DEVELOPMENT OF A 10 STAGE MULTIPLE LIGHTNING SURGE HYBRID GENERATOR WITH VARIABLE TIME INTERVAL AND PEAK VALUE

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Abstract
The development of a Hybrid Generator that generates up to 10 x 8/20µs current impulses or 10 x 1.2/50µs voltage impulses is described. The new feature of this generator is the variable time between two pulses and the variable peak value of each impulse using triggered spark gaps and high voltage switched mode power supplies. Both polarities can be chosen within a series of pulses.

1 Introduction

A lightning strike has a devastating effect to objects. Nearby electrical devices can be damaged due to the rise of earth potential and the induced voltages caused by the rate of rise of the electromagnetic field.
During a direct lightning strike into a building, the potential of the foundation ground electrode increases suddenly to some 100 kV. The Protective Earth is also grounded at the foundation ground electrode. If spark gap arresters are installed in the low voltage installation, these respond in the case of multiple flash discharges repeatedly and must carry off and extinguish the follow current. Therefore, the development of a spark gap arrester also must consider this case.

2 Design of a multiple lightning surge hybrid generator

In (1) a multiple impulse generator for current impulses is described which is based on a capacitor bank with spark gaps. This principle allows multiple current impulse generation with constant time between the individual pulses. To simulate real multiple lightning currents, a variable time between the individual pulses should be realised. Fig.1, and Photo1,2,3,45, show the 10-stage Hybrid Generator which is constructed on the basis of a 1-stage Hybrid Generator (2). The 10 stage Hybrid Generator produces 10 x 8/20µs current impulses in short circuit operation or 10 x 1.2/50µs voltage impulses in open circuit operation, either polarity and each impulse with variable amplitude, compare Fig.2,3,7. The time between two individual pulses can be varied in a wide range.
The basic performance data of the generator are listed in Table 1.

Table 1: Basic performance data. 1) Without air flow; 2) with air flow in spark gaps.
The limitation of the Minimum Time between Impulses (MTI) is explained in 2.4.

	Short Circuit	Open Circuit
Number of Impulses	1-10	1-10
Waveform	**8/20** µs	**1.2/50** µs
Peak Value	**38 kA**	**20 kV**
Minimum Time between Impulses (MTI)	**7 ms,1)**	**25 ms,1) 5ms,2)**

2.1 Function of the hybrid circuit

The Hybrid Generator is based on the principle of a RLC circuit (Fig. 1). The capacitors are charged up to U_n=20 kV. The spark gaps (SG) are triggered sequentially according to the set time. Depending on the impedance of the Equipment under Test (EUT), the generator produces either 8/20µs current impulses in short circuit operation (e.g. testing of arresters) or 1.2/50µs voltage impulses in open circuit operation (e.g. testing of insulation).

2.2 Charging system

Capacitors are charged on the set value by a switched mode power supply. A Cockroft-Walton cascade rectifies the voltage and charges the capacitors up to 20 kV, either polarity. A control device compares the set value with the actual value, which is measured by a voltage divider.

2.3 Trigger system

A trigger system with a wide trigger range and a resolution of 100 ns is described in (3). A Digital Time Control Device (DTCD) is necessary to realise the short intervals between every stroke. The set time can be varied in a scale of 100 ns up to 10 s. Spark gaps can be triggered at a set time and below the actual static breakdown voltage by the use of ignition amplifiers (3), compare Fig.5 and Photo6.
The ignition amplifier transforms a battery voltage of 1.5 V up to 5 kV. This voltage causes a spark between the inner W/Cu-Electrode and the outer Grafite-Electrode (Figure 5). The spark distorts the electric field between the two Grafite-Electrodes and causes a breakthrough of the charged spark gap. Using this trigger system, spark gaps can be triggered down to 50% of their static breakthrough voltage. This advantage can be utilised when charging the individual stages of the generator with different voltages without self triggering of gaps. If e.g. the second capacitor is negative charged, the range of safe triggering is depending on the difference of voltage across the spark gap. Therefore the generation of a sequence of positive and negative impulses is limited.

