HIGH RESISTANCE SURFACE COATING OF SOLID INSULATING COMPONENTS FOR HVDC METAL ENCLOSED EQUIPMENT

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Abstract

The field distribution of DC insulation systems is controlled by the conductivity κ of the insulation material. It can be improved by using a high resistance surface coating. Furthermore this coating can prevent charge accumulation on the surface of the insulation. This paper reports about the investigations regarding such a coating that is applied to HVDC stress. The influence of voltage, electrical stress and temperature on the resistance of the coating are investigated.

1 *Introduction*

In contrary to AC the field distribution of DC insulation systems is mainly controlled by the conductivity κ of the insulation material. Surface charge accumulation due to ion motion may lead to field distortion and a reduction of the breakdown voltage of the system. For a spacer used in Gas-Insulated-Substations (GIS) which is applied to DC voltage it is of advantage to use a special coating to improve the field distribution[1]. A certain value of the surface resistivity is necessary to gain suitable results. This special surface coating is applied to high voltage stresses and electrical fields in the order of about 30 kV/cm.

2 *Influence of Surface Coating*

For the investigation concerning the surface coating, a cylindrical sample of polyethylen with a diameter of 2cm is used which is more comfortable to handle than a real epoxy spacer for GIS. Figure 1 shows the geometry of the test arrangement. Two cylindrical electrodes are used. The length s of the sample can be varyied from 4 to 8cm to gain different field stresses.

As a first step the influence of surface resistivity on the field distribution is investigated. For this aim numerical calculations based on the Boundary-Element-Method (BEM)[2] are made.

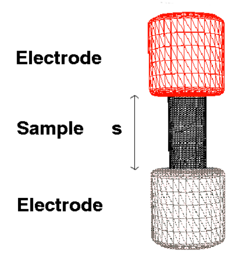

Figure 1: Geometry for the field calculation

The boundary conditions are modified to calculate fields with surface resistivity[3].

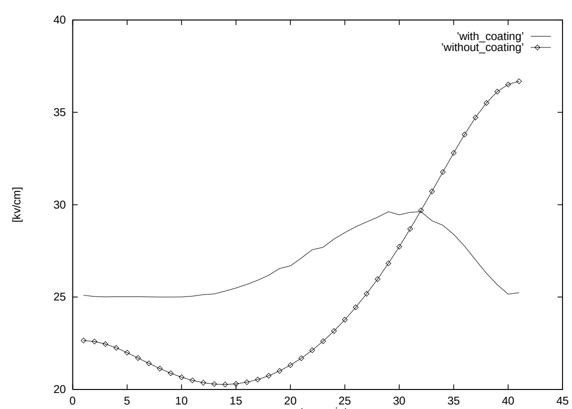

Figure 2: Field distribution E_{res}

The results of the calculation are shown in figure 2. The applied voltage is 100 kV DC. Without a surface coating the field distribution is inhomogeneous and the peak value is achieved at the high voltage electrode. Using a surface coating with a resistance of $10^{11}\Omega$ the resistive field is more homogeneous. The maximum value E_{max} is reduced from about 36.7 kV/cm down to 29.6 kV/cm. Therefore surface coating improves the field distribution.

3 Coating

The problem is to find a coating with a resistance of about $10^{11}\Omega$ that can withstand high voltage conditions with electrical field stresses around 30 kV/cm. An electroconductive powder of *DuPont* is a possible coating with these features[4]. The powder consists of a dense layer of crystallites of antimony-doped tin oxide on inert core particles. The antimony-doped tin oxide is the conductive phase. To gain different values of resistivity the conducttive powder is mixed with TiO_2.
For the first investigations the coating is put manually on the surface of the sample. Therefore the thickness of the coating can vary slightly on the surface.

4 Experimental Setup

For the investigations a high voltage test setup as shown in figure 3 is used. A test voltage up to 140 kV DC can be realised. This voltage U is measured by the current in resistance $R3$. The resistance $R2$ (50 kΩ) is inserted for protection purposes. The resistance of the sample is simply gained by $R_s = U * I$. The influence of $R2$ on R_s can be neglected.

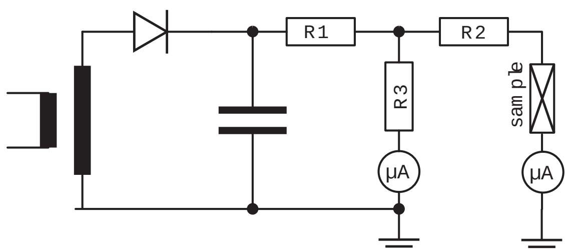

Figure 3: Experimental setup

The sample is installed in a pressure tank to withstand the high electrical stresses without flashover. The air pressure is varyied from 0.1 MPa to 0.25 MPa. The measuring equipment can detect currents down to 1 nA. This means a maximum resistance of $10^{14}\Omega$ can be measured.

5 Results

Breakdown voltage

First of all the breakdown voltage of the system is investigated. Due to the field calculation, the breakdown voltage of the sample with surface coating should be higher than without coating.
This assumption is checked by 100 breakdown tests (p=0.1 MPa) with coated and non-coated samples.

