Power Demand-Supply Management System and VPP Solution

OKABAYASHI, Hiroki* TERADA, Takeo* FUJIO, Takahiro*

ABSTRACT

The number of power producers and suppliers that enter the power business has been increasing since the full deregulation of retail electricity in April 2016. For these power utilities, Fuji Electric provides a power demand-supply management system that allows users to operate according to the process flow diagram and to achieve high-precision and efficient operation using a high-precision prediction and other support functions. This system supports a balancing group operation, in which the delegate of contractors coordinates power companies (power producers and suppliers) by sharing data with external agencies to perform planned-value balancing. We have also been participating in virtual power plant (VPP) demonstration projects and can offer VPP solutions for power producers and suppliers, including the services using our demand-supply management systems and large storage battery systems.

1. Introduction

Fuji Electric has been offering demand-supply management systems to power producers and suppliers since the full deregulation of retail electricity in April 2016. Our demand-supply management systems are capable of the new planned-value balancing operational rules. Furthermore, this system has various functions that achieve high-precision and efficient operation of demand-supply management. Its functions includes acquisition of demand results from transmission system operators, demand forecasting functions to suppress increase in imbalances between forecasts and actual values, submission of plans to the Organization for Cross-regional Coordination of Transmission Operators, and power trade through the Japan Electric Power Exchange.

Moreover, since the Great East Japan Earthquake, the country has been building a scheme that utilizes demand-side distributed energy resources (DERs) as a means of stabilizing power systems. Fuji Electric has continuously participated in a demonstration project for virtual power plants (VPPs). In this paper, we will introduce our power demand-supply management system and VPP solution.

2. Fuji Electric's Power Demand-Supply Management System

Table 1 shows the providing method and features of the power demand-supply management system. The business scale of power producers and suppliers varies from small to large. Therefore, for small- and medium-scale power producers and suppliers, we are providing our power demand-supply management system at an affordable price based on monthly pay-as-you-go cloud service according to the number of consumers that they are managing. Large-scale power producers and suppliers (PPSs) often require unique functions. For these types of PPSs, we are providing technologies, such as optimizing power generation plans by on-premise*1.

Table 1 Supply configuration and features of the power demand-supply management system

Supply configuration	Feature
Cloud service	○ Accesses the power demand-supply management system on the cloud and performs supply and demand operations ○ Monthly pay-as-you-go system based on the number of utility customers
On-premises	○ Provides a power demand-supply management system, allowing power producers and suppliers to operate the system as its own asset ○ Supports add-ons according to individual need

2.1 Features of Fuji Electric's Power Demand-Supply Management System

(1) Power demand-supply management system based on business process flows

As shown in Fig. 1, the power demand-supply management system can support the creation and submission of daily plans by allowing operators to check results based on each business process from power demand forecasting to plan submission.

It creates FIT power generation plans two days before the actual supply and demand dates. It then creates next-day plans the day before. On the actual day, it performs monitoring and revises plans when imbal-

* Power Electronics Systems Energy Business Group, Fuji Electric Co., Ltd.

*1: On-premise: Install, deploy, and operate information systems such as servers and software in facilities managed by users (usually companies)

