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A new triggered multiple gap system for any kind of voltages

A. Rodewald

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Multiple gap systems, i.e. several series connected gaps, are often used for short-time of high voltages switching (in the order of 10^6 V). So as to be sure that each single gap takes over an equal part of the total voltage, it is necessary to have a voltage distribution control. Such a control by means of capacitors and parallel connected resistors having a high ohmic value is certainly the most common method. as it is effective with d.c., a.c. and steep impulse voltages. However, this method has been seldom used till now, the reason being that most of the known multiple gap systems are fired with nonlinear voltage distribution along the chain of the grading elements. An equally effective control for high and low frequencies results however in a very uniform distribution of all voltage shifts on all elements, so that such multiple gap systems of the common type are difficult to trigger, i.e. just under the natural firing voltage.

To fire nevertheless at far lower values than at the natural firing voltage the individual gaps of a multiple gap system having good control caracteristics at any frequency, the idea of using for this purpose the existing charge of the grading capacitors C_{sn} becomes quite obvious. This can be done in principle by two means. One can try to realize a so-called cross-triggering in each gap, or find ways of producing high overvoltages on the individual gaps. The latter method, i.e. firing with overvoltages, would be the better solution, this sort of triggering, as is well known. showing a more favourable time-dispersion behaviour than cross-triggering.

The simplified circuit shown in fig. 1 allows a very efficient overvoltage production. In this lay-out, the individual gaps are not connected directly with the chain of grading elements C_{sn} and R_{sn}, but by means the resistors R_n.Inductances can also be used instead of resistances, or even a combination of both.

This circuit operates as follows: each grading capacitor C_{sn} is charged to voltage U_o either by a d.c. or an impulse voltage source. Thus, the voltage U_o lies equally on each single gap F,. If, under these conditions. the first gap F_1 is triggered and fired, for instance with an auxiliary spark, the first grading capacitor C_{s_1} will discharge through resistor R_1. A transient voltage u_{R_1} (t) is generated. The essential characteristic of the circuit fig. 2 is the fact that

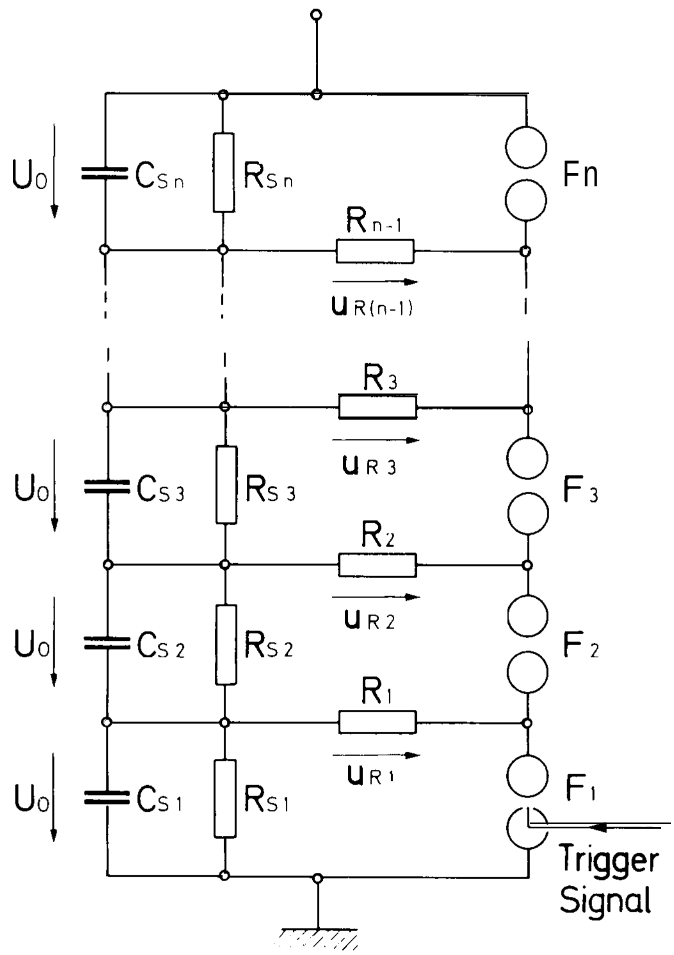

Fig. 1: Multiple gap with resistive-capacitive voltage grading (C_{sn} ; R_{sn}) and overvoltage generation on cross-resistances R,.

