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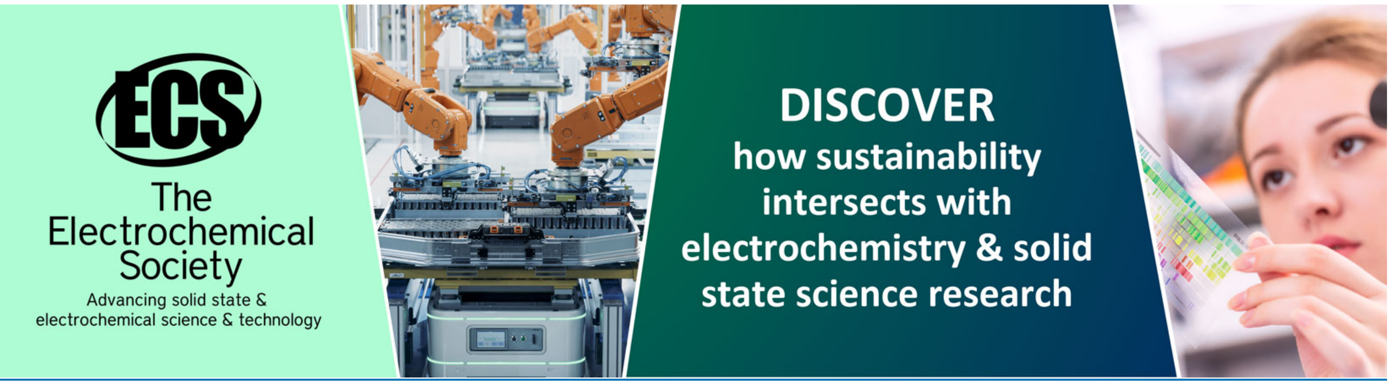
A monitoring system based on electric vehicle three-stage wireless charging



A monitoring system based on electric vehicle three-stage wireless charging

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Abstract. An monitoring system for three-stage wireless charging was designed. The vehicle terminal contained the core board which was used for battery information collection and charging control and the power measurement and charging control core board was provided at the transmitting terminal which communicated with receiver by Bluetooth. A touch-screen display unit was designed based on MCGS (Monitor and Control Generated System) to simulate charging behavior and to debug the system conveniently. The practical application shown that the system could be stable and reliable, and had a favorable application foreground.

1. Introduction

Considering the increasingly prominent fuel supply contradiction and environmental pollution, energy-saving and emission-reduction have become a trend all the world. In recent years, under the guidance of national policy and the efforts of all parties, new energy EV(electric vehicle) industry has developed vigorously in our country. EV is playing a more and more significant role in development of national economy industry, but charging diversification and convenience are still bottlenecks, which restrict its development. To solve this problem, thus, wireless charging technology emerges. As WCT(Wireless Charging Transfer) doesn't contain exposed ports, doesn't need manual operation, doesn't occupy a large of space, relative to wired charging, it provides a more comfortable and safe travelling environment for drivers[1-3].

At present, most of the researches have been devoted to the realization and optimization of wireless energy transfer system. When it comes to monitoring and management system, reference [4] proposed an online monitoring system for EV charging stations, optimizing the operation management of charging station. While reference [5] designed a wireless charging system for small power electronic devices, based on the theory of electromagnetic propagation and magnetic induction, but it didn't discuss on the large power equipment.

Currently there have been some EV surveillance applications. Most of them are based on BMS (Battery Management System)to collect the information of battery, and the communication between EV and charging control apparatus is based on the CAN(Controller Area Network) bus. However there are some defects in domestic battery management system, such as limited industrialization, unstandardized systems, verified standards and different reliability, which have restricted the large-

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scale applications of it. And additionally, CAN Bus communication doesn't apply to non-contacting wireless charging system.

Considering the above problems, this paper proposed the monitor system of EV wireless charging, including independently designed acquisition circuit of voltage and current signals as well as a software development platform based on ARM. And the system was independent of SOC(State of Charging) and battery information collected by EV BMS system. Taking charging and discharging characteristics of Li-Ion into consideration, the system adopted the three-stage charging method to achieve safe and efficient charging management. And a touch-screen display unit was designed based on MCGS to debug the system conveniently.

