AC-charged High Voltage Trigger Generator with an Optical Control Signal

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Abstract

Trigger generator is a significant device for triggering the high voltage spark-gap switch. We present the relation between breakdown delay at the load and the polarity of output voltage of trigger generator with regard to variations of pressure and how charging voltage affects the discharge time.

Keywords : Trigger Generator Spark-Gap Switch Breakdown Delay

1. Introduction

In recent years, high power electromagnetic systems are emerging and continue to advance in various fields. Particularly, high power warfare systems such as directed energy transmitters attract the notice of developed nations. Those systems need electrical power supply to transmit and radiate high power rf signal at the front end. According to system's operation mode, there are largely two modes such as one-shot mode and repetition mode. As how to design the electrical power supply affects the efficiency and reliability of the systems, operation modes are related to the electrical power supply. There are several methods to make power supply to generate the high voltage and current to the load. Namely, Marx which uses various capacitors in series or parallel is combined to pulse-forming-network (PFN) [1] which matches the impedance of load using RL C circuit and pulse-forming-line (PFL) [2] which does that using coaxial line. And the output voltage of each induction cell is summed in the cavity structure as the induction voltage adder (IVA) [3]. The output voltage of cavity can be increased by containing more number of induction stages. High voltage power supply uses series or parallel capacitor's banks to make high voltage. Those capacitor's banks are related to the high power switches such as spark-gap switch. To turn on or off the high power switch, generally trigger generator is used [4][5]. One of the important components in trigger generator is a switch which has a spark-gap with modest pressure. In this paper, we design the tunable spark-gap to adjust time delay and jitter according to method of the operation of load. And we analyze the relation between charging voltage and polarity of pulse trigger signal to reduce the breakdown delay which is an important parameter to take an action against requirements of the instantaneous operation. Also, we check the discharge falling time of spark-gap switch with respect to the different charging voltages.

2. Implementation of Trigger Generator

Trigger generator consists of several electrical modules. As shown in Fig. 1, the AC power enters and passes through the EMI filter which is connected to a circuit breaker. The AC power through EMI filter is fed to the primary of the transformer T1 and then AC power is amplified to 750 VAC on the secondary of the transformer T1 connected to the full bridge rectifier which converts 750 VAC to 1 kVDC. Switching Module Power Supply generates ±24 VDC which are used to drive the switching board. The optical signal from Trigger Command Control Unit controls SCR which delivers the energy to transformer T2 which has the voltage ratio of 1:120. Practically, T2 amplifies the secondary voltage up to the 100 kV to take the safety into account.

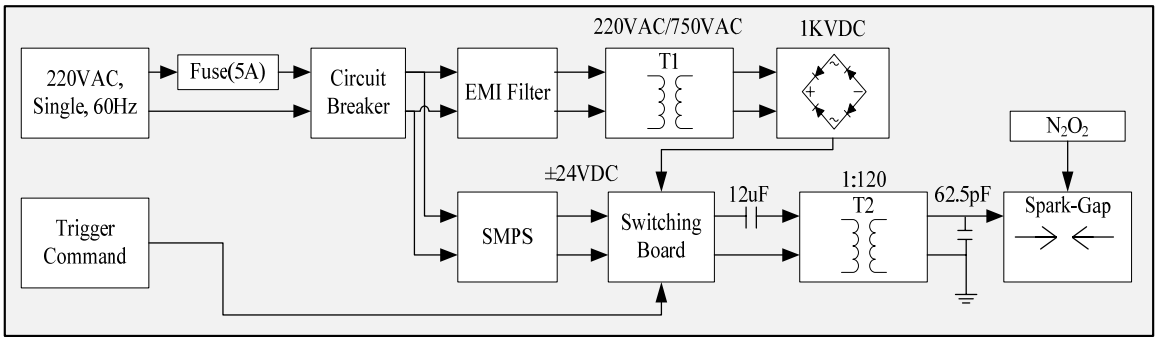

Figure 1: Block Diagram of Trigger Generator

The operation of Spark-Gap is varied by the condition of pressure and the distance between two electrodes. The lower distance between two electrodes, the more easily it breaks down. Also, the electrical breakdown delay differs according to the condition of the polarity of the input high voltage. Fig. 2 shows the structure of the implemented Trigger Generator.

