Energy Storage Devices and Systems

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Shin-Kobe Electric Machinery Co., Ltd. has been promoting the development of energy storage devices such as lead-acid batteries, lithium ion batteries for industrial use, and lithium ion capacitors. In this paper, we outline the key features of these storage devices for application in both a renewable energy generation scheme and a micro-hybrid automobile system. In a MWh-scale power generation system that collects energy from both wind and large-solar units, hybrid-energy storage devices are required to enhance operating rate and efficiency. In micro-hybrid automobiles that make use of an idling stop system (ISS), enhanced lead-acid batteries are key energy storage devices, and are required to have high dynamic charge acceptance to recuperate braking energy and high cycle durability under stop-start cycle conditions.

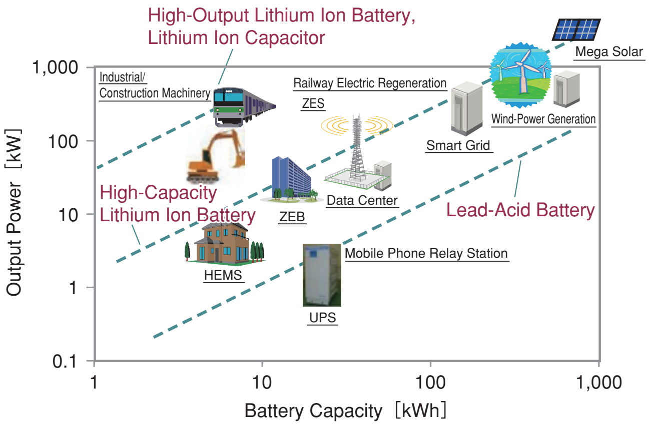
1 Introduction

An energy storage device is an apparatus used for storing electric energy when needed and releasing it when required. As a measure to counter global warming, the role of energy storage device technology in fields such as renewable energy generation and hybrid automobile systems will become increasingly important. Case examples of the role of energy storage and its relationship with infrastructure systems in our society in future promoted by the newly established Energy Storage Device Division of Shin-Kobe Electric Machinery Co., Ltd., are introduced in this report.

The lead-acid battery has a history of 150 years or more[1] and provides superior output performance over a wide temperature range, from extremely low temperature zones to high-temperature environments, e.g. engine rooms, while ensuring high reliability. Recycling technologies of materials of used lead acid batteries have already been established, and the lead-acid battery and its market have been still progressing technically and expanding, respectively[2]. Following the increasingly widespread use of new energy storage devices as represented by the lithium ion secondary battery (LIB), a lithium ion capacitor (LIC) was newly developed as a next-generation energy storage device[3]. The basic LIC construction comprises an active carbon cathode as a material used for an electric double-layer capacitor, and an LIB anode. Despite low energy storage capacity, it features superior power output/input performance especially within a short time window and durability. Shin-Kobe Electric Machinery Co., Ltd. is promoting the energy storage device business to cover lead-acid batteries, large LIBs for industrial use and LICs.

Figure 1 shows the relationship between output power and battery capacity, and characteristic outlines of the above three different energy storage devices are indicated. As shown in **Figure 1**, energy storage devices must meet wide-ranging device system needs, ranging from domestic applications to very-large capacity (MWh) used for wind power generators, etc.

Hereinafter we introduce the role and performance required for renewable energy generation systems and hybrid automobile



ZEB : Zero Energy Building, ZES : Zero Emission Station, HEMS : Home Energy Management System,
UPS : Uninterruptible Power Supply

Figure 1 Large Energy Storage Systems and Energy Storage Devices micro-systems, which are new and differ from existing units.

2 Renewable Energy Generation System

Lead-acid batteries and LIBs, as indicated in **Figure 1**, are suitable for large capacity storage devices. LICs and LIBs, which are designed with high power output specifications, show superior performance in high output applications. There is even a good example of our lead-acid battery product group where the battery capacity with a minimum voltage level (2 volts) exceeds 1000 Ah. Renewable energy, e.g. solar and wind power, largely depends on natural conditions and is unstable since the former fluctuate. To reduce fluctuations in the power supply and convert such systems to more stable and efficient power supply systems, it is crucial to combine different types of energy storage devices.

