Priority Subjects — **Development of a Supply/Demand Infrastructure for Next-Generation Electric Power**

Acceleration of Electrification with Electric Vehicles and Secondary Battery Systems

Background and Objective

As countermeasures to global warming issues, the introduction of a low carbon electric power supply and promotion of energy-saving are important. The electrification of the public welfare and transportation sectors, which increase energy consumption and carbon dioxide emissions, is effective for energy-saving. In this project, a policy is proposed for acceleration of popularization of electric vehicles (EV) and charging technologies are developed to provide safety and high performance in the transportation sector. Moreover, a hybrid energy storage battery system with a heat pump hot-water supply system for residences is proposed in the name of electrification in the public welfare sector involving utilization of secondary battery technologies.

Main results

1 Expansion of a layout optimization model for EV charging infrastructure

In a questionnaire on EV/PHV (plug-in hybrid cars) targeting residential users, "Too short mileage per each charge", "Not enough charging equipment on roads and in cities", etc. are mentioned as points of dissatisfaction (Y12029). Therefore, we have developed a driving range model to exhibit the area where EVs can reach using a EV driving mileage simulation code, and have established a layout optimization model for EV charging infrastructure by utilization a traffic simulator. In the layout optimization model for EV charging infrastructure, we expanded the function to take into account the effects of increasing energy consumption and recharging by regeneration when an EV goes up and down a mountain road respectively, which inputs altitude information on road map data. Consequently, it was clearly shown that there was a need to install quick charging stations a high density in mountainous areas. Furthermore, we estimated the optimum layout of quick charging stations, and summarized the installation priority of quick charging stations as (a) major city area, (b) major urban area, (c) trunk roads interconnecting cities, and (d) peninsula areas or high altitude areas. Figure 1 shows the result of an optimum layout of quick charging stations using a traffic simulator in Okayama and Tottori prefectures*1.

2 Develpment of a bi-directional inductive charging technology

A bi-directional magnetic-resonant power transfer setup was developed, whereby the secondary circuit had the same inverter as the primary one. The setup was a combination of four spiral coils and inverter assemblies used in commercial hybrid electric vehicles (Fig. 2). By increasing a voltage up to 429 V with a boost converter included in the primary assembly, the setup delivered a DC power boost to 1.5 kW with power efficiency*2 of 71 % although the coupling coefficient between the primary and secondary circuits was only 0.1. Since a calculation model including internal-resistors of the coils was in good agreement with the experimental results, we concluded that a Joule heat emitting from the coils mainly determined the transfer loss (Fig. 3).

3 Hybrid energy storage battery system with a heat pump hot water supply system for residences

We developed a time-shift control method for a residential hybrid energy storage battery system with a heat pump hot-water supply system. This method is effectively used for improving the COP (coefficient of performance) of heat pumps by practical application of outside and water temperatures, and for suppression of radiation energy losses from the hot water tank. We constructed a simulation program for the estimation of year-round effect of energy-saving by our residential hybrid energy storage battery system under several conditions with load-pattern data of hot water supply and outside temperature data. We verified the estimation data in comparison with the experimental data of our prototype system, subsequently providing it as an estimation tool.

*1 This study of "Analysis on Optimum Layout of EV Charging Stations (2013)," is supported by Next Generation Vehicle Promotion Center.
*2 (Power Efficiency) = (The secondary DC power) / (The primary DC power)

