Part 04

Developing Technologies for Operation and Maintenance Services

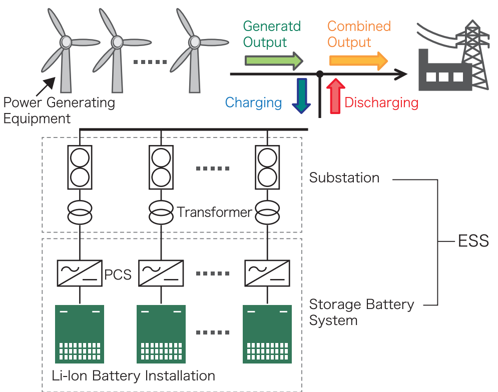
Using Battery Life Prediction for Optimal ESS Design

Energy storage systems (ESS) that use lithium ion (Li-ion) battery installations are increasingly being adopted worldwide. An ESS can be linked to a renewable energy source, or the like (Fig. ●1). The number of series- or parallel-connected cells (i.e., the cell configuration) in the ESS is chosen based on the scale or usage environment of the power-generating equipment. Li-ion battery installations gradually deteriorate and their storage capacity diminishes with repeated charging and discharging over 10 or more years of use. Thus, the cell configuration of an ESS is designed to provide a desired charging and discharging capacity even at end-of-life where the battery installation is well-deteriorated.
GS Yuasa has spent many years researching and mathematically modeling the deterioration mechanisms of Li-ion batteries[1]. Using this knowledge, we developed a simulator for predicting the life of a battery installation, and found the simulator to be useful for designing ESS cell configurations. This article introduces load patterns and describes predicting battery life and designing ESS using load patterns. This article also introduces our support tool which simplifies generating and modifying load patterns.

1. Predicting Battery Life and Designing ESS using Load Patterns

An ESS that is linked to a renewable energy source (●Fig. 1) charges the battery installation with excess power, i.e., when the power-generating equipment outputs lots of power, and discharges from the battery installation when the power-generating equipment outputs little power to prevent fluctuations in the combined output. These charging and discharging patterns are the load patterns for the battery installation. Thus, a variety of load patterns may be applied to the battery installation depending on the season or weather, and the installation environment or usage conditions of the ESS while the ESS is in use.
The deterioration of a Li-ion battery may be classified as electrical deterioration (cycle deterioration) that is due to the flow of electricity, or non-electrical deterioration (calendar deterioration) that is due to causes other than the flow of electricity. Both cycle deterioration and calendar deterioration progress while electricity is flowing through a cell. Only calendar deterioration progresses while no electricity is flowing[2].
A simulator for predicting battery life would compute the level of cycle deterioration and calendar deterioration in a designated battery installation when virtual load patterns are applied to that installation over a predetermined period (one day, one month, one year, 10 years, etc.). Thus, virtual load patterns, which are numerical representations of the charging and discharging of the ESS must be prepared in order to predict the battery life.
●Fig. 2 shows a portion of a sample virtual load pattern. The positive direction along the vertical axis of the line graph (right, ●Fig. 2) represents the size of the charge power and the negative direction represents the size of the discharge power; the horizontal axis represents time (in seconds). In this example, the charge power to the battery installation increases linearly from 5.5 kilowatts (kW) to 10 kW over 0 to 3600 s, after which the battery installation is left with a charge power of 0 kW until 10800 s. Then, the discharge power from battery installation is constant at 8 kW until 14400 s.

●Fig. 1 Large-scale Storage System for use with Wind Power Generation

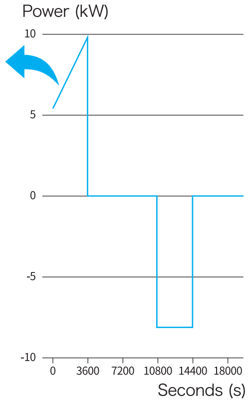


The load pattern (numerical list file, left, Fig. 2) corresponds to the line graph (right, ●Fig. 2); therefore, the load pattern represents the power transitions in the battery installation in one-second increments where the numerical value for the power increases linearly from 0 to 3600 s. This kind of virtual load pattern is then entered in the simulator to predict the battery life. The simulator computes both the cycle deterioration, which progresses with the size of the increasing charge power and the calendar deterioration, which progress with time from 0 to 3600 s and computes only the calendar deterioration which progresses with time from then up to 10800 s in the battery installation.

