ANALYSIS OF EXPANDED ALLOWABLE CAPACITY OF WIND POWER IN POWER GRID BY CHARGE CONTROL FOR PLUG-IN HYBRID ELECTRIC VEHICLES

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Overview

The total capacity of wind power generations connected to power grids has been increasing in Japan. However, wind power generations can affect the power system frequency negatively, because the output of wind power changes drastically depending on the wind conditions. In particular, the problem of the frequency fluctuation becomes significant at night-time, when the capacity of Load Frequency Control (LFC) tends to be insufficient.

On the other hand, Plug-in Hybrid Electric Vehicle (PHEV) is being developed as environment-friendly vehicles in transport sector. PHEV is a kind of hybrid electric vehicles (HEV), which can be charged from power grid and can drive several tens of kilometres in an electric driving mode. The electric energies of PHEVs are mainly charged during night-time when the electricity price is low and the utilization ratio of car is low; hence, we proposed a charging power control of batteries installed in PHEVs to keep the demand-and-supply balance. The charging power control compensates the LFC capacity at night-time. As for the output change problem of wind power generations, useful techniques have already been proposed; for example, there is using charge and discharge of the battery. The remaining main topics are the following:

(1) When equipment cost increases by the newly added battery, the economic efficiency deteriorates.
(2) It is necessary to manage the charge and discharge balance of the battery under operating condition.

The advantages of using the battery of PHEV are as follows:

(1) Additional equipment cost would be only a charge controller, if PHEVs spread.
(2) It is no necessary to manage the charge and discharge balance of the battery under operating condition because the PHEVs discharge in electric driving mode.

In order to introduce wind power generations on a large scale, there are variety of issues that must be examined such as short period fluctuation, long-term fluctuation, and voltage variation. In this study, we focused on the problem of short period fluctuation (5-20 minutes).

Methods

We assumed the linear characteristics of charging power control (Fig. 1). PHEVs charge at 500W per car when the frequency is 50Hz; then, PHEVs decrease the charging power with decreasing frequency and increase the charging power with increasing frequency. There is no voltage rise caused by a reverse-current because PHEVs control only the charging power.

We made three area models in Japan. Table 1 shows the number of passenger vehicles and minimum demands in each area. Figure 2 shows the daily charge curves under 100 percent market share in PHEVs. This curve is calculated from the following assumptions:

(1) The battery on board a PHEV is 4.3kWh, which corresponds to 30km of all electric-driving range.
(2) The batteries are charged when PHEVs are parked at home.
(3) The batteries are charged during night-time by using a timer
(4) Charging power is 500W with 10% energy loss.
(5) PHEVs start electric-driving mode every morning; then, after the running distance exceeds all electric-driving range, PHEVs will run on hybrid mode.

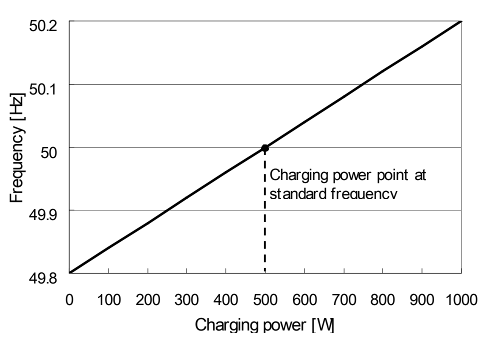

Fig.1. Characteristics of charge control.

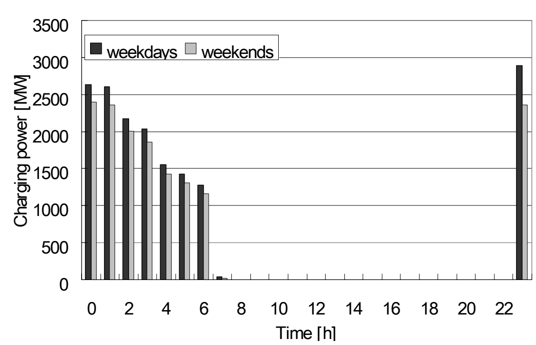

Fig.2. Charge pattern of a day in area C.

Table 1. Number of passenger vehicles and minimum demands.

Area	Number of passenger vehicles [1,000]	Minimum demand [MW]
A	2,400	2,513
B	5,410	6,320
C	7,640	6,085

Results

Figure 3 shows the simulation result of frequency change when 1200MW of wind power generations are introduced into "Area C". It is clear that charging power control for PHEVs can suppress the frequency deviation effectively. Figure 4 shows the Standard Deviation (SD) of frequency to charging power in "Area C". It is apparent that the SD of frequency decreases with increasing charging power. The SD of frequency without wind power has resulted in 0.042Hz, which is referred to as "reference case". When the SD of frequency becomes same level as reference case, we would judge the introduction of wind power generations as no problem in terms of frequency quality. Figure 5 shows the result of needed charging power to keep the frequency quality at same level as reference case. The minimum value of the charging power during the night-time is about 1100MW at 6:00 (Fig.2). Therefore, the allowable capacity of wind power generations is equal to 2800MW (Fig.5). Similarly, the allowable capacity of wind power generations in area A and B is 1100 and 2000MW respectively.

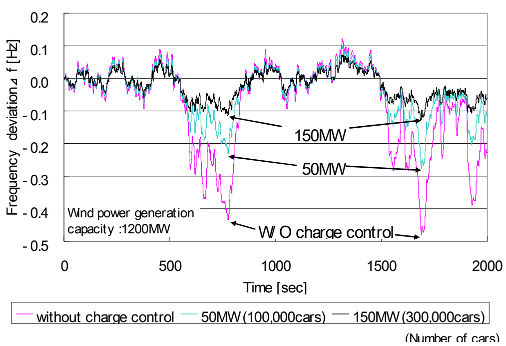

Fig.3. Frequency deviation in area C.

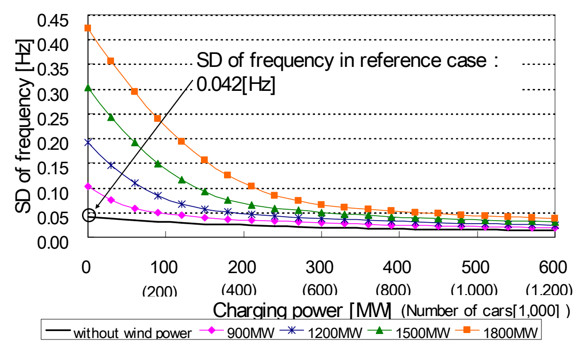

Fig. 4. Standard deviation (SD) of frequency to charging power in area C.

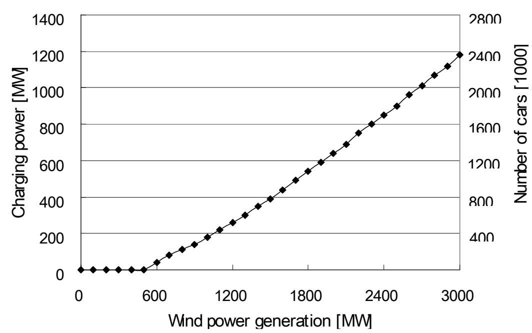

Fig.5. Needed charging power to keep the frequency quality same level as reference case in area C.

Conclusions

The authors obtained the following results.

(1) Charging power control can effectively suppress the frequency deviation caused by the fluctuation of wind power outputs.

(2) Current frequency quality can be maintained by the charging power control with 30-50 percent of capacity compared to the rated outputs of wind power generations.

(3) Charging power control can solve the problem of the short period fluctuation, and can be the effective measure for introducing renewable energies.