Practical Use of Demand Response (DR) in Regional Infrastructures

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Abstract

In fiscal 2020, we applied for a public funding program for "The fiscal 2020 Subsidy for Virtual Power Plant Construction and Demonstration Project Expenses Utilizing Energy Resources on the Demand Side," which is subsidized by the Agency for Natural Resources and Energy of the Ministry of Economy, Trade and Industry in Japan. We developed a Resource Aggregator (RA) system necessary for the above demonstration project and conducted a Demand Response (DR) demonstration project that utilizes water supply facility pumps.

In this demonstration project, we used the newly developed RA system to confirm that DR can be implemented at water supply facilities. In anticipation of our participation in the Electric Power Reserve Exchange (EPRX) in fiscal 2022, we will continue to expand the RA system, enable flexible and accurate DR using a wide variety of water supply facility resources, and develop the DR business.

1 Preface

Currently, as energy shifts and decarbonization are in progress, the role of distributed energy resources and aggregators is expected to grow. There are growing expectations for Demand Response (DR) and Virtual Power Plants (VPPs) in addition to strengthening conventional energy-saving measures that reduce power consumption. These two things change demand patterns according to the status of power supply. Fig. 1 shows an overview of the VPP system.

With the progress of electric power system reform, multiple new electric power markets are being considered, one of which is an Electric Power Reserve Exchange (EPRX) that conducts DR according to product requirements of the market. Table 1 shows the product requirements for the EPRX.

Aiming to participate in the EPRX in fiscal 2022, we applied for a grant program: "The fiscal 2020 Subsidy for Virtual Power Plant Construction and Demonstration Project Expenses Utilizing Energy Resources on the Demand Side," a project subsidized by the Agency for Natural Resources and Energy of the Ministry of Economy, Trade and Industry in Japan.

In this demonstration, we developed a Resource Aggregator (RA) system and conducted a DR demonstration using the pumps of water supply facilities. This paper introduces an overview of the RA system developed in fiscal 2020, as well as details and results of the demonstration project.

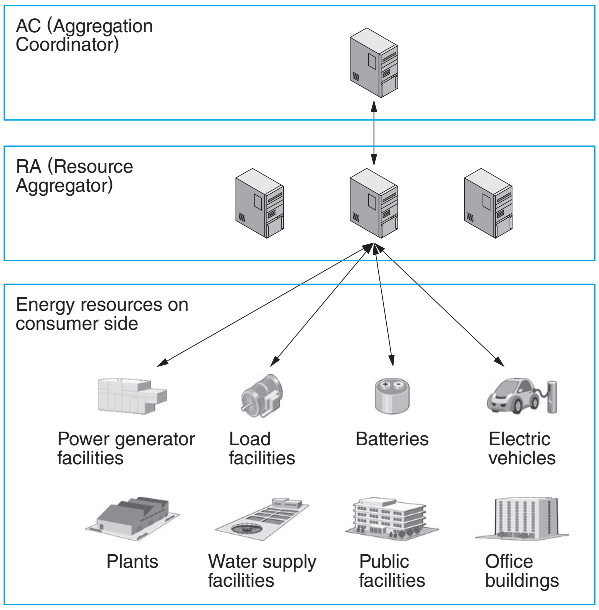


Fig. 1 VPP System

The overview of the VPP system is shown.

Table 1 Product Requirements for EPRX

Factors of product menus for the EPRX are shown. At present, tertiary adjustment ② is considered the major product menu.