2.4 Problem of reignition

The spark gaps of the multiple generator are triggered sequentially. After the breakdown of a spark gap the air between the electrodes is ionised and therefore conducting. The molecules of the air have recombined after a short time. The triggering of the following spark gap causes a transient voltage u_{tr} at the preceding one. The voltage u_{tr} can reignite the preceding spark gap if the molecules are not sufficiently recombined. The minimum time between impulses (MTI) is the shortest time where reignition does not occur. The MTI for different voltage combinations were measured for short circuit and open circuit operation. Fig 6 shows the recovery time (MTI). To reduce the recovery time of an ionised spark gap we use pressurised dry air which is blown through the spark gaps. This reduces the recovery time remarkable as shown in Fig. 6.

3 Performance of the generator

In Fig. 7 the first shot of 5 open circuit impulses of 1,2/50 µs is shown. The peak voltage varies from 20 kV,15kV and 10 kV. As a first effect in the very first shot a resistor which was designed for a withstand voltage of 25 kV and tested with one 1,2/50µs pulse flashed over when exposed to the sequence of 5 pulses as shown in Fig.7. This experience shows that there is an effect of the number of pulses on the strength of air gaps or the external insulation of surge arresters as shown in (4).
Following improvements of the generator are planned:
- A coupling of the multiple generator to a surge generator with crowbar switch. The surge generator will simulate the high energetic first return stroke of natural lightning using a 10/350µs high current impulse.

Bibliography

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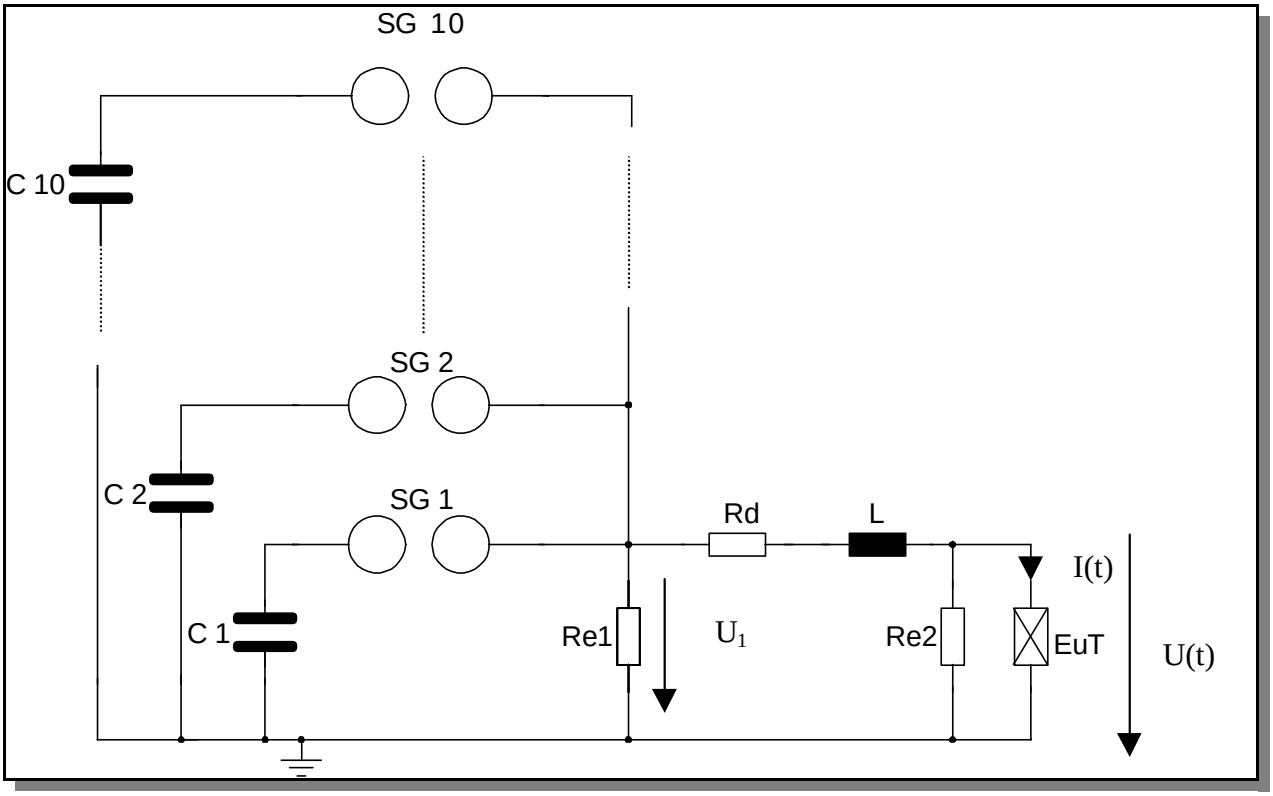

