BATTERY SCADA DEMONSTRATION SYSTEM IN YSCP

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ABSTRACT

This paper discusses about Yokohama Smart City Project (YSCP) together with battery aggregation technology demonstration, one of sub projects carried in YSCP. We have developed a system to virtually aggregate numerous and various batteries to contribute to power grid operation. This paper discusses about background of the system development, system overview, functions, system configuration, and components of the system.

INTRODUCTION TO YSCP

The Yokohama Smart City Project is a Japanese government funded smart grid demonstration project aiming to realize a smart grid, low-carbon emission city based upon an existing economic district with fixed social infrastructures yet maintaining the quality of life.

Yokohama City, as one of the major economic districts in Japan, is composed of diverse actors such as commercial districts, residences, and factories. In each of these areas, technology development and demonstrations regarding energy-conservation and renewable energy (RE) implementation are being undertaken. Total of 32 partners such as power and gas utility, various manufactures are undertaking below demonstrations.

-The project team of Home Energy Management System (HEMS): demonstrates introduction of HEMS into 4,000 homes, energy consumption reduction and Demand Response (DR).
-The project team of Electric Vehicle (EV): demonstrates introduction of 2,000 EV, verification experiment regarding Vehicle-to-Home system and EV charging system involving a combination of multiple quick charges and large-capacity storage batteries.
-The project team of Building Energy Management System (BEMS): demonstrates implementation of next-generation BEMS, energy consumption reduction of buildings, and DR.
-The project team of Community Energy Management System: demonstrates 10% reduction of the city's power demand by sending DR signal to Customer EMS such as HEMS and BEMS.
-The project team of Battery SCADA (B-SCADA) system: demonstrates battery aggregation technology for power grid operation contribution.

The duration of this project is from April 2010 to March 2015. The total budget of YSCP is approximately 850million US dollar.

Of all the projects, the battery aggregation technology demonstration which we will discuss in this paper is a demonstration to virtually aggregate numerous and various batteries in the community to create a Virtual Power Plant (VPP) and contribute to power grid operation. The aim of technology development is to enable mass deployment of RE while maintaining power quality. From the next chapter, we will discuss about the background of this technology development, together with functions and components of this demonstration.

BATTERY AGGREGATION TECHNOLOGY -ITS BACKGROUND OF DEVELOPMENT-

Distributed Energy Resources (DER), often represented as rechargeable batteries have been deployed to benefit and realize its owner's efficient power use, and to provide backup source of power, therefore batteries were seldom recognized as an actor in power grid operation.
However, as DER began to be deployed rapidly to the grid, it has been recognized that aggregating these DER and allowing them to contribute to power grid operation can be a secondary benefit for its owners. As for its future purpose, deploying DER in the purpose of power grid operation itself has being discussed and considered.
In order to operate DER based on such new thoughts, a technology capable of aggregating various and numerous DER to create one VPP that is able to contribute to power grid operation were needed to be established. Our battery aggregation technology was developed with such a background.

With the development of this technology, in countries which permits customer's participation in electricity market, DER deployed in the power grid will gain opportunity to participate in electricity market, regardless of the size and type of DER. For grid operators, this technology will be equivalent to having a controllable VPP. For power utilities, this will equal to reducing investment cost for new generators. Battery aggregation technology will hence deeply contribute to smart grid.
The aim of battery aggregation technology development is to aggregate various and numerous DER in the grid to create a VPP, presenting as if there is one generator controllable for grid operators. Then, enabling grid operators to control the VPP in the same way as existing generators such as thermal and hydro power plant, letting the VPP operate such functions as Load Frequency Control (LFC) and Peak Shift (PS).

CONCEPT OF BATTERY SCADA SYSTEM

The system is composed of four components, with B-SCADA playing the key role, followed by Stationary battery (S-battery), Customer side battery (C-battery), and Grid EMS.
The system name "Battery SCADA" was named after SCADA (Supervisory Control and Data Acquisition) system that is specialized to control batteries.
Figure1 describes system overview of the B-SCADA system.

