Optimization Design of a Discharge Control Circuit for Communication System

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Abstract: The communication circuit system was affected by high temperature environment when the discharge circuit was working. The heating of the discharge resistor aggravates the temperature of the whole discharge circuit. This phenomenon will lead to the problem of the discharge function of the system. In order to solve the problem, a monitoring and optimization of a discharge control circuit based on communication system was designed. This paper analyzed the principle of the discharge circuit and proposed a method of increasing the conduction current to realize the optimal discharge control of discharge resistance. This method effectively avoided the trouble of discharge resistance with heating and smoking caused by temperature environment and improved the reliability and stability of communication circuit system.

Index Terms: Communication System， discharge control circuit， optimization design.

Ⅰ.Introduction

Communication technology has been well developed with the rapid development of science and technology in modern society and plays an important role in people’s life. At the same time, this influence is expanding. As a new industry, it has great significance to our country with the development of communication engineering. In the current information age, people have got the demand of information through communication engineering, and communication engineering has brought convenience to people’s life, and people’s work efficiency is greatly improved. Communication circuit system is the core of communication technology reserch, it can realize the effective connection of communication information between user and terminal equipment [1][2]. Discharge circuit is widely used in communication circuit system, and it was used to provide control power and dynamic power to the system, and complete the orderly power of the system and the pumping voltage discharge on DC generator. Discharge control circuit was the core component of the communication system. When communication circuit system worked at a high temperature, the temperature of communication circuit system rises sharply with the state of discharge. When it worked more than an hour, the temperature of the communication circuit system can reached 60℃, and the system goes wrong with the failure of discharge function. This problem affects the stability of the system. Therefore, how to solve this problem is a difficult thing faced by the stable operation of the system [3].

Ⅱ.Schematic of Discharge Circuit

The discharge function of communication circuit system consists of two parts. Discharge control circuit and discharge main circuit. The discharge control circuit mainly detects the bus voltage, and generate IGBT power tube signal of switch main circuit after setting the discharge point and stagnation point. The main discharge circuit includes IGBT power tube and discharge resistor, and it was mainly used to discharge the pumping energy of bus voltage. The schematic diagram is shown in Fig.1.

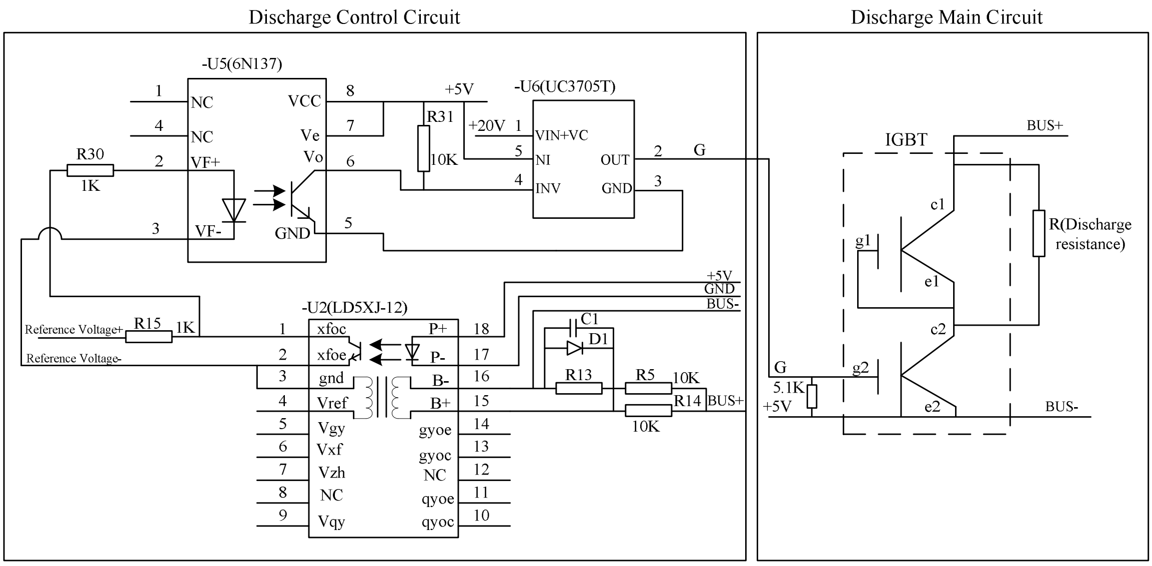


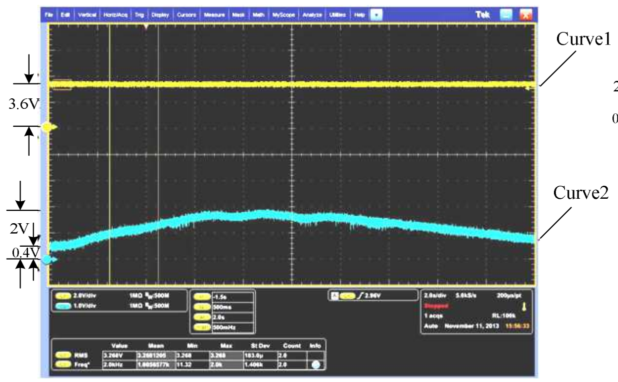
Fig.1 Schematic diagram of discharge circuit

