BMS

Part 04

Developing Battery Management Systems

Charge Control of the Storage Battery

In recent years we have seen rising power demands as well as clear moves toward decarbonized power systems globally. It is expected that as more renewable energy systems are introduced into power grids, the amount of dispatchable power needed and the congestion in those power grids will increase. Thus, storage batteries are gaining importance as dispatchable power that provides rapid responsiveness, given that storage batteries store generated power in order to supply power at peak demand times[1].

GS Yuasa developed a highly safe-by-design modular energy storage system (ESS)[2]; we then devised a new ESS, which integrated a power conditioner (PCS)[3], thus providing space-saving in shipping and installation (●Fig.1). Both ESS use our own lithium ion (Li-ion) batteries and battery management unit (BMU), which are manufactured by us in Japan.

As one part of a battery management system these ESS perform charge control that achieves rapid charging while suppressing abnormalities such as dendrite growth in the storage battery. This article explores the technical concepts we devised in the process of developing this kind of charge control.

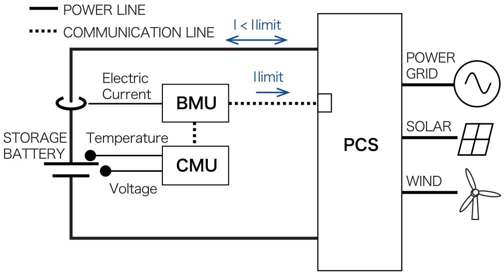
1. Basic Configuration of the ESS

The base of the ESS is the storage battery. The storage battery is configured by connecting multiple Li-ion battery cells in series to form a cell group (also called a "bank"), and connecting multiple banks in parallel. In the ESS in ●Fig. 2, the storage battery (left) is connected to an electric power grid, or to renewable energy equipment (right) by way of the PCS. A cell management unit (CMU), which has a monitor IC, acquires the voltage of each cell and a representative temperature for each bank, and communicates these to the BMU. The BMU further acquires the electric current flowing through each bank.

Based on the present cell voltage, the BMU then outputs to the PCS a maximum electric current (electric-current limit value) that can flow through the storage battery. In times of surplus power, the PCS converts, for example, the electric power supplied from the power grid or the renewable energy equipment to a voltage that is suited for charging, and charges the storage battery at an electric current that does not exceed the electric-current limit value it obtained from the BMU. Additionally, in times of peak power demand, for example, the PCS discharges the storage battery at an electric current that does not exceed the electric-current limit value it obtained from the BMU.

●Fig. 1 PCS-Integrated Energy Storage System

●Fig. 2 ESS charging-discharging based on an electric-current limit value from the BMU.



2. Applying the Electric-Current Limit Value based on the Temperature

To prevent dendrite growth (i.e., the phenomenon in which metal ions, such as lithium, are deposited on the negative electrode of the cell), GS Yuasa came up with the concept of applying different electric-current limit values in accordance with temperature of the cell or the cell group.

The relationship between the cell voltage (horizontal axis) and the electric-current limit value (vertical axis) is presented in ●Fig. 3. As indicated by the solid line, charge control is performed such that charging progresses with a fixed value I_{max} serving as the electric-current limit value until the cell voltage reaches a first electric-current reduction startpoint 1. The electric-current limit value is gradually reduced after the cell voltage has reached the first electric-current reduction startpoint 1.

Nevertheless, dendrite growth tends to occur easily during the last stage of charging (i.e., when the cells are nearing full charge) when the cell is at low (e.g., less than 0 ° C) temperatures. Therefore, as shown by the dashed line in ●Fig. 3, we came up with reducing the electric-current limit value at the stage when the cell voltage reaches a second electric-current reduction startpoint 2, which is less than the first electric-current reduction startpoint 1[4]. Thus, reducing the charge current at an early stage when the cell is at a low temperature can prevent dendrite growth.

3. Improving Charge Acceptance

Next, let us consider a case in which, as shown in ●Fig. 4(A), immediately before entering the region where the cells are charged while reducing the electric-current limit value, the BMU, which has acquired the present (n) cell voltage and current (V_n, I_n), outputs to the PCS a large value in the vicinity of I_{max} as the electric-current limit value. In this case, because of the communication delay, the control delay in the PCS, and the like, there is the risk that at the next control cycle (n+1), the cell voltage and current (V_{n+1}, I_{n+1}) exceed the safe operating range, and dendrite growth occurs.

