Projects on New Energy Services

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Demand for electric energy systems is diversifying to counter global warming, and to address resource depletion and secure safety. In this context, renewable energy is an important option that meets all these requirements, and its wide diffusion is highly expected. However, renewable energy generation systems are characteristically unpredictable due to the fluctuation of power generation as they depend on natural phenomena such as sunlight and winds. This aspect makes it difficult to adopt them in terms of supply-demand control. To address this point, the future power generation systems must utilize information on power consumption in coordination with the power supply system, and this is stimulating efforts to develop standards in this field. Meanwhile, the Internet of Things (IoT) is increasing its utility, connecting not just computers and other information devices but all kinds of items. We consider that the future will see a new form of energy service that combines highly networked energy systems with the IoT. This paper describes the trend to standardize energy systems and the IoT, and it explains Fujitsu Laboratories' projects in this area and its efforts to realize a new energy service.

1. Introduction

There are high expectations for renewable energy to become widely available from the viewpoints of countering global warming and resource depletion, as well as ensuring sustainability. However, renewable energy is characteristically unpredictable due to its fluctuation in power generation, making it an option that is difficult to manage in terms of the supply-demand control. To help with this, controlling energy demand from the consumer side is considered crucial. Demand response (DR) is a system of coordinating the supply-demand balance by collaborating with customers. In the USA, pioneering in commercializing DR, there are DR services offering a variety of service formats. One such standard service is the Open Automated Demand Response (OpenADR), and it is being promoted proactively. This DR service is expected to be introduced in Japan in tandem with the deregulation of electricity. In view of this, Fujitsu Laboratories has been participating in efforts to standardize OpenADR, and spearheaded the industry players that are developing software in compliance with the latest standard of OpenADR 2.0b.1)

Meanwhile, the Internet of Things (IoT) is increasing its utility, connecting not just computers and other information devices but all kinds of items. We consider that the future will see a new form of energy service that combines highly networked energy systems with the IoT.

This paper explains the trends in the standardization of energy systems and the IoT, and then it describes Fujitsu Laboratories' projects in connection with this initiative: mechanisms of data-communication between OpenADR and IEC 62746, and connection between OpenADR and ECHONET Lite.2) The paper then describes the initiative towards the realization of new energy services—an energy consumption analysis service and system to control consumer demand for electricity.

2. Trends in standardization of energy system and IoT

Figure 1 illustrates the emerging energy services that combine an energy system with the IoT. The energy system shown is being discussed by energy-related parties as they attempt to standardize an information model made by the International Electrotechnical

Commission (IEC) and the U.S. National Institute of Standards and Technology (NIST).[3)–7)] The standardization is currently underway for IEC 62325 on electricity market trades,[8)] IEC 61970 on grid systems operations,[9)] IEC 61968 on power network and substation management,[10)] and IEC 61850 on information models. The trend is to extend and apply these standards to the customer domain.

The customer domain depicted in Figure 1 is a new area in the energy system, and the NIST has paid the most attention to it. The areas currently under consideration for standardization are the OpenADR targeting demand response services, Facility Smart Grid Information Model (FSGIM) which focus on commercial buildings and industries, and ZigBee Smart Energy Profile (SEP) 2.0.[11)–14)] Also, recent developments include the standardization of the interface to connect energy suppliers, the market and customers (factories, commercial buildings and domestic houses) under the IEC 62746 category.[15)]

In relation to the IoT, for example, household appliances and residential equipment are connected to the network, giving rise to new applications. There are ECHONET and ECHONET Lite for the telecommunication protocol for these appliances and equipment. The ECHONET consists of the transmission media below the transport layer and the communication process layer that absorbs the difference between media specifications and controls devices. The current version published in 2011, ECHONET Lite, differs from ECHONET in its specifications; IP addresses or MAC addresses are used instead of standardizing sections below the transport layer. Standardization of these lower layers was published by the Telecommunication Technology Committee (TTC) in the technical report TR-1043.[16)] This report generally defines standards, largely based on IP communication, for connection via the Ethernet, Wi-Fi, as well as the power line communication (PLC) and 920 MHz radio communications (ZigBee, Wi-SUN).

