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THE TRIGGERING OF HIGH CURRENT PSEUDO-SPARK SWITCHES

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Introduction

The pseudo-spark geometry is particularly well suited for switching high currents and voltages at high peak and average power levels. The principles of the low pressure pseudo-spark discharge have been described earlier[1,2] and the basic switching features in Ref. 3. Contrary to the case of a high pressure spark the pseudo-spark discharge path is predictable and reproducible. It always follows the system axis through the holes in the centre of both hollow electrodes. The current transition to the electrodes is spread over a relatively large surface area around, inside and behind the centre holes (Fig. 1) and not concentrated into small spots like in high pressure or vacuum discharges. As shown in Ref. 3 the pseudo-spark chamber can be triggered with low energy from the rear side of the cathode. The main discharge gap remains free from elements like grids, trigger pins, etc. After a pseudo-spark discharge rapid de-ionization is observed, hence high repetition rates can be obtained. Moreover, the dead time can be controlled to some extent from the hollow cathode space[4].

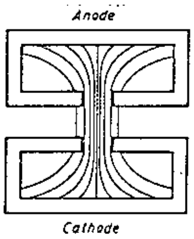


Fig. 1 Current flow in a pseudo-spark switch.

In this paper we deal with the problem of triggering high current discharges of the order of 100 kA and more. Pseudo-spark switches have been developed for a 20 kV pulse generator which delivers current pulses of 500 kA and 12 μs half-wave length on an impedance level of approximately 40 mΩ. Four switches are triggered simultaneously in parallel every 3 to 4 seconds. The switch and the trigger systems have to be well taylored to meet the severe conditions of erosion and metal vapor contamination. After the initial breakdown phase the discharge in the main gap has the characteristics of a z-pinch discharge. The principal insulator is protected against metal deposition by dielectric and metallic screens (Fig. 2). The magnetic self field confines the plasma in the centre region.

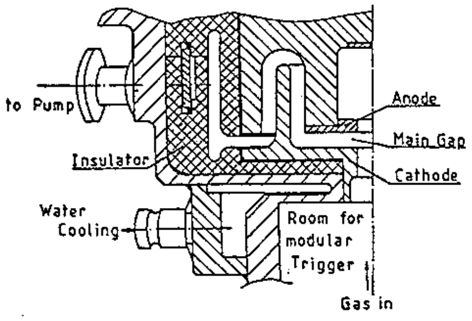


Fig. 2 Main insulator protecting screens.

Trigger methods for high current pseudo-spark switches

Two requirements have to be met in the application described above:

- protection of the trigger system against destruction by the main current pulse and against metal vapor deposition.
- precise triggering of better than ±100 ns to guarantee simultaneous operation of four switches.

Trigger methods, which are good candidates to fulfil these objectives are discussed below.

a) Dielectric surface breakdown trigger

This method has been described in Ref. 3. It most efficiently works when the trigger electrode is incorporated into the cathode centre hole. However, in high current discharges destruction happens after a few pulses due to metal vapor deposition. When displacing the surface trigger away from the main cathode plate the protection becomes better, but delay and jitter are gradually increasing (Fig. 3). Both are functions of gas pressure, main and trigger voltage, size and potential of the virtual anode and distance from the main cathode surface. With the trigger system shown in Fig. 4 we switched 100 kA with a precision of ±20ns (Fig. 5). The distance d_t between the main and trigger gap was 34 mm. Several hundred pulses of 100 kA amplitude did not change the characteristics of this trigger.

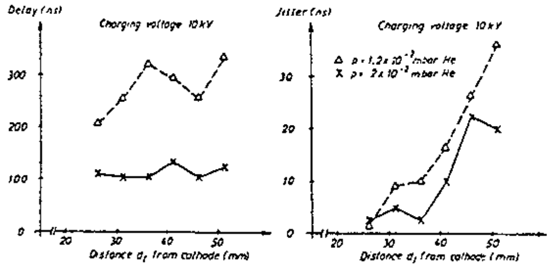


Fig. 3 Delay and jitter as function of triggering distance d_t from main gap.

