Short-term Balanced Supply and Demand Control System for Microgrids

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OVERVIEW: There is a growing demand for renewable energy resources with the rise of concern for the environment. Many fear that the increasing distributed energy resources will degrade the power quality of the distribution systems. While microgrids can reduce the amount of degradation, they can also operate almost completely independently, thus complicating the balancing of supply and demand control in the grid. To solve this problem, we have developed a short-term balanced supply and demand control system. The system adopts a highly accurate method for correcting the accumulated deviation in the power generation targets setting, based on the short-term demand forecast. When we examined the verification using a real-time simulator, which simulates distributed resources, we confirmed the ability of the microgrid and distributed resources to balance supply and demand loads for short periods of time. The developed system enabled the supply and demand balance term to be adjusted about 1/3 of the conventional systems.

INTRODUCTION

RECENTLY, the environment for electric power systems, such as the progress of the electric power, the liberalization and spread of distributed resources, etc., is changing rapidly. In particular, we expect an acceleration in the quest to find renewable energy resources. The increasing use of distributed energy resources is expected to degrade the power quality of distribution systems, which will complicate the construction of new electric power systems.

Microgrids, which combine distributed resources with the load and can operate almost completely independently, are attracting much attention. A major focus of the R&D (research and development) in this area is the balancing of supply and demand control in electric power system grids. Hitachi has developed a prototype system for balancing supply and demand control in microgrids (see Fig. 1). It combines remote operation with optimal operation of distributed resources.

The developed system enabled the supply and demand balance term to be adjusted about 1/3 of the conventional systems.

Here, we will outline the system for balancing

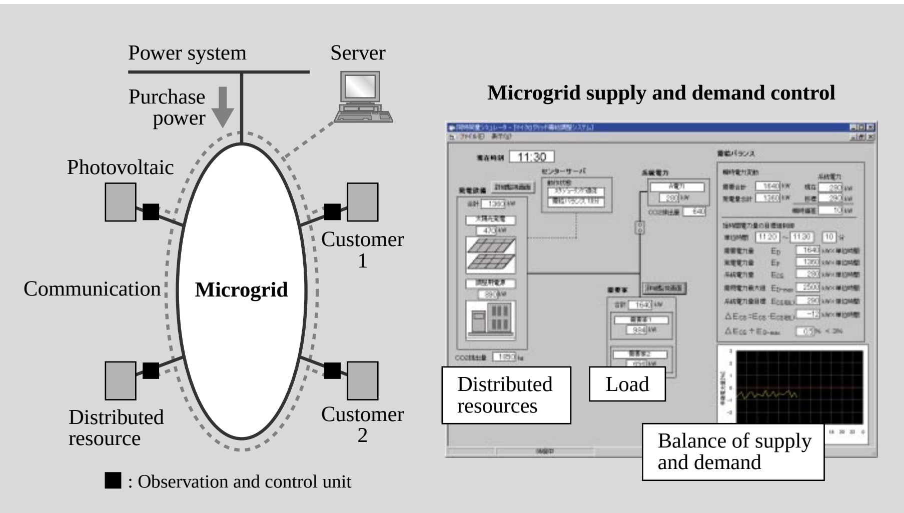

Fig. 1—Overview of Short-term Balanced Supply and Demand Control System.
Short-term balanced supply and demand control systems calculate the power generation target settings, and balance them for a short time, based on measured data, which is sent to controllable distributed resources. They enable microgrid operations, reducing the influence on electric power systems.

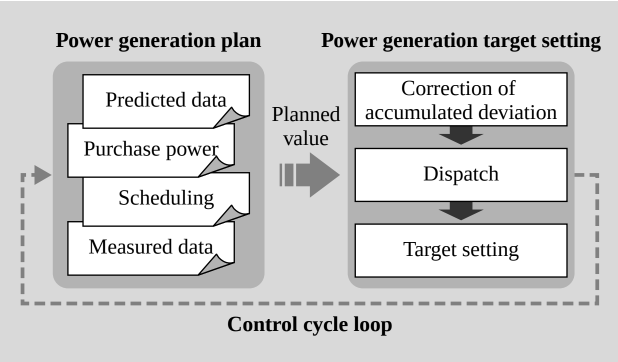

Fig. 2—Flow of Short-term Balanced Supply and Demand Control.
It includes power generation scheduling, based on power demand predictions for measured power consumption, and power generation target setting considering supply and demand deviations.

