Design of Battery Charging Protection Circuit Based on Simulink

Xingjun Lin, Huarong Wang*, Zihui Xian, Xinglin Huang
Guangdong University of Science and Technology, Dongguan, Guangdong, China
**Corresponding Author.*

Abstract: With the growth of energy storage demand of electric new energy vehicles, the utilization rate of batteries is becoming higher and higher. Circuit protection is very important in the process of charging and discharging. This paper carries out the design of the relay protection circuit after the rectification and filtering of the power supply, and uses the Simulink simulation software to simulate the normal work of the drive circuit and the instantaneous overcurrent fault. The results show that the simulation value of the output drive signal is close to the theoretical value under normal working conditions. When transient overcurrent fault occurs, the voltage slowly returns to normal voltage after troubleshooting, the output voltage and output current decay more smoothly, and the voltage will not reverse too much to achieve the purpose of overvoltage protection.

Key words: Electric Vehicle; Storage Battery; Protection Circuit

1. Introduction

With the continuous development of new energy technology, as a clean and efficient energy storage device, batteries are more and more used in various power systems, such as electric vehicles, subway trains, etc. Due to the internal chemical reaction, the battery will show a large number of nonlinear phenomena, when the output current gradually increases, the voltage will gradually decrease (the relationship is approximately arcsine function). And such as lithium batteries, nickel-metal hydride batteries in the discharge will be permanent failure, so in the actual use of the process of the need for over-discharge protection of the battery[1,2].

New energy vehicles are powered by 15V batteries. In order to maintain the high endurance and reliability of the battery and prevent serious accidents caused by over-discharge of the battery, it is necessary to undervoltage protection of the battery. In the laboratory debugging environment, the system uses switching power supply or linear power supply, in order to prevent human factors or power failure caused by system damage, also need to over-voltage and under-voltage protection of the system.

Power electronic devices in power electronic devices can be used as part of the overvoltage protection scheme [3,4], or can be made into independent power electronic overvoltage protection equipment [5,6]. The overcurrent protection, overvoltage protection and overheating protection based on IGBT can effectively solve the negative effects caused by the common problems of instantaneous high voltage, instantaneous high current and substrate overheating in the operation of active power filter, and ensure that active power filter can better play the filtering role in AC power supply system [7,8].

2. Design of Protection Circuit

2.1 DC Buck Circuit after AC Voltage Rectification and Filtering

After AC voltage rectification and filtering, The DC circuit is Buck circuit[7]. The DC Buck circuit is a single-tube non-isolated DC transform circuit whose output DC voltage is less than or equal to the input DC voltage.Its working principle is to use the adjustable current amplifier as the control circuit, by controlling the impedance of the triode, to control the output voltage of the chopper. It can be used in two ways:

1) Effectively reduce the voltage so that the output voltage is lower than the input voltage, which is especially important for electronic devices used for low voltage loads.

2) It can react to the power supply with large voltage fluctuations and maintain the stability of the output.

The structure diagram of the DC buck chopper circuit is showed in Figure 1. IGBT is used as switching device with input voltage of 220V.

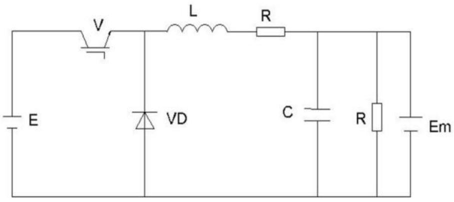

Figure 1. Structure Diagram of DC Buck Circuit after AC Voltage Rectification and Filtering

2.2 The Protection Circuit

The protection circuit is an additional circuit set up to protect the main circuit from damage or danger because of anomalies such as short circuits.There are three common types, respectively, overheat protection, overvoltage protection, overcurrent protection, etc. This design uses two types of protection circuits, overvoltage protection and overcurrent protection.

Overvoltage protection is a kind of protection circuit that automatically disconnects the supply circuit when the supply voltage exceeds the rated voltage. In electronic circuit design, the common way of protection is the use of Zener diode overvoltage protection. Zener diodes and bipolar transistors are used for automatic overvoltage protection, which can be implemented in two ways: Zener regulator circuit and Zener diode overvoltage protection circuit. The former regulates the input voltage and protects the circuit from overvoltage by providing a regulated voltage, but it does not disconnect the output part when the voltage exceeds the safety limit and will always receive an output voltage less than or equal to the Zener diode rating. The latter circuit disconnects the output section or load from the circuit whenever the input voltage exceeds a preset level.

Over-current protection is when the current exceeds the predetermined maximum value, so that the protection device action of a protection mode. When the current flowing through the protected original exceeds a predetermined value, the protection device starts, and the time limit is used to ensure the selectivity of the action, so that the circuit breaker trips or gives an alarm signal. Overcurrent protection includes short circuit protection and overload protection. Short circuit protection is characterized by large setting current and instantaneous action. Electromagnetic current tripper (or relay) and fuse are commonly used as short circuit protection components. The overload protection is characterized by small setting current and anti-time limit action. Thermal relay and delay type electromagnetic current relay are commonly used as overload protection components. The fuse is also commonly used as an overload protection element, and the impact current is not large.

