Industrial Storage Device for Low-carbon Society

Masayuki Terada
Hisaaki Takabayashi

OVERVIEW: As the capacity of the telecommunication network grows, there is a need for backup storage batteries to ensure the reliability of the communication infrastructure. Meanwhile although the power produced by new energy sources such as wind and solar power is very clean, the instability of its output means that grid control, storage batteries, and other output leveling techniques are required. To meet these requirements, Shin-Kobe Electric Machinery Co., Ltd. has been developing highly reliable stationary storage batteries, including lead-acid batteries with an estimated life of 17 years when used to stabilize the output of wind power generation and large lithium-ion batteries for float-charge applications with excellent battery life and safety features as well as the ability to be fitted into a small space.

INTRODUCTION

GROWTH in the capacity and reliability of telecommunication networks is essential for providing the public with ubiquitous broadband and it is anticipated that power supply reliability will be recognized as an important requirement for public infrastructure even more so than in the past. Meanwhile, with growth in power demand and load variation both expected to increase in future, much attention is being paid to topics such as smart grids and the introduction of new energy sources that help create a low-carbon society, and stabilization and leveling of the electric power grid are seen as serious challenges for the future.

This article describes the development by Shin-Kobe Electric Machinery Co., Ltd. of large lithium-ion batteries, lead-acid storage batteries, and other electrical storage devices for industry that are used for applications such as ensuring the reliability of telecommunication networks and stabilizing the electric power grid.

VALVE-REGULATED LEAD-ACID BATTERIES USED FOR POWER STORAGE

Reducing emissions of greenhouse gases to prevent global warming and coping with the future scarcity of fossil fuels are becoming important issues.

Shin-Kobe Electric Machinery has commercialized

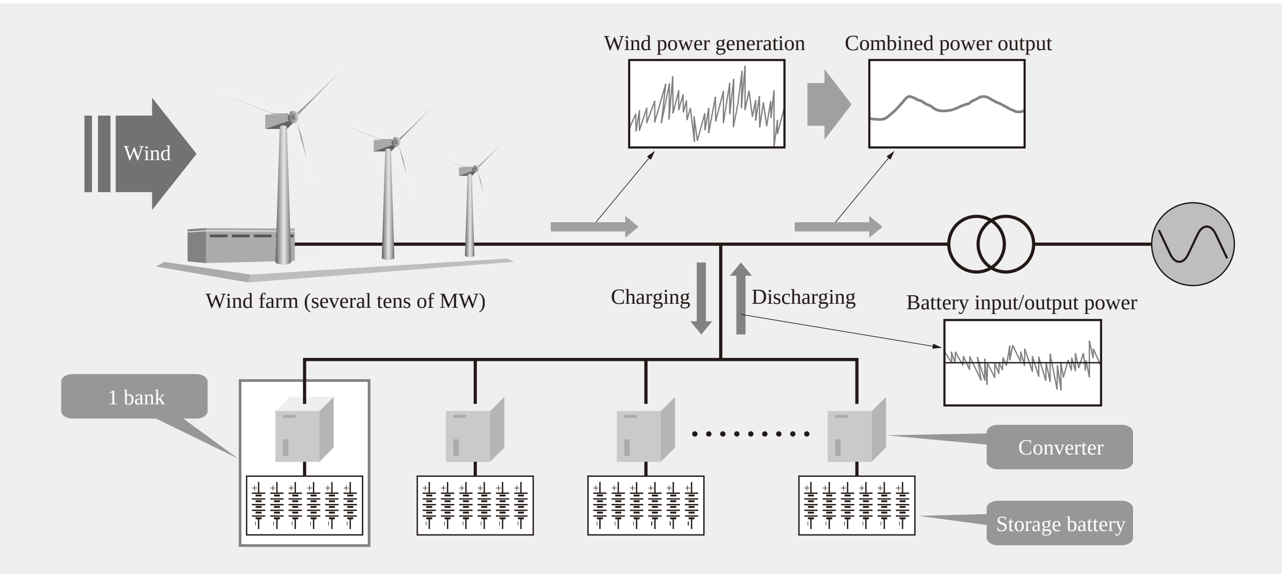


Fig. 1—Overview of Use of Storage Batteries at Generation Sites to Stabilize Output Fluctuation.
The variation in system output can be stabilized by charging and discharging batteries.