voltage u_{R_1} (t) adds up with the voltage of the loaded grading capacitor C_{s_2}, so that the second gap F_2 will be stressed by the voltage

$$u_{F_2} = U_o + u_{R_1}(t) \qquad (1)$$

When F_2 fires under the action of overvoltage u_{R_1} (t), the discharging of $C_{s_1} + C_{s}$, produces on the resistor R_2 an

overvoltage u_{R_2} (t) which leads to the firing of F_3; again. an overvoltage u_{R_3} (t) is produced, leading to the firing of F_4, etc.
Should the circuit have no srray capacitances and if there is no additional charge flow to the chain of grading capacitors during the firing of the individual gaps u_{R_1} (t) would become

$$u_{R_1}(t) = \begin{cases} 0 & \text{for } (t \leq 0) \\ U_o \exp\left(-\frac{t}{R_1 C_{s1}}\right) & \text{for } (t > 0) \end{cases} \qquad (2)$$

Under these conditions the voltage on the second gap

$$u_{F_2}(t) = U_o \left(1 + \exp\left(-\frac{t}{R_1 \cdot C_{s1}}\right)\right) \quad (t > 0) \qquad (1a)$$

for this short time would reach value of $2U_o$.
Overvoltage obtained experimentally fully corresponds to expectations. Fig. 2 shows the measured and the calculated voltage curve on the second gap. The calculation is not based on formula (la), but a computer program was used, which allowed to take into account the stray capacitances of the circuit. The calculation was based upon following data: C_{sn} = 10 nF; R_n = 1 kΩ; stray capacitance in the gap K = 20 pF.
For the calculation of u_{F_2} in fig. 2, it was assumed that the voltage on the first individual gap F_1 breaks down in about 10^{-9} sec. Firing conditions get better for gaps F_3, F_4, etc.. as increasingly higher overvoltages make their apparition. As regards fig.2, u_{F_3} was, for instance, calculated under the assumption that voltage on F_2 breaks down. 20 ns after the firing of F_1, in 10^9 s. It can be seen that u_{F_3} reaches the considerable amplitude of some 2.9 u , .

The remarkably high overvoltages on the individual gaps F_2 to F,, are provision for a wide trigger range of the multiple gap. This circuit feature can however be fully utilized only if the triggering range of the first gap F_1 is also correspondingly wide, i.e. the characteristics of the whole multiple gap depend essentially on the trigger system used on F_1. These assumptions were confirmed by results obtained experimentally and which are the subject of another paper [1].
The circuit shown in fig. 3 allows to improve the efficiency of overvoltages by irradiating additionnally by means of an auxiliary spark the electrode surface of each individual gap. Voltage drops occurring on the resistors R_{1b}, R_{2b}, etc. will be used each time for generating auxiliary sparks, but they do not get lost as overvoltage on the gap. The reason is. are, that immediately upon firing of the auxiliary sparks, resistors R_{1b}, R_{2b}, etc., are short-circuited and the other chain of R_{1a}, R_{2a} resistors takes over the full voltage.
In some applications using gaps as switches. several parallel sparks are necessary instead of a single one. As is well known, the solution of this problem is rather difficult, particularly in case of high voltages. Parallel sparks are. for instance, required to keep the inductance of the spark channel as low as possible in circuits with extremely low inductance, or to distribute the total current in case of high-current discharges, in order to limit the burning-off on the electrodes. The new multiple gap system described herein allows easy generation of parallel sparks, simply due to the fact that each grading capacitor C_{sn} is discharged not only over one, but over several parallel-connected inpedances and gaps.

