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Electrical strength of the MOV varistors and ceramic C-130 with modified surface and glass with silicone rubber cover

Streszczenie. *W pracy przedstawiono mechanizm rozwoju wyładowań powierzchniowych na ceramice, szkle z powłoką z elastomeru silikonowego oraz pomiędzy polimerem a warystorem. Na tej podstawie określono wytrzymałość powierzchniową materiałów oraz zarejestrowano wyładowania powierzchniowe podczas prób. Napięcie przeskoku izolatorów oraz urządzeń chroniących sieć elektryczną może być zwiększone poprzez zastosowanie półprzewodzących powłok, które odprowadzają ładunek generowany na powierzchni oraz prowadzą do ujednorodnienia rozkładu pola elektrycznego wzdłuż powierzchni materiału. (**Wytrzymałość elektryczna modyfikowanych powierzchniowo tlenkowych ograniczników przepięć, ceramiki C – 130 oraz układów szkło – elastomer silikonowy).***

Abstract. *The paper describes mechanisms of surface discharges development on ceramic, glass with silicone rubber cover and between polymer and varistor. Underlying these mechanisms are these materials electrical strength and behavior. Flashover voltage of both insulating and power protecting systems can be increase by applying of semi – conducting covers which will carry away the generated surface charge and uniform the distribution of electric field on material surface.*

Słowa kluczowe: napięcie przeskoku, wyładowanie powierzchniowe, ceramika C – 130, napięcie impulsowe.
Keywords: flashover voltage, surface discharge, varistor, ceramic C - 130, high impulse voltage.

Introduction

Ceramics is a dielectric, which is widely used in the low, semi and high voltage systems. It is useful as a material for insulators, housings, varistors, some types of capacitors and other electrical appliances (fig.1). The C–130 porcelain characterised by its high content of alumina and high mechanical endurance is applicable to high voltage outdoor insulators, which are to be both mechanically and, above all, electrically durable and reliable [9]. Devices for protecting electrical systems such as metal oxide surge arresters contain ceramic varistors, which are made of zinc oxide doped with other metal oxides. The most important property of varistor ceramics is the non-linearity of its voltage – current characteristics [1].

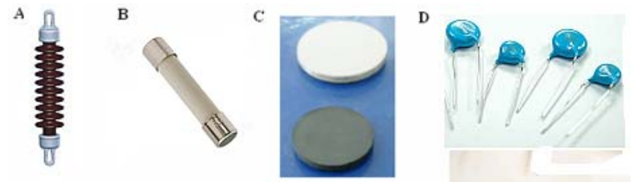

Fig.1. Ceramic materials used in different applications, as : A – line insulator [12], B – fuse housing [1], C – varistors, D – capacitors [14]

Electrical devices powered from the electric grid need to be supplied with electricity in a save manner. The surges are a menace to failure-free operation of many types of the electrical and electronic devices. The surges may cause very dangerous occurring's like flashovers and surface discharges
which can lead to permanent failure of low and high voltage appliances. The surges can be divided into following groups: atmospheric, joining and commutation discharges.

The surface discharging is a dangerous phenomenon which can damage ceramic materials. It is a discharge, which develops on the phase boundary between solid body and gas, liquid or vacuum.

From discharge severity point of view, the surface discharges can be divided into two groups: the one, under which the system losses its insulating properties without the prior damage of the insulating property of the solid dielectric, and the other, under which the system losses its insulating properties only when the insulating property of solid dielectric has been damaged [3].

The dielectric material type influence on the development of a surface discharge

The type of the dielectric material and the type of the filler both strongly influence the surface discharge development. This is caused by numerous material properties: material surface resistivity, material conductance, homogeneity or rather heterogeneity of the surface charge distribution, as the positive charge accumulates near positive electrode, negative charge gather near negative electrode. Another influencing factor is the emission of secondary electrons (fig.2).

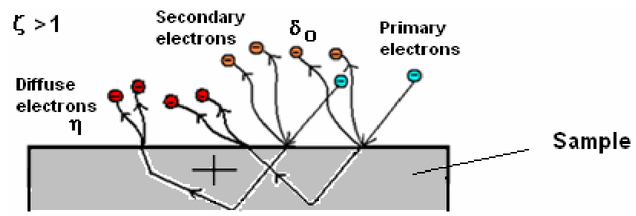

Fig.2. Secondary electrons emission

Material with coefficient ζ below 1 is charged by negative charge, material with coefficient above 1 is charged by positive charge and electrons from materials are injected in the space between electrodes [4]. All these properties can change the resultant electrical field as well as the trajectory of surface discharges (fig.3) [7].

