Summary of Lead-acid Battery Management System

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Abstract. Lead-acid batteries are widely used in all walks of life because of their excellent characteristics, but they are also facing problems such as the difficulty of estimating electricity and the difficulty of balancing batteries. Their large-scale application is partly due to the powerful battery management system. This paper reviews the current application of parameter detection technology in lead-acid battery management system and the characteristics of typical battery management systems for different types of lead-acid batteries, and looks forward to the development trend of lead-acid battery monitoring system.

Keywords: Parameter detection, Lead acid battery, Battery Management System.

1. Introduction
Since its inception, lead-acid batteries have been developed for more than 100 years. Compared with lithium-ion battery and nickel-cadmium battery, lead-acid battery have good high-low temperature tolerance and high-current discharge performance, low-cost electrode materials and loose The assembly environment, mature charging mechanism and high security have an absolute advantage in the communications and UPS power industry, the automotive industry, industrial and mining enterprises and weapon systems. However, as a rechargeable battery, lead-acid batteries are also faced with problems such as difficulty in estimating battery power, short life, and difficulty in balancing battery packs. In order to achieve real-time monitoring of battery status, prevent overcharging and over-discharging of batteries, and prolong battery life. In order to improve the utilization rate of the battery, the battery management system has become the focus of technology research and development in the battery industry. This paper mainly introduces the battery parameter detection technology currently applied in battery management system and the battery management system characteristics, existing problems and prospects of lead-acid batteries for different purposes.

2. Basic structure of battery management system
The battery management system is a device that integrates integrated electronic measurement technology, communication technology and computer technology to realize online monitoring and management of the battery system. The basic principle is that the data acquisition circuit directly or indirectly measures the voltage, current, temperature and other parameters of the battery unit. The control unit (MCU, microcomputer) uses the corresponding algorithm to cooperate with the collected external parameters to evaluate the state of charge of the battery and the state of health SOH. And so as to control the on and off of the external circuit of the battery pack to achieve equalization of the
individual cells of the battery pack. The main functions are real-time monitoring of battery status and battery equalization. The auxiliary functions include charging control, thermal management, data communication, etc. The battery management system has different emphasis in different occasions. All functions are realized by real-time detection of external parameters of the battery.

3. External parameter detection method

3.1. Voltage detection

Voltage is the most basic parameter of the battery. There are many measurement methods. The simplest is common mode measurement. The common mode measurement is relative to the same reference point, and the voltage of each point is measured by proportional attenuation of the precision resistor, and then the voltage of each single cell is obtained by sequentially subtracting. The circuit of the method is simple, but is susceptible to the drift voltage of the resistance of the large resistance, and is only suitable for occasions where the series battery is small and the precision is not high.

Another method is the differential amplification and direct sampling method using an operational amplifier proposed in [1]. The circuit has low cost and good linearity. However, the accuracy is greatly affected by the resistance matching, and the leakage current is large, which affects the consistency of the battery pack. Similar to the direct measurement method proposed in [2] combined with an operational amplifier and a MOSFET. The method utilizes a photoelectric relay to eliminate the influence of leakage current, and has the advantages of simple circuit structure and good linearity of the direct sampling method. However, when measuring a single-cell battery with a 6 V or 12 V lead-acid battery, the utilization efficiency of the integrated op amp is greatly reduced. Another common method is to use an isolated operational amplifier [3] for each cell. This structure converts the battery voltage to a uniform reference ground voltage, and avoids drift errors and leakage currents caused by resistor divider. The problem. However, excessive use of an isolation amplifier results in a large circuit and high cost, which is suitable for applications where measurement accuracy is high and leakage current and cost are not considered.

When the number of batteries in series is large and the accuracy is high, only differential mode measurement can be used. Differential mode measurement is to directly measure each single cell through a switching circuit for direct measurement. The measurement strategy is usually a multi-channel voltage loop sampling method [4]. Simply put, the dynamic loading circuit is used to time-separate the voltages of the individual cells in the battery pack. Some people use a mechanical relay array to select the voltage to be measured [5]. The relay control logic is complex and the measurement speed is affected by the mechanical relay switching time, which requires a large driving current. Then some people use analog switch chips instead of mechanical relays. Although the analog chip has obvious advantages in switching speed and drive current compared with mechanical relays, it has insufficient on-resistance and small withstand voltage, and the accuracy error is large. At present, the application is more than photoelectric relays. Photoelectric relays have the advantages of high withstand voltage, fast switching speed, small on-resistance and small drive current, which are widely used in engineering.

