Yokohama Smart City Project (YSCP)

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Abstract

The Energy Management System (EMS) is a system that plays an important role in building a smart grid. We joined the Yokohama Smart City Project (YSCP) for the development and verification testing of the smart EMS. For Yokohama World Porters, we built a smart energy system that combines smart Building Energy Management System (BEMS) and distributed energy resources. Current results show that the introduction of the smart energy system reduce CO_2 emission by approximately 20%. When the master system requires the demand response, we are able to reduce incoming power at the rate of about 40% by managing the responses of energy supply facilities and by reducing load with effective system operation. Going forward, by drawing on the technologies and know-hows developed through this demonstration project, we will develop businesses of the smart EMS which makes optimal control of distributed energy resources such as Combined Heat and Power systems and energy storage systems.

1 Preface

The smart grid is getting increased attention against the background of such factors as demands of greenhouse effect gas emission reduction, energy saving, and impacts of the big earthquake in Japan. There is also rising awareness on energy saving and a serious review on the Business Continuity Plan (BCP) and also the necessity for power system stabilization against the increased introduction of renewable energy resources. The smart grid is intended to make an integrated operation and management of information on power transmission and distribution power network and power consumer's demands. This system is made by actively using information and a communications network. The Energy Management System (EMS), plays a vital role in building a smart grid.

As for our programs for the Yokohama Smart City Project (YSCP), we conducted verification tests on the smart grid regarding the improvement of the efficiency of energy use on the energy consumer side as well as the handling of the Demand Response (DR). Drawing on the gained technical knowledge and know-hows developed through this demonstrative project, we are developing EMS businesses.

This paper introduces our programs for the YSCP and business development for EMS.

2 Our Program for the YSCP

The YSCP is a project selected in 2010 by the Ministry of Economy, Trade and Industry (METI) as an area for "Next-Generation Energy and Social System Verification." It is intended to promote system introduction and verification for balance optimization of energy demands and supply in an existing urban area with buildings such as homes and businesses. As a key member company of the YSCP, we joined the YSCP and supplied a smart Building Energy Management System (smart BEMS) to Yokohama World Porters ("YWP"), a smart Factory Energy Management System (smart FEMS) to Yokohama Works of the Sumitomo Electric Industries, Ltd., and a demand balancing energy storage system to the annexed site of Tsunashima Substation of Tokyo Electric Power Corporation. A verification test program was carried out there. An outline of the verification program and the results of the verification test program at YWP are described below.

2.1 Purpose of Verification Test Program

According to the request of the Community Energy Management System (CEMS) or such an upstream master system, the smart grid has to provide an arrangement so that energy consumers can actively regulate the power demand. In such a case, compliance decisions based on economic rationality are indispensable. Even in regular energy management, economics and efficiency are the basic requirements and assurance of convenience for energy consumers is also important. In this verification test program, it aimed to build a new energy system to cope with DR and more efficient DR energy use by best utilizing energy supply facilities such as distributed energy resources and energy storage systems installed on energy consumer premises.

2.2 Outline of Verification

YWP (total floor space: approx. 100,000m^2), is a large-scale commercial facility located in Minato Mirai 21. We delivered to this facility two smart BEMSs and a stationary large-scale lithium ion storage battery system (which was produced under a joint project with NEC Corporation). Using these systems, we established a smart energy system combining the existing Combined Heat and Power system (CHP). Fig. 1 shows the demonstrative system for YWP.

The smart BEMS is intended to realize proper energy management flexibility under the various situations and conditions including DR. This includes its role for master system as an information and communication terminal. For this goal, the smart function was added on top of the conventional monitor and control functions and visualization function. Fig. 2 shows the functional Configuration of the EMS.

