Supply-demand balancing system for electricity retailers

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This case study discusses the community energy management system (CEMS) developed as part of the Kita Kyushu Smart Community Project by Fuji Electric. The Kita Kyushu project is one of the four smart community projects that were funded by the Japanese central as well as local governments in collaboration with the private sector. The primary objective of these projects was to realise resilient and sustainable energy infrastructure. This project was executed from FY2010 through FY2014.

The CEMS was developed by Fuji Electric, as part of a broader energy management system project (including end-user installations of home energy management systems or HEMS and building energy management systems or BEMS and other energy resources) in partnership with IBM Japan, Nittetsu Elex, Nippon Steel & Sumikin Engineering, Kita Kyushu city and others. Budget details for the CEMS have not been disclosed. However, estimates of the system cost are discussed later in this note under economics. The overall original budget put forward by the Kita Kyushu Smart Community Project team for the broader energy management system project which included the CEMS was JPY 2.7bn (USD23.2m[1]).

THE CHALLENGE

The CEMS was developed to address two related needs:

Balancing in deregulated retail markets: Electricity retailers have to ensure electricity demand from their customers is balanced in real-time[2] with electricity supply both to ensure the physical stability of the power grid as well as to meet their regulatory and financial obligations. Independent retailers operating in competitive deregulated markets, typically secure electricity from a variety of sources such as the wholesale electricity market, independent power producers and their own generation assets. These retailers may not be able to easily make real-time adjustments to their electricity supply. While they may be able to purchase additional supplies in real-time, financially, those supplies could be too expensive. Failing to ensure demand from their customers remains balanced with contracted supply may result in hefty imbalance penalties even if the network remains physically balanced. Under many circumstances, it can be more economical for the retailer to pay some of its customers to reduce demand so that the retailer does not have to procure additional expensive supplies and/or pay hefty imbalance penalties. The CEMS developed for the Kita Kyushu project enables such demand response (DR) schemes that help the retailer avoid or lower imbalance fees. The CEMS achieves this objective by integrating economic signals such as imbalance penalties, wholesale power prices, residential demand response incentives and dynamic retail pricing into its supply-demand forecasting to develop the most optimum load-dispatch algorithm.

Balancing in independent grids subject to high-levels of intermittent renewables: In larger grid networks with relatively low penetration of solar and wind, the intermittent output from solar and wind can be balanced by reliance on other generation and energy storage systems. In independent grids, for example those on small islands, it is harder to balance the intermittent output from renewables, particularly if the share of renewables is relatively high. The CEMS developed for the Kita Kyushu project overcomes this challenge by integrating accurate weather forecasting and local demand projection into its supply-demand balancing.

WHAT THEY DID

For the Kita Kyushu project, Fuji Electric developed the CEMS (Figure 1) from the perspective of an independent retailer operating in a competitive retail market as well as exposed to a grid with a high level of renewable energy penetration. The CEMS primary function is supply-demand control. It can also act as a demand response management system (DRMS).

Supply-demand control function: To achieve the optimum supply-demand balance, forecasting and control functionalities are implemented. Forecasting covers projections of electricity demand as well as output from renewable resources taking into account detailed weather conditions.

The control function integrates the following four grid operation components:

[1] Exchange rate used is 116.6 JPY/USD

[2] Typically, the retailer has to ensure its supply-demand projections are balanced one-hour ahead.

- Supply-demand operation plan: This takes into account actual output from renewable resources to determine whether to adjust output from other generation as well as energy storage sources. This functionality enables the meeting of objectives such as lowering supply costs, lowering emissions, reducing peak-demand and peak-shifting.
- Economic dispatch: This functionality optimises the dispatch order for each power plant to achieve the lowest cost generation mix overall. Taking into account the specific network region and period of time, based on forecast supply and demand, the system calculates how much power from existing thermal generators should be adjusted, how much external power should be purchased and to what extent energy storage systems should be charged or discharged depending on output from renewables.
- Load frequency control: To control the frequency of the power grid within the target range, this feature controls output from generators as well as energy storage units.
- Real-time balancing: This functionality ensures supply and demand remain in balance within the 30-minute compliance period by controlling generators as well as energy storage units.

Demand response management system: in addition to the above functionalities, the CEMS communicates information on dynamic pricing and incentive programmes to energy management systems at the end user. The details of the information exchange is as follows: first from the CEMS side, weather data or retail menu is sent to the energy management systems (EMS) installed at the end user sites, then the end user energy management systems such as a home energy management system (HEMS) or a building management system (BEMS) determines its own action plan and sends feedback to the CEMS. Additionally, on the CEMS side, based on the weather data, forecast output of solar PV, as well as updated operation plan based on the end user EMS feedback, it recalculates a new DR retail menu and feedbacks to the end user EMS. The end user EMS based on updated operation plan together with the DR information, controls the load as well as the batteries, and provides dynamic pricing / incentive programme information to consumers as well as third parties such as building owners and DR aggregators.

