Research on Reliability of Chemical Power Supply for Lead-Acid Batteries Based on Wide Ambient Temperature Range

Xinxin Fan*, Shizhou She, Xiuguo Chen, Jianbin Wang
State Grid Tongling Electric Power Supply Company, Tongling 244000, China
*Corresponding author e-mail:Fanxxok@126.com

Abstract. This article describes the principles of the use and maintenance of lead-acid battery chemical power supplies for power systems based on a wide range of ambient temperature range, combined with the actual requirements of power systems for the monitoring and maintenance of lead-acid battery chemical power supplies. The power supply reliability detection system uses sensor technology and photoelectric coupling technology to collect lead-acid battery data, and determines the operating state of the battery pack by monitoring the battery pack's single voltage, total voltage, charge and discharge current, and temperature, and innovates to achieve online balance. The voltage between the battery and the battery is used to effectively maintain the operation of the battery pack, so that the operating state of the battery pack is easy to observe to minimize the possibility of accidents in the system, and the battery pack is well maintained, thereby increasing the service life of the battery pack. To achieve the purpose of saving resources and environmental protection.

1. Introduction
Lead-acid batteries are also called lead-acid water batteries. The electrodes are made of lead and its oxides. The electrolyte is an aqueous solution of sulfuric acid. It has the advantages of stable voltage and low price. It has been widely used in our military equipment. However, after-sales service statistics show that about 30% of the batteries have problems such as serious power feeding, inability to activate, short discharge time, and liquid leakage due to improper use and maintenance, causing the batteries to be scrapped in advance. Therefore, in the daily use and maintenance process, we must pay attention to ways and methods to make it play a real effect, otherwise it will greatly shorten the service life of lead-acid batteries. In the power system, as an important component to protect the safe operation of the unit, how to increase the life of lead-acid power storage during use has important practical significance for ensuring the reliable operation of the equipment and improving the economic efficiency of production [1].

2. Working principle of lead-acid battery for wind turbine
Valve-regulated sealed lead-acid (VRLA) batteries have been popularized in China for more than ten years. Due to their small size, light weight, small self-discharge, long life, saving investment, easy installation, safe and reliable, easy to use, less It maintains excellent characteristics such as no acid mist, no corrosion to the environment, no pollution, etc., and can realize the modern management
mode of unattended and centralized computer monitoring, so it is widely used in communication stations [2].

When the VRLA battery releases chemical energy, the porous active material PbO₂ and the dilute sulfuric acid H₂SO₄ Electrolyte form an oxidized half-cell, called an oxidized electrode (reduction reaction). In the battery, velvet lead (sponge lead) and dilute sulfuric acid H₂SO₄ electrolyte constitute a reducing half-cell, called a reducing electrode (for oxidation reaction). As a result of the battery reaction, both the positive and negative active materials become PbSO₄. Part of the sulfuric acid electrolyte in the battery will become water H₂O. Due to the large volume of PbSO₄ particles, the small holes in PbO₂ and velvet lead are gradually blocked. When most of the small holes are blocked, the battery cannot continue the electrochemical reaction, which is called the end of discharge. Lead-acid batteries are generally composed of positive and negative plates, electrolytes, separators, electrolytic cells, connecting strips, exhaust plugs, and terminals. The conversion equation between charge and discharge is as follows:

\[ Pb + HSO₄ \rightarrow PbSO₄ + H^+ + 2e^- \]  \hspace{1cm} (1)

\[ PbO₂ + 3H^+ + HSO₄ + 2e^- \rightarrow PbSO₄ + 2H₂O \]  \hspace{1cm} (2)

The battery reaction formula of the battery balance state can be obtained:

\[ PbO₂ + 2H₂SO₄ + Pb \rightarrow PbSO₄ + 2H₂O + PbSO₄ \]  \hspace{1cm} (3)

When the battery is in an open circuit state, Pb on the negative electrode has a tendency to release electrons to become Pb²⁺ ions and interact with the electrolyte to form PbSO₄, while Pb²⁺ ions in PbSO₄ have a tendency to adsorb electrons on the electrode surface. Figure 1 shows the working principle of a lead-acid battery.

![Figure 1. Working principle of lead-acid battery](image)

3. Maintenance of lead-acid batteries
The quality of battery maintenance is an important aspect to ensure the normal operation of valve-regulated batteries. If the maintenance quality is high, the valve-regulated battery can maximize the
efficiency and extend the service life. Therefore, to maintain the valve-regulated battery, it is necessary to understand the relationship and problems in the following aspects [3].