The smart function is composed of functions such as energy demand prediction, optimal control of energy supply, and a supporting function for BCP. The energy demand prediction is used to predict heat and power demands on the next day based on past demand data and meteorological data. The function of optimal control of energy supply is used to minimize energy costs and environmental impact costs by making an optimal management plan and automatic control of energy supply equipment based on predicted demands. In regard to the DR request from a master system, a management plan is made with due consideration to the incentive unit price. Then the DR acceptance is decided. Fig. 3

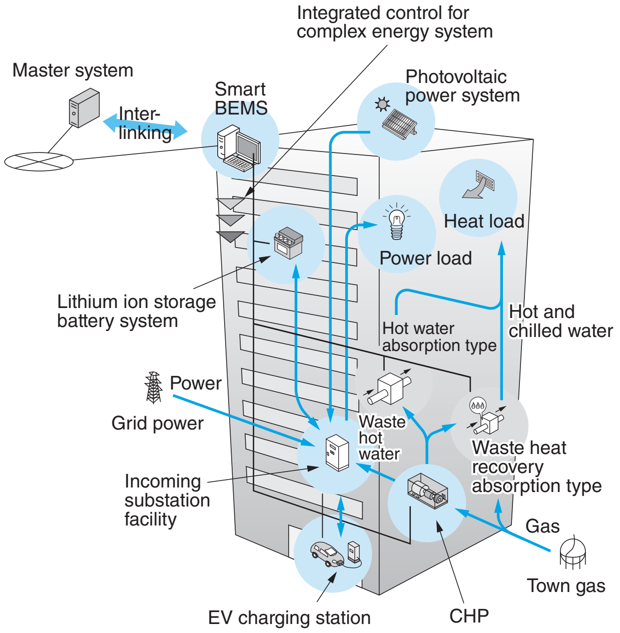

Fig. 1 Demonstrative System for YWP

The smart BEMS and lithium ion storage battery systems were introduced to YWP for smart energy system building.

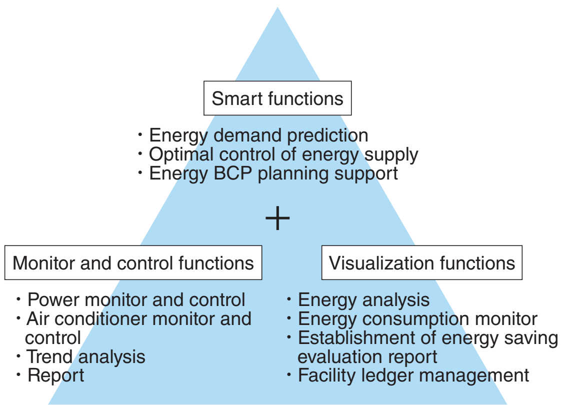

Fig. 2 Functional Configuration of the EMS

In addition to conventional functions of monitor, control, and visualization, the smart BEMS is provided with smart functions.

shows image of the optimal control for energy supply. If there is any discrepancy between the demand prediction value and actual value, there is a function to smart EMS auto-re-plan after automatically correcting the demand prediction value.

The energy BCP response function supports management of distributed energy resources in emergency case such as a power outage of the receiving power. We can customize according to consumer power requirements and facility configuration at each case.

In this verification test program, the effectiveness evaluation of this system were conducted by

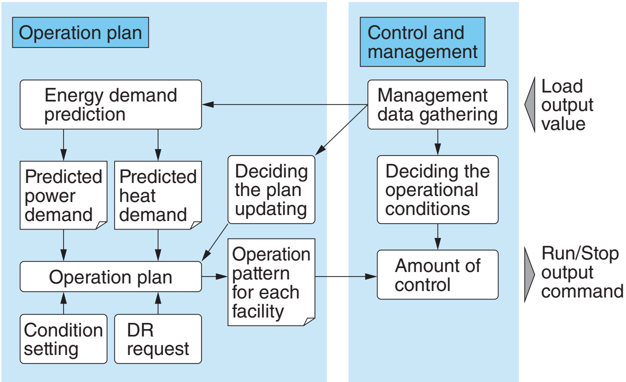

Fig. 3 Image of Optimal Control for Energy Supply

Based on demand prediction, the system drafts an optimal operation plan for energy supply facilities and makes automatic control. As a result, we aim to reduce both the energy cost and environmental cost.

