The Battery Charging Technology of the Coal Mine Substation —A Review

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Abstract. Battery is still widely used in coal mine substation. Battery performance not only has direct contacts with its own quality factor, but also is closely linked with the battery charging methods. This article starting from the main factors influencing the performance of lead-acid battery, discussed the characteristics of all kinds of charging technology and its application in the field of lead-acid batteries.

Introduction

Coal mine substation DC system is mainly responsible for signal control, safety protection, emergency lighting and other functions, its reliability directly affects the security and stability of substation equipment operation. Battery as backup power plays an important role in the DC system. At present, with the popularization and application of the valve regulated lead-acid batteries, the new question how to maintain these batteries to improve its performance and service life is always faced by associated personnel.

Theory about Battery Charging

In the mid-1960s, Joseph A. Mas carried out a large number of tests about the charging process of batteries, and finally put forward the lowest gassing rate as the premise, the battery can accept charging curve, as shown in Figure 1. Experiments show that if the charging current is changed according to the curve, it can greatly shorten the charging time, and has no effect on the capacity and the life of the battery. In principle, this curve is called the optimal charge curve, thus laying the research direction of the fast charging method.

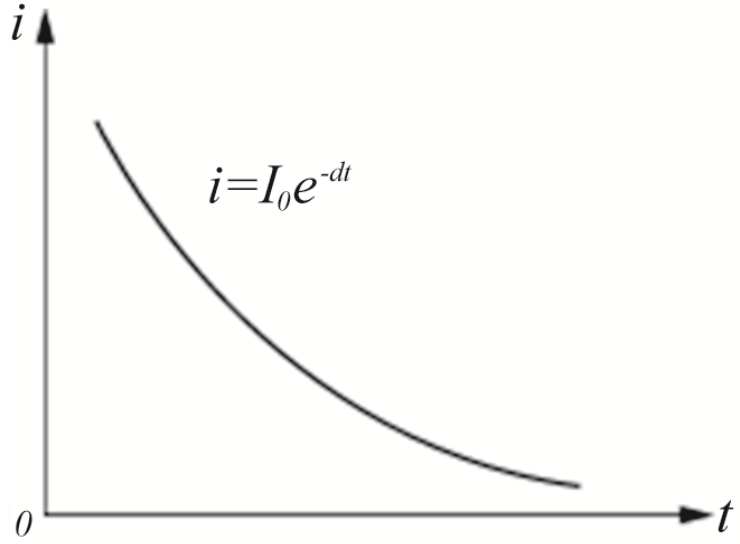

Fig.1. Optimal Charge Curve

As it is shown in Figure 1, it's clear that the initial charge current is very large, but the attenuation is very fast. The main reason is that the polarization of the charging process. In the

sealed battery charging process, the internal generation of oxygen and hydrogen, when the oxygen cannot be absorbed in time, they are packed in the positive plate (positive plate), so that the internal pressure of the battery, battery temperature rise, while reducing the area of the positive plate, the performance of the internal resistance increased, polarization phenomenon.

Factors affecting the performance of lead-acid batteries

The main factors affecting the performance of traditional lead-acid batteries are: positive plate expansion, dehydration, acid stratification, charging less. These defects were resolved in the following ways: increase the creep strength of the positive plate using Pb-Sb alloy, add water, extend the charging time or gassing stirred solution of sulfuric acid intentionally, fully charge the batteries regularly to maintain the battery capacity.

