



Assessing ESS Revenue Potential in PJM's Energy and Ancillary Markets

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Project Objective

Review recent PJM electricity market rules for energy storage system (ESS) participation in energy and ancillary services. Develop an optimization formulation to assess how these rules and operating conditions influence potential ESS revenues.

Why This Work Is Needed

- Provide clarity on how evolving RTO/ISO market rules affect the economic opportunities and limitations for energy storage participation.

What We Do

- Identify and summarize the latest regulations governing ESS participation in PJM's energy and ancillary service markets
- Conduct an optimization-based assessment to evaluate how market rules and operating constraints affect potential ESS revenues under different scenarios.

Progress

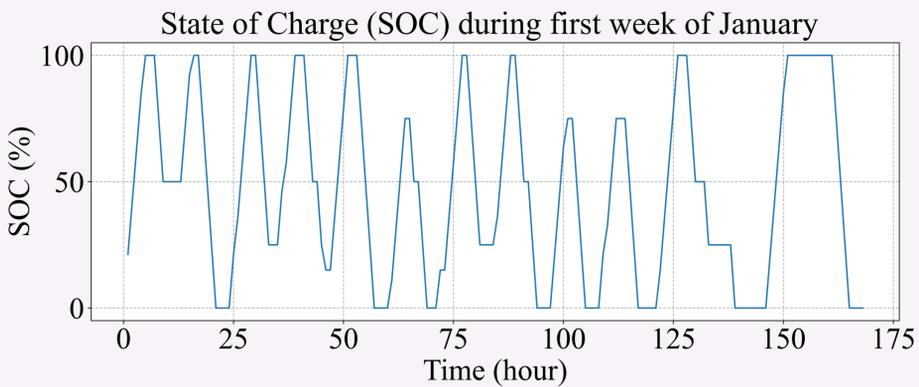
- Developed an optimization model for ESS participation in PJM, targeting revenue from energy arbitrage and ancillary services, including spinning and non-spinning reserves.

Methodologies

- ESS participating in energy arbitrage and ancillary service
- Optimization Formulation:

$$\max \sum_{t=1}^T \left[P_t^{DA} (q_t^D - q_t^R) + q_t^{SR} (MCP_t^{SR} + P_t^{SR,eff}) + q_t^{NSR} (MCP_t^{NSR} + P_t^{NSR,eff}) + q_t^{SecR} (MCP_t^{SecR} + P_t^{SecR,eff}) \right]$$

Subject to: ESS constraints and other constraints



- State of charge at the end of period is maintained same as it was in the beginning of the period

P_t^{DA} = day ahead (DA) LMP for energy at time t [\$/MWh]
 q_t^D, q_t^R = energy discharged, energy recharged at t [MWh]
 $q_t^{SR}, q_t^{NSR}, q_t^{SecR}$ = SR, NSR, SecR capacity at time t [MWh]
 $MCP_t^{SR}, MCP_t^{NSR}, MCP_t^{SecR}$ = DA market clearing price for SR, NSR, SecR [\$/MWh]
 $P_t^{SR,eff}, P_t^{NSR,eff}, P_t^{SecR,eff}$ = effect price for energy at time t [\$/MWh]

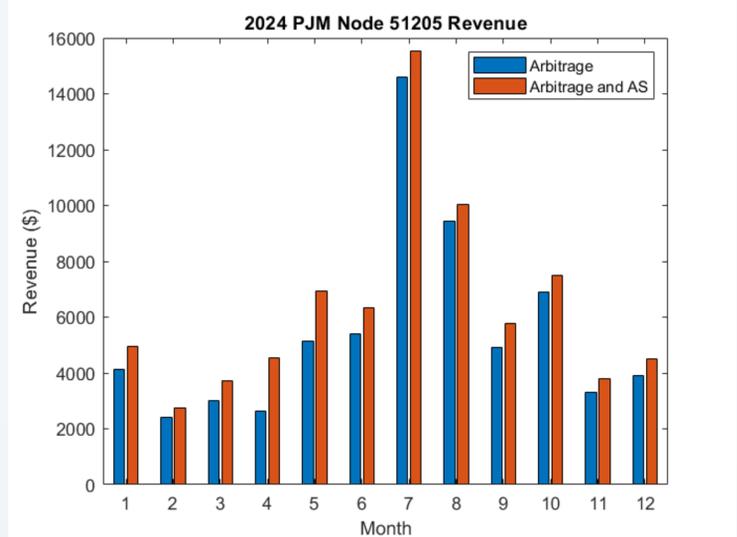
Case Studies/Results

Table 1: Li-ion BESS Model Parameters

Value	Units	Parameter	Description
1	MW	P_{max}	Maximum power rating
4	MWh	\bar{S}	Maximum state of charge
1	MWh	\bar{q}	Maximum quantity that can be charged or discharged in a period t
1.0	Fraction	γ_s	Storage efficiency on SoC
0.85	Fraction	γ_c	Conversion efficiency on SoC
1	Hours	Δt	Time interval

Table 2: Revenue captured by node 51205 in 2024

Month	Arbitrage (\$)	Ancillary services (\$)	Total revenue (\$)
Jan	4,112.63	835.68	4,948.31
Feb	2,408.52	345.31	2,753.83
Mar	3,001.62	730.28	3,731.90
Apr	2,642.17	1,895.41	4,537.58
May	5,144.70	1,788.57	6,933.27
Jun	5,406.52	913.21	6,319.73
Jul	14,604.90	940.20	15,545.10
Aug	9,437.17	603.87	10,041.00
Sep	4,933.00	849.25	5,782.26
Oct	6,915.58	578.01	7,493.58
Nov	3,303.26	496.49	3,799.75
Dec	3,909.45	592.41	4,501.86
Total for year			76,388.20



Next Steps

- Run the formulation on all of PJM's pricing nodes for the year 2024 and 2025.
- Run a break-even capital cost analysis for a ESS participating in PJM's electricity markets.
- Develop the linear programming optimization formulation for PJM's real-time markets (energy and ancillary services).
- Update QuESt Evaluation tool with new market rule and formulation

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