INFLUENCE OF RADIATION ON THE STABILITY OF ELECTRICAL FILTERS CHARACTERISTICS AS COMPONENTS FOR OVERVOLTAGE PROTECTION

by

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The paper represents the results of testing the effect of neutron and gamma radiation of radioactive ^{60}Co on electrical filters. Neutron and gamma radiation was chosen because of its conductivity. The analysis of the standard structure of the electric filter found that neutron and gamma radiation can affect the value of the capacitance as the most important component of the filter. The presented results are a contribution to the wider research of the radiation resistance of elements for the coordination of insulation at the low-voltage level. The experiments were performed on commercial capacitors that are installed in electric filters. Measurements were made with professional equipment under well-controlled laboratory conditions. The combined measurement uncertainty of the experimental procedure was less than 5 %.

Key words: neutron and gamma radiation, radiation resistance, electrical filter, insulation low voltage

INTRODUCTION

Miniaturization of electronic components greatly reduces their resistance to overvoltage phenomena. Overvoltage phenomena occur directly as a consequence of commutation processes within the devices themselves, *i. e*., within the networks to which the devices are connected, or indirectly as a consequence of the interaction of the device's wire structures with electromagnetic discharge near the device. Possible sources of transient electromagnetic phenomena are impulse overvoltages on lines, atmospheric discharge, radar pulses, and nuclear explosions [1-3]. In the case that the overvoltage protection of the device is not effective enough, overvoltage phenomena can cause damage to electronic elements, circuits, and the entire device, leading to its partial or complete destruction [4, 5].

The transient overvoltages can also cause temporary disruption in the functioning of the device [6, 7]. The destruction effects are usually related to semiconductor components, although the insulation damage can also be caused to the other components due to the act of relatively high transient overvoltages. Semiconductor components in low-voltage signal and control circuits are indirectly coupled to the power supply lines but may be susceptible to destruction due to the relatively small permitted current and voltage operating range. It is also necessary to mention the possibility of the destruction of electronic components coupled to other wire structures (for example, antennas), which can become a source of transient overvoltages due to the action of electromagnetic pulses [8]. The coupling mechanisms in these cases are conditioned by the high-frequency component of the voltage transient. Typical electronic ones that are subject to this destruction mechanism are thyristors and low-voltage and hish-voltage signal and control circuits [9].

The aim of this paper is to examine the gamma and neutron radiation effect on the characteristics of capacitors as filter elements, which are useed for overvoltage protection due to the necessary reliable device protection of the effects of trasients.

OVERVOLTAGE PROTECTION

Overvoltage protection elements can generally be classified as non-linear and linear. Non-linear elements of overvoltage protection include different types of arresters such as gas-filled surge arresters, varistors, and overvoltage diodes. Linear elements of overvoltage protection include various types of electric filters [10]. For practical applications, a combination of these elements is often used because most com-

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mercial filters are not provided for overvoltage protection that reaches voltage values of several thousand volts. In addition, it is very difficult to provide the required level of protection using the filter itself. The protective arresters by themselves have some disadvantages in the case when it is necessary to ensure the protection of particularly sensitive semiconductor electronic components. Therefore, in such situations, it is necessary to use hybrid (combined protection schemes to compensate for the deficiencies of linear and non-linear protection elements) [11-13].

CHARACTERISTICS OF NON-LINEAR OVERVOLTAGE PROTECTION ELEMENTS

Since the electrical network most often appears as a source of overvoltages that are crucial for the functioning of protected devices, for testing, devices designed to protect devices from direct network overvoltages, *i. e*., components with higher nominal voltages, are selected. These are overvoltage diodes, varistors, gas-filled surge arresters, and capacitors [14-16].

Overvoltage diodes and varistors are characterized by the following parameters: maximum voltage on the element at the moment of conduction, the dependence of conduction resistance on the voltage on the element, energy dissipation on the element during transient action, nonlinearity coefficient (determines the quality of the overvoltage diode or varistor and demonstrates to what extent the volt-ampere characteristic to the ideal, *i. e*., horizontal) [17-19].

The gas-filled surge arresters are characterized by DC breakdown voltage, impulse breakdown voltage, and impulse characteristics [20-22].