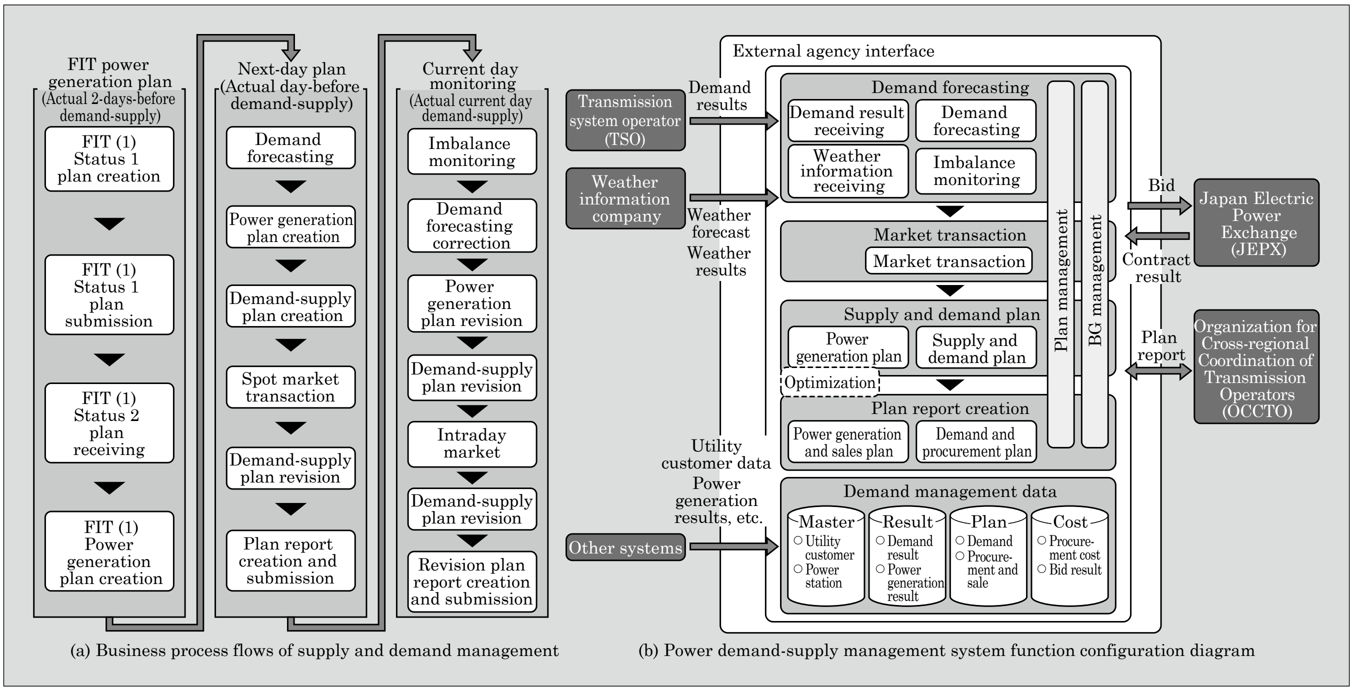

Fig.1 Business process flows and power demand-supply management system function configuration diagram

Table 2 List of demand-supply management system functions

○: Function used for each process

Function	Description	Response to process flow		
		FIT	Next day	Current day
Demand result receiving	Acquires actual power demand values every 30 minutes from a transmission system operator (TSO)	—	○	○
Weather information receiving	Acquires weather forecasts / actual results data from weather information companies	—	○	○
Demand forecasting	Forecasts demand for power consumption every 30 minutes for each forecast group	—	○	○
Imbalance monitoring	Calculates the imbalance between actual demand values and forecast values	—	—	○
Market transactions	Performs bidding and contract result receiving for day-before and current day markets	—	○	○
Power generation planning	Creates power generation plans for power plants on a 30-minute basis	○	○	○
Supply and demand plan	Allocate own power and procured power from other companies to fill the demand forecast results (plans)	—	○	○
Planning report creation	Creates a plan report (demand and procurement plan, power generation and sales plan) based on the results of the supply and demand plan	○	○	○
Plan management	Manages demand plans, power generation plans, and supply and demand plans daily and every 30 minutes	○	○	○
BG management	Manages demand plans, power generation plans, and supply and demand plans for each individual company	○	○	○

ances are expected to increase.

Table 2 shows the main functions of the system. The system comes with a planning management function that enables the creation of daily supply and demand plans in the future to balance the demand and procurement amount of electricity. Furthermore, operators can see past plans and cost data, as well as results, stored in the system.

(2) Data linkage functions with external agencies to provide a one-stop service

Daily supply and demand management operation data must be shared with 3 external agencies, including the Organization for Cross-regional Coordination of Transmission Operators (OCCTO), transmission system operators (TSOs), and the Japan Electric Power Exchange (JEPX). We have developed the application interface for data linkage functions with external agencies described in Table 3 and implemented it in the power demand-supply management system as standard functionality. These functions in combination with the business functions described in Table 2 enable one-stop service operation for supply and demand management.

