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Optimized Marketing of Bidirectional Charging Capacities for Commercial Freight Transport

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Abstract : The electrification of the transport sector is increasingly recognized as a vital strategy for decarbonization. However, integrating electric vehicles (EVs) into the energy grid poses challenges due to decentralized power units and the intermittent nature of renewable energy sources. Vehicle-to-grid (V2G) technology offers a compelling solution by enabling EVs to function as mobile storage units, providing system services, reducing grid congestion, and offering economic incentives. This potential is particularly significant in freight transport, which accounts for 38% of transport-related emissions. The aggregated use of energy storage in this sector can facilitate grid stability and renewable energy integration. Despite this, existing optimization methods for energy markets frequently overlook operational constraints, such as fixed schedules and state-of-charge requirements, while redispatch markets remain underutilized. This study introduces a risk-averse optimization model for marketing EV flexibilities across multiple energy markets in Germany. Using a linear optimization framework, the model incorporates technical, regulatory, and user constraints. EVs are modeled as energy storage units, and the integration of renewable energy sources, such as photovoltaic (PV) and wind energy, is evaluated. To benchmark performance, unidirectional charging with dynamic tariffs is used as the reference scenario. The research examines four distinct logistics depot fleets, each with varying capacities and schedules, to simulate commercial EV operations. The methodology employs a multi-market optimization model that integrates Day-Ahead, Intraday, and Redispatch energy markets, each with specific trading conditions and temporal offsets. The tool, developed using the Python-based library energy pilot by Fraunhofer IEE, also explores scenarios where proprietary renewable energy sources are incorporated to maximize benefits. By accounting for charging schedules, market requirements, and technical constraints, the study aims to enhance grid stability and improve economic outcomes and integration of renewable energies. The findings highlight the economic, environmental, and grid-related advantages of optimizing EV flexibility. Compared to the reference scenario of unidirectional charging, bidirectional strategies delivered an approximate economic benefit of 20%. Furthermore, the integration of proprietary renewable energy sources increased by 15%, demonstrating the potential for environmental gains. The study revealed that the duration of a single charging cycle has a greater impact on economic benefits than the total daily charging time spread across multiple cycles. This underscores the marketing potential of vehicles with extended idle times rather than frequent charging cycles. In conclusion, optimizing energy trading through flexible EV portfolios and efficient charging infrastructure offers substantial cost savings, particularly by increasing the number of charging stations and extending charging cycle durations. By leveraging multiple marketing options, high investment costs can be offset through enhanced revenues. Further gains could be achieved by simultaneously optimizing all trading options, though this approach introduces risks from price volatility and unreliable redispatch capacities. As electrified trucks are modeled as energy storage units, the study's findings are applicable to other forms of energy storage, offering a scalable and transferable framework for future energy systems.

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