A R C H I V E S O F M E T A L L U R G Y A N D M A T E R I A L S
Volume 54 2009 Issue 4

K. KOGUT*, B. MAZUREK*, K. KASPRZYK*, B. ZBOROMIRSKA-WNUKIEWICZ*

FACTORS AFFECTING THE MECHANISM OF FLASHOVER IN METAL OXIDE SURGE ARRESTER

CZYNNIKI WPŁYWAJĄCE NA MECHANIZM PRZESKOKU TLENKOWYCH OGRANICZNIKÓW PRZEPIĘĆ

The paper describes the mechanism of an electric flashover on a boundary surface between a ceramic varistor and polyamide casing of a metal oxide surge arrester. The role of a surface charge in the development of surface discharge was shown. The surface flashovers lead to constant destruction of a varistor pile and to stratification of the surfaces which lower the electrical strength of the metal oxide surge arrester. It was found that this problem can be solved by means of covering the ceramic varistor surface with a semi-conducting layer which carry away the generated surface charge and compensate the distribution of a electric field along the boundary surface.

Keywords: ceramic varistors, flashover, metal oxide surge arrester, semi-conducting varnish, surface charge

W tym artykule opisano mechanizm przeskoku elektrycznego na powierzchni granicznej między ceramiką warystorową i poliamidową obudową odgromników tlenkowych. Wykazano rolę ładunku powierzchniowego w rozwoju wyładowania powierzchniowego. Przeskoki powierzchniowe prowadzą do trwałego niszczenia stosu warystorowego oraz tworzenia się rozwarstwień, które obniżają wytrzymałość elektryczną odgromnika. Stwierdzono, że problem może być rozwiązany przez pokrywanie powierzchni ceramicznych warystorów warstwą półprzewodzącą umożliwiającą odprowadzenie generowanego ładunku powierzchniowego i wyrównywanie rozkładu pola elektrycznego wzdłuż powierzchni granicznej.

1. Introduction

Electrical devices supplied from energetic system, require safety electrical energy provide. The surges are a menace to failure-free working of many type of the electrical and electronic devices. The following kinds of surges can be identify: as a result of lightning and a joining or commutation surges. In order to protect electroenergetic systems the metal oxide surge arresters are used. The metal oxide surge arresters protect electrical net and the receivers from destructing effects of surges [1]. The basic part of surge arresters constitute zinc oxide varistors with the addition of different metals oxides. Varistors are made with the use of a ceramic technology. They are distinguished by non linear current - voltage characteristic. The metal oxide surge arrester contain two electrodes and varistors pile in polyamide housing (Fig 1.)

The surge arrester containing metal oxide varistors ceramic (ZnO) with two types of the electrodes on the plane area are presented in figure 2. In the first type – diameters of an alumina electrodes of the varistors were smaller than those of the varistors while in the second type – alumina electrodes of the varistors had the same diameter as varistors.

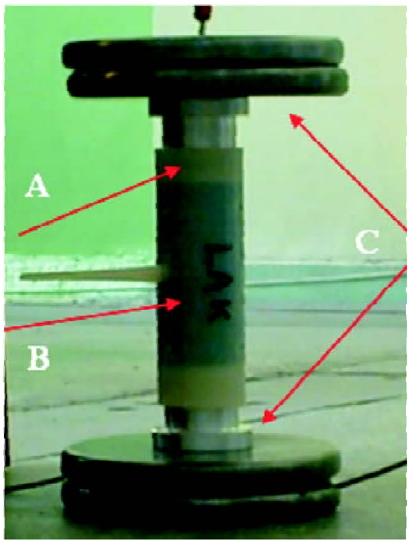

Fig. 1. Metal oxide surge arrester A – insulating housing – polyamide, B – varistors block, C – electrodes

* ELECTROTECHNICAL INSTITUTE DIVISION OF ELECTROTECHNOLOGY AND MATERIALS SCIENCE WROCŁAW, 50-369 WROCŁAW, 55/61 SKŁODOWSKIEJ-CURIE STR., POLAND

The tests on metal oxide surge arresters are carried both voltage and current impulse with high amplitude [1]. The authors of this paper present that surface discharges are generated during impulse voltage tests. It can lead to constant destruction of polyamide housing of the surge arrester (Fig. 2).