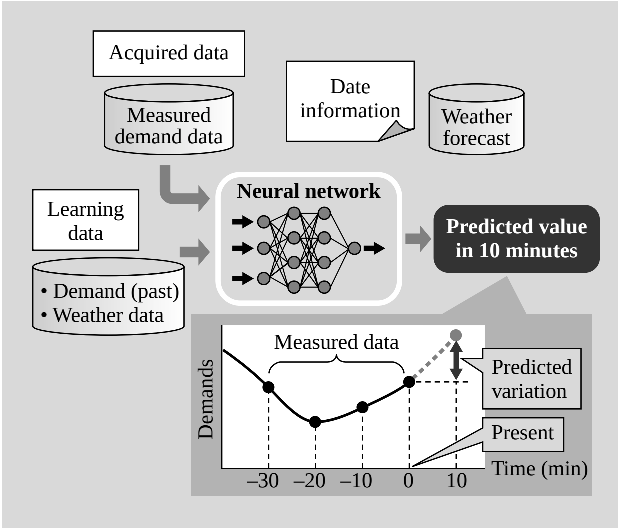

Fig. 3—Overview of Short-term Demand Prediction Using Neural Network.
We verified real-time measurements and the use of the neural network method to accurately predict demand in a few minutes.

supply and demand in microgrids. We will then describe the simulation we ran to evaluate its operation and present some of the results.

CHALLENGES IN MICROGRIDS

Microgrids are composed of distributed resources, such as PV (photovoltaic) generators, an electric power storage device, a comparatively small-scale power supply network, and a power supply for customers within a specific area. They can be operated independently of the power company's supply system.

Microgrids are expected to result in a decreasing influence of distributed resources on power systems, thus improving the supply reliability, the energy use efficiency, and the power quality in the area. The challenges to realizing these features are:
(1) Adjusting the supply and demand balance;
(2) estimating the operating schedule of distributed resources; and
(3) securing the quality of electric power.

SUPPLY AND DEMAND CONTROL TECHNIQUES

We need to evaluate the supply and demand balance of microgrids in a short time period to decrease their influence on electric power systems. Fig. 2 shows the flow of the supply and demand control. Based on the operation schedule, corrected by the measurement, the demand prediction and the amount of power generated by the grid in every control cycle, the power generation targets are set and sent to distributed resources.

To control and balance supply and demand for short periods of time, we used the accumulation deviation correction method and a power generation target, set using the short-term predictions and the neural network method.

Short-term Demand Prediction [1]

In general, consumer demand for electric power varies greatly with the season, the day, and the time of day. The predicted demands of large areas should be accurate, because they are averaged out using the cancel effect when a lot of customers are on line.

However, the leveling effect is minimized in microgrids in which the number of customers and the load pattern are limited. So the demand prediction for the following day often contains large errors.

Then, as shown in Fig. 3, the measured demand is processed in real time, and the predicted demand in the few minutes necessary to control the distributed resources. A neural network method was used for the prediction. Information included past and present demands, the temperature, the day of the week, etc.

Supply-and-demand Balance Correction [2]

Fig. 4 shows the correction considering the accumulated deviation. To clarify understanding, we assumed no response delay for the control order, and a constant output of the distributed resources during the control cycle.

When $P(t)$ stands for the total generated electric power, and $D(t)$ stands for the difference between the total electric power demand and the purchased electric

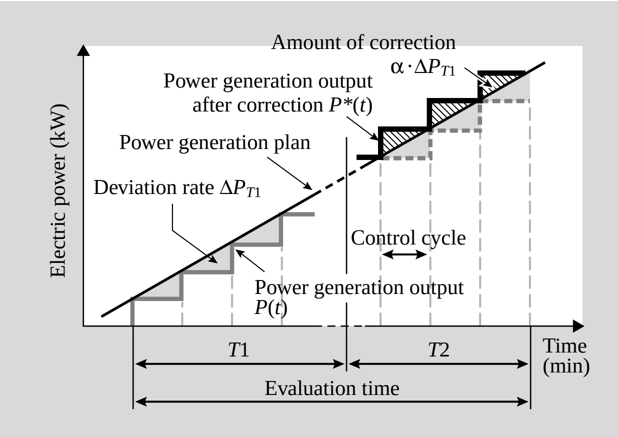

Fig. 4—Correction Considering Accumulated Deviation.
To correct accumulated deviation in the balance of supply and demand and improve the short-term supply and demand balance.

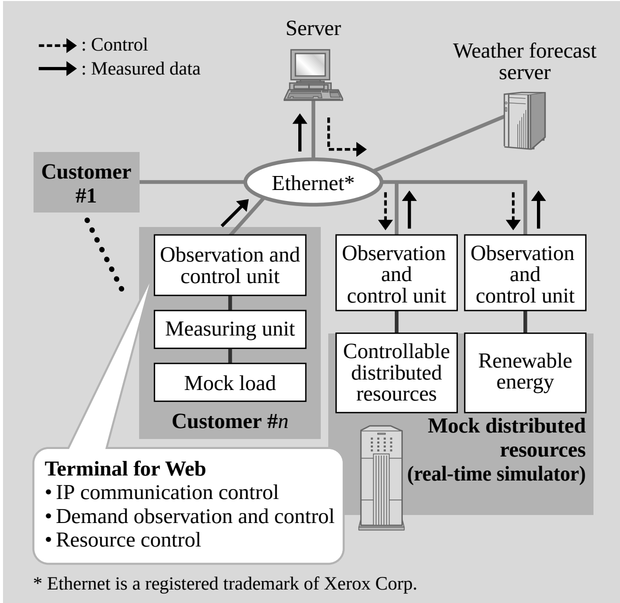

Fig. 5—Experimental Setup to Verify Supply and Demand Systems.
A server, simulated load, simulated distributed resources, measurement device are connected through observation and control units. They enable verification of operations in real time.

