D4.3: Optimization and control strategies

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1. Executive Summary

This deliverable reports on the development and validation of smart charging and V2X control and optimization strategies addressing both planning-level assessment and real-time operation. The work spans multiple system layers, including vehicle and thermal subsystems, charging point and aggregation management, microgrid operation, and grid interaction, with the overall objective of improving grid stability, increasing the utilization of local renewable energy, and ensuring user satisfaction across diverse charging scenarios.

At the planning stage, in a simulation framework, advanced optimization tools based on optimal control were developed to assess low-power and fast-charging strategies under technical and economic constraints. Automated scenario generation and large-scale testing capabilities enable systematic evaluation of key performance indicators such as grid energy consumption, energy exchanges among system components, and operational costs. These tools were validated using a combination of real (non-real-time) and synthetic data and were complemented by demand response strategies to assess the interaction between charging and grid flexibility options.

For real-time operation, smart charging and V2G control strategies were implemented and validated within a microgrid context integrating bidirectional EV charging, energy storage systems, and local renewable generation. Real operational data from charging infrastructure and on-site photovoltaic systems were used to optimize power flows between EVs, storage, and the main grid, prioritizing self-consumption of renewable energy while maintaining grid stability and user satisfaction. These strategies were further supported by digital twin environments enabling monitoring, validation, and performance analysis.

At the charging infrastructure and aggregation level, smart charging and V2G strategies were developed to coordinate multiple vehicles while balancing user requirements and grid constraints. The control approaches were validated using real-world V2G data and extended to virtual demonstration environments representing urban on-street parking scenarios, supporting scalability analysis in smart city contexts.

In parallel, dedicated control strategies for thermal batteries and vehicle energy systems, including HVAC operation, were designed, implemented, and optimized. These developments enhance overall system energy efficiency and enable the coordinated integration of thermal and electrical subsystems within comprehensive smart charging and V2X frameworks.

To address uncertainty and variability, stochastic prediction algorithms based on historical time-series data were developed and evaluated. Multiple advanced prediction methods were compared in terms of accuracy and robustness, providing reliable inputs for informed control and optimization decisions.

Finally, advanced eco-charging and routing strategies were developed to support grid-friendly charging behaviour. These include detailed mathematical modelling of routing options, vehicle powertrain dynamics, and energy and speed profiles for both light-duty

and heavy-duty vehicles. Optimization algorithms were designed, extended to more complex vehicle models, and evaluated under various scenarios, including those based on real data, to assess performance, robustness, and computational efficiency.

This work has been performed by EUT, AIT, FEV, RTWH, IFPEN, ABB and ABEE.

Keywords: V2G, Optimization, Simulation, Prediction, Artificial Intelligence, Machine Learning, V2X, Smart Charging