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Analysis of online diagnosis and repair technology of lead acid battery faults

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Abstract. Lead-acid battery, as a basic component of DC power supply equipment in power communication system, is also known as maintenance-free battery. It is believed that it does not need maintenance treatment in the initial stage of application research. However, as an electrochemical product, it has relatively high requirements for both use environment and operation. It is the main problem discussed in electric power industry at present. In this paper, on the basis of understanding the research status of online fault diagnosis technology of lead-acid battery, according to the basic principle of lead-acid battery and online detection system, discharge treatment of two groups of tested single battery load, calculate and analyze the battery resistance value. The final experimental results show that this method can solve the safety hazard of the whole battery line discharge, control the equipment cost, and ensure the fault location is more accurate and effective.

Keywords: lead-acid battery; Online fault diagnosis; Repair technique; Power communication system; Internal resistance

1. Introduction

The DC power supply equipment in the power industry provides DC load electricity for the system operation, which can ensure the independence and reliability of the overall system operation. At present, there are two forms of DC power supply equipment used in power communication systems. One refers to the battery pack and the other refers to the silicon rectifier device, in which the battery pack needs to be equipped with a DC generator as a strong charging source. In the communication industry and power plants, the important 35-110kV substations and unmanned on-duty substations all need to use lead-acid battery packs as DC power supply, while the general 35-110kV substations need to use small-capacity cadmium-nickel battery devices or capacitive energy storage devices as DC power supply. Under normal operating conditions, only the power supply device can provide closing power for the circuit breaker; In the case of problems or normal power failure, DC power supply equipment can play its own independent power supply role, for automatic devices, DC motor, accident lighting, communication system and so on. In the late 1850s, French Plant first invented the lead-acid battery. In practice, it has the characteristics of simple production process, rich application materials, low cost, wide range of temperature and so on. The development is still one of the most widely used and most mature batteries, which are mainly used in the electric power communication industry. In the mid-1980s, researchers developed the valve-controlled sealed lead-acid battery based on the liquid-rich lead-acid battery. This battery stores most of the electrolyte in the fine glass fiber diaphragm of the liquid-absorbing plate and a small part in the pores of active substances in the positive and negative electrodes, so that there is no flowing electrolyte in the battery shell, so it is also called the lean battery pack. Lead-acid battery has been invented for more than 150 years. Although it has very high application value, it is inevitable that there will be safety failures during use. If it cannot quickly find fault types and put

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forward effective solutions, it will inevitably affect the overall system operation. Therefore, researchers pay more attention to the study of lead-acid battery fault diagnosis and repair technology, accurate judgment of battery fault types, in order to improve the battery cycle life on the basis of.[1-3]

According to the accumulated experience of science and technology research in recent years, there are many reasons for the safety failure of the battery, among which the internal water loss of the battery and the plate sulfate is one of the most common factors leading to the problems of lead-acid battery. If the battery string is not maintained in time after a fault occurs, the performance and service life of the battery will be affected. When studying the fault diagnosis and repair technology of lead-acid battery, we put a lot of manpower, material resources and time into it. The relevant research subjects and technical theory have got good results. For example, Southwest Jiaotong University designed and studied the polarization and sulfuric acid fault repair system based on lead-acid battery as the core by combining the charge-discharge characteristics of lead-acid battery and effectively evaluating the health state of the battery. The new Buck-Boost topology was used to complete the hardware design, and the process of data acquisition, algorithm control, regeneration repair and charging was quickly realized. Shandong Qingdao University in the study of lead-acid battery repair technology, the use of pulse resonance to complete the battery repair treatment, switching power supply as a converter, scientific use of microcontroller for effective regulation, in order to complete the high frequency pulse repair work of lead-acid battery; East China University of Science and Technology in the study of battery electrochemical repair work, according to the electrochemical characteristics of lead in the electrolyte, focus on the analysis of lead electrode electrochemical reaction phenomenon and the performance of lead-acid battery, and then the battery sulfuric acid chemical repair treatment. Nowadays, lead-acid battery repair technology mainly uses switching power supply to optimize control methods as far as possible, such as artificial intelligence, fuzzy control algorithm, etc. Some enterprise experts have also developed related technical equipment for battery repair technology, which can repair batteries according to the remaining number of batteries. On the basis of understanding the application and development status of lead-acid battery, this paper makes clear the hardware and software design of online fault diagnosis and repair technology according to the working principle of lead-acid battery, and then takes valve-controlled sealed lead-acid battery as an example for experimental analysis, to clarify the technical advantages of the application system.[4-6]