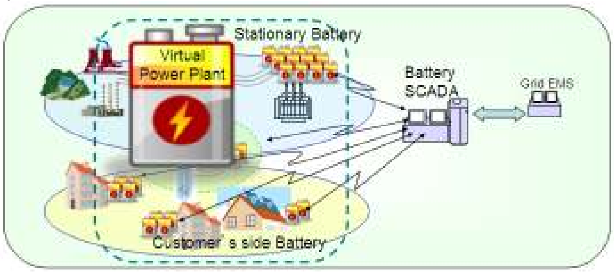

Figure1. Overview of the Battery SCADA system

B-SCADA, aggregating numerous and various batteries, is positioned under Grid EMS with grid operation functions, to receive LFC and PS control values. Upon receiving LFC control value for instance every second, B-SCADA calculates control value for each S-battery and sends it to control each S-battery. When B-SCADA receives PS control value, at first it creates PS plan using S-batteries and C-batteries, and then operates based on the plan made. When creating PS plan, B-SCADA negotiates with Customer EMS (CEMS) to use available capacity of C-battery. When operating, B-SCADA controls S-batteries, and CEMS controls C-battery.

FUNCTIONS OF BATTERY SCADA SYSTEM

We have developed LFC, PS and Reserve Margin(RM) function as three functions to be contributed by VPP to power grid operation. We will discuss the three functions in detail.

LFC function

LFC function operated by Virtual Battery (VB) aims to cover the lack of adjustment ability for LFC caused by mass deployment of photovoltaic (PV) power generation systems along with decreased adjustment ability of total thermal and hydro power plants.
Only S-batteries will be used to operate LFC function.
When operating LFC function, B-SCADA controls S-batteries according to LFC control value from Grid EMS.
Processes of LFC function is described in Figure2. Numbers 1 to 10 mentioned is done in every 1 second.
1. Grid EMS with LFC operation function obtains ⊿Ptie (tie line power flow deviation) and ⊿f (frequency deviation) from the grid.

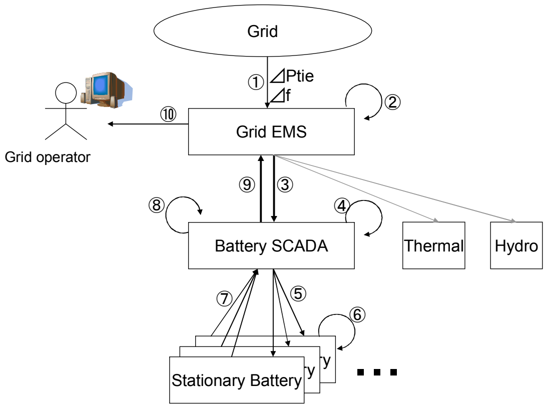

Figure2. LFC function operated by VB

2. Grid EMS calculates Area Control Error (ACE) from ⊿Ptie and ⊿f, which is the total difference in electricity demand and supply within the power grid.
3. Grid EMS allocates the calculated ACE to thermal and hydro power plant and to VB as control value of LFC.
4. B-SCADA calculates the control value of LFC to be allocated to each S-battery.
5. B-SCADA allocates the control value to each S-battery.
6. S-battery charges/discharges based on control value it receives.
7. S-battery sends its charge/discharge output power and maximum chargeable/dischargeable energy to B-SCADA.
8. Virtual aggregation process is done by B-SCADA calculating total power output and upper/lower limit of power output as a single VB. This calculation is done by using charge/discharge output power and maximum chargeable/dischargeable energy information sent from each S-battery.
9. B-SCADA sends the power output, and upper/lower limit of power output of VB used for LFC to the Grid EMS.
10. Grid EMS displays the control value and actual power output of the VB in the same way as thermal and hydro power plant. Grid ACE will also be displayed. This way, grid operator will be able to recognize the grid's demand and supply balance status, adjustment ability of all generators including VB.