Fig. 1 : 10-stage Hybrid Generator.

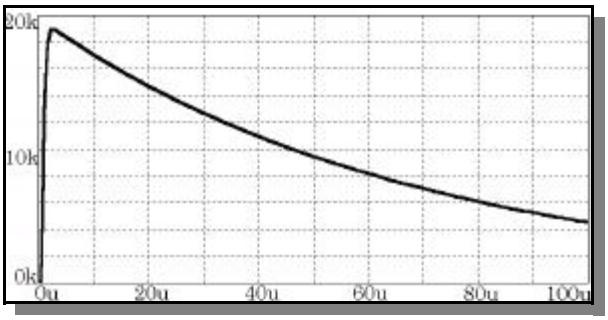

Fig.2 : Shape of one pulse of the open circuit voltage 1,2/50 µs as a result of simulation of the circuit in Fig.1.

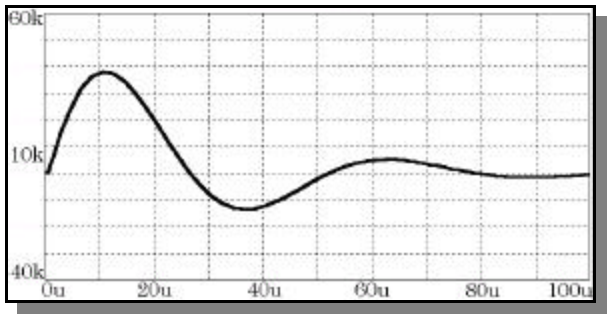

Fig.3 : Shape of one pulse of the short circuit current 8/20 µs as a result of simulation of the circuit in Fig.1.

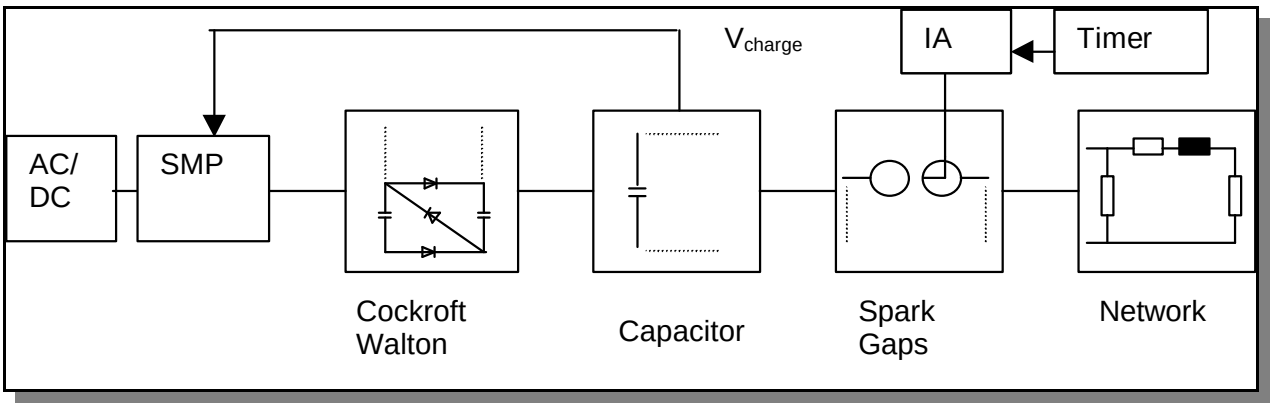

Fig. 4 : Basic circuit diagram of on e charging unit. SMP:Switsched mode power supply; IA: High