its “sefla system” load leveling system and produced valve-regulated lead-acid batteries (LL and LL-S models) with a long cycle life that can be used to store excess electric power available at night and use it to level peak power demand(1), (2), (3). By making improvements including better positive plate durability and negative plate charging performance and prevention of stratification, the estimated life of these power storage batteries when used under recommended conditions have been significantly improved to 3,000 cycles for the LL and 4,500 cycles for the LL-S type. The estimated life of these new battery models are six and nine times better respectively than the 500-cycle life of Shin-Kobe Electric Machinery’s conventional valve-regulated lead-acid battery (the MSE type).

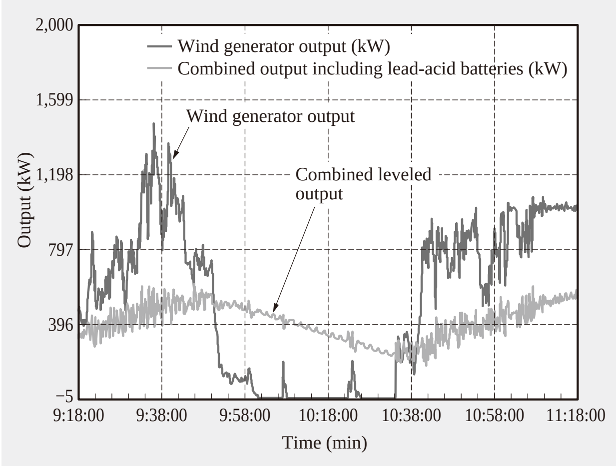


Fig. 2—Example of Output Leveling at Wind Power Generation System Incorporating Storage Batteries.
The graph shows how variation in the system output can be stabilized by charging and discharging batteries.

Use of Valve-regulated Lead-acid Batteries in New Energy Fields

Although new energy sources are being adopted more widely in recent years as a countermeasure to environmental problems, it is anticipated that problems with fluctuating voltage and frequency on the electric power grid will be exacerbated by greater use of energy sources such as wind or solar power with outputs that vary depending on weather conditions.

One method being investigated to help stabilize the electric power grid is to use a system that installs storage batteries at wind farms to stabilize output fluctuation. The results of these studies have demonstrated the viability of the method(4). Fig. 1 gives an overview of how output fluctuation can be stabilized by installing storage batteries at generation sites.

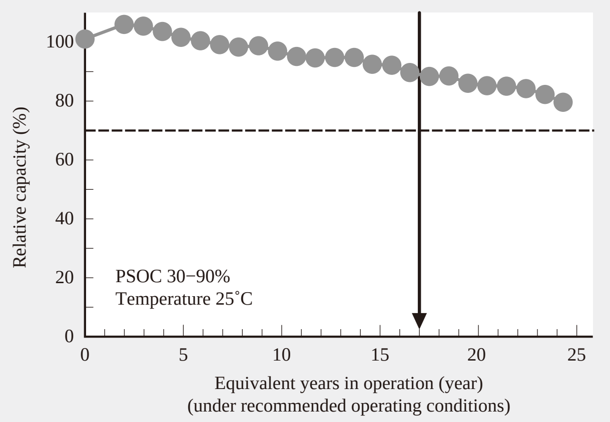
Conventional valve-regulated lead-acid batteries have been operated cyclically whereby they undergo repeated cycles of being fully charged and then discharged. However, batteries used to stabilize the output of wind power generation are typically in a PSOC (partial state of charge) in which they are subject to repeated short-duration periods of charging and discharging and it is believed that this difference in operating practice compared to conventional products also results in the degradation mode being different.

