Virtual Power Plants Using Electric Vehicle and Plug-in Hybrid Vehicle Batteries

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Sumitomo Electric Industries, Ltd. has conducted a virtual power plant pilot program jointly with Nissan Motor Co., Ltd. and Kansai Electric Power Co., Inc. (KEPCO). In this project, 60 electric vehicles (EVs) parked at home and KEPCO were linked to the virtual power plant demonstration system, which simultaneously controls vehicle battery charge. This system is expected to enable the effective use of renewable energy, mitigating its output fluctuation. Through the adjustment of power supply and demand, we will add value to EVs.

Keywords: virtual power plant, VPP, charge control, electric vehicles

1. Introduction

Renewable energy has become more common in Japan in recent years, and the percentage of renewable energy sources within domestic power generation as a whole reached 7% in 2016.(1) Renewable energy is an important type of energy source as it does not emit CO_2 during the generation process and contributes towards the country's self-sufficiency in energy. However, one downside is the fluctuations in power output, usually depending on the weather. In particular, in areas where solar power is widely used for generation, the daytime electricity supply to users tends to be redundant, although a rise in power consumption is observed in the early evening when residents return home.(2),(3) Securing a balance between supply and demand in such an area is an imminent issue to be addressed.

Approaches to balancing this supply and demand include controlling the volume of electricity generated by thermal power plants etc. In addition to this, a new approach has been the focus of attention in recent years, which is the utilization, as a power system, of demand-side energy equipment, including accumulators, electric vehicles (EVs), and "negawatt" power (saved electrical power) across the country. Although the capacity of an individual energy device is small, in mass they can provide a capacity comparable to a single power station if they are managed in an integrated manner utilizing Internet of Things (IoT) technology. This is known as a "virtual power plant" (VPP).(4) This approach is expected to help stabilize the balance of electricity supply and demand by setting such energy devices to charging mode in order to store excess electricity when the supply is in surplus during the renewable power generation, and then switching off the charging mode all together when demand rises.

Sumitomo Electric Industries, Ltd. participated in the 2017 Virtual Power Plant Configuration Demonstration Project Utilizing Consumers' Energy Resources, a project subsidized by the Agency for Natural Resources and Energy under the Ministry of Economy, Trade and Industry (METI). In this project, together with Kansai Electric Power Company, Inc. (KEPCO) and Nissan Motor Co., Ltd. (Nissan), Sumitomo Electric has configured a system that comprehensively manages multiple EV batteries as an energy device.(5) This paper reports our achievements in this project.

2. System Overview

2-1 Power charge remote control system

To utilize the energy devices owned by electricity users as a VPP, a server that manages and controls these devices in an integrated manner is necessary. In our system, the energy devices to be managed are specifically EV batteries—thus we developed an EV server for that purpose. The EV server submits a charging mode control signal to individual households based on the VPP order received from the VPP server of KEPCO, which controls the overall balance of electricity supply and demand. We also developed an EV switch and a network device (gateway) to remotely control the charging mode of the EVs. These switches and network devices were then installed at multiple locations within the demonstration test area mainly in Kansai (West Japan). The entire system could control the charging mode of 60 EVs as shown in the following Table 1.

Table 1. EVs used in the VPP demonstration test

Demonstration locations & vehicles	No. of vehicles
Business-use cars	42
Commuting cars*	10
Private cars	8

* Cars charged at business premises

2-2 Consideration of EVs when being driven

The period when EVs are actually traveling must be taken into account when considering utilizing EV batteries for a VPP. During the time that an EV is being driven, and therefore disconnected from the EV switch, obviously the charging mode cannot be switched on or off. Thus, if the number of disconnected EVs is large, the expected volume of electricity may not be secured. At the same time, it is important not to lose the original function of EVs as a means of transport, for example, by avoiding EV usage when going out for the sake of securing the required volume of electricity. Achieving both of these functions—to balance electricity supply and demand and as a means of transport—would be an issue to be addressed in real-life operations.

To solve this issue, Sumitomo Electric has developed the following two mechanisms, as shown in Fig. 1. One is a mechanism to coordinate the EV server, which controls EV power charging, and Nissan's telematics server, which collects vehicle information from EVs. The other is a smartphone app to enable EV owners to indicate their availability to participate in the central charging control system.

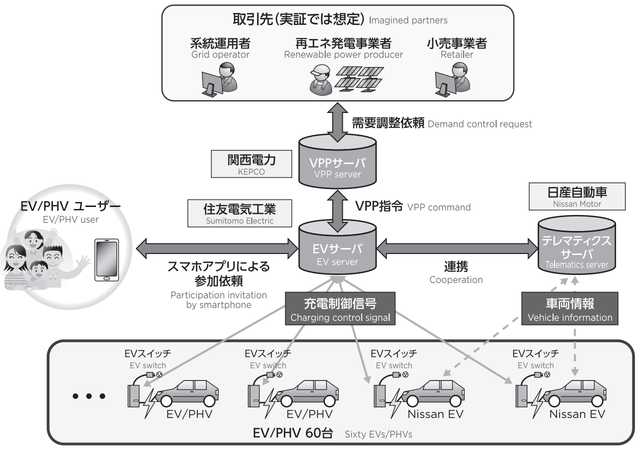

Fig. 1. Configuration of VPP demonstration system utilizing EVs

3. Demonstration Test Details

3-1 Test method

Based on the use cases(6) presented in the Energy Resource Aggregation Business Working Group under METI, two control types were adopted to balance the electricity supply and demand in the demonstration test of the VPP system configured as described above. One control is Demand increasing Response that commences energy charging when the electricity supply from solar power plants is surplus during the daytime; and the other is Demand reducing Response (negawatt) that turns off charging in the early evening when energy demand becomes high (Table 2).

