Integration of Electric Storage Resources

Value of ESRs in providing grid services

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Feb 4, 2021 DOE Electricity Advisory Council





Electric Storage Resource (ESR) Services and Contributions

Installed capacity to ensure adequacy

Energy arbitrage

Flexibility and rapid response

Operating reserve & other reliability services

T & D congestion management and deferral

Key Challenges to value of ESRs as a flexibility resource





Flat Energy prices/costs limit arbitrage benefits

Key Challenges to value of ESRs as a flexibility resource

State of charge management

Limited by real-time scheduling horizons

Degradation impacts and costs

EMS/MMS software intricacies

State of Charge Management: Options

Self-Schedule

ESR self-

price.

dispatches its

output and is

insensitive to



Self-SOC-Management



SOC-Management-Lite



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

- across intervals to optimize ESR

SPP, ISO-NE, MISO, **PJM ESRs**

ISO-SOC-Management

- ESR may or may not provide offer curve.
- ISO ensures SOC feasibility and optimizes **ESR** schedules across intervals.

Allowed by all ISOs/RTOs

CAISO, NYISO, PJM ESRs

ESR provides an

offer curve

traditional

resources.

to ensure

levels.

desired and

feasible SOC

analogous to

• ESRs can modify

submitted offers

CAISO, NYISO, PJM PSH units

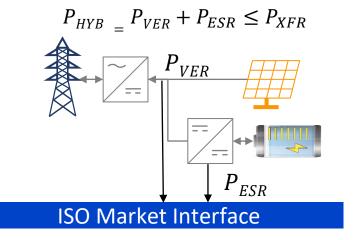
ISO Scheduling Responsibility / Theoretical Economic Efficiency and Reliability Benefits / Complexity

ESR Asset Owner Participation Responsibility and Flexibility / Computational Efficiency

Hybrid Storage/VER Market Modeling Options

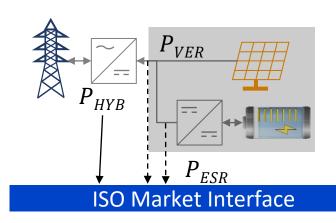
Option 1: Separate Independent Resources

Separately represent each resource, with minimal changes to existing market designs

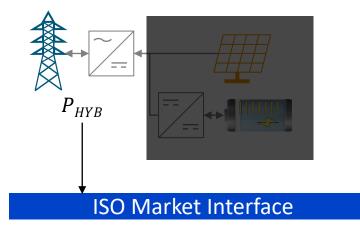


Option 3: Single Hybrid Resource, ISO-Managed Feasibility

Add telemetry requirements to allow ISO to limit infeasible schedules



Option 2: Single Hybrid Resource, Self-Management



Single offers and operating parameters allows participant bidding strategy flexibility

Option 4: Separate Resources, Linked

$$P_{HYB} = P_{VER} + P_{ESR} \le P_{XFR}$$
 $P_{VER} \longrightarrow P_{VER}$

ISO Market Interface

Add linking constraint to increase ability to operate resource in combined fashion

^{*}figure illustrates dc-coupled strategy for demonstration purposes



Storage as a Capacity Resource

Increasing Penalties for Unavailability

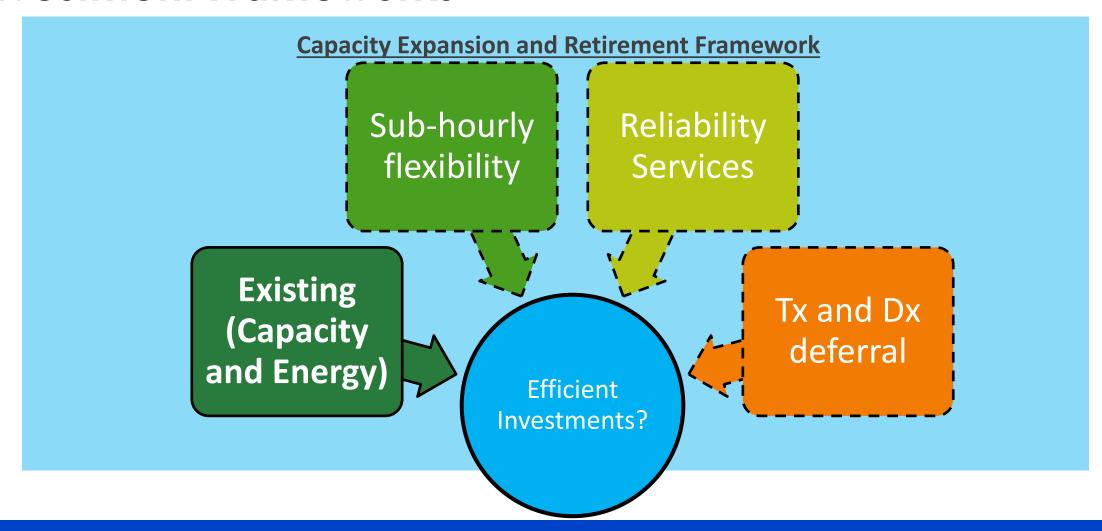
Increasing Duration

Duration	No Penalty	1000 \$/ MWh Penalty	\$5000 / MW h Penalty	\$9000 / MWh Penalty
1 hr	32-42%	81-83%	89-91%	92%
2 hr	60-67%	89-95%	96%	98%
4 hr	81-92%	100%	100%	100%
6 hr	95-97%	100%	100%	100%
8 hr	95-100%	100%	100%	100%

Lannoye et al, Energy Storage Capacity Value Estimation, EPRI, Palo Alto, CA: 2019. 3002013491.

