THE INFLUENCE OF GAMMA AND X–RADIATION ON PRE-BREAKDOWN CURRENTS AND RESISTANCE OF COMMERCIAL GAS FILLED SURGE ARRESTERS

by

Boris LONČAR[1], Srboljub STANKOVIĆ[2], Aleksandra VASIĆ[3], and Predrag OSMOKROVIĆ[4]

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The aim of this paper is to examine the influence of gamma and X-radiation on relevant characteristics of commercial gas filled surge arresters in the d. c. regime. This question is very important because of the wide application of gas filled surge arresters in telecommunications, military industry and space technology. We found that both types of radiation had significant influence on the performance of gas filled surge arresters.

Key words: gas filled surge arresters, pre-breakdown current, resistance, gamma radiation, X-radiation

INTRODUCTION

The possibility of blocking over-voltage occurrences is significantly reduced by the miniaturization of electronic components. Therefore, efficient over-voltage protection of electronic devices and components at low-voltage level is of great importance for their correct functioning. Over-voltage transients in power or signal lines arise directly from the commutation process, electrostatic discharge, lightening stroke, or, indirectly, as a consequence of interaction between wire structures of the system and an electromagnetic field. A permanent or temporary malfunctioning of the equipment caused by a surge, may be the result of an improperly designed protection circuitry [1].

The over-voltage components are divided into two categories: (1) linear and (2) non-linear. Linear over-voltage protection components include various types of filters made up of capacitors and coils. Non-linear over-voltage protection components include transient suppresser diodes (TSD), metaloxide varistors (MOV) and gas-filled surge arresters (GFSA) [2].

The GFSA design is very simple. It consists of a ceramic housing and an electrode system. It is a two-electrode symmetric component with gas insulation. Noble gases are most frequently used as the insulation medium. The electrodes are profiled so as to provide a pseudo-homogeneous macro component of the electric field [3].

GFSA operation relies on the principle of the electrical breakdown of a gas, which in itself is a consequence of a self-sustained avalanche process that depends on the relative activity of electron generation and loss mechanisms [4].

GFSA possesses certain advantages compared to the other over-voltage protection components. These are [1, 2]:

(1) the ability to conduct high currents (up to 5000 A),
(2) a low intrinsic capacity (~1 pF), and
(3) low costs.

The disadvantages of GFSA are:

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Authors' addresses:
[1] Faculty of Technology and Metallurgy, University of Belgrade, P. O. Box 3503, 11001 Belgrade, Serbia and Montenegro
[2] VINČA Institute of Nuclear Sciences, Radiation Protection Department, P. O. Box 522, 11001 Belgrade, Serbia and Montenegro
[3] Faculty of Mechanical Engineering, University of Belgrade, 16, Kraljice Marije, 11120 Belgrade, Serbia and Montenegro
[4] Faculty of Electrical Engineering, University of Belgrade, P. O. Box 3554, 11001 Belgrade, Serbia and Montenegro

E-mail address of corresponding author:
bloncar@eunet.yu (B. Lončar)

(1) the practical irreversibility of the characteristics after the electric arc effect, and
(2) a delayed response.

The stability characteristic of the GFSA is of great importance, particularly if a device is operating in high-risk conditions, *i. e.* when the radiation influence must be taken into account [5]. The results obtained in previous investigations imply the possibility of replacing commonly used semiconductor over-voltage components (transient suppresser diodes, metal-oxide varistor) whose protective characteristics significantly degrade when subjected to radiation by GFSA [6, 7].

The aim of this work is to establish the criteria, which a commercially available GFSA should meet if it is to be considered for use in high-risk systems.

EXPERIMENTAL

The examination was carried out on the following commercial components: (1) SIEMENS (type A) gas surge arresters (nominal voltage 230 V), and (2) CITEL BB (type B) bipolar ceramic gas surge arresters (d. c. spark over-voltage 230 V). The outer dimensions and shapes of all components of the one type were identical. The effects of gamma and X-radiation on the following GFSA characteristics were examined:
(1) pre-breakdown current as a function of applied voltage, and
(2) resistance as a function of applied voltage.

The schematic diagram of the test cycle for investigating the influence of radiation on GFSA characteristics by a d. c. voltage is depicted in fig. 1.

Examination of GFSA characteristics was carried out in a gamma radiation field of ^{60}Co at the VINČA Institute of Nuclear Sciences. The average energy of the applied gamma quantum was 1.25 MeV. The dose rate in air was 87,5 cGy/h, 875 cGy/h, and 1750 cGy/h, respectively. The distance between the radioactive source and the examined over-voltage components was 272 cm, 86 cm, and 60 cm, respectively. All testing was performed at room temperature, 20 °C.