(3) Support for balancing groups

The system supports balancing group (BG) operation*2 in which the delegate of contractors coordinates multiple individual companies (PPSs) to conduct planned-value balancing operation. As shown in Fig. 2, the master structure has 3 layers, including de-

*2: Balancing Group (BG): Consolidate multiple individual companies (PPSs) including one's own company, and have delegate of contractors (one's own PPS) perform supply and demand management.

Table 3 Methods for sharing data and communicating with external agencies

Destination	Data	Communication method
OCCTO	Planning report data	EDI common standard for recipients of power generation planning (OCCTO)
TSO	Actual power demand values	EDI common standards between retail electricity utilities and general electricity transmission and distribution utilities (OCCTO)
JEPX	Bidding and contract information	Market participant API (JEPX)

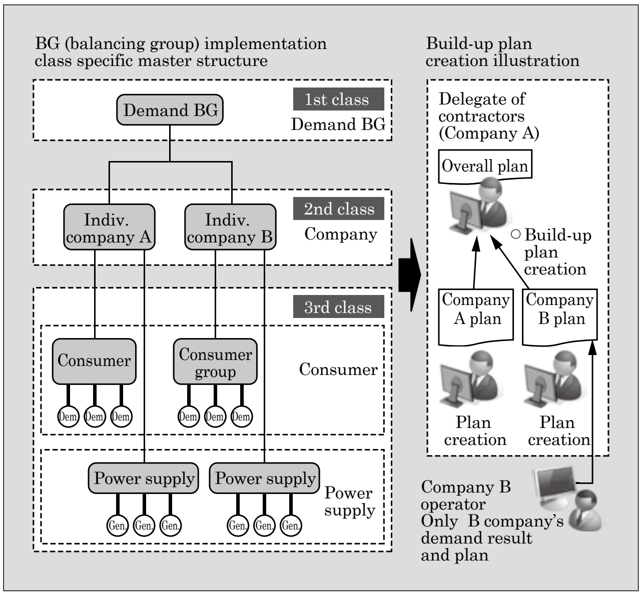

Fig.2 BG implementation achieved by hierarchical master structure

mand BGs, individual companies, and consumers and power supplies. Each piece of master data is linked to its upper layer. By using this structure, the operator can create plans independently on an individual company basis. After this, the plans for each individual company are aggregated to create a plan for the entire demand BG. Furthermore, the operator can revise the plan for the entire demand BG.

By using BG management authority setting, the planning and demand results of the individual company can be published exclusively to the person in charge of that individual company.

2.2 Power demand forecasting technology

Setting up forecast groups of consumers categorized by their business characteristics having similar demand-curves, users can forecast demand by the group. As shown in Fig. 3, the forecast results for each forecast group are aggregated, and demand forecast values are created for each area of TSO. In addition, it leaves room for the forecast values of the entire area to be corrected on the basis of the knowledge and ex-

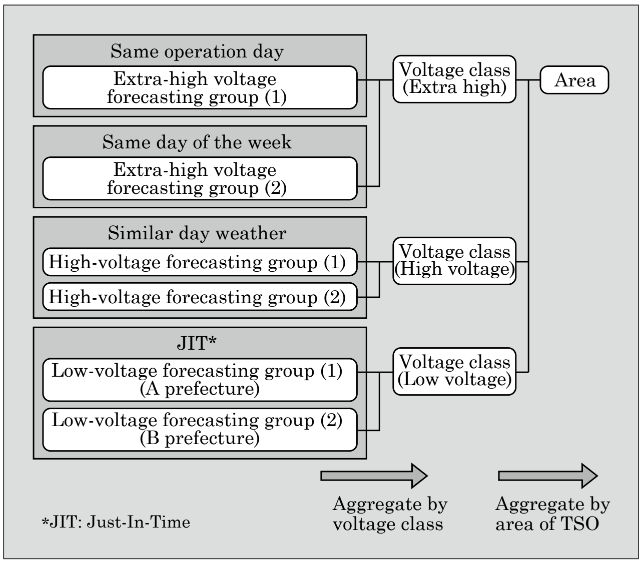

Fig.3 Creation of area power demand forecasting value

pertise of the operator so that the operator's intentions can be reflected in the forecast results.