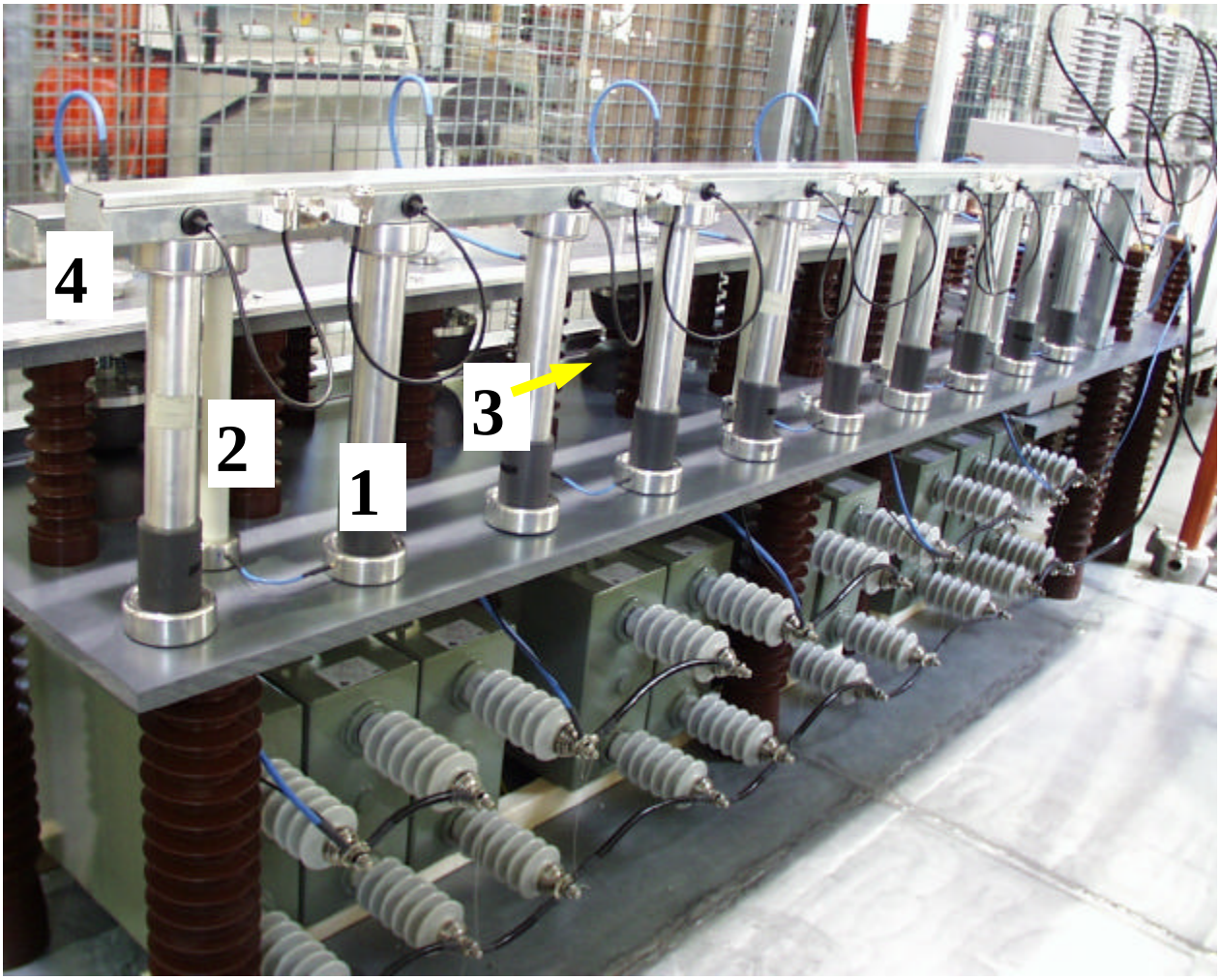

Photo 1 : 10 stage hybride generator (partial view of 5 stages)
1: Cockroft-Walton cascade; 2: Voltage divider; 3: Spark gap; 4: Cable tranch;

Photo 2 : View of the charging units inside a cabinet.