Capacitors are characterized by their capacity, the loss tangent, and the frequency characteristic of the dielectric constant [23-25].

ELECTRIC FILTERS

For overvoltage protection, different types of electrical filters are used. Among the simplest are those that are used to drain the energy of the disturbance, that is, the inductance that is connected to the regularly protected device and used to limit the rising rate of the current transient. Complex filters of types *L*, *T*, and *P* are also often used, as well as other complex configurations of these types.

The principle of filter protection consists in reflecting the energy of the transient (which is situated outside the bandwidth of the filter) back into the network, *i. e*., its transformation on the internal active resistances of the filters for protection from the action of the transient. They are designed for a previously known and defined value of the resistance (frequently 50), which is not satisfying for most of the protected devices. In that case, the frequency characteristic of the filter is distorted due to the appearance of the *leakage peaks*. For this reason, filters by themselves do not represent reliable protection from the effects of overvoltage.

Capacitors as the most important filter elements or protective elements are among the most sensitive components. Capacitors based on synthetic polymers that are used in filters, in addition to their certainly good properties, which are: (1) low degree of loss and (2) high capacitance with small dimensions, may depend on the type of polymer, and depend on the increase in losses with increasing temperature and damage to the dielectric due to effects of ionizing radiation. Additionally, the dielectric of the capacitor is affected by the time flow, *i. e*., by its aging. Other materials are used to make resistance and inductance that are not subject to the influence of temperature, ionizing radiation, and aging during the formation of the filter. Thus, when examining the effect of these effects on filters, one should focus, particularly on capacitors.

The quality of the capacitor mostly depends on the quality of its dielectric. At high voltages, losses in the dielectric are caused by the polarization and conductivity of the dielectric. The conduction-related phenomenon produces losses caused by the active current component. The power losses P_g are calculated by

$$P_g \quad UI\cos\varphi \tag{1}$$

where $\cos\varphi$ is the power factor expressed as a percentage. In the case of small losses, the losses are expressed by the tangent of the loss angle, $tg\delta$, where δ is the angle that complements the angle φ up to 90º.

The capacitor with losses can be represented by the equivalent diagram of an ideal capacitor (the capacitor without losses).

Figure 1 represents parallel and series schemes of capacitors with losses and equivalent vector diagrams.

These schemes with capacitors with losses are equivalent to electrically but do not match $tg\delta$ with the temperature well enough. This deficiency can be eliminated if it considers that the active resistance is determined by the ionic and electronic conductivity and, that it determines the fictitious and temperature dependence of the active current component.

Conduction losses are determined by electrons and ions that move freely throughout the dielectric. These are the carriers that are responsible for the stationary component of the specific conductivity of the dielectric.

Polarization losses in the dielectric of the capacitor can be caused by the following mechanisms: (1) some molecules of the dielectric oscillate in time with the applied voltage, and (2) similar oscillations occur between the core and the electron shell. These phenomena occur in non-polar material. Other polarization losses are conditioned by the presence of polar

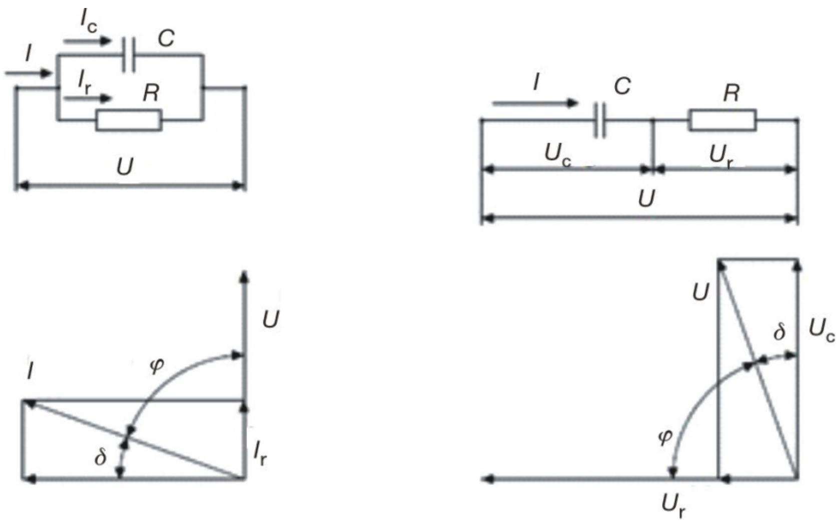

Figure 1. Equivalent diagram of a real capacitor

molecules in the material. When applying voltage, these dipoles are placed in the direction of the field. The third mechanism of loss is caused by the presence of loss at the boundary surfaces.

