Triggered graphite spark gaps using build in battery driven high voltage impulse amplifiers with an opto electronic input

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Abstract

Spark gaps can be made from brass copper or other metallic electrodes. Under high current and high charge transfer the metal may vaporize and create some deviations in trigger performance. A new approach using graphite electrodes avoids the disadvantages of metal electrodes because no metallic plasma is generated.
The trigger of such electrodes can be reached using a spark plug, which is driven by a small impulse amplifier inside the graphite electrode. A battery of 1,5 volt can continuously provide the required trigger voltage for more than one year. The amplifier ha s a build in pin diode which can be triggered using a fibre optic cable coming from a digital time control system with laser outputs. The advantage of such a system is the potential independent triggering either on anode or cathode. The trigger range reaches 50 % of the nominal static breakdown voltage. The abrasion of electrodes is low even under thousands of shots of 10/350µs impulse currents. The latest technology in miniaturization of electronic devices has even more reduced the size of the high voltage trigger amplifier. The paper shows the design and the trigger range as well as some pictures of electrodes after use in a crow bar switch.

1 Introduction

A spark gap for high voltage or high current switch is still a cheap and reliable solution. When a triggered spark gap is required, a spark plug may be build into the spark gap which is triggers using a trigger voltage of some kV. To provide the spark plug with the trigger voltage of some kV, various solutions e.g. using coupling capacitor or a grounded spark gap may be used. One solution is the integration of the trigger voltage generator inside the electrodes of the spark gap. The trigger electrode can be realised using commercial spark plugs. The best range of reliable triggering can be reached using a low energy spark. Using copper electrodes or other metal electrodes metal vapour may condense on the surface of the insulating material of the spark plug. Therefore

2 Design of the trigger system

Fig. 1 shows the principle circuit of the trigger system. The high voltage electrode contains a spark plug. This spark plug is triggered using a high voltage impulse of16 kV. The circuit is shown in Fig. 2 .The trigger voltage is generated using a 1,5 V battery, which drives a switching mode power supply. To generate the high voltage impulse a capacitor is charged to some 100 volt. This capacitor will be discharged using FET-switch into a high voltage impulse transformer, which generates the trigger voltage as shown in Fig. 3. The command for trigger is controlled using a digital timer unit with a resolution of 100 ns. The output is transferred into a laser impulse. A fibre optic cable is connected to the high voltage impulse amplifier. The laser impulse triggers finally the impulse amplifier as shown in Fig. 2. The impulse amplifier can be placed into one or both electrodes.

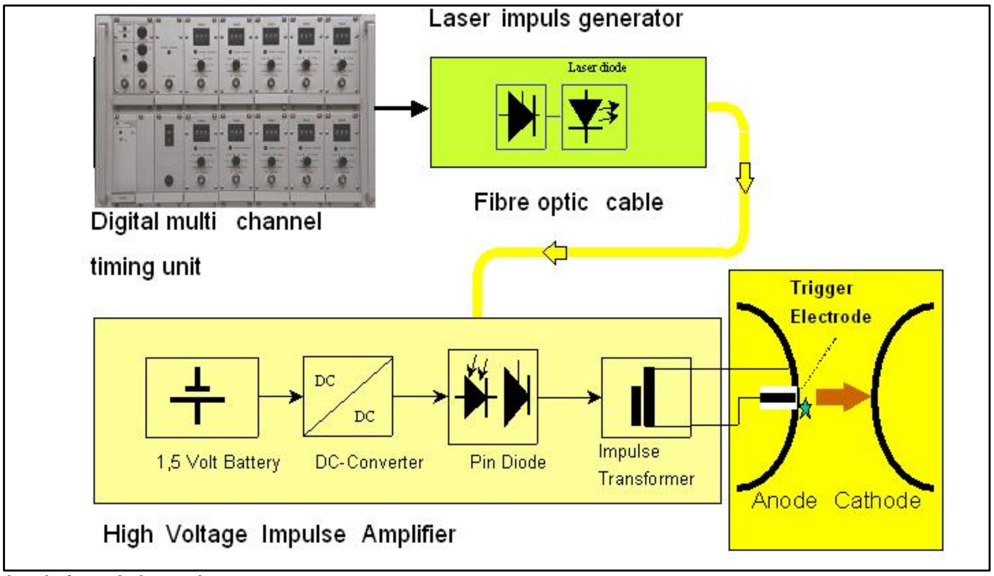

Fig. 1 Principle of the trigger system.