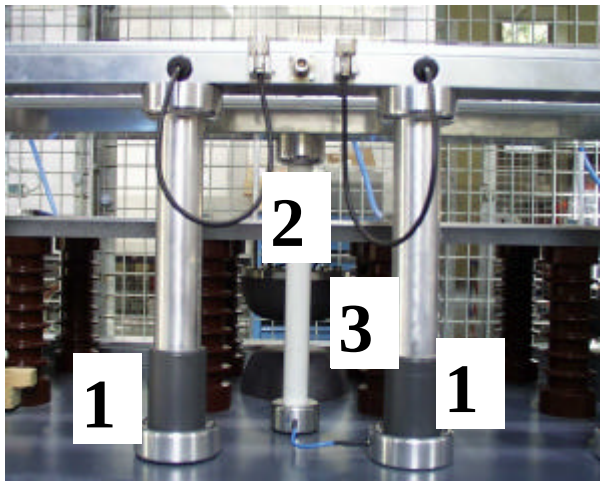

Photo 3 : Detailed view of Photo 1
1: Cockroft-Walton cascade;
2: Voltage divider;
3: Spark gap behind the Voltage divider

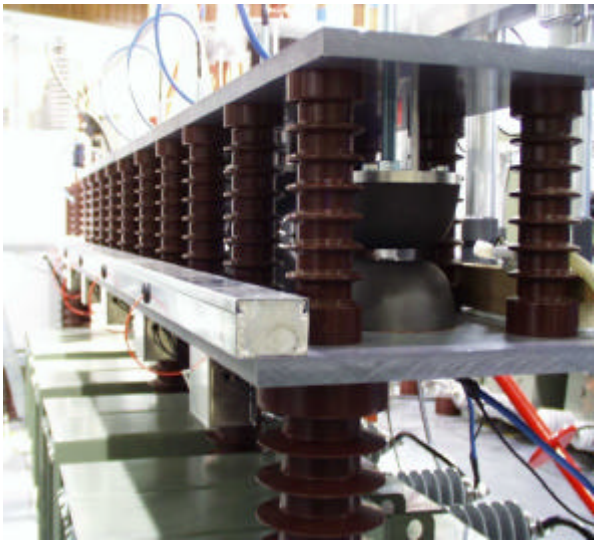

Photo 4 : View from the back side.

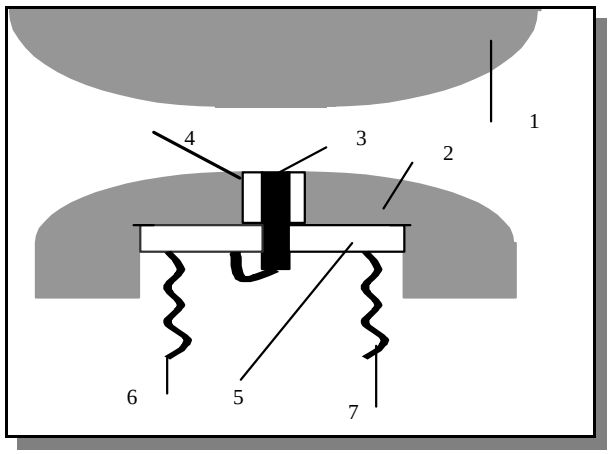

Fig.5 : Cross section of a spark gap.
1,2 : Graphite –Elektrode; 3 : Al_2O_3 Ceramic;
4 : Cu/W Elektrode; 5 : High voltage impulse Amplifier; 6 : Fibre Optic Cable;
7: Battery 1.5V

Photo 5 : View of Spark gaps of one bank of 5 units.

