Part 04

Developing Battery Simulation Technologies

AI-based Predictive Failure Detection for Storage Battery Systems

Lithium ion batteries are used widely for various power applications: as temporary storage to minimize fluctuations in the energy output from renewables such as solar and wind power generation; as backup power source for power equipment or communication equipment; and as mobile power source for transportation such as trains, ships, or automated guided vehicles. A predictive failure detection technology that allows for safe, secure, and reliable operation of the lithium ion battery is therefore in great demand.

GS Yuasa and NTT Communications, Inc. (NTT Com) have developed an artificial intelligence-based (AI-based) predictive failure detection technology from NTT Com' s chronological data analysis tool[1]. This article discusses the implementation of this AI-based technology for battery systems which uses a type of AI technology known as deep learning, our specialized knowledge of storage batteries and failure detection, as well as storage battery data from our own lithium ion battery installation (●Fig. 1).

This article also introduces how a type of unsupervised learning, i.e., an autoencoder, is used to detect failure warning signs.

1. Background: The Need for AI in Predictive Failure Detection

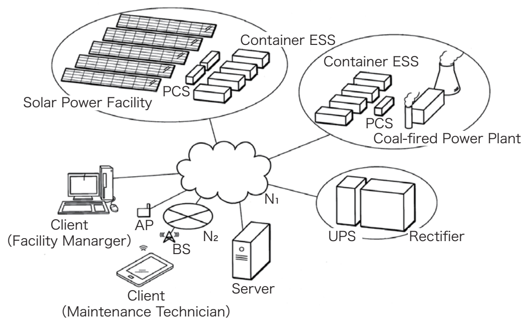
Existing deterioration diagnosis technology for storage batteries acquires the storage battery characteristic data for a number of deterioration modes in advance, and diagnoses or estimates deterioration on the basis of operation data and a numerical model for the storage battery. The storage battery undergoing deterioration diagnosis is assumed to be a storage battery that has aged within a foreseeable deterioration mode.

However, the threshold used to assess a failure may vary in accordance with the usage conditions of the system, and thus it tends to be difficult to set and adjust the appropriate threshold. Moreover, the analysis of whether the fluctuations in operating data are due to normal aging or failure required diagnosis by an experienced operator. Problems also remain with regard to unforeseen failures, such as foreseeing and acquiring characteristic data in advance, or setting the threshold.

If an AI could promptly discriminate between a storage battery that is normally aging and one that is likely to experience unforeseen failures, allowing exchange of only the storage batteries that may fail, it would be possible to more efficiently monitor and operate larger scaled systems (●Fig. 2) with less personnel.

●Fig. 1　Container-type Power Storage Device

●Fig. 2　Remote Monitoring of an Energy Storage System



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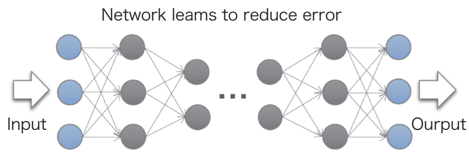
2. Unsupervised Learning

Supervised learning, where the AI learns the characteristics of failure samples, requires preparing a sufficient amount of learning data. However, the incidence of failures among the storage batteries in a storage battery system is extremely low, and it tends to be difficult to use the data from storage batteries that have experienced failure as learning data.

Whereas, unsupervised learning allows for analysis of the characteristics in the data of the sample being evaluated. Thus, unsupervised learning allows for analyzing the characteristics in the chronological data obtained while operating the battery system. This also makes it possible to detect the storage batteries exhibiting behaviors different from that of a normal storage battery.

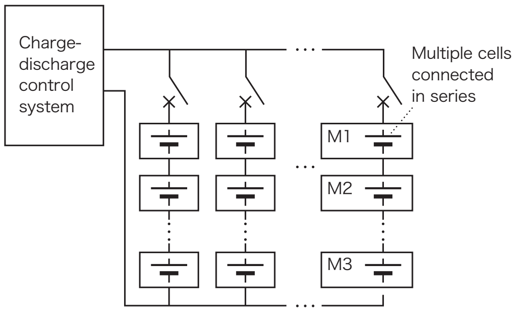
●Fig. 3 Training an Autoencoder



3. Predictive Failure Detection Using an Autoencoder

An autoencoder is a type of dimensionality reduction technique that uses a neural network (●Fig. 3). The neural network is trained to reconstruct the data that was input into the neural network from an output. The data from the actual operation of the battery system, or virtual data obtained by simulating the behavior of a battery system are entered and a model is created that is trained to reduce the difference between the input and output.

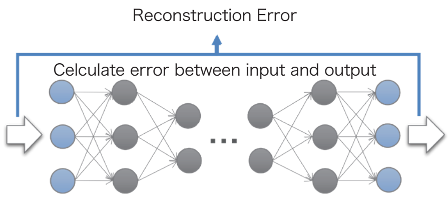
●Fig. 4 The Battery System



A typical battery system (●Fig. 4) is comprised of multiple battery modules connected in series, with each battery module comprised of multiple battery cells connected in series. The real operation data (e.g., voltage values, etc.) of the multiple battery cells in each of the battery modules are used to train the autoencoder. The operation data of the battery modules that have aged normally under given usage conditions are entered in the neural network (Fig. 3) and learning repeated to thereby extract the characteristics of the operation data and reflect these characteristics in the model.

A model built in this fashion is used for monitoring, assessment, and failure detection of battery modules. The operation data of the numerous battery modules included in the battery system are entered sequentially into the autoencoder (●Fig. 5) and the error between the input and output, i.e., the reconstruction error is calculated. Most battery modules age normally. Moreover, the reconstruction error calculated is small when the operation data from the battery cells in normally aged modules are of the same nature as the operation data used in training the model. However, the reconstruction error calculated is greater when operation data from battery cells in a battery module are a different nature from the operating data entered during learning[2]. Therefore, it becomes possible to have early automatic detection of the battery modules that may fail on the basis of the size of the reconstruction error.

●Fig. 5 Assessment with an Autoencoder



This article introduced the concept of detecting warning signs of failure in the battery system using an autoencoder. GS Yuasa continues to work towards furthering research and development by establishing technology for predictive failure detection in storage batteries from the big data collected by remote monitoring systems.

1. The technology in NTT Group's AI corevo® (corevo® is a trademark of Nippon Telegraph and Telephone Corporation).
2. International Publication No. WO2020/137914 (Filed in 2018)

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