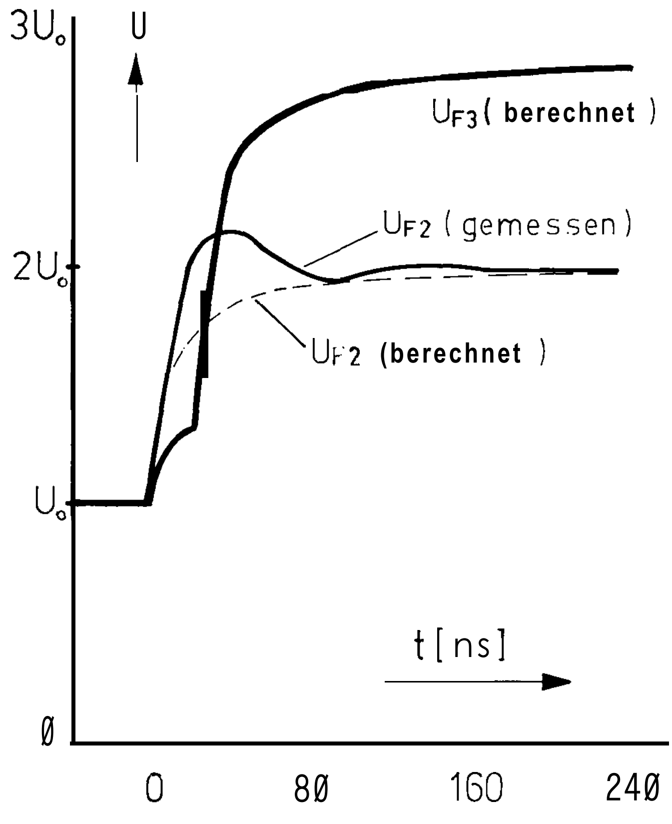

Fig.2: Overvoltages on the 2nd and 3rd individual gaps

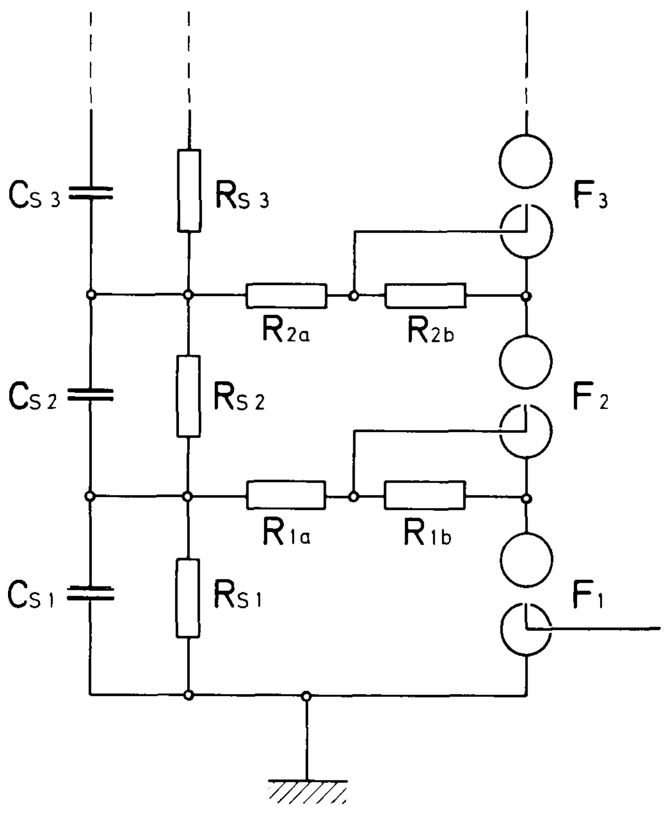

Fig. 3: Overvoltage generation on cross-resistances with voltage lapping for cross-triggering.

Fig. 4 shows, as an example, a circuit generating two parallel spark-channels. The firing of every individual gap creates a good conductive connexion between the high voltage pole HV and the earthing point E, not only across the chain of F_{nx} gaps, but also across the F_{ny} chain. F_{nx} and F_{ny} gaps in fig.4 still fire in parallel, even if triggering pulses reach gaps F_{1x} and F_{1y} with a mutual delay of some 10^{-8} s. This is also the case if, with a successive firing of the gaps, there is a further delay of some 10-s s. The reason is that after a gap has fired, the corresponding grading capacitor loses a substantial load quantity only after some 10^{-7} s., if the value resistances R_n is not to low. However, as long as voltage subsists on the grading capacitor, firing conditions of the parallel associated gap are not reduced.