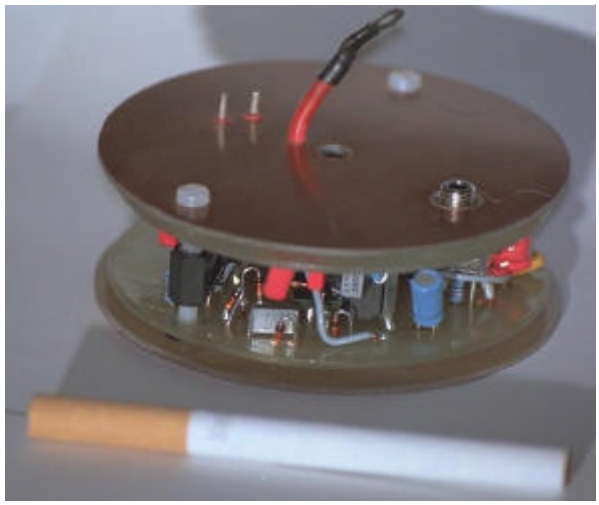

Photo 6 : High voltage impulse amplifier

Photo 7

Digital Time control device.
Resolution : 100 ns
Maximum Time : 10 s.
Operation : Sequential mode or parallel mode.
Synchronisation on AC-Voltage
Output : 20 W Laser Impulse Diode into a fibre optic cable.