In the demonstration system in YSCP, we collected actual power output of S-battery by inputting ACE data from various periods of time to grid EMS simulator to send various LFC control values to B-SCADA. As a result, we collected battery output data which indicates VB covering fast component of ACE that were not able to be covered by thermal and hydro power plant.
As explained above, with VB operating LFC function, grid operator will be able to operate many S-batteries in the grid as one VB, which is able to be used in the same way as thermal and hydro power plant for LFC.

Peak Shift function

In PS function, a VB is created logically within B-SCADA by accumulating available chargeable/dischargeable power of S-batteries and C-batteries, and visualize the VB to grid operator. Grid operator is able to control this VB to operate PS. Upon using C-batteries to PS, following condition is needed in between customer and grid utility.

1. Data transaction of C-battery operation schedule, and negotiation is possible in between B-SCADA and CEMS
2. Grid operator is able to use available usable capacity of C-batteries without restricting customer's battery use through negotiation.

Representative steps of grid operator operating PS are described below.

1. Grid operator, in order to understand the potential of VB, is able to set tentative PS plan (i.e. desired PS amount per period of time). When set, B-SCADA calculates and accumulates available usable capacity of both S-battery and C-battery, and show to grid EMS operator the entire amount (i.e. maximum available charge/discharge power per period of time) to grid operator. With this, grid operator will be able to understand if the requested PS is possible to carry (or how much of it is possible). Before this calculation, B-SCADA obtains each battery's operation plan.
2. Grid operator sets actual PS plan using VB.
3. B-SCADA calculates most economic charge/discharge plan of batteries. When calculating charge/discharge plan of each battery, B-SCADA considers the following;
(a) Uses C-battery that is cheap in charging/discharging cost.
(b) Will not change C-battery's initial State of Charge (SOC) and SOC after participating PS. In other words, when discharging (or charging) takes place, recharging (or redischarging) plan will also be operated so that the SOC of C-battery will return to its original SOC before participating to PS operation. This calculation is done by using only the usable capacity of it to calculate charge/discharge plan of each battery.
4. B-SCADA, based on the calculated result, communicates and negotiates with CEMS in order to decide charge/discharge plan.
5. When PS plan is successfully created, S-batteries are controlled by B-SCADA and C-batteries are controlled by its CEMS.

Figure3 describes the results of calculated schedule of battery assignment for PS plan. This is an example result when operating peak cut by battery discharge to provide 120MW, 240MW, 180MW to the grid from 13PM to 16PM. In Figure3, letters within the boxes such as "X1","Y01" represents the name of each S-battery and C-battery. This function is also able to be used as load levelling during night time and daytime.

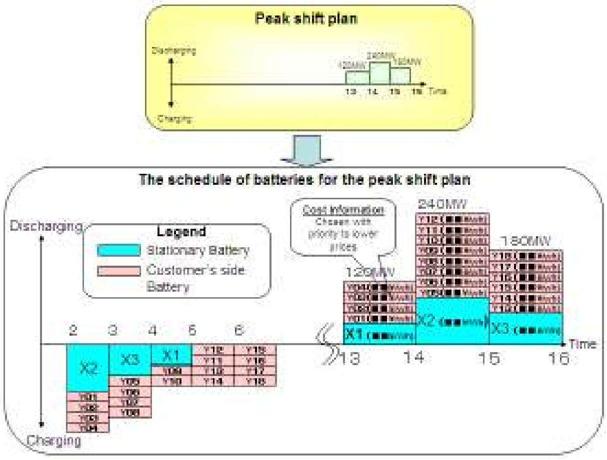

Figure3. Result of battery charge/discharge calculation

In the demonstration system, we operated PS by actual C-battery and many C-batteries created by battery simulator. Throughout the demonstration, we have recognized the feasibility of algorithm and interface between systems that enables PS without restraining customer's battery use and power use, which is the uniqueness of this function. Also, we have recognized that it is technology-wise possible to virtually aggregate numerous batteries to create one VB, enabling grid operator to carry PS easily.

Reserve Margin function

RM function provides to grid operator spinning reserve. Spinning reserve using batteries are able to be used in many purposes, such as power supply to meet sudden high power demand, and power supply until thermal power plant activation.

