Grid balancing using energy storage aggregation

29 February 2016

This case study discusses the battery-based energy storage aggregation system developed as part of the Yokohama Smart Community Project[1]. Dubbed battery SCADA, it has been used to explore how distributed battery-based energy storage systems can be virtually aggregated to provide ancillary services such as frequency regulation to the grid as well as peak-shifting for the end-consumer.

The Yokohama Smart Community Project is one of the four smart community projects[1] funded by the Japanese central government, as well as local governments, in collaboration with the private sector. The primary objective of the projects was to realise resilient and sustainable energy infrastructure. The projects were planned in FY2010, and executed from FY2011 until FY2015.

The battery SCADA system was developed by Toshiba, in partnership with Hitachi, Kansai Electric Power Company, Meidensha, Mitsubishi Heavy Industry, NEC, Sharp, Sony and Tokyo Electric Power. The plan for the system was developed in FY2011, with installation completed in FY2012, and testing conducted over the following two years.

Budget details for the battery SCADA system have not been disclosed. The overall original budget put forward by the Yokohama Smart Community Project team for the broader Community Energy Management System (CEMS) project, which included the battery SCADA system, was JPY 2.6bn ($22.5m[1]).

THE CHALLENGE

There are continuous discrepancies between supply and demand in an electricity grid. To maintain balance, system operators perform tasks (or externally procure services) such as frequency regulation – ensuring the grid frequency stays within a specific range – and deployment of reserves to address short-term supply-demand imbalances. These tasks/services are collectively called ancillary services. The traditional approach to ancillary services is to reserve a certain portion of power output from existing assets such as coal plants and pumped hydro to provide ancillary services. However traditional approaches to ancillary services are facing increasing physical, environmental and economic challenges that can be addressed by relying on faster responding scalable battery-based energy storage systems:

Changes to supply: as the overall share of variable renewable electricity sources, ie, wind and solar, increase in the overall generation mix, the need for ancillary services also increases due to weather dependency of output from wind and solar. Additionally, even for electricity systems with relatively low or no reliance on renewable energy, real-time events such as a mechanical failure of a gas turbine require the ability to quickly respond to changes in the supply-demand balance.

Changes to the demand: Uptake of rooftop PV is transforming the demand-side of the grid to a supply source too. The electricity injected into the grid by rooftop PV sources can pose challenges to the regular voltage distribution along the grid thus requiring new means for voltage control on the distribution network.

WHAT THEY DID

Utilisation of battery-based energy storage systems for ancillary services has already been demonstrated by various projects around the world. The goal of this project was to develop a system that could virtually aggregate different sized battery-based energy storage systems deployed at various nodes within the grid as well as at the consumer end to provide ancillary services as well as peak shifting.

The battery SCADA system (Figure 1) developed in this project integrated three large stationary lithium-ion battery energy storage systems: 300kW/100kWh (Toshiba), 300kW/100kWh (Hitachi), and 250kW/250kWh (NEC in partnership with Meidensha). The battery SCADA system was designed to also be able to communicate with energy storage systems installed at the user end. The battery SCADA system itself was interconnected to the central grid operating system to be able to receive grid control commands.

The battery SCADA system was designed in accordance with IEC61850 communication standards[2] for substation automation, part of IEC's smart grid standards. It performed two functions:

[1] Exchange rate used is 116.6 JPY/USD

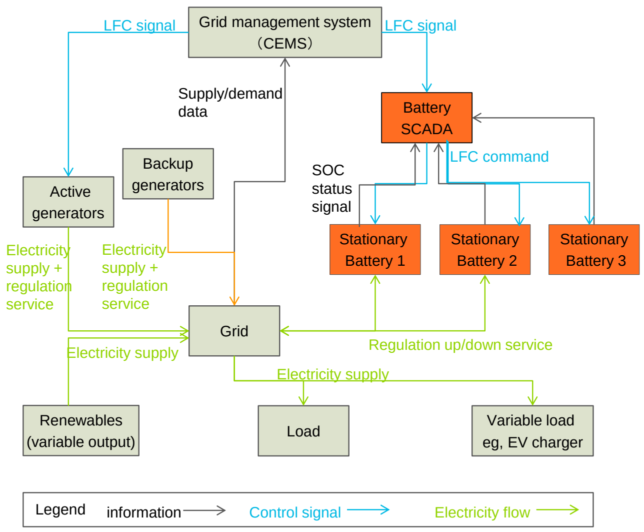

Figure 1. Battery SCADA schematic
Source: Toshiba, Mitsubishi UFJ Research Consulting. Note: SOC stands for state of charge.

