World Academy of Science, Engineering and Technology
International Journal of Energy and Power Engineering
Vol:19, No:11, 2025

Optimized Integration Of Bidirectional Charging Capacities As Mobile Energy Storages

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Abstract : The integration of renewable energy into the energy grid is essential for decarbonization, and leveraging electrified vehicles (EVs) as mobile storage units offers a pathway to address grid challenges. The decentralized nature of EVs and the intermittency of renewable energy sources, such as photovoltaic (PV) and wind power, complicate grid stability. Vehicle-to-Grid (V2G) technology presents a promising solution, enabling EVs to support grid stability through services like redispatch, congestion mitigation, and enhanced renewable energy utilization. Freight transport, contributing 38% of transport emissions, holds significant potential as its aggregated energy storage capacity can stabilize the grid and optimize renewable energy integration. This study introduces a risk-averse optimization model for marketing EV flexibilities in Germany's energy markets, with a strong focus on improving grid stability and maximizing renewable energy potential. Using a linear optimization framework, the model incorporates technical, regulatory, and operational constraints to simulate EV fleets as scalable energy storage solutions. The integration of proprietary PV and wind energy systems is also modeled to evaluate benefits. Benchmarks compare bidirectional charging with unidirectional charging under dynamic tariffs. The methodology employs the Python-based energypilot tool to optimize participation in Day-Ahead, Intraday, and Redispatch markets, accounting for trading conditions and temporal offsets. Results demonstrate that redispatch utilization substantially supports grid stability, while bidirectional charging increased renewable energy integration by 15% and economic benefits by 20%. Longer charging cycles offered greater financial returns compared to fragmented cycles, emphasizing the potential of fleets with extended idle periods for storing renewable energy. This research highlights the critical role of EVs in stabilizing the grid and utilizing renewable energy effectively by expanding storage capacity. The optimization framework addresses key challenges in energy trading, offering a transferable methodology for broader energy storage applications. This supports the transition to a sustainable energy system by improving environmental outcomes and economic incentives.

Keywords : Electric Vehicles, Energy Grid, Energy Storages, Redispatch
Conference Title : ICEERET 2025 : International Conference on Energy Efficiency and Renewable Energy Technologies
Conference Location : New York, United States
Conference Dates : November 04-05, 2025