A cell configuration of optimal size may be chosen through trial and error to design an ESS capable of exhibiting a prescribed charging and discharging capacity over longtime use of the ESS. Here, trial and error involves repeatedly establishing temporary cell configurations (e.g., the number of parallel connections) and running simulations.

●Fig. 2 Load Pattern and Line Graph

Second(s)	Power(W)
1	5500.00
2	5501.25
3	5502.50
:	:
3599	9998.75
3600	10000.00
3601	0.00
:	:



2. The Load Pattern Generating Tool

The load patterns (numerical list files) needed for predicting battery life can be created manually when the load patterns correspond to simply-shaped line graphs like the example in ●Fig. 2. However, real ESS design also requires various types of load patterns that correspond to more complex line graphs, and those kinds of load patterns are extremely difficult to create manually.

We therefore developed a support tool (software) that can be run on a terminal device such as a PC or tablet to generate and modify load patterns easily.

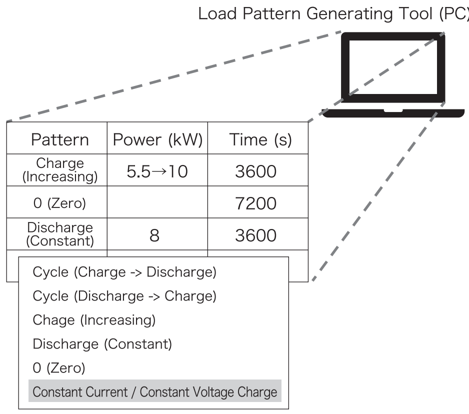
The support tool presents a reception screen on the display unit of a terminal device for accepting selections or input regarding charging and discharging in the ESS (●Fig. 3). The *Pattern* column presents multiple types of charging and discharging operations as a pull-down where any of the options may be selected. The *Power* column allows a configuration value to be entered with respect to the charging and discharging operation selected. The *Time* column allows entering a time for which the selected charging and discharging operation should continue.

Once a pattern is generated with the particulars depicted in ●Fig. 3, the line graph (right, ●Fig. 2) is shown on the display unit of the terminal device. The line graph thus allows for visual confirmation of whether the intended load pattern was generated. The user can return to the reception screen when a modification is necessary, such as changing the target charging value (e.g., changing the value from 10 kW to 12 kW). The file is then output (i.e., output of the numerical list file, left, ●Fig. 2). This series of operations take no more than a few minutes. Thus, the amount of work hours can be cut significantly and the possibility of human error can be mitigated compared to when load patterns are created manually.

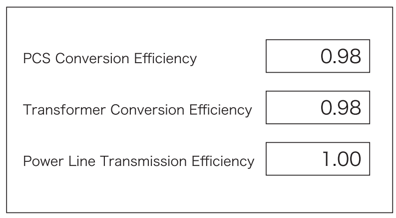
Various efficiencies can also be set at the reception screen (●Fig. 4). In addition to the battery installation, an ESS is provided with a power conditioner (PCS) or transformer, and the power lines connecting them (●Fig. 1). Load patterns can be generated that reflect the actual power entering and leaving the battery installation by accounting for the conversion efficiencies of the PCS or transformer and the propagation efficiency of the power lines; this further improves the accuracy of the battery life prediction made by the simulator.

This article introduced load patterns and our support tool for generating load patterns. This article also described using load patterns to predict battery life and design ESS. GS Yuasa will continue to offer ESS that are well-suited to their environment by leveraging our research-backed battery life prediction technology that considers a wide range of conditions.

●Fig. 3 Load Pattern Generating Tool[3]



●Fig. 4 Entering various efficiency numbers[3]



1. https://www.gs-yuasa.com/jp/newsrelease/article.php?ucode=gs210415592602_975
2. https://www.gs-yuasa.com/jp/technology/making_history/pdf/no18.pdf
3. Japanese Patent No. 6835140 and Japanese Patent No. 7173180 (Filed in 2019)

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