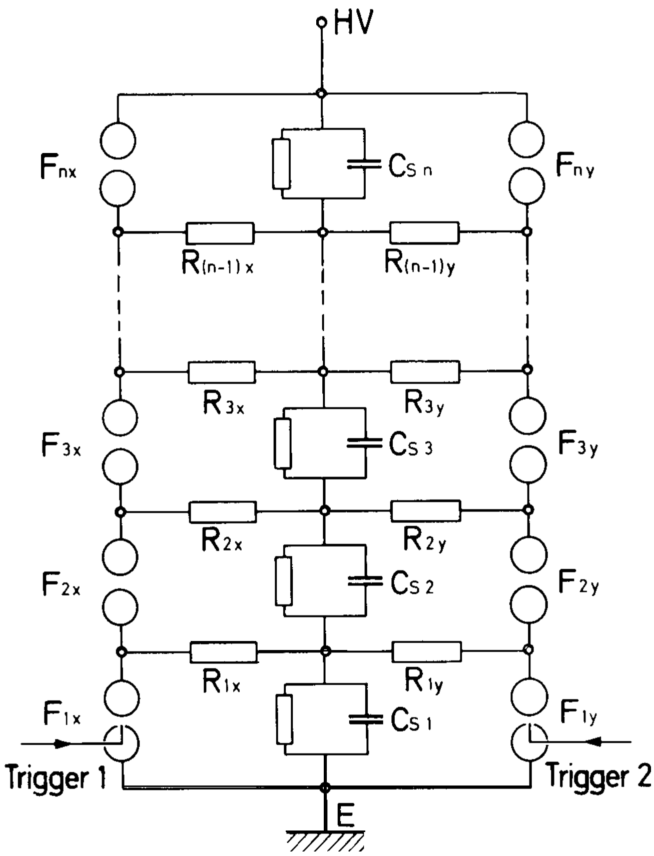

Fig.4: Multiple gap with two parallel spark tracks.

This new type of multiple gap finds a number of possible applications, of which some of the obviously interesting ones will be mentioned:

1. Chopping gap for lightning impulses during quality tests on high voltage equipment. Due to rather high overvoltages on the individual gaps, a wide triggering range can be expected and voltage can thus be chopped with full certitude at the required time instant. Grading capacitors can be further used as load capacitors, in order to obtain the desired voltage shape.
2. Chopping gap for switching impulses. These must be occasionally trigger chopped when investigating gas discharge processes and no appropriate means were available up to date for extremely high switching impulses.
3. High speed short-circuiting device or a level-gap for high d.c. voltages, a.c. or combined voltages such as in EHV d.c. systems. Either a trigger signal can be applied to the first gap, should an adjusted voltage value be exceeded, or the natural flashover voltage of the gap will be used, without any trigger signal on the first stage.
4. Generator for HV rectangular pulses, e.g. for gas discharge investigation. It is, in such a case, possible to produce by means of an impulse generator a voltage wave having a steep front and a very long tail, and to crop off the tail with the multiple gap in a similar way as mentioned under 1. and 2.
5. Untriggered preliminary gap in lightning arrestors, either to obtain a reliable control of high voltages, or to produce parallel sparks in order to unburden the electrodes.

Summary

Description of a new type of multiple gap, having the advantage over all known similar systems that it is equally suitable for switching d.c., a.c. and impulse voltages. In particular, this systemcan be used with combined voltages, such as d.c. voltage with superimposed impulses. The gap can be triggered, but may also be used as an untriggered gap. Possible applications in test techniques, gas discharge research and overvoltage protection are further mentioned.

Literature

[1] ***Feser K.,*** *Rodewald* A. : A triggered multiple chopping gap for lightning and switching impulse voltages. Intern. Symposium for H.V.Techniques, Munich 1972

Emile Haefely & Co Ltd Basel
CH-4028 Basel/Switzerland
Post Office Box Telephone 061 4118 17