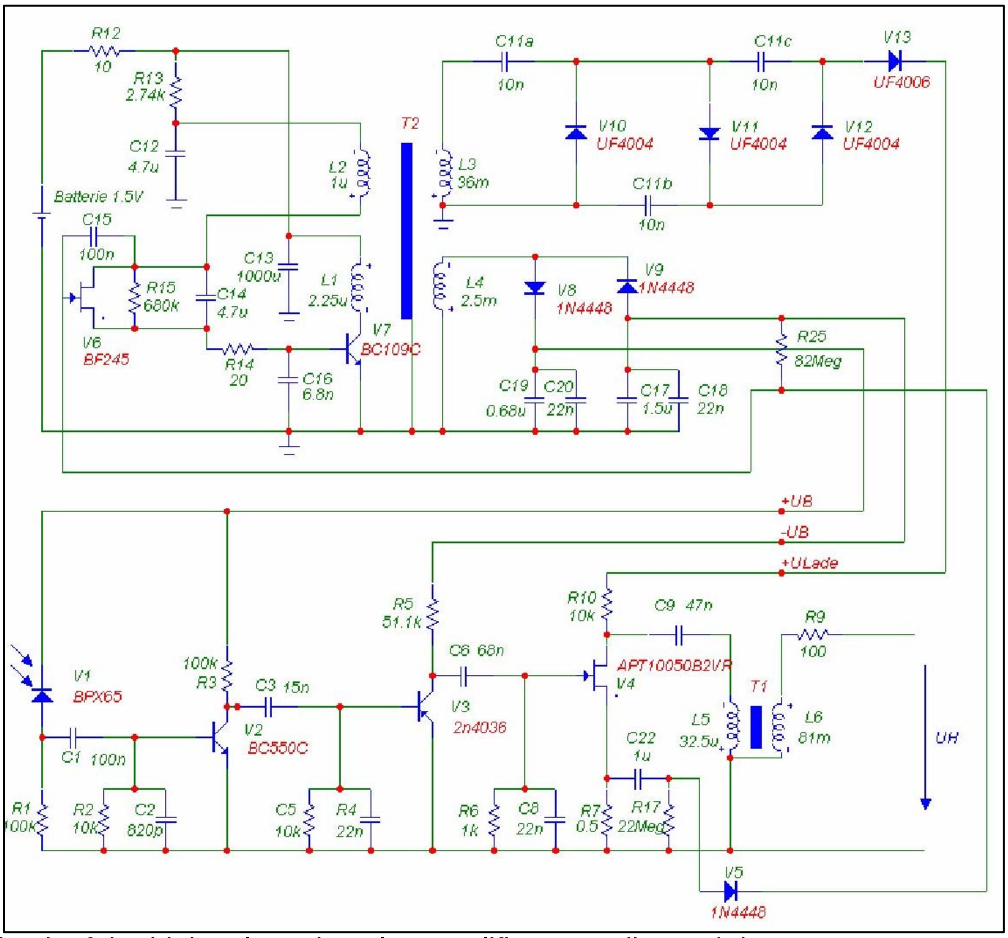

Fig. 2 Circuit of the high voltage impulse amplifier according to /1/.

The material of the electrodes of a high voltage or high current spark gap has to be designed according to the transferred charge. For triggered spark gaps the spark plug is also influenced by the transferred charge. Conventional spark plugs consist of a ceramically insulated electrode. When metal electrodes are used, metal vapour may condense on the Surface of the ceramic insulation. Since the impulse amplifier as shown in fig. 3 provides only a low energy impulse, the condensed metal would act as a short. Therefore graphite was used as electrode material. Table 1 compares the properties of graphite and metal electrodes.

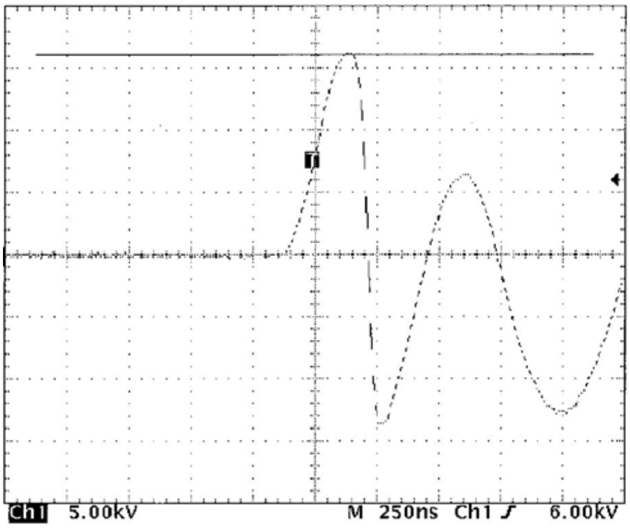

Fig. 3 Open circuit voltage of the high voltage impulse amplifier. 5kV/Div.

