Optimal Sizing and Annual Operation of Stationary Batteries in EV Park-and-Ride Facilities Considering Charge/Discharge Cycles

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Introduction

The decarbonization of the transportation sector is essential to achieve Japan's target of reducing greenhouse gas emissions by 46% by 2030 under the Paris Agreement. In Okinawa, limited public transportation and frequent traffic congestion from private vehicles increase CO_2 emissions. This study investigates Park-and-Ride (P&R) electric vehicle (EV) charging station powered by renewable energy such as photovoltaic (PV) and wind generation (WG), aiming to reduce CO_2 emissions while improving annual profits. The study applies model predictive control (MPC) to manage renewable generation uncertainty in simulation-based optimization. It also highlights the role of battery energy storage systems (BESS), which reduce grid purchases and CO_2 emissions, and examines annual operation in terms of charge/discharge cycles to evaluate long-term sustainability [1].

System Model and Optimization

The proposed P&R EV charging facility is shown in Fig. 1. It consists of PV units rated at 500 kW, WG units at 250 kW, and BESS at 200 kW/1200 kWh, with grid connection for electricity trading. EVs are grouped by charging priorities and fees to reflect diverse user needs.

The study formulates an annual cost minimization problem that considers equipment investment, electricity purchase, and revenues from EV users. Decision variables are the capacities of PV, WG, and BESS and the BESS charge/discharge schedule. MPC with a 96 hour horizon and a 24 hour cycle supports scheduling under renewable uncertainty.

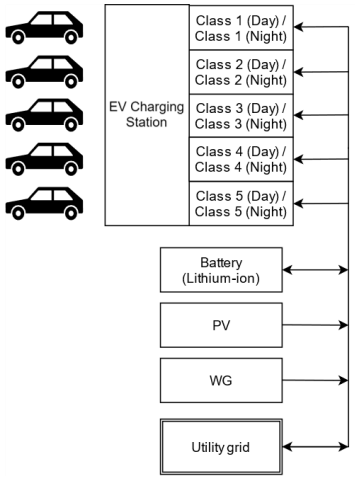

Fig. 1. Charging Station System Model.

Results and Discussion

The annual simulation (April 2019 to March 2020) used meteorological data from the Japan Meteorological Agency. Fig. 2 shows Pareto fronts of annual profit versus CO_2 emissions under different BESS capacities. Increasing BESS reduced grid purchases and CO_2 emissions, but raised costs due to investment.

Annual charge/discharge cycles remained around 100, giving capacity loss of about 1%, so degradation was negligible. Although CO_2 reduction could in principle raise profits under carbon pricing, Japan's low CO_2 price meant little impact on annual profit. These results highlight trade-offs between cost, emission reduction, and battery sustainability, and provide useful insights for designing environmentally conscious and economically feasible EV charging station.

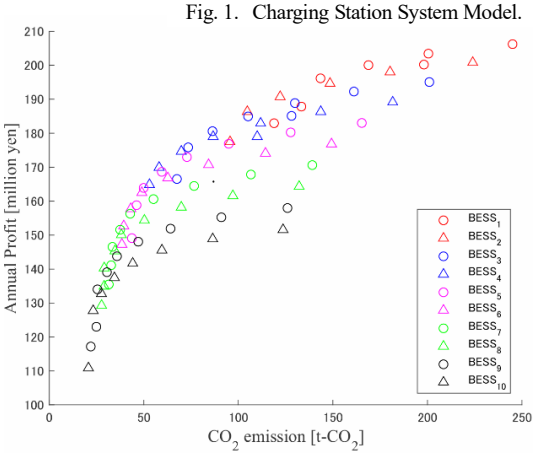

Fig. 2. Simulation Results.

Acknowledgement

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References

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