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Optimization of Multi-Use Battery Storage Systems under Non-Firm Grid Connection: Quantifying Opportunity Costs and Mitigation through Dynamic Stacking

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Extended Abstract

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Abstract Summary

As battery energy storage systems (BESS) become crucial for the energy transition, limited distribution grid capacity often leads to connection delays. This study investigates Non-Firm Grid Connections (NFGC) as a faster alternative, focusing specifically on the storage operator's perspective to quantify opportunity costs arising from temporary curtailment.

The research introduces an optimization framework based on Mixed-Integer Linear Programming (MILP) to determine the optimal multi-use strategy for industrial BESS. This model co-optimizes behind-the-meter (BTM) applications, such as peak shaving, with front-of-the-meter (FTM) services like arbitrage and frequency reserves. By utilizing rolling-horizon logic and virtual power partitions, the framework allows for dynamic capacity allocation across these services while adhering to regulatory standards.

Results from a techno-economic case study reveal that static grid restrictions significantly harm profitability by blocking lucrative market participation. In contrast, dynamic NFGC approaches—which curtail assets only during actual congestion—minimize financial losses. A key finding is the mitigation effect of dynamic value stacking: during curtailment periods, the system reallocates storage capacity from restricted FTM services to available BTM applications, effectively recovering lost revenue.

Ultimately, the findings demonstrate that the economic viability of BESS is not necessarily jeopardized by non-firm access if flexibility is dynamically managed. This provides a transparent foundation for policymakers and distribution system operators to design incentive-compatible compensation schemes and regulatory frameworks that support decentralized flexibility.

Presenting Author Biography

Research Associate and PhD candidate at Technical University of Applied Sciences Würzburg-Schweinfurt and at the Center for Applied Energy Research. Her research topic is the Techno-Economic Integration of Multi-Use Battery Storage Systems in Congested Distribution Grids.