Load frequency control: for this functionality, once the battery SCADA receives a grid control signal from the CEMS ie, the system operator, it takes into account the available electricity stored in each of the three batteries and rapidly determines how much power to charge or discharge from each of three units to achieve the frequency correction needed.

Spinning reserve: in this case, the energy storage system provides (or removes) considerable amount of energy to the grid, whereas in load frequency control it is primarily about provision of power ie, megawatts and not energy ie, megawatt-hours.

OUTCOME

Technical results: In tests with just the Toshiba battery for frequency regulation, the battery SCADA showed it could achieve changes from providing 300kW to the grid (regulation up) to reducing 300kW from the grid (regulation down) in one second ie, a response time of over 100% the maximum power rating of the battery system per second. The test results have been disclosed as part of the use cases filed with the Electric Power Research Institute's smart grid USE Case Repository[3].

System advantages

Battery based frequency regulation systems can provide a far faster response than conventional means of frequency regulation. As mentioned above, in the Yokohama Smart Community project, the system has been able to provide 100% of its maximum power output in less than one-second. For comparison a typical efficient 500MW+ gas turbine such as the GE 9HA.02[4], has a ramping rate of 70MW/min ie, it has a ramping rate of 0.23% of max output /second compared to the ramping rate of 100%/second for the energy storage system. While faster gas turbines exist eg, the GE 7E.03[4] , it still takes more than two minutes for the turbine to ramp up to its maximum output ie, a ramping rate of 0.73% of max output /second.

Battery based systems also do not directly emit any pollution or create noise, which makes it easier to place them in urban centres. Additionally, as the size of the underlying battery system can be easily scaled up or down, the overall system size tends to be more flexible than pumped hydro systems as well as thermal generators.

While the aforementioned advantages are common among all battery-based systems, an additional advantage of the battery SCADA system designed for the Yokohama Smart Community project is the ability to independently replace each of the battery systems controlled by the SCADA system if and when needed.

Is the outcome replicable?

In February 2015, Toshiba commissioned a 40MW/20MWh energy storage system[5] – as a commercial-scale pilot project – at Tohoku Electric's Nishisendai transmission substation based on the same technology used in the Yokohama Smart Community Project. That installation has been providing ancillary services for Tohoku Electric which is seeing a rapid uptake of solar and wind installations. According to Toshiba, the Tohoku installation has matched the performance of the Yokohama project. Specifically it has been able to achieve regulation up/down on 10MW within 430 milliseconds ie, a response time of 58% of the maximum power rating per second, far faster than typical thermal generators. Toshiba is currently developing a second 40MW/40MWh project for Tohoku Electric[6] set for commissioning by February 2016.

Separately in June 2014, Toshiba started to develop a 2MW/1MWh pilot[7] in collaboration with the University of Sheffield at the Willenhall primary substation of the Western Power Distribution's network in the UK. In April 2015, Toshiba also started developing a commercial 6MW/2MWh project[8] in collaboration with Sumitomo Corporation and Renewable Energy Systems Americas (RES) in Hamilton County, Ohio to participate in the frequency regulation market of the PJM Interconnection.

In short, there is ample evidence that Toshiba, and other parties, have had sufficient confidence in the technology to utilise the technology for new projects. There are also about 170MW of battery based energy storage installations providing ancillary services in to the PJM interconnection in the US, showing greater confidence in the technology.

Economics: The technical performance of Toshiba's system certainly appears to meet emerging needs for ancillary services. The question is whether it can meet those needs in an economical manner. Detailed cost information has not been provided for the Yokohama project. However, estimations by NEDO[9] suggest a 40MW lithium-ion battery system for frequency regulation would be JPY 6bn ($51.46m), while technical publications by Toshiba suggest the capital cost associated with the battery SCADA is about JPY 1bn ($8.57m) ie, in total a 40MW system would cost JPY 7bn ($60m). O&M costs are expected to be relatively minimal as the battery system does not require any fuel. Additionally the net amount of electricity used to charge and discharge to provide frequency regulation on a net-basis is relatively low.

Comparing the capital costs of the energy storage system with Japan's vertically integrated utilities' annual costs for frequency regulation (Figure 2), Toshiba expects the technology to be cost competitive.