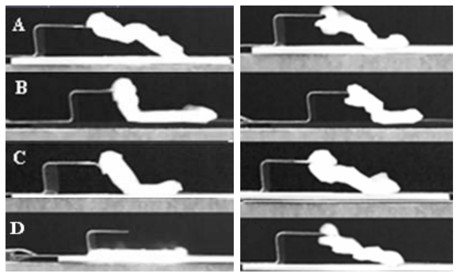

Fig.3. Pictures of the discharges on the samples with edge electrode lifted 16 mm over the sample, left – negative polarization, right – positive polarization A – polyamide - clear, B – polyamide with 20% glass fiber, C – polyamide with 40% glass fiber , D - polyamide with 50% glass fiber

Increasing the electrical strength using semiconducting layers

Ceramic insulators are very important for the safety of electro-energetic systems. Mechanical and electrical requirements for insulators are very severe. It is caused by the fact that for many electrical and electronic devices, they have to provide mechanical support as well as electrical insulation. From the electrical point of view the electrical surface strength is crucial, as insulator is endangered with action of a high electrical field, which can lead to flashover and surface discharges. To investigate how the surface resistivity influences the flashover voltage, the surface of the C-130 porcelain was covered with semiconducting varnish characterized by various values of surface resistivity (tab.1). Flashover voltages for the samples with different varnishing and without varnish were recorded and compared.

Table 1. Surface resistivity of the varnish

Sample No.	Surface resistivity of the varnish, [Ω]
I	$25.4 \cdot 10^{9}$
II	$14.8 \cdot 10^{9}$
III	$25.4 \cdot 10^{10}$
IV	$3.22 \cdot 10^{15}$
V	$23.3 \cdot 10^{10}$
VI	$\sim 10^{6}$

When specimens were subjected to AC electric field, the two best exhibited the resistivity of ca. 10^{9} Ω and ca. 10^{10} Ω. After exposing all the samples to AC and DC stress the best sample (resistivity ca. 10^{10} Ω) was selected. This sample exhibited the highest flashover voltage under AC voltage and positive DC voltage (fig. 4) [5].

Another material subjected to high voltage tests in this experiment was a varistor ceramics, typically used to impose a non-linear property into surge arresters. The housing of a surge arrester constitutes an insulating cover made of polyamide. The discharges between insulating housing and varistors' pile can lead to destruction of the housing. To prevent this, the surface discharges could be eliminated using the same method as in case of porcelain C-130 i.e. coating with semiconducting varnish. Applying it, the generated surface charge can be carried away and the density of electric field along the interface boundary surface equalized. To increase the flashover voltage by carrying away the charge, the ceramic varistor blocks were covered with various types of layers (insulating or semiconducting, depending on resistivity). However, different breakdown processes of the semiconductors (surface flashover and bulk breakdown) are presented in the literature and that is why the applied varnish should exhibit the surface resistivity laying between the one at which it is semiconducting and the other at which it is an insulator [11].

Measurements with the use of impulse, ac and dc voltage

The measurements of the flashover voltage and recording of the surface trajectory on the metal oxide, varistors and on the glass covered with silicone rubber were made by applying impulse voltage, whereas the porcelain C-130 materials has been subjected to DC and AC electric field. For stressing with impulse voltage the impulse voltage generator HAEFELY, 700 kV, 35 kJ was used. The results of the flashover voltage measurements with the use of DC and AC voltage for the C-130 porcelain samples without varnish and with semiconducting varnish are showed in figure 4 [5].

Impulse characteristics have shown that the (flashover) impulse voltage depends on the period of time ad to the cut of impulse (fig.5). This observation can give us some important information on the system e.g. on the uniformity of the electrical field density [2].

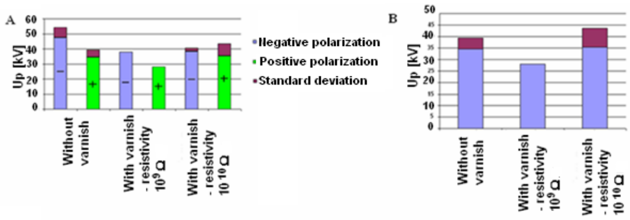

Fig.4. The results of flashover voltage measurements of C-130 porcelain subjected to DC (A) and AC(B) electric field

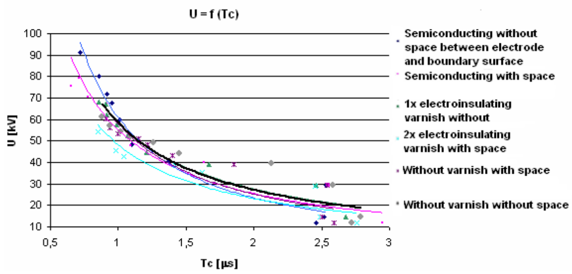

Fig.5. Impulse characteristic of varistors' block [6]

Flashover voltage measurements with the use of impulse voltage and recording the discharges trajectory on the glass with the silicon rubber coating

A discharge on the phase boundary of two dielectrics is a very important and interesting phenomenon. It can be helpful in fighting failures in metal oxide surge arrester which consist of a block of ceramic varistors, polyamide insulating housing and fixtures [10]. The damage arises as a result of discharge development at phase boundary between ceramic varistors and the polymer insulation [6].