3.1. Relationship between temperature and capacity
The general standard of VRLA batteries (valve-regulated batteries) is: when the temperature is 25 °C, the capacity of the battery is 100%; when it is above 25 °C, the capacity of the battery will be reduced by half for every 10 °C rise; and when it is below 25 °C, The relationship between temperature and capacity is shown in Table 1.

Table 1. The relationship between the temperature and the current capacity of the battery under 25 °C

| Temperature / °C | Current capacity /% |
|-----------------|---------------------|
| 25              | 100                 |
| 20              | 95                  |
| 15              | 90                  |
| 10              | 84                  |
| 5               | 76                  |
| 0               | 71                  |

It is not difficult to see from Table 1 that the capacity of the valve-regulated battery changes with temperature. The maintenance personnel must carefully adjust the discharge current of the battery according to the actual temperature change, and at the same time control the battery temperature It is kept within 22 °C to 25 °C.

3.2. Relationship between charging, discharging, life and capacity
The maintenance of valve-regulated lead-acid batteries requires the establishment and implementation of an accurate charging system in order to achieve the optimal performance and longest service life of the battery. A large number of domestic and foreign studies have shown that the charging method determines the use of the battery Lifetime, some batteries are not so bad as to be damaged by improper charging. At this convenience, many domestic battery manufacturers and scientific research institutes or schools have done similar experiments. For example, there is a unit that divides the battery into two groups for experiments. One group uses the ordinary constant voltage current limiting method for full capacity life test, and the other group uses the stage constant current charging method to control the charging capacity and uses it in the later stage of charging. The capacity cycle life test is conducted in a short-term medium current impact mode. As a result, the two sets of storage batteries have very different cycle lives due to the different charging methods, and the storage battery using the phase constant current charging method has a longer cycle life. It can be seen that the current constant-voltage current-limiting charging method widely used, especially in the later stage of charging, is quite regrettable. Because the rectifier equipment currently used, especially the switching power supply does not have a constant current characteristic, there are still certain difficulties in using the second charging method, so further exploration of this problem is needed. As we all know, the discharge current of different rates will make the battery have different capacities, as shown in Table 2.

Table 2. Relationship between discharge and capacity

| Discharge rate / h | Percentage of battery rated capacity /% | Discharge current multiple | Termination voltage / V |
|-------------------|------------------------------------------|---------------------------|------------------------|
| 0.5               | 45                                       | 7                         | 1.7                    |
| 1                 | 55                                       | 5.14                      | 1.75                   |
| 3                 | 75                                       | 2.5                       | 1.8                    |
| 10                | 100                                      | 1.0                       | 1.8                    |
3.3. Thermal runaway
Because the valve-regulated battery uses a poor liquid design, the electrolyte poured into the battery is adsorbed on the glass fibre board. When the charging current increases, the gas needs to be released through the safety valve, which causes the battery to lose water and increase the internal resistance. Capacity decay and generate a lot of heat during charging and discharging. If the heat is too late to diffuse and the temperature increases sharply, it will form a thermal runaway. The cause of thermal runaway is not to reduce the float charge pressure in time, the safety valve is not strict or the valve opening pressure is too low, etc. If the thermal runaway is severely punished, if it is discharged, it may cause a sudden battery voltage drop and battery case the temperature rises to 70 °C- 80 °C, so the issue of thermal runaway must be highly valued.

4. Research on battery reliability in a wide temperature range
The ABM battery management system is a three-stage intelligent battery management design scheme monitored by a microprocessor. It is a short-term fast uniform charging and charging y constant voltage float charging and charging a long time small current discharge battery management system. It uses a gap-type periodic charging scheme, dividing each charging cycle into three time periods [4].

(1) Balance charging stage. As shown in Figure 2, the UPS rectifier first charges / equalizes the battery to 0, that is, the charging voltage of the battery is increased to the average charging voltage. In order to prevent the battery from having the disadvantage of over-current 0 charging due to the increase of the charging voltage, the charging current is limited to the range of its safe current value. This charging method is also called / over-charging 0. When the battery voltage reaches 2.25V / unit, a 48h timer is started to enter the floating charge stage.

![Figure 2. Schematic diagram of ABM charging method](image)

(2) Floating charge stage. In the following 48h, the battery is charged with / constant voltage and floating charge 0, and the charging voltage is controlled not to exceed 2.28V / cell. During this period, the battery pack capacity is charged from 90% to 100% capacity by a small current float charge flow.