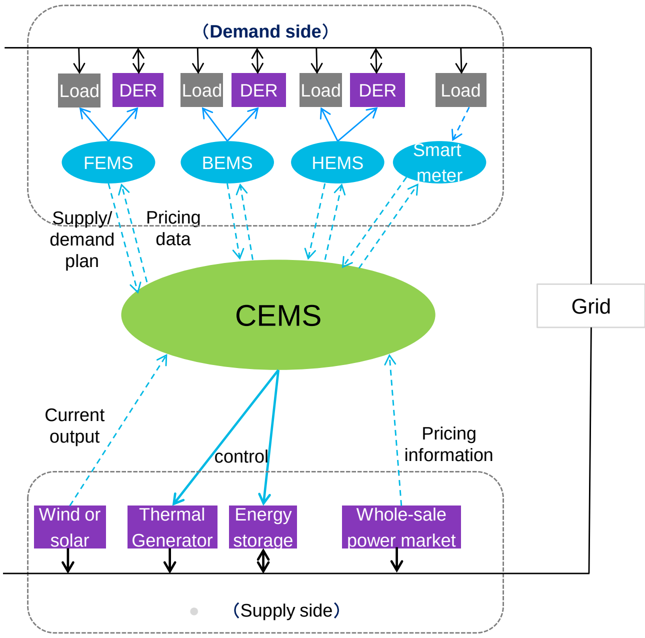

Figure 1. Simplified schematic of CEMS integration.
Source: Fuji Electric, Mitsubishi UFJ Research Consulting.
Note: DER stands for distributed energy resources such as rooftop PV, residential energy storage or fuel cells, etc. FEMS stands for factory energy management system. Dashed lines mark information flow and sold lines mark control signals.

Beyond the supply-demand control functionality including DRMS, the CEMS also offers two more features:

Voltage control: The CEMS can direct underlying systems to adjust their output to ensure the voltage in specific parts of the grid is within the targeted range.

Autonomous operation: During blackouts caused by disaster, the CEMS can direct the subsystems under its control to autonomously operate the segment of the network they are connected to if there are sufficient local generation and storage assets available.

Figure 2. Fuji Electric's Kita Kyushu CEMS
Source: Fuji Electric

BUSINESS MODEL

The primary users of the CEMS would be electricity retailers in particular those operating in deregulated competitive markets. For example, in Japan under the current regulatory framework (in place since 2005 and set to change from April 2016 onwards), the retail market for customers with demand above with 50kW is deregulated, and independent retailers can serve these customers. These independent retailers referred to as PPS in the Japanese regulatory context, for instance, have to ensure their customers demand within 30-minute intervals does not deviate from supply by more than ±3%, otherwise they will have to pay hefty imbalance penalties to the local utility whose network they rely on.

Figure 3 shows the operation scheme as utilised by a PPS. In this schematic, it is assumed the PPS has access to other generators as well as storage systems in its area along with the wholesale power market.

The primary objective of the PPS is to meet its customers electricity demand. The CEMS enables the PPS to come up with the most optimised merit order to meet its customer's demand without having to rely on excess generation either from its own assets and/or external procurement. Furthermore, the CEMS develops an economic load dispatch order that will determine whether to purchase power from the wholesale market and/or surplus power from other generators. The CEMS also enables the PPS to implement demand response either directly or via an aggregator. By relying on the CEMS, the PPS can control its customers demand to ensure it does not end up violating the real-time balancing rule and hence avoids paying an imbalance penalty. The CEMS also optimises the procurement cost of electricity thus allowing the PPS to increase its revenues overall. Additionally the system facilitates important political targets such as increasing regional self-sufficiency, by enabling the ability to utilise locally generated electricity from renewable energy resources to serve public facilities. Introduction of this system enables a smooth control of supply and demand and can act as a platform for business improvement.

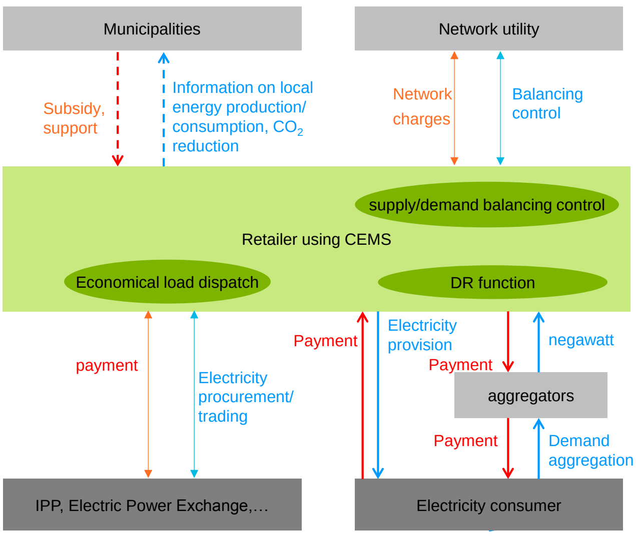

Figure 3. Business models enabled by the CEMS
Source: Fuji Electric, Mitsubishi UFJ Research Consulting.