The following parameters of the radiation field of the X-ray generator Philips MG-320 were employed: high voltage 300 keV, electric current 15 mA. The filtration used was in accordance with ISO standards. The energy of X-rays amounted to 48 keV, 118 keV, and 248 keV, respectively. The testing was performed at room temperature of 20 °C.

For experimental purposes, we used specimens consisting of 50 commercial components of a single manufacturer, with identical characteristics. While forming the experimental specimen consisting of 50 components, we measured their nominal characteristics. When the measured values of nominal characteristics of a particular component exhibited significant discrepancy with respect to the declared values, we employed Sovene's criterion in order to read reject the bad ones; *i. e.* the experimental specimen excluded them [8].

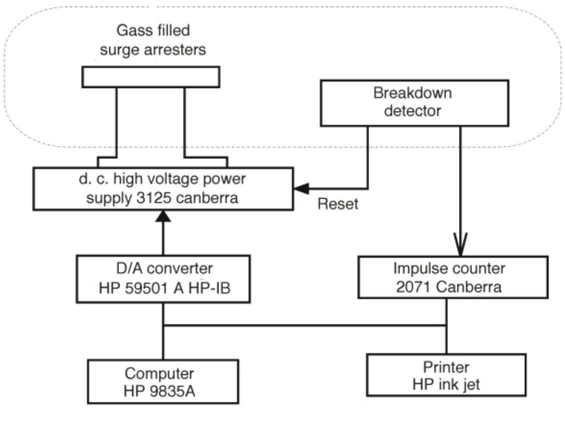

Figure 1. The scheme of the test cycle for investigating the radioactive resistance of GFSA by a d. c. voltage

RESULTS AND DISCUSSION

The GFSA pre-breakdown current as a function of applied voltage without radiation, with gamma radiation and with X-radiation is shown in figs. 2-4, respectively. From these diagrams we have concluded the following:
(1) In the absence of radiation, GFSA shows a very sharp current increase during the breakdown (the breakdown voltage is 212 V for type A components and 223 V for type B components). Before the breakdown, the current is constant, of the order of 0.1n A. When the voltage reaches the breakdown level, an abrupt in-