In addition to power storage applications, LL batteries have also been used in applications such as stabilizing fluctuations in wind power output and for storage of solar power(5), (6). Fig. 2 shows an example in which LL batteries are used to stabilize fluctuations in wind power output.

The figure shows how fluctuations in the output of wind power generation can be stabilized using batteries. Also, an investigation of batteries that have been used to stabilize fluctuations in the output of a 1.2-MW wind power generation system for approximately seven years indicated that they are capable of an operating life of about nine years(6), confirming that LL batteries are suitable for load leveling of wind and solar power generation.

Development of LL-W Battery

In anticipation of greater use of storage batteries at wind farms, Shin-Kobe Electric Machinery received a request for batteries with a level of durability equivalent to the length of period electric power is supplied and received. Consequently, the company embarked on development of a long-life battery with an estimated life of 17 years when used to stabilize fluctuations in wind power output. The development included a survey of LL batteries already in use at wind farms and considered the results of studies of usage conditions and battery degradation based on experiments in which batteries at various different PSOC cycle tests were subject to the repeated short-duration periods of charging and discharging likely to occur when used to stabilize fluctuations in wind power output. Based on these, Shin-Kobe Electric Machinery established technologies for extending battery life including highly durable positive plates that use a strongly corrosion-resistant alloy positive plates and high-density active materials as well as new additives that help prevent sulfation.

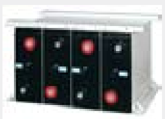


PSOC: partial state of charge

Fig. 3—Results of Battery Life Testing of New LL-W Battery.
The batteries achieved a life equivalent to more than 17 years of operation under recommended operating conditions.

Table 1. Specifications of New LL-W Battery
The new long-life valve-regulated lead-acid battery shown below has the following specifications.

Model		LL1500-W
Battery structure		VRLA
Rated capacity at the 10-h discharge rate		2 V–1,500 Ah
Dimensions	Height	507 mm
	Width	172 mm
	Length	437 mm
Weight		110 kg
Estimated life*		Operating life: 17 years Total discharge: 4,720 kAh
SOC range		SOC30–90%
Control voltage		1.80–2.42 V/cell
Balancing conditions		Conditions recommended by Shin-Kobe Electric Machinery
Operating temperature		5–35°C



Battery unit (LL1500-W 8 V–1,500 Ah)

VRLA: valve-regulated lead-acid battery SOC: state of charge
* The estimated life assumes operation at recommended operating conditions and is not guaranteed.

Using operating conditions and battery specifications based on these battery life extension technologies, Shin-Kobe Electric Machinery in 2009 developed the LL1500-W (2 V−1,500 Ah) long-life valve-regulated lead-acid battery with an estimated life of 17 years when used to stabilize fluctuations in wind power output (see Fig. 3 and Table 1).

The new batteries were installed at the Shiura Wind Farm in Goshogawara City, Aomori Prefecture where they have been in demonstration testing since February 2010 (see Table 2). Another system of similar size in which the batteries will be installed at a wind farm is currently under construction at Yuza Wind Farm in Yamagata Prefecture (Japan).

Table 2. Specifications of System Installed at Shiura Wind Farm
Trials commenced in February 2010.

Wind farm capacity	15.44 MW
Wind turbine	Eight E-82 1.93-MW turbines
Battery	Lead-acid batteries: 3,456 LL1500-W batteries (10.4 MWh) (Six sets consisting of two blocks of 288 series-connected cells in parallel) Maximum input/output: 4.5 MVA (capacity of AC/DC conversion unit) Discharge power: 3,700 kW (approx.) Charge power: 2,600 kW (approx.) Inverters: 6 × 750 kVA

Shiura Wind Farm (Japan)

Battery installation

AC: alternating current DC: direct current

LARGE-CAPACITY LITHIUM-ION BATTERIES

Background and Challenges for Development of Stationary Lithium-ion Battery

The lithium-ion battery’s characteristics of small size, light weight, and high output have seen an acceleration of development targeted at a wide range of applications including mobile phones, PCs (personal computers), and more recently automotive and industrial applications. In particular, factors such as improvements in battery capacity and the shift to large-scale production of automotive lithium-ion batteries are behind their wider adoption in industry.

