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Short communication

Vibration test methods and their experimental research on the performance of the lead-acid battery☆

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HIGHLIGHTS

- Collects the real-time state parameters for calculation, analysis and judgment.
- Self-adapts to the ideal target values.
- Load compensation technology.
- A number of lead-acid battery voltage self-adaption and accomplished a variety of high-precise tests.

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ABSTRACT

As we know, Lead-acid battery is difficult to balance many factors such as the accuracy and the on-line testing requirement. The detecting system, as stated in this article, is based on the vibration test procedure, dynamically following the electrochemical process of the Lead-acid Battery, and collects the real-time state parameters for calculation, analysis and judgment. It also quantizes precisely the degradation and chargeability of the battery and therefore self-adapts to the ideal target values. During the test, it has not charged and discharged large current to the lead-acid battery, it only plus a smaller and shorter time of impulse voltage signal on both ends of lead-acid battery, so the battery measured is damage free, and the system energy consumption is small; Using the load compensation technology, it has solved the influence of load on the test results. What's more, the load characteristics are improved at the same time, it realized the online detection. The vibration detection is based on the adaptive fuzzy inference model which has taken various factors into account, concerning the choices of input aspects which may influence the output value. It realized a number of Lead-acid Battery voltage self-adaption and accomplished a variety of high-precise tests.

1. Introduction

In 1859, Plante invented the lead-acid battery which has many advantages like rich material source, high power, stable performance, safety, technology and mature manufacturing technology, high electromotive force and good charge and discharge reversible electrochemical principle [1]. It also has a wide temperature range, clearly electrochemical principles, high rate renewable resources recovery and the power performance and practical application efficiency are high but technique of production is easy to grasp and low in price [2]. At present, it has become one of the maturest technical batteries. Lead-acid batteries, however, is a complex electrochemical system, its performance status, such as capacity, failure mode and aging degree were affected by the lead-acid battery's pole plate corrosion, sulfation, electrolyte dry and hot out-of-control. Therefore, the fast accurate examination to lead-acid battery performance condition is very difficult [3]. Compared with the rapid development of the lead acid battery, the research and development of the performance test is lagging way behind, whether early method for measuring the voltage value or recent widely applied methods, the discharge method and the conductance measurement method are all have obvious deficiencies [4].

Voltage measurement method, due to the fact that under the lead-acid battery floating state, whether the performance is good or

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bad, there are no obvious differences nor the reliable regularity to follow, thus this technology were soon be eliminated [5].

The check and discharge test, namely the lead-acid battery at a constant current or voltage of load discharge, checks and calculates the real capacity through the discharge parameters and the expert data [6]. The advantage of this method lies in the accurate and reliable test that can accurately judge whether battery is failure or not. Nowadays it is still the most effective and reliable way to test the state of battery performance [7]. To some extent, checking the discharge of the battery can also do maintenance to the battery [8]. But the downsides of this method are fairly obvious, which can be showed mainly in the following aspects: it requests the battery to work off the system and can't be monitored online. What's more, the operating time is too long and accompanied by high risk, besides, the tested battery must be out of work status, the energy stored in the battery are consumed in the form of heat energy during the offline measurement, then, at the same time the tedious process causes the waste of energy [9]. The conditions are complicated as to ensure the utility would not be affected by the test, so it generally requires a spare battery, otherwise it will increase the risks of system power failure. Battery internal chemical reaction is irreversible, frequent deep discharge will cause the lead sulfate precipitation, result in the plate sulphation and eventually make its capacity drop, shorten its life. The detection method discharge the energy to the entire group of work in series battery, therefore it can only measure the capacity for the whole and not measure the battery capacity for each session, while each of the monomer battery capacity is not the same. The standard to be calculated in the process of testing would become the minimum capacity, at the same time, higher capacity battery is not completely discharged which also can affect the accuracy of the test [10]. So the check the discharge test is only applicable to the regular maintenance of storage battery, it cannot meet the daily maintenance and online monitoring [11].

Conductivity measurement, refers to by monomer battery conductance or resistance within the size to measurement and calculation that determine the performance of the lead-acid battery. But a lot of experimental data show that only after the battery capacity decreased to 50% [12], its conductivity or the resistance value should have more obvious changes. So, degradation of high measure battery is suitable for using this method, while this method is not for degradation of low battery to provide accurate data for reference [13]. Therefore the method of testing conductance or calculated value can only provide valuable judgment basis in a certain range of battery performance, and it has no enough energy to accurately calculate all state performance of the lead-acid battery.

