Part 03 EMS

Developing Techniques for Monitoring Battery Operations

Techniques for Assessing Residual Performance

Local communities are increasingly seeking better ways to source electricity through initiatives such as community choice aggregation and local energy storage. This has led to the storage battery fulfilling new roles for local communities. This expanding role for the storage battery has thus increased the need to more accurately understand the battery's current state and health. GS Yuasa has dedicated many years to researching the processes involved in the deterioration of lithium-ion based storage batteries; in this time, our researchers have also sought to create a mathematical model that describes the mechanism behind deterioration[1-3]. This article will explore the technical concepts developed at GS Yuasa for evaluating and predicting the residual performance of a storage battery (primarily, the lithium ion battery).

1. Electrical versus Non-Electrical Deterioration

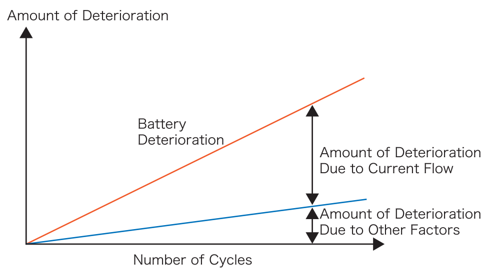
Lithium-ion batteries deteriorate for a combination and variety reasons. These reasons may be changes in the active material; changes in the electrolyte; changes in the SEI film; the temperature of the usage environment; and the like. Typically, discussions surrounding the deterioration of a battery often involve two factors: the deterioration relating to the number of charge-discharge cycles (cycle life) and deterioration relating to periods of inactivity (calendar life). However, depending on the method used to measure deterioration, cycle life may include calendar life. This is because aging continues during the charging and discharging (cycle) of the battery.

Instead, this article will discuss deterioration of the battery in terms of electrical deterioration, i.e., due to the flow of current, and non-electrical deterioration, i.e., due to factors other than current flow; here, non-electrical deterioration means the same as calendar life. We consider battery deterioration at a certain point as the sum of the electrical and the non-electrical deterioration. Monitoring the battery or successively recording the battery state may be used to detect whether or not the battery is energized. This makes it possible to make a strict distinction between electrical deterioration and non-electrical deterioration. Moreover, the increased sophistication of information communication technologies in recent years has made it easier to acquire this kind of very detailed data and to perform various calculations based on this data (●Fig. 1).

●Fig. 1 Monitoring a Smart Device[4]

If the battery can be monitored, and the electrical and non-electrical deterioration can be understood on the basis of an appropriate mathematical model, then the residual performance of the battery can be assessed at any time. Additionally, the electrical and the non-electrical deterioration may be calculated on the basis of simulated data that contains parameters such as the assumed charging and discharging of the battery, and the temperature in the usage environment. With this information it is possible to perform simulations when designing a power system such as a storage system.

●Fig.2 Transitions in Amounts of Electrical and Non-electrical Deterioration[5]



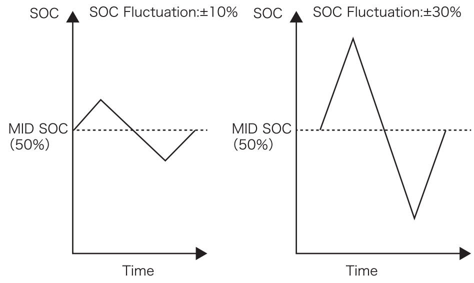
2. Cycling Accelerates Electrical Deterioration

Non-electrical deterioration can be considered deterioration of the battery in a static state. Non-electrical deterioration can also be acceptably estimated based on present theories, i.e., the square root rule which states that the battery capacity is proportional to less than the square root of time.

On the other hand, electrical deterioration can be considered deterioration of the battery in a dynamic state. Unfortunately, existing theories tend not to provide a satisfactory explanation of electrical deterioration. Recent findings have made it clear that electrical deterioration accelerates with additional cycles of the battery. One hypothesis is that energization increases the amount of SEI film generated on the negative electrode of the battery.

Therefore, for example, one approach would be to establish a deterioration coefficient for calculating the electrical and the non-electrical deterioration. The amount of deterioration of the battery may be calculated so that the difference between the amounts of electrical and non-electrical deterioration increases according to an increase in the number of cycles (●Fig. 2). Thereby, the principle of deterioration of the battery can be more correctly simulated.

●Fig. 3 Charging and Discharging within Different SOC Fluctuation Ranges

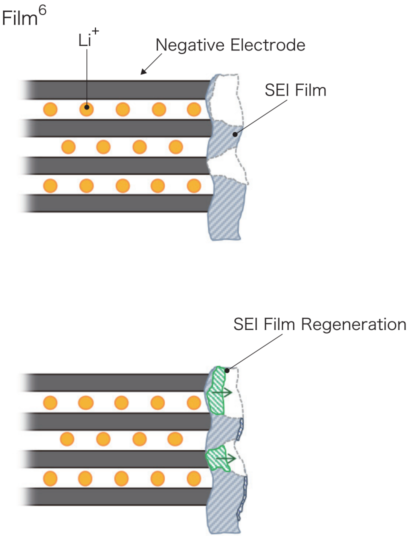


3. Estimating the Electrical Deterioration according to the SOC Fluctuation Range

Another new finding suggests that even if the overall amount of electrical energy flowing is the same, the electrical deterioration will also change if the amount of fluctuation in the battery charging state (SOC) changes. ●Fig.3 depicts the charging and discharging of the battery. Assuming a certain SOC (e.g., 50%) is the middle of the range, greater electrical deterioration takes place when the SOC fluctuates one time within ±30%, compared to when the SOC fluctuates three times within ±10%.

One explanation is that the larger SOC fluctuation range increases the degree to which the negative electrode expands and contracts. The larger the SOC fluctuation range, the more likely the SEI film will partly break away from the negative electrode (top, ●Fig. 4). The SEI film will also likely regenerate at sites where SEI film separated from the negative electrode (bottom, ●Fig. 4).

●Fig. 4 Separation and Regeneration of the SEI Film[6]



Therefore, data on the battery SOC may be acquired over time, and the amount of deterioration in the battery may be calculated accounting for the increase in electrical deterioration when the SOC changes over a large fluctuation range. Chronological data on the SOC may be acquired through monitoring or through simulation. This type of calculation may be used to acceptably simulate the deterioration phenomenon for a real battery, allowing for proper assessment of the residual performance of the battery. The simulation may also make it possible to propose an optimal design or operation for the real battery.

This article explored technical concepts that may be applicable to assessing and predicting the residual performance of a storage battery. At GS Yuasa, we will continue to combine our long and well-cultivated expertise in electrochemistry and computational science to conduct research and provide the technological developments that respond to society's needs.

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5. Japanese Patent No. 6428958 (Filed in 2017)
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