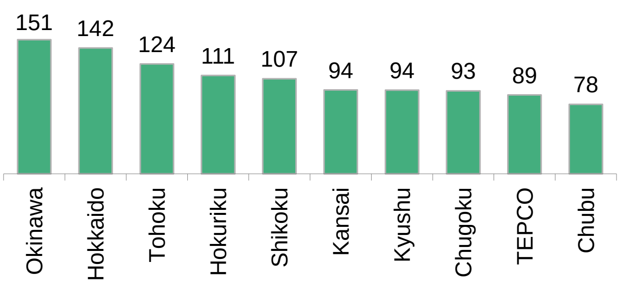

Figure 2: Japanese utilities estimated average spending on frequency regulation ($/kW)
Source: Mitsubishi UFJ Research & Consulting based on disclosures by each utility to the Electricity Market Surveillance Commission[10]

FUTURE PLANS

As the amount of variable renewable energy in Japan's energy mix increases, Toshiba and its partners expect increasing need for frequency regulation. They expect the battery SCADA system will be able to address those needs in a more economical, and environmentally friendly manner than thermal generators and pumped hydro. Another potential area of adoption is by Japan's many small remote islands. Integration of energy storage in the small grid systems of such islands could enable far higher uptake of renewable resources.

FINAL THOUGHTS

Provision of ancillary services is an increasingly attractive application for energy storage which can reduce the volume of balancing services required in a market and lead to fewer emissions. The technology is also well suited for smaller grid systems on islands as well as in regions with limited grid infrastructure. The battery aggregation technology demonstrated by Toshiba and its partners at the Yokohama Smart Community can enable further adoption of energy storage for grid balancing provided supportive regulatory mechanisms and business models are adopted.

REFERENCES

1. Japan Smart City Portal accessed on 8 January 2016.
2. IEC61850 communication standards accessed on 8 January 2016.
3. Electric Power Research Institute's smart grid USE Case Repository accessed on 8 January 2016.
4. General Electric Gas Turbine Product Page accessed on 1 February 2016.
5. Commencement of operation of large-scale battery energy storage system for Nishi-Sendai substation of Tohoku Electric, Toshiba Review, Vol.70 No.9 (2015).
6. 29 May 2015 Toshiba Press Release
7. 24 June 2014 Toshiba Press Release
8. 21 April 2015, Sumitomo Corp Press Release
9. Demonstration and Business Method of Peak Shifting using Battery Aggregation Technology by Demand Response without Restriction of Customers Electricity Usage IEEJ Transactions on Power and Energy. Vol.135 No.1 pp.78–84
10. Utility submissions to the electricity rate committee of the Electricity Market Surveillance Commission.
11. PJM Interconnection data directory, accessed on 12 January 2016.

BLOOMBERG NEW ENERGY FINANCE'S VIEW

The technical performance of Toshiba's technology certainly appears well suited for emerging ancillary service needs. The company also appears to be accumulating practical experience deploying different sized installations across the world which showcase the versatility of its technology. The important factor going forward will be the economics of the technology. This is not simply dependent on the capital cost of the equipment, but also the financing cost.

Another important factor is how Toshiba's battery SCADA technology can be adopted for use under different business models suitable to the local electricity market structure. Under Japan's current market, the country's 10 vertically integrated utilities have sole responsibility for ancillary services in their respective regions and they pass on that cost to rate payers as part of regulated network charges. Under such circumstances, economic comparisons are relatively simpler as the utility is more or less guaranteed a cost recovery mechanism.

In liberalised electricity markets such as those operating within the PJM interconnection in North-eastern US, a competitive market for ancillary services exists whereby third-parties compete to sell services to the network operator. As shown in Figure 3 this results in highly volatile pricing for regulation services. Under such circumstances, it is paramount for the battery SCADA system to also offer optimised trading strategies to maximise revenue streams for the battery system owner. This need may also arise in Japan, as the country proceeds with its electricity market reform process and unbundles the vertically integrated utilities by 2020. Toshiba has indicated that its system is already incorporating such functionality which it will be testing via its Hamilton project.

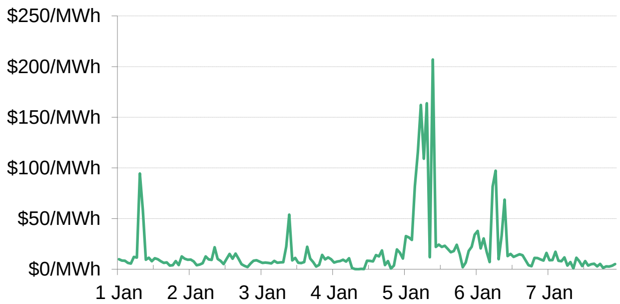

Figure 3: Hourly frequency regulation clearing prices for PJM for the first week of 2016 ($/MWh).
Source: PJM Interconnection. Note: chart created by Bloomberg New Energy Finance based on publicly available data from PJM Interconnection[11].

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