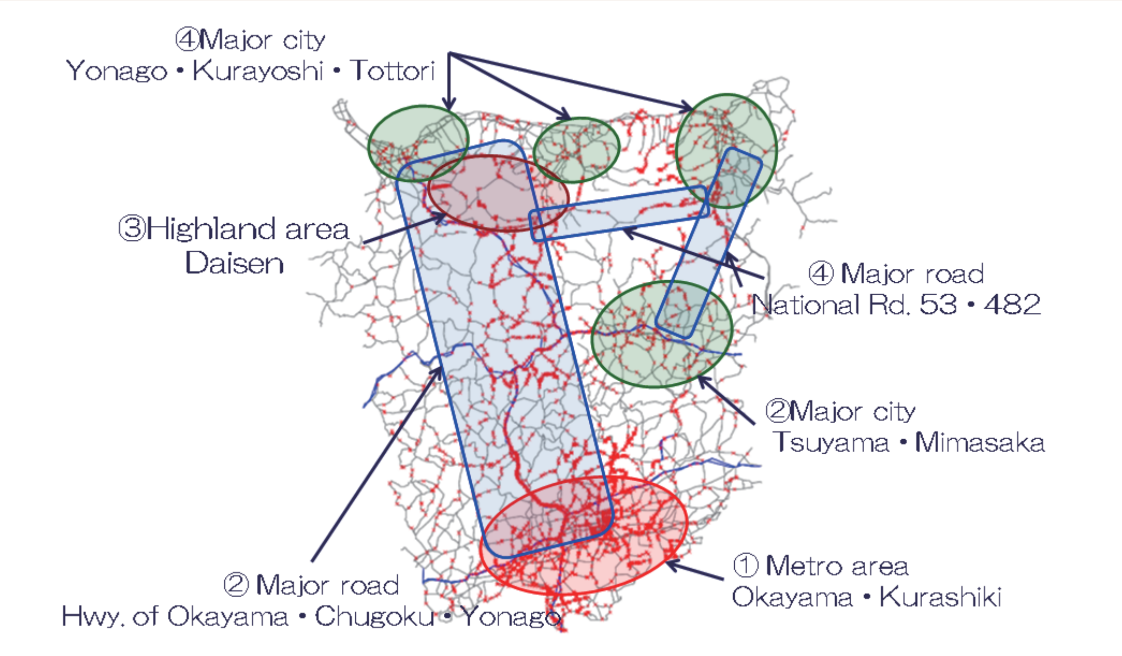

Fig. 1: Result of an optimum layout of quick charging stations by a traffic simulator in Okayama and Tottori prefectures

Using a traffic simulator in Okayama and Tottori prefectures, we analyzed the optimum layout of quick charging stations which prevents EV batteries from running flat. It turned out that in order to install quick charging stations, the 1st installation should be in the major city of Okayama, the 2nd along the trunk road of Okayama-Chugoku-Yonago highway, and core cities of Tsuyama and Mimasaka, the 3rd to the Daisen mountain area, and the 4th to the core cities of Yonago, Kurayoshi, and Tottori.

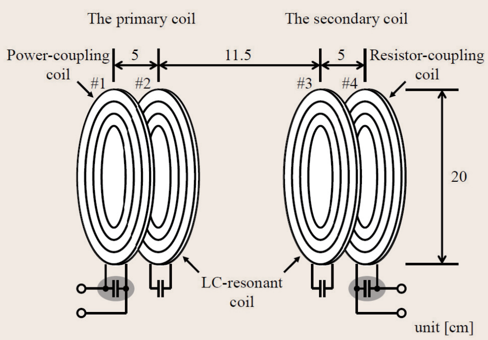

Fig. 2: Alignment of high-frequency coils for bi-directional magnetic-resonant power transfer

By using four spiral coils, the transferring circuit had a series of three transformers. Coupling ratios between the first and the second coil, and between the third and the fourth coil were 0.2. Coupling ratio between the second and third coil was 0.1. Thus the symmetry circuit assured a bi-directional power transfer.

*(Coupling ratio) = (Mutual inductance)/(Self inductance)

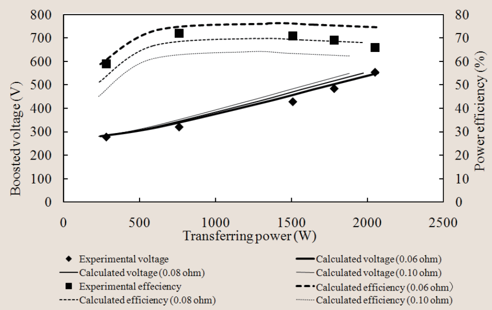

Fig. 3: Boosted voltages fed into the primary inverter and efficiencies measured at different power transfers

By increasing the voltage up to 429 V with a boost converter included in the primary assembly, the setup delivered a DC power boost to 1.5-kW with an efficiency of 71%. A calculation model including internal-resistors of 0.08-ohm was in good agreement with the experimental results.