Currently, the bulk of demand for storage batteries in industry is for batteries designed for stationary float-charge applications and is mainly filled by lead-acid batteries. In the information and telecommunications industry, meanwhile, the power consumption of computer and communications equipment continues to increase due to the processing of large volumes of data at high speed. The batteries used to backup this equipment against the risk of power outages are also becoming progressively larger, creating an ongoing problem of finding enough space to house these large battery installations in urban settings and increasing demand for the space-saving features of lithium-ion batteries.

Because lithium-ion batteries used in float-charge applications are kept in a fully charged state, measures to prevent thermal runaway due to overcharging and other causes are required and this makes battery fire prevention an essential technology.

In response to this demand, Shin-Kobe Electric Machinery has developed long-life stationary float-charge lithium-ion batteries with excellent space-saving and safety performance. The following section gives an overview.

Overview of Technology Development

The development of large lithium-ion batteries for float-charge applications faces two major technical challenges. The first is how to make the batteries resistant to flame and the second is how to extend their operating life. Shin-Kobe Electric Machinery undertook the following research aimed at solving these problems(7).

(1) Fire resistance

Whereas batteries in hybrid cars tend to operate around a safe 50% SOC (state of charge), the SOC of stationary float-charge batteries is kept close to 100% and the batteries themselves are larger. Also, because large numbers of batteries are housed indoors in a building or other facility, it is necessary to ensure that the batteries do not become a fire hazard or similar even under extreme circumstances. This means that making battery fire resistent is the top priority.

In this research, Shin-Kobe Electric Machinery developed an electrolyte that complies with the equivalent of the UL94-V0 fire safety standard by devising technology for fire retardant additives that can be added to the electrolyte without affecting battery performance, particularly operating life (see Fig. 4).

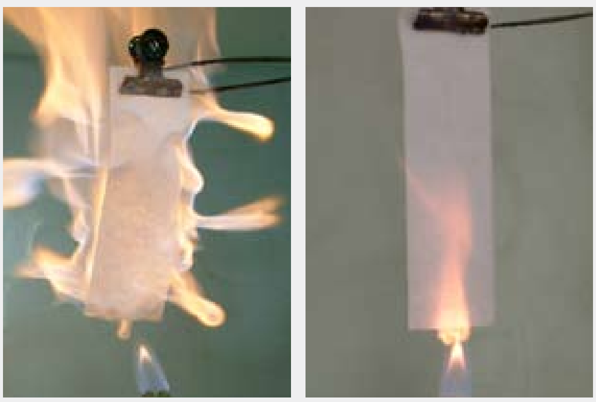


Fig. 4—Electrolyte Flammability Test.
By equipping the electrolyte with self-extinguishing properties, the fire risk was largely eliminated.

Technology for forming a layer of fire-retardant film on the electrodes was also developed. This technology has been demonstrated to prevent thermal runaway by suppressing combustion of the electrodes as well as the electrolyte even if the battery temperature continues to rise.

(2) Operating life extension

Lead-acid batteries used in stationary float-charge applications require an operating life of at least 10 years. Because most existing lithium-ion batteries have been used in applications where they undergo frequent charge/discharge cycles, there has been a lack of study into float-charge applications in which the batteries remain charged for long periods of time. It is also known that lithium-ion batteries suffer greater deterioration in capacity if left fully charged for a long period(8). To counter this, Shin-Kobe Electric Machinery analyzed the deterioration mechanisms of float-charge batteries and discovered that the primary cause was the formation of a resistive skin on the anode surface. It also discovered that the formation of this resistance layer was heavily dependent on the level of Mn (manganese) elution from the active materials in the cathode. By developing a new electrolyte and electrode materials to prevent this, Shin-Kobe Electric Machinery was able to achieve an estimated life of 10 years for float-charge batteries (see Fig. 5).

