

Triggering device for the long-gap triggered vacuum switch

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Abstract. This manuscript represents a triggering device applied on long-gap triggered vacuum switch. The time delay between the optical signal and the pulse current is about 100ns. From the image of the initial plasma captured by the high speed camera, the triggering device presented in this manuscript is reliable.

1. Introduction

Triggered vacuum switches(TVS) are the circuit switching devices based on the technology of vacuum gap and trigger spark gap. As the key device applied on high power pulse power technology, different kinds of TVS have been researched a lot these years. And the long-gap triggered vacuum switches have been widely used in high power pulse power technology. The triggering device plays an important role on the reduction of switching losses and the improving of switching rate of the long-gap triggered vacuum switch[1]. As the development of the high power pulse power technology, the cascade applications and the parallel applications of triggered vacuum switches are gradually taken seriously. In this manuscript, a kind of triggering device for the long-gap triggered vacuum switch has been studied.

2. The conduction mechanism of triggered vacuum switch

Fig. 1 is the schematic of the long-gap triggered vacuum switch. The high voltage is applied between anode and cathode, and the distance between anode and cathode is larger than 2 cm. The triggering pulse from the triggering device is applied between cathode and trigger pin, and the distance of the trigger gap is about 3 mm. When the triggering pulse is applied between cathode and trigger pin, the initial plasma is generated in the trigger gap. Consequently, the initial plasma will be accelerated in the electric field between anode and cathode, and bombardment the anode. Finally, more and more charged particles will be generated to conduct the long-gap triggered vacuum switch. Since the research of J. C. Martin on the factors of the pulse front, there are many scholars have tried to establish the circuit model of the spark, so as to explore the conduction mechanism of triggered vacuum switch[2,3].

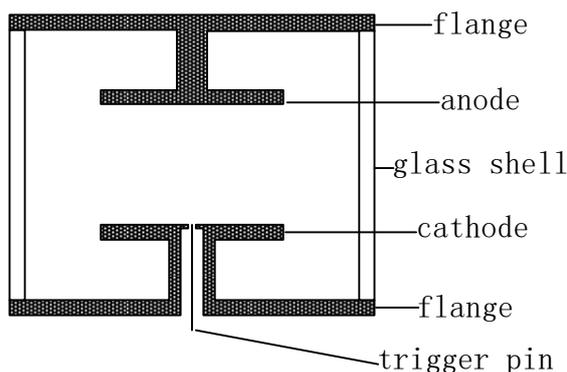


Fig. 1 The schematic of the long-gap triggered vacuum switch

The work process of the long-gap triggered vacuum switch could be divided into the initial stage and the conducting stage of the main gap(the space between anode and cathode). In the initial stage, the initial plasma is generated from the triggering gap, and diffused into the main gap. As the density of plasma increases, the metal vapor arc in the main gap conducts the anode and cathode, and this could be named as the conducting stage[4,5]. There are mainly three kinds of conduction theory. The first theory is that field emission affects the breakdown of trigger gap in the initial stage[6-8]. The second theory is that the escape of the internal gas from the coating material of the cathode affects the breakdown of trigger gap[9,10]. The third theory is that the charged particles emission from the cathode spot and sheath theory affects the breakdown of trigger gap in the initial stage[11]. In general, it is important for the triggering device to guarantee reliable operation of the long-gap triggered vacuum switch in either theory.

Most of the triggering devices generates high voltage pulse to breakdown the trigger gap and generate initial plasma. And the duration of output pulse current is short(several us). In this manuscript, the duration of output pulse of the triggering device is much longer than the traditional devices.