Figure 2 shows a large-capacity hybrid energy storage system used for renewable power generation which features a lead-acid battery, LIB and LIC connected in parallel.

To build a system capable of supplying stable power highly efficiently, these energy storage devices must not only store generated electric power but also level the fluctuation of output power.

Waveforms of electricity generated by windmill or mega solar systems change in response to weather conditions such as wind, day or night and sunny or rainy, as seen in (a) schematic diagrams of the waveforms of generated power. To supply stable electric power as seen in **Figure 2** (b) after converting from such unstable generated power, large-capacity hybrid energy storage systems are equipped with power-conditioning systems (PCS). This system undertakes an important role to deliver stable electric power (b) by outputting electric power with a charge/discharge pattern of (c) and superimposing it on waveform (a) to obtain a smooth leveled waveform (c).

The lead-acid battery, among the three energy storage devices seen in **Figure 2**, has sufficient energy storage capacity to handle generated power within a certain range and with waveforms involving long cycle fluctuations. The LIB also has a large energy storage capacity and can handle generated power with a waveform of long cycle fluctuations stabilized by lead-acid batteries as well as short-term fluctuations. Conversely, although the LIC has a small energy storage capacity, it can handle short-term fluctuations or pulse waveforms of generated power which lead-acid batteries or LIBs cannot handle. Therefore by hybridizing these three energy storage devices, not only can generated power be stored efficiently by wind power or mega solar batteries, stable power can also be delivered with waveform (b) obtained after superimposing pattern (c).

The lead-acid battery can have the advantage of a greater storage capacity at lower cost compared to LIB. Conversely, the LIB is superior in terms of its ability to form a large energy storage capacity system in a confined space due to the LIB's higher energy density and output power density.

In response to the trend for scaled-up electric power generators, multi-serial and multi-parallel control systems for energy storage devices will be needed. Currently a standalone lead-acid energy storage battery supplies a total of 10 MWh or more power at the Shiura windmill electric power station in Aomori-Prefecture[4]. Shin-Kobe Electric Machinery Co., Ltd. can now offer not only standalone operation of energy storage devices but also a new hybrid energy storage system combined with high space utilization, improved capacity utilization and high reliability, based on the aforementioned energy storage devices.

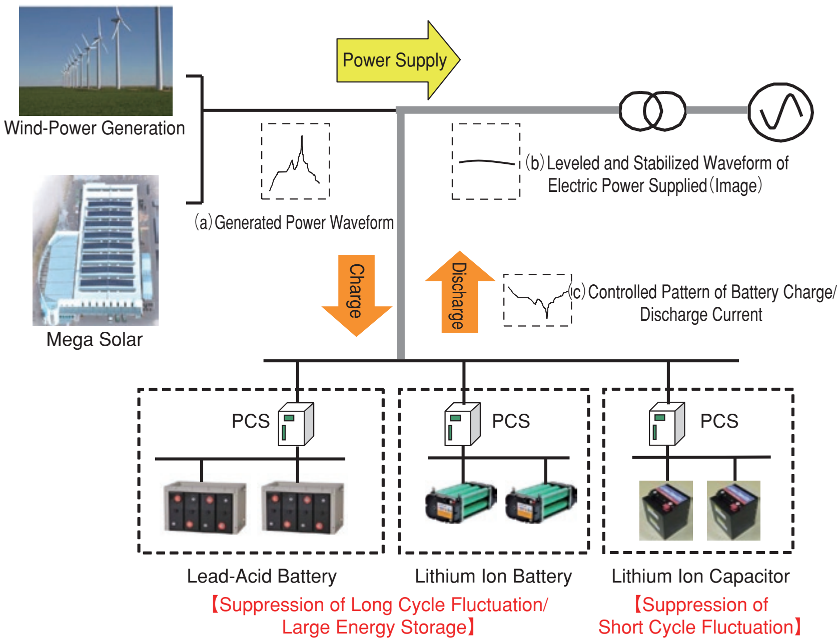


Figure 2 Scheme for Renewable Energy Generation Systems with Hybridized Large Energy Storage Devices

