Demonstration of a Renewable Energy Self-Consumption System for an Apartment in Germany

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1 Abstract

To prevent global warming, renewable energy sources, such as PV (photovoltaic) and wind power, are becoming increasingly popular throughout the world. In particular, Germany is focusing on installing renewable energy sources in their power systems so that 80% of generated power will be from renewable energy by 2050. However, the FIT (Feed-in-tariff) rate is decreasing with the increasing number of renewable-energy installations, and the FIT rate is now less than half the electricity rate. As a result, much attention is being paid to the "self-consumption model" in which PV power is consumed within a household, and the amount sold outside the household is decreasing. With this background, we developed a self-consumption system that enables more effective use of PV power. The system uses both rechargeable batteries and a heat pump, and has been operating since it was installed in June 2016.

2 Characteristics of the Energy Self-consumption System

- The system has storage batteries and a heat pump to maximize the consumption of PV-generated power and minimize the cost of energy of apartment homes.
- The Home Energy Management System (HEMS) generates optimal operation plans for the storage batteries and heat pump based on forecasts of the demand for electricity and hot water.
- The system consists of containers compliant with German and EU regulations and standards, and can be installed in existing homes.
- The system includes a remote monitoring function that enables the real-time observation, from locations such as Japan, of the system's operating status.

3 Background of the Development

Germany leads the world in the field of renewable energies and the FIT rate in Germany is already cheaper than the electricity rate. To reduce the reverse energy flow in a household, it is important to achieve the self-consumption of PV power. Since July 2015, we have been working on a smart community technology demonstration project (hereinafter the "demonstration project") commissioned by NEDO to establish a model for the self-consumption of PV power and for reducing energy costs, and have started operation according to the following schedule.

June 2016: Installed a system consisting of PV, storage batteries (LIBs), inverters, a heat pump, various sensors, and an HEMS and started operation of the system for demonstration purposes.

September 2016: Constructed a hybrid power storage system[2)] equipped with lead-acid storage batteries (LABs) in addition to LIBs, and started the operation of the system.

April 2017: Started energy cost-minimizing operation through the optimization of the storage batteries and heat pump based on the HEMS's forecasts of the demand for electricity and hot water.

This report describes the compliance of the project with German and EU regulations and standards, and the energy cost-minimizing operation achieved through the optimization of the storage batteries and heat pump. Out of consideration for the residents of the apartment building selected for this project, the hot water supply was left as it was to avoid the otherwise necessary indoor refurbishment. In other words, the hot water supply from the heat pump was used exclusively to heat the apartments.

Moreover, a remote monitoring system was introduced so that the operating status of the system installed in Germany could be monitored from Japan.

4 Technical Details

a) Compliance with German and EU regulations and standards

Obtaining a fire license was the largest challenge for this demonstration project, which required the installation of largecapacity lithium ion batteries (LIBs) in a residential area. Experts and the relevant fire department assessed risks with respect to the installation of fire extinguishing equipment. Based on the assessment, our approach to fire protection included directly monitoring the temperature of the lithium ion batteries, in addition to using to general-use sensors to detect gas, heat, etc. Furthermore, to prevent false detection, fire extinguishing measures start only after multiple sensors are activated. Finally, as a measure against adverse impacts on the environment, such as soil contamination due to the discharge of untreated water, the demonstration system includes a tank for containing fire water (water that has been used to extinguish fire).

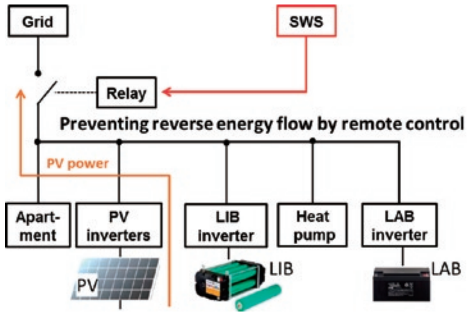


Figure 1 System configuration

Figure 2 External view of the demonstration system

Figure 1 is a system configuration diagram, while **Figure 2** shows the external view of the final demonstration system. In Germany, in accordance with the Renewable Energy Sources Act (EEG* 2017), facilities with a PV output of 30 kW to 100 kW are required to have a remotely operable disconnection mechanism that stops the power supply to the utility grid upon request from the power company. To meet this requirement, this system, which has a PV output of 46.8 kW, is equipped with a function that turns the connection to the grid on and off in response to remote commands from the demonstration project counterpart, Stadtwerke Speyer GmbH (SWS).