3. Circuit Design

Fig. 2 is the schematic of the triggering device for the long-gap triggered vacuum switch. The low voltage charger is made up with lithium battery, DC boost module and the voltage detecting circuit. The charging voltage range to the capacitors is from 100 to 300 V. The ratio of the high voltage pulse transformer is 1:10000. The high voltage silicon stack is used to prevent high voltage pulse from C2. The optical pulse from the optical pulse generator transmits through the optical fiber, and received by the pulse trigger. In the meantime, the pulse trigger generates electric voltage to drive MOSFET, and the circuit 1 is turned on. The circuit 1 is composed of C1, MOSFET and the primary side of the high voltage pulse transformer. Carefully choose the capacitance of C1, make sure that the circuit 1 is an underdamped circuit, and the attenuation coefficient is about 0.5. Once circuit 1 is turned on, the underdamped circuit generates an oscillating current. In consequence, the high voltage pulse is generated from the secondary side of the high voltage pulse transformer. The trigger gap is breakdown by the high voltage pulse. Then circuit 2, which is composed with C2, high voltage silicon stack and the trigger gap, is turned on. In consequence, the energy storing in C2 is released through the trigger gap, and the initial plasma is generated.

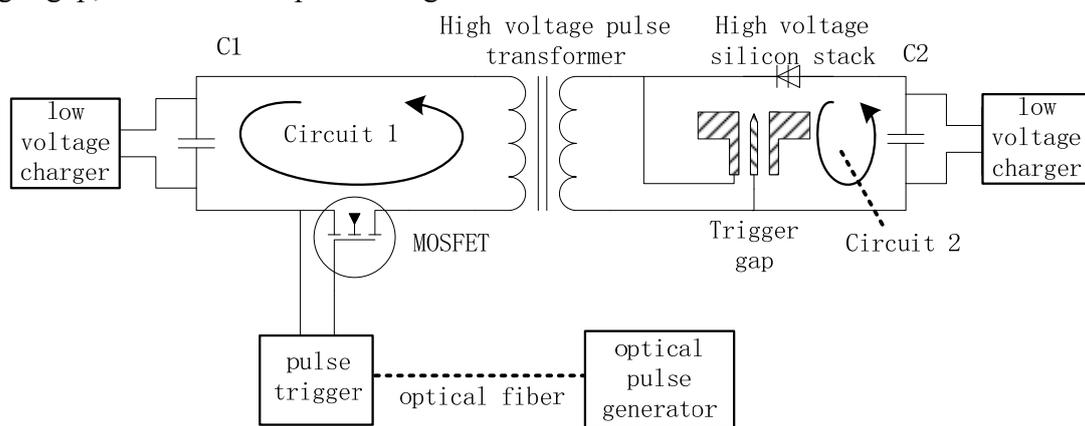


Fig. 2 The schematic of the triggering device for long-gap triggered vacuum switch

4. Circuit Design

If the initial voltage of C2 is 0V, the breakdown current of the trigger gap is shown as Fig. 3. It is easy to find out the natural oscillation frequency of circuit 1 is about 20 MHz. The total duration of the pulse cluster is about 0.3 us. The duration of single pulse is about 25ns. And the oscillation current is alternating.

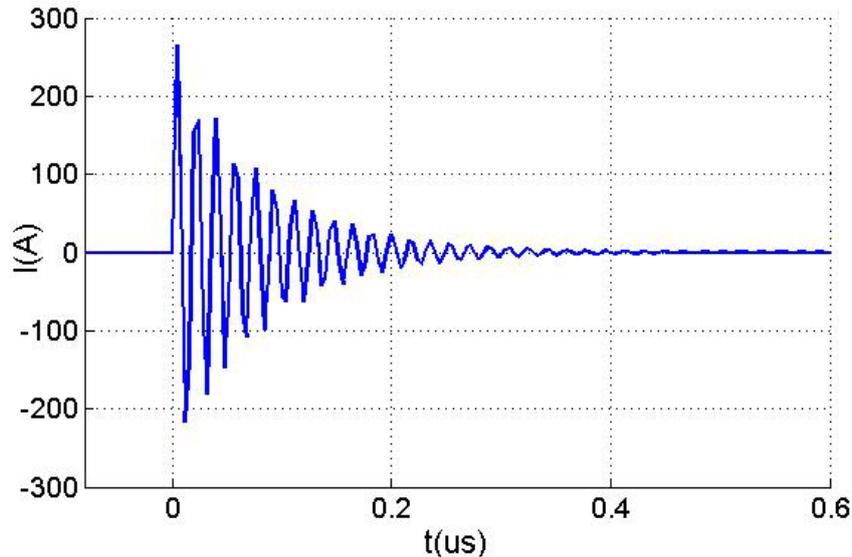


Fig. 3 The breakdown current of the trigger gap without C2

If the initial voltage of C2 is 300V, the breakdown current of the trigger gap is shown as Fig. 4. The total duration of the pulse cluster is longer than 50us. And the most of the breakdown current is direct. In this situation, the duration of the initial plasma is longer, and the operation of the TVS is much more reliable.