Value of storage for meeting peak also varies by system and storage penetration

Key Challenge: Emerging Technologies and Resource Investment Frameworks



New features not currently part of expansion processes (i.e., for Integrated Resource Plans) may need to be considered.

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Management

ISO-SOC-

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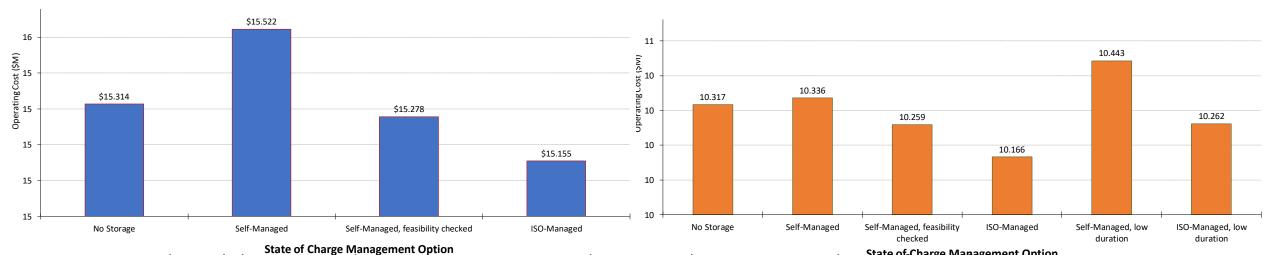
ESR Asset Owner Participation Responsibility and Flexibility / Computational Efficiency



Operation and Market design

Low Renewable Scenario

High Renewable Scenario

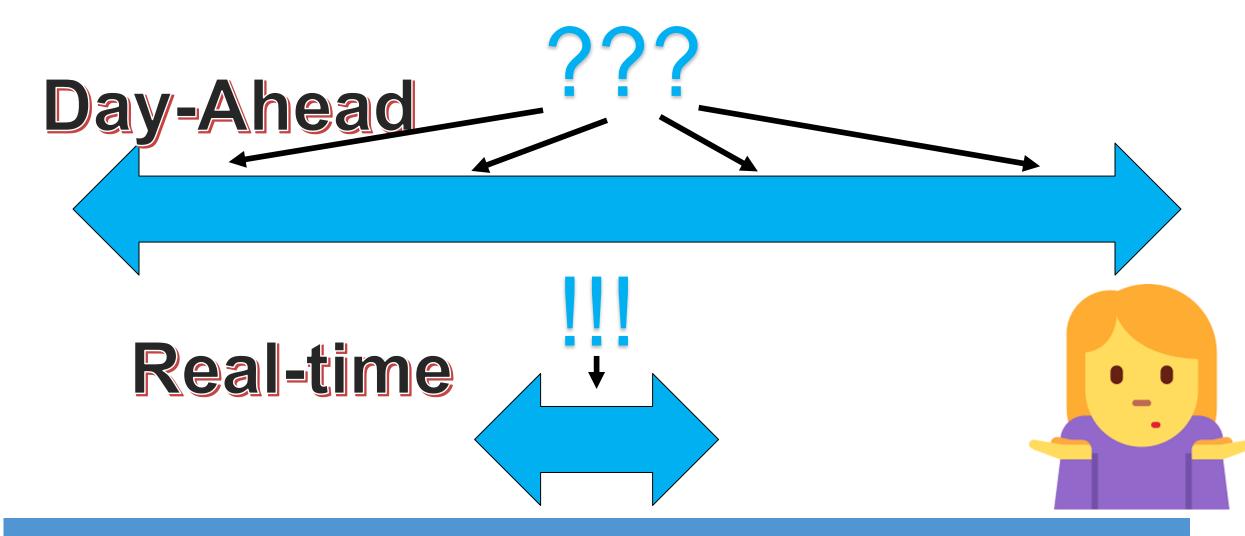


Ela, Singhal, Integrating Electric Storage Resources into Electricity Market Operations: Evaluation of State of Charge Management Options, EPRI, Palo Alto, CA: 2019. 3002013868.

- ✓ 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 <u>exacerbated</u> 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.

The Storage Forecast Dilemma



Lots of data, but potentially "bad data" vs. Good data, but not much of it...