3 Micro-hybrid Automotive Systems

Hybrid cars are largely grouped into full, medium and micro-hybrid cars based on the function and voltage of the hybrid system. In the full hybrid zone, the system voltage of which is around 300 volts, the primarily power source is usually nickel metal hydride or lithium-ion batteries, with the lead-acid battery as an auxiliary power source. Micro-hybrid systems, so-called idling stop systems (ISS) with 14 volts, tend to use lead-acid batteries. An ISS-equipped car has a function to stop an idling engine while stopping at traffic lights, curb exhaust gas emissions and improve the gas mileage.

Figure 3 shows a correlation between the global total of cars manufactured and ISS cars[5]. As is self-explanatory from the diagram, half or more of manufactured passenger cars are predicted to be equipped with the ISS function, meaning the future market for lead-acid batteries mounted on such ISS cars will be huge.

The way in which lead-acid batteries are used for ISS cars differs significantly from the traditional approach. Traditionally, a large current was only required when the engine was started, whereupon a generator mounted on the car would continually charge the current to a battery. In the case of an ISS car, however, the lead-acid battery not only discharges a current of a few hundred amperes when restarting the engine but also repeats relentless operations such as supplying power to run audio equipment, fans, etc. during idling-off time when stopping at traffic lights. Accordingly, the magnitude of discharge current and frequency of charge/discharge cycles should increase significantly. If discharged electric power loss is recharged only when the engine is running, this further increases the level of exhaust gas from cars and impairs fuel efficiency. Accordingly, many ISS cars now mount a kind of system to recuperate braking energy by a motor generator in order to allow efficient recharging and retain fuel efficiency. A mounted lead-acid battery should be rechargeable to a sufficient extent to allow regenerative braking. However, as the traditional lead-acid battery has an intrinsically high resistance to the flow of charge current, the battery charge will soon be depleted if it is mounted on ISS cars. Therefore, to ensure ISS for cars remains sufficiently functional, the first step is to considerably boost the dynamic charge acceptance of a lead-acid battery, and subsequently secure sufficient durability of the battery to endure repeated charge/discharge cycles between idling stops and engine starts.

To meet such technical challenges, battery manufacturers are striving hard for a breakthrough in lead-acid battery technology. On-board lead-acid batteries for ISS cars have been considered different products from conventional automotive batteries because of their very different performance criteria, meaning very few battery manufacturers may be responsive to market needs from markets requiring a technical breakthrough[6]. Shin-Kobe Electric Machinery Co., Ltd. has actively been engaged in developing new lead-acid batteries for ISS cars and has a proven track record for applications in this market.

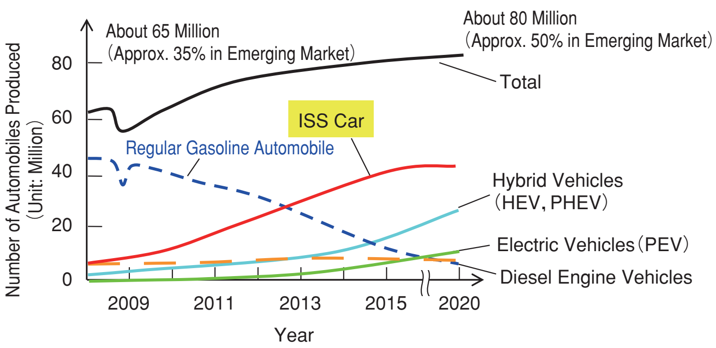


Figure 3 Global Production Prospect, Including ISS Cars and Others

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