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High Voltage Security System Design and Testing of Electric Car

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Abstract

Safety design of high voltage part is the foundation of the whole automobile design; it is based on safety design requirements of the electric car, and the security function of hardware. The design the different functions of hardware modules are presented, through circuit principle diagram layout of PCB, and circuit board is made, the systems hardware test board is design according to the functional test of the system. Test results show that relative errors between the measurement of insulation resistance value of the safety system and the theoretical value is only 0.3%, thus the rationality of the design calculation model of the insulation resistance is verified. The response times of DC (direct current) contactor are higher than the national standard requirements, so the system security design meets the design requirements.

Keywords*: electric vehicle, high voltage, safety design, test*

1. Introduction

The working voltage of electric vehicles in more than 200v, working current can reach tens or even hundreds ampere, when there exists a high voltage safety failures, high voltage and large current will not only endanger passengers safety can also affect the normal work of low voltage electrical [1-3]. Therefore, high voltage safety design in the electric car has the extremely important significance. High voltage system for electric car is proposed in the paper, characteristics of the electric car high-voltage circuit are analyzed. Through the high voltage circuit parameter calculation model, and detection of important electrical parameters in real-time, we can keep the safety of the vehicle [4].

In the paper, it is based on the design requirements of the high voltage system of electric vehicle and design related functions, on this basis, the hardware circuit design and development system of each function module are given out, and the principle of hardware composition and its realization of each function module are also presented [5-9].

2. System Security Hardware Design Requirements

In the process of the electric car research and its high voltage system, every safety indicators must meet safety requirements; the system should have the following main functions:

1. The insulation resistance testing;
2. The transient impact;
3. High and low voltage protection;
4. The over-current detection;
5. High pressure loop interlock testing.

3. Related Hardware Circuit Design

In this study, the high voltage safety design of electric vehicle mainly includes:

1. The main control circuit.
2. The power supply circuit;
3. The positive and negative side contactor control and current sampling circuit;

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4. The battery positive and negative voltage and total voltage acquisition circuit;
5. High voltage circuit voltage measurement circuit;
6. High and low voltage protection circuit;
7. High pressure loop interlock circuit,
8. Insulation resistance monitoring circuit;
9. Power battery temperature measurement circuit.

Introduction of main circuit design are given out as below:

3.1. Power Supply Circuit

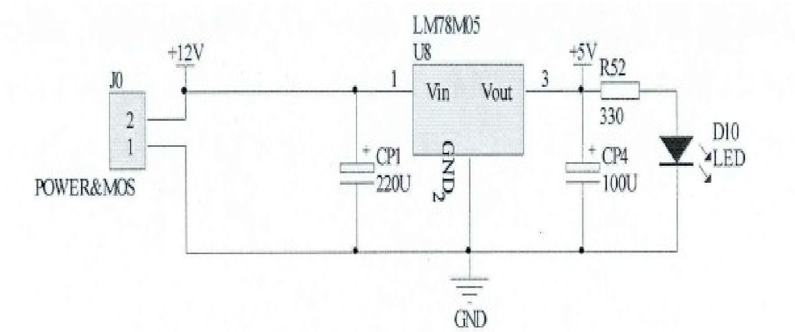

Figure 1. Power Supply Circuit

In the design of the whole circuit, first of all it needs to design the power supply circuit; power circuit design principle is to improve the reliability of power conversion circuit, at the same time in order to make the design of the system more practical. Designed security system is supplied with 12V and 5V two power forms, because the electric car of the low voltage power source is DC 12V, so it needs to convert 12V power supply to 5V power supply circuit. Schematic circuit diagram is shown as in Figure 1.

3.2. Contactor Control and Current Sampling Circuit

High pressure loop must install the corresponding high voltage DC contactor, and high voltage DC contactor need specific on-off control circuit to drive the contactor, so the system design is shown in Figure 2. At the same time it also has the function of acquisition of the contactor coil current. High voltage DC contactor should be arranged in the location of the power battery pack, which is to ensure the reliability and high efficiency of the high voltage circuit. And on the positive side and negative side of each connection, we respectively connect and disconnect the positive and negative side of high voltage circuit and make the connection between the positive and negative side of battery. Battery through two DC contactor are connected to the positive and negative side in the high pressure system, in which a DC contactor malfunction can't be disconnected, another DC contactor also can guarantee the normal work of the contactor, so as to lose control of the high voltage circuit, when high voltage circuit in any contactor disconnect, high pressure circuit will be cut off, which is more security than just using a contactor.