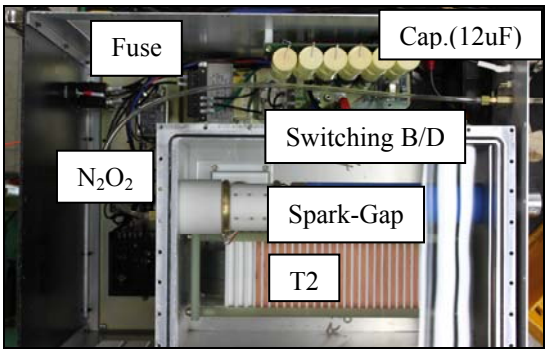

Figure 2: Structure of the implemented Trigger Generator

3. Experimental Results

To test trigger generator, we make the test bench of trigger generator which is composed of Capacitor Charged Power Supply (CCPS), N_2O_2 gas tank controls the pressure of up to 0.5 MPa and Load comprising spark-gap switch, model 40265, made by L3 Company in USA and high power resistor of 2 kΩ, which are dipped into silicon-oil tank and provided by Pohang Accelerator Laboratory (PAL), as shown in Fig. 3. Capacitance of series-capacitors connected to the CCPS is approximately to 13.3 uF. Charged voltage by CCPS is divided into 1/4 of amount by series-resistor of 10 MΩ. Therefore, the voltage on trigger plate of spark-gap switch keeps minus half of charged voltage. To analyze the breakdown delay, we test trigger generator by externally-connected optical signal with different polarity. We set the N_2O_2 gas pressure to 0.4 MPa and charge the spark-gap switch up to -60 kV. And then we check the breakdown delay at the TP1 and TP2, as shown in Fig. 3. First of all, we trigger spark-gap switch by the positive pulse of the output voltage of trigger

generator. The horizontal axis is referenced to the rising time of the remote optical pulse signal from Trigger Command Unit to trigger generator (TG).

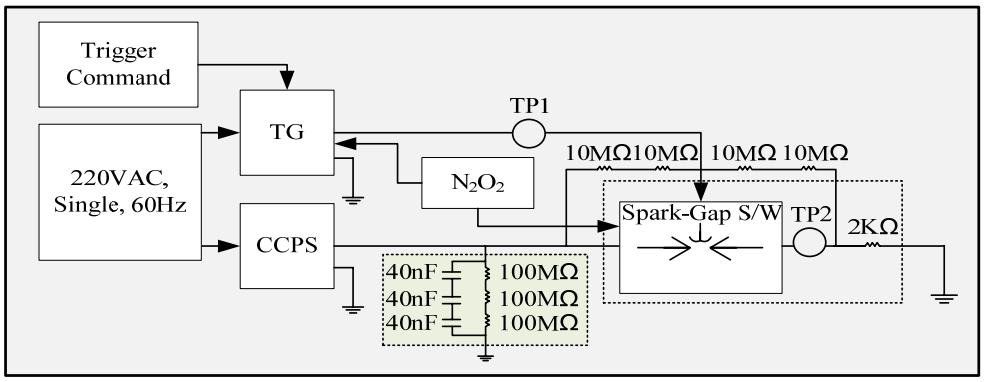

Figure 3: Test Bench of Trigger Generator

Figure 4 shows the breakdown delay of 14.6 us approximately at the point of TP1. -60 kV charged is divided into -30 kV on the trigger plate of spark-gap switch by 4 series-10 MΩ resistors. The output voltage of trigger generator, which is fed into the trigger plate of spark-gap switch, is similar to the positive sinusoidal pattern so that its voltage is raised up to about +6 kV at the point of TP1. As the voltage between the electrodes of spark-gap switch is charged up to -60 kV, the voltages of input and output of spark-gap switch are 66 kV and 6 kV respectively. Because of the self breakdown voltage of spark-gap switch limited to about 45 kV, instantaneously breakdown voltage is established across spark-gap switch. Its voltage reaches a maximum voltage higher 20 kV than the self breakdown voltage. However, Figure 5 presents the breakdown delay of 29.3 us approximately at the same point. That's why more time is needed to change the polarity of the output voltage of trigger generator from negative to positive. The output voltage pattern of trigger generator is sinusoidal as that of the resonant equivalent circuit of RLC.