2. The three-stage charging method and control algorithms

In order to balance the safety and rapidness of charging process, and considering the efficient use of the battery, wireless charging system adopted three-stage charging method. The method divided the process into three parts based on fitting the characteristic curve of the battery charge and discharge, containing current limiting, balanced charging and float charging.

Take the rated voltage 4.1V battery as an example. Firstly, in the early stage of charging, if the battery voltage is less than 2.9V, then charging circuit enter the current limiting stage, using a constant rate of 0.1C to charge, with 1C represents the battery is full of 1 hours in the ideal state. The current limiting stage is mainly to avoid the impact of current when the battery voltage is too low. And then the charging mode is converted to balanced charging, adopting constant current to speed up the charging, when the monomer battery voltage rises to saturation voltage(4.1V/4.2V), the capacity of the charge is close to 40% -70% of total capacity at this point. Next, adopting the constant voltage to charge with charge current gradually decreasing. When the current down to 0.1C, it is therefore rational to consider that the battery is full. After that, charging process will enter the floating stage, charging with 0.01C until the end of the charge. Figure 1 shows the three-stage curve diagram of the battery.

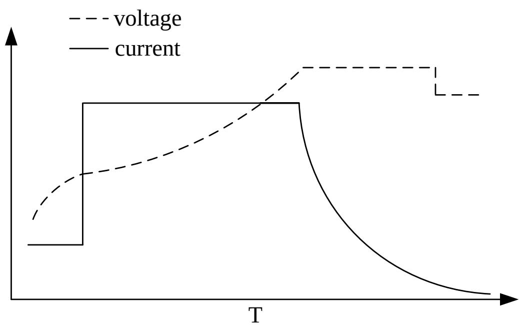

Figure 1. The three-stage curve diagram of the battery diagram

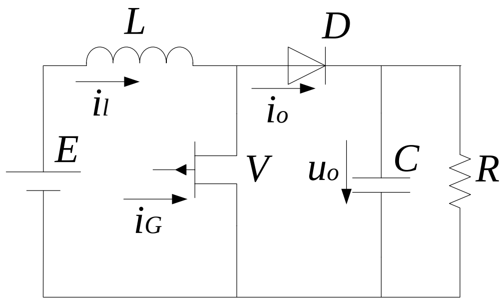

Figure 2. Chopping circuit principle diagram

The system was designed mainly based on the boost chopper circuit in wireless charging to achieve charging current and voltage control. As shown in Figure. 2 is the boost chopper circuit.

When the switch V is on the state, power-E charge to inductive-L, at this time current and output voltage is constant, while when the V-Switch is off, power-E and nductive-L charge to capacitance-C, providing electric energy to load at the same time. The relationship between conduction duty cycle and voltage as well as the average value of the output current are shown in (1)and (2).

$$U_o = \frac{1}{\beta} E = \frac{1}{1-\alpha} E \tag{1}$$

$$I_o = \frac{U_o}{R} = \frac{1}{\beta}\frac{E}{R} \tag{2}$$

In the formula (1) and (2), α represents the PWM duty cycle, while the β represents reciprocal of boost ratio. It is obvious that the output current and voltage value can be regulated through controlling the PWM duty cycle. So we could use the relationship between the duty cycle and the output voltage and current to achieve the three stage charging. By examinating and judging the parameters such as battery voltage and charge current to realize charging mode switching: when the charging voltage and current is higher than the set value, then increasing the duty factor, and vice-versa.

In order to achieve stable and rapid charging, this paper applied double closed loop control system. First of all, substracting the reference voltage value and the measured value can obtain the deviation, next the current reference value can be got after PI adjusting and limiting operation. The duty ratio of the chopper circuit can be real time regulated from the deviation.of current operated by PI and limiting. Figure.3 shows the algorithm block diagram.