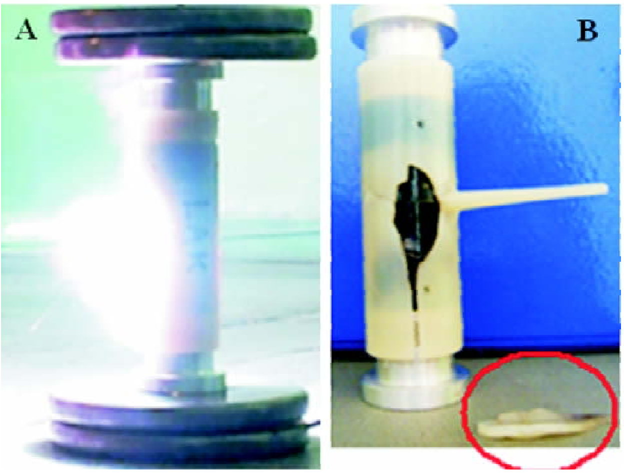

Fig. 2. Damage the polyamide insulating housing (B) of metal oxide surge arrester as a result of surface discharge (A)

In the order to describe the mechanism determining discharges development on dielectric or ceramic varistor, many measures with impulse voltage and AC voltage were carried out.

2. Surface discharges on dielectric

The discharge, which develop between boundary phases such as: solid body and gas, liquid or vacuum is called surface discharges. While, they are occurring there is the possibility that the construction will lose the insulating properties conditioned by solid dielectric decay of insulating. The surface discharges occur in the electrical field, which forces line are parallel (without normal component) or cross the surface of the dielectrics separating. Lack of the normal component or occurring influence on appear of sliding discharge [2,3].

The type of the used material have fundamental effect on kind of the discharges [4,5]. The electron bombarded, ions, and quantum radiation emitted by excited atoms, impact on charging of dielectric material by charge, which density and polarization are influence of the material and electrical stress [6]. Charge can lead to discharging, which develop on dielectric material surface, near surface or can be partly attracted to dielectric surface and partly develop in gas (Fig. 3) [7].

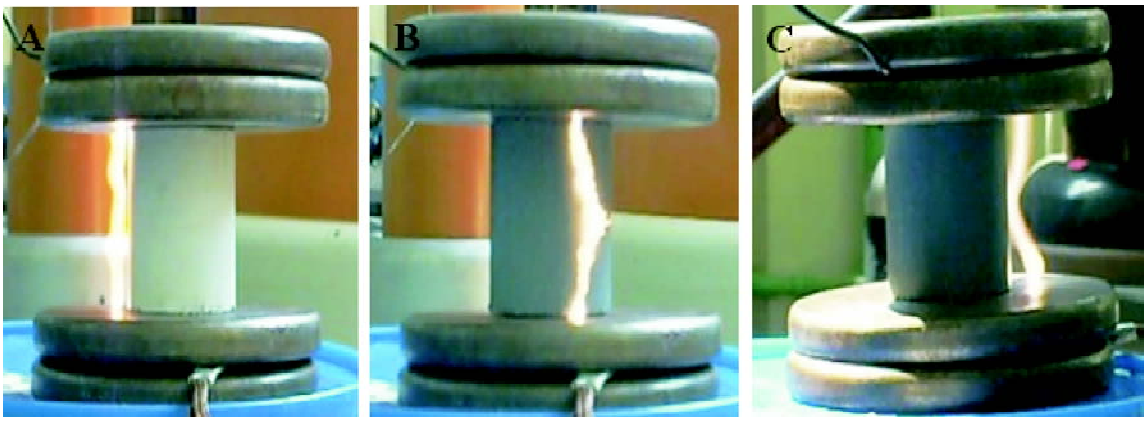

Fig. 3. Pictures of discharges on dielectrics A – discharge near dielectric surface B – discharge on dielectric surface C – discharge partly attracted to dielectric surface

Another important factors which influence on the development of the surface discharge are voltage type and polarity, and also electrodes shape [8]. In the case of the varistors, tested with impulse voltage, two types of the electrodes were used. Alumina electrode, which has diameter smaller then varistor, can meaningfully impact on charging of the varistor surface and as a result facilitate the development of the surface and local discharges between varistors.