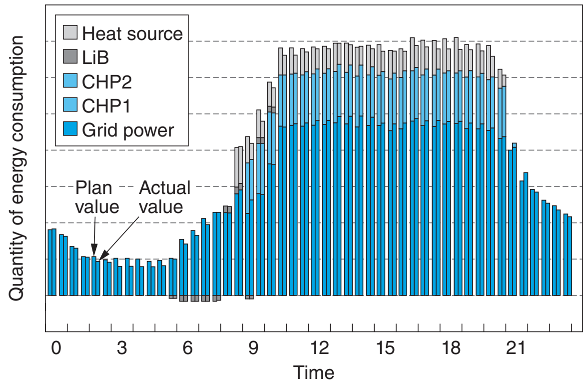

Fig. 4 Example of Graph for Optimal Energy Supply Plan

By the optimal energy supply control, effective use of waste heat from CHP can be arranged and efficient energy management was realized.

building and operating a smart energy system in YWP.

2.3 Test Items and Verification Schedule

Major test items and verification schedule are shown below.

(1) Building a smart energy system (Fiscal 2011)

Two BEMS and a stationary large-scale lithium ion storage battery system (250kWh) were introduced to this verification site. We constructed a smart energy system in combination with the existing CHP system.

(2) Verification of optimal control for energy supply (Fiscal 2012 to 2014)

By performing the smart BEMS's, optimal control on the energy supply facilities CHP system and energy storage system, we verified the effect of improvement of energy use.

(3) Verification of DR by energy supply facility (Fiscal 2012 to 2014)

Against the DR requests from a master system, automated DR verification tests were carried out by using an adjustment power margin in the existing CHP system and energy storage system.

(4) Verification test program of DR for load reduction (Fiscal 2013 to 2014)

In addition to DR from energy supply facilities, DR verification tests were conducted for load reduction by operation.

2.4 Result of the Verification

2.4.1 Verification for the Improvement of Energy Use Efficiency in Facilities

Fig. 4 shows an example of a graph for the optimal energy supply plan. This is an operation plan for the optimal integrated control by the smart BEMSs for the existing CHP and energy storage system. The CHP system was designed to make effective use of waste heat. In addition, the energy storage system is used to perform a load shift operation making full use of the difference in electricity unit prices between nighttime and daytime.

Before implementation of the smart energy system, the operation of the CHP system was stopped from 8:30 to 9:30 to prevent reverse power flow although waste heat recovery of the CHP can be expected during this time frame. When an energy power storage system was combined with charging control, however, it's possible to perform a rated capacity CHP operation from 9:00 to 9:30. As a result, more efficient energy management was realized.

2.4.2 Verification of Automated DR in Energy Supply Facilities (Wintertime)

Fig. 5 shows an example of a DR graph for energy supply facility in wintertime. Based on the aforementioned optimal operation pattern in facilities, this graph shows the results of DR verification tests in wintertime. The outline of DR features in this case is as described below.

(1) DR class: Peak Time Rebate (PTR)

(2) Time frame for DR: 17:00 to 20:00

(3) DR incentive unit price: ¥10/kWh

According to the plan after the reception of DR information, the second CHP system was operated in the DR time frame and both systems maintained rated operation. This program controlled receiving power. In addition, the discharge time frame of the

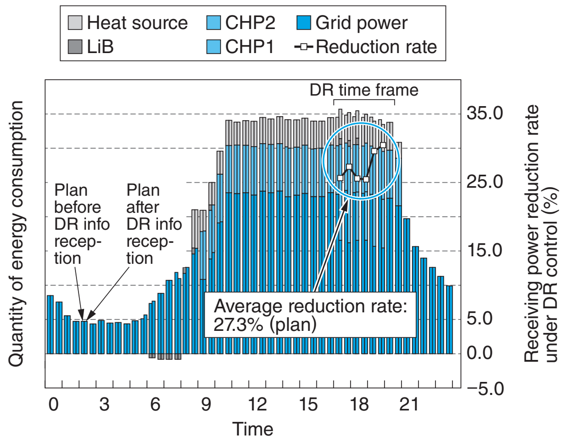

Fig. 5 Example of DR Graph for Energy Supply Facility in Wintertime

The second CHP system is operated in the DR time frame and two CHP systems are running at rated operation. In this manner, we aim to reduce receiving power.