A loop that cannot be bypassed in the voltage measurement circuit of the signal conditioning circuit is used to remove the common mode and linearly transform the signal voltage collected by the pre-stage circuit, so as to meet the requirements of the sampling circuit. Many combinations of isolation amplifiers and integrated operational amplifier linear conversion circuits are used. Some people also use integrated operational amplifiers to build anti-common mode circuits [6][7][8] to overcome the high frequency difference and delay of isolation amplifiers. All of the above are the case of only one microprocessor in the voltage acquisition system. In current engineering applications, each battery is usually equipped with a separate microprocessor and voltage detection circuit. The single voltage information is transmitted through the CAN bus protocol, TCP/IP. The protocol or other protocol is transmitted to the host computer, and the communication between the systems is avoided to avoid the problems of multiple relays and complicated control in differential mode measurement.
3.2. Current Detection

The dc current acquisition circuit is the same as the voltage, but the current cannot be directly measured. In industrial production and scientific research experiments, the main methods used are precision resistance method, shunt method and current sensor method. The current sensor includes hall effect principle, magnetic modulator principle, magnetic amplifier principle, fiber optic measurement principle and so on.

Due to the particularity of the working condition of battery system, considering the complexity, power consumption, cost, volume and other factors, the current detection equipment used in battery monitoring system is mainly shunt and hall current sensor.

The shunt works in a principle similar to the precision resistance method, which measures the current indirectly by measuring the voltage on the series resistance in the measured current loop. Advantages are simple structure, short information chain, responsive, accurate and reliable. The disadvantage is that when measuring the large current above kiloampere, the volume of the shunt is large and bulky, which is difficult to manufacture and install. The primary and secondary side is not isolated, so the microprocessor and shunt to add isolation devices. The measurement error mainly comes from the resistance value temperature drift, the current distribution is uneven, the potential end knob and the thermoelectric potential.

Hall current sensor is based on hall effect principle made of sensor parts, divided into direct detection (open loop) and magnetic balance (closed loop), no need to contact the high-voltage circuit can be measured current information, avoid high-voltage interference while eliminating the isolation device, easy to install, good dynamic characteristics, fast conversion speed; The disadvantage is that the linearity at the low end of the measuring range is difficult to guarantee and the power consumption of the closed loop hall current sensor is large. Well-known manufacturers include American Honeywell, Swiss LEM, etc.

3.3. Temperature

Battery because the electrode material, electrolyte activity is greatly affected by temperature, practical engineering also to battery shell or plate temperature measurement, often used for lead-acid battery temperature measurement methods such as thermistor method, thermocouple bridge method and temperature sensor method.

It is a traditional temperature measurement method to use discrete components such as thermistor and integrated operational amplifier to build circuit and AD sampling chip to realize temperature measurement [9]. Thermistor is a kind of semiconductor thermal sensitive element whose resistance value changes exponentially with temperature. It has high sensitivity and low price, but its resistance value changes linearly with temperature, and its stability and interchangeability are not good. Similarly, a semiconductor analog temperature sensor is used to build a circuit to realize temperature measurement. The voltage or current output of the sensor has a linear relationship with the temperature to some extent, and the temperature value to be measured is obtained by amplifying and sampling the analog quantity. Analog temperature sensor provides voltage or current output proportional to absolute temperature, with high precision and no external calibration, etc. Commonly used are LTC29 series of Analog Devices, AD59 series, and LM94 series of American national semiconductor company.

Thermocouple with its unique advantages has become widely used in the industry temperature measurement components. The principle is that two metals of different materials are welded together. When there is an error between the reference end and the measurement end, a thermoelectric potential is generated. The temperature can be measured according to the single value relationship between the thermoelectric potential and temperature. It has simple structure and fast response, but it has problems of cold end compensation and broken couple, so it is often used together with other sensor elements [9][10].

Digital temperature sensor integrates traditional signal amplifying circuit, sampling circuit and AD conversion circuit, which can directly convert the analog signal of sensor into digital signal and transmit it to microprocessor for data processing. Compared with other temperature measurement methods,
digital temperature sensor chip has the advantages of simple peripheral circuit, good expansibility and high precision. DS18B20 of Dallas Semiconductor is commonly used, which can achieve 9-bit accuracy in the range and support single-bus communication. The DS1624, 13 bit precision, supports I2C bus communication.

3.4. Internal resistance

Battery internal resistance does not belong to battery external parameters strictly speaking, internal resistance is one of the inherent characteristics of the battery. Most battery management systems take internal resistance parameters as auxiliary parameters for battery state estimation, but there are battery management systems in the market that rely on internal resistance as the main parameter to estimate battery SOC and SOH.

The measurement of internal resistance is a relatively complicated process, which cannot be measured directly. It is mainly measured indirectly by density method, open circuit voltage method, dc discharge method and ac method.