Ionization losses in the dielectric are conditioned by the occurrence of partial discharges in the dielectric. These discharges usually occur in cracks in the dielectric and can cause their destruction. For this loss component is characteristic that it increases with the voltage on the capacitor if that voltage is higher than the one required for the partial breakdown of the dielectric.

EXPERIMENT

Examinations of overvoltage protection elements were performed on commercial components. The commercial capacitors used during the experiment were DC voltage polycarbonate capacitors.

To test the stability of the capacitor characteristics (the loss tangent – $tg\delta$ and capacity – C) both as a function of preliminary work and as a function of the effects of neutron and gamma radiation, a double-exponential voltage form with a rise and decline time $T_1 = 1.2$ μs and $T_2 = 50$ μs was used with a maximum voltage U_{max} of 320 V, 480 V, and 640 V.

The source of nuclear and gamma radiation was californium whose characteristics are given in fig. 2. The source of californium is fissionable. The half-life of this element is 2.65 years. The element used was produced in 2021, and its mass was then 2265 μg. The source is made in the form of a Cf_2O_3 capsule. The fission neutron spectrum of californium is usually given in the form of Watt's formula [26], which for a specific source and 4π geometry has the form

$$Sn(E) = \frac{1.98}{4\pi}\exp(-0.88E)\,sh\sqrt{2E}\;10^{9}\,\mu s^{-1} \qquad (2)$$

where E is the energy in MeV. Equation (2) gives the number of neutrons emitted per second depending on the neutron energy, this functional dependence is given in fig. 2.

From fig. 2, it can be concluded that the maximum number of neutrons is emitted at energies values around 0,8 MeV, while the maximum neutron energy in the spectrum reaches 20 MeV. During the fission process of californium, gamma photons are also emitted, however, a significant contribution to this emission is also made by photons resulting from the fission products of decay [27]. The summary gamma spectrum of the californium source (including both fission and gamma photon produced from the product of decay) is given in fig. 3.

The need for using modern electronic devices in conditions of ionizing radiation (nuclear techniques, military, and space technology) specify problems related to the radiation resistance of electronic components, that is, their reliability in such operating conditions, about which there are many references.