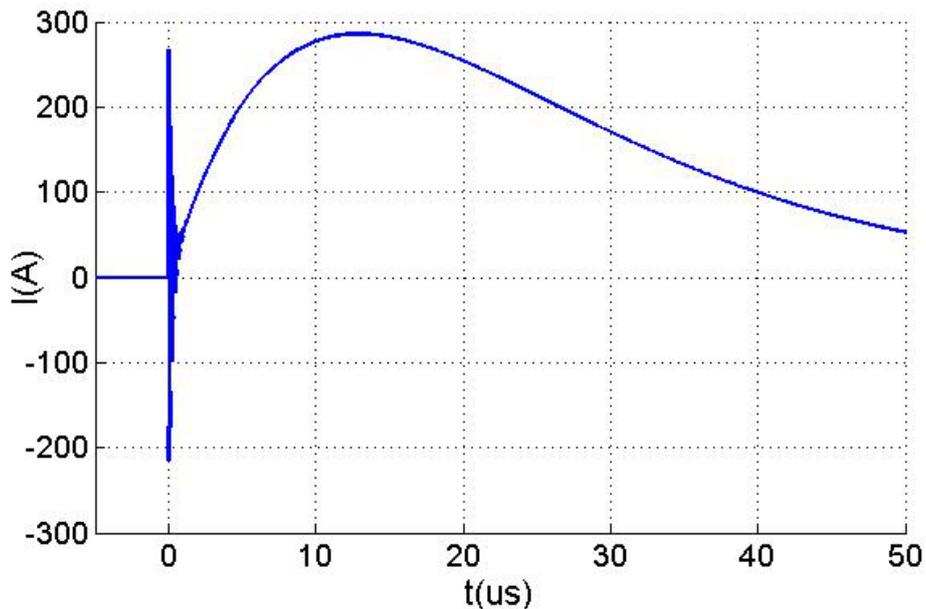


Fig. 4 The breakdown current of the trigger gap with C2

Fig. 4 shows the delay between the optical signal and the breakdown current. Experiments show that the delay is about 100ns, and the error of delay is within 10ns. The response rate of MOSFET is the major factor causing delay between the optical signal and the breakdown current.

The total duration of the pulse cluster is about 300 ns, and the conduction time of long-gap triggered vacuum switch is about several us. Generally, the error of delay, which is within 10ns, is acceptable. Fig. 5 shows the delay between the optical signal and the triggered current. It's worth noting that the duration of optical pulse signal should be much longer than the total duration of the pulse cluster generated by circuit 1, otherwise MOSFET may be in risk of overvoltage fault.

