Part 02

Developing the Power Conditioner

The Quest for a Peak-Shaving Energy Storage System

The impact of widespread and prolonged power shortages resulting from the Great East Japan Earthquake escalated the importance of the ability to handle power outages and need for power conservation solutions. Brownouts are a means of power conservation, and can be effectively handled through peak-load shifting and through peak shaving to reduce the maximum power demand (demand value). Peak-load shifting involves storing energy in a storage battery during the night when demand is low, or during the daytime while solar panels generate energy. Peak shaving specifically addresses the brownout problem by having the storage battery discharge when power is scarce, to thereby reduce the peak energy demand.

In the early 2000s, relying on our well-cultivated expertise in storage batteries and power conditioners, we began experimenting with ways to apply these technologies to create a peak shaving system. At that time GS Yuasa was also actively striving for an energy storage system that would replace the traditional lead-acid battery with an industrial large-format lithium ion storage battery. In this article we discuss our quest for a peak-shaving lithium ion energy storage system (●Fig. 1).

1. Maximizing Performance through Innovative Control

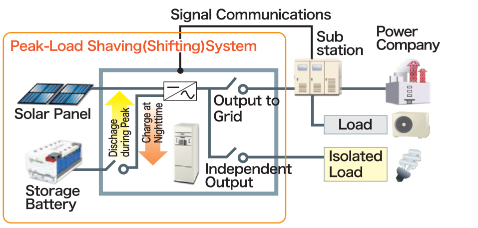
In our peak-shaving system, the inverter built into the power conditioner converts the direct current output from the solar panels or the storage battery into alternating current for an electrical device (the load). Consequently, the peak shaving system reduces the amount of power used from the power company. However, the voltage of the storage battery gradually decreases with the continued output (discharge) of electrical power.

When the temperature is low, the voltage of a storage battery decreases at a faster rate as the battery discharges, versus at the normal temperature (top, ●Fig. 2). In other words, the voltage of the storage battery decreases to the minimum operable voltage (end of discharge voltage) in a shorter time in low-temperature environments. A similar trend is also apparent in a degraded (e.g., older) storage battery. An inverter typically stops converting power the instant the storage battery reaches the end of discharge voltage to stop the storage battery from discharging. A storage battery degrades even further when it continues to operate in excess of its end of discharge voltage and the voltage of the storage battery decreases. The inverter is therefore controlled in the aforementioned manner to prevent the storage battery from entering this over discharge state.

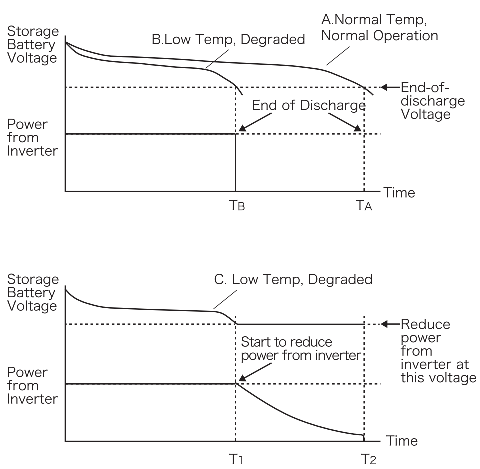
We then realized that existing control techniques could not be used to obtain the maximum performance from the storage battery. That is, with conventional techniques, the inverter ceases to operate right at the moment the storage battery reaches a certain (i.e., pre-set) voltage. Thus the system must use electrical power from the power company from that point on. If the aim is to conserve electricity, it is more desirable to continue discharging from the storage battery for as long as possible.

GS Yuasa therefore proposed an alternate control technique where we would extract as much output power as possible via the inverter while continuing to discharge the storage battery (bottom, ●Fig. 2). That is, the inverter would continue to operate even after the voltage of the storage battery reached the aforementioned pre-set voltage. More specifically, where previously the inverter would shut off around time T1, we proposed to keep the inverter operating until time T2 while gradually decreasing the output power from the inverter.

●Fig. 1 An Energy Storage System (ESS) supporting Peak Shaving



●Fig. 2 Relationship between Storage Battery Voltage and Converted Power from Inverter[1]



This control technology allows us to provide a device where the amount of electrical energy corresponding to roughly 14% of the total electrical energy extractable from the storage battery under normal temperature conditions (25˚C) could be comfortably extracted in low-temperature environments (0˚C). We adopted this technology in the Power Solar II that went on sale in 2004. The Power Solar II was a power conditioner for solar power generation systems and came with an integrated lead-acid battery.