2. Methods

2.1 Working principle of lead-acid battery

According to the analysis of the charge-discharge chemical equation shown below, in the discharge process, the positive electrode will change from lead dioxide to sulfuric acid, and after the reduction reaction, the chemical energy will be converted into electric energy to supply power to the load. The principle structure is shown in Figure 1 below:[7]

$$PbO_2 + 2H_2SO_4 + Pb \Leftrightarrow 2PbSO_4 + 2H_2O$$

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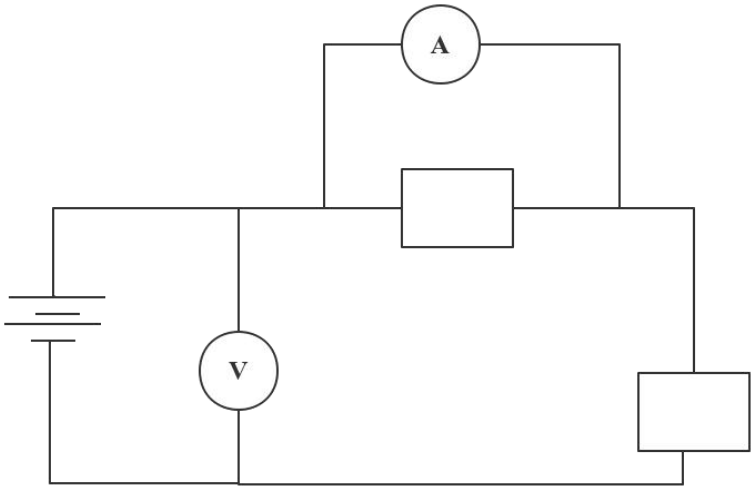

Figure 1. Schematic diagram of the discharge principle of lead-acid battery

The chemical equation of the reaction is as follows:

$$PbO_2 + 3H^+ + HSO_4^- + 2e \rightarrow PbSO_4 + 2H_2O$$

The negative electrode will change from spongiform lead to lead sulfate, and the overall oxidation reaction will occur, which will convert chemical energy into electric energy to power the load. The specific reaction formula is as follows:

$$Pb + HSO_4^- \rightarrow PbSO_4 + H^+ + 2e$$

The overall discharge reaction formula of lead-acid battery is as follows:

$$PbO_2 + 2HSO_4^- + 2H^+ + Pb \rightarrow 2PbSO_4 + 2H_2O$$

During the charging process, the positive electrode will change from lead sulfate to lead dioxide. After the oxidation reaction, the electric energy will be converted into chemical energy and stored in the shock plate. The charging reaction principle is shown in Figure 2 below:

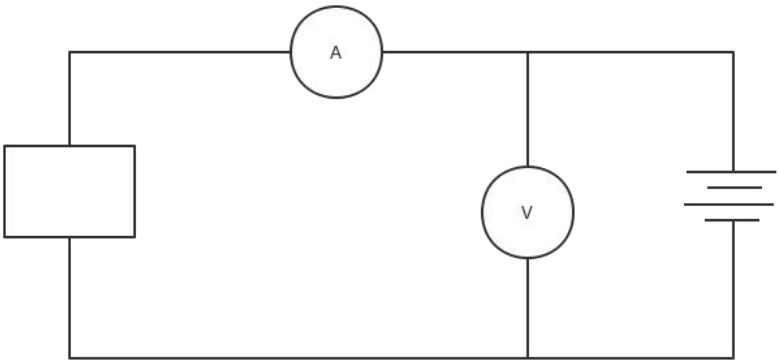

Figure 2. Schematic diagram of the charging principle of lead-acid battery

The corresponding chemical equation is as follows:

$$PbSO_4 + 2H_2O \rightarrow PbO_2 + 2HSO_4^- + 2H^+ + Pb$$

The negative electrode will change from lead sulfate to spongiform lead, and after a reduction reaction, the electrical energy will be converted into chemical energy, the specific reaction formula is as follows:

$$PbSO_4 + H^+ + 2e \rightarrow Pb + HSO_4^-$$

The overall reaction formula of lead-acid battery charging is as follows:

$$2PbSO_4 + 2H_2O \rightarrow PbO_2 + 2HSO_4^- + 2H^+ + Pb$$

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2.2 Online diagnosis and repair system

After understanding the fault types, fault phenomena, occurrence mechanism and repair mechanism of vulcanization fault of the current lead-acid battery, the structure of online diagnosis and repair system as shown in Figure 3 below is constructed, which includes multiple modules such as data acquisition, pulse repair, protection and temperature control. The purpose of this system is to carry out online fault detection of a single lead-acid battery. Repair of lead-acid storage batteries with vulcanization.[8-9]