SYSTEM ADVANTAGES

Technology: The underlying foundation of the aforementioned functionalities of Fuji Electric's CEMS is its unique forecasting technology. Without accurate forecasting the CEMS would not meet its desired functionality. For example it wouldn't be able to properly balance supply and demand, nor forecast amount of output from solar and wind. The forecasting technology is based on the latest data mining techniques for Big Data.

During the Kita Kyushu demonstration experiment, the CEMS was able to improve daily load curve forecasting. By taking into account detailed characteristics of each consumers' demand profile, and the weather forecast for the next day, it was possible to automatically forecast the amount of electricity each consumer would use. The forecasting model takes into account quantitative weather information such as temperature, humidity and cloudiness, to develop accurate forecasts of solar output.

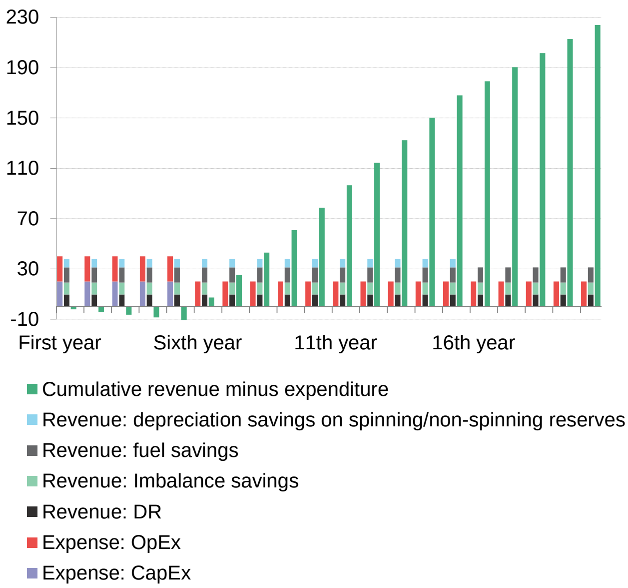

Figure 4. Estimated CEMS cash-flow (JPY million)
Source: Fuji Electric, Mitsubishi UFJ Research Consulting.
Note: inflation and financing costs are not considered.

Economics: The system at a minimum requires 200 electricity customers ie, monthly consumption of 6,000MWh. For the minimum size, the initial introduction cost of the system is around JPY 100m, while the O&M cost of the system is estimated to be about JPY 20m/year. Based on the cost savings associated with lower electricity procurement costs, and revenue from demand response, Fuji Electric expects the payback period for the system to be about five years, as shown in Figure 4.

FUTURE PLANS

Domestic market: in Japan, ENERES has already introduced a balancing system. However Fuji Electric expects its CEMS system's additional functionality would increase the economic competitiveness of its offering. As more entities are considering entering Japan's electricity retail market as a result of the ongoing market reforms, demand for the CEMS technology Fuji Electric is offering will increase.

International market: Fuji Electric believes CEMS can improve electricity quality in developing countries suffering from black outs and brownouts. CEMS also supports better management of electricity retail payment. The business model would be very similar to the PPS case in Japan:

- The CEMS would improve the quality of the electricity service by ensuring better balance between supply and demand.
- It will improve integration of renewable energy as well as energy storage.
- In cases where there are lower level energy management systems such as at a factory, the CEMS can interact with the EMS in a similar manner to the PPS model. Fuji Electric has already introduced the system in an industrial park in Indonesia. The experience in Indonesia is expected to enable further expansion to other markets.

CHALLENGES

Fuji Electric envisions the CEMS can be widely adopted in Japan if the following conditions are met:

- The ongoing electricity market reform process leads to a supporting regulatory framework.
- Increasing base of renewables leads to greater need for grid stabilisation
- Electricity procurement via the wholesale market becomes mainstream

If the above conditions are met, retailers adopting the CEMS can develop new business models. For example if the proposed 'negawatt' trading scheme is successfully implemented, the CEMS can become a critical tool for retailers and aggregators to enable expansion of demand response in Japan.

FINAL THOUGHTS

To take advantage of the technical benefits of Fuji Electric's CEMS, an electricity regulatory framework conducive to greater competition and reliance on power market trading would be needed.

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