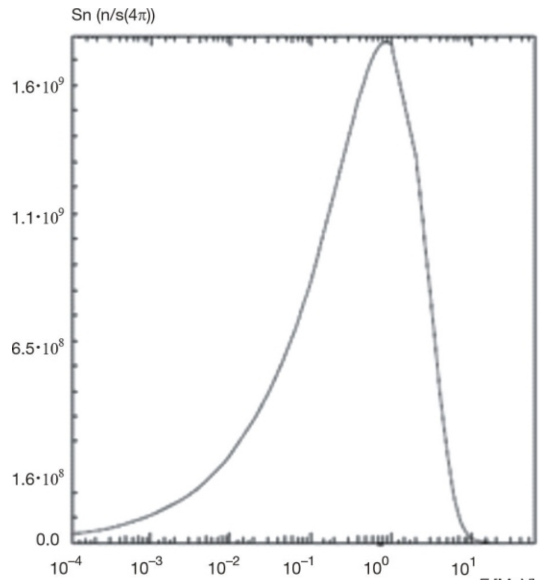

Figure 2. The spectrum of neutron radiation of a californium source

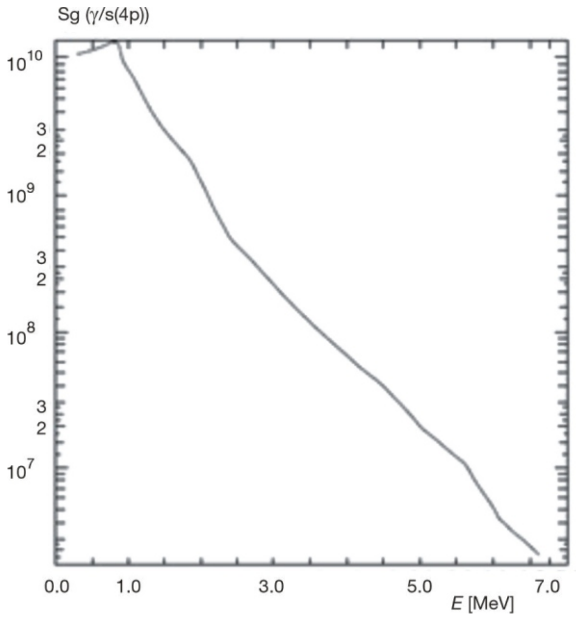

Figure 3. The spectrum of gamma radiation of a californium source

The workshop environments in which it is necessary to enable the functioning of electronic devices can be different. For example, a nuclear explosion is a source of strong gamma radiation with a duration of several nanoseconds and delayed pulses of fast neutrons lasting several hundred microseconds.

Depending on the type of nuclear explosion – surface, aerial, and high-altitude – the generation of other forms of ionizing radiation is also possible, for example, a secondary gamma pulse during an aerial or high-altitude explosion.

In nuclear energy devices – continuous and pulsed nuclear reactions, the fission process is followed by generations of n and γ radiation. Modeling devices are widely used in research: nuclear reactors of continuous and pulse types, pulse X-ray and gamma devices, continuous gamma devices, continuums, and accelerators of electrons and protons. Cosmic space is a natural radiation environment in which they operate: galactic radiation – protons, alpha particles, other heavy nuclei, solar radiation (especially during the period of solar activity) as well as radiation from natural radiation sources illustrates the variety of radiation conditions and factors that affect electronic devices in real conditions of exploitation.

Since in the mentioned conditions it is necessary to reliably protect the devices from the effects of transients (for example, energy pulses of a high-altitude nuclear explosion), it was of interest to examine the influence of ionizing radiation on overvoltage protection elements (overvoltage diodes, varistors, surge arresters, capacitors). The stability test of the characteristics of overvoltage elements was limited to the n and γ radiation of the californium source.

Three experiments were performed to determine the change in the capacity of the experimental radiation due to: 1 – the effect of n and γ radiation from the californium source, 2 – the neutron component of the californium source radiation, and 3 – the gamma component of the californium source. Experiments were performed three times by 50 polycarbonate capacitors with a capacity of 1 F.

In electrical filters used for overvoltage protection, capacitors with a dielectric in the form of a film made of synthetic material (*e*. g., polystyrene, polyethylene, *etc*.) are often used for overvoltage protection due to their very good characteristics. These capacitors are characterized by very high insulation resistance (in the range from 10 to 100 T), a small value of loss tangent ($tg\delta = 0.00015$), high stability of characteristics as well as a very good size to capacity ratio, which is why this type was chosen for radiation resistance testing capacitor.

The effect of radiation was measured on all irradiated capacitors 120 hours after the last irradiation. Measurements were made at 100 kHz as a function of radiation fluence. The first measurement procedure consisted of placing the experimental capacitor at 5 m from the californium source and irradiating it for an hour. After that, a break of 120 hours was made and the capacitance and the loss tangent of the capacitor were measured. All 50 capacitors were irradiated at the same time, and their small size ensured that they all received the same dose of radiation. 120 hours after irradiation, the capacitance of each of the fifty capacitors was measured.

The second measurement procedure was accomplished so that a shield of 1 m of lead was placed between the 50 capacitors and the californium source. This shielding, as determined, ensured that the capacitors received a dose only from neutrons.

The third measuring procedure was accomplished so that between 50 capacitors and the californium source, a 50 cm thick glass vessel full of water was placed, behind which there was a multilayer layer of cadmium of 25 cm. This law ensured that the capacitors received only a dose of gamma radiation.

The measured fluence values of neutron and gamma radiation are represented in tab. 1.

RESULTS AND DISCUSSION

Figures 4(a-c) show the change in the capacity as a function of the fluence values of n and γ, n, and γ – radiation. None of the applied radiations led to a change in the loss tangent value.

