2011 International Conference on Transportation, Mechanical, and Electrical Engineering (TMEE)
December 16-18, Changchun, China

Research on Battery Management System for Light Electric Vehicle

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***Abstract*—To study the operation characteristics of light electric vehicle, the paper developed a battery management system of light electric vehicle. The system mainly contains battery protection module, battery equalization module, battery data management module. It could be real-time monitoring the operation parameters of batteries effectively: rotational speed of motor, State of Charge (SOC) of the batteries, voltage and current of the batteries, temperature of the feature points in the battery package. It can also equal the voltage inconsistency between different batteries and realize the protection and alarm functions etc. The results showed, the system ran stable, reliable, and met the precision requirements, thereby the system lays a foundation for the engineering application.**

Keywords-Light Electric Vehicle; State of Charge; Equalization; Data Acquisition

I. INTRODUCTION

With the problems of emissions of traditional fuel vehicle and shortage of oil energy, a lot of traditional automobile industry faces severe challenges of sustainable development. Development of energy saving and new energy vehicles is an important way to Chinese automobile industry to realize energy saving. Pure electric vehicle as the main strategic orientation of automotive technology route transition is basically clear. Therefore, research of light electric vehicle has important social significance and potential economic value.

Through the research of battery management system for light electric vehicle, it realized the real-time acquisition and display of the batteries' operation parameters, SOC estimation of batteries, equalization of batteries, protection and alarm functions etc.

II. HARDWARE DESIGN OF THE SYSTEM

A. Structure Diagram of the System

The battery management system of light electric vehicle had been designed, according to the function requirements of battery management system and the characteristics of controlled object and controller, Figure. 1 shows the structure, using modular design idea to divide the system into different function module. The system selected the Freescale microcontroller MC9S12DG128B as the controller. The data which are collected by voltage sensors, current sensors, temperature sensors, motor rotational speed sensor, will convert into digital by analog to digital (A/D) converter which the microcontroller comes with. The microcontroller will complete the SOC estimation of batteries, battery equalization control, protection and alarm function through the acquisition data. After analysis, the acquisition data will display on the touch screen through RS232 serial port. The operator can choose to display different content by the different buttons on the touch screen.

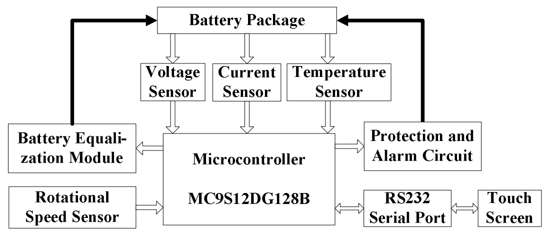

Figure. 1 Structure Diagram of the System

B. Structure Diagram of the Data Acquisition Module

Figure. 2 shows the structure diagram of the data acquisition module. The rated voltage of each signal cell in the battery pack is 12V, and the full charge voltage is 14.4V, so, selecting hall voltage sensor CHV-25P with 0~25V measuring range to measure signal cell's voltage, hall voltage sensor CHV-100VS to measure the batteries' total voltage, hall voltage sensor CHK-100Y4 to measure the batteries' total current, temperature sensor DS18B20 to measure the temperature of the feature points in the battery package.

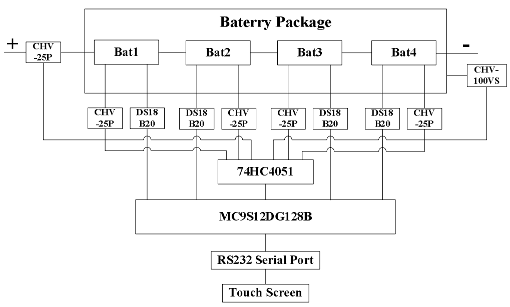

Figure. 2 Structure Diagram of the Data Acquisition Module

The microcontroller's A/D port is limited, so the microcontroller selects sensors on in turn through 74HC4051.

C. Structure Diagram of the Equalization Circuit

From the usage of electric vehicle found that signal cell works long than battery pack, research shows that voltage inconsistency between batteries is the main reason, and charge-discharge process exacerbate the inconsistency, rechargeable batteries have a short life, causing the battery life shortened [1]. Therefore, equal the battery's voltage can improve the battery's working time.