In the Figure 2, it includes the contactor control and the contactor coil current sampling circuit. As can see from the table, the DC contactor control is connected to one end of the coil and the 12V power.

By controlling whether the other end of the coil grounding, it can realize the on-off control of the contactor. In the figure, VCRelay+ and VCRelay– are the control signal from control part. The signal is through the field effect tube IRFD9120 (Q2, Q5) to control whether the relay coil is in formation of conduction. The principle of use effect tube to control the output current is through changing the input voltage. Contactor coil current is through the LM258 single basic subtraction circuit to obtain the current.

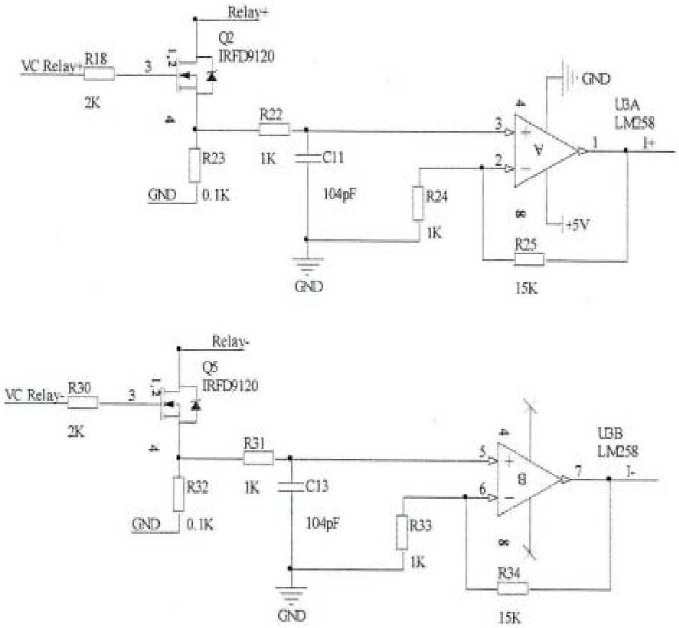

Figure 2. Positive and Negative End of the Relay Control and Current Sampling Circuit

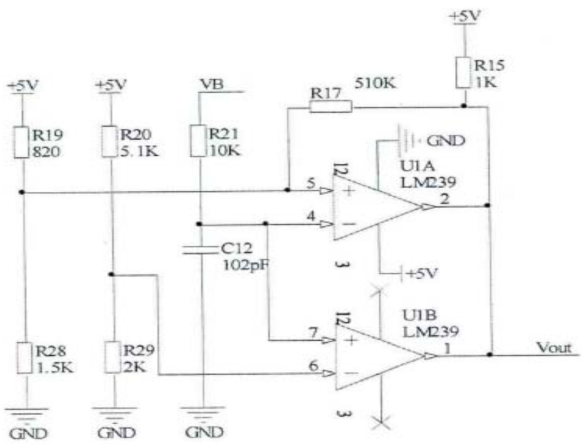

Figure 3. High and Low Voltage Protection Circuit

3.3. Insulation Resistance Monitoring Circuit

Electric cars are usually equipped with higher power supply voltage, the purpose is to reduce the transmission line current, thereby reducing the loss of lines and equipment, thus improve the transmission efficiency of the vehicle energy system. However, higher power supply voltage of the vehicle electrical safety is put forward higher requirements, especially for high voltage insulation performance of the system, more requirements are put forward. Through the related electric vehicle safety standards, it can be found that the insulation resistance is one of the important parameters to evaluate the electric car electrical safety, and in order to eliminate the high voltage of vehicle and driving personnel personal potential threats, guarantee the safety of electrical system of pure electric vehicles. According to the national standards, in order to meet the vehicle under any circumstances for insulation condition detection and fault handling requirements accordingly, we design a set of real-time detection circuit; the insulation resistance is to satisfied with quantitatively analyzing of the DC insulation performance. Detection circuit principle diagram is as shown in Figure 4.

