Integrated Operation and Control Techniques of Supply and Demand Sides in Autonomous Demand Area Power System

Background and Objective

Penetration of distributed power generation (DG), in particular photovoltaic (PV) power generation, is expected to be accelerated to cope with global environmental problems, etc. To achieve secure operation of a utility grid and to keep appropriate power quality with large penetration of DG., development of integrated operation and control methods of supply and demand, i.e., DGs and demand appliances in a customer is expected to be effective in addition to improved operation and control of an electricity distribution system.

The objective of the project is to develop an integrated operation and control methodology for supply and demand in Autonomous Demand Area Power System (ADAPS) to achieve smooth introduction and utilization of DG by renewable energy.

Main results

1. Demonstration and improvement of PV surplus power utilization technique using HP water heater

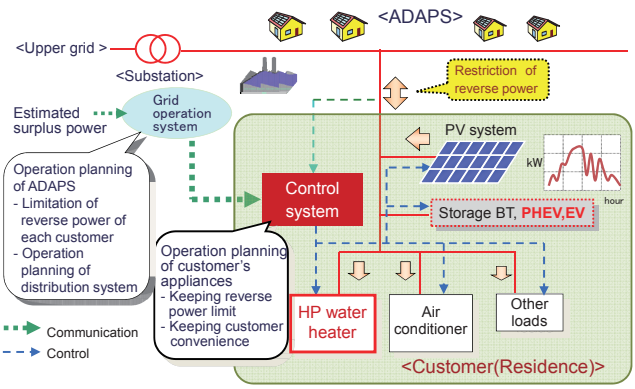
An operation planning method of customer's appliances on the next day using various forecasts was proposed in 2009 focusing on utilizing PV surplus power by operation of heat pump (HP) water heater during PV operation time (Fig. 1a). To establish the method, annual demonstration test was carried out using an experimental customer system. The results show that the system works as designed (Fig. 1b) and curtailed energy due to surplus power is reduced effectively. Countermeasures to the problems encountered in the test were also devised and their validity was demonstrated (Table 1) [R10042].

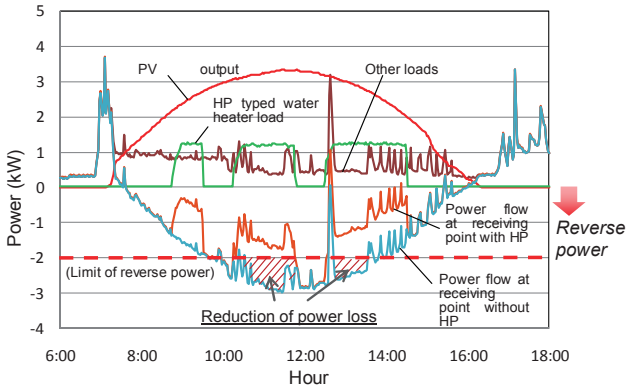
2. Proposal of distribution line voltage control method by controlling customer's capacitor

Ferranti effect is often observed in a distribution system due to customers' capacitor (SC) to compensate their power factor as well as massive introduction of PVs. As a countermeasure, a distribution line voltage control method that coordinates SC and SVC (Static Var Compensator) is proposed. In the method, a function called "Voltage preference mode," by which SC is automatically disconnected when distribution line voltage at the customer exceeds an upper limit, is proposed. . Sample simulation study shows that permissible penetration of PV can be increased by about 20% of the rated capacity of a distribution line (Fig. 2)[R10026].

3. Proposal of islanding prevention method in a distribution system with SVC

In the case where power flow at a circuit breaker on a distribution line is nearly equal to zero, there remains possibility that islanding detection functions on DG cannot detect islanding within a predetermined time limit. A method for controlling SVC for distribution line voltage control is proposed to prevent islanding of a distribution line by keeping reactive power flow in a circuit breaker at non-zero intentionally Simulation studies on a residential area model show the method is promising because the periods when voltage control is needed (in the daytime) are different from those when islanding prevention is needed (in the morning). They also show required reactive power for islanding prevention is smaller than SVC capacity required for voltage control (Fig. 3) [R10040].





(a) Concept of operation planning method on the next day

HP type water heater is operated when surplus power is expected according to PV power output and demand forecasts. Taking account of uncertainty of forecasts, multiple forecast scenarios are prepared using past statistical data.

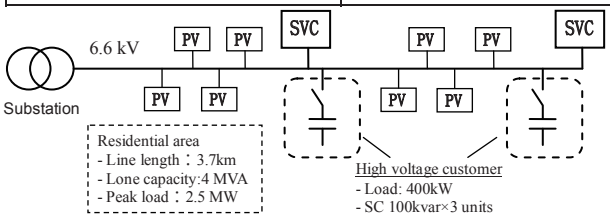
(b) Example of demonstration result using simulated experimental customer system

An example of 4kW class PV and 1kW (3kWh) class HP water heater on clear day assuming that the threshold level of reverse power is 2kW. Curtailed energy due to surplus power is decreased by daytime operation of HP according to planning on the previous day.

Fig. 1 Concept of operation planning method on the next day and demonstration result

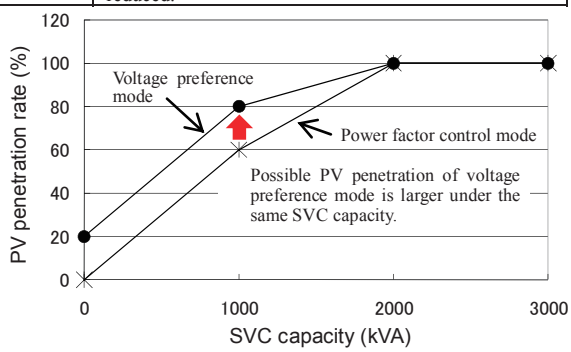
Table 1 Issues clarified by demonstration test and measures

Issues	Measures	Confirmation results
Decrease of operation efficiency due to increase of operation start/stop of HP water heater.	New restrictions concerning operation start/stop times and minimum continuous operation time.	Daily operation efficiency goes up 20% compared with the case of no measures.
Occurrence of hot water shortage in HP water heater in case of unexpected increase of hot water demand.	If the forecasted error of actual hot water demand is larger than the threshold level, additional operation and re-planning are carried out.	Reliable prevention of hot water shortage is confirmed. Additionally the measure contributes to suppression of PV surplus power because lower limit of hot water storage at planning on the previous day can be reduced.



(a) Distribution line model for simulation

If voltage still exceeds the limit, SC of a high voltage customer is disconnected in turn. Since SVC promptly operates when distribution line voltage exceeds upper limit (107V in low voltage line), the threshold level for voltage control of SC is set lower than that of SVC.



(b) Effect on increase of PV penetration rate in line capacity by SC control

Fig. 2 Effect of proposed distribution line voltage control method using customer's SC control

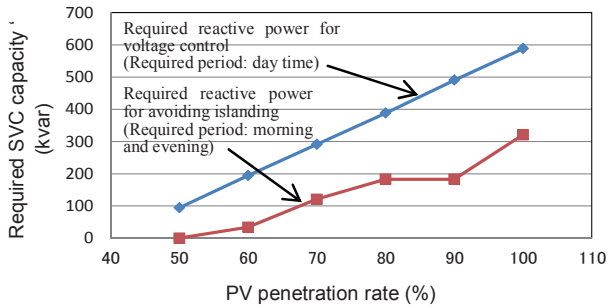


Fig. 3 Required SVC reactive power for preventing islanding on distribution line

Required SVC output for islanding prevention is lower than that for voltage control