Based on the mentioned figures it can be concluded the change in the capacitance depending on the radiation is relatively small, it certainly leads to a change in the structure of the dielectric due to the destruction of polymer chains. The destruction of the

Table 1. Fluence values of neutron and gamma radiation

N_F	F_n [cm^{-2}]$\cdot 10^{10}$	F [cm^{-2}]$\cdot 10^{13}$
0	0	0
1	2.79	6.8
2	5.59	13.6
3	8.37	20.4

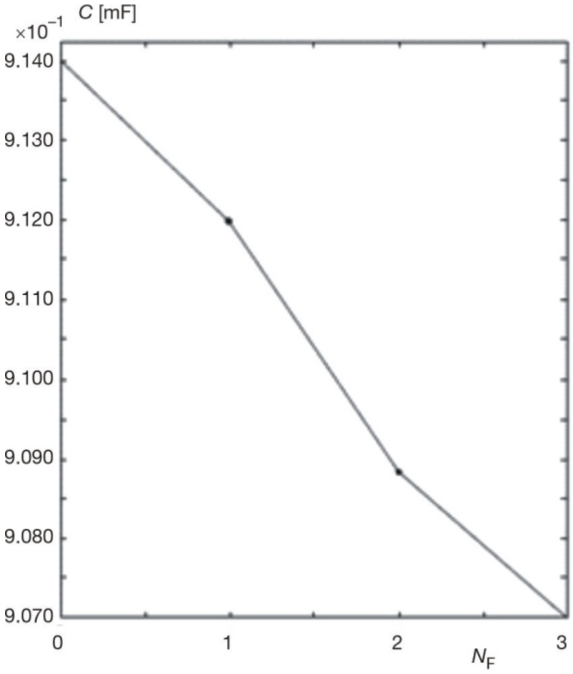

Figure 4(a). Capacity change due to neutron radiation flux N_F

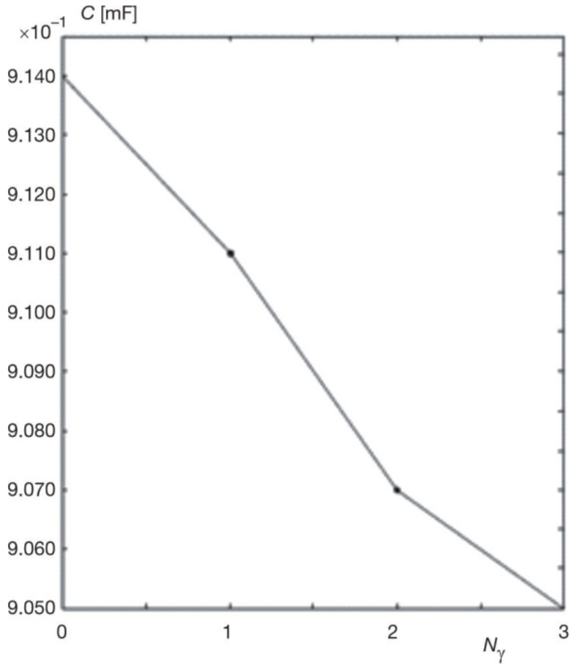

Figure 4(b). Capacity change depending on gamma radiation flux N_γ

polymer chains of the capacitor dielectric leads to an increase in the probability of the breakdown of the ca-

