Cloud Server Architecture to Optimize the Use of Distributed Energy Resources

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For the next-generation power systems, a mechanism called Virtual Power Plant (VPP) is expected to be deployed, where distributed energy resources are aggregated and remotely controlled by a resource server so that it operates like a virtual power plant. Sumitomo Electric Industries, Ltd. has developed what is called a resource aggregation server, *s*EMSA server, which plays a core role in this mechanism. Sumitomo Electric has been working to develop VPP systems and extend energy resources in order to enter a new electric power market that will be created after 2020. This paper presents the features of *s*EMSA server and its verified performance in pilot projects for VPP operation and photovoltaic power generation control.

Keywords: VPP, resource server, supply and demand management

1. Introduction

In Japan, where energy resources are not abundant, renewable energy is attracting great attention. The proportion of renewable energy used in domestic power generation rose to 8.1% in 2017. Meanwhile, affected by weather and other factors, renewable energy is subject to substantial fluctuation in the amount of power generation. Therefore, it is pointed out that the conventional supply and demand management system relying exclusively on power generation output control at large scale power plants could become unable to maintain stable electricity supply.

To counter this situation, construction of a next-generation power system that uses consumer-end energy resources is under way, as a novel scheme designed to balance electricity supply and demand. This scheme is known as a virtual power plant (VPP), since it enables adjustment of electricity supply and demand, as carried out by a power plant, through the integrated remote control of distributed energy resources owned by factories and residential houses with the help of information and communication technologies.[(1), (2)]

Sumitomo Electric Industries, Ltd. has developed a resource aggregation server (*s*EMSA server) that plays a core role in a VPP, and has participated several pilot projects. These efforts are intended for Sumitomo Electric to make inroads into the supply and demand management market and the capacity market to be created in or after 2020. Accordingly, Sumitomo Electric is actively working on system construction and energy resource expansion.

2. System Overview

Figure 1 shows a VPP system diagram. Located between servers (aggregation coordinators) at power companies and consumers' energy resources, the *s*EMSA server plays a role in calculating the optimal combination of energy resources and organically controlling them based on the request of the electric energy adjustment (the amount, starting date and time, and duration of energy adjustment) by the aggregation coordinator.

For the *s*EMSA server to achieve optimal control of energy resources, certain functions must be incorporated, including communication functions used to transmit control information and measurement data, and application functions for demand forecasting, generation forecasting, and optimal controlling.

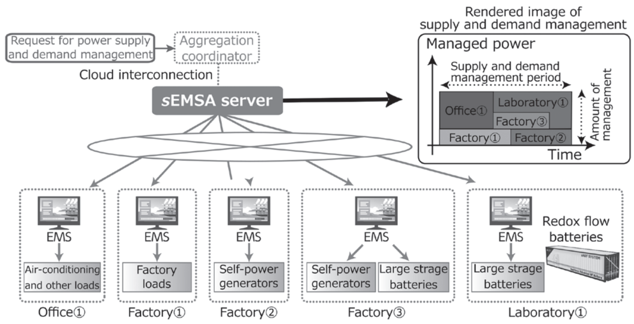

Fig. 1. VPP system diagram

3. Features of *s*EMSA Server

3-1 Module structure

The *s*EMSA server can be broken down into two functional blocks, a communication platform block and a service application block. These function blocks are connected with each other by the Hypertext Transfer Protocol representational state transfer (HTTP REST) and Structured Query Language (SQL) interfaces. Figure 2 presents a functional block diagram of the *s*EMSA server.

3-2 Extended OpenADR 2.0b specification

The *s*EMSA server has a virtual end node (VEN) and a virtual top node (VTN) mounted in the communication block. These nodes comply with the OpenADR 2.0b profile specification[(3)] and come, in addition to the standard OpenADR communication functions, with capabilities that

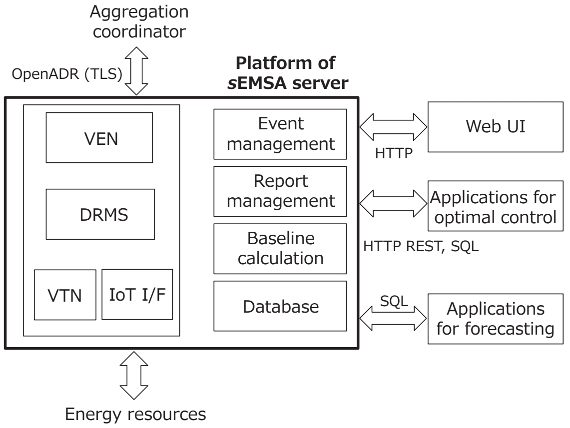

Fig. 2. Functional block diagram of *s*EMSA server

meet the following two sets of requirements specified in Edition 1.1 of the OpenADR Device-Specific Implementation Notes.(4)

• Appendix 2-A:
Implementation Notes for Communications Traffic Reduction
• Appendix 2-B:
Implementation Notes for Abnormality Detection and Recovery

The aim of Appendix 2-A is to reduce the communications cost and server load by reducing communications traffic. The document sets out techniques such as payload compression and cached authentication keys anticipated to be effective for the reduction. Sumitomo Electric had these functions embedded in the *s*EMSA server and successfully reduced communications traffic by 71% at a maximum, as verified with an actual system.