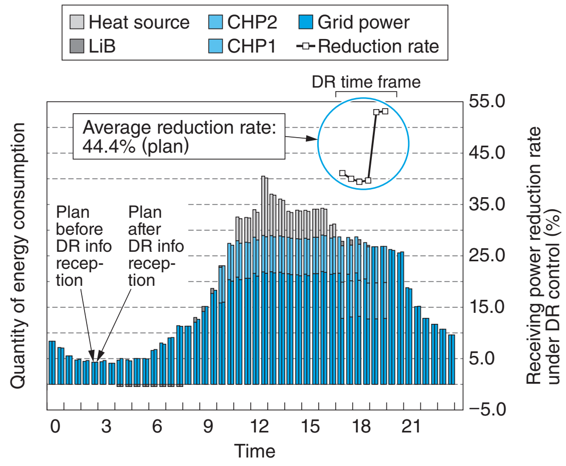

Fig. 6 Example of DR Graph in Wintertime by Load Operation

In addition to DR application by energy supply facilities, DR application by load operation was additionally carried out and further reduction of receiving power was realized.

energy storage system was shifted to the DR time frame for further reduction of incoming power. It was considered that these time frames of operation had been inefficient unless a DR request was introduced. The economic rationality is, however, ensured by taking into account the incentive by night and day unit price differences.

2.4.3 Verification Test Program of Load Reduction by DR during Operation (Wintertime)

Fig. 6 shows an example of a DR graph in wintertime by load operation. In winter 2013, we carried out DR verification test program of “load reduction by operation” in addition to tests of DR from energy supply equipment. An outline of the DR tests in this case is as described below.

(1) DR class: Capacity Commitment Program (CCP) for negawatt power bidding by REP (see below (3).)

(2) Time frame for DR: 17:00 to 20:00

(3) DR incentive unit price: ¥30, ¥30, ¥30, ¥30, ¥10, ¥10/kWh (rate change in every 30min after 17:00)

According to the plan after receiving DR information, the second CHP system was put into operation in the DR time frame and both systems were made to maintain rated operation. In addition, the discharge time frame of the energy storage system was shifted to the DR time frame. Because of the introduction of incentive unit prices, economic rationality was evaluated and the operation plan was updated accordingly. The original plan was based on the plan before receiving DR information. Primarily, Retail Energy Provider (REP) bidding was

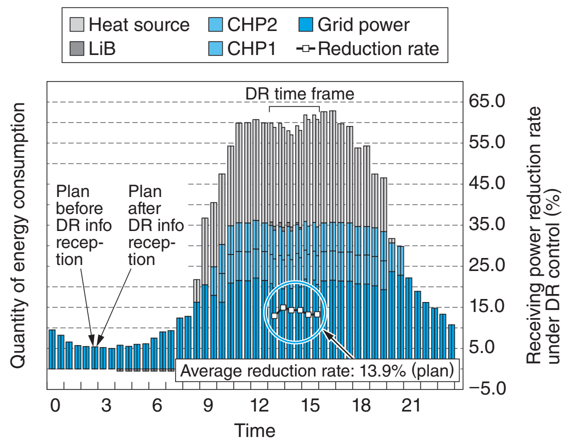

Fig. 7 Example of DR Graph in Summertime by Load Operation

Since energy supply equipment in this verification site has no margin for control in the DR time frame in summer, DR application was conducted only by load reduction through load operation.

concluded so that the unit price provided by REP would not give rise to any economic losses. After the tests, the unit price was considered to be proper.

Since the actual energy operation in the YWP is different from the case shown in **Fig. 5**, it is impossible to make comparison between both cases. According to the plan, however, the quantity of receiving power is estimated to be reduced on average by 44.4% during the DR time frame.

2.4.4 Verification Test Program of Load Reduction by DR during Operation (Summertime)

Fig. 7 shows an example of a DR graph in summertime by load operation. Similarly, as for the case in winter 2013, we carried out DR verification test program on "load reduction by operation" in addition to the tests of DR from energy supply equipment. An outline of DR tests in this case is as described below.

