerformanceReportforSeptember2022.pdf

Storage Performance in Summer 2022

Out-of-merit instructions to charge and hold SoC



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7 $2000/MWh adjusted bid cap

Misalignment of dispatch instructions and telemetered storage production levels

	Actuals	161	160	157	162	-2	-2	-2	124	-95	-166
Hour	Interval	RTD1	RTD2	RTD3	RTD4	RTD5	RTD6	RTD7	RTD8	RTD9	RTD10
16	11	161									
16	12	163	163								
17	1	0	0	0							
17	2	0	94	0	0						
17	3	0	0	0	0	0					
17	4	30	0	0	0	33	158				
17	5	163	8	0	0	163	163	-166			
17	6	163	158	0	92	163	163	-166	-166		
17	7	163	163	64	162	163	119	-166	-166	-120	
17	8	163	163	163	163	163	163	-166	-166	-55	-166
17	9		163	163	163	163	130	-117	-166	-55	-166
17	10			163	163	163	71	-55	-117	-55	-110
17	11							-110	-55	-55	-110
17	12							-166	-110	-55	-110
18	1							-166	-166	-3	-8
18	2							-166	-166	-3	-166
18	3								-166	-3	-34
18	4									-3	-8
18	5										-8

HE 17 Interval 5: First instance of charge dispatch instruction

# of five-minute RTD intervals (5): 10 | 10 | 10 | 9 | 8 | 7 | 10 | 10 | 10 | 10

The real-time horizon can vary and be as short as 35 minutes

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CAISO, *Performance of Storage Resources in Summer 2022*, EPRI ISO/RTO Energy Storage Market Modeling Technical WG, Feb. 2022. [Online]. Available: http://www.caiso.com/Documents/SummerMarketPerformanceReportforSeptember2022.pdf

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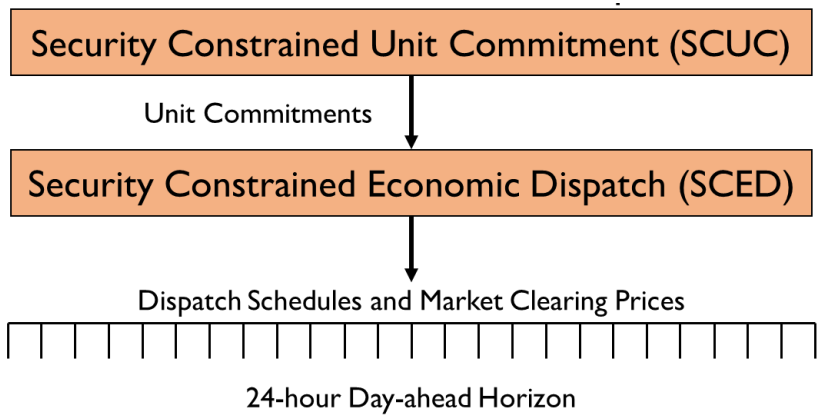
Appendix

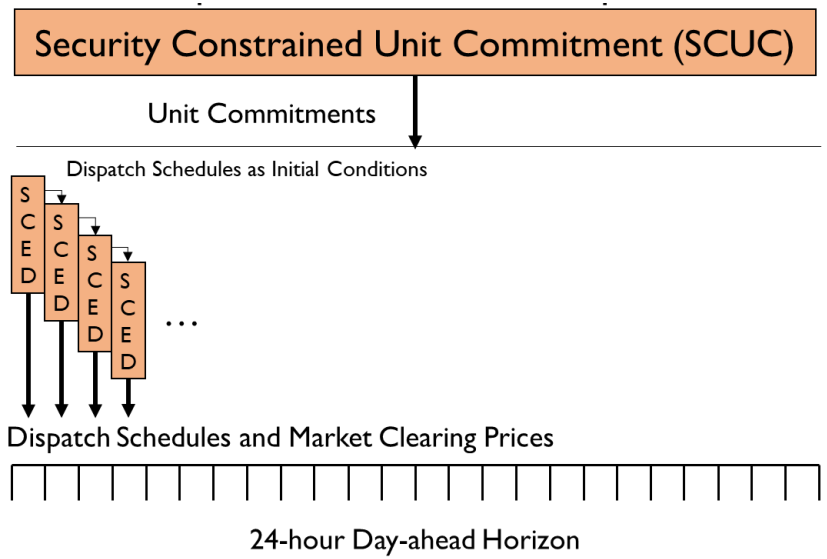
Market Clearing Software Differences

ISO-SOC-Management
Simultaneous SCED Approach



- **RTO/ISO**: CAISO, NYISO
- **DASCED Objective**: Maximizes social welfare / minimizes total system operating costs over the entire DA operating horizon (i.e., 24-hours)
- Previous hour's SOC and dispatch schedules (charge, discharge decisions) are variables in the SOC and ramp rate constraints (impacts dispatch/LMP calculations)

SOC-Management-Lite
Sequential SCED Approach



- **RTO/ISO**: SPP, ISO-NE, MISO, PJM
- **DASCED Objective**: Maximizes social welfare / minimizes total system operating costs for each DA time period or market interval individually (i.e., 1-hour)
- Previous hour's SOC and dispatch schedules (charge, discharge decisions) are parameters in SOC and ramp rate constraints (impacts dispatch/LMP calculations)

*PJM uses a separate software program, referred to as pumped hydro optimizer, for determining pumped storage hydro (PSH) schedules

SOC Management Options

ISO-SOC-Management

1. Simultaneous Multi-interval economic dispatch
2. All 24 hours are solved simultaneously as one problem
3. Previous hour's SOC is a variable in economic dispatch/ LMP calculation
4. SOC is managed across a known horizon to ensure feasibility and optimality
5. Does not require offers, but ESRs can still submit offers, e.g., to account for degradation costs
6. May include an additional feature to avoid myopic decisions, particularly if no offers are attached, e.g., a desired SOC at the end of the horizon, or a value in $/MWh provided by the ESR to demonstrate the value of keeping energy left over at the end of the day

SOC-Management-Lite

1. Sequential economic dispatch
2. Each hour is solved independently and sequentially, only using previous hour's data for initial conditions
3. Previous hour's SOC is a parameter in economic dispatch/ LMP calculation
4. SOC is used in each market interval to ensure the ESR's schedule is feasible
5. Requires offers to be submitted by market participants
6. Because offers must be submitted by ESRs, no additional features required to avoid myopic decisions at the end of horizon