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

Market Design Considerations for Battery Operation

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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.
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**

<table>
<thead>
<tr>
<th>Participation Model</th>
<th>NYISO</th>
<th>PJM</th>
<th>SPP</th>
<th>ISO-NE</th>
<th>MISO</th>
<th>CAISO</th>
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<tbody>
<tr>
<td>1. Most entities are proposing two separate participation models: <strong>Continuous</strong> (e.g., batteries) and <strong>discontinuous</strong> (e.g., PSH) models</td>
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<td>2. ESRs can participate in energy, ancillary services, and capacity markets (wherever applicable)</td>
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<tr>
<td>ESRs and ELRs; PSH cannot submit a charge and discharge offer in the same hour</td>
<td>ESRs; PSH plants can still use pumped hydro optimizer</td>
<td>MSRs; PSH plants cannot submit a charge and discharge offer in the same hour</td>
<td>CSFs and BSFs</td>
<td>ESRs</td>
<td>NGRs and PSH model</td>
<td></td>
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</tbody>
</table>

**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.

**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

**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.

**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.

Allowed by all ISOs/RTOs
CAISO, NYISO ESR/PSH
SPP, ISO-NE, MISO, PJM
CAISO, NYISO ESR, PJM PSH

ISO scheduling responsibility / theoretical economic efficiency and reliability benefits / complexity
ESR asset owner participation responsibility and flexibility / computational efficiency
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.

- 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 Forecast Dilemma

Day-ahead Market

Security Constrained Unit Commitment (SCUC)

Unit Commitments

Security Constrained Economic Dispatch (SCED)

Dispatch Schedules and Market Clearing Prices

Real-time Market

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

Storage Performance in Summer 2022

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

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 an inaccurate estimation of initial SoC parameter

Impact of high scarcity pricing and congestion-related challenges

1. Initial SoC parameter in the day-ahead market
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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