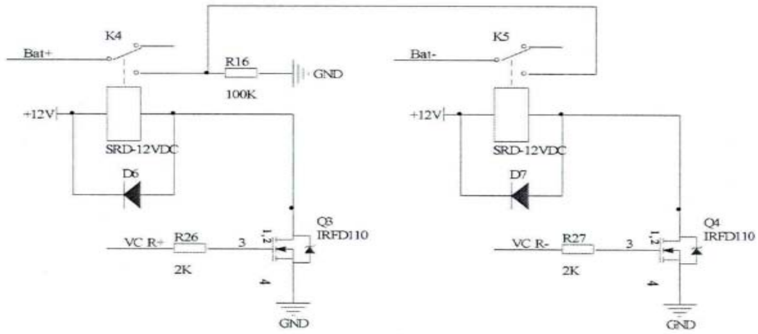

Figure 4. Insulation Resistance Monitoring Circuit

3.4 Anti-interference Design of Hardware

As for electric vehicles, the high voltage DC system is definitely a strong electromagnetic interference source, and the high voltage safety monitoring system in such a strong electromagnetic interference environment, the electromagnetic interference resistance is very important. The electromagnetic interference resistance could determines whether the security system is stable and reliable, more important is that the system can detect the reliable electric parameters so as to realize the system function. So it is not hard to see how the importance of security monitor system for high voltage.

The main interference sources are: high pressure system DC interference, space electromagnetic interference and the power interference. For high voltage DC interference, system adopts high pressure damper, shunt capacitance and high tension line method to reduce interference; as for space electromagnetic interference, radio interference, the system adopts the shielding method to reduce the space electromagnetic interference. As for the power interference, it adopts integrated manostat to reduce the power interference.

In addition, in the circuit design, the design of the single point grounding that is to separate the digital and analog grounding can reduce the interference. Through these measures, it can effectively reduce the interference; the system can work in the reliable and stable state. After adopting hardware anti-jamming measures, according to the stated before each module circuit schematic diagram, system hardware PCB diagram can be obtained, which is shown as in Figure 5.

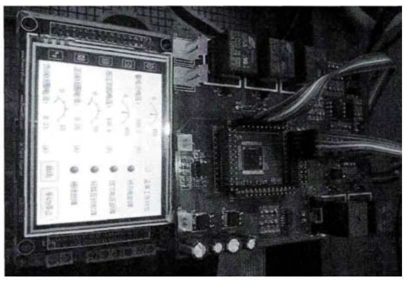

Figure 5. System Hardware Circuit Board

Figure 6. High Voltage System Test Platform of the Electric Car

4. Related Experimental Tests

Experimental test object is the electric car is high voltage safety system circuit, as shown in Figure 6. It is the electric car high voltage safety system inside before adding closed shell structure, which can be seen from the chart, the system hardware is made up of a main control circuit board and a data display panels, respectively, they are used to complete the data collection process and data display. Five relay are used in the main control circuit board, including a charging relay, two control on-off relays and two bias resistors connected to the relay data display panel, it also contains a TFT-LCD screen, real-time test results can be dynamically displayed on the screen.

4.1. The Test Platform

Electric car high voltage safety test experiment platform of the testing system, mainly including 200V high voltage DC power supply, regulated DC 12V power supply, oscillograph, multimeter, and computer and high voltage safety monitoring and control system. The debugging and testing data of the whole system work are to be done on this platform.

4.2. Validation Experiment

In order to verify whether the high voltage system insulation conditions are in good condition, it is necessary to make quantitative analysis of high voltage insulation performance of the system. The impedance of the insulation resistance is need to measure, so it is not convenient and directly to make the validation experiments. The measure method is to put impedance of resistance into the positive or negative of circuit, system can calculate model of insulation resistance according to the collection of electrical parameters, and finally through comparing measured values and the theoretical value, the model for calculating the insulation resistance can be verified.

In the test experiments, the output voltage is 200V high voltage DC power; the measurement of insulation resistance is simulated through the resistance between power supply and big resistance. As shown in the Table 1, relative error between the measured values relative to the theoretical value of insulation resistance is 0.3%, the standard deviation is 4.15, which can prove the correctness of the calculation model for insulation resistance.

Table 1. The Insulation Resistance Test Results ($K\Omega$)

Measured value		Theoretical Value	error
The first time	96	100	-4
The second time	104		+4
The third time	100		0
The fourth time	98		-2
The fifth time	96		-4
The sixth time	102		+2
The seventh time	101		+1
The average value	99.5		-0.5
Standard deviation		4.15	

4.3. Experiment of Contactor Response

The high voltage Contactor used in closing and opening test is TYCO KILOVAC EV200, the its charged capacity is more than 500A, in the DC 320V the current can be changed to 2000A; its Built-in energy-saving coil can remain 7W under DC 12V power only, and its counter electromotive force is 0V.