	Primary adjustment power	Secondary adjustment power ①	Secondary adjustment power ②	Tertiary adjustment power ①	Tertiary adjustment power ②
Major requirement items	Frequency Containment Reserve (FCR)	Synchronized Frequency Restoration Reserve (S-FRR)	Frequency Restoration Reserve (FRR)	Replacement Reserve (RR)	Replacement Reserve-for FIT (RR-FIT)
Applicable case	・Applicable to variations during regular time from GC to actual demand and supply, and to phenomena of power source tripping (Falling in GF functions of generators)	・Applicable to variations during regular time from GC to actual demand and supply, and to phenomena of power source tripping (Falling in LFC functions of generators)	・Applicable to prediction errors during regular time from GC to actual demand and supply (Falling in EDC functions of generators)	・Applicable to prediction errors during regular time from GC to actual demand and supply, and to phenomena of power source tripping (Falling in EDC functions of generators)	・Applicable to power generation prediction errors from previous day to GC in regard to the renewable energy utilizing the FIT Special Permission System
Command and control	OFF line (Own terminal control)	ON line (LFC signal)	ON line (EDC signal)	ON line (EDC signal)	ON line
Response time	Within 10 s	Within 5 min	Within 5 min	Within 15 min	Within 45 min
Duration time	5 min or more	30 min or more	30 min or more	Merchandise block time (3 h)	Merchandise block time (3 h)
Suppliable quantity (Bidding quantity upper limit)	Output changeable quantity within 10 s (GF range upper limit for equipment performance)	Output changeable quantity within 5 min (LFC range upper limit for equipment performance)	Output changeable quantity within 5 min (Upper limit of on-line adjustable range)	Output changeable quantity within 15 min (Upper limit of on-line adjustable range)	Output changeable quantity within 45 min (Upper limit of on-line "including simplified command system" adjustable range)
Minimum bidding quantity	5 MW (2 MW for OFF-line monitoring)	5 MW	5 MW	Dedicated line: 5 MW Simplified command system: 1 MW	Dedicated line: 5 MW Simplified command system: 1 MW
Pitch width (Bidding unit)	1 kW	1 kW	1 kW	1 kW	1 kW

Source: Agency of Natural Resources and Energy, Ministry of Economy, Trade and Industry: "Introduction to the Electric Power Reserve Exchange (EPRX)" (13 October 2020, p.6)

2 RA System Overview

In the demonstration, we created a consortium with a power utility company acting as Aggregation Coordinator (AC). The DR was implemented by linking the AC and the consumers with the RA system. **Fig. 2** shows the configuration of the RA system. The RA system consists of a host link server, application server, Web server, and database server.

(1) Host linkage server

RA and AC has a "communication partner" function.

(2) Application server

RA main functions are installed.

(3) Web server

RA HMI functions are installed.

(4) Database server

Database functions used by RA are installed.

2.1 Functions of RA System

Major functions of the RA system are as follows:

(1) Host system linkage function

The AC server is linked to the controllable amount, standard value sum, sensor data, and DR information.

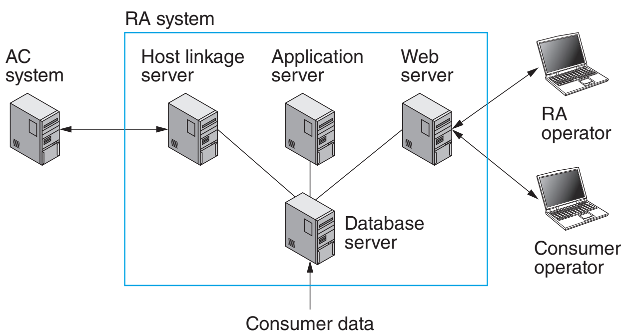


Fig. 2 Configuration of RA System

The RA system consists of four servers on cloud and its role is mainly linkage with the AC and data acquisition from consumers.

(2) Power prediction function (Functions of standard value calculation)

Based on past consumer data (actual values, day of the week, operational information), the system calculates standard values.

(3) Water level prediction function

When the customer answers the controllable amount, it predicts changes in the water level of the distribution and clean water reservoirs as an aid to confirming that there is no problem with the stable supply of water.

(4) DR distribution function

Based on DR information from AC, the system calculates DR allocation for each consumer.

(5) Results management function

In addition to collecting sensor data from each customer as needed and aggregating it to respond to requests from ACs, it is also used for power forecasting (reference value calculation) and water level forecasting as described above.