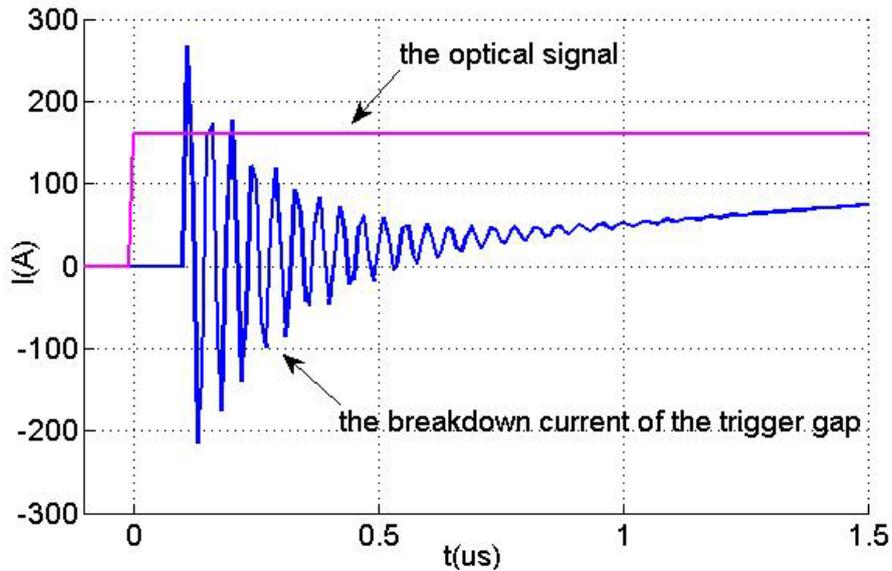
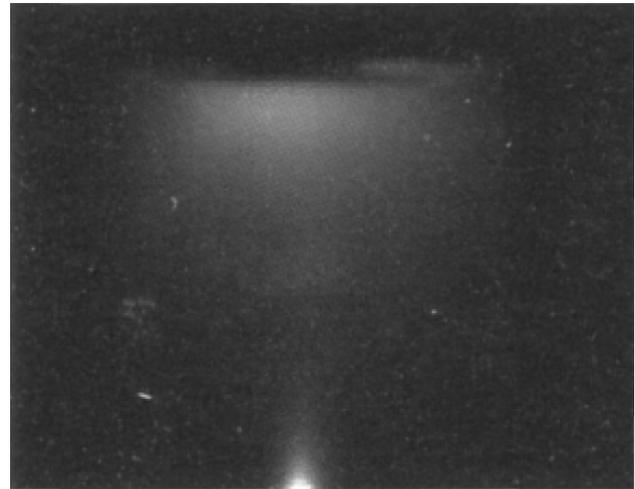
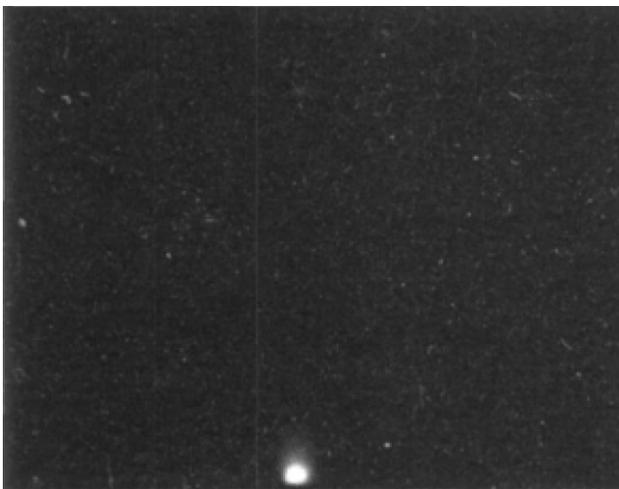


Fig. 5 The delay between the breakdown current of the trigger gap and the optical signal

The images in Fig. 6, which were captured by high speed camera, show the initial plasma generated from the triggered gap. In Fig. 5a, the initial plasma behaved like a small light spot, and filled the trigger gap. In Fig. 5b, the initial plasma diffused into the main gap, and the charged particles were accelerated by the electric field between anode and cathode. Part of those charged particles bombardment the anode. The bright area near the anode in Fig.5b indicates that more and more charged particles were generated from the bombardment. Obviously, the long-gap triggered vacuum switch was not conducted at the moment when Fig.5b was captured. Consequently, the longer duration of the initial plasma is helpful to improve the reliability of the long-gap triggered vacuum switch.



a) the initial plasma generated from the triggered gap

b) the initial plasma diffusing into the main gap

Fig. 6 The initial plasma generated from the triggered gap

5.Summary

This manuscript represents a triggering device applied on long-gap triggered vacuum switch. The time delay between the optical signal and the pulse current is about 100ns. From the image of the initial plasma captured by the high speed camera, the triggering device presented in this manuscript is reliable.

Acknowledgments

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