There are two methods for forecasting demand. One is a method in which the operator himself creates a forecast values by referring to actual past demand results, actual weather results, and weather forecasts for the target day displayed on the screen of the power demand-supply management system. The other method is to automatically calculate forecast values by using the system forecasting function. The system forecast function outputs the demand forecast for the current day, the next day and the day after the next day. Moreover, the current day forecasting is corrected one after another by obtaining the latest actual demand values every 30 minutes and the latest weather forecast.

Four system forecasting methods are implemented as standard system forecasting functions. These include 3 simple forecasting methods based on the calendar and weather conditions: same operation day forecasts, same day of the week forecasts and similar day weather forecasts. The other is a Just-In-Time (JIT) forecasting method utilizing an automatic factor analysis. From these 4 methods, operators can choose a method suitable for the demand characteristics of each forecast group using their own knowledge so that accurate forecasting can be made for the whole area.

We would now like to introduce Fuji Electric's latest demand forecasting technology, "JIT Forecasting."

JIT forecasting calculates forecast values using actual demand values of past days with similar conditions through the following 3 steps (see Fig. 4):

(a) Correlation factor analysis

Automatically analyzes factors on a daily basis that have strong correlation with actual demand results

(b) Similar day extraction

Uses the strongly correlated factors analyzed in

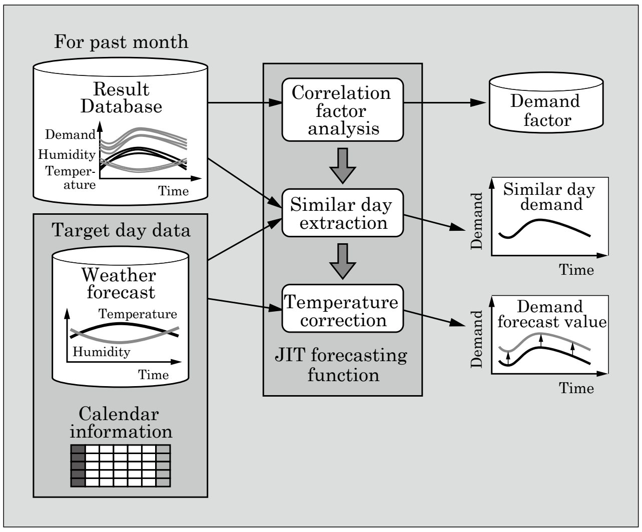

Fig.4 Just-In-Time (JIT) forecasting configuration

(a) to extract similar dates closest to the target forecast date.

(c) Temperature correction

Corrects the demand forecast values from the difference between the actual temperature values of the similar days extracted in (b) and the forecast temperature values of the target day.

JIT forecast can deliver forecasting results at high speeds of consumer groups where it is difficult to ascertain the correlation between demand fluctuations and factors.

2.3 Technology for optimizing power generation plans

Electricity utilities that supply electricity to various generators and limited areas develop power generation plans as a way to reduce fuel costs and CO_2 emissions. Fuji Electric's technology for optimizing power generation plans(1) uses a linear programming to quickly create plans on a current day, next day and weekly basis. This planning system provides demand forecasting and the output forecasting of renewable energy sources, such as photovoltaic and wind power generation. It also delivers start-up and stop plans of generators and storage batteries, as well as their operating results when optimizing control variable, considering generator operating conditions, such as continuous operating constraints and continuous stopping constraints.

3. VPP Solution

3.1 Overview of VPP solution

VPP is a technology that controls demand-side DERs as if they were a single power plant by utilizing information and communication technology (ICT). Fuji Electric has positioned large-capacity storage batteries as the future's most important VPP energy resources and is working to develop and provide a high-level resource aggregator (RA) system and resource system as a platform. By utilizing this technology, we are aiming to create a business service that provides system operators with the 5 types of services shown in Table 4.