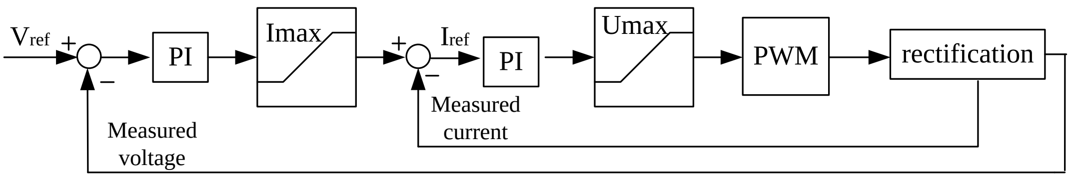

Figure 3. The algorithm block diagram

3. The composition of the monitoring system

Considering that currently we can’t collect a large amount of user data to establish a database, thus, this paper proposed a charge monitoring system based on the thought of modularization, which is aimed at a single EV. It specifically included transmitting control module, receiving module, measuring module, display module and so on.

Transmitting control and receiving module adopt STM32F103 as core board, using Bluetooth hands-free communications to realize real-time connection as well as ensure the reliability of the three stage charging. The receiving module includes a current voltage measurement circuit, and the data is transmitted to the transmitting end core board via the receiving side, to achieve real-time control of the charging and discharging. In addition, as the battery has the working temperature limit, the temperature detection also has great significance during charge-discharge process. Based on this, the receiver sets the temperature sampling sensor, communicating with the core board through the serial port.

It’s necessary to collect the real-time voltage and current during charging process, sending the collected data to the receiving core board through ADC conversion. The signal is transmitted to the control core board via Bluetooth to implement feedback control. By comparing the real time voltage current with the standard voltage and current, the PWM waveform is continuously adjusted.

As shown in Figure 4, the R1 is a standard resistor, and the charge current is transmitted back to the control panel through a differential amplifier circuit. Differential amplifier circuit has a strong ability of common mode rejection and small output drift voltage, which can accurately measure the magnitude of the R1 voltage, thus the size of the charge current is obtained. What was more, there’s a voltage acquisition, as shown in Figure 5. This paper adopted the method of precision resistance voltage divider to regulate the voltage signal. The collected battery terminal voltage was divided into the resistance voltage through the resistance, using a filter capacitor and a voltage stabilizing diode as the subsequent circuit to meet the requirements of ADC input voltage.

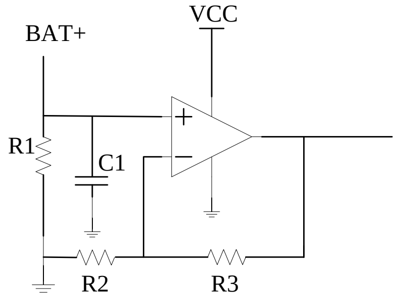

Figure 4. The current acquisition circuit

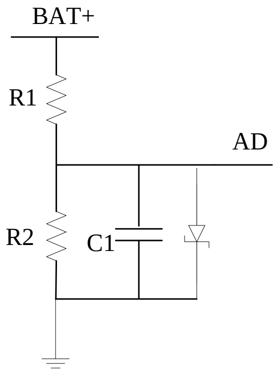

Figure 5. The voltage acquisition circuit

In the system, we adopted LT-111 as the core of metering module, which could accurately measure the electrical parameters of the line, to provide voltage and current, power, energy and power factor, communicating with the transmitting terminal core board through the RS232. The display module chosen 7 inch MSCG display, to simulate the user side charging control and display parameter in system debugging, which could communicate with the core board though RS485.

As shown in Figure 6 is the communication process.

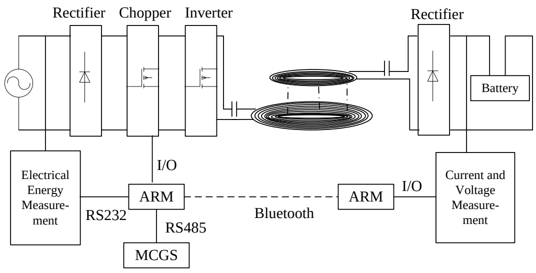

Figure 6. The communication process diagram

3. Monitoring system implementation and function display

After the system design was completed, choosing "the Taiun 100" EV as a reference to test. Its battery rated voltage is 74V, rated current is 20A.

As the internal battery pack of the EV is composed of series connected cells, based on the laboratory environment, we adopt a series of lithium battery with rated voltage of 12V to simulate the voltage of the electric vehicle. The experimental apparatus is shown in the following Figure 7.