2.3 Protection Circuit Simulation Analysis

2.3.1 Over-current protection

Overcurrent may occur in common circuits when they are not operating properly or when faults occur. Overcurrent is divided into overload and short circuit. Generally, several overcurrent protection measures are used at the same time in power electronic devices to improve the reliability and rationality of protection.

This design adopts over-current protection measures, adding circuit breaker and relay protection module in the circuit, taking 0.01s as the fault time to set the over-current, the absolute value of the circuit is about 100A when there is no fault, 0.01s, we set the current to exceed 1e5, the current is too large, adding relay protection module, the input is the measurement voltage, the output is the fault signal.

The output of the current protection module of the relay protection circuit is reversed connected to the Black pin of the trigger, and the setting value of the Switch device is changed to 1e5. The circuit breaker selects the external trigger, and the current protection output is used as the control signal. It can be verified that the over-current protection device is rigorous and feasible.

The over-current protection device is subdivided into the following parts.

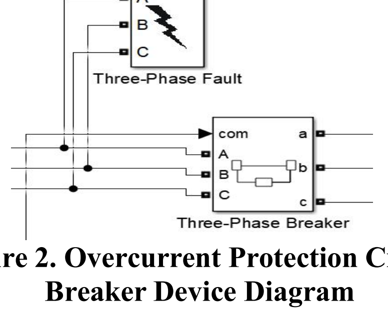

Figure 2. Overcurrent Protection Circuit Breaker Device Diagram

The circuit breaker is set to be normally closed and not opened during the simulation time to obtain the normal current waveform in Figure 2.

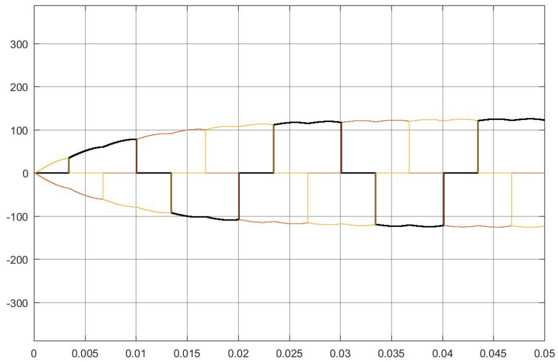

Figure 3. Output Current Waveform Under Normal Conditions

The absolute value of the output current is about 100A under normal conditions in Figure 3.

In order to verify the feasibility of the open circuit protection, set the parameter from 0.01s,then observe the current size when the fault occurs.

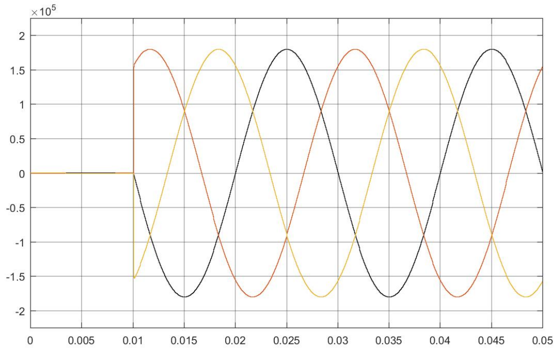

Figure 4. Output Current Waveform at Fault

As shown in Figure 4, the maximum absolute value of the output current exceeds 1e5, which means the current is too large, and the relay protection circuit module is added as shown in Figure 5.

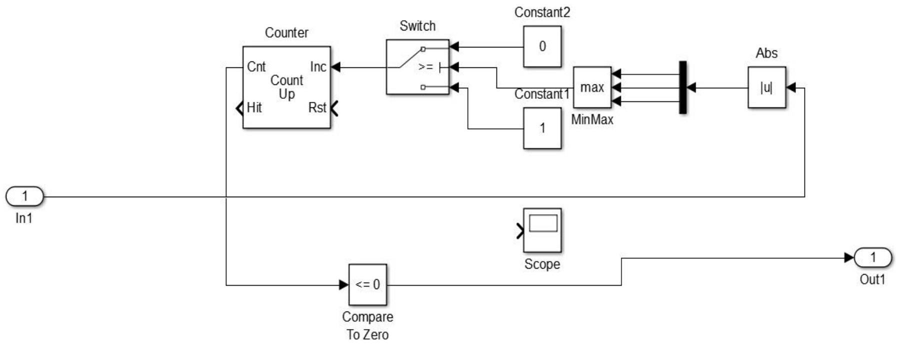

Figure 5. Relay Protection Circuit Module

The input of the relay protection circuit is the measured voltage and the output is the fault signal. The output of the current protection module of the relay protection circuit is reversed to the trigger black pin, the setting value of the Switch device is changed to 1e5, the circuit breaker selects the external trigger, and the current protection output is used as the control signal. The simulation waveform obtained by the simulation operation is shown in Figure 6.