Through the collection of high-voltage DC contactor coil current calculation, and the quantitative data curve, we can analyze the contactor on process performance, and then judge the contactor whether is reliable, also can judge whether the related features of high voltage security system of the design is reliable.

Through the change of contactor process current curve, it can clearly show current change process in the high voltage contactor coil, and it can show the time needed for closing, also can provide comparative data for subsequent analysis. As shown in Figure 7, the current changes of DC contactor closing coil is given out.

From the Figure 7, it can be found that the contactor dynamic process can be divided into the three stages that is the response process, stable process and normal closed, when the input MCU electricity is low, contactor coil current will have a less than 1ms response lag, the lag is caused by MCU and the hardware circuit. After anther 20ms, contactor coil current there will be in the process of decline, at this point, it can be judged as the first contacts of contactor. As can be seen from the figure, from producing of the contactor coil current to the contactor first contact, this process takes for 16ms, in the later period of 115ms is the stable process of contactor, then contactor can be normally closed.

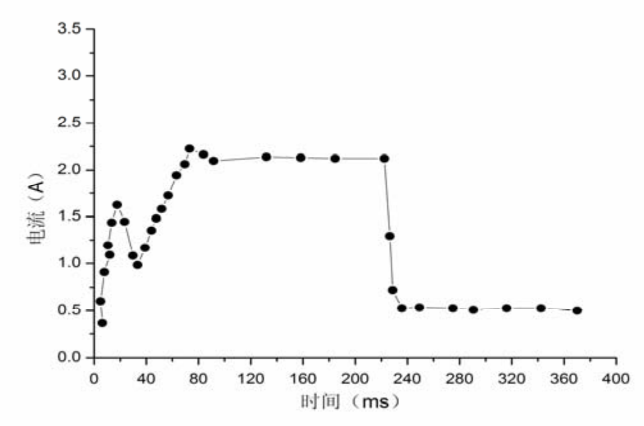

Figure 7. Closed for DC Contactor Coil Current Change Curve in the Process

Through the experiments, it can be known that in design of control program of the system, the closed signal judgment time should be set to at least more than 230ms. The mechanical vibration of high voltage contactor is inevitable. However in Figure 7 it shows no vibration, contact bounce time can be ignored, this is because the frequency of the contact bounce is greater than the lKHz, and systematic data collection interval is 2ms, which makes it impossible to collected the data in the process of rebound. But the problem does not affect the response test of the contactor closing process.

5. Conclusion

This article is mainly aimed at the electric car high voltage part of hardware design and testing of the security system. First it presents system basic composition and design of key circuit corresponding experimental data are obtained through the relevant test platform and experiments, and the test data of the experiment are analyzed and summarized, results show that the design of safety performance of the system is reliable, and it can be used in the practical application of electric cars.

References

[1] Wang Zhanjiang. *Is it safe to electric vehicle*. World cars. 2011; (4): 86-89.
[2] The Car of the Year 2011: *the Close win for Nissan Leaf [EB/OL].* 2010 29. http://www.caroftheyear.org/winner/Nissan/Leaf / 2011 _52 / coty.
[3] Jiang Jiuchun, jack neo, wu Qiu Ruichang etc. *Electric car insulation online monitoring system of research*. Journal of manufacturing automation. 2005; 27(5): 74-77.
[4] Li Jingxin Fan YanJiang, Jiang Jiuchun etc. *Electric motor insulation online monitoring method*. Journal of automobile engineering. 2006; 28(10): 884-887.
[5] Wang Jinzhong. *The development of the electric insulation detection device*. Beijing Jiaotong University. 2006.
[6] Guo Hong slippery, Jiang Jiuchun Wen Gu Peng etc. *New electric car insulation detection method research Gui*. Journal of electronic measurement and instrument. 2011; 25(3): 253-257.
[7] Wang Jiajun, Hong Bin, Wang Hongmei. Electric Insulation Detection Method for High-voltage Insulators. *TELKOMNIKA Indonesian Journal of Electrical Engineering*. 2013; 11(7): 4086-4090.
[8] Zhengren Wu, *Mei Liu, Xin Wang. Prediction of Electric Power Consumption Based on the Improved GM (1, 1). TELKOMNIKA Indonesian Journal of Electrical Engineering*. 2013; 11(8): 4669-4675.
[9] Lin Xu, Yang Han. Research on the AVC Testing Platform for the Regional Grid based on Real-Time Digital Simulator (RTDS). *TELKOMNIKA Indonesian Journal of Electrical Engineering*. 2013; 11(1): 476-483.