power from the electric power system in a regional system, the power generation electric power deviation ΔP_T at evaluation time T is given by expression (1).

$$\Delta P_T = \int_T (D(t) - P(t)) \cdot dt \text{ (kWh)} \quad \text{——— (1)}$$

Evaluation time T was divided into time sections, $T1$ and $T2$. The generation target set using $T2$ is corrected using ΔP_{T1} (the electric power amount deviation in $T1$), similar to expression (2), and the deviation caused in $T1$ is counterbalanced by $T2$.

$$P^*(t) = P(t) + \alpha \cdot \Delta P_{T1} \text{ (kW)} \quad \text{——— (2)}$$

Here, $P^*(t)$ is the total generated electric power after the correction, and α is the coefficient to adjust the amount of the correction.

SUPPLY AND DEMAND CONTROL SYSTEM

Basic Function and Verification Test Device

The supply and demand control system consists of observation and control units and a server on which the supply and demand control software operates. The main functions of the system are as follows:
(1) Short-term balanced supply and demand control;
(2) supply and demand display controls the results and balance evaluation;
(3) optimal, controlled operations of distributed resources.

Web terminals were used as the observation and control units.

Fig. 5 shows the experimental setup for verifying the supply and demand systems. It is composed of a server, which imitates the control center with short-term balanced supply and demand controls, a simulated load, a measurement device and simulated distributed resources. These were connected with Ethernet through the observation and control units. The power generation target setting, which was calculated in the server, based on measured demand and power generation output data, was transmitted to the simulated distributed resources at preset time intervals. The movement of the distributed generations was copied using a real-time simulator.

Verification Test

The effect of the supply and demand control technique was verified using the above-mentioned setup. We assumed that there was a PV generation system (rating 700 kW), controllable distributed resources (rating 1,500 kW), and a load (2,500 kW or less) in a microgrid system. We estimated the purchased electric power to be 300 kW constant.

We examined the time zone, in which there was a significant change in the load and the PV output, as shown in Fig. 5. Here, the output control interval for the supply and demand control was assumed to be 10 minutes at evaluation time T of the supply and demand balance.

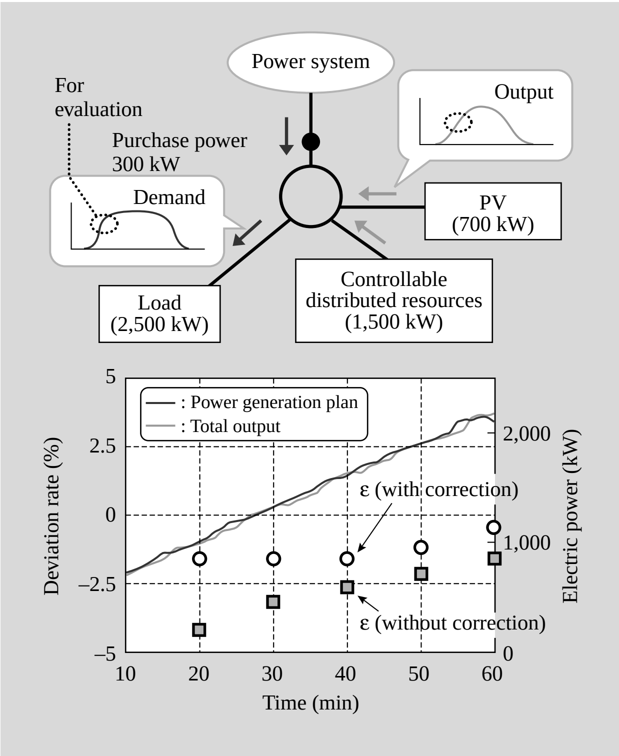

Fig. 6—Verification Results.
The results with output correction using the developed method (○ mark) and without correction (□ mark) show that correction improves the accuracy of supply and demand control.

Fig. 6 shows the verification results. It shows the difference $D(t)$ between the total demand and the purchase electric power that corresponds to the power generation target setting, total power generation electric power $P(t)$, and electric power amount deviation rate ε (%). After correction, the deviation rate ε of the electric power amount was decreased to about 1/2, compared to that without correction. We know that the difference of both decreases due to the effect of the correction in section $T2$.

We thus confirmed that the accuracy of the supply and demand control improved after correction.

CONCLUSIONS

We have developed a system for short-term balancing supply and demand control in microgrids. Real-time simulation showed that it can almost completely balance supply and demand loads for the short periods of time.

Hitachi plans to further develop operation and control technologies for the practical application of microgrids, support broad use of distributed energy resources, contribute to reducing the burden imposed on the environment, and improve the efficiency of energy use in the future.

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