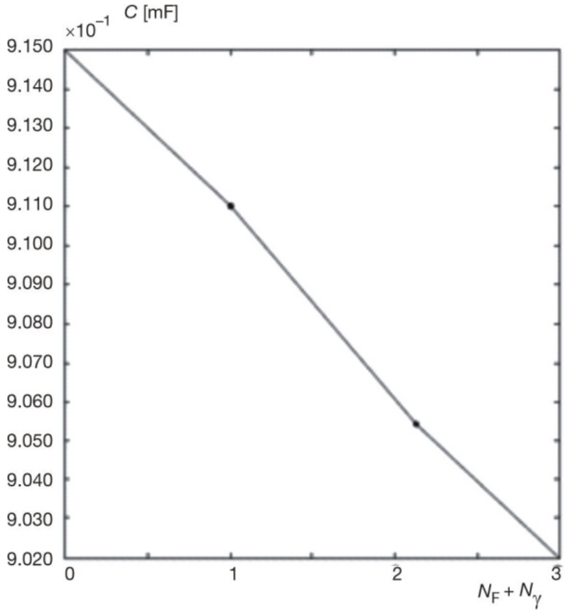

Figure 4(c). Capacity change depending on neutron and gamma radiation

pacitor and the concept of partial expansion at the points of damage that cause so-called branching. Although the change in the capacitance is relatively small, the existence of ionization structures within the volume of the dielectric that affects the shielding of the electric field can lead to a decrease in the breakdown voltage of the capacitor, which accelerates the aging process, *i. e*., reducing their lifetime in the overvoltage protection circuit. The change of the capacitance as a function of fluence is given in fig. 5 and in tab. 1 the values of n and γ fluence correspond to the value of N_F.

These processes lead to faster aging, that is, reducing the lifetime of the capacitor in the overvoltage protection circuit. Mutual comparison of fig. 4(a-c), clearly shows that the neutron flux component contributes to about 80 % of all unwanted effects. The process of radiation action on the dielectric is as follows: as a result of the first phase of ionizing radiation, free electrons, positive ions, excited ions, and excited molecules appear. In the second phase of radiation-chemical reactions, the formation of free radicals occurs, which can occur as a result of [28, 29]: (1) decay of excited and overexcited molecules, (2) dissociated capture of electrons from molecules, (3) transfer of protons (RH^+ RH R_2^+), 4 – the breaking of hydrogen atom (RH $R^0 + H_2$) and 5 – joining of the hydrogen atom with unsaturated compounds.

The stability of free radicals depends on their chemical structure, aggregate state, temperature, and presence of impurities. Large amounts of free radicals in the polymer lead to irreversible changes, which are based on the processes of structuring and destruction. As a result of radiation structuring, chemical bonds of the following types appear four-functional intermolecular, three-functional intermolecular, intramolecular as well

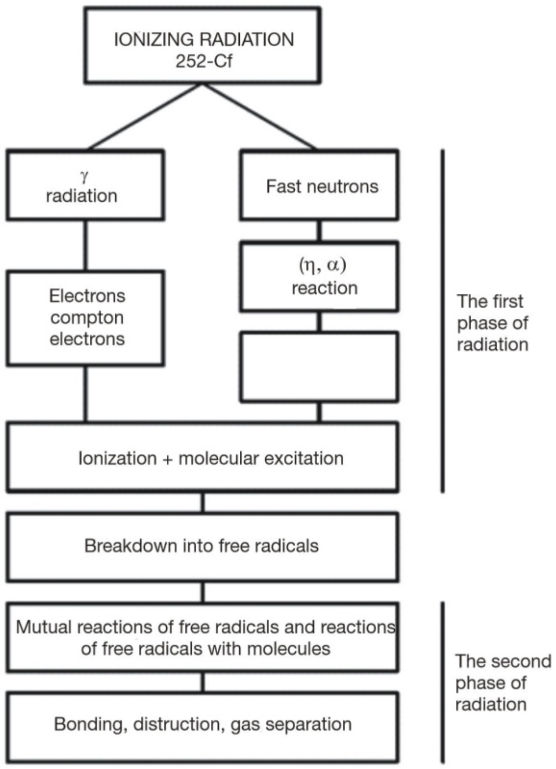

Figure 5. Scheme of the influence of radiation on the organic dielectric of the capacitor

as between molecules and aggregates of filler molecules. Destruction refers to the process of breaking the main chains of macromolecules, which results in a decrease in the molecular weight of the polymer, which is followed by the release of gas. The mechanism of destruction is determined by the individual characteristics of the chemical structure of the irradiated material and is unknown for most polymers.

It is necessary to emphasize that when materials are irradiated, noticeable changes in their physical properties can be caused by radiation doses. Sometimes only one out of 100 000 bonds in the molecules of some types of polymer chains can lead to the splitting of the entire chain into two parts, which can fundamentally change the properties of the material, while at the same time chemical changes do not exceed 0,001 %. The diagram of the influence of radiation on organic capacitors is given in fig. 5.