GS Yuasa continued to lead the way. In 2001, we were the first to propose techniques for controlling a peak shaving system that employed a lithium ion storage battery[2] (●Fig. 3). Lithium ion storage batteries can be charged to a high-voltage during periods of considerable power consumption or when the storage battery has not yet degraded. Keeping these special characteristics in mind, our approach was to extend the life of the storage battery by slightly reducing the end of charge voltage when there is little power consumption or when the storage battery is degraded.

The lithium ion storage battery is also highly durable in situations requiring repeated charging and discharging. Therefore, this kind of battery is suited for peak shaving where the battery is repeatedly charged at nighttime and discharged during the day.

●Fig. 3 Industrial Large-Format Lithium-Ion Battery

●Fig. 4 LINE BACK GAMMA

2. Offering Solutions for a Varie

Our journey began in 1993 with the offer of the LINE BACK series of grid connected power conditioners. LINE BACK offered a way to expand into solar power as well as the answer to the various needs of the market.

Eleven years later, in 2004, we developed our 100kW large capacity power conditioner, the LINE BACK Omega. The LINE BACK Gamma offered five years later, in 2009, was another large capacity power conditioner (●Fig. 4). At 250 kW the LINE BACK Gamma was developed for mega solar, i.e., solar generation facilities handling over 1000 kW.

Thus, we are able to handle a wide variety of needs, from private homes to mega solar facilities. Our years of development have also given us the technology and the expertise to offer the right solutions for a variety of purposes and environments.

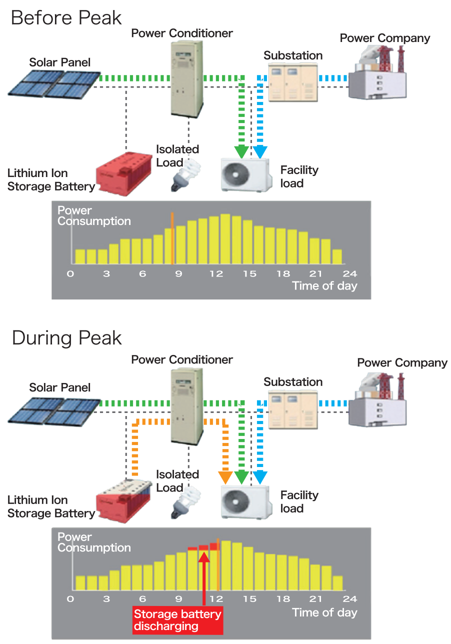
3. Arriving at a Peak Shaving Lithium Ion ESS

The LINE BACK ΣIII Power Conditioner developed around 2012 was the amalgamation of all our internal knowledge and expertise. The device is capable of supporting lithium ion storage batteries. Ordinarily, the power generated by solar panels is supplied to the load, and power is purchased from the power company when needed (top, ●Fig. 5). In contrast, the LINE BACK ΣIII starts discharging the lithium ion storage battery on receiving a control signal, regardless of whether the solar panels are generating power (bottom, Fig. 5). Another bonus is that with this technology the storage battery used in the peak shaving system could be deployed on a much smaller installation area than if a lead battery were used.

Our pursuits also lead us to be the first custom large-format energy storage system manufacturer in Japan to qualify for subsidies[3, 4] promoting collaboration and innovation in sustainable technologies.

In this article we discuss our pursuit of a peak-shaving lithium ion energy storage system. In our next article, we will discuss power conditioner efficiency and our creation of a fanless power conditioner design.

●Fig. 5 Overview: the LINE BACK Σ III



1. Japan Patent No. 3858673 (Filed in 2001)
2. Japan Patent No. 4019734, U.S. Patent No. 6674265, European Patent No. 1667308 (Filed in 2001)
3. GS Yuasa Technical Report Volume 9, No. 2, published 2012
4. Subsidy for “Manufacturers Facilitating Introduction of Stationary Lithium Ion Storage Batteries” offered by the Sustainable Open Innovation Initiative (SII); 2012

For inquiries, contact:
Intellectual Property Division,
GS Yuasa International Ltd.