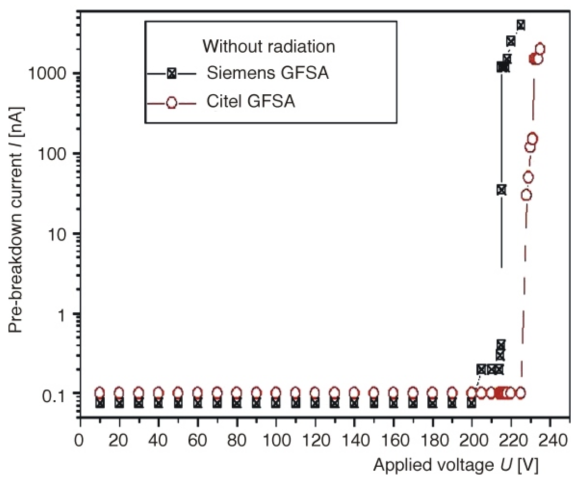

Figure 2. Pre-breakdown current versus applied voltage without radiation

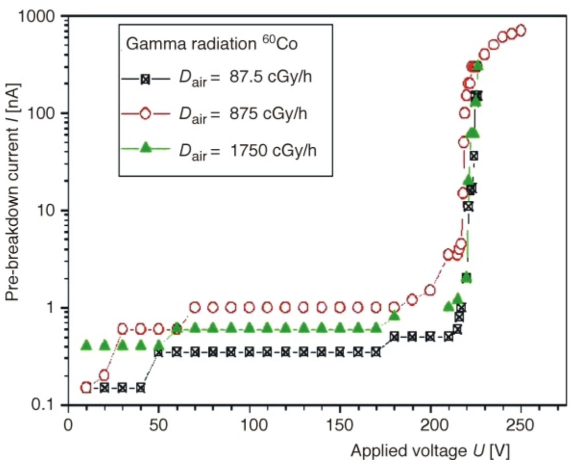

Figure 3. Pre-breakdown current versus applied voltage in gamma radiation field

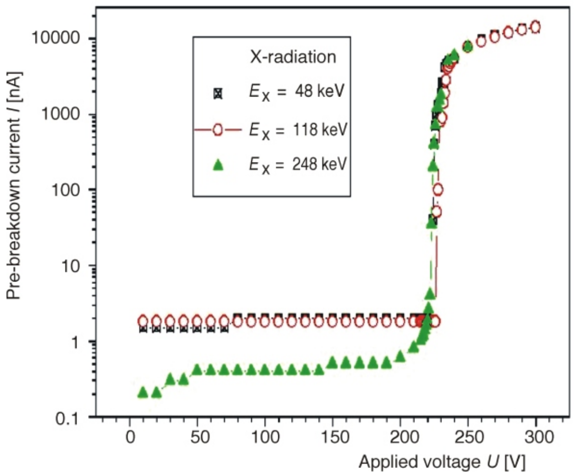

Figure 4. Pre-breakdown current versus applied voltage in X-radiation field

crease of the current is observed; current values reaching up to a μA level. The effect of the rapid current increase at the moment of the breakdown can be explained by the increase of the ionization effective cross-section for the atoms of the gas, with the increase of applied gamma radiation energy. The increased number of electron-ion pairs in the area between electrodes leads to the increase in the pre-breakdown current (consisting of free electrons and ions reaching electrodes per unit time). In the moment of the breakdown, that is, when one of the free electrons generated in this way is initialized, an avalanche process generates a breakdown current whose magnitude is independent of the pre-breakdown current. Ohm's law is not valid in this region, since the observed two-electrode system is in saturation. In this case all electron-ion pairs, generated per unit time, reach the electrodes per unit time.

(2) gamma radiation significantly influences GFSA performance. In the pre-breakdown regime, the current is ten times stronger than without radiation. Pre-breakdown current increases with the increase of the radiation dose rate. In a gamma radiation field, breakdown occurred at a lower voltage (205 V). The current increase is not as sharp as in the case where there is no radiation field during the transition from a non-conducting to a conducting regime.

(3) GFSA is especially sensitive to X-radiation; pre-breakdown current is larger than in a gamma radiation field. At higher levels of X-ray energy (248 keV), lower values of pre-breakdown current are observed. Breakdown occurred at lower voltage levels than in gamma field, and the current increase is sharper than with gamma radiation.

Effective cross-section for the ionization of the gas is not a linear function of the applied radiation. During X-ray irradiation (fig. 4), a resonant increase of the effective cross-section for ionization is apparent for the radiation values corresponding to the limits of the continual atomic spectrum of the gas in the gas filled surge arresters. Accordingly, lower values of the X-ray energy correspond to the higher values of the pre-breakdown current.

The obtained results regarding the increase in the influence of the X-ray irradiation (compared to the gamma radiation) on the pre-breakdown current increase can be explained by the fact that X-rays have higher ionization probability during the interaction with the atoms of the gas. Namely, greater wave length, *i. e.* lower X-ray energy, lead to the interaction of the X-rays with the gas atoms as a whole, resulting in the excitation or ionization of the atom. On the other hand, smaller wave length, *i. e.* higher gamma energy, produces interaction with the individual (single) electron in the atom, resulting in the lower effective cross-section for ionization in the case of the applied gamma irradiation (Compton effect, photoionization) [9].