Table 2. Electricity supply and demand balancing in the test

Control types	Test dates and time	Control contents
Demand increasing Response	12:00-13:00, Feb 20, 2018	Turning on charging mode
Demand reducing Response	17:30-18:30, Feb 21, 2018	Turning off charging mode

On both occasions, the EV owners were asked whether they were available to be included in the central charging control test, and the central control was conducted only on those EVs of owners that had indicated their availability.

3-2 The result of Demand increasing Response

Changes in the EV charge demand on the Demand increasing Response test day are shown in Fig. 2. The graph also shows the EV charge demand of a normal day (average demand over five weekdays) with a dotted line. During the Demand increasing Response period between 12:00 to 13:00, the command to turn on power charging was submitted to 52 vehicles and achieved an approx. 48 kW demand increase compared with the normal average. It is assumed that the actual contributors to the increase were 32 vehicles. The reason why there was a gap between the number of vehicles to which the command was submitted and the number of actual contributors may have been because some of the vehicles were already fully charged, and some of the other vehicles were not connected to the switches as they were being driven.

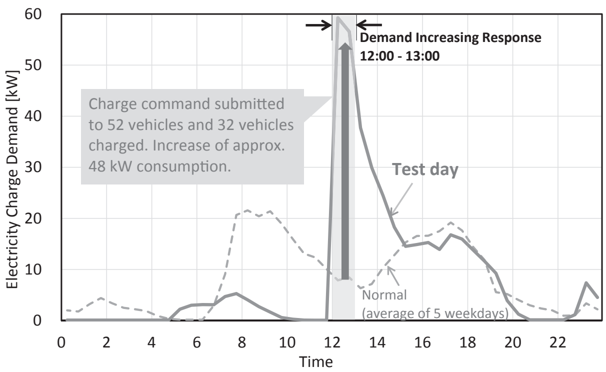

Fig. 2. Changes in charge demand in the Demand increasing Response test (out of 60 vehicles)

3-3 The result of Demand reducing Response (negawatt)

Changes in the EV charge demand on the Demand reducing Response (negawatt) test day are shown in Fig. 3.

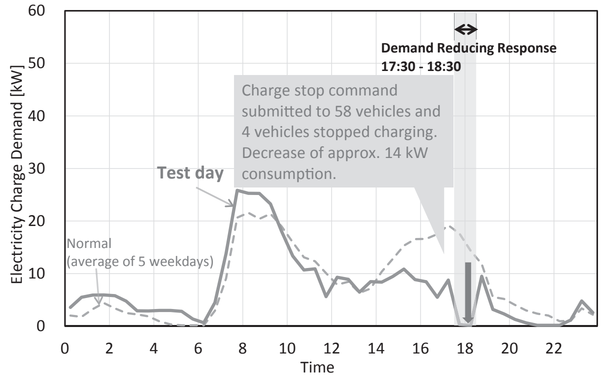

Fig. 3. Changes in charge demand in the Demand reducing Response test (out of 60 vehicles)

During the Demand reducing Response period between 17:30 to 18:30, the command to turn off power charging was submitted to 58 vehicles and achieved an approx. 14 kW demand reduction compared to the normal average. Since the electricity charge demand is reduced to 0 kW by a negawatt command, we can say that the difference between the normal charge demand and the test day demand was a successful reduction in demand.

3-4 Connection with the telematics server

During the test period, we confirmed that the EV server could receive the vehicle information from the telematics-ready EVs through the telematics server. As described earlier, not all the controlled EVs were available for balancing electricity supply and demand either due to their battery being fully charged or their connection status to the switch. To correctly estimate the volume of consumption that can be controlled, utilization of the vehicle information gathered would be critical. To further improve the control accuracy, we would need to determine the details of the necessary types of information to be collected and the frequency of information gathering.

4. Conclusion

The key to establishing a VPP as a business is how we can control a high number of the EVs that are owned by electricity users scattered across different locations as a single resource in order to manage the electricity demand. To promote the practical usage of VPPs, it would be important to attain a more accurate estimate of controllable demand and optimize the control mechanism, taking account of battery charge levels and whether the EVs are in use or not, securing the convenience of EV owners, and maintaining the original function of the EV as a means of transport.

We built a system that connects a telematics server and EV owners' smartphones for the demonstration test, and the test provided us with useful data and technological insights for the future. We plan to analyze such data and further study how we can increase the accuracy of power control. We will also refine the technology to control a greater number of energy equipment in an integrated manner and address any business issues towards realizing practical VPP usage. We hope to develop this prototype into an enhanced electricity demand control system and further promote usage of renewable energy, which will contribute to efficient energy usage across the whole of society.

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