Control Method for Reverse Power Flow of Photovoltaic Generation System – Operation Planning for Heat Pump Water Heater in accordance with Uncertainty Forecast –

Background

Many distributed generation systems such as photovoltaic (PV) generation systems will enter into power distribution networks. We have proposed Anonymous Demand Area Power System (ADAPS)*1 to maintain power quality in distribution networks in case of increased surplus power flow by PV systems. Furthermore, we are proposing a cooperated management of customer load in accordance with PV output to prevent excess reverse power flow in cases of extreme penetration by PV. Management of heat pump water heaters is one of them. However, we have to make operation planning considering uncertainty of forecast of PV output, heat and electric demand because heat and electric demand in residential customers and PV output of each customer fluctuate day by day.

Objectives

The purpose of this study is to develop optimal operation plan for heat pump water heater and battery storage for next day to minimize reverse power flow and energy cost without shortage of hot water considering uncertainty of forecast of PV output, heat and electric demand.

Principal Results

1. Development of optimal management plan for heat pump water heater and battery storage concerning uncertain prediction

Optimal management plan for efficient use of photovoltaic generation output with heat pump water heater and battery storage was developed. This plan can prevent shortage of hot water at least expensive cost concerning multiple scenarios corresponding to uncertainty of prediction. In this method, predicted values of hot water demand and electrical demand were represented as probability distribution with past data, while predicted PV output was represented as probability distribution with weather forecast. Using these probability distributions, multiple scenarios of predicted hot water demand, electrical demand and PV output were prepared. Genetic algorism was also used in this method.

2. Simulation analysis

Simulation analysis of daily operation in May, when surplus PV power became serious with the proposed method and measured hot water demand, electric demand and PV output, was conducted. Several installation capacities of battery storage are concerned. Monthly energy cost with multiple scenarios was reduced to 85% compared to that with single scenario, while surplus power flow was kept to a permissible amount. The reason for cost reduction is due to reduced risk in operating heat pump water heater during day time with small PV output.

Future Developments

Evaluation of developed method through annual simulation and demonstration in Akagi Testing Center will be conducted. Modification of the model by on-line recalculation of plan will also be conducted.

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Reference

M. Asari, et al., 2009, “Control Method for Reverse Power Flow of Photovoltaic Generation System – Operation Planning for Heat Pump Water Heater in accordance with Uncertainty Forecast –”, CRIEPI Report R08025 (in Japanese)

*1：50% capacity of DG can be installed in ADAPS (H. Kobayashi, et al., 2008, “Development of Operation Control Techniques for the Autonomous Demand Area Power System”, CRIEPI Report R08 (in Japanese)), Simulations were conducted using 23 days’ data in May 2008. Energy costs were calculated by selling price (6.42 yen/kWh at off-peak; 23:00-7:00, 9.2 yen/kWh at other periods) and purchasing price (9.2 yen/kWh at off-peak; 23:00-7:00, 28.23 yen/kWh at peak period;10:00-17:00, 23.1 yen/kWh at other periods).