(3) Sleep stage. After 48h of float charging, the UPS will turn off the charging of the battery and enter the sleep state. With the self-discharge of the battery, the battery voltage will slowly decrease., Restart the charging cycle [5].

4.1. System design
The realization of this system is controlled by the single chip microcomputer to control the duration of the three charging stages and the conversion of each stage. The control program flow of charging management is shown in Figure 3.
Figure 3. Intelligent battery charging platform design

At the beginning of each charging cycle, the ADC (Analog-to-Digital Converter) samples the battery voltage first. If it is less than 10.5 V, the undervoltage alarm and inverter are not allowed, and the two charge control ports of the microcontroller are set to 1 at the same time, charging. The device overcharges the battery with a voltage of about 14.5 V for 6 h, charges the battery to 90% of the capacity, and then float charges for 48 h, charges the battery from 90% to 100%, and charges the two charging control ports of the microcontroller. At the same time, it is cleared to 0, so that the battery is in a self-leakage micro-current discharge state; if the battery voltage is sampled before charging and found to be higher than 10.5 V, the overcharge state is skipped, and the two charge control ports of the single-chip microcomputer are set to 1 and cleared, the charger floats the battery with a voltage of about 13.5 V for 42 h, and then puts the battery in a self-leakage micro-current discharge state. Check the battery voltage again, and restart a charging cycle, so that the cycle is repeated. As long as it is in the state of mains power, it will be charged in this cycle. When powered by the inverter, the microcontroller controls the charger not to charge. Once the inverter is over, the battery voltage is immediately sampled and a new charging cycle begins.

4.2. Functional analysis
Measurement function: can measure and record the battery temperature, total voltage, total current, each cell voltage and other conditions at any time; setting function: can set the number of monitoring batteries, the total battery and the upper limit of the cell voltage according to the specific environment and lower limit value; abnormal alarm: when the battery pack voltage and temperature are abnormal, an alarm will be issued; online voltage equalization function: balancing the voltage of individual batteries in the battery pack by charging and discharging the single cells online. The general battery pack monitoring system monitors the entire battery pack, that is, the terminal voltage and terminal current of the battery packs used in series. You can only tell if the entire battery pack is normal. The battery intelligent monitoring system studied this time can monitor each battery in the battery pack used in series. It can detect abnormalities of individual batteries as early as possible, discover problems in time before they affect the entire battery pack, and prevent the failure of the battery to cause irreparable major accidents. The system can set the number of batteries and the upper and lower voltage limits according to the specific application environment, which increases the versatility and
flexibility of the entire system, so that the system can be widely used in fields that require different voltage values [6].

5. Conclusion
In recent years, lead-acid battery technology has been continuously developed, especially the maintenance-free and sealed lead-acid battery technology has made tremendous progress, making lead-acid batteries not only widely used in traditional fields such as military defines, transportation, but also by a large number of It is used in many fields such as photovoltaic power generation, wind power generation and communication power supply. However, the use and maintenance of lead-acid batteries is still a blind spot for many users, and needs to be further popularized. Only when properly used and maintained can the true effect of lead-acid batteries be exerted.

References
[1] Han, M., Zhao, W., Cheng, Y., Ji, X., & Xu, Y. Concept design of water hydraulic circuit for manipulator of cfetr blanket maintenance. Journal of Fusion Energy, 34(4) (2015) 765-768.
[2] Yu, Y., Chang, Z., Qi, Y., Xue, X., & Zhao, J. Study of a new hydraulic pumping unit based on the offshore platform. Energy ence and Engineering, 4(5) (2016) 352-360.
[3] Senthilkumar, R., & Tamilselvan, G. M. Design of a hybrid accumulator architecture for harvesting and storing of power in wsn using an adaptive power organizing algorithm. Journal of circuits, systems and computers, 28(8) (2019) 1950130.1-1950130.30.
[4] Zhao, D., Ge, W., Mo, X., Liu, B., & Dong, D. Design of a new hydraulic accumulator for transient large flow compensation. Energies, 12(16) (2019) 3104.
[5] Jian, H. L., Fitrian, I., Amri, M. S., Hafiz, I. M., & Irfan, B. New variable stiffness damper with magnetorheological-based accumulator control. Key Engineering Materials, 775(4) (2018) 204-209.
[6] Ochkov, V. F., Stepanova, T. A., Katenev, G. M., Tumanovskii, V. A., & Borisova, P. N. Study of cycling air-cooling system with a cold accumulator for micro gas-turbine installations. Thermal engineering, 65(5) (2018) 300-303.