From the Fig.1, it was input to the relief control module U2 after the bus voltage (BUS+—BUS-) is divided. Compare with the discharge point and stagnation point, it output discharge control signal. When it is detected that the bus voltage is grater than the set discharge point voltage, from high level discharge signal of 1-pin of module U2 to front end of resistor R30, after optocoupler U5 isolation, then through the operational amplifier power amplification by U6, and output high level signal to turn on the power transistor of c2→e2, and pumping energy on bus voltage is releasing through the circuit" BUS+→ Discharge Resistor→ BUS-", the bus voltage decreases after energy release. When the bus voltage is detected to be less than the set stagnation point voltage, the resistance R30 front end signal becomes low level voltage, and the output signal of operational amplifier is also low level voltage, it can turn off the power tube IGBT [4]. The whole circuit loop is break off with "BUS+ →Discharge Resistor →BUS-", the discharge processing stops.

Ⅲ.Analysis of Discharge Problem

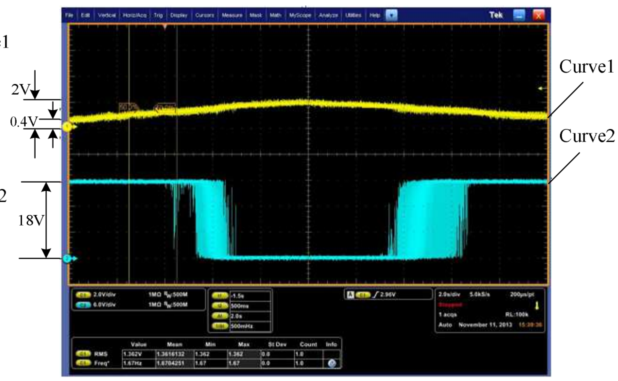
The failure of discharge function occurs after the communication circuit system worked continuously for a long time. At this time, the temperature of the communication circuit system increases due to the heating of the discharge resistance during the discharge process. Consequently, under the condition that the discharge control circuit works normally, and discharge control module outputs the discharge open signal, heating model U2, optocoupler U5, operational amplifier U6 with heat gun and measuring the temperature [5]. When the temperature of the communication circuit system was rises to 61.5℃, and from the oscilloscope, the output curve was different from that normal atmospheric temperature. Consequently, the relief control module U2 and operational amplifier U6 are no relationship with the problem of discharge function.

Heating the optocoupler U5, and measuring the temperature of the optocoupler. It can seen that the discharge indicator light goes out gradually with heating the optocoupler to 61.5℃, and stop heating, the indicator came on again. Under these circumstances, observed the output signal of the optocoupler with an oscilloscope. The waveform is shown in the Fig.2.



Curve1— Intput signal of optocoupler U5 2V/grid
Curve2— Output signal of optocoupler U5 2s/grid

Fig. 2 Output curve of optocoupler

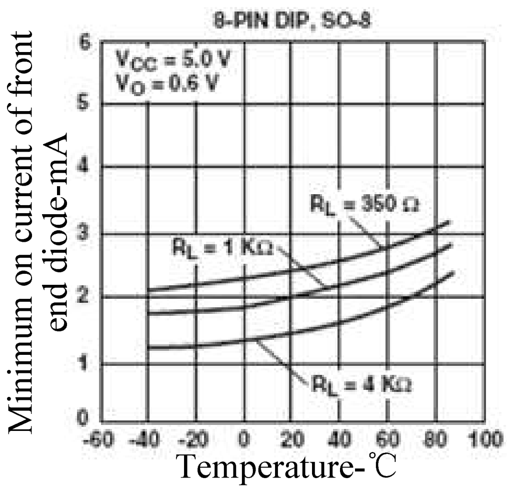


Curve1— Input signal of operational amplifier U6 2V/grid
Curve2— Output signal of operational amplifier U6 2s/grid