3. Surface charge and interfacial space charge

The surface charge play very important role in surface discharge development. The area of the solid dielectric can storage a charge. It can be cause of the change the distribution of the electric field along the boundary surface. The kind of the charge generated on surface, which deciding the discharges trajectory are showed in figures 3, 4 [8]. It can distinguish two types of the forces, which influence on discharge development such as from electrical field, and force from surface charge.

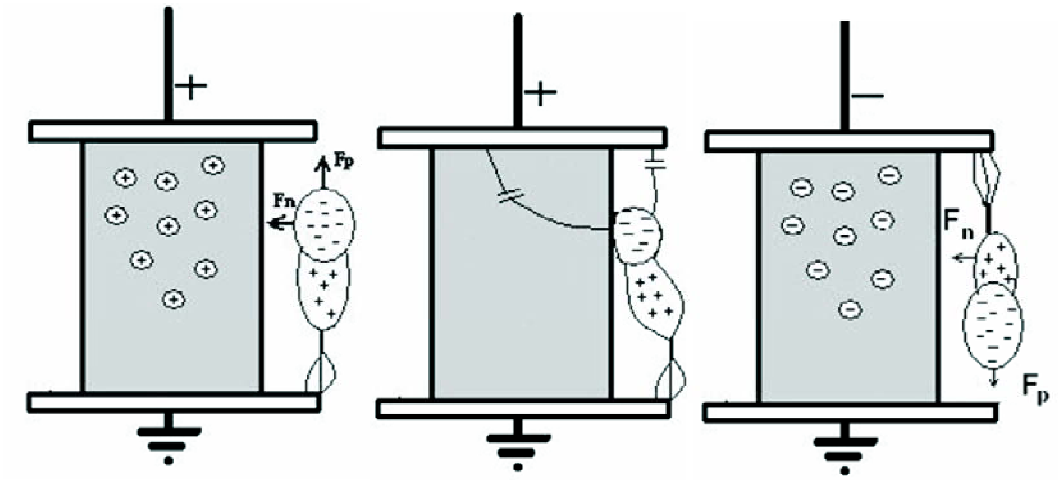

Fig. 4. Influence of surface charge on discharges developing F_p – force from electrical field F_n – force from surface charge

The interfaces are always part of the electrical insulating and protecting systems, and have significant influence on properties of the power systems.

The interfacial space charge between ceramic varistor and housing insulation of the metal oxide surge arrester is the reason of damage, during voltage and current impulse tests. Many scientist try to explain the sense of the interfacial space charge in the developed of discharges in surge arresters [9]. In order to measure of charge thermal stimulated depolarization and acoustic method are used.

4. Materials and experimental

Surge arresters with high impulse voltage tests were carried out. The measurements were made with the use of High Impulse Voltage Generator Haefely® 700 kV, 35 kJ with seven stages generator in Marx configuration. This equipment allow to obtained of standardized surges how also the surges with considerably faster rise of the voltage.

Shape of the standardized surge are introduced in Fig. 5, while discharge in metal oxide surge arrester are showed in Fig. 6.

