Part 05

Developing Technologies for Operation and Maintenance Services

Anomaly Detection and Factor Estimation for Storage Battery Installations

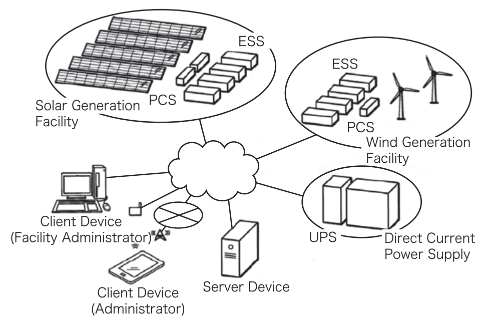
Storage batteries are often employed as a backup during a power outage; moreover, the adoption of storage batteries, e.g., for power conditioning of renewables, energy management, and power trading is also expected to increase in the coming years.
GS Yuasa builds remote monitoring systems for storage battery installations[1], and collects data from products delivered to various regions (●Fig. 1). The long-term data are retained on a server device, which allows for confirming past and present operating conditions for a storage battery installation. Signs of possible malfunction can also be detected on the basis of the data to help prevent glitches[2].
Ideally, a storage battery installation should be always-on to be able to supply backup power at any time, or to provide charging/discharging in accordance with the present need. Additionally, a storage battery installation should never be unnecessarily shut down due to false positive recognition of an anomaly. This article introduces anomaly detection that accounts for the special characteristics of storage battery installations as well as some technical concepts for estimating anomaly factors.

1. Relevant Characteristics of a Storage Battery Installation

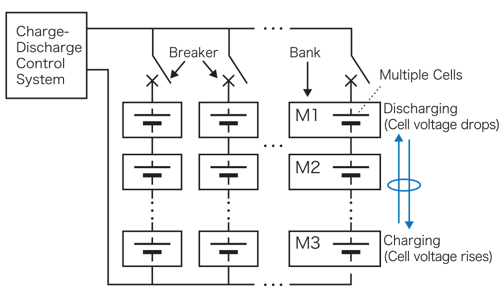
A storage battery installation that utilizes Li-ion batteries (●Fig. 2) is made up of multiple modules, each of which is made up of multiple cells connected in series. The multiple modules are also connected in series to form a single unit referred to as a bank. Multiple banks are then connected in parallel depending on the storage capacity that is required. A single bank or multiple banks may be stowed in an enclosure which is referred to as a battery board.
By switching on a breaker, a current flows in the cells contained in the modules M1, M2, M3 of each bank in accordance with the power that needs to be supplied from (discharge) or absorbed into (charge) the storage battery installation. In each of the cells, the flow of current causes the cell voltage drop, or to rise and generate heat to raise the temperature of the cells.

A charge-discharge control system uses sensors to collect the current data for each of the banks, the voltage data for each of the cells, and the temperature data for each of the modules. These data are sent to a server device via a network.
It is assumed in advance that temperature differences among the cells will occur inside the battery board and in the modules (●Fig. 3). A battery board contains multiple racks and a module is installed on each rack. Inside the battery board, the heat emanating from the modules increases, and the temperature of the cells in the modules M1 and M2, which are installed at the upper part inside the battery board is predicted to be higher than the temperature of the cells in the lower module M3. Additionally, the temperature of the battery cells B located at the center within each module is predicted to be higher than the battery cells A at both ends among the lineup of battery cells.
Here, predicted values for what would happen to the temperature distribution inside the battery board and the modules when a given current flows can be obtained through a simulation that accounts for heat transfer. The voltage behavior of the cells and predicted values can also be computed for when a current flows through the cells A and B which have different temperatures.

●Fig. 1 Overview of the Remote Monitoring System



●Fig. 2 Construction of a Storage Battery Installation



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2. Predicted Value-based Anomaly Detection and Factor Estimation

In some cases there may be no anomaly present even when there is a temperature difference as seen with the cells A and B (●Fig. 3). The cell A, whose temperature is low compared to the cell B whose temperature is higher due to the location inside the battery board (the installation environment), has a higher internal resistance than that of the cell B, and the cell voltage tends to increase during charging. The cell B, whose temperature is high, has a relatively low internal resistance and the cell voltage tends to decrease.

Thus, as illustrated in ●Fig. 4, defining a normal range (tolerance range) that accounts for environmental differences on the basis of the predicted values obtained through simulation, makes it possible to avoid erroneously recognizing an anomaly in the cells A and B which are normal but have a temperature difference. And, it can be determined that an anomaly has occurred in the storage battery installation when the measured data for a given cell C indicates a voltage behavior that deviates from the normal range (dotted line, ●Fig. 4). Moreover, the cause of the anomaly can be estimated as this cell C (which may be more deteriorated than another cell, for example) and not the environment.

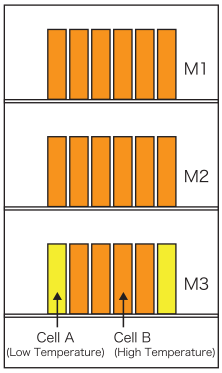
The measured data collected by the charge-discharge control system (●Fig. 2), and the predicted data obtained accounting for the environment of the cells may be compared, thus making it possible to detect the cases where the cause of an anomaly is in the environment. An example of this is described using ●Fig. 5.

The solid line in ●Fig. 5 shows there is a temperature difference in the measured temperature data; however, as illustrated in ●Fig. 3 by the cells A and B, the difference neither increases nor decreases and is substantially constant.

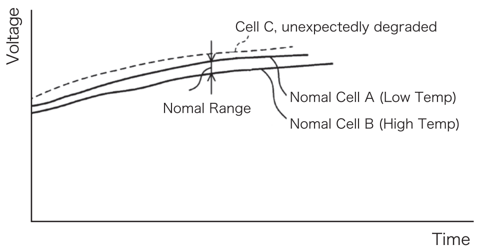
The dotted line in ●Fig. 5 is the difference between the measured values and the predicted values for the temperature differences between the cells A and B. Around the first time point the dotted line transitions to a low value, in other words, the measured values and the predicted values are substantially the same; however, around the second time point the dotted line shows that the gap between the measured values and the predicted values are greater. In such a case, it can be estimated that no anomaly has occurred in the cells A and B, and that an anomaly has occurred in the environment, such as the breakdown of air conditioning equipment installed for the battery board, or the like.

Here, it is clear how more advanced factor estimation helps avoid unnecessary shutdown of a storage battery installation due to false positive recognition of an anomaly. This article introduced anomaly detection that accounts for the special characteristics of storage battery installations as well as some technical concepts for estimating anomaly factors. Through our sophisticated remote monitoring service, GS Yuasa will continue to improve the reliability of storage battery installations that serve as social infrastructure.

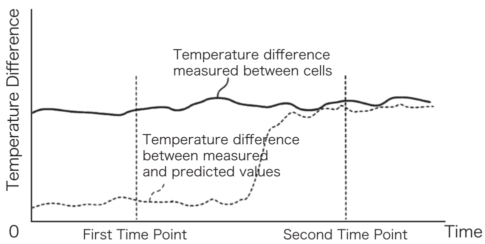
●Fig.3 Temperature Distribution in a Storage Battery Installation



●Fig.4 Variation in the Behavior of the Cells due to Environmental Differences[3]



●Fig.5 Change in Measured and Predicted Values



1. https://www.gs-yuasa.com/en/technology/making_history/pdf/no19.pdf
2. https://www.gs-yuasa.com/en/technology/making_history/pdf/no28.pdf
3. Japanese Patent No. 6555440, US Patent No. 10,996,282 (Filed in 2018)

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