Research on Rapid Detection of Battery Health Based on Som Neural Network

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Abstract

This article describes a method for quickly separating the same set of unhealthy batteries and predicting the health of unknown battery sample by machine learning. The IEC60896-22-2004 and GB/T19638.2-2005 standards specify the capacity standards and testing methods for lead-acid batteries. The standard capacity test method requires a constant current discharge of for 10 hours. The test method is difficult to apply to a large number of in-used battery groups in practice. In this paper, an alternative method based on machine learning is studied. The method is to perform fast 5 minute high current charging and 5 minute high current discharge on the battery group which have been voltage balanced, extract the characteristics of charge and discharge, and map each battery characteristic through SOM neural network to 2D plane and then separated by cluster analysis for batteries of different capacity properties. Furthermore, through multiple machine learning and acquisition of real capacity according to standard methods, a training set for supervised learning is established, and SOM neural network cluster center or a time series similarity search algorithm is used to quickly evaluate the capacity of unknown battery samples.

Keywords*: Som neural network, Acid-battery capacity, Hoc, Machine learning, Time series similarity search*

Ⅰ. Introduction

Lead-acid batteries are widely used in uninterruptible power supply systems and DC power supply systems. As the last line of defense for safety, it is very important that the battery can function normally. Battery capacity is one of the important parameters for measuring battery performance. According to statistical information, once the battery capacity degrades to 80%, it will rapidly degrade in about 3 months, often resulting in a detection window period, leading to battery failures and safety accidents.

The IEC60896-22-2004 and GB/T19638.2-2005 standards define the capacity testing methods and evaluation criteria of lead-acid batteries. The standard testing requires the use of C_10 constant current discharge for 10 hours. For example, a 800A battery needs to be discharged for 80 hours. Ampere current constant current discharge for 10 hours, the actual capacity of the battery is obtained through the termination voltage and the actual discharge time.

At present, storage batteries are widely used in backup power supplies. In actual projects, it is necessary to carry out capacity detection according to regulations and avoid the empty window period. The workload is very large, mainly due to the lack of sufficient constant current discharge equipment and the huge discharge time required. Therefore, research How to quickly detect and evaluate battery HOC is very meaningful.

The reasons for the degradation of battery capacity performance are very complex, such as sulfation, internal micro-short circuit, pole corrosion, long-term low-current discharge, lack of maintenance, etc. However, regardless of the reason, the battery capacity performance declines, its charging and discharging characteristics It will change. It is not enough to detect the battery's performance by simply detecting the battery terminal voltage. The reason is that there is a capacitance effect inside the battery itself, and the battery's virtual voltage masks its performance. However, under the condition of higher current charging and discharging, different capacity performance is different. The voltage characteristic curve of the battery is different.

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This paper studies a method of quickly separating batteries of the same group of different HOCs through short-term and rapid charging and discharging characteristic curves and using machine learning. At the same time, it can be performed by collecting multiple machine learning data, combining supervised learning and timing similarity search. Quickly and accurately predict the capacity performance of the new sample battery.

Ⅱ. Detection Scheme Design

A. Design Principle

There is a large capacitance effect inside valve-regulated lead-acid batteries, and its terminal voltage often contains virtual voltage. The more the battery with poor capacity and performance, the greater the virtual voltage. For a group of batteries, after the equalization voltage is charged, the batteries with different performance The terminal voltage is usually not significantly different. However, once the battery's performance is degraded, its internal substances must have changed. When charging and discharging at a higher current, its characteristic curve will have obvious differences, as shown in Figure 1 and Figure 2. This is the result of our collection of short-term high-current charging and discharging. The characteristic curve provides a data basis for evaluating the HOC of the battery.

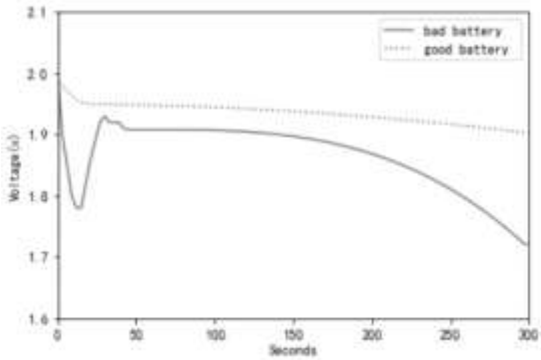

Fig.1 Typical Battery Discharge Curve

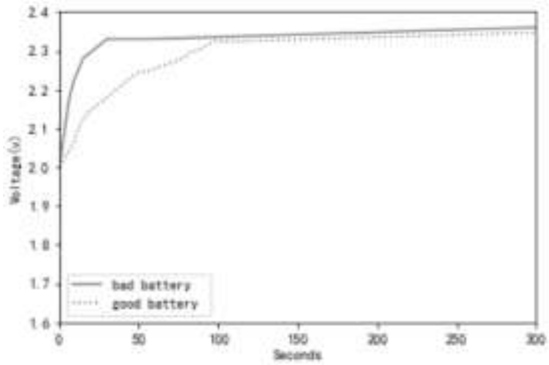

Fig.2 Typical Battery Charging Curve

The research idea is to separate the batteries of different HOCs by charging and discharging a group of batteries that have been voltage-balanced with a larger current and using their voltage characteristic curves. The process is:

Take a 2v, 300AH battery as an example. At first, the voltage of the battery pack is equalized to 2V through voltage equalization, and then a constant current discharge of 3C 10 or 90A is performed for 5 minutes, and then the voltage of the battery pack is equalized to 2V for 5 minutes With 90A constant current charging, the charge-discharge voltage characteristic curve for a total of 10 minutes is obtained for characteristic engineering processing. The variable data obtained through the characteristic engineering is mapped to a two-dimensional plane using the SOM neural network algorithm, and then the Euclidean distance is calculated. So as to realize the linear

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expression of battery HOC based on distance.

Through the above method, we have separated the batteries of the same group with different HOC. The battery pack is charged and discharged many times, obtained many times as a training set, and the classification results corresponding to the training set are obtained through standard methods, and the time-series similarity search algorithm is used to evaluate unknown samples.

B. Voltage Characteristic Processing

To perform data analysis, the characteristic engineering of voltage must be processed first. After one charge and discharge, we obtained the voltage curve data for 10 minutes and a total of 600 seconds. We intercepted the amplitude of the voltage curve at a time interval of 3 seconds (△T=3 seconds), and each battery has a total of 200 characteristic quantities. In order to reduce the impact of translation and zooming on subsequent similarity calculations, we need to standardize the original data. The method used is z-score, which is to subtract the average value from each data point and divide it by the partial standard deviation. The formula is:

Where μ represents the average and σ represents the standard deviation.

After such processing for each dimension data, the average value of each dimension data becomes 0 and the standard deviation is 1.

C. Som Neural Network for Feature Preprocessing

The feature is mapped to a two-dimensional plane array, and the output is organized according to the two-dimensional plane, which is the most typical organization method of the SOM network, which has the image of the cerebral cortex. Each neuron in the output layer is laterally connected with other neurons around him, arranged in a chessboard-like plane, and the structure is shown in the figure:

D. Timing Similarity Search

Euclidean distance refers to the true distance between two points in the m-dimensional space, or the natural length of the vector (that is, the distance from the point to the origin). The Euclidean distance in two-dimensional and three-dimensional space is the actual distance between two points. Formula for two-dimensional space:

$$\rho = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

Among them, ρ is the Euclidean distance between the point (x_2, y_2) and the point (x_1, y_1).

Comparing two time series can usually be measured by Euclidean distance, the formula is:

$$\mathrm{ED(S,Q)} = \sum (S_i - Q_i)^2 \qquad (3)$$

Euclidean distance is used to perform similarity search for time series with equal sampling time intervals.

Ⅲ. Test Procedures and Test Data

The test was carried out with a 24-cell series battery pack of a certain brand of 2V and rated capacity of 400AH, which has been on the line for 4 years. The capacity test was carried out using the CTS2000 constant current charging and discharging equipment of Zhuhai Yituo Technology Co., Ltd., and the voltage recording data was recorded. The discharge and charge characteristic matrix with sample number p=24 and characteristic number n=100 is as follows:

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$$X_{discharge} = \begin{pmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{11} & x_{11} & \cdots & x_{11} \\ \cdots & \cdots & \cdots & \cdots \\ x_{p1} & x_{11} & \cdots & x_{1n} \end{pmatrix} = \begin{pmatrix} 2.0 & 1.92 & \cdots & 1.72 \\ 2.01 & 1.93 & \cdots & 1.74 \\ \cdots & \cdots & \cdots & \cdots \\ 1.99 & 1.98 & \cdots & 1.90 \end{pmatrix}$$

$$X_{charge} = \begin{pmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{11} & x_{11} & \cdots & x_{11} \\ \cdots & \cdots & \cdots & \cdots \\ x_{p1} & x_{11} & \cdots & x_{1n} \end{pmatrix} = \begin{pmatrix} 2.0 & 2.08 & \cdots & 2.35 \\ 2.01 & 2.06 & \cdots & 2.36 \\ \cdots & \cdots & \cdots & \cdots \\ 2.0 & 2.02 & \cdots & 2.34 \end{pmatrix}$$

Combine the discharge and charge matrices to obtain a charge-discharge characteristic matrix X with sample number p=24 and characteristic number n=200:

X=(X_discharge,X_charge)

Plot the feature samples:

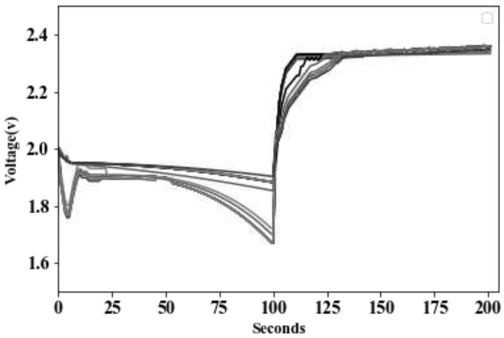

Fig.5 Characteristic Diagram of Battery Sample

Perform z standardization on this feature matrix to obtain a feature matrix X_z that has been processed by feature engineering.