Fig. 3 Output curve of operational amplifier

During the whole heating process of the optocoupler, the input signal is always at a high level voltage with 3.6V, and the output signal increases gradually from low level 0.4V to high level 2V with the increase of temperature. Stop heating with optocoupler, and with the decrease of temperature, the output of optocoupler gradually changes from high level 2V to low level 0.4V with the increase of temperature. This moment, the optocoupler U5 outputs the signal to the next operational amplifier U6, and the U6 input and output voltage waveform with Fig.3. With the increasing temperature, the input voltage of operational amplifier U6 also changes. And the input voltage of U6 from low level 0.4V changes to high level 2V. The output voltage of operation changes from high level with 18V to low level with 0V after a high frequency oscillation transition period, then the temperature decreases, the output voltage of operation changes from low level with 0V to high level with 18V after a high frequency oscillation transition period, and the output signal of the operational amplifier is output to the grid of the power transistor. Consequently, the reason of abnormal operation of optocoupler under high temperature is the failure of IGBT and discharge resistance.

More analytic discussion of the test and product data of optocoupler.(The model of optocoupler is 6N137). Replace the failed optocoupler with a new one [6]. With the discharge circuit working, heating the optocoupler to 60℃, we find that the discharge circuit working well. But with the increasing temperature, there is still be anomalies. Therefore, it can draw a conclusion that optocoupler is unreliable at high temperature. According to the product manual of 6N137, the conduction current of the front-end diode of the optocoupler increases with the increase of temperature.



voltage:5V/grid，time:20μs/grid

Fig.4 Minimum on current of front end diode　　**Fig.5 Output waveform of operational amplifier**

For the discharge control circuit, the resistor of R15 and R30 is used to control the conduction current of the front-end diode of the optocoupler U5. According to resistance R15, R30, voltage of the front-end of the optocoupler, it can be calculated that conduction current value of the optocoupler U5 is 2mA. According to the minimum on current of front end diode of Fig.4.Below 60 degrees, when the conduction current is 2mA, the optocouple in the circuit can be turned on. But when the temperature is higher than 60℃, the minimum conduction current of the optocoupler is more than 2mA. It makes the diode can not conduct reliably. At high temperature, when the optocoupler is unreliable, it can output a high frequency oscillation signal, as the curve2 of Fig.3. The driving voltage of IGBT from high voltage level to low voltage level and from low voltage level to high voltage level, and the enlarged waveform is shown in Fig.5.

When the output signal frequency of the operational amplifier exceeds the maximum operating frequency of the power transistor，and it can damaged the G and E of IGBT[7][8]. This damage can leads to a short circuit problem to burn out discharge resistance. By measuring the gate resistance of the damaged power transistor IGBT, the resistance value is less than 1Ω (The normal resistance is greater than 1MΩ).Consequently, the failure of the discharge resistor and IGBT is caused by the unreliable conduction of the optocoupler U6 at high temperature. And the unreliable conduction of the optocoupler U5 at high temperature is caused by the insufficient conduction current margin. Even if the current margin can ensure the normal operation of the normal operation of the normal temperature discharge circuit, but it is easy to cause unreliable conduction of optocoupler due to insufficient conduction current at a high temperature.

The type of IGBT in the main discharge circuit is CM100DY-12H, its specified current is 100A, withstand voltage is 600V. Since the discharge point of the discharge circuit is 70V, and stagnation point is 62V. By calculation, the discharge current of the main discharge circuit is 35A. It can be seen from the value that withstand of IGBT which meets the specification well.

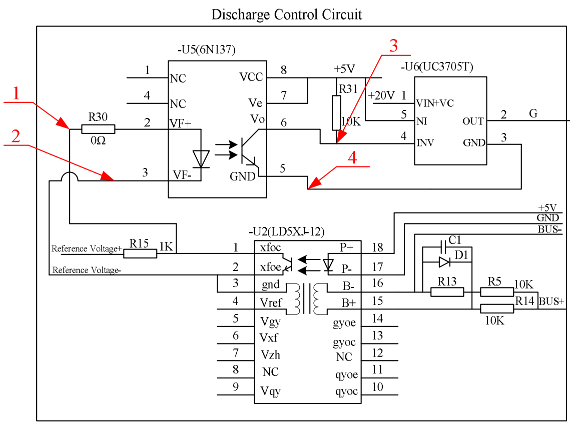
Therefore, the main reason for the failure of the discharge function of the power supply box is that the resistance of the front end of the optocoupler is too large, and make the current margin of optocoupler is insufficient, this makes the temperature of the system increases. Form the product manual of 6N137, components cannot conduct reliably under high temperature, then damaged the gate and source stage of the power transistor IGBT, and it's also causes the discharge resistance to burning-out.