The density method is similar to the open-circuit voltage method, and uses the external parameter - internal resistance curve to estimate the internal resistance of the battery.

The dc discharge method is used to discharge the battery with instantaneous large current, and the internal resistance of the battery can only be calculated by using ohm's law combined with instantaneous pressure drop and single current, which can only be carried out offline and is not suitable for online parameter estimation.

By injecting a low-frequency ac current signal into the battery, the low-frequency voltage at both ends of the battery, the low-frequency current flowing through the battery and the phase difference between the two are measured, so as to calculate the internal resistance of the battery. The ac method requires no discharge, no static or offline operation, which avoids the impact on the safety of the equipment, and is suitable for online application.

In the battery internal resistance estimation theory, someone proposed battery equivalent circuit model, using the measured voltage and current online real-time identification of battery equivalent circuit of resistance method to estimate the battery internal resistance indirectly, its precision by equivalent circuit order time and greatly influenced by the estimation algorithm, widely applied in the battery management system.

4. Typical lead-acid battery management system

Lead-acid batteries can be roughly divided into four categories according to their operating conditions. The typical characteristics of battery management system under the four operating conditions are described below.

4.1. Backup Power battery

The backup power battery is mainly used for communication backup power supply, uninterruptible power supply (UPS), emergency lighting power supply and other backup power supply batteries. As a backup power supply that supplies power to the load under abnormal conditions, its reliability is related to computer systems, telecommunication systems, Safety and stability in many important occasions such as petrochemical reactors.

Backup power battery system is generally centralized management, fixed application occasions, usually in the state of floating charge, battery monitoring system has few restrictions, sensor module is not restricted by consideration of volume, power consumption and other factors, its parameters can also complete real-time online monitoring.

Currently, in engineering applications, the backup power Battery management system has the following characteristics : (1) VRLA, Valve Regulated Lead Acid Battery is widely used as backup power in communication, transportation and military fields due to its maintainable free features. But VRLA thermal management is extremely strict, which requires the battery management system to have a good ability to prevent overcharge, overdischarge and balance. (2) the management system topology
is usually a three-layer distributed structure. Bottom is usually for each single Battery Monitoring Module (BMM, ‘Monitoring Module), directly connected with monomer Battery Monitoring Module, power supply by the Battery itself, but in the floating charge, charge and discharge, offline cases such as single detection and record the voltage, temperature, monomer Battery impedance, middle is each Battery matching set of control unit (BCM, Battery control and management Module), to collect the underlying Module of Monitoring data and Battery voltage, current, And through the interface upload detection system data to the top main system, the top layer is usually the local user interface, for local query and system Settings. The communication between the three layers is usually cable communication such as CAN and MODBUS. (3) the monitoring system develops to multi-layer and network. With the popularity of unattended base stations in the telecommunication industry, the remote management function of battery management system becomes increasingly important. Currently, backup power battery systems such as UPS usually add a network layer on the user layer to realize remote monitoring of distributed system. At present, the research focus of battery management system of backup power source is more intelligent and networked.

Fig. 1 Backup power battery management system

4.2. Energy storage battery
Energy storage battery refers to the storage battery used for solar power generation equipment, wind generator and other renewable energy in the micro grid, which mainly plays the role of stabilizing output power fluctuation and ensuring continuous and stable electricity load.

Lead-acid battery energy storage cost is low, good reliability, high efficiency, is one of the leading technology, early on a large scale electrochemical energy storage but is short cycle life, low energy density, single cycle cost higher, but the late application and development is limited by a lot. At present, lithium ion batteries occupy the mainstream in energy storage field, lead carbon batteries, a new type of lead-acid batteries, account for more and more energy storage at power station level due to its stability, safety and large capacity.

In the energy storage System, the battery mainly works in two states: the energy storage battery interacts with the energy storage converter (PCS, Power Conversion System) on the high voltage, and the converter takes electricity from the ac Power grid to charge the battery pack; The battery pack supplies the converter, which converts the energy into alternating current and sends it to the ac grid.