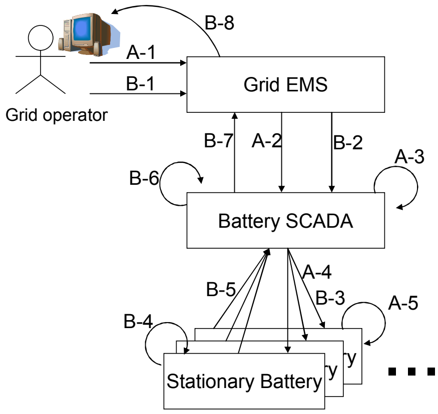

Figure4. RM function operated by VB

Preparation sequence for RM is described below. The numbers corresponds to that in Figure4.

A-1. Grid operator specifies the total capacity of VB for RM.
A-2. Specified VB capacity will be sent to B-SCADA.
A-3. B-SCADA specifies which S-battery to use in RM, and how much capacity to devote on RM mode for each

S-battery. This calculation is done based on S-batteries' information such as rated charge and discharge power, and available chargeable and dischargeable energy.
A-4. B-SCADA allocates control value to each S-battery. In RM mode, control value means how much capacity to charge for each S-battery.
A-5. Each S-battery charges as commanded.

Sequence of activating spinning reserve is described below. The numbers also corresponds to that in Figure4.
B-1. When activating RM, grid operator enters activation command and output schedule to Grid EMS.
B-2. Grid EMS sends activation command and output schedule to B-SCADA.
B-3. B-SCADA sends discharging signal according to output schedule.
B-4. S-battery discharges according to the signal from B-SCADA.
B-5. Each S-battery sends its discharge power, available chargeable/dischargeable energy to B-SCADA.
B-6. B-SCADA aggregates each S-battery's data, and calculates discharge power and available chargeable/dischargeable power and energy for VB.
B-7. B-SCADA sends the calculated result to grid operator.
B-8. Grid EMS will display grid operator VB's discharge power, available chargeable/dischargeable power and energy to monitor.

The two sequences described are a representative process and application. Hence when in the near future the cost of batteries decreases it is anticipated that RM using batteries will have a variety of uses.

DEMONSTRATION SYSTEM IN YSCP

The components of the B-SCADA demonstration system for YSCP are shown below.

Battery SCADA

B-SCADA, as the core component of this system, aggregates numerous and various S-batteries and C-batteries to create VB, enabling grid operator to use it to operate LFC function, PS functions, and RM function. B-SCADA also shows the VB to grid operator as if one VB exists, hence enabling similar operation as thermal and hydro power plant.

Stationary battery

Three lithium-ion S-batteries produced by different manufacturers are connected to the 6.6kV distribution line of the Tokyo Electric Power Company. S-batteries are controlled by B-SCADA when operating LFC and PS functions.

Customer-side battery

C-battery is composed of battery and CEMS. In the demonstration, total of four lithium-ion C-batteries are installed to customers in Yokohama city. C-batteries normally operates based on its owner's plan. When creating PS plan, it provides B-SCADA its operation plan, negotiates for PS participation. When operating PS, CEMS controls charge/discharge of C-battery based on the PS plan made by negotiating with B-SCADA.

Grid EMS simulator

Grid EMS simulator substitutes actual grid EMS functions. It creates mock LFC control value to dispatch to B-SCADA as LFC control value. In YSCP, various control values are settable for demonstration.

Battery simulator

In YSCP, in order to obtain practical data to assess the effectiveness of battery aggregation, a sufficient quantity and response of C-batteries are simulated by computer.

INTERFACE BETWEEN COMPONENTS AND CONTRIBUTION TO SMART GRID RESEARCH

B-SCADA and battery system is made in accordance to IEC61850 standards. We have also registered use cases[1][2] of functions demonstrated in this project to EPRI smart grid use case repository, contributing to development and improvement of smart grid technologies.

CONCLUSION

In this paper we discussed the concept of Battery SCADA system, and that used in YSCP. As a result we recognized the feasibility of three functions demonstrated by battery aggregation for power grid operation contribution.

REFERENCE

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