	Melting	Vaporization	Condensation	Solidification
Metal WCu, Cu, Fe	Liquid phase	Vapour phase with high pressure	Condensation with conductive layer on insulating materials	Strong erosion due to solidification of melt
Graphite	•Quasi-sublimation •Liquid phase oxidates immedialtely to CO_2	Very little vaporization	No liquid phase	Little deposit of soot

Table 1 Properties of electrode materials.

2.1 Design of electrodes of the spark gap

To reduce the volume of the spark gap, the electrodes were designed as Rogowski profiles. Fig. 4 shows one graphite electrode containing a high voltage impulse amplifier. The high voltage impulse amplifier is continuously operating. With one battery a safe operation of nearly one year is possible. The repetition rate is nearly 1 Impulse per min. Fig 5 shows a set of 5 spark gaps of a multiple impulse generator with triggered electrodes on anode and cathode, designed for 100 kV charging voltage. The electrodes are made from commercial available graphite. The electrodes are tested with many different impulse shapes in high voltage and high current impulse generators. Especially, current impulses of 10/350µs up to 200 kA with a charge transfer of 100 As have been used. The ageing of the graphite is very little. The surface of graphite electrodes remains smooth even after a high number of impulses. This experience however is gained using impulses. The behaviour under long duration impulses may differ due to thermal heat conduction.

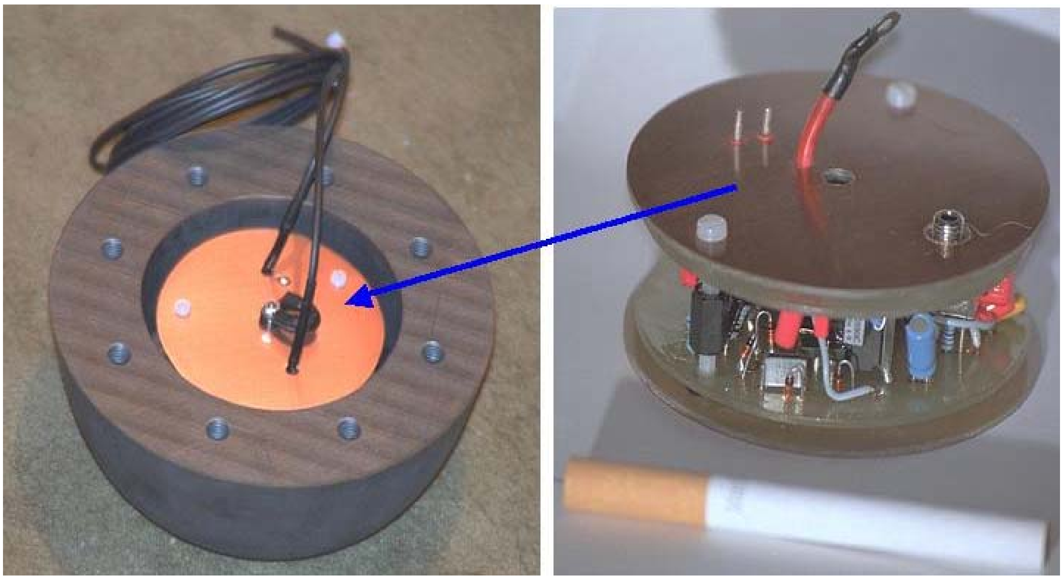

Fig. 4 Rogowski electrode with integrated high voltage amplifier.