Characteristics of power station level energy storage battery management system (ESBMS, energy storage battery management system) :(1) the requirements of energy storage power station on management system balance ability are very urgent. The scale of the module of energy storage battery is relatively large, with multiple strings of batteries in series. Larger single voltage difference will cause the capacity of the whole box to decline, and the more series batteries there are, the more capacity they will lose. From the perspective of economic efficiency, energy storage power station needs sufficient
equilibrium. (2) the energy storage power station does not require much computing power for the battery management system. The battery is expected to have a long life, no fault, low operating current threshold setting, the battery will not work at full load, the application environment is relatively stable, the state parameter fluctuation is small. (3) the scale of energy storage system is large, and the topology structure usually adopts three-layer distributed management. Generally, each Battery group is equipped with a set of bottom Battery Management Unit (BMU), which is responsible for monitoring the external parameters of each Battery Unit in the Battery pack. The middle Battery Cluster Management System (BCMS) is responsible for monitoring the voltage, current and capacity balance of a series of Battery packs. BAMS (Battery Array management system) on the top floor completes data collection, statistical analysis and processing as well as communication with BCMS, energy storage converters and SDS, Supervision and Dispatch system. (4) large amount of information and diverse protocols. The three-layer management structure of ESBMS communicates with each other through CAN bus or RS485 bus protocol to convey real-time state information of storage battery. Top BAMS communicates with PCS and SDS through CAN, RS485 or TCP/IP protocols. BAMS and PCS determine high-voltage power interaction through information exchange, and report battery monitoring information to SDS for their decision-making of energy storage system scheduling.

4.3. Power battery
Power battery is mainly used in electric bicycles, electric special vehicles (electric tour vehicles, police vehicles, forklift, forklift), low-speed electric passenger vehicles, hybrid electric vehicles.

Such batteries are mainly used to provide power for transportation vehicles. They are usually small in size, have limited installation space, are charged and discharged frequently, and have large fluctuation range of voltage, current and other parameters.

Compared with lithium battery electric bicycles, electric bicycles and special electric vehicles powered by lead-acid battery usually do not have battery management system. On-board monitoring module only obtains battery real-time voltage parameters to estimate battery SOC, which has a large error and does not have the balance function between single batteries. The service life of vehicle battery is mainly related to the matching of electric drive system, especially the matching of charger.

Currently, BMS (battery management system) for low-speed electric vehicles and hybrid electric vehicles is a hotspot of research. Its features are as follows: (1) in addition to collecting battery voltage, current, temperature and other parameters, BMS often requires driving speed and other parameters to predict battery parameter changes. (2) the working conditions of electric vehicles are complex, the current fluctuations are severe, and the sampling and computing capabilities of BMS are required to be high; (3) limited vehicle space and battery capacity limit the power consumption and volume of the sensor; (4) the estimation error of battery SOC and the balance of battery pack directly affect the range, so electric vehicles have high requirements for dynamic battery detection and battery balance; (5) the topology structure is usually one layer of centralized Management System or two layers of Distributed Battery Management System (DBMS). At present, CAN protocol communication is adopted in the communication of ev Management System.

4.4. Starter battery
The starter battery is mainly used for starting, ignition and lighting of fuel engine in automobile, motorcycle and weapon system.

Application status of lead-acid battery : (1) lead-acid battery is still the main body of automotive starter battery due to its good low temperature, high current discharge ability and safety. Relative to the application of lithium battery to start the car, the application of lead-acid battery automobile starter batteries are usually single 12v battery or two monomers in series, there is no similar to lithium battery cell battery protection board, only the car instrument to display the battery voltage, can't do the real-time monitoring of battery parameters such as voltage, current, also can't accurate estimate remaining power. (2) motorcycle starter battery is usually single 12V, which plays the role of electricity storage and voltage regulation. Similar to fuel oil generating set, the number of single units in series is small
and the battery is changed frequently. There is no special starting battery management system. (3) at present, most lead-acid batteries for start-up are not equipped with battery management system, and a single battery monitoring device will be equipped in a few special working conditions, for example, the starter battery of diesel generator set for submarine [11].

5. Future prospect of lead-acid battery monitoring system
(1) battery life monitoring system has very important engineering application value and research needs. The key of battery state monitoring is real-time and accurate monitoring of battery state. The battery management system mentioned above can only be used in a fixed environment for real-time monitoring, once leaving the corresponding fixed environment, the real-time collection of parameters is lost. SOC estimation methods commonly used in engineering, such as kalman filter method, particle filter method, neural network method, etc., need prior knowledge of these algorithms, or input variables needed for online identification, all need state parameters before the battery.

(2) low-power monitoring module. At present domestic companies of monomer battery monitoring module BMM and group control unit adopts the wireless communication between BCM, brought about by the antenna power consumption is very big, this kind of situation can be optimized by strategy to solve, such as labels regularly sleep, passive awakens active tag strategy, active tag radio frequency micro energy collection, antenna power adaptive control methods [12].

6. Conclusion
Lead-acid battery as the modern industrial production and life, modern battlefield necessary backup energy, its status and performance management directly affect the efficiency of industrial production, the trend of the battlefield, this paper summarizes the application on the outside of the battery management system of battery parameters testing method and the characteristics of different types of lead-acid battery management system, and discussed the future development of battery management system.

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