All in all, currently, the methods of testing lead-acid battery performance is in low accuracy, with high measurement requirement, narrow range and long measurement cycle; what's more, its risk is big, and lowers the quality of the battery, and can't be monitored online as well [14]. In order to ensure the normal work of the power system on traction, communications and many other areas, it needs to increase the lead-acid battery to a significant level on maintenance and inspection [15]. Therefore, at present, to explore a rapid, accurate, reliable and safe test method has become the enthusiasm on research topics.

2. Test method of vibration on lead-acid battery performance

2.1. Loop of the detection

Fig. 1 shows the lead-acid battery performance of the on-line detection in main loop. In the battery equivalent model, R_{01}, R_{02} were positive and negative electrode polarization resistance, for R_{03}

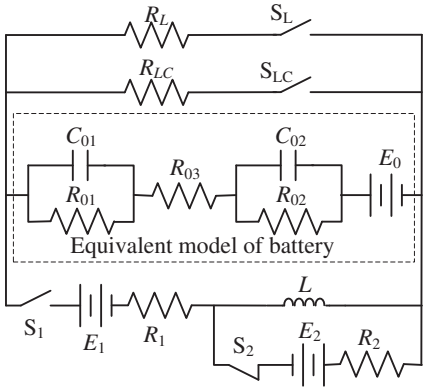

Fig. 1. The main loop of the lead-acid battery performance testing.

batteries is ohm resistor, C_{01}, C_{02} are polarization capacitance of the positive and negative electrodes, E_0 works for the positive and negative electrode voltage; E_1, R_1 and E_2, R_2 are two numerical control dc voltage source. L is a standard inductor. S_1, S_2 and S_{LC} are electric control switch; R_{LC} is automatic compensation resistor. R_L is load and S_L is manual control switch.

During detection, the first thing is to get the lead-acid accumulator electrode voltage E_0 to match numerical control power supply E_1 ($E_1 = E_0$); Depending on the battery under test, adjust the calibration resistor of R_1 to ensure the high quality on damping oscillation; E_2 and R_2 must be guaranteed to obtain a suitable current on L as the impact test power source; And disconnect the S_2 and close S_1. Then both ends of the battery will be plus a very small damping oscillation superimposed on the E_0. The oscillating voltage can comprehensive characterize battery's characteristic parameters (such as ohm resistor R_{03}), then it can obtain and analyze the performance of the battery. Since the oscillating voltage attenuation is small enough to maintain a short time, so it does not affect load work and can realize on-line measurement.

To overcome the effects of load variation on the detection accuracy, across the load we paralleled with a program-controlled variable resistor R_{LC}, when the trigger switch is detected by the S_{LC} we can realize intelligent compensation. Fig. 2 shows the relationship between load current i_{RL}, compensation resistor current i_{RLC} and the output current i_R, under normal circumstances, when the load changes, the output current of the battery can be kept constantly by compensating i_R. Therefore, compensation resistor R_L eliminates the effect of changes in the load on the battery performance test accuracy, compensating output current i_R can be

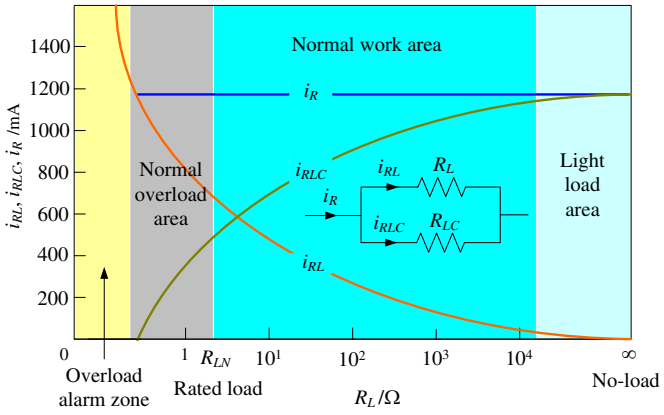

Fig. 2. Relationship between the load current and the compensation current.