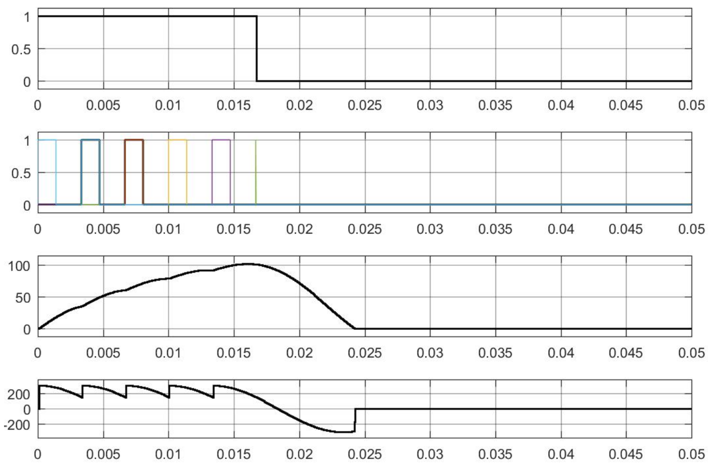

Figure 6. Waveform Diagram of the Relay Protection Circuit after Working in Fault

As shown in Figure 2.10, when the time reaches 0.01s, the fault starts to occur, the protection effect of the module is generated, the trigger pulse is closed, the circuit breaker jumps, and the output current and voltage gradually drop to 0.

2.3.2 Over voltage protection

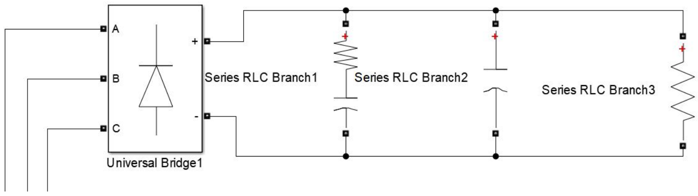

Figure 7. Overvoltage Protection Device Diagram

On the basis of the open circuit protection, the over-voltage protection is added. The device used is composed of a two-stage pipe bridge, inductor and capacitor, as shown in Figure 7, and the simulated waveform is shown in Figure 8.

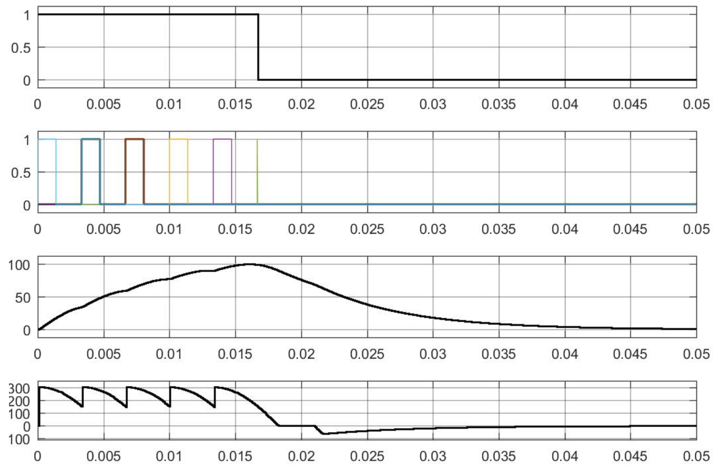

Figure 8 Waveform diagram of overvoltage protection circuit after operation during fault

The output voltage and output current decay more smoothly, and the voltage will not reverse too much to achieve the purpose of overvoltage protection,compared with only one open circuit protection.

In summary, the battery charging protection circuit is shown in Figure 9.

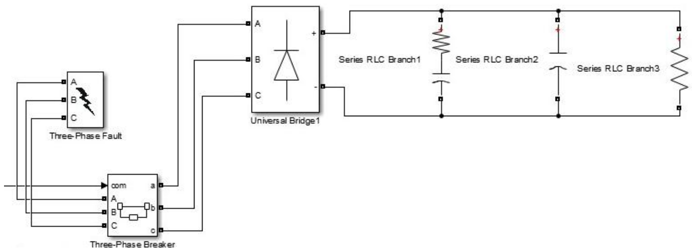

Figure 9 Simulation of the Protection Circuit

3. Conclusion

The protection circuit design, composed of two pipe bridge, inductor, capacitor and other devices, output voltage and output current attenuation more smooth, the voltage will not reverse too much, to achieve the purpose of overvoltage protection. It realizes the voltage protection of the battery and the debugging power supply, and solves the voltage protection misaction caused by the instantaneous power pulse generator, and improves the service life of the battery. The whole circuit has the characteristics of simple design, reliable operation and low cost.

Acknowledgments

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