To operate in the environment of these specifications, there must be a mechanism to connect different information models each defined by the respective standards. In the following, we will describe data-exchange between OpenADR and IEC 62746, and data-relay between OpenADR and ECHONET Lite, as examples of Fujitsu Laboratories' endeavors.

3. Data-exchange between OpenADR and IEC 62746

Standardization is underway regarding the interface that connects energy suppliers with the market and customers (IEC 62746). Meanwhile, in the USA and other countries, there is OpenADR as the international standard for the existing DRs. Therefore, there are discussions on how to exchange data between these different standards. This data-exchange can be

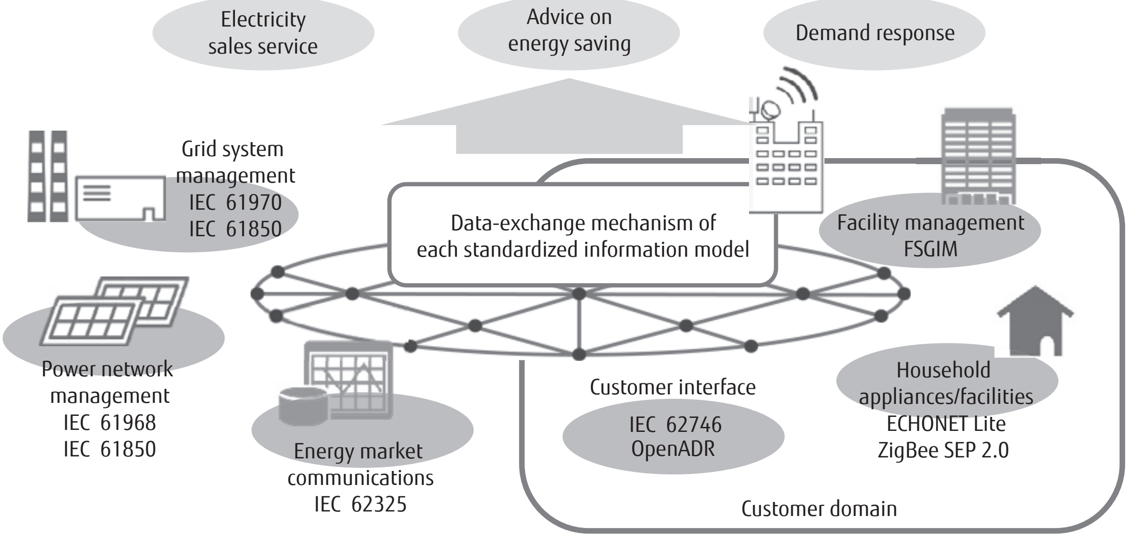

Figure 1
Emerging energy services.

realized by an adapter that converts information models between the Common Information Model (CIM), which is extended for the DR, and OpenADR (referred to as CIM OpenADR adapter hereafter). Thus, Fujitsu Laboratories has developed its own CIM OpenADR adapter.

We will explain the data communication using this adapter in **Figure 2**. The energy supplier sends out a DR event request to reduce energy demand by 1.0 MW to a DR aggregator, using the standard information model according to the IEC 62746. The DR aggregator converts the request into the information model standards by OpenADR by means of the CIM OpenADR adaptor, and the converted information will be sent to customers.