Figure 7. The experimental apparatus

In the three-stage charging process, the trickle threshold was set at 54V, constant current setting value was set at 1A and the constant pressure value is set at 74V to make the charging and discharging completely. When the start key of the operations panel MCGS was pressed, the charging command can be sent to the control board via RS232/485 networks. After that transmitter and receiver Bluetooth chip perform handshake, the current and voltage information collected by the receiver is sent to the transmitting end and the display screen at the same time. The three stage charging process controlled by ARM is displayed on the screen. The designed interface includes voltage and current power display in real time, as shown in Figure 8.

Drawing from measured data, the charging voltage curves were obtained, as shown in Figure 9. The experimental data shown that the wireless charging monitoring system could complete information acquisition and real-time control in the process of charging. Besides the system was reliable on security, expansibility and universality, and could be used in different models.

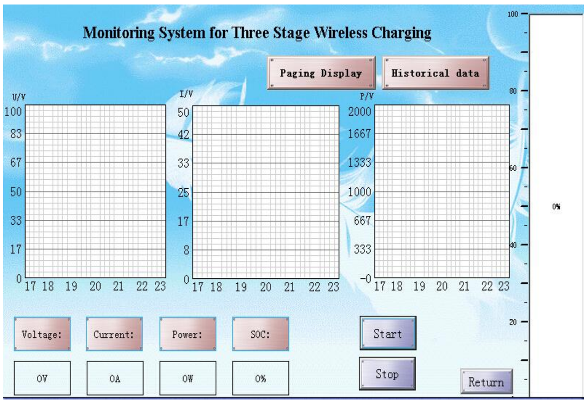

Figure 8. The display interface of MCGS

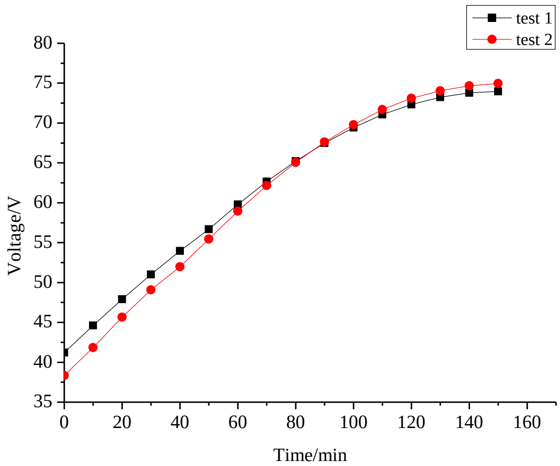

Figure 9. The charging voltage curves

4. Conclusion

Based on the introduction of the three section type EV battery charge and discharge characteristics, a wireless charging monitoring system was designed, which achieved an organic unity of rapidity and efficiency. Besides, a current & voltage monitoring circuit is specially designed to make the system more universal and a tangibly screen is adopted to facilitate debugging and control, which makes the system more intelligent.

Experiments showed that the system can complete the real-time charging monitoring reliably and its charging process meets the battery characteristics. That is to say, it prolongs battery life and has a high cost performance ratio. In addition, the system is not for a given vehicle segment. It avoids drastic alteration to the car and it applies to a variety of application scenarios. Therefore, it has good market prospects. But it must be noted that this system is designed for the changing process of a single EV, without considering the scheduling problem of large scale EVs charging. The direction of research is to optimise the system to achieve coordinate charging, and to make the charging more efficient

References

[1] Wang Z Y, Wang X M, Zhang B and Qiu D Y 2014 Advances of wireless charging technology in electric vehicle *J. Power Supply* **3** 27-32
[2] Ni G Q and Wang L N 2013 Design scheme of wireless charging system *Electronic Engineer* **39** 51-4
[3] Ai M H and Qi L H Electric vehicle charging stations' on-line monitoring system based on ordered charging *Shanxi Electric Power* **42** 6-11
[4] Du C Q and Du G 2015 Remote monitoring technology research and platform development for electric vehicle *Automotive Engineering* **37** 1071-6
[5] Yang Y, Liu Z Z, Qu D M and Wang J 2015 *Research on coordinated charging for electric vehicles* International Conference on Electrical Machines and Systems (ICEMS) 525-30