Appendix 2-B specifies handling of faults. In this respect, the lack of a definite provision in the profile specification becomes a matter of concern when establishing an interconnection. The communication block of the *s*EMSA server has a recovery mechanism, which, in the event of a packet loss or other faults, will resend payloads and carry out other tasks in accordance with the 2-B implementation note.

3-3 Forecasting model

The *s*EMSA server provides several sample models designed to accurately forecast demands and amounts of power generation. For example, the server allows the user to select from several models according to the intended use, including an hourly time-series model, a quantitative time-series model, and its derivative, an autoregressive model.(5) Additionally, these models have a common interface, allowing users to add their original forecasting models.

3-4 Optimal operation planning

Upon the receipt of a supply and demand management request from an aggregation coordinator, the *s*EMSA server issues a control command to energy resources. In this process, one of the challenges is how to determine a control value for each energy resource. The *s*EMSA server selects an ideal combination of energy resources to meet the supply and demand management request from the aggregation coordinator based on the results of demand and/or power generation forecasts. Moreover, the server monitors the control states of energy resources in real time during the supply and demand management period. In the event of a discrepancy between the actual control performance value and the target value, the server issues an additional control command to correct the control.

3-5 HA cluster system structure

The *s*EMSA server can have a high-availability (HA) cluster system structure by making the system redundant. Figure 3 illustrates an example cluster system structure dividing the VTN block into a working system and a standby system. This system structure comes with an alive monitoring function to switch over the process to the standby node upon detection of a fault and a node management function to manage the processing state of the local node and the active state of the network. These functions ensure operation continuity by transferring the process to the standby system in the event of any trouble on the working system during operation. Furthermore, this system structure comes with one virtual IP (VIP) address assigned to the working and standby systems. This feature allows VENs on the consumer end to be able to maintain connection without the need to discern the switchover between the working and standby systems when a failure occurs.

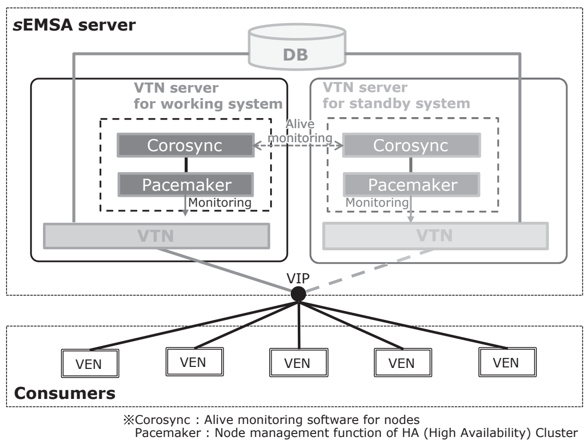

Fig. 3. Example HA cluster system structure

3-6 Electricity data analysis function

The *s*EMSA server comes with a graphical user interface for operation and maintenance. Available functions include user registration, event reception and transmission states management and analysis of measurements and various other data.

Figure 4 presents a graph of electricity consumption data measured in the past one year, sorting the data in decreasing order of the level of power usage per hour. The graph can represent the annual peak electricity value and a threshold specified at a desired proportion to the peak. Figure 4 makes it easy to find a guideline for reducing the peak demand. Figure 5 shows a screen used to manage information on devices connected to the *s*EMSA server. Owing to Fig. 5, the server operator becomes able to ascertain measurements and detect faults in equipment in real time.

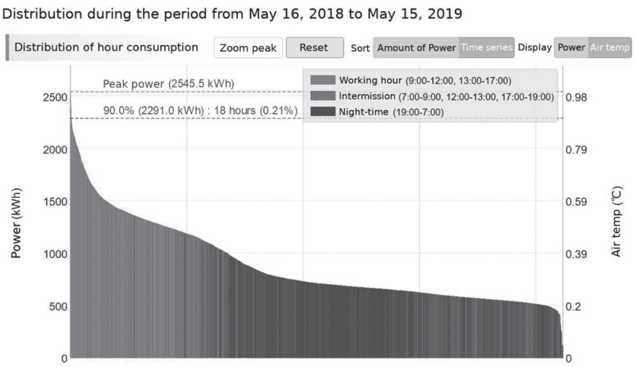

Fig. 4. Data analysis visualization function (demand analysis)