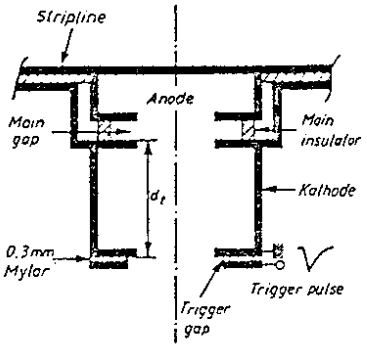
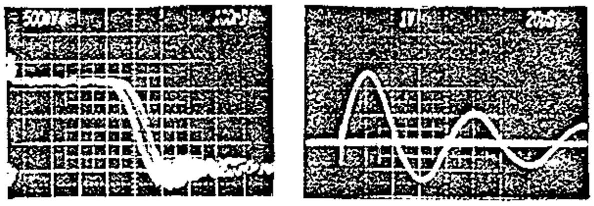


Fig. 4 Surface trigger for high current switch.



a) b)

Fig. 5 Jitter of voltage pulse a) and current wave form of pseudo-spark switch at 100 kA.

b) Charge injection trigger

The principle of the d.c. electron beam trigger introduced in Ref. 3 has been further improved by Metersheimer[4] for laser applications. It is also well suited for our high current switching application. Figure 6 shows the scheme of this trigger type which combines a pre-ionizing glow discharge and the blocking potential method with a superimposed trigger pulse onto the glow discharge region. The whole trigger system is well protected from the main discharge by a cylindrical cage around the centre hole at the rear cathode surface. The cage contains the virtual anode and is accessed by the blocking potential (≈300 V) and the trigger pulse (≈200 mA) via several holes. The blocking potential is switched to zero before and during the main discharge phase. In spite of long switching delays (≈1 μs) jitter values less than 5 ns are observed.

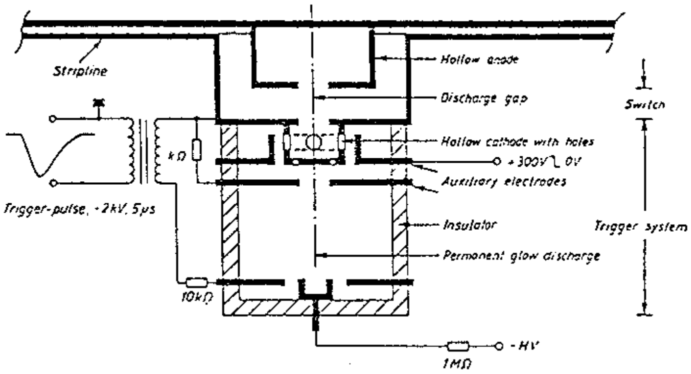


Fig. 6 Principle of charge injection trigger.

In high current discharges the metal cage protects the different insulators of the trigger system efficiently against contamination and damage. From the viewpoint of lifetime this trigger system is superior to the surface discharge trigger. Gas pressure, d.c. current value and trigger pulse amplitude are important parameters for the trigger process as well as the external trigger circuit layout. Figure 7 shows the delay and the jitter as functions of trigger pulse amplitude for two d.c. current values. Good triggering is only achieved in the region where the burning voltage u across the d.c. chamber is increasing with rising current i (du/di > 0). The blocking potential switching and the trigger pulse can be both generated with transistorized circuits. Though a time jitter of less than ±1 ns has been observed with such a trigger system, the severe influence of the main discharge in a high power switch on parameters like temperature and gas pressure leads to a deterioration of the switching precision. The performance depends on the uniformity of operating conditions at the moment of discharge. Delay times of 400 to 2000 ns with a time jitter of ±20 ns has been measured with 100 kA pulses.

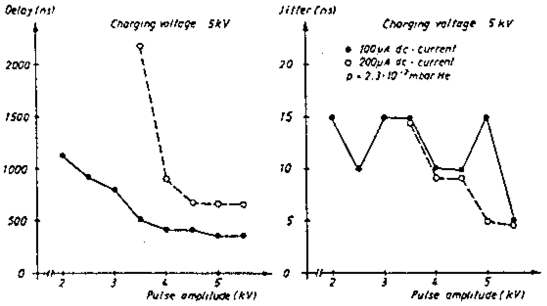


Fig. 7 Delay and jitter as functions of trigger pulse amplitude for two d.c. current values.

Conclusions

Pseudo-spark switches have been developed for switching more than 100 kA at 20 kV on an impedance level of 40 mΩ. Four switches are triggered simultaneously with a precision of better than ±20 ns each discharging a capacitor bank of 5 kJ into a common z-pinch load. Different trigger systems can be inserted into the high current switches in a modular way. The surface trigger system needs a short pulse of 2 mJ energy only, but has a limited lifetime to 10^4-10^5 shots. A second trigger system based on charge injection into the virtual anode region, is much less prone to damage by the main discharge. However, it requires more elaborated trigger circuits. The necessary d.c. power is approximately 100 mW. Both trigger methods demonstrate the unique precision of breakdown control with very small trigger energy in the virtual anode region of pseudo-spark systems.

References

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