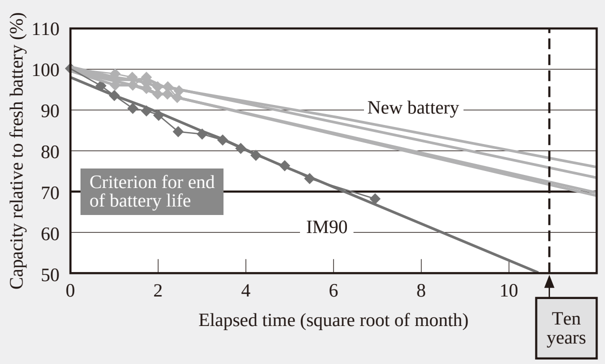


Fig. 5—Change in Battery Capacity with Age under Float-charge Conditions.
A projected life under float-charge conditions of ten years was obtained.

Overview of Large Lithium-ion Battery System

Shin-Kobe Electric Machinery has developed a large lithium-ion battery system featuring large lithium-ion batteries designed for safety and long life

Fig. 6—Lithium-ion Battery System for Communication Applications (48 V).
Even when the protection and control circuit is included, the battery footprint is still only half that of a lead-acid battery system of equivalent capacity.

together with battery control technology optimized for float-charge applications (see Fig. 6).

The system incorporates control circuits from a newly developed BCU (battery controller unit) designed for float-charge applications. The system can be configured with between 12 and 48 lithium-ion battery cells each with a capacity of 210 Ah which provide a maximum storage capacity of approximately 36 kWh.

Systems with a capacity of between 210 Ah and 840 Ah for telecommunications applications (systems with a rated voltage of 48 V) can be configured in a single cubicle with a footprint of approximately 0.36 m^2. HVDC (high-voltage direct current) storage systems for ICT (information and communication technology) applications (systems with a rated voltage of 380 V) can be configured with a 210-Ah capacity using two cubicles with a footprint of approximately 0.72 m^2. This significantly reduces the space requirements for a battery system installed in a building, with the floor space required for installation being approximately half that of previous battery systems with equivalent capacity implemented using lead-acid batteries.

CONCLUSIONS

This article has described the development by Shin-Kobe Electric Machinery of large lithium-ion batteries, lead-acid storage batteries, and other electrical storage devices for industry that are used for applications such as ensuring the reliability of telecommunication networks and stabilizing the electric power grid.

The newly developed LL1500-W battery is aimed at large-scale applications in the energy sector including grid stabilization for smart grids and handling of the surplus electric power that results from the growing installed capacity of wind, solar, and other forms of power generation with fixed output. Shin-Kobe Electric Machinery also intends to apply the technology in comparatively small applications such as energy management systems for homes, office buildings, and other facilities by developing a battery product range that spans different capacities. Development of lithium-ion batteries will continue, including commercializing large lithium-ion batteries suitable for use in cycled applications that benefit from the space-saving features of these batteries, such as electric power storage and electrically operated industrial machinery. Shin-Kobe Electric Machinery Co., Ltd. intends to continue developing energy storage devices that strike a good balance between considerations such as cost, performance, and size by combining the different advantages and characteristics of various types of energy storage devices such as lithium-ion batteries, high-performance lead-acid batteries, and lithium-ion capacitors.

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ABOUT THE AUTHORS

Masayuki Terada
Joined Shin-Kobe Electric Machinery Co., Ltd. in 1986, and now works at the Lithium Ion Division. He is currently engaged in the development and design of industrial lithium-ion batteries.

Hisaaki Takabayashi
Joined Shin-Kobe Electric Machinery Co., Ltd. in 1988, and now works at the Battery Design Department, Nabari Works. He is currently engaged in the development and design of lead-acid batteries.