A. Hoc Evaluation of Batteries in the Same Group

Use SOM neural network algorithm to learn the feature matrix X and map it to a two-dimensional plane space. The normalized and unnormalized two-dimensional plane diagrams are:

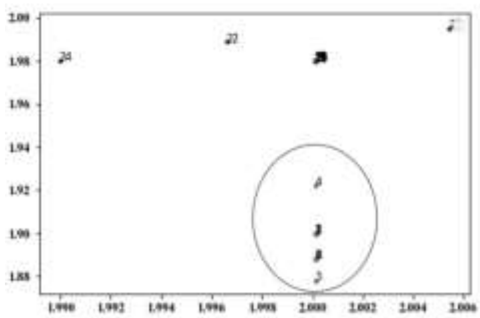

Fig.6 Unnormalized Som Neural Network Mapping Results

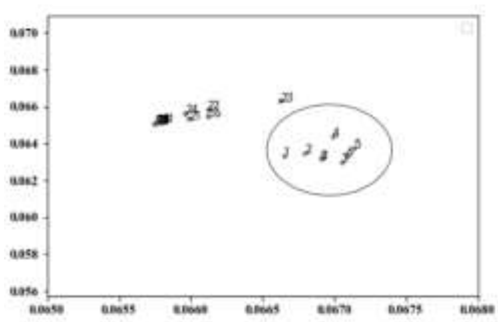

Fig.7 Normalized Som Neural Network Mapping Results

From the comparison chart, the clustering effect is obvious after data normalization. The circled part is the battery with poor performance. The farther the battery is from the center of the battery with better performance, the worse the performance of the battery. Compared with the result of the standard capacity test, the evaluation result matches better.

In actual engineering, for unknown battery samples under the same conditions of use, the center of high-quality batteries can be used as a reference point. The farther away from the center, the worse its performance:

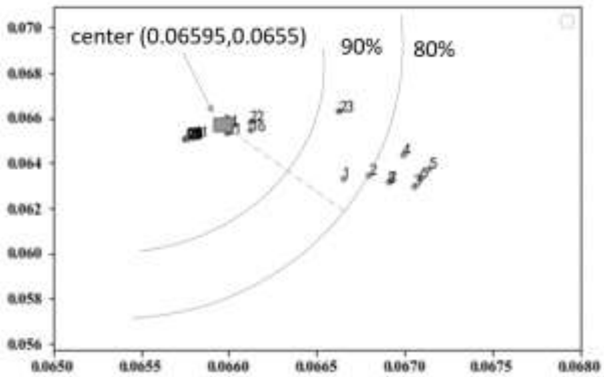

Fig.8 Based on Som Neural Network Graph and Euclidean Distance Prediction Sample

As shown in the figure above, the center point of the high-quality battery cluster of this test sample is center (0.06595, 0.0655). The battery HOC can be judged by calculating the distance between the sample and the center, that is, the Euclidean distance. The inner curve distance is 90% capacity, and the outer curve is 90% capacity. The curve distance is 80% capacity. According to the current industry statistics, once the battery capacity performance degrades to 80%, rapid decay may occur.

B. Hoc Prediction of Unknown Battery Samples

In addition to using the above Euclidean distance to evaluate the performance of unknown samples, we can also use the principle of sequence similarity to collect the characteristic curves of batteries with different performances in advance to establish a mapping set of sample characteristics and performance, as shown in Figure 9, and then use the time sequence The sequence similarity search method calculates the similarity between the unknown sample and the battery with different performance, and takes the minimum value as the matching result to judge the performance of the unknown battery sample:

Take No. 2 sample with the smallest Euclidean distance of 2.43 as the most similar sample feature of x_test, and infer the battery performance of x_test based on the actual capacity test result of No. 2 sample.

Ⅳ. Conclusion

The SOM neural network feature mapping method introduced in this article can effectively visualize the two-dimensional visualization of batteries with different performance differences. According to the actual test data, the batteries of different HOCs are successfully separated, and the clustering center based on the SOM diagram and the time sequence sequence are discussed. Similarity is a method for predicting battery performance of unknown samples. In the process of establishing the sample characteristics, 3 seconds is used as the time interval. This hyperparameter may need to be adjusted under different characteristic curves. In addition, you can also consider introducing more battery parameters such as temperature to enhance the robustness of the model. In addition, wave recording equipment or external interference may produce waveform noise, which will affect the evaluation effect of Euclidean distance. You can consider using more complex dynamic time warping (DTW), longest common subsequence (LCSS) and other algorithms.

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