(1) DR class: CCP for negawatt power bidding of REP

(2) Time frame for DR: 13:00 to 16:00

(3) DR incentive unit price: ¥50, 50, 50, 50, 50, 50/kWh (in the unit of 30min from 13:00)

According to the plan before and after the reception of DR information, there is no difference in the operation plan between CHP and energy storage system in the DR time frame. Since the initial regular operation of CHP, the plan was intended to operate two CHP systems in the DR time frame and there was no more margin for control as the energy storage system was also programmed to discharge power at the peak time. Since the DR time frame and the peak time frame were overlapped, there was no margin for control as a result.

Power demand in the plan after the reception of DR information is indicated after deducting the subtraction of the load reduction by operation. This fact is expressed in the form of reduction of receiving power. As the results, the quantity of receiving power is suppressed on average by 13.9% during the DR time frame.

2.4.5 Summary of Verification Test Results

We confirmed that adequate management of energy supply facilities can be accomplished under integrated control by the smart BEMS and the energy use efficiency is higher than that of conventional control systems. Based on the result of control on the CHP and energy storage system, the evaluation concluded that we will be able to realize the reduction of CO_2 emission by approximately 20%. This is also benefitted by the introduction of the BEMS. In addition, in Fiscal 2014, the control span was reduced to a shorter period so that our approach to a higher efficient energy use was advanced. We could, thus, realize more delicate control and higher efficient energy use.

In regard to the DR request from a master system, operation checks were carried out on the automated DR function that is in response to the incentive-contained DR menu of the PTR and CCP. As a result, we confirmed its soundness and adequacy. In these verification tests, a sequence of operations, such as demand control in regard to DR, data exchange, authentication judgment, and operation plan updating and control upon reception of a response, were completely automated and DR were given without influencing the load. At the time of DR verification tests in winter, the reduction of receiving power for 25% to 30% on average was realized by making adequate control of existing CHP systems in the DR time frame. Further, load reduction by energy storage system control and operation was combined to increase the amount of power reduction. For DR verification test in summertime, there was no control margin in CHP and power storage system, there was no advantage from the DR system. Despite such difficulties, however, we could attain the reduction of receiving power on average by about 10% as a result of load reduction by operation while the DR system was used. When the DR effect of receiving power reduction by wintertime is compared with that by summertime, the former case shows a greater effect. The records at operation in this verification site show that the DR system can offer a sufficient control margin in wintertime.

According to industry trends to promote OpenADR2.0b, (an internal standard for the DR interface) in Fiscal 2014, we performed DR verification test on communication between a master system including "Demand Response Automation Server (DRAS)" and the smart BEMS. We confirmed that the DR system was effective at a practical management level even in such an application case conforming to the communication protocol.

3 Business Development in the Future

We have been promoting business development in the field of smart energy system. We introduce the smart BEMS for hospitals and universities.

Drawing on our knowledge, techniques, and operation know-hows developed through the YSCP verification test program, we will continue to improve the EMS functions in order to increase our supply to businesses like hospitals and industrial factory facilities. At the time of proposal to the customer, we investigate for optimal facility configuration (kW) and optimal facility management (kWh) based on customer's profile and propose the effect of energy cost reduction and payback period (year). We will also offer a comprehensive proposal in regard to reduction of CO_2 emission, maintenance efficiency, more specific BCP planning and its contribution to society.

This system is applicable to wide-area energy sharing by the same energy user like energy delivery over its own transmission line or energy delivery generated by an in-house energy resource over a transmission line of an electric power company. This was made possible by electricity market deregulation in Japan. In addition, it can be applied to optimal management of heat and power by REP and regional heat supply systems. We will continue to develop and customize each application.

In addition, electricity market deregulation in Japan will produce new markets such as supporting service for a new energy contract scheme, a system for new REPs, virtual power plants, and ancillary services. We will also continue to make system application development based on proposals of systems and services in response to new business models.

4 Postscript

In the near future, there will be a more substantial introduction of smart grids along with the advent of electricity market deregulation and more introduction of renewable energy resources. We consider that our smart BEMS and smart FEMS developed in the YSCP can be regarded as our basic systems for smart grid building. We will contribute to a sustainable society through further functional improvements and system extensions.