In contrast, let us consider a second case in which, as shown in ●Fig. 4(B), the BMU outputs a small value to the PCS as the electric-current limit value, and gradually increases the cell voltage and current by small increments over multiple control cycles. In this second case, although there is less risk of dendrite growth occurring, the charge acceptance is insufficient for an ESS.

Here, we considered predicting the change in the cell voltage and electric current based on the internal cell resistance, and computing a target value for a voltage and electric current that would match the decreasing line of the electric-current limit value shown in ●Fig. 5[5].

For instance, one can consider only the direct-current resistance component (the Ohm resistance), or the non-Ohm resistance in addition to the Ohm resistance. Values for the present voltage and electric current (V_n, I_n) and the internal resistance (R_i) are applied to a cell equivalent-circuit model, which is stored in the BMU. The internal resistance (R_i) may be a value that changes in accordance with the cell temperature. When considering only the Ohm resistance as the internal resistance (R_i), the following formula can be derived based on a simplified equivalent-circuit model ($V_n = OCV + I_n \times R_i$). Note that OCV represents the open-circuit voltage of the cell.

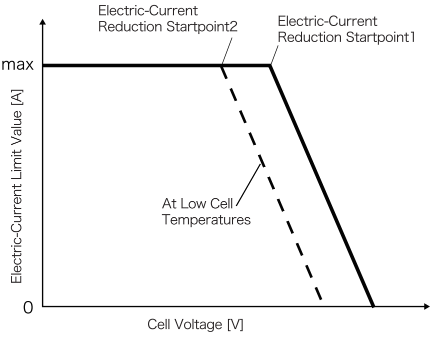
$$I_n = \frac{1}{R_i} \times V_n - \frac{OCV}{R_i}$$

Here, $1/R_i$ represents the rightward sloping line that passes through (V_n, I_n) in ●Fig. 5. The BMU determines the intersection of this straight line of the slope and the decreasing line of the electric-current limit value as the target value (V'_n, I_{limit}), and outputs the Ilimit computed to the PCS as the electric-current limit value. The PCS charges the cells at an electric current that does not exceed I_{limit}.

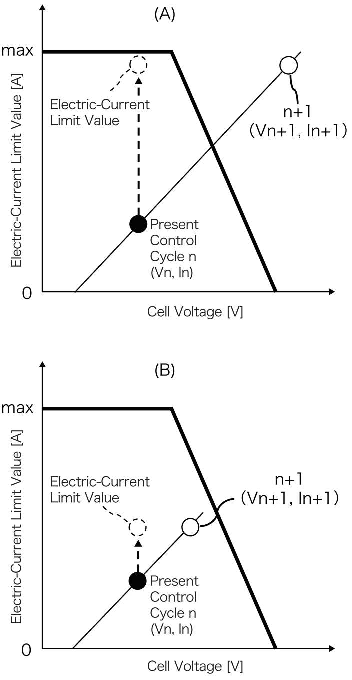
Thus, we are able to predict the behavior of the voltage and electric current based on the internal cell resistance. By incorporating this kind of behavior prediction, the BMU is able to prevent dendrite growth while coordinating with the PCS to maintain the highest possible charge current, thereby improving the charge acceptance of the ESS.

This article introduced creative technical concepts we devised regarding charge control of the storage battery. GS Yuasa will continue to offer products that are backed by our longstanding and proven expertise, and ensure that these products, which are safe by design, will create the future of widespread use of renewable energy and the realization of a sustainable society.

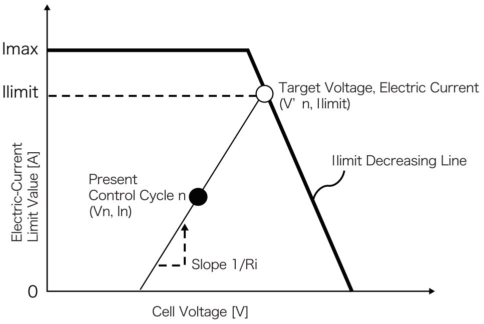
●Fig.3 Applying the electric-current limit value based on the temperature.



●Fig.4 Comparison of large and small electric-current limit values during the last stages of charging.



●Fig.5 Target Voltage and Electric Current based on Internal Cell Resistance



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2. GS Yuasa Technical Report Volume 19, No. 2, published 2022
3. GS Yuasa Technical Report Volume 22, No. 2, published 2025
4. Japanese Patent No. 7437605
5. Japanese Patent No. 7605070, US Patent Publication No. 2024/0377461, Chinese Patent Publication No. 118159856

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