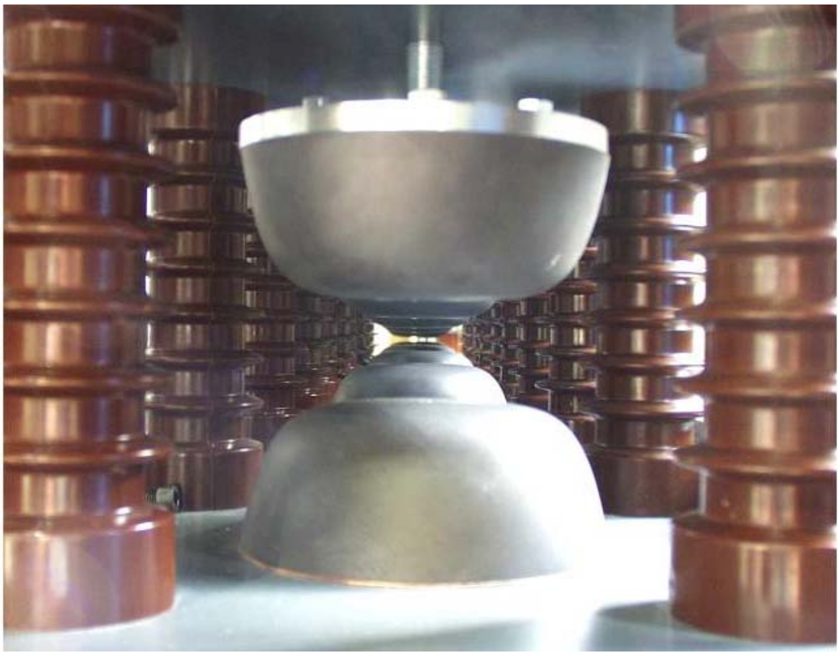

Fig. 5 Set of 5 spark gaps in a multiple impulse generator.

2.2 Performance of triggered graphite spark gaps

The performance of a triggered spark depends on a few parameters like the time to breakdown, the jitter and the range of reliable trigger. Fig. 6 shows as an example the range of reliable trigger for 6,5 mm gap distance. The static breakdown voltage is considered as 100 %. Fig 6 shows that a reliable trigger is possible even fewer than 60 % of the static breakdown voltage of the gap; however with an increased delay time and increased jitter. In many technical applications of high voltage or high current switching, a relative voltage of 70-80% is sufficient to prevent self-trigger of the gap and the related jitter is acceptable. In other cases of multi-gap applications the operation at 50-60% relative voltage is required to prevent triggering caused by voltage spikes from adjacent gaps. However the increased jitter limits the application.

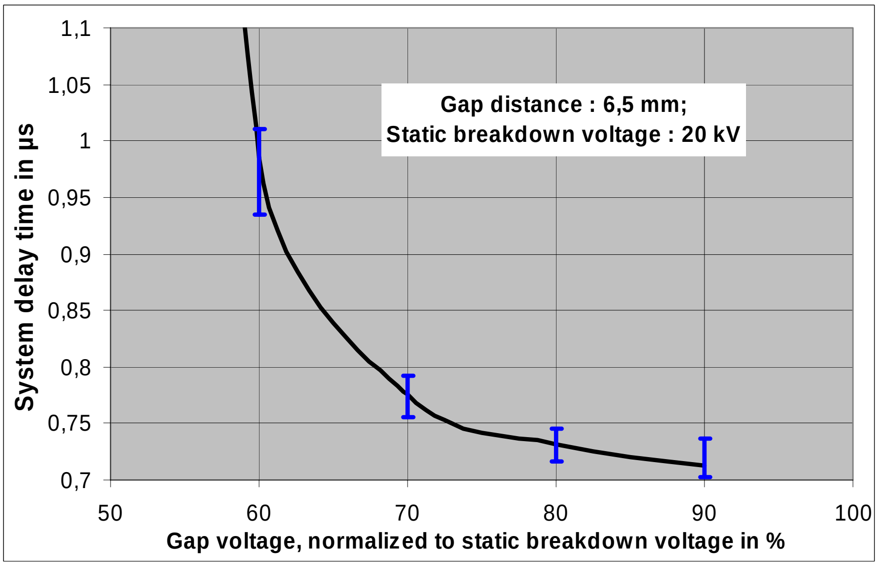

Fig.6 System delay time and Jitter of a 6,5 mm triggered 100 kV graphite spark gap

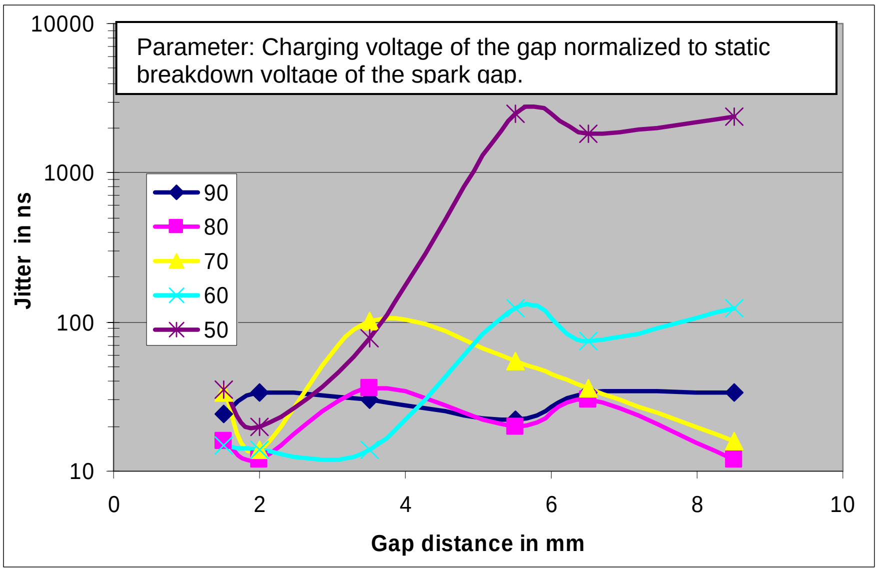

Fig 7 Jitter of a triggered graphite spark gap depending on the gap distance.

