BUSINESS FEASIBILITY ASSESSMENT OF VIRTUAL POWER PLANT USING SIMULATOR: IMPACTS OF EV CHARGE/DISCHARGE AND ELECTRICITY MARKET TRADING

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Overview

Maximum use of distributed energy resources (DERs) is expected towards the realization of a low-carbon society. Deploying virtual power plant (VPP) is one of useful systems for the low-carbon society. In this study, VPP business feasibility assessment simulator is developed and applied to smart meter data pertaining to Utsunomiya City in Japan. The impact from utilizing EV charge/discharge and electricity market trading on electricity cost reduction in the VPP area is investigated through the simulation.

Methods

The simulation flow is described in Figure 1. The objective function of the simulation is to minimize the cost of electricity in the VPP area. The simulation assumes the VPP holds solar power generation and electricity is traded between the VPP and the day-ahead spot market. The time unit for optimization is 96 half-hour periods over two days, which we enhanced the simulation capability from [1] to incorporate extended maximum time units for the planning period. The results of the first 48 half-hour periods are stored and the same calculation is repeated, shifting by one day. This allows the electricity stored in the EV to be carried over to the next day for effective use. This objective function is optimized under various constraints to formulate a feasible plan.

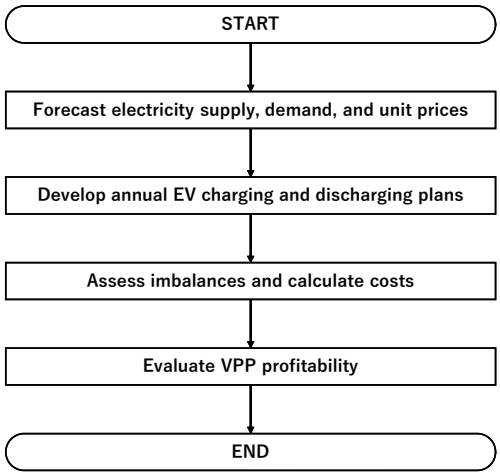

Fig. 1: Simulation flow.

This study uses smart meter data from the 1st of April in 2022 to the 30th of September in 2023 in Utsunomiya City in Japan. From a statistical analysis of the data, we identify trends in electricity demand for high-voltage and extra-high-voltage consumers, and low-voltage consumers. As for the former group, more consumers are observed in the 'no reverse power flow' category, which consumes a smaller volume of electricity, while for the 'with reverse power flow' category, fewer consumers are observed, but they consume a larger volume of electricity. A similar trend is observed for the low-voltage consumer group. In particular, a marked difference between the two categories, with and without reverse power flow, is presented in winter, when the outdoor air temperature is low. In addition, to improve the simulation accuracy, we compile EV driving data to calculate EV driving demand from statistics of person trip origin-destination (OD) volume data. The OD data is published by the Ministry of Land, Infrastructure, Transport and Tourism (MLITT).

Statistical mesh information of the smart meter for low-voltage consumers provides us with the annual electricity consumption and sales. From the data observation, this study identifies that the 'Yui no Mori' area is high in reverse power flow and electricity sales. Therefore, the simulator of this study set the 'Yui no Mori' as the VPP verification area, and a business feasibility assessment is conducted based on the predicted values such as electricity supply and demand and market prices.

For the Yui no Mori area, the number of meters in the low-voltage category is regarded as the number of households, which is multiplied by the average number of cars owned by households to estimate the total number of EVs in the area. The EV penetration rate is set at 1.1%, which is assumed from the actual statistics for Utsunomiya City. The number of trips by time and the distance traveled are calculated from distributions of frequency and trip distance by trip purpose generated from the OD data. The PV installed capacity is estimated by multiplying the households with reverse power flow by the average PV installed capacity of 4.8 kW.

Results

We set four EV options and combinations among them as comparative cases. The case in which the supply-demand balance is not adjusted by EV charge/discharge is the “Base Case,” and the case in which all of these options are utilized is the “Best Case.” From the simulation results, it is noted that the fulfillment of demand by generation in the VPP area increases from 32.9% in the Base Case to 40.6% in the Best Case, while the total annual costs show a reduction of approximately 50% from the Base to the Best cases. These differences can also be observed in the electricity trading for an example time period of autumn in 2022: in the Best Case, compared to the Base Case, there are several time units where electricity is sold at higher market prices, contributing to a reduction in the total cost of electricity in the VPP.

Conclusions

We developed a VPP business feasibility assessment simulator and examined the cost savings from using EV charge/discharge and electricity market trading. The simulator was applied to the smart meter data from Utsunomiya City in Japan, particularly focusing on the area with high reverse power flow. The simulator confirmed supply/demand adjustment by EV and market trading could contribute to cost reduction in the VPP area. Future issues include examining the influence of user behavior in EV charge/discharge and extending the trading function to the supply-demand adjustment and the hour-ahead markets.

References

[1] Mika Goto, Tomoki Inoue, Daishi Sagawa, “Development and application of VPP business model simulator considering EVs and electricity market trading,” Proceedings of the 43rd Energy System, Economic, and Environment Conference, University of Tokyo, Japan, June 2024.