Positive plate susceptible to corrosion is one of the main reason for poor performance of lead-acid batteries. The speed of this recession process is affected by grid composition, alloy microstructure, plate potential, electrolyte composition and temperature. In recent years, with Pb-Sn alloy instead of Pb-Ca alloy, widely used in VRLA batteries, weakening the corrosive effect of the positive electrode plate, while, using Pb-Ca-Sn alloy as VRLA batteries positive plate material, further weakening the corrosive effect:

It is worth noting that the performance of the batteries not only have a direct relationship with its own quality, but also influenced by charging method. For VRLA batteries, the main factors affecting their life, include the charge voltage, charge current, depth of discharge, discharge times and frequency and so on. Many batteries' failure of the charge process is not due to insufficient charge but overcharge. Figure 2 shows that overcharging, especially severe overcharging, can make the active material of positive plate loose, fall off, soften and make the positive grid corrode, what's more, VRLA batteries are also possible to produce thermal runaway and fail soon. However, in the case of undercharging, PbSO4 in plates will form coarse crystals, which is not easy to be restored, it will seriously shorten the battery life. Therefore, using a more complete battery charging method can truly enhance the lifecycle of the battery.

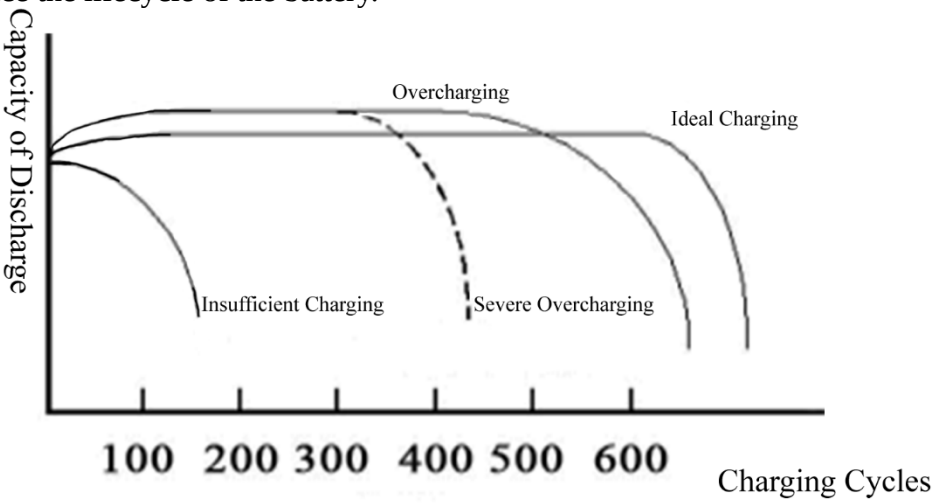

Fig.1. Charging Cycles and Capacity Curves under Different Charging Conditions of VRLA Battery

Charging technology of lead-acid batteries

1.Traditional Charging Method

Battery charging method is generally divided into constant current charging and constant voltage charging two kinds. Constant current charging current is maintained at a constant value. The method can achieve rapid charging but it is easy to charge. The constant voltage charging is in charge process. The charging voltage is kept constant and the voltage level is generally controlled in equal or slightly lower than in the storage battery.

Floating method is a continuous long time constant voltage charging method to ensure the battery and the battery is fully charged, and the charge current will shorten battery life, which is mainly used to the standby power supply (UPS). The trickle charge is making the battery continuous small current charging in the fully charged state approximation, also known as the "maintenance charge". With the method of charging time is long, so it is rarely used alone, but in combination with other charging method.

2.Fast Charging Method

In recent years, fast charging technology has made rapid development, maximizing the speed of batteries' chemical reaction, thereby shortening the time that batteries reach the full charge state, at same time, and minimizing the polarization phenomenon of batteries' positive and negative plates. However, fast charging method using high input current limit, will injury the performance and lifetime of batteries.

A more traditional Fast charging method is the pulse current charging method. There are two ways to control it: one is constant cycles while reduces the amplitude, the other is constant amplitude while decreases cycles. Its ultimate aim is to reduce the amount of the overcharge and gassing, with the charge termination approaches, each pulse passing a decreasing input power to the batteries. During the time pulse closed the batteries can be set to completely stop charging, discharging, or a combination of these two ways. The aim is to reduce or eliminate the impact of polarization in this period, and allow sufficient time for the occurrence of battery heat dissipation and solution diffusion, thereby enhancing the charging efficiency and charging with higher end current.