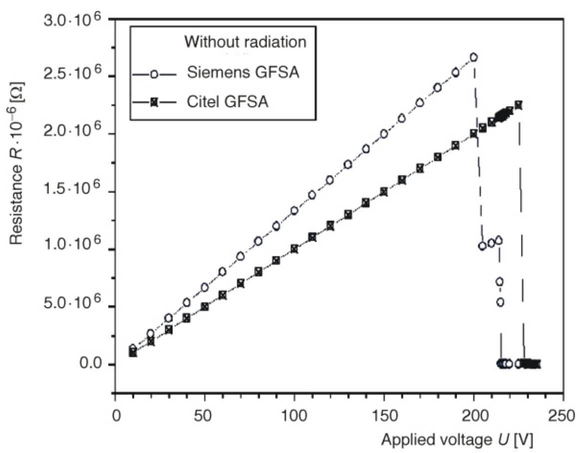

Figure 5. GFSA resistance versus applied voltage without radiation

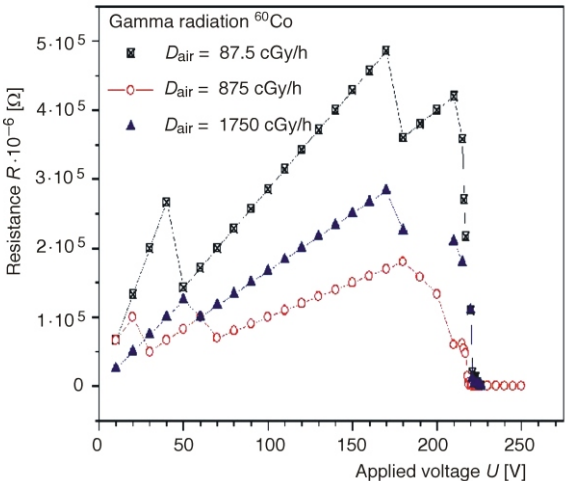

Figure 6. GFSA resistance versus applied voltage in gamma radiation field

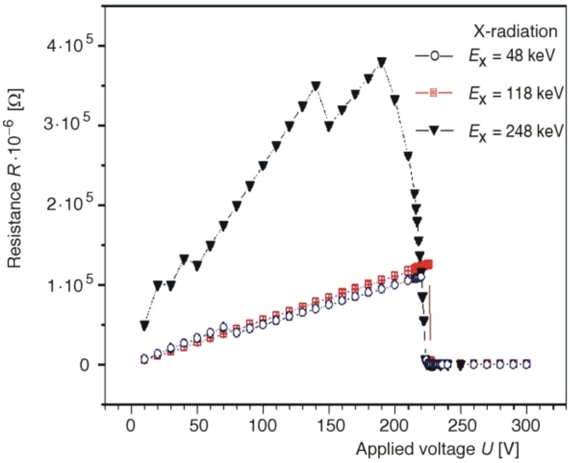

Figure 7. GFSA resistance versus applied voltage in X-radiation field

The GFSA resistance versus applied voltage without radiation, in Co gamma field and with X-rays, is shown in figs. 5-7, respectively. The volt-ohm characteristic can be easily calculated from the volt-ampere curve. Using the linear regression (least-squares minimal error method) formulae defining the relationship between resistance and voltage are obtained. The conclusions are the following:

(1) In the pre-breakdown regime GFSA resistance shows linear increase with the applied voltage. The increase is more prominent for type A commercial components than for type B commercial components. As voltage reaches breakdown level, an abrupt decrease of the resistance is observed.

(2) In a gamma radiation field, the resistance also exhibits a linear increase with the applied voltage, but has lower values of one order of magnitude than without radiation. A slight decrease of the resistance is observed at voltage values near breakdown voltage; at breakdown voltage the decrease is decidedly pronounced.

(3) At lower X-ray energies (48 keV and 118 keV), the increase of the resistance with the applied voltage is slower than at higher X-ray energies (248 keV). Variations in the resistance values are observed for higher X-ray energies; breakdown occurred at lower voltages followed by a sharp decrease in resistance.

CONCLUSIONS

The results of examining the radioactive reliability of commercial GFSA are presented in this paper. The influence of gamma radiation from a cobalt gamma source, as well as the influence of X-radiation, was tested on SIEMENS gas surge arresters (type A) and CITEL BB bipolar ceramic gas surge arresters (type B).

Our main conclusions are as follows:

The values of breakdown voltages for the two types of commercial GFSA in the presence of gamma and X-radiation and without radiation have been determined.

According to the obtained experimental results, it can be concluded that both types of radiation had significant influence on GFSA pre-breakdown currents and resistance. Also, it was found that GFSA is particularly sensitive to X-radiation. The obtained results are of practical value for the manufacturers of these components.

All observed effects of gamma and X-radiation on GFSA commercial components have reversible character; *i. e.* after a short period of time, GFSA characteristics are the same as before irradiation.

In the future, our intentions are the following:

To investigate the influence of n_+ γ-radiation, as well as the influence of α-rays and β-rays, on the characteristics of commercial GFSA;

To determine the relevant characteristics of GFSA under the influence of radiation in the pulse regime;

To examine the influences of different types of radiation on an originally developed GFSA model;

To take into account the variations in pressure in the gas chamber;

To further examine the influence of electrode materials and electrode diameter on GFSA characteristics.

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Борис ЛОНЧАР, Србољуб СТАНКОВИЋ,
Александра ВАСИЋ, Предраг ОСМОКРОВИЋ

УТИЦАЈ ГАМА И X-ЗРАЧЕЊА НА ПРЕТПРОБОЈНУ СТРУЈУ И ОТПОРНОСТ НЕКИХ КОМЕРЦИЈАЛНИХ ГАСНИХ ОДВОДНИКА ПРЕНАПОНА

Циљ овог рада је да се испита утицај гама и X-зрачења на релевантне карактеристике неких комерцијалних гасних одводника пренапона у једносмерном режиму рада. Ово питање је веома значајно због широке примене гасних одводника пренапона у телекомуникацијама, војној индустрији и свемирској технологији. Показано је да оба типа зрачења значајно утичу на карактеристике гасних одводника пренапона.

Кључне речи: гасни одводник пренапона, претпробојна струја, отпорност, гама зрачење, X-зрачење