CONCLUSION

In engineering practice, the results of this paper can be applied in the field of nuclear technology, and military and space technology. More precisely, in those areas that impose problems of the influence of radiation on the stability of the characteristics of the filter as an element of overvoltage protection in the presence of neutron or gamma fields. The established change in the capacity value from the radiation fluence is important when designing hybrid circuits of overvoltage protection since in such circuits it is possible to compensate for changes in the protective characteristics of the electric filter as one of the components with other protected components of overvoltage protection. Also, the experimental procedure presented in the paper, based on the application of high-quality equipment, can serve to improve the standards of testing the effectiveness of overvoltage protection at the high-voltage level.

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AUTHORS' CONTRIBUTIONS

All authors contributed equally to this manuscript.

REFERENCES

[1] Standler, R. B., Protection of Electronic Circuits from Overvoltages, Dover Publications, 2002
[2] Beyer, M., Boeck, W., High Voltage Technology, Theoretical and Practical Basics, Springer- Verlag, Berlin, 1986
[3] Osmokrović, P., *et al.*, Investigation of the Optimal Method for Improvement of the Protective Characteristics of Gas-Filled Surge Arresters – With/Without the Built-In Radioactive Sources, *IEEE Transactions on Plasma Science, 30* (2002), 5I, pp. 1876-1880
[4] Vujisić, M., *et al.*, Influence of Working Conditions On over-voltage diode operation, *Journal of Optoelectronics and Advanced Materials, 9* (2007), 12, pp. 3881-3884
[5] Stanković, K. D., Perazić, L., Determination of Gas-Filled Surge Arresters Lifetime, *IEEE Transactions on Plasma Science, 47* (2019), 1, pp. 935-943
[6] Osmokrović, P., *et al.*, Stability of the Gas Filled Surge Arresters Characteristics Under Service Conditions, *IEEE Transactions on Power Delivery, 11* (1996), 1, pp. 260-266
[7] Osmokrović, P., *et al.*, Influence of the Electrode Parameters on Pulse Shape Characteristic of Gas-Filled Surge Arresters at Small Pressure and Inter-Electrode Gap Values, *IEEE Transactions on Plasma Science, 33* (2005), 5II, pp. 1729-1735
[8] Lončar, B., *et al.*, Radioactive Reliability of Gas Filled Surge Arresters, *IEEE Transactions on Nuclear Science, 50* (2003), 5, pp. 1725-1731
[9] Saranya, A., *et al.*, Role of Hexamine in ZnO Morphologies at Different Growth Temperature with Potential Application in Dye Sensitized Solar Cell, *Materials Science in Semiconductor Processing, 92* (2019), Mar., pp. 108-115
[10] Frigura-Iliasa, F. M., *et al.*, Case Study About the Energy Absorption Capacity of Metal Oxide Varistors