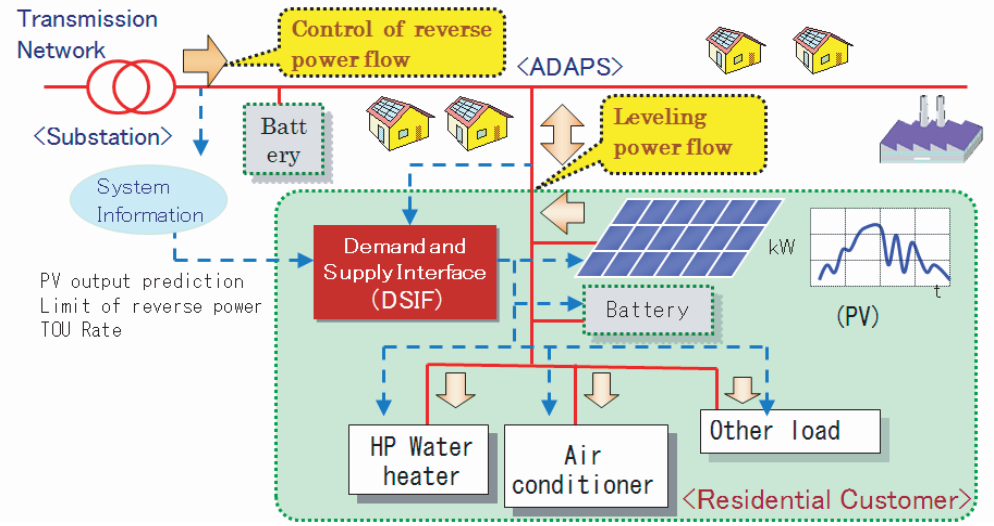

Fig.1 Cooperation operation of PV, Battery, and HP Water heater

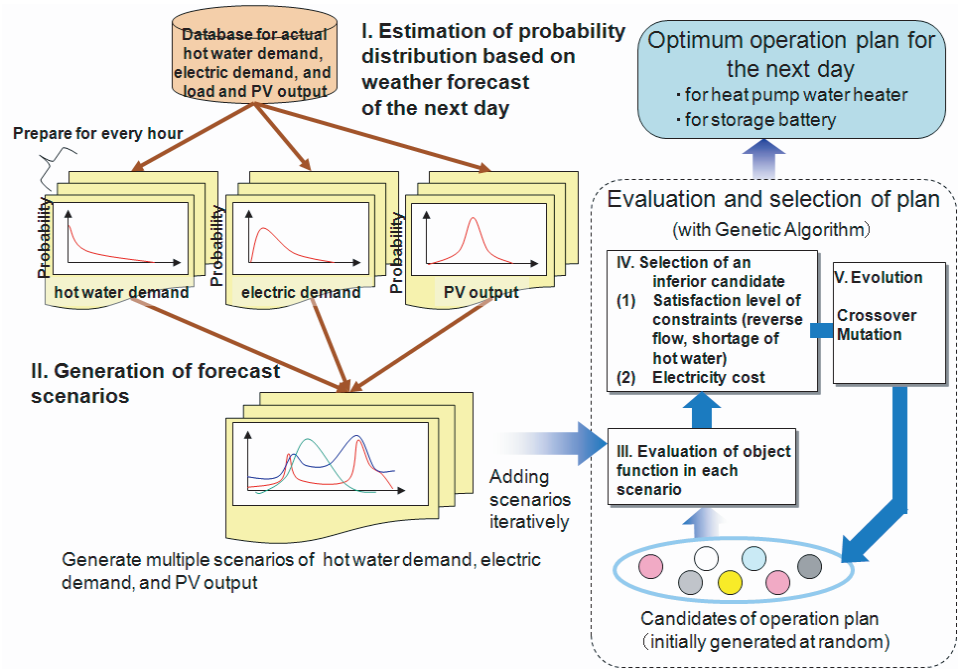

Fig.2 Optimum operation planning method for heat pump water heater and storage

Table 1 Energy cost

Capacity of battery	Multiple scenarios	Single scenario
0kWh	4,541yen	5,426yen
2kWh	4,375yen	5,042yen
4kWh	4,173yen	4,901yen
8kWh	3,958yen	4,370yen

Battery cost and demand charges are not included

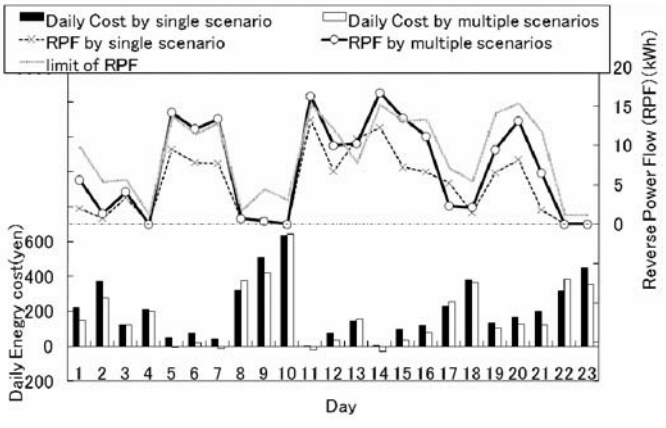

Fig.3 Comparison of single and multiple scenarios