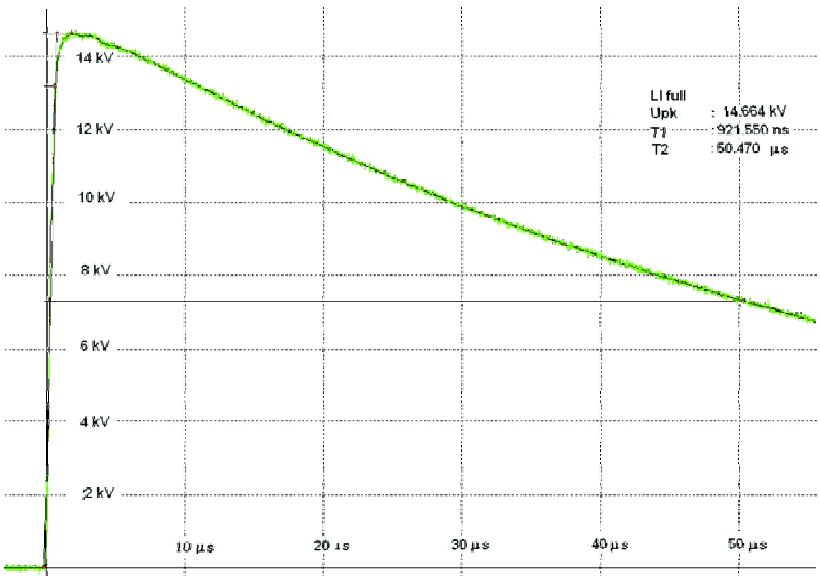

Fig. 5. Standardized shape of surge

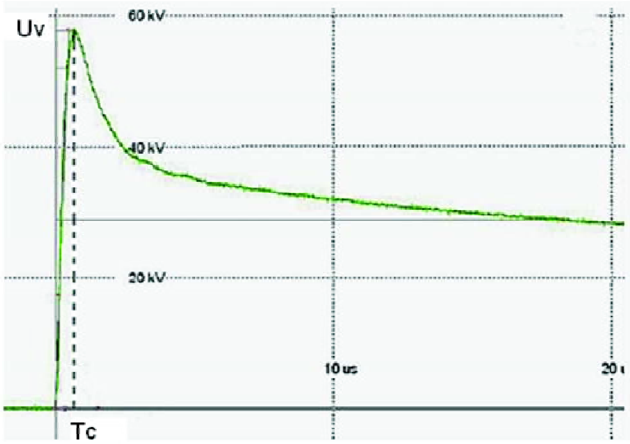

Fig. 6. Surge recorded in metal oxide surge arrester

The measures with impulse voltage were carried out on surge arresters with two types of the varistors blocks. First blocks were covered by electroinsulating varnish, while second one were no covered. The results of the U_g, U_v, T_c of the surge arrester with the varistors with electroinsulating varnish and without varnish are showed in tables 1 and 2 respectively.

TABLE 1

Surge arrester with varistors with electroinsulating varnish

U_g	U_v	T_c
kV	kV	μS
12	11.69	2.71
30	28.07	2.48
50	34.55	1.34
70	39.77	1.08
100	47.40	1.02
120	52.27	0.89
140	57.76	0.87
160	56.99	0.65
190	77.81	0.63

TABLE 2

Surge arrester with varistors without varnish

U_g	U_v	T_c
kV	kV	μS
12	11.78	2.55
30	28.02	2.53
50	34.45	1.34
70	39.69	1.16
100	47.32	0.98
120	52.31	0.88
140	57.34	0.87
160	57.52	0.70
190	79.53	0.63

Letter sign:
U_g – voltage on generator,
U_v – voltage measured on surge arrester,
T_c – time for surge amplitude.

The local discharges between varistors and discharge in middle part of the surge arrester during tests were recorded. Consecutive tests showed that stratification between polyamide insulating housing and varistors block (Fig. 7). Probable cause of the successive stratification and therefore weakness of the electrical withstanding. The discharge developing on ceramic varistors surface, effect of what was the total damage (tearing on polyamide housing) of the metal oxide surge arrester (Fig. 2).

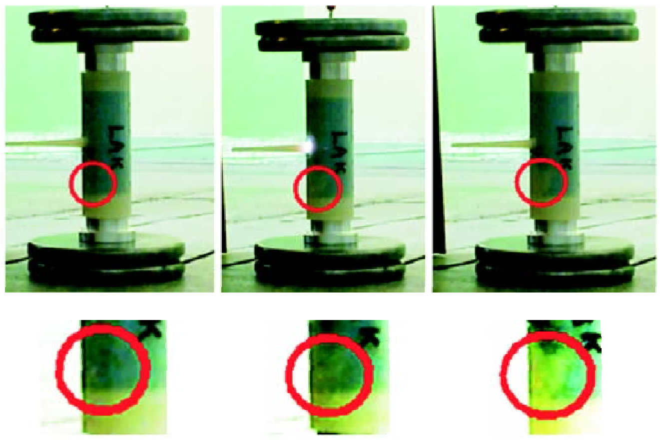

Fig. 7. Stratification between polyamide insulation and ceramic varistors surface A – picture before discharge B – picture during discharge C – picture after discharge with clear stratification