* EEG: Erneuerbare-Energien-Gesetz

b) Energy cost-minimizing operation

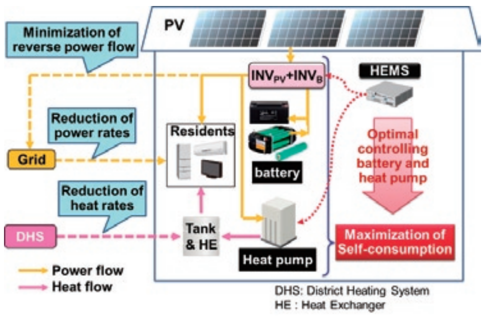
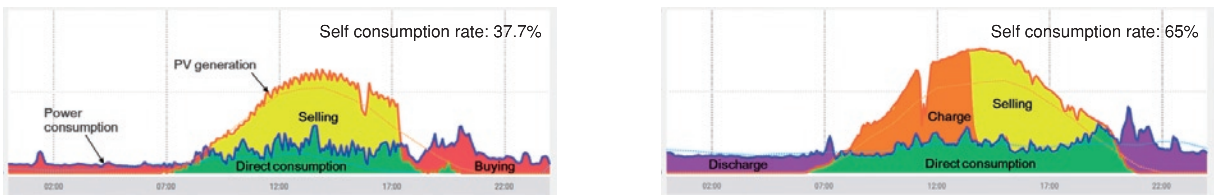


Figure 3 Control image

Figure 3 shows the control concept for this system. This system uses PV power to recharge the storage batteries and to produce hot water by heat pump. The power accumulated in the storage batteries during the day is discharged at night, and the hot water produced by the heat pump is fed out to heat rooms, thus minimizing the reverse power flow and reducing the costs of heating and lighting. However, as PV power generation peaks in summer and the demand for heating peaks in winter, it is necessary to distribute PV power to the storage batteries and to the heat pump according to the demand for power and heating. To this end, the HEMS is capable of energy cost-minimizing operation via the following three steps: 1) it forecasts the PV power generation output and the demand for power and heating, 2) it uses linear programming to generate an operation plan for several days ahead based on the forecast results, and 3) it charges and discharges the storage batteries and controls the production of hot water by the heat pump according to the operation plan. In this way, the system achieves efficient and effective use of PV power in a way that accounts for changes in the weather. **Figure 4(a)** shows operation of the system with PV generation only, whereas **Figure 4(b)** shows energy cost-minimizing operation controlled by the HEMS. With PV generation only, the self-consumption ratio is 37.7% because all surplus power generated during the day is sold, and the power required at night must be purchased. On the other hand, under energy-cost minimizing operation, the storage batteries are recharged with just enough power as is needed at night, and the remaining surplus power generated during the day is sold. Because the power required at night is supplied from the storage batteries, no power needs to be purchased, resulting in an improved self-consumption ratio of 65% and lower energy cost.



(a) Operation with PV generation only (August 2016)

(b) Energy cost-minimizing operation (July 2017)

Figure 4 Comparison of self-consumption rates and behavior when (a) only PV generation is applied and (b) operation to minimize energy costs is applied

[References]

1) Morozumi and Yamakawa: "Demonstration of a PV self-consumption system for houses in Germany," Electrical Review, Vol. 102, No. 5, pp. 55-60 (May 2017)

2) Arita and Takeda: "Large Format Hybrid Energy Storage System for Power Leveling," Hitachi Chemical Technical Report, No. 57, pp. 20-21 (December 2014)