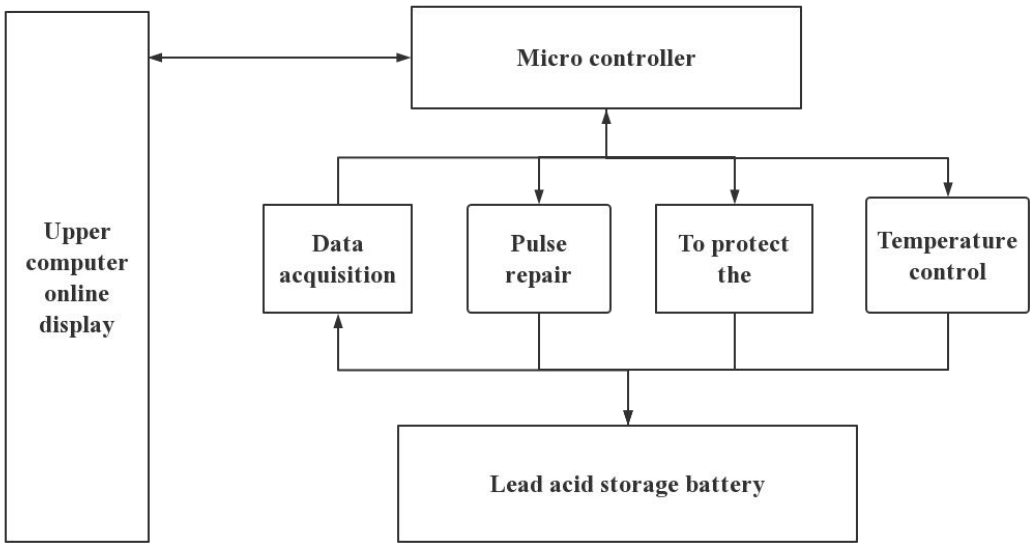

Figure 3 System structure diagram

From the perspective of practical application, the system functions are mainly divided into two aspects: on the one hand, the system to complete the online detection of common faults, pay attention to the combination of the host computer to show the relevant parameters, accurately judge the working state of the battery, and then judge and analyze the application type of various faults, system users can quickly develop solutions according to the alarm prompts; On the other hand, online repair of the battery after sulfated. The system should be combined with the early fault judgment, after curing the lead-acid battery pulse repair treatment, during the repair to real-time monitoring system current, voltage, temperature and other parameters change, in order to facilitate the scientific adjustment of the working state of the battery.

The software part is mainly for real-time detection and analysis of the charging state of the battery after the application of specific charging current. It is necessary to collect and process various battery parameters, compare the judgment conditions of various faults, analyze whether the battery has a fault, and make effective fault warning. After the problem of vulcanized battery is detected, the system will automatically switch to the positive and negative wheat charging repair program, carry out online repair treatment on the battery set, and present the changing trend of each parameter value in real time, so as to facilitate the staff to quickly grasp the state of battery repair. The specific design process is shown in Figure 4 below:

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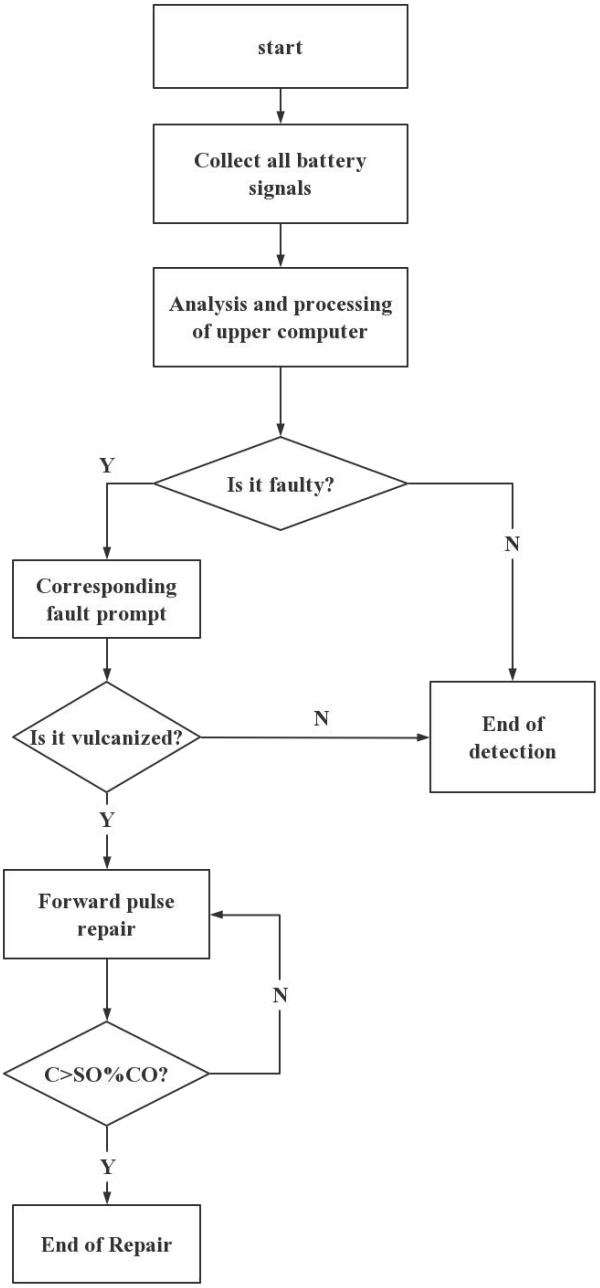