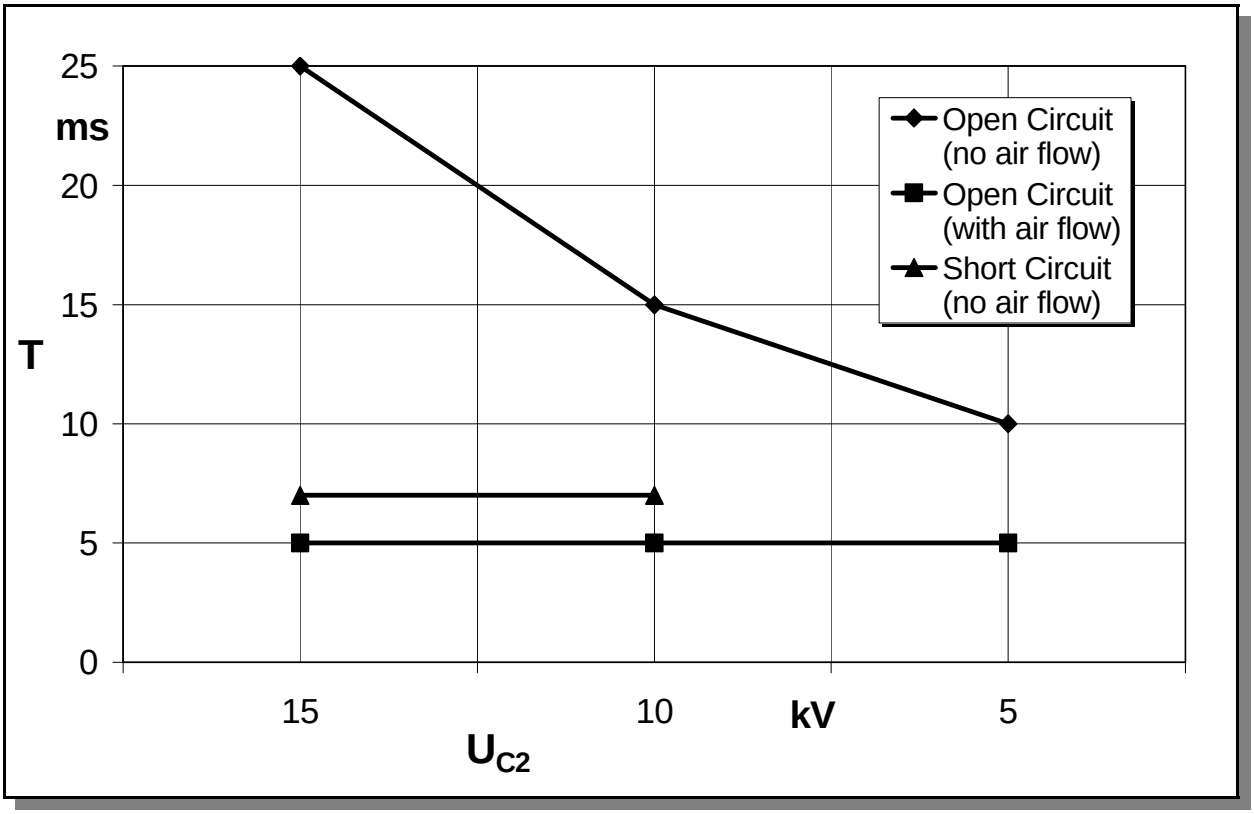

Fig.6 : The recovery time T of spark gap 1 depending on the charging voltage of C2 , C1 is charged on 15 kV(Compare Fig.1). Spark gap 1 (Fig.1) triggeres at first. After the recovery time T, the spark 1 has reached its initial strength to withstand the voltage stess caused by the triggering of gap 2. The curves show the influence of the air flow on open circuit operation.

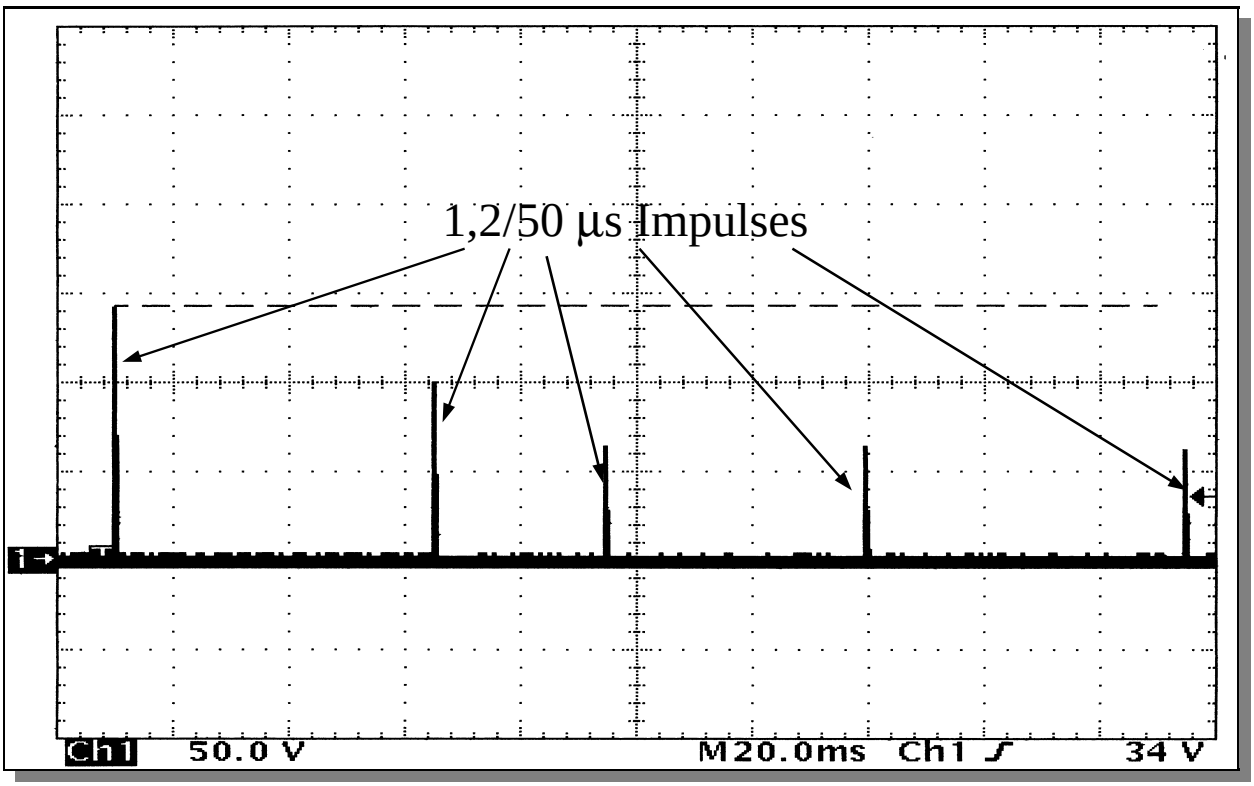

Fig.7 A sequence of 5 multiple impulses 1,2/50ms. 6,75kV/DIV; 20 ms/DIV.