The OpenADR has the following IDs, and these need to be mapped to the CIM in the future:

1) eventID: defines DR events
2) requestID: manages responses to the DR events
3) signalID: distinguishes details of the requested events
4) VTN (Virtual Top Node) ID, VEN (Virtual End Node) ID: specify DR event sender and recipient
5) partyID, groupID: specify customer group
6) mRID: specifies the resources held by customers

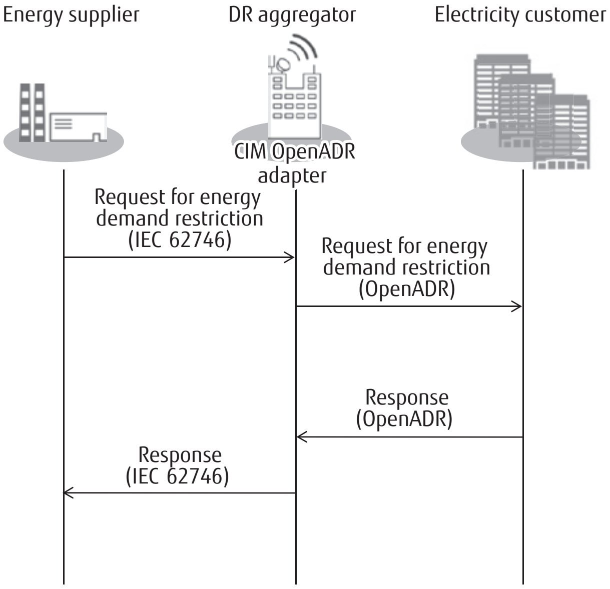

Figure 2
CIM OpenADR adapter.

4. Data-relay between OpenADR and ECHONET Lite

Figure 3 illustrates the constellation of data-relay between the OpenADR and ECHONET Lite. In this illustration, it is supposed that the energy supplier issues the energy-restraint event via the OpenADR, and the customers have ECHONET Lite-enabled devices installed. The DR aggregator in the middle is compatible with the protocols of both the OpenADR and ECHONET Lite. In connecting the OpenADR and ECHONET Lite, the adapter extracts, and supplements if necessary, applicable pieces of information to relay, such as the device IDs, and time, items and amounts subject to the control request.

ECHONET Lite mainly enters control commands for customers' devices and receives their responses. It identifies the devices by the IP addresses of the devices or gateways. The OpenADR may directly control specified devices, or assign charges by different hours and/or an amount of reduction on demand for certain hours. In the case of direct control, the control command has to be interpreted, and the designated devices must be identified. Where the aggregator specifies the limit to the energy demand, it needs to create a control plan

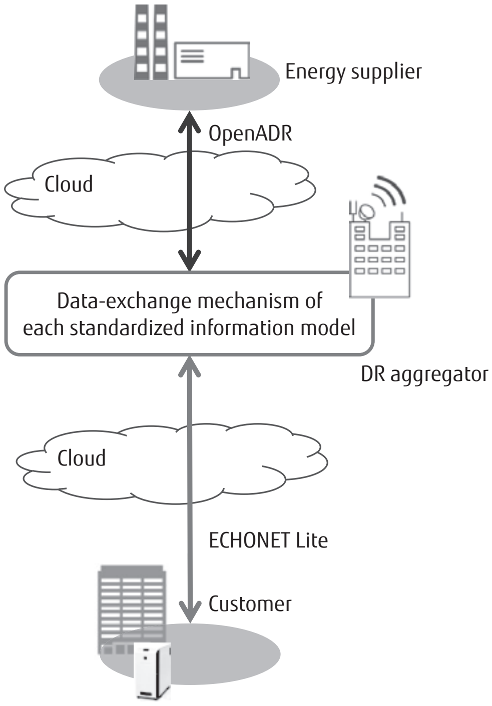

Figure 3
Data-exchange OpenADR and ECHONET Lite.

and assign the energy reduction quota to each customer in order to satisfy the reduction order. In the following, we will explain the communication from the aggregator to customer in both cases.

4.1 DR event for direct control

The information required for a direct control includes device IDs, the time, item, and the amount of energy subjected to control. First of all, the OpenADR determines the devices by identifying the customer based on VEN ID, followed by the device types or resource IDs. The DR aggregator manages the IP addresses of customers' ECHONET-Lite-enabled devices and gateways, and this makes it easier to identify the devices to be controlled by referencing their associations with the OpenADR IDs.

The DR event signals from the OpenADR contain the inscription of executing periods, from which the adapter determines the start and end times of the control execution, and sends commands to ECHONET Lite at these specified times.