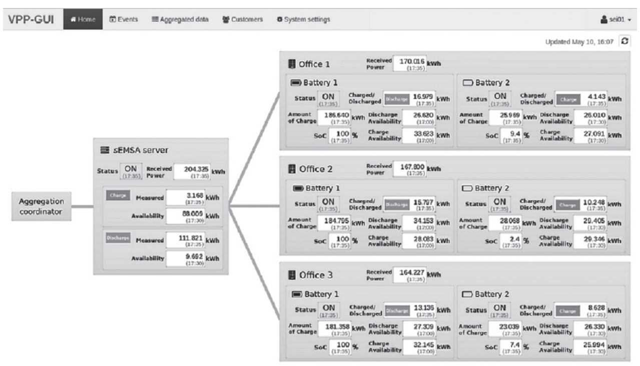

Fig. 5. Device state management function

4. Operation Examples

4-1 Pilot VPP project by METI

Toward the creation of new energy markets in the near future, the Ministry of Economy, Trade and Industry (METI) is promoting the expansion of energy resources in a five-year pilot VPP construction project starting in fiscal 2016. Sumitomo Electric is a member of the consortium managed by the Kansai Electric Power Company, Incorporated and has provided *s*EMSA server. At the same time, Sumitomo Electric participates in the project as a consumer and provides energy resources on the largest scale in the consortium by implementing optimal control of redox flow batteries and gas generators installed in its Osaka Works, Itami Works, and Yokohama Works. In fiscal 2018, Maebashi Works of Nissin Electric Co., Ltd. began to take part in the project. In combination with Sumitomo Electric's Yokohama Works, it achieved high-precision control (within ±10% of the target). Figure 6 provides an example of the results of the pilot project.

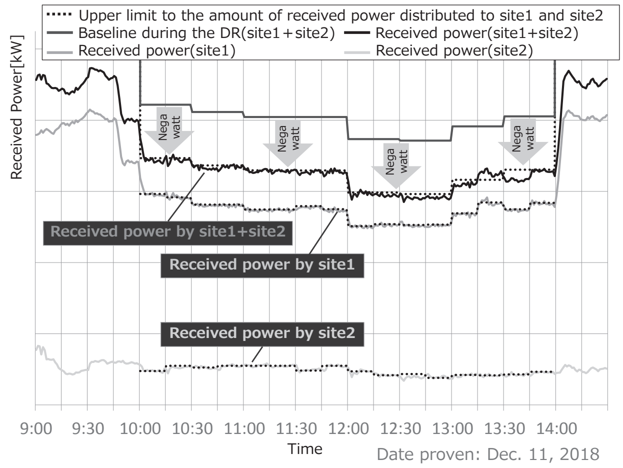

Fig. 6. Optimal operation control using *s*EMSA server

4-2 NEDO-PV power control pilot project

The New Energy and Industrial Technology Development Organization (NEDO) worked on the R&D Project on Grid Integration of Variable Renewable Energy: Enhanced renewable energy connection with power grid to address challenges, such as supply and demand fluctuations envisioned to occur along with the increasing introduction of the amount of renewable energy. Commissioned from NEDO, Tokyo Electric Power Company Holdings, Incorporated (TEPCO) and Waseda University developed what is called a smart inverter, a photovoltaic power conditioning system equipped with a grid stabilization function and conducted a proving test. Sumitomo Electric provided a server as a distributed energy resources management system (DERMS) that monitored and controlled the smart inverter.

Considering trends in the state of California and Europe, this project verified 14 control functions, including Volt-Var control and constant power factor control. Sumitomo Electric's server was equipped with the capability to send control information, such as Volt-Var control characteristic curves, to the smart inverter, as well as the capability to collect detailed data, including reactive power and power factor data. Sumitomo Electric also contributed to the exploration of communication interface specifications, enabling these data transmission capabilities in OpenADR 2.0b. The effectiveness of the specifications was proven in a test conducted by TEPCO and Waseda University.

Incidentally, Sections 3-2 and 3-5 of this paper contain achievements obtained as part of this project.

5. Conclusion

This paper described the architecture of the *s*EMSA server, designed to perform optimal control of energy resources. The *s*EMSA server has a strong track record principally in the VPP pilot project being promoted by METI. In this fiscal year, some pilot projects are being planned taking business into consideration. Through the pilot projects, Sumitomo Electric is committed to expanding the functionality and improving the quality of the *s*EMSA server, aiming at applying the *s*EMSA server to supply and demand management services in the new energy market to be created in or after 2020.

• *s*EMSA is a trademark or registered trademark of Sumitomo Electric Industries, Ltd.

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