with Thermal Coupling, *Energies, 12* (2019), 3, art. no. 536
[11] Metwally, I. A., Heidler, F. H., Lightning Transients in Low-Voltage Installations Inside Different Types of Class II Lightning Protection Systems, *IEEE Transactions on Power Delivery, 24* (2009), 2, pp. 930-938
[12] Metwally, I. A., Heidler, F. H., Reduction of Lightning-Induced Magnetic Fields and Voltages Inside Struck Double-Layer Grid-Like Shields, *IEEE Transactions on Electromagnetic Compatibility, 50* (2008), 4, pp. 905-912
[13] Metwally, I. A., Computation of Transient Overvoltages in Low-Voltage Installations During Direct Strikes to Different Lightning Protection Systems, *IEEE Transactions on Electromagnetic Compatibility, 49* (2007), 3, pp. 602-613
[14] Geibig, K. F., *et al.*, Use of Fiber-reinforced Composite Materials in Sparking Gaps, *Zeitschrift fuer Werkstofftechnik/Materials Technology and Testing, 14* (1983), 6, pp. 197-201
[15] Osmokrović, P., *et al.*, The Influence of the Electric Field Shape on the Gas Breakdown Under Low Pressure and Small Inter-Electrode Gap Conditions, *IEEE Transactions on Plasma Science, 33* (2005), 5I, pp. 1677-1681
[16] Howard, C., New Avalanche Diode for Transient Protection, Electronic Product Design, 1983
[17] Osmokrović, P., *et al*., Mechanism Of Electrical Breakdown Left Of Paschen Minimum, *IEEE Transactions on Dielectrics and Electrical Insulation, 1* (1994), 1, pp. 77-81
[18] Osmokrović, P., *Et Al*., Mechanism of Electrical Breakdown of Gases for Pressures from 10 -9 to 1 bar and Inter-Electrode Gaps from 0.1 to 0.5 mm, *Plasma Sources Science and Technology, 16* (2007), 3, pp. 643-655
[19] Osmokrović, P., Electrical Breakdown of SF6 at Small Values of the Product pd, *IEEE Transactions on Power Delivery, 4* (1989), 4, pp. 2095-2099
[20] Nedić, T. M., *et al*., Optimization of Fast Three-Electrode Spark Gaps Isolated with a SF6 and He Mixture, *Nucl Technol Radiat, 36* (2021), 3, pp. 234-242
[21] Osmokrović, P., Djogo, G., Applicability of Simple Expressions for Electrical Breakdown Probability in Vacuum, *IEEE Transactions on Electrical Insulation, 24* (1989), 6, pp. 943-947
[22] Antić, V. M., Semi-Automatic Positioning of the Protective Screen Based on Integration with a C-ARM X-RAY Device, *Nucl Technol Radiat, 36* (2021), 1, pp. 85-90
[23] Böttscher, C. J. F., Theory of Electric Polarization, Dielectric in Static Fields, Vol. I, Elsevier, Amsterdam 1973
[24] Erdogan, M., et al., Indoor Radon Activity Concentration and Effective Dose Rates at Schools and Thermal Spas of Ilgin, *Nucl Technol Radiat, 35* (2020), 4, pp. 339-346
[25] Arbutina, D. S., *et al*., Possibility of Achieving an Acceptable Response Rate of Gas-Filled Surge Arresters by Substitution of Alpha Radiation Sources by Selection of Electrode Material and The Electrode Surface Topography, *Nucl Technol Radiat, 35* (2020), 3, pp. 223-234
[26] Dautbašić, N. J., Mujezinović, A. Z., Time Domain Solution of Electromagnetic Radiation Model Of The Grounding System Excited By Pulse Current, *Nucl Technol Radiat, 35 (2020), 1, pp. 74-81*
[27] Osmokrović, P., *et al*., Stability of The Gas Filled Surge Arresters Characteristics Under Service Conditions, *IEEE Transactions on Power Delivery, 11* (1996), 1, pp. 260-266
[28] Osmokrović, P., Djogo, G., Applicability Of Simple Expressions For Electrical Breakdown Probability In Vacuum, *IEEE Transactions on Electrical Insulation, 24* (1989), 6, pp. 943-947
[29] Kartalović, N. M., *et al.*, Influence of Gamma Radiation on Josephson Junction, *Nucl Technol Radiat, 36* (2021), 4, pp. 352-357

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УТИЦАЈ ЗРАЧЕЊА НА СТАБИЛНОСТ КАРАКТЕРИСТИКА ЕЛЕКТРИЧНИХ ФИЛТЕРА КАО КОМПОНЕНТИ ЗА ЗАШТИТУ ОД ПРЕНАПОНА

У раду су приказани резултати испитивања утицаја неутронског и гама зрачења радиоактивног ^{60}Co на електричне филтере. Неутронско и гама зрачење је изабрано због његове проводљивости. Анализом стандардне структуре електричног филтера утврђено је да неутронско и гама зрачење може утицати на вредност капацитивности као најважније компоненте филтера. Приказани резултати доприносе ширем истраживању отпорности на зрачење елемената за координацију изолације на нисконапонском нивоу. Експерименти су изведени на комерцијалним кондензаторима који су уграђени у електричне филтере. Мерења су вршена професионалном опремом под контролисаним лабораторијским условима. Комбинована мерна несигурност експерименталног поступка била је мања од 5 %.

Кључне речи: неутронско и гама зрачење, радијациона отпорност, електрични филтер, изолација на ниском напонском нивоу