For example, OpenADR may command charging/discharging of storage batteries, or temperature setting for air-conditioning units. It expresses the command type in combinations of signalName and signalType IDs, and it specifies in the Interval IDs the amount of energy to be saved. Based on this information, the adaptor selects the property items of the device on the ECHONET Lite side for specifying the instructed values.

We will describe an example of the relay between OpenADR and ECHONET Lite to control the storage battery charging/discharging based on the above method. OpenADR's demand response event consists of the following: signalName = CHARGE_STATE, signalType = delta, specified value for DR period = -1.0 kWh. In this case, the command signifies a discharge of 1.0 kWh. To control the storage battery, using the storage battery class of ECHONET Lite, the adapter sets the property value at -1000 Wh for the charging/discharging volume setting 1 (EPC = 0xE0).

4.2 DR event to specify energy charges and reduction targets

OpenADR can handle incentive-based DR events, with regards to energy charges and saving amount. The DR event types can express real-time pricing (RTP), critical peak pricing (CPP) and peak time rebates (PTR). The incentive-type event can either determine the peak consumption level or give an incentive based on the saving made from the baseline, and OpenADR can express the maximum value by time-period, baseline, and saving amount.

The information thus contains items relating to the restriction on energy consumption, but no data regarding the details of control commands for individual devices. Therefore, the aggregator is equipped with a logical expression to generate control plans for devices corresponding to the DR event requests, and sends control commands to ECHONET Lite at designated times. It generates control plans to optimize the cost against DR events in relation to the electricity pricing. If the events are on the saving amount calculated from the baseline, the plan will ensure that energy consumption stays below the baseline during the specified time-period.

5. Projects on energy services for enterprises

Introducing DR services will help energy utilities to avoid excessive infrastructure investments to counter peak-hour energy demand. It will also bring benefits to customers, as they will be able to reduce their energy cost by leveraging the DR services. In the future, it is expected that enterprises will take advantage of DR services to reduce their energy cost by adjusting their group-wide energy demand by adapting to varying charges by time-period. In order for a company to conduct group-wide demand adjustment, there needs to be a system in which the function of a DR aggregator is performed by certain agents, such as procurement or general affairs departments, which analyze the energy demand factors by office, branch or division, and internally share the information and execute the demand adjustment, as shown in **Figure 4**.

We have developed a pricing/cost simulator to analyze the energy demands and calculate the most cost-effective operations, as a service aiming to realize a system of company-wide demand adjustment. This tariff simulator offers the following service consisting of energy-consumption analysis and operation simulation. In the energy-consumption analysis, it analyzes the factors that underlie the energy demands by division, branch, etc., and calculates the prospective savings to be made by leveraging the DR services. Operation simulation evaluates the operation methods