The measures with impulse voltage were carried out of the blocks contain five ceramic varistors, covered by electroinsulating or semiconducting varnish and also varistors without cover. For the tests were used varistors with two types of electrodes. Influence side varistors cover by different varnish on flashover voltage are showed in tables 3, 4, 5. (Letter sign as for tables 1 and 2).

TABLE 3

Varistors block without varnish

U_g	U_v	T_c
kV	kV	μS
12	11.73	2.72
30	9.38	2.58
50	39.72	2.13
70	44.12	1.45
100	49.15	1.26
120	52.04	1.09
140	54.39	1.02
160	57.22	0.94
190	61.16	0.88
190	79.53	0.63

TABLE 4

Varistors block with electroinsulating varnis

U_g	U_v	T_c
kV	kV	μS
12	11.68	2.76
30	29.08	2.45
50	37.04	1.44
70	43.53	1.04
100	53.14	0.96
120	59.69	0.93
140	63.50	0.83
160	70.23	0.79
190	79.35	0.77

TABLE 5

Varistors block with semiconducting varnish ($\rho \sim 10^{10} \Omega$m)

U_g	U_v	T_c
kV	kV	μS
12	11.70	2.95
30	29.32	2.55
50	40.36	1.39
70	47.32	1.21
100	57.31	1.03
120	63.89	0.96
140	70.63	0.90
160	76.99	0.86
190	84.03	0.78
190	79.35	0.77

The dependence of the flashover voltage on time to flashover defines the impulse characteristic (Fig.8). Shape of the characteristic can also qualify is the construction in uniform field or not [2].