(6) Consumer/resource information management function

The system manages and edits consumers and resources registration information

3 DR Actively Utilizing Water Supply Facilities

For the DR of pumping facilities in water supply systems, the volume of pondage at the distribution reservoirs and pure water reservoirs is used as a buffer. While the stabilized supply of pure water is maintained, pumps are started and stopped on the inflow and outflow sides of the distribution reservoirs and pure water reservoirs. The DR that changes the demand pattern comes in the rising DR and the lowering DR. The rising DR means that consumption at the demand machines is caused by the DR actuation or the amount of electric power demand is increased because of the battery charging. The lowering DR means that consumption at the demand machines is suspended by the DR actuation or the amount of electric power demand is decreased because of reducing the output.

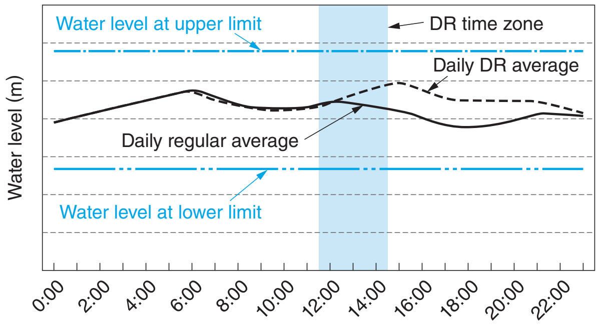
4 Demonstration Overview and Demonstration Results

The purpose of this demonstration was to verify the effects of DR response and to understand the impact on water supply operations. Since we could use the existing facilities for DR of water supply facilities, we could reduce the initial investment. This is a merit. **Table 2** shows the outline and results of the DR demonstration. The DR demonstration was conducted at two consumers (A and B). A high success rate was confirmed for both consumers in the lowering DR. **Fig. 3** shows the water level change when the lowering DR was implemented for two consumers, A and B. Since the stable supply of water is the top priority for water supply facilities, a mechanism was put in place

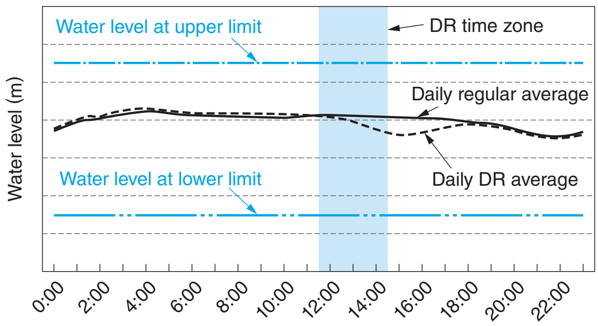
Table 2 Outline and Results of DR Demonstration

A high success rate was confirmed for both customers A and B in the lowering DR. The rising DR needs to be implemented in coordination with the water supply facility. Although the number of implementations is not large, it was confirmed that demand and supply adjustment is feasible.

DR command	Verification field	Outline of verification	Verification result
Tertiary adjustment ② Lowering DR	Consumer A	Verification: 6 times No. of frames: 28 DR command value: 74 kW	Success rate: 75% (21/28 frames)
	Consumer B	Verification: 12 times No. of frames: 72 DR command value: 70 kW	Success rate: 98.6% (71/72 frames)
Tertiary adjustment ② Rising DR	Consumer A	Verification: Twice No. of frames: 8 DR command value: 18.5 kW	Success rate: 87.5% (7/8 frames)



(a) Lowering DR at Consumer A



(b) Lowering DR at Consumer B

Fig. 3 Water Level Change when Lowering DR was Implemented for Two Consumers, A and B

Since the outflow pump of pure water reservoir stopped due to the lowering DR at Consumer A, the water level rose during the DR performance. At Consumer B, the inflow pump of pure water reservoir stopped due to the lowering DR, therefore, the water level lowered during the DR performance. At both Consumer A and Consumer B, the water level never deviated from the regular control range, and we confirmed that the lowering DR is feasible.

to ensure that the water level of distribution reservoirs and clean water reservoirs did not exceed the operating range and that DR response did not become a burden on normal operations. The demonstration results confirmed that the developed RA system is capable of DR between the AC and the consumers.

5 Postscript

This paper introduced a RA system overview and the DR demonstration conducted in fiscal 2020. Looking ahead to the market entry from fiscal 2022, we will continue to improve the RA system and plan to further develop the DR business.