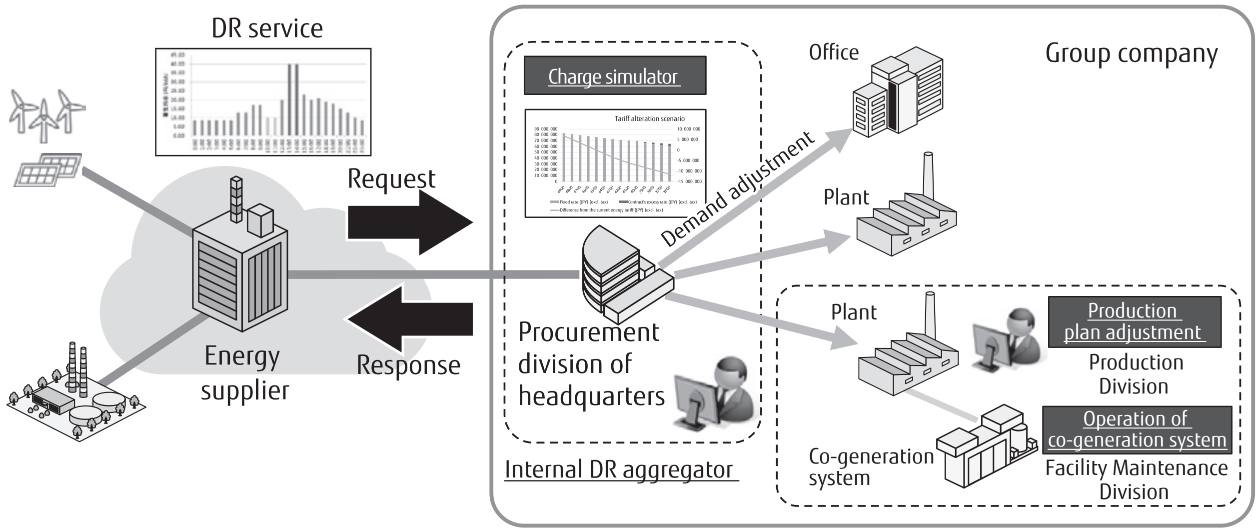

Figure 4
Energy cost optimization for the entire business group.

and anticipated cost-reduction, supposing that the demand adjustment were to be adopted, for example, in terms of utilizing the power-generation facility owned by the company, or modifying the production plans.

5.1 Energy consumption analysis

First, it analyzes the actual energy consumption using a pattern analysis, change point detection and other statistical methods, to predict the cost-saving effects through demand-adjustments and peak-hour consumption cuts according to the DR.

1) Energy demand factor analysis

The analysis that makes it possible to conduct energy demand forecast for offices and plants is the essence of how to leverage DR services or other new pricing programs. Using data on energy consumption from the past few years, demand/consumption analysis is conducted to obtain the demand/cost patterns by high-demand hour and season. Through the analysis, businesses can be categorized; some businesses may be a conventional type and use the most electricity in the evenings in summer, while other businesses may consume electricity in winter as much as in summer due to the need to run heating systems on electricity. Also taking into consideration the energy consumption tendencies in May and October, the months when PV power supply is likely to generate a surplus, the business is assessed to see whether it is likely to benefit from DR services.

Furthermore, the correlation between climatic conditions such as temperature and humidity and energy demand is analyzed to identify weather-dependent factors, and explore the possibilities of energy-cost reductions.

2) Charge choices and pricing simulation

Reviewing the charges of several utilities, the simulator identifies the best energy-pricing program based on the data of energy demand fluctuation patterns and seasonal factors.

From the analysis results, it runs a simulation on the energy cost, applying the charge of the chosen DR service. In order to realize the most cost-effective practice, the system clarifies energy-consumption guidelines for day-to-day operations based on the energy demand forecast technology.

The internal DR aggregator, say, a procurement department, shares the results of the analysis and evaluation as explained above with facility maintenance and production divisions via the cloud.

5.2 Operation simulation

Internal demand adjustments can be executed, for example, by introducing a co-generation system (the exhaust heat from a gas generator is reused in an air-conditioning system), and modifying the plant's production plans. In this case, it is important that the simulation service makes it easier to achieve the most optimal energy cost for the entire business through efforts to adjust energy demand across the company.

1) Adjustment simulation based on the operation of co-generation system

Supposing a co-generation system is operated, it is necessary to consider the energy cost for generating the electricity and heat, and the impact of employing the co-generation system on the cost cutting during the peak hours, the data to be leveraged in the cost prediction and management. Daily operations are simulated by calculating the amount of energy demand to be controlled under DR events, and hours of operating the co-generation system to minimize the electricity/gas cost.

2) Adjustment simulation based on the modification of production plans

A level production strategy is a standard practice in manufacturing today. However, this is not necessarily an ideal production operation from the viewpoint of energy cost. The simulation helps to reorder the production processes of different energy consumption levels in order to maximize the effects of cost reduction. It does so by means of a mathematical optimization method, while maintaining adherence to the restrictions posed by the leveling principle. Postulating a production planning service like this, we are working on the development of a production scheduler.

