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TECHNICAL BRIEF

Overview of Energy Storage Wholesale Market Participation

KEY INSIGHTS

- All ISOs/RTOs under FERC jurisdiction have largely met FERC Order No. 841 requirements to enable participation of electric storage resources (ESRs) in wholesale electricity markets.
- Since Order No. 841, a surge in ESR participation in wholesale electricity markets across the United States has been observed.
- Top ESR applications were capacity, frequency regulation, arbitrage, and spinning reserve.
- Key challenges exist related to state of charge (SoC) management, interconnection process improvements, capacity valuation, and unique cases for aggregations of large quantities of small storage.

The integration of **electric storage resources (ESRs)** into wholesale electricity markets in the United States, catalyzed by FERC Order 841 in February 2018, has reshaped the energy landscape. ESRs, crucial for grid flexibility and renewable integration, have expanded in key regions where market operators have gained experience on best ways to manage them efficiently and reliably. This insight report delves into their participation, examining key aspects and the evolving landscape in electricity markets across the United States.

OBSERVATIONS AND IMPACTS

1. Increased Participation

Figure 1 illustrates a rising trend, anticipated to intensify through the decade. CAISO and ERCOT lead the way, adding nearly 6.5 GW and 3 GW, respectively, between 2020-23. Other ISO/RTO regions showed modest growth, totaling around 250 MW in 2022 and slightly over 400 MW in 2023.

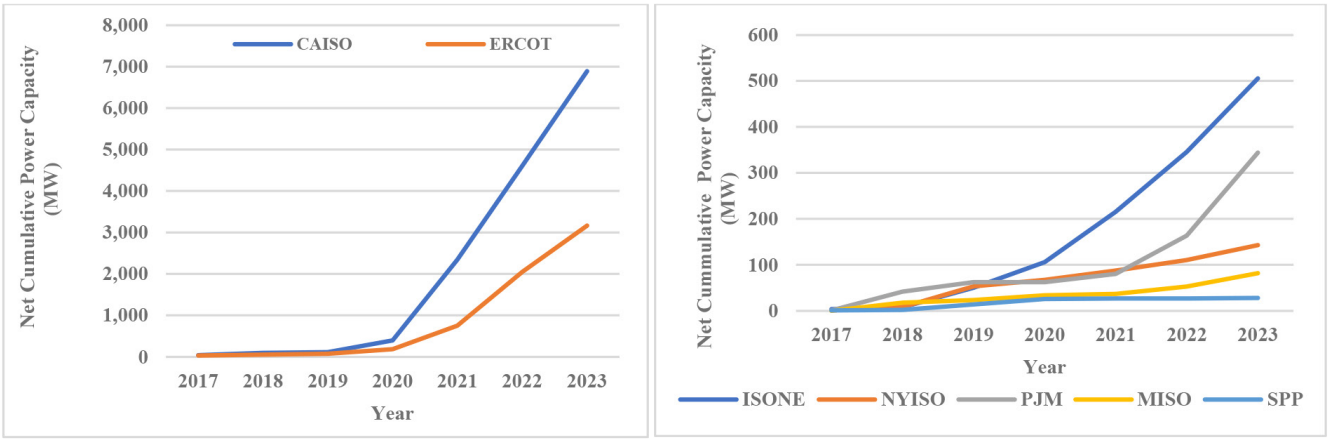

Figure 1: *Net Cumulative Power Capacity of Storage in various ISOs [1]*

2. Storage can Provide Many Services to the Market

Enhanced participation options in U.S. markets offer ESR's increased value stacking opportunities, allowing BESSs to engage in multiple roles.

Figure 2(a) indicates that in 2022, top BESS applications were frequency regulation, arbitrage, and ramping/ spinning reserve. Revenue sources vary among ISOs based on diverse storage applications (Figure 2(b)). Resource adequacy is another key value.