Figure 4 Design flow chart of system software

The initialization of this program represents the operation and setting of the initial environment of the software of the single chip microcomputer. The specific process is shown in Figure 5 below:

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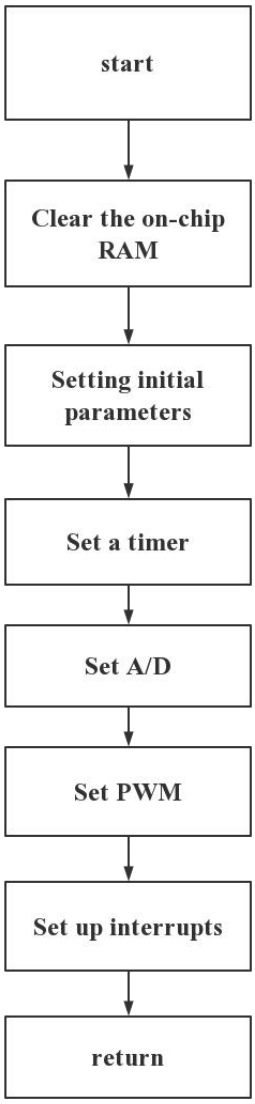

Figure 5. A flowchart for initializing the program

3. Result analysis

According to the modeling process shown in Figure 6 below, the application of online diagnosis and repair technology was studied, and the simulation results shown in Table 1 were obtained by using MATALAB software:

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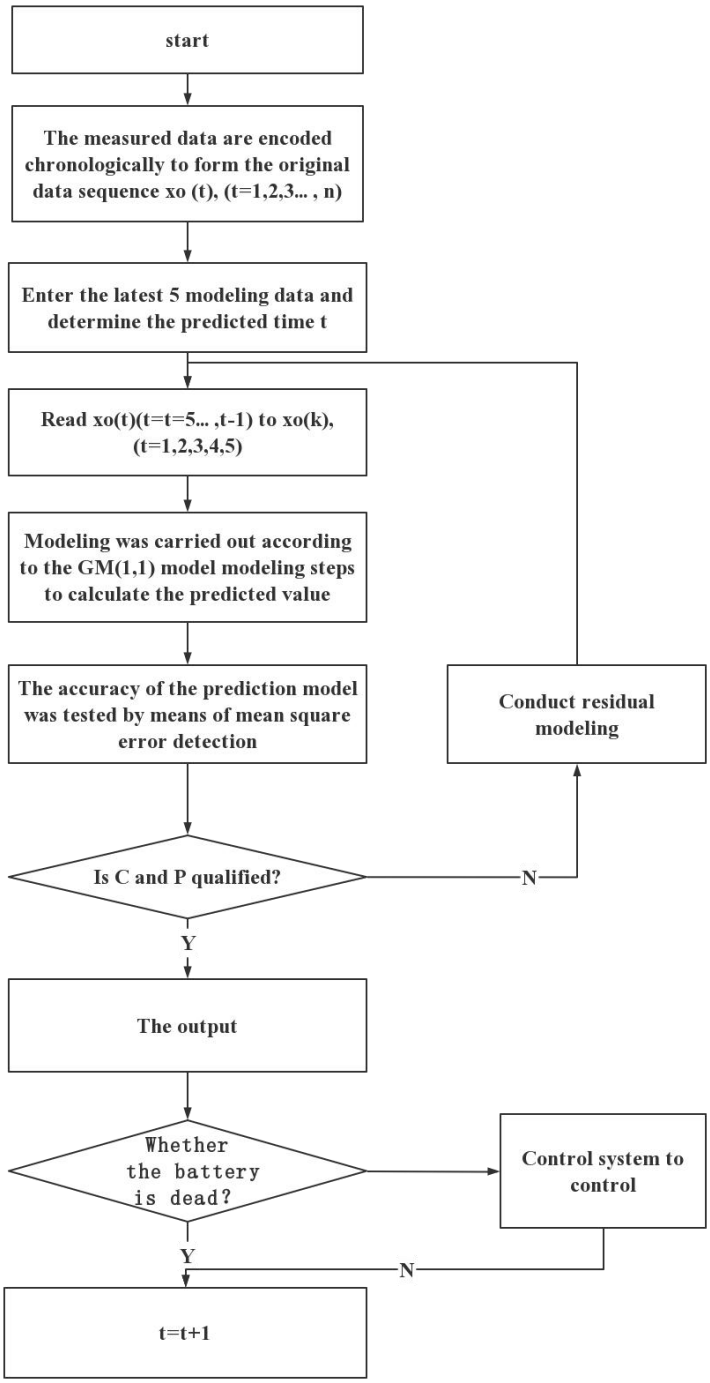