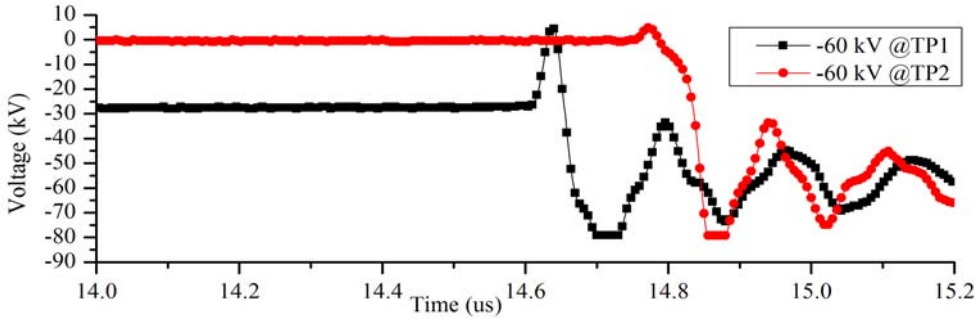

Figure 4: Breakdown delay with positive trigger pulse

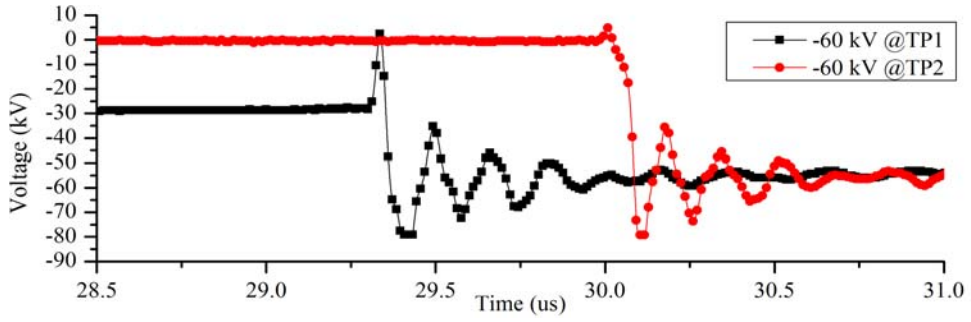

Figure 5: Breakdown delay with negative trigger pulse

We set pressure to 0.4 MPa and use the positive pulse duration of trigger generator to trigger spark-gap switch. Figure 6 shows that the higher charging voltage is, the shorter discharging time. The discharge falling time of the first trigger is about 143 ns on TP2 when -40 kV is applied and around 112 ns on the same point when -60 kV is charged. It can reduce jitter which can be generated after the load if we use sufficient charging voltage.

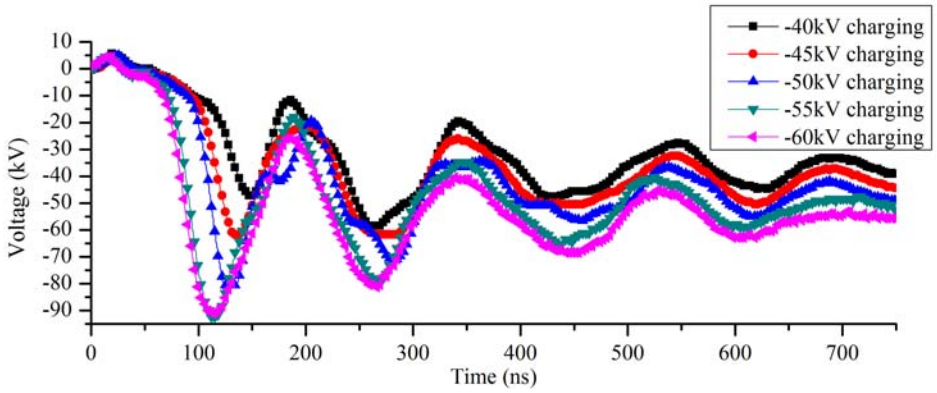

Figure 6: Comparison of the discharge time with different charging voltages

4. Conclusion

The performance of trigger generator with the output voltage of different polarity is compared and analyzed through experiments. Breakdown delay is faster when the positive pulse of the output voltage of trigger generator is applied to the load. When charging voltage is higher, the discharge time is faster. Future work is to test trigger generator and spark-gap switch with independent pressure unit respectively to tune the delay and jitter for more precision.

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