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OPTIMIZING ENERGY BALANCING AND FLEET ELECTRIFICATION THROUGH INTELLIGENT CHARGING SYSTEMS: A DATA-DRIVEN APPROACH FOR SMALL-SCALE ENERGY STORAGE AGGREGATORS

Aivars RUBENIS^{1*}, Ģirts ALEKSĀNS², Aigars LAIZĀNS³

^{1,3} Latvia University of Life Sciences and Technologies, Lielā iela 2, Jelgava, LV-300, Latvia

² PC Consulting, Svēteju iela 2, Stūnīši, Olaines nov., LV-2127 Latvia

* **Corresponding author.** Email address: aivars.rubenis@ivorygroup.eu

Abstract – The rapid electrification of transportation necessitates the development of intelligent energy management solutions to ensure the efficient operation of electric vehicle (EV) fleets while maintaining grid stability. Traditional energy balancing methods primarily target large-scale power systems, leaving smallscale energy storage aggregators – such as distributed EV charging hubs – without effective optimization frameworks. This paper presents a data-driven approach to optimizing fleet electrification and energy balancing through an intelligent IT system that integrates distributed energy storage with real-time charging coordination. We propose a mathematical optimization model that dynamically adjusts charging strategies based on energy availability, grid demand, and fleet operational requirements. By integrating ISO 15118 communication standards with advanced energy balancing algorithms, our system enables realtime interaction between EVs and the power grid, allowing vehicles to dynamically adjust their charging rates based on grid conditions and electricity pricing. ISO 15118 facilitates seamless authentication and bidirectional energy transfer, while energy balancing algorithms optimize fleet-wide charging schedules to distribute load efficiently. This synergy reduces peak demand stress by preventing simultaneous high-power charging events and minimizes charging costs by leveraging off-peak tariffs and vehicle-to-grid (V2G) capabilities. The proposed model is validated through simulation-based case studies, demonstrating up to a 20–30 % improvement in energy efficiency and a reduction in grid dependency compared to conventional unmanaged charging strategies. The results highlight the potential of IT-driven energy balancing solutions in enhancing the sustainability and cost-effectiveness of fleet electrification. This research contributes to the broader transition toward decentralized energy management, offering actionable insights for fleet operators, energy providers, and policymakers. Future work will explore real-world deployment and machine learningdriven predictive optimization to further enhance system performance.

Keywords – Demand response in Electric vehicle (EV) charging; grid-aware charging; ISO 15118 and energy balancing; time-of-use pricing optimization; vehicle-to-grid (V2G)

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