Glass was used as one of the investigated dielectric. The transparent properties of glass facilitate the observation of discharge phenomenon occurring between phases. The measuring system used for the impulse voltage tests is shown in figure 6. The glass was coated with two types of the silicon rubbers. Surface resistivity of the glass and silicon rubbers was measured according to the PN 88 – E04405 standard [7] Results are showed in table 2.

Table 2. Surface resistivity of the glass and silicon rubbers

Type of dielectric	ρ_s, [Ω]
Glass	1.72×10^{13}
Silicon rubber LSR I	3.22×10^{15}
Silicon rubber LSR II	1.59×10^{14}

Next, the impulse characteristics for positive polarization were recorded and the results were compared with those for pure glass. HAEFELY, 700 kV, 35 kJ generator was used for high impulse voltage tests.

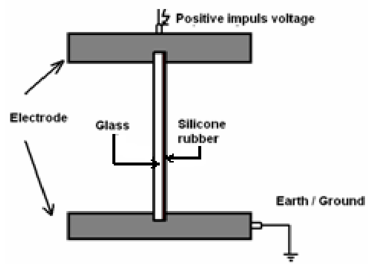

Fig.6. Configuration of the electrodes and samples for observation of discharge between dielectrics

The impulse characteristics of glass and glass with silicon coating are showed in figure 7 and images of discharge developed on glass and glass with silicon coating are presented in figure 8.

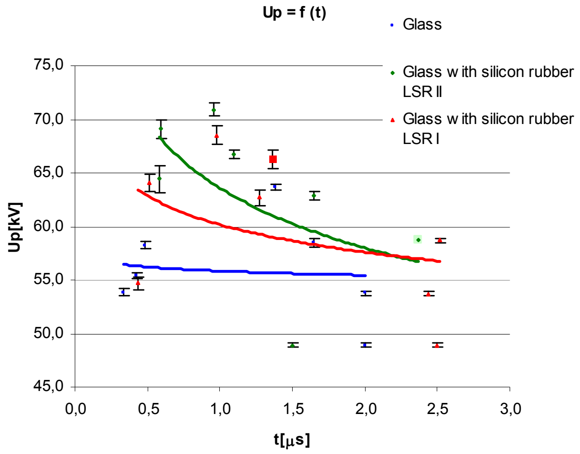

Fig.7. Impulse characteristics of glass and glass with silicon coating

The impulse characteristics show that the silicon rubber coating increases the flashover voltage. The highest value of flashover voltage was exhibited by glass–silicon rubber LSR II system.

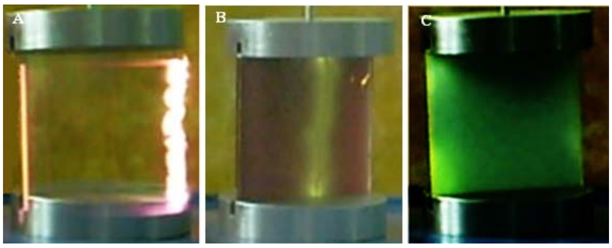

Fig.8. Discharges on: A - glass; B - glass with silicon coating, silicon rubber II, C - glass coated with silicon rubber I

From the observation during testing for impulse voltage endurance one can conclude that the surface discharge develops more readily on the glass side with lower surface resistivity and on the sharp edge of the samples.

Conclution

Surface discharges are a very dangerous phenomenon for failure-free operation of the power grid protecting devices. They occur as a result of surges, which can lead to flashovers in dielectrics.

Ceramic materials are used for insulating, housing switches, producing varistors, capacitors elements and in other electrical equipment. The porcelain C-130 (used for high voltage outdoor insulators) is a material with a high content of alumina oxide and high mechanical properties.

The tests performed by the authors indicated that semiconducting varnish layer (with surface resistivity ~10^{10} Ω) on the surface increases the flashover voltage of ceramic insulators by 10-15%.

The ceramic varistors are produced sintering zinc oxide powder added with other metal oxides. Those varistors are used to construct surge arresters. They protect a system and electronic devices against the destruction caused by surges. Discharges in a metal oxide surge arrester can develop on a boundary surface between a ceramic varistor and the polyamide casing of the surge. The flashover voltage can be increased using a semiconducting varnish layer (with surface resistivity ~10^{10} Ω).

From the observation of the discharges on the glass–silicon rubber phase boundary were it was found that a discharge develops more readily on a glass surface with a lower surface resistivity then on silicon rubber. Sampling after impulse voltage tests confirmed that observation. Measuring the flashover voltage confirmed that the silicon coating increases the electrical strength of the glass–silicon rubber composite. However, a development of a surface discharge was not observed between these two dielectrics and this fact will be subjected to further investigation and analysis.

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