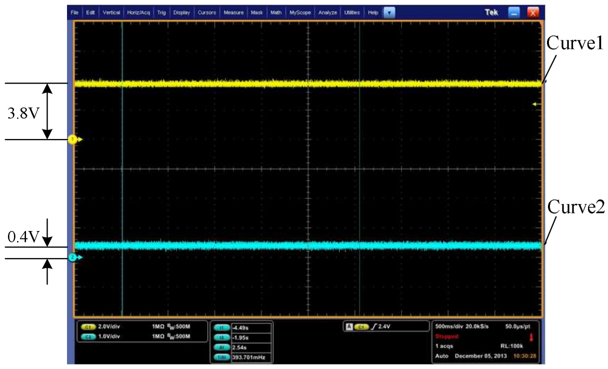
Ⅳ.Experimental Verification of Discharge Circuit Optimization

a. Conduction reliability Test of Optocoupler

According to the above analysis on the failure of relief function, it can be seen that, if reduced the current limiting resistance of the front end of the optocoupler from 1KΩ to 0Ω, and the conduction current can be increased from 2mA to 4mA.At this time, the conduction current reaches the maximum threshold current. This method can solve the problem of unreliable conduction in high temperature.

Next, the verification test of the optimized discharge circuit is carried out. As shown in the Figure 6. The four test wires are respectively welded to the corresponding positions in the circuit, and extend the four test lines out of the test chamber. First, verify the box discharge function under normal temperature. Observe the waveform of oscilloscope. It can be seen that, the output waveform of oscilloscope is perfectly. Next, raise the chamber temperature to 60℃, and then observe the waveform of oscilloscope. The waveform of oscilloscope discharge function is shown in the Fig.7.





Curve1— Discharge control module U2 output，2V/grid

Curve2— Optocoupler output ofU5，1V/grid，500ms/grid

Fig.6 Welded position diagram of test wires

Fig.7 Output curve of optocoupler

It can be seen from the above test results that when the test chamber temperature is 60℃, the output curve of U2 is consistent with the output curve of U5. Therefore, this test meets the discharge function requirements of communication circuit system. The optimized circuit meets the system performance requirements.

b. Continuous Working Test of Discharge Control Circuit

Connect the components of the system. Power up the system, and after the system working continuously for one more an hour, and observe the phenomenon of the discharge indicator light at the power supply box. If the light continues to flash, it indicates that the discharge function of power supply box is normal. The test results are shown in List.1.

List.1 Continuous working test of discharge control circuit

No. / Items	***023	***024	***025	***026	***027	***028
Cable core voltage 1	56.35V	55.67V	55.83V	56.26V	56.38V	55.72V
Cable core voltage 2	55.91V	55.58V	56.35V	56.42V	56.58V	56.15V
Over voltage protection	Normal	Normal	Normal	Normal	Normal	Normal
Discharge function indicator	Normal	Normal	Normal	Normal	Normal	Normal

It can be seen from the above test data that the optimized discharge control circuit fully meets the performance index of communication circuit system. Furthermore, the discharge function of the communication circuit system completely normal.

Ⅴ. Conclusion

This paper analyzed the problem of discharge control circuit at a high temperature, and concluded that the unreliable optocoupler leads to the failure of the discharge function. Proposed an optimal design of discharge circuit, and verified the optimized circuit. The results show that the threshold current of the optocoupler can be increased by reducing the discharge resistance. This optimization method not only meets the functional requirements of the communication system, but also improves the reliability of the system.

References

[1] Joseph Carr, Microwave & Wireless Communications Technology, Newnes,1996.

[2] Andrew Leven, Telecommunication Circuits and Technology, Elsevier, 2000.

[3] P. W. Tuinenga, SPICE: A Guide to Circuit Simulation and Analysis Using PSPICE. Englewood Cliffs, NJ: Prentice-Hall,1988.

[4] The Simulation Standard Designing a High-Voltage IGBT Structure with TCAD April, May, June 2010.

[5] K. V. Dubovenko, Yu. 1. Kurashko, "The Design, Fabrication and Testing of a Closing Switch for Compact Electrical Discharge Industrial Equipment", 11th IEEE Pulsed Power Conference, Baltimore, Maryland, 1997, pp. 868-874.

[6] H. G. Kerkhoff, Theory, Design, and Applications of Digital Charge-Coupled Devices PhD Thesis, Twente University of Technology, Enschede, The Netherlands, Apr. 1984.

[7] Allen R Hefner. Analytical Modeling of Device-Circuit Interactions for the Power Insulated Gate Bipolar Transistor (IGBT) [J]. IEEE Trans. on Industry Applications, 1990, 26(6):995-1005.

[8] Sheng K, Williams B W, Finney S J. A Review of IGBT Models [J]. IEEE Trans. on Power Electronics, 2000, 15(6):1250-1266.