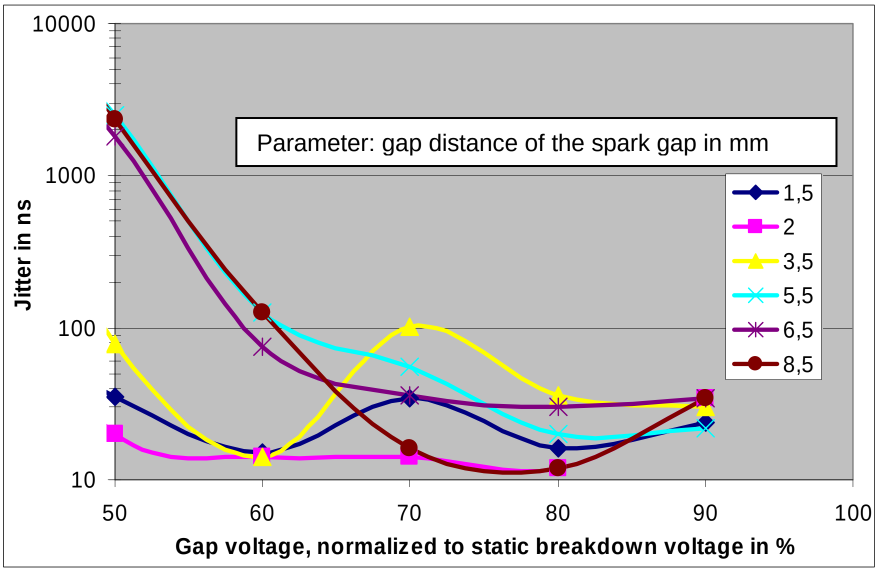

Fig.8 Jitter of a triggered spark gap depending on the relative voltage

3 Application

Fig 9 shows a 200 kA crow bar impulse generator /2/ which contains 6 graphite spark gaps. Fig 10 shows a detailed view of the spark gaps in the crow bar part of the generator. All spark gaps are encapsulated using epoxy resin tubes for reduction of noise.

Fig. 9 Crow bar generator for 10/350µs wave shape, 200 kA peak current, 100 As charge transfer and 10 MJ/Ohm specific energy.

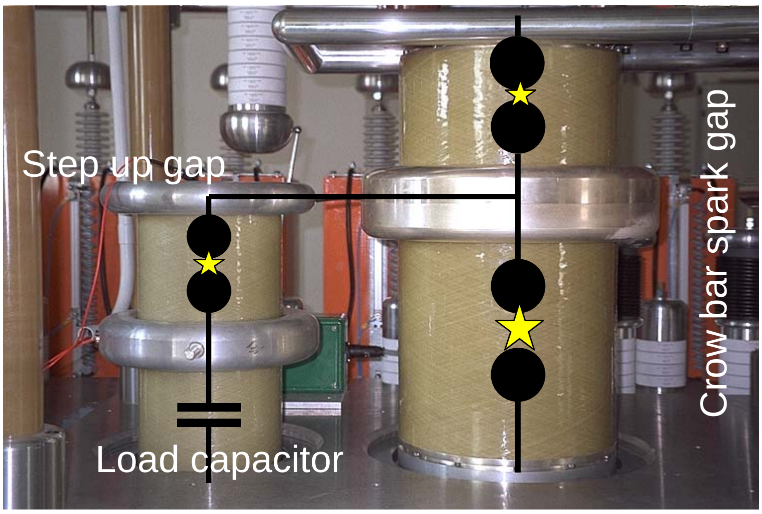

Fig 10 Detailed view of the crow bar switch.

References

[1] Reinhardt, H.J.: Untersuchungen über den Zündmechanismus einer getriggerten Funkenstrecke. Dissertation, Berlin 1977.

[2] Drilling, C. Droldner,M., E.G. Jordan, Jan Meppelink. A new generator for testing .of SPd´s using multiple lightning current impulses for combined tests with follow currents. Proceedings of 24^{th} International Conference on Lightning Protection: 14^{th}-18^{th} September 1998, Birmingham, United Kingdom.