3.2 Initiatives to utilize demand-side large-capacity storage batteries

Fuji Electric has been continuously developing and demonstrating VPP functionality by participating in the "Kansai VPP Project" overseen by the Kansai Electric Power Company, Incorporated, which is promoted in the "Virtual Power Plant Construction and Demonstration Project Using Consumer Energy Resources" started in FY2016 by the Ministry of Economy, Trade and Industry.

(1) Configuration of large-capacity storage battery RA system

Figure 5 shows the system configuration and Table 5, the role of each component. Fuji Electric is developing a large-capacity storage battery RA server, OpenADR-MODBUS*3 conversion gateway (GW), VPP storage battery system and VPP controller.

(a) Large-capacity storage battery RA server

The RA server optimally distributes demand responses (DR) received from the higher-level aggregation coordinator (AC server) to the large-capacity storage batteries installed on the premises of multiple DER owners. It also aggregates the results from resources to deliver them to the AC

Table 4 Service utilizing VPP

Item \ Service	Peak cut energy savings	Renewable energy output suppression avoidance	Demand response	Planned-value balancing	Power system adjustability
Objective	Power cost reduction	Renewable energy suppression avoidance adjustability	Adjustability during tight BG supply power	Adjustability of BG imbalance suppression	Adjustability during tight power system supply and demand
Service beneficiary	DER owners	Renewable energy companies	Power retailers	Power retailers	TSOs
Control content	Demand increase / decrease	Demand increase	Demand decrease	Demand increase / decrease	Demand increase / decrease
Control cycle	30 minutes	30 minutes	30 minutes	30 minutes	1 to 30 minutes

*3: MODBUS is a trademark or registered trademark of Schneider Automation, Inc.

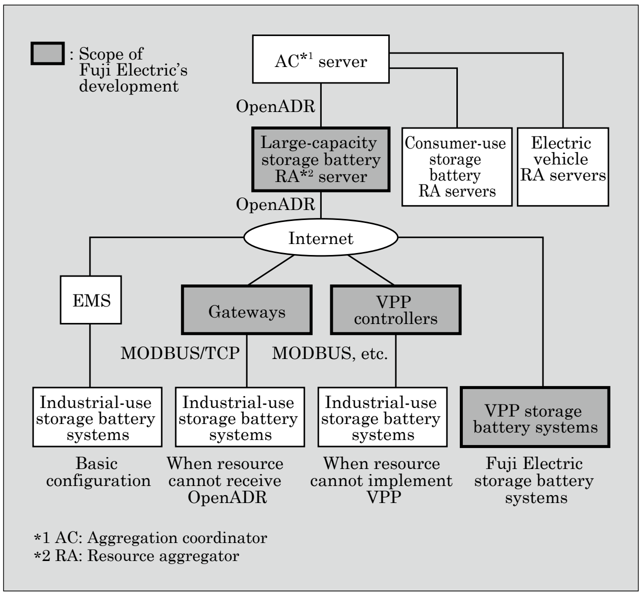

Fig.5 Configuration of large-capacity storage battery RA system

Table 5 Table of large-capacity storage battery RA system sharing functions

Component	Role
Aggregation coordinator (AC)	○ Connection with service providers and reception of DR (supply and demand adjustment) ○ DR activation and DR distribution to RA ○ Summary of all RA results
Large-capacity storage battery RA server	○ Demand forecasting, photovoltaic power generation forecasting ○ DR cooperative capacity calculation ○ DR distribution to each resource ○ Summary of underlying resource results
Gateway (GW)	○ OpenADR-MODBUS/TCP conversion
VPP storage battery system	○ Local control such as peak cut ○ Charging and discharging control based on DR ○ Creation and notification of operation plans ○ RA server linkage function
VPP controller	○ Same functionality as VPP storage battery system ○ Interface with conventional battery systems

server. Whereas storage batteries have the convenience of instantaneous control in both the charging and discharging direction, charging and discharging times are limited since they depend on the capacity of the storage battery and the state of charging. Therefore, when distributing DR, it is important to estimate the cooperative capacity of the DR for each time zone by monitoring the status of each resource. In order to do this accurately, the RA server forecasts the power consumption of each utility customer for each time zone, determines the reference value of DR, plans the change of state of charge (SOC) for the storage battery, and estimates the cooperative capacity. The demand forecast used here is JIT forecasting, which has undergone improvement through smart community demonstration projects and power demand-supply management system field testing by Fuji Electric.