When conducting these simulations, demand adjustment items are interrelated rather than independent from one another. For this reason, we created a model to illustrate the flow of the electric and thermal energies consumed by shared facilities, such as the co-generation system and freezers, on the one hand, and offices and production lines, on the other, as shown in **Figure 5**. The aim is to realize a comprehensive simulation of energy demand adjustment.

This energy flow model makes it easy to calculate energy cost by actual production performance, visualizing the comparison between the actual cost distribution and cost-reduction effects obtainable through the demand adjustment for each section. Moreover, even more detailed energy cost distribution can be achieved by contrasting the energy flow model against production plans and other data, which are not energy-related, even in the case where energy consumption is not measured minutely by facility or process. Utilizing this operational simulation, energy cost is understood in detail, and this helps to enhance the efficiency of company-wide energy demand adjustment.

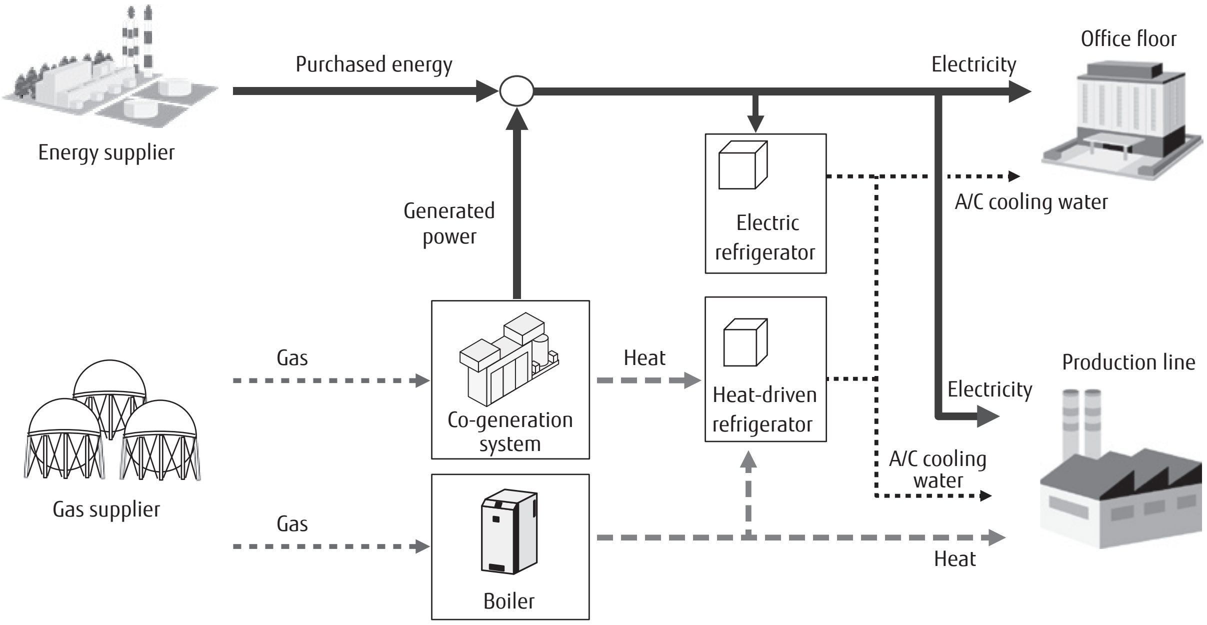

Figure 5
Energy flow model (illustration).

6. Conclusion

This paper described the trends in standardization of energy supply systems and the IoT, efforts made by Fujitsu Laboratories, and the projects towards realizing new energy services.

Renewable energy is expected to be more widely used, but it is difficult to predict the level of power generation due to the volatile nature of the generation systems. Therefore, it is not an easy option to view energy supply from the perspective of supply-demand balance. To address this point, it becomes increasingly important to have information on the customer domain in coordination with the power supply system, and this is stimulating efforts to develop standards in this field. Meanwhile, as the IoT continues to progress, we consider that the future will see new forms of energy services that combine highly networked energy systems with the IoT.

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