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# Influence of Gas Parameters on the Spark Gap Functioning

B. Loncar [1], M. Vujisic[2], S. Stankovic[3], G. Ilić[2]

*[1]Faculty of Technology and Metallurgy, University of Belgrade,*
*Karnegijeva 4, P.O. Box 3503, 11120 Belgrade, Serbia*
*E-mail: bloncar@tmf.bg.ac.rs;*
*[2]Faculty of Electrical Engineering, University of Belgrade,*
*Bulevar Kralja Aleksandra 73, P.O. Box 3554, 11120 Belgrade, Serbia*
*[3]Vinca Institute of Nuclear Science, Radiation Protection Department,*
*P.O. Box 522, 11001 Belgrade, Serbia*

The development of a three-electrode spark gap used with synthetic circuit was considered in this paper. Two types of three-electrode gas insulated spark gaps have been tested: a spark gap with a third electrode being inside the main electrode, and a spark gap with a separate third electrode. The theoretical model enabling the optimal design of spark gap has been presented. By applying that model both types of spark gaps were theoretically sized in the optimal way.

Several characteristics were determined experimentally:
1) the influence of the gas insulation parameters on the spark gap functioning,
2) the influence of the working and triggering voltage polarities on the spark gap functioning,
3) the influence of the triggering voltage rate of rise on the spark gap functioning and
4) the degree of spark gap irreversibility under conditions of exploitation.

Three types of gases were applied: $SF_6$ gas, $N_2$ gas and mixture of 60 % $SF_6$ with 40 % $N_2$. Also, three electrode materials were used: copper, steel and tungsten. The spark gap switching time and delay time were measured. The statistical analysis of results is presented. It was found that the switching time decreases with application of pressure decrease, and the statistical dispersion of switching time raises with the pressure decrease. By comparison of results obtained for the vacuum insulated spark gap and the $SF_6$ or $N_2$ gas insulated spark gap, it was found that the vacuum spark gap has a slightly shorter switching time and a significantly higher corresponding statistical dispersion. Also, it was found that under a higher trigging time rate of rise-the switching time and its statistical dispersion increase with the triggering pulse rate of rise for the vacuum spark gap. The decrease of delay time and its statistical dispersion with rate of rise was observed. The influence of insulator or electrode materials type on delay time was not observed. For the vacuum spark gap the significant decrease of switching time and its statistical distribution with increase of injected trigger pulse energy was observed. This phenomenon exits also for gas spark gap but less significant. The most striking irreversible changes appeared in the vacuum spark gap with steel electrodes. The least irreversible changes appeared in the spark gap isolated by $N_2$ with tungsten electrodes.

The influence of the spark gap parameters (gas insulation parameters, the influence of the working and triggering voltages polarities, the triggering voltage rate-of-rise, the degree of spark gap irreversibility under conditions of exaltation), not encountered by the model, was determined experimentally. It can be concluded that the numerical calculation produces satisfactory results from the point of view of optimal spark gap design.

Also, it was found that better characteristics of the spark gap insulated by $N_2$, in comparison with the spark gap insulated by $SF_6$, can be explained by higher concentration of the free electrons in $N_2$ than in electronegative $SF_6$. It was found that both switching time and statistical dispersion of switching time increase with the higher rate of rise of triggering pulse. Also, the delay time and statistical dispersion delay time decreased with increase of rate of triggering pulse. For the switching time random variable, it was found that there were irreversible changes appeared in the spark gas isolated by $SF_6$ with copper electrodes. The significant influence of the electrode materials on the spark gap functioning was not evaluated. During experiments, the dependence of random variable delay time from working voltage polarity was not evaluated, too.

The influence of the previous discharges on the delay time random variable was not found. For the switching time random variable it was found that there were irreversible changes during operation. The most interesting irreversible changes appeared in the spark gap isolated by $SF_6$ with cooper electrodes. It was found that the irreversibility characteristics of spark gaps were not affected by the type of spark gap and the way of triggering.

On the bases of the obtained testing results for the three-electrode spark gap, it can be undoubtedly stated that triggering pulse parameters and the gap insulation have significant influence on spark gap working characteristics. Accordingly, the presented results can be useful in engineering practice for the selection of optimal spark gap and the triggering system. Although the spark gap applications determine the more relevant characteristics, it can be generally stated that constructive solution of the type B spark gap (spark gap with a separate third electrode) has some advantages in respect of constructive solution of the type A (spark gap with a third electrode being inside the main electrode). This statement is based on the fact that although there is no significant advantage of the type B spark gap in comparison with the type A spark gap, the symmetrical construction as well as the triggering from fixed potential are favoring type B spark gap in many applications. Depending on application, in many cases triggered $N_2$ gaps or vacuum gaps are superior to the $SF_6$ gaps. However, on the bases of results obtained and other relevant insulation characteristics of gases and vacuum (electrical arc extinguishing, dielectric recovery and turn-on time), it can be generally stated that type B spark gap with cooper electrodes, insulated with $SF_6$ gas, has optimal characteristics.