Shunt resistance method is the most common equalization method in industry at present which is inefficient, but simple and reliable. The principle is, the signal cell will discharge through the bypass resistor when its' voltage is higher than the average voltage. This equalization method is a waste of energy, and it can't work when the signal cell voltage is less than the average voltage. This paper adopts nondestructive equalization way [2], using energy storage component capacitor to achieve power transfer between different cells. The cell with higher voltage will charge the one with lower voltage, the higher voltage cells and the lower voltage cells will be all equaled in this way. Figure. 3 shows the structure diagram of the equalization circuit [3].

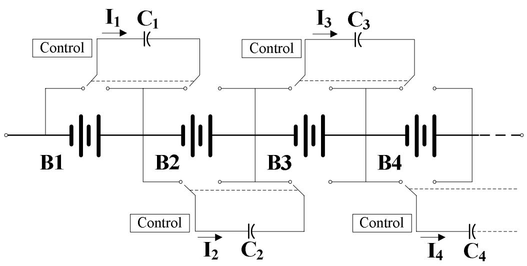

Figure. 3 Structure Diagram of Equalization Circuit

D. Structure Diagram of the Protection Circuit

Figure. 4 shows the structure diagram of the protection circuit, the microcontroller detects and processes voltage data, current data, temperature data of each signal cell, and turns the load and charger on or off according to the switching devices by the test results.

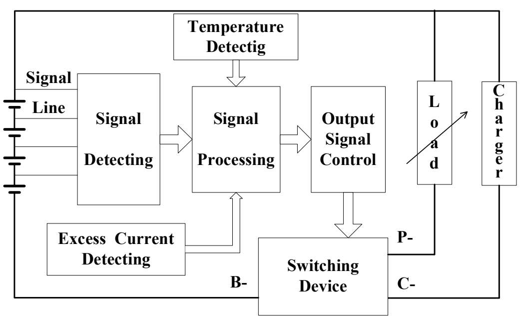

Figure. 4 Structure Diagram of Protection Circuit

III. SOFTWARE DESIGN OF THE SYSTEM

To ensure the program's versatility and portability, the software was written by ASNI C language. The main functions of the software are as follows:

- The microcontroller selects sensors on in turn through 74HC4051 and gets the data by A/D port, then, converts and calculates the data.
- To meet the requirement of real-time display, the software should make full use of the microcontroller's hardware interrupt resources.
- To estimate SOC of the batteries, and make its error is less than 8%.
- To complete battery equalization, and ensure the voltage difference between two adjacent cells is less than 80mV
- Sound and light alarm will be started and battery power supply will be cut off when fault occurs.
- The touch screen displays acquisition data, and can display different content by choosing different buttons on the touch screen.

The Program adopts modular design idea, and mainly contains the following function modules: data acquisition and display module, interrupt module, SOC estimation module, equalization of batteries, protection and alarm module. Figure. 5 shows the flow chart of system.

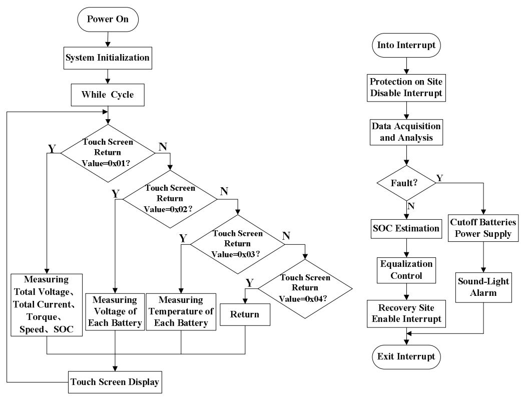

Figure. 5 Flow Chart of System

IV. SYSTEM FUNCTION AND TEST ANALYSIS

Battery management system for light electric vehicle has following functions:

A. Parameters detection

Collecting running parameters in charging and discharging process, and real-time display it. The collected data include: total voltage of the batteries, total current of the batteries, voltage of signal cells, temperature of the feature points in the battery package, rotational speed of motor. Touch screen real-time display the acquisition data.

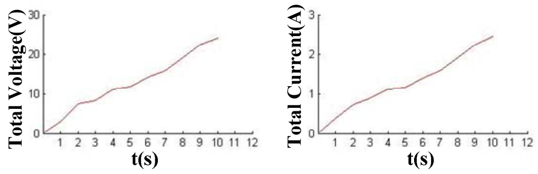

Figure. 6 Curve of System Operating Parameters

Rotational speed of motor had been controlling from 0 to 600 (round per minute) in 0~10 seconds, Figure. 6 shows the total voltage, total current parameters which were got by the system.

