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Storage Battery Technologies that Support the Decarbonization of Power Sources

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The role of storage batteries in decarbonization

In February this year, developers unveiled a plan to construct a storage battery facility with up to 1,200 MW rated output in the Hunter Valley, New South Wales (Australia). This is four times the output from the Moss Landing Energy Storage Facility (300 MW (rated power)/1,200 MWh (storage capacity)) that commenced operation in Monterey, California (United States) in December last year as the largest battery storage system in the world. Storage batteries are becoming ever-larger, and a new record is constantly being set for the "world's largest" storage battery.

What is the role of battery storage technologies? Batteries smooth the output fluctuation of "variable renewable energy," as solar power and wind power are called, because their power generation output varies depending on weather conditions. Storage batteries are charged with this variable renewable power and discharge electricity as needed; and this cycle of charging and discharging is repeated. Promoting electrification as widely as possible is key to decarbonization. At the same time, it is important to increase power sources that are capable of generating electricity in a stable manner without emitting carbon dioxide during power generation.

There are various types of storage batteries. Some are designed for "consumer applications" and can be found in consumer electronic devices such as smartphones and laptop computers. Others designed for "automotive applications" are used in electric mobility. Batteries for "stationary applications" are installed on the grid side, at substations and power plants, to stabilize the power grid, or installed behind-the-meter to complement on-site solar power systems for self-consumption. This paper focuses on grid-scale stationary storage batteries that are used to stabilize the power grid.

Grid-scale storage batteries are expected to fulfill the following three roles: (1) power storage; (2) variation regulation; and, (3) frequency regulation.

Firstly, with increasing amounts of renewable energy, storage batteries perform the role of storing surplus electricity generated during hours or seasons of low electricity demand, when supply exceeds demand depending on weather conditions.

Secondly, "apparent power demand," which is obtained by deducting from total demand the amount of electricity generated by consumers for self-consumption and power storage, falls during daytime when there is sunlight and starts to increase rapidly at sunset. These rapid fluctuations are difficult to compensate by increasing or decreasing output from sources such

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as thermal power and hydropower. Battery storage systems can offer a solution.

Thirdly, electrical frequency drops when demand exceeds supply capacity, and rises when demand falls. Frequency fluctuations may degrade the performance of various devices. Thermal power and hydropower have conventionally taken on the role of maintaining frequency at a constant level. However, the rule for "priority dispatch" of electricity, which suppresses thermal power generation output when the amount of renewable power increases, makes it difficult to secure regulating capacity. Instead, large-scale storage batteries, which are highly flexible and responsive, can be used to regulate frequency. Even if the adjustment to be made is only for a few seconds, it will require utility-scale capacity equivalent to an entire power plant.

Different storage batteries and their adoption in Japan

In Japan, battery storage systems of several tens of megawatts have been introduced in the Hokkaido, Tohoku, and Kyushu regions in various ways (Figure).

Tohoku Electric Power's Nishi-Sendai Substation and Minami-Soma Substation are equipped with 40 MW lithium-ion batteries. A transmission system operator in Hokkaido is also currently building one of the world's largest lithium-ion battery storage system in Toyotomi Town, Teshio County. With a rated output of 240MW and storage capacity of 720 MWh, this facility will smooth the output of a 600 MW-wind power generation plant. Lithium-ion batteries are characterized by high energy density and high charge/discharge efficiency, as well as low self-discharge. Furthermore, their ability to rapidly charge and discharge allows quick response to small frequency fluctuations.

Kyushu Electric Power's Buzen Power Plant is equipped with a sodium-sulfur battery (NAS battery) system with total output of 50 MW. The energy density of NAS batteries is about three times higher than that of lead storage batteries. They are large-capacity, long-duration batteries suitable for storing electricity for long periods. In 2002, a Japanese company, NGK Insulators, became the first in the world to launch commercial production of NAS batteries, which have been deployed at more than 200 projects around the world to date.

At Hokkaido Electric Power's Minami Hayakita Substation, a redox flow battery system with a rated output of 15 MW has been installed to stabilize the grid and absorb surplus electricity. Redox flow batteries make use of oxidation-reduction reactions of vanadium ions to charge and discharge the cell. Their low energy density makes redox flow battery systems bulkier than other systems; however, they bear advantages in safety as they do not use any ignitable materials and can be operated at normal temperatures. They also feature a long service life with almost no degradation of electrodes and the electrolytic solution.

Microgrids have been constructed on Japan's remote islands, combining renewable energy and battery storage systems. These are small-scale independent energy networks serving a specific local area that can offer stable electricity and heat supply by combining and regulating multiple variable renewable energy sources and controllable power sources within a certain area of demand.

[Figure] Comparison of the characteristics of storage batteries

	Lead storage battery	Lithium-ion battery	NAS battery	Redox flow battery
Active material (cathode/anode)	Lead dioxide/Lead	Lithium metal oxide/Carbon-based material	Sulfur/Sodium	Vanadium ion/Vanadium ion
Energy density	Low	Medium	High	Low
Safety	Medium	Medium	△Medium	High
Resource availability	○	△	◎	△
Lifespan No. of cycles	17 years 3,150 cycles	10～20 years 3,500 cycles	15 years 4,500 cycles	20 years No limit
Pros	Overcharge resistance Established domestic recycling system	High charge/discharge efficiency Low self-discharge	Large storage capacity/space-saving Free of rare-earth elements, low cost	High performance in arbitrary charge/discharge operations Capability to instantaneously discharge large amounts of power
Cons	Requires regular reset of SOC (state of charge)	Possibility of ignition Performs poorly against overcharging/over-discharging	Requires heating at 300℃ Uses combustible materials	Bulkiness Shunt current loss

Note: The number of cycles refers to the number of times a battery can charge and discharge. Figures may differ from updated data published by the respective manufacturers.
Source: Compiled by the author based on METI "Storage Battery Strategy," and websites of NEDO and Sumitomo Electric Industries.

Ever-increasing storage battery capacities

The significant growth in large-scale battery storage capacity not only supports global trends of mass deployment of renewable energy, but is also aligned with the movement to phase out thermal power generation, which is a source of carbon emissions.

In addition to the incentive for market participation to sell (discharge) electricity during hours when prices are high, encouraging policies have also supported recent trends. For example, a leader in the mass deployment of renewable energy, California State made it mandatory for electric power companies to install stationary battery storage systems in 2013. This has been followed by other states in the United States, including New York. Amidst a rise in the number of companies using renewable power to cover all the electricity needs of their business, more companies are installing battery storage systems at large-scale power facilities for self-consumption. Apple Inc. (U.S.) has announced plans to construct an energy storage project capable of storing 240 MWh of energy to support the nearby solar power plant that supplies energy to all of the company's facilities in California.

Pilot projects harnessing Japan's state-of-the-art technology are also being conducted overseas. A demonstration project in California involved installing a redox flow battery storage system at a substation for grid stabilization. In Lower Saxony, Germany, where a large amount of electricity is generated from wind power, a pilot hybrid system combining lithium-ion and NAS batteries was installed. These trends are expected to create new business opportunities for Japanese companies in overseas storage battery markets.