Furthermore, in order to improve the control accuracy, we have implemented a forecasting function of photovoltaic power generation used[2] for utility customers. Typically, DER owner demand is controlled by the amount of power received. Since photovoltaic power generators installed by DER owners are included on the demand side, this tends to increase the error in demand forecasting. Our system forecasts the amount of power generated by the photovoltaic power generators installed by DER owners to improve demand forecasting accuracy and control accuracy.

(b) OpenADR-MODBUS conversion gateway

RA servers and resources are connected using the OpenADR protocol in accordance with the guidelines of the Ministry of Economy, Trade and Industry. However, OpenADR requires mutual authentication using encryption and electronic certification. Therefore, it is difficult to receive OpenADR directly when there is only a controller on the resource side. To easily connect with RA servers, we have developed the GW that converts OpenADR to MODBUS/TCP. This gateway has greatly reduced the hurdles surrounding the use of battery resources in VPP, and has facilitated the use of more resource groups in VPP.

(c) VPP storage battery system

A VPP storage battery system controls the permissible amount of charging and discharging according to measures, such as peak-cut, during normal operations to support VPP. When DR is activated, it performs high-precision monitoring and control to coincide the power system interconnection point with the DR value by controlling charging and discharging using forecasting in consideration of various constraints. These operation typically requires an energy management system (EMS) and controllers. Fuji Electric has developed a controller with built-in EMS functionality to share communications function with RA servers, helping achieve these functions needed. It is provided as a standard package and has been released to the market as a VPP storage battery system.

(d) VPP controller

For storage battery systems that do not come with the advanced functions required by VPP, we have developed a controller that implements VPP logic for achieving the same functions as Fuji Electric's VPP storage battery system and the interface for conventional storage battery systems.

(2) VPP challenges and measures

When there are many resources with large demand fluctuations or when the demand forecasting accu-