3.Pulse Charging Method

The pulse charging method not only follows the inherent charge acceptance rate of the battery, but also can improve the acceptance rate of the battery charge, so as to break the limitation of the battery charge acceptance curve, which is also the new development of battery charging theory.

The pulse charging mode is first used to charge the battery, which is to allow the battery to stop for a period of time (shown in Figure 2). Pulse charging the battery is fully charged, and intermittent period then let the battery produced by chemical reaction of oxygen and hydrogen has time re combined and absorbed, concentration polarization and omics polarization naturally eliminated, thus effectively reduce battery internal pressure and guarantee the next round of constant current charging can be carried out smoothly, the battery can absorb more energy. Intermittent pulse to make the battery has a more sufficient reaction time, reducing the gas evolution, improve the battery's charge current acceptance rate.

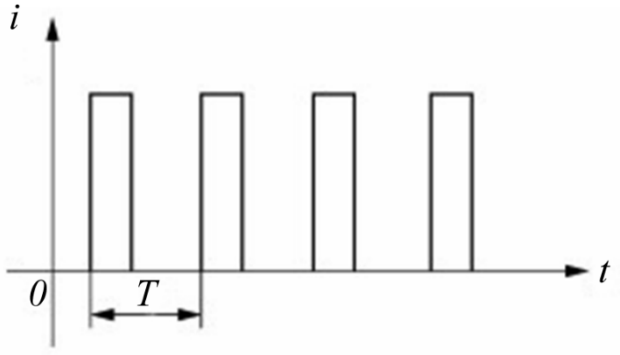

Fig.1. Curve of Pulse Charging

4.Smart Charging Method

As the traditional charging method has many defects. For instance, can not follow particular batteries' intrinsic charge acceptance or make a different operating mode for different work, long charging cycles, large plate damage and big energy losses. So there are many researchers conducted research of smart charging method application. During the charging process smart charging method will collect voltage, current, temperature, pressure and other signals of secondary cell in real time, applying smart control algorithm such as fuzzy control theory to optimize control, to make the charge according to the maximum charging acceptance of specific batteries and achieve the smart

charging for the batteries have variety of voltage levels and different kind of models. Meanwhile, the smart charging technology can set functions: system self-diagnosis, fault location, real-time processing, and interactive windows and so on. Smart charging method is efficient. It can maintain a good match relationship between the charging current and the acceptable charging current from beginning to end and let the charging process always in the best condition.

At the same time, the smart charging control system can also monitor the battery capacity. Using a smart optimization algorithm, which support vector regression algorithm in prediction of VRLA battery capacity, the prediction error is less than 8% lower than the advanced test instrument of battery capacity existing in domestic. Actual capacity of lead-acid batteries affected by temperature, cycle times, time of use, depth of discharge and many other factors, it is difficult to measure fast online accurately. At present, there are two categories of battery capacity prediction technology: One is based on the internal battery working principle to find the relationship between the capacity of the battery and external parameters; the other is based on the system identification and parameter estimation modeling sometimes called smart algorithms. After summarizing the current prediction methods of remaining battery capacity at home and abroad, we can know the trend is the use of combining a variety of smart algorithms with new theories.

From the foregoing, smart charging method has great advantages in terms of charging efficiency and equalization effect, but there still has a problem needed to solve, the smart charger taking smart charging technology costs higher and more expensive.

Conclusion

With the development of new secondary battery and the new energy sources, emerged many new lead-acid batteries like gelled electrolyte batteries and grid of copper batteries, and the lead-acid batteries have also been applied to some new areas, such as starting low temperature and high current, and using with super capacitor complementary and so on. Therefore, improving cycle life and performance of batteries, charging technology is also facing new and deeper challenges.

Acknowledgement

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