B. SOC estimation

For the convenience of the driver to master the remaining capacity of batteries, system estimate SOC of the batteries in real time by the acquisition data. The United States Advanced Battery Consortium defined SOC in “Electric Vehicle Battery Test Manual” as the remaining battery capacity(Ah) and the ratio to the battery rated capacity(Ah) in the same discharge rate conditions. To assume that $\int_0^t i(\tau)d\tau$ is the released capacity by a full charged battery during its discharge process, and Q0 is the rated capacity of the battery. SOC of battery is expressed as:

$$SOC = \frac{Q_0 - \int_0^t i(\tau)d\tau}{Q_0} \tag{1}$$

Formula (1) as the definition of SOC can not be used for accurate estimation. The main methods for SOC estimation contain: discharge test, internal resistance method, open circuit voltage method, load voltage method, Ah counting method, neural network method and Kalman filtering method. This paper combined open circuit voltage method with Ah counting method to estimate SOC. The system uses Ah counting method during the batteries are charging and discharging and uses open circuit voltage method to estimate the initial SOC value when the batteries have rest for 30 minutes or more, and fixes the influence of temperature, self-discharge, aging and other factors.

This paper used 3.2V/15Ah lithium-ion battery as its test object. The full charged battery discharged at 0.2C, 1C, 3C constant current respectively, until the end of the discharge. Figure. 7 showed the SOC and the variation curve of voltage in battery constant current discharge process. It can be seen from the curve, the discharge time is the longest when the battery voltage is about 3.2V, the SOC is inversely proportional to time when discharge at constant current.

C. Equalization control

Connected four 12V/60Ah batteries with large insistency to a 48V system. It could be seen from TABLE I, there had large insistency between signal cells’ voltage before equalization, B4 was significant higher than average while B2 was significant lower than average. Voltage of B1, B4 began to decrease while voltage of B2, B3 began to increase gradually after starting equalization.

TABLE I. COMPARISON OF VOLTAGE BEFORE AND AFTER EQUALIZATION

Batt-eries	Before Equalization	Equalization (10minutes later)	Equalization （2 hours later）
B1	12.56[V]	12.30[V]	12.46[V]
B2	11.84[V]	12.22[V]	12.44[V]
B3	12.32[V]	12.41[V]	12.48[V]
B4	13.19[V]	12.97[V]	12.51[V]

As time went on, voltage of B2, B3 was been rising, while voltage of B1, B4 dropped further, and made the voltage of each cells to be consistency finally.

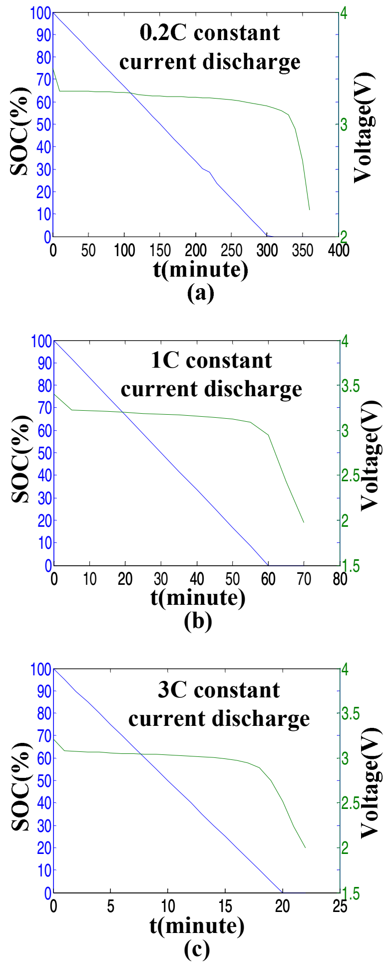

Figure. 7 SOC and Variation Curve of Voltage in Battery Constant Current Discharge Process

D. Protection and alarm function

The system analyzes the detected voltage, current, temperature, and other data, and will start the alarm program when one of the parameters beyond the scope of default. The way of alarm contains: buzzer chirping, LED flashing, displaying an error icon on the touch screen, and cutting off battery power supply by controlling the switching devices.

V. CONCLUSION

The tests showed that, the battery management system implemented all expected functions, voltage measurement error and current measurement error was less than 0.5%, temperature measurement error was less than ±1%, SOC estimation error was less than 8%, and realized the real-time acquisition and display of the batteries' operation parameters, SOC estimation of batteries, equalization of batteries, protection and alarm functions etc, and the system ran stable and reliable.

ACKNOWLEDGMENT

The authors gratefully acknowledge the supports from the National Natural Science Foundation of China (NSFC: 51075010, 51007003), the key funding project of Beijing Municipal Commission of Education and the natural science funding project of Beijing (KZ200910005007).

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