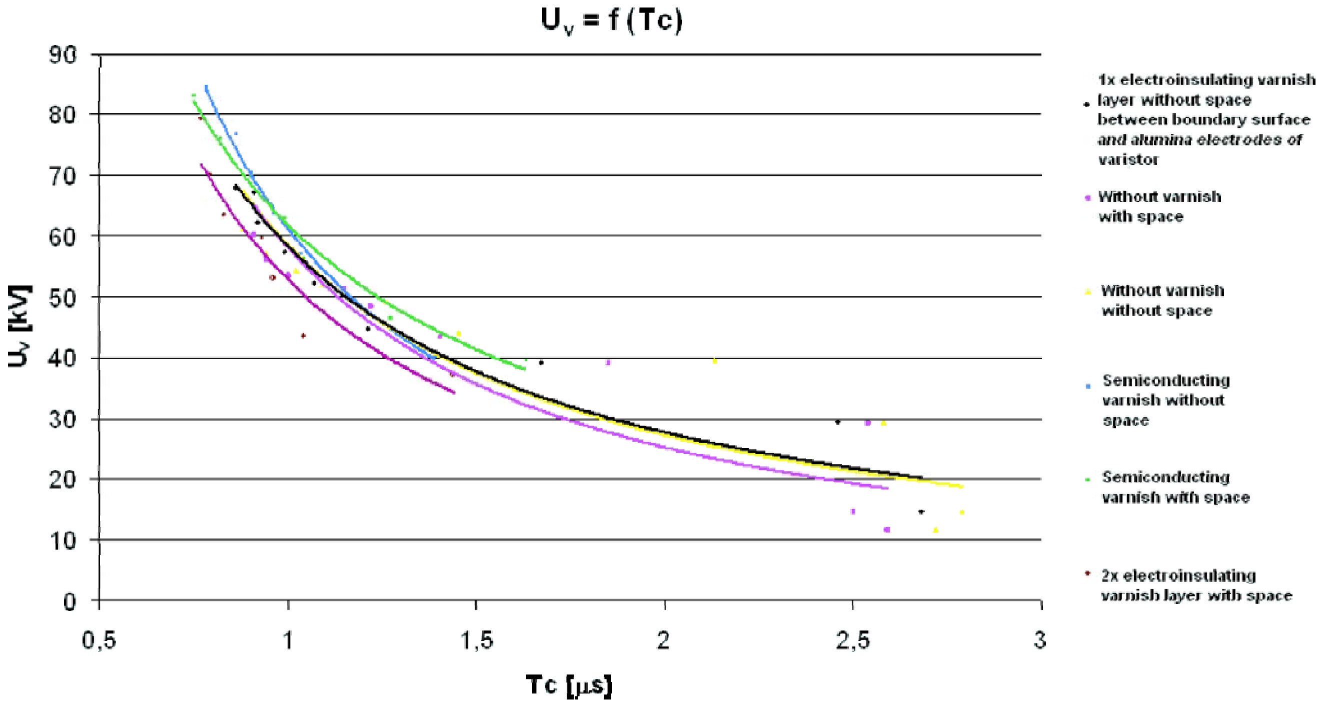

Fig. 8. Impulse characteristic for varistors block covered by different type of varnish

5. Discussion

The comparison of the voltage of varistors, suggests that the covering of the side surface of the varistors by the semiconducting varnish with resistivity about $10^{10}\Omega$m is the most profitable solution. That varnish based on electrical withstand measures of the dielectric materials was assorted. It was affirmed that covering of the dielectric surface by varnish with that resistivity increase flashover voltage about 10-15% [7].

The pictures of discharges during impulse voltage tests were recorded (Fig. 9). In the case of the samples without varnish, discharge developing is visible on whole varistors block area. However, for the same amplitude of the impulse voltage for samples covered by semiconducting varnish visible are only local discharges between varistors. With higher impulse voltage the discharge developing on few varistors in the block was observed. Interesting is our observation that for the samples covered by electroinsulating varnish voltage measured on the varistors block, is lower then voltage on the block with varistors covered by semiconducting varnish. However the samples covered by electroinsulating varnish have no clear surface discharges. Visible are luminescence between high voltage electrode and varistor and also between varistors in the pile.