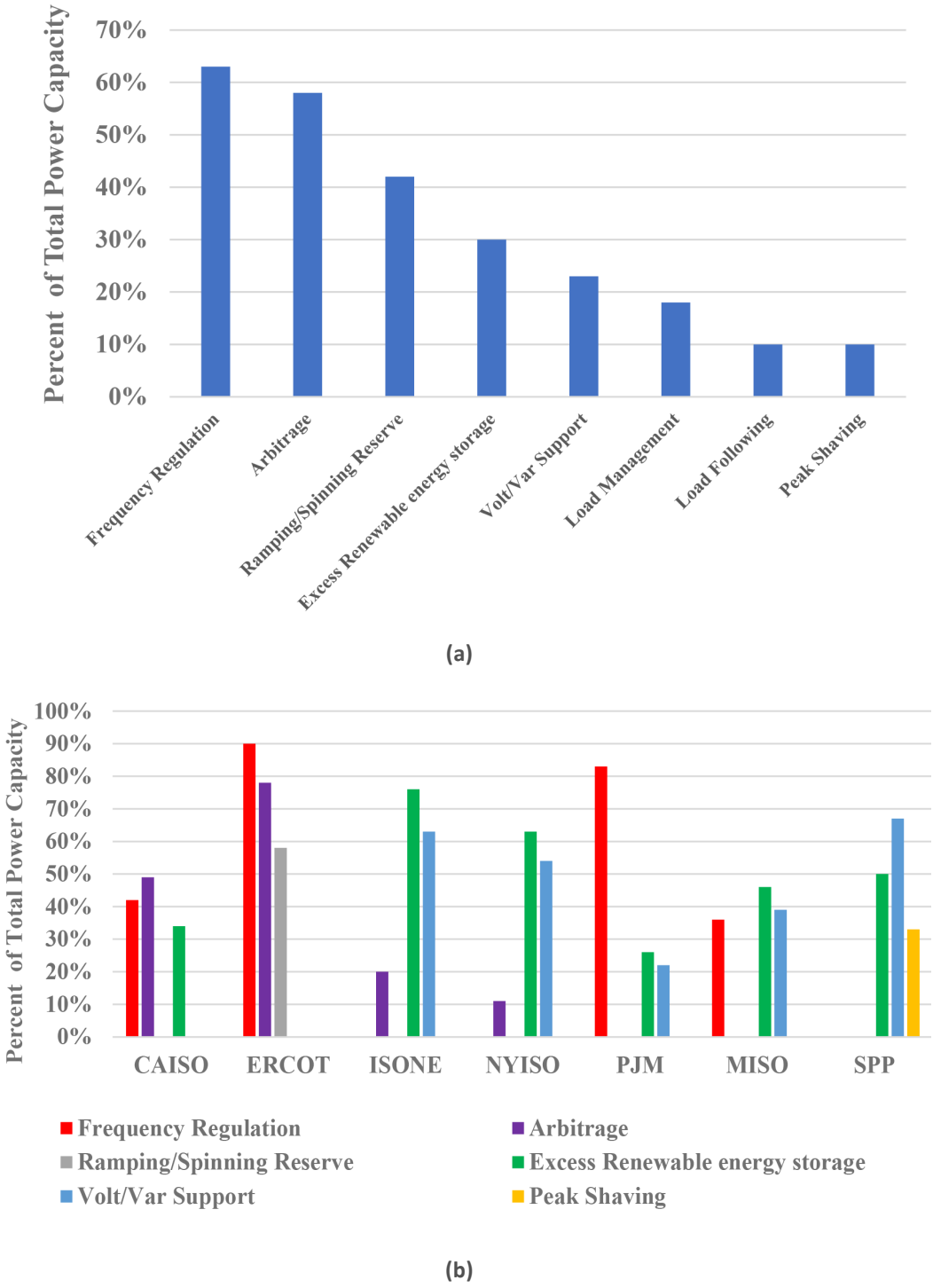

Figure 2. *(a): Various services provided by storage in US markets/grid in 2022; (b) Top three services in various ISOs. [2]*

3. **Enhanced Market Efficiency and Market Innovation**

   (a) **Participation Models:** RTO/ISOs have introduced continuous (e.g., batteries) and discontinuous (e.g., PSH) participation models, incorporating specific bidding parameters and qualification criteria reflecting energy storage resource characteristics.

   (b) **Offer Parameters:** For continuous ESR participation models, a continuous offer curve from charging to discharging provided to the market. This excludes commitment-related parameters but includes charging/discharging ramp and capacity, efficiency, and min/max state-of-charge limits.

   (c) **Pricing and Settlements:** ESRs set wholesale prices while charging or discharging, at nodal levels, and receive make-whole payments for out-of-market dispatch.

CHALLENGES AND GAPS

1. **State of Charge (SoC) Management:** Challenges such as accurate initial SoC estimation, real-time SoC management, and accurate SoC accounting for ancillary services underscore the need for comprehensive enhancements to market design and market clearing software [3].
2. **Long-Duration Energy Storage Participation:** The uncertainty surrounding long-duration energy storage (LDES) arises from questions about its specific use cases, including the necessity for extended and seasonal storage. This includes uncertainties about the value it adds to the grid, its operational roles, and the underlying technology.
3. **Interconnection Processes:** Streamlining storage project interconnection remains challenging, with delays hindering timely ESR deployment.
4. **Capacity Valuation:** Ongoing challenges persist in accurately valuing ESR capacity contribution, particularly in capacity markets, necessitating enhanced assessment methods for fair compensation and resource adequacy.
5. **Market Rules for Aggregators:** Evolving rules for aggregating distributed resources, including storage, pose challenges. Establishing clear guidelines facilitates efficient storage resource participation.

REFERENCES

[1] Battery Storage in the United States: An Update on Market Trends https://www.eia.gov/analysis/studies/electricity/batterystorage.

[2] Storage data 2022, (based on Form EIA-860), https://www.eia.gov/electricity/data/eia860/.

[3] *Storage as a Supporting Actor During Emergency Conditions: Performance Evaluation and State-of-Charge Management Enhancements Under Critical Events.* EPRI, Palo Alto, CA: 2023. 3002026960.

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PROGRAMS

Program 246: Electricity Market Design and Operation

Project Set 178A: Energy System Technology Cost, Performance, and Technoeconomic Analysis

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