Figure 6 Modeling flow chart

Table 1 Software simulation results

Actual resistance value	Predicted resistance value	Relative error	Actual resistance value	Predicted resistance value	Relative error
0.021	0.021	0	0.0147	0.0252	0.011
0.02131	0.0209	0.019	0.02616	0.0258	0.014
0.02143	0.0211	0.015	0.02661	0.0263	0.012
0.02188	0.0216	0.013	0.017	0.0268	0.007
0.02218	0.0219	0.013	0.02740	0.0271	0.011
0.02267	0.0222	0.021	0.02763	0.0274	0.008
0.02318	0.0230	0.034	0.02772	0.0276	0.004
0.02353	0.0234	0.023	0.028131	0.0278	0.012

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In the experiment of this paper, the internal resistance change and charge state of the valve-controlled sealed lead-acid battery with grey system, neural network and fuzzy control are compared and analyzed, and then the subsequent change trend is accurately analyzed. In the gray system to study the kind of changes of battery, we can know that the dynamic information model can accurately predict the factors in the battery internal resistance, quickly find the fault area, the application only needs to carry out a simple mathematical calculation, the overall implementation is very easy; Using neural network to predict battery internal resistance, although can improve the prediction accuracy, but need a large number of training samples to learn, the overall learning speed is slow, the practical operation process is more complex, if can establish a rich battery internal resistance database, then can achieve the expected application effect; By using the fuzzy control method to predict the internal resistance of the battery, the actual prediction accuracy is relatively high, and the fault area can be quickly and accurately judged. After the off-line fuzzy control table is established, the system program runs very fast and can fully meet the requirements of real-time online work. However, due to the unique characteristics of fuzzy controller, certain static errors cannot be eliminated in the result of prediction. Therefore, the staff should scientifically adjust the proportional factors and quantitative factors, pay attention to the oscillation of the control system, continuously improve the membership function and refine the control rules, so as to reduce the static errors of the system. Through the comparative analysis of the final application results, it is found that both the grey system and fuzzy control methods have high prediction accuracy, which can help the system users quickly find the fault location, and can be really put into practice production. From the perspective of practical application, it is necessary to continue to summarize practical application experience and gradually improve the membership function and application rules of the fuzzy controller to predict the state of SOC by using the fuzzy control method, so as to improve the technical accuracy and better meet the changing trend of the battery and the state. It should be noted that if an off-line fuzzy control table is established, then the algorithm of fuzzy logic reasoning control will become a simple table lookup method, and the overall system program operation will become simpler and faster. It can be seen that the fuzzy control method can be used to predict the change of internal resistance and the state of charge of lead-acid battery after the on-line fault diagnosis and repair technology of lead-acid battery is defined.

Conclusion

To sum up, in the modern social economic and technological innovation and development, the application of lead-acid battery technology in the power industry is getting higher and higher, but the actual capacity shortage has caused serious safety problems. Therefore, in the practice of research scholars put forward the online diagnosis and repair technology system, to help the staff quickly find the fault area, timely develop effective solutions, In order to improve the safety and reliability of the power industry production, reduce unnecessary costs, increase the economic benefits of the power industry. At the same time, it is necessary to strengthen the training of professional and technical personnel, learn from the research results proposed by foreign scholars, and continue to optimize the failure, online diagnosis and repair system of lead-acid battery, so as to enhance the safety and effectiveness of battery sets.

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