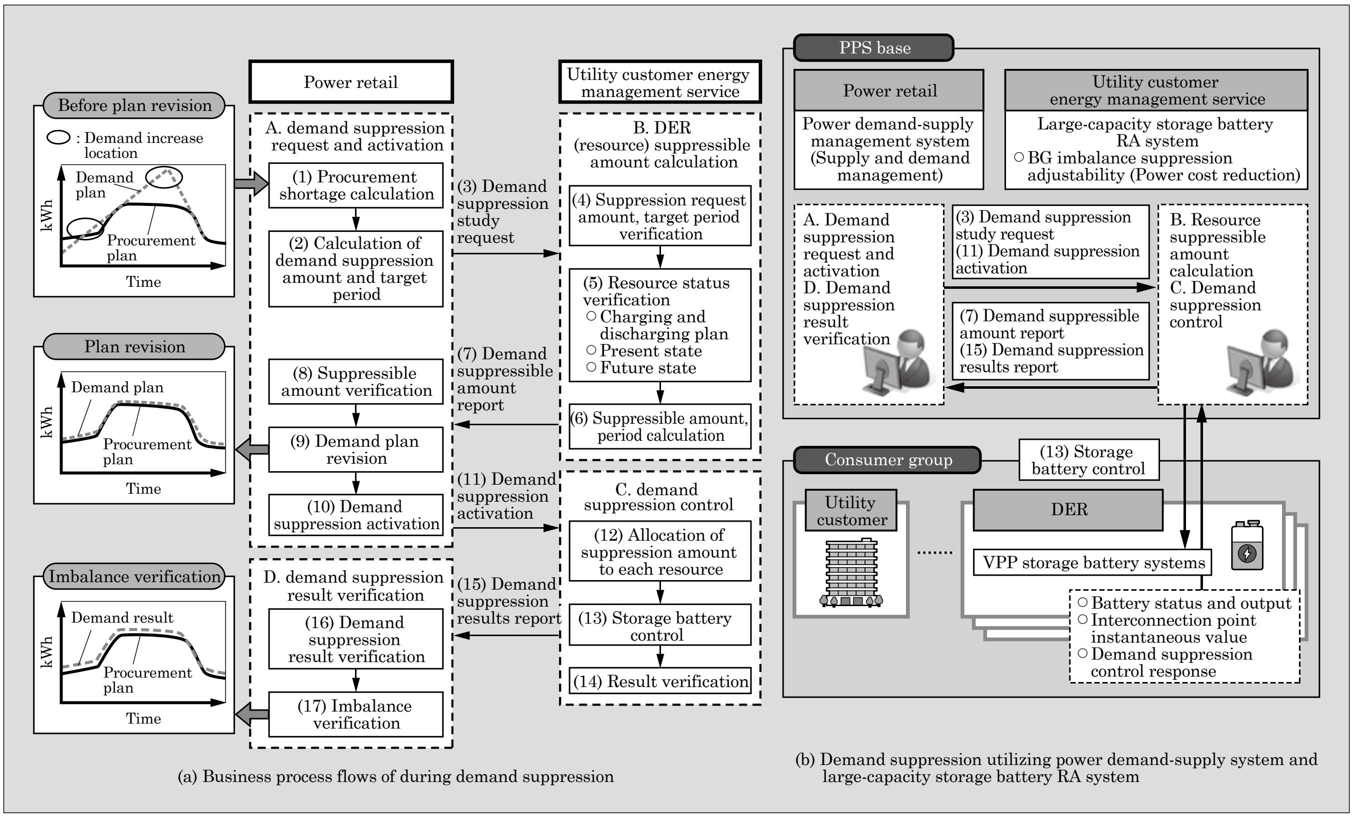

Fig.6 Power utility VPP solution combining demand-supply management system

racy deteriorates, it becomes difficult to control power within the target value. As a countermeasure, we are working to improve forecasting accuracy and provide feedback control throughout the entire resource group.

Furthermore, we plan to examine the evaluation index for contributing to the supply and demand adjustment of each resource in VPP demonstration projects in consideration of the balancing market that will be established in the future.

3.3 Power utility VPP solution combining demand-supply management system

Figure 6 shows the VPP solution for PPSs. This solution is designed to enable the retailing section of power producers and suppliers to minimize imbalance costs by utilizing storage batteries through the utility customer energy management system to suppress the demand of customers. This will enable utility customers to receive benefit from contribution costs based on their contribution. When a shortage imbalance, which is a state in which the demand forecast is larger than the actual demand, is expected to increase, the large-capacity storage battery RA system receives a demand suppression request from the power demand-supply management system and controls the utility customer's storage batteries to suppress the imbalance. In addition, the effect of introducing storage batteries is improved by providing multiple services, for example, it is used for customer services, including a peak cut and energy saving, during normal times.

4. Postscript

In this paper, we introduced our power demand-supply management system and VPP solution.

Electricity System Reform is intended to open up new power markets, such as a base-load market, real time market and capacity market. Furthermore, we expect the external environment to continuously change since the business policies of electricity utilities are also being influenced by the "Act on the Promotion of the Use of Non-Fossil Energy Sources and Effective Use of Fossil Energy Source Materials by Energy Suppliers" (Act on Sophisticated Methods of Energy Supply Structures), which seek to reduce environmental burdens.

In response to these changes, we will continue to study and create services that maximize the profits of electricity utilities.

References

(1) Katsuno, T. et al. Supply and Demand Control System for Power Systems with Distributed Power Supplies. FUJI ELECTRIC REVIEW. 2013, vol.59, no.3, p.191-195.

(2) Ishibashi, N. et al. Photovoltaic Power Generation Forecasting Technology for Supporting Energy Management Systems. FUJI ELECTRIC REVIEW. 2013, vol.59, no.3, p.196-200.

Fuji Electric

Innovating Energy Technology