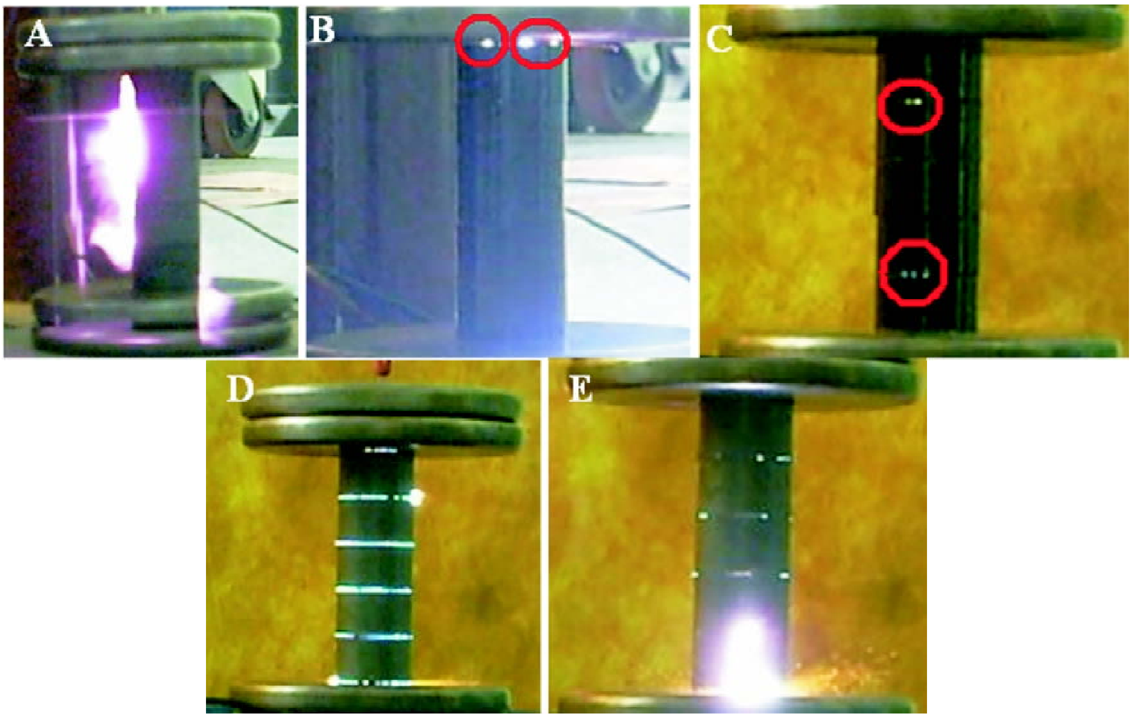

Fig. 9. Pictures of discharges in five varistors block A – varistors without cover, B, C – varistors covered by electroinsulating varnish, D, E – varistors covered by semiconducting varnish

6. Conclusions

The stratification between polyamide insulation and ceramics varistors are caused by surface discharges in metal oxide surge arrester. Damage with high impulse voltage tests due to surface discharges and local discharges between varistors, confirm the registered pictures of the discharges.

Interfacial space charge and surface charge generated on varistors are cause of the damage with high impulse voltage and high current tests [9, 10].

The authors investigations confirm the thesis that the covering the side of the dielectric by semiconducting varnish increase electrical withstand of the construction and flashover voltage about 10-15%.

It was found that problem of the surface discharges over surge arresters and dielectric materials (due to surface roughness and high electric field action) can be solved by covering of the sides of varistors with semiconducting (resistivity ~ $10^{10}\Omega$m) varnish, as it equalizes electric field and increases the flashover voltage by 10-15 % in the effect.

The key to the without breakdown operation of the surge arresters is in production technology of their housings. Material for housing, temperature and pressure of the insulating shield injection, the way of the housing deposition on varistors and good contact between varistors in pile are essential.

REFERENCES

[1] European Standard EN – 60099-4/A2 Metal oxide surge arresters without gaps for a.c. systems.

[2] Z. Flisowski, Technika wysokich napięć, WNT Warszawa (1992).

[3] J. Juchniewicz, Podstawowe prawidłowości niektórych odmian wyładowań powierzchniowych w powietrzu, Prace Naukowe Inst. Podst. Elektrotechniki i Elektrotechnologii PWR, Nr 7, 79-87 (1971).

[4] M. Abdel - Salam, P. Weiss, Discharges In air from point electrodes in the presence of dielectric plates – theoretical analysis, IEEE Trans. On El. Insul. **27**, 2, 320-333 (April 1992).

[5] M. Abdel - Salam, P. Weiss, Discharges In air from point electrodes in the presence of dielectric plates – experimental results, IEEE Trans. On El. Insul. **27**, 2, 309-319 (April 1992).

[6] J. Staroń, Wytrzymałość powierzchniowa dielektryków w atmosferze czynników roboczych rur cieplnych, Doctoral thesis, Wrocław University of Technology, Electrical Faculty, Wrocław (1999).

[7] K. Kogut, B. Mazurek, K. Kasprzyk, Czynniki wpływające na wytrzymałość powierzchniową dielektryków – Przegląd Elektrotechniczny, ISSN 0033-2097, R.84 No 10/2008, 79-82, (2008).

[8] B. Mazurek, J. D. Cross, The effect of metallic particle near a spacer on flashover phenomena in SF6, IEEE Trans. On El. Insul. **28**, 2, 219-229 (April 1993).

[9] Shengtao Li, Jianying Li, G. Chen, A. E. Davis, Interfacial space charge between ZnO varis-

tor ceramics and coating materials, IEEE 2002, 2002 Annual Report Conference on Electrical insulation and Dielectric Phenomena, 478-481, (2002).

[10] M. Derveniza, Saha K. Tapan, Surface flashover on metal oxide varistor blocks, IEEE 1998, International Conference on Conduction and Breakdown in Solid Dielectrics, June 22 - 25, Vasteras, Sweden, 406- 409 (1998).

Received: 10 September 2009.