	E_{max}	U_{bd}
non-coated surface	36.7 kV/cm	71.2 kV
coated surface	29.6 kV/cm	79.3 kV

Table 1: Influence on breakdown voltage

The results of table 1 prove that the ratio of the maximum field stresses of coated and non-coated surfaces is similar to the ratio of the breakdown voltages. Therefore surface coating improves the withstand voltage of a DC insulation system.

Achieved resistances

With the mentioned coating material it is possible to achieve different values for the resistance. The resistance of the coating can be varyied from 10^8 up to $10^{14}\Omega$. Figure 4 shows the achieved resistance range of the coating.

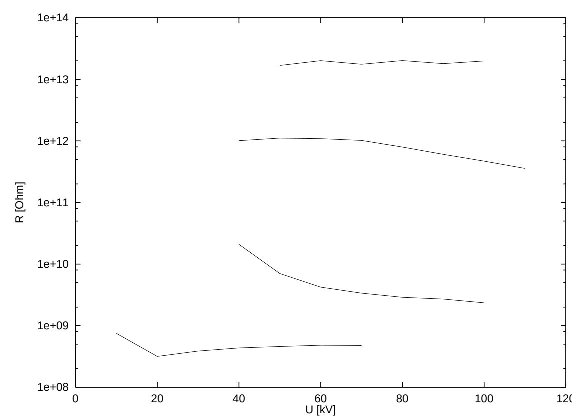

Figure 4: Achieved resistance range

Influence of temperature

An important point of interest is the influence of voltage, electric field stress and temperature on the behaviour of the coating. Several investigations are made with that respect.
The influence of temperature caused by the power loss in the coating has been investigated. The temperature on the surface of the sample has been measured during the tests. It is dependent on the value of the resistance. For a resistance of $10^{11}\Omega$ and more the power loss of the system is not sufficient to heat the sample. The temperature and the resistance of the sample is almost constant. Figure 5 presents the results for a sample with a resistance in the range of $10^{10}\Omega$. The power loss causes a heating of the coating. With rising temperature the resistance is decreasing. When the

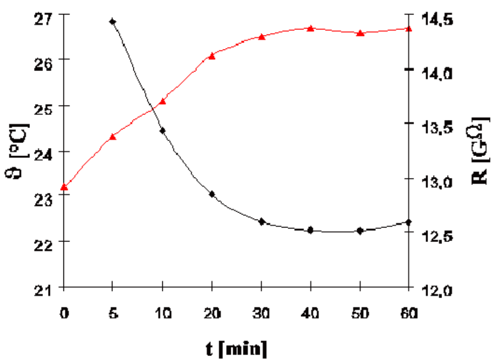

Figure 5: Influence of temperature

maximum temperature ($\vartheta = 26.5$°C) is reached the resistance remains constant (R=12.5GΩ).

A further point of interest is the behaviour of the coating when it is applied to HVDC for a long time period. Investigations were made over a time period of three hours. Figure 6 shows the results of a coating with a resistance of $10^9\Omega$. The temperature at the start of the test was 27°C and increases up to 42°C at the end. As a result the resistance is decreasing over the time period.

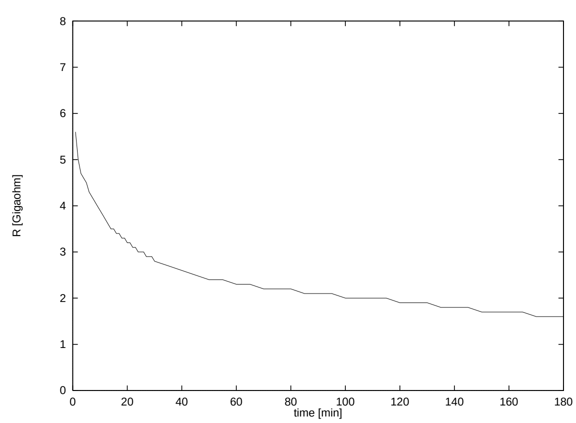

Figure 6: 3-hour test

To gain different field stresses the length of the probe is varyied from 4 to 8cm. The voltage is increased in steps of 10 kV every 10 minutes.

Figure 7 shows the results for two samples (4 and 8cm). Regarding the 4cm sample the electric field stress is twice as much as for the 8cm sample. But there is no change of the resistance due to the electric field stress. It is again the influence of temperature. Both samples were heated during the tests. To understand this fact it is useful to regard the power in an unit element of the coating (fig. 8).

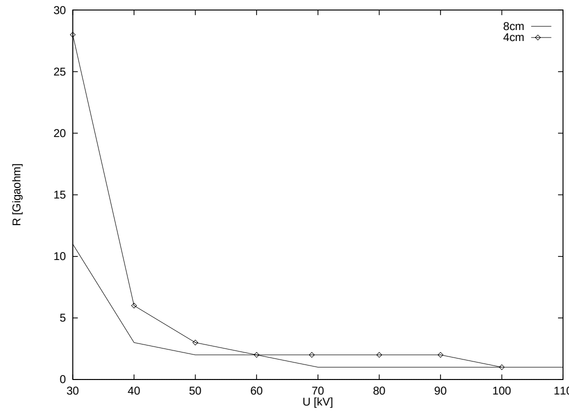

Figure 7: Influence of field stress

The power input P' into such a coating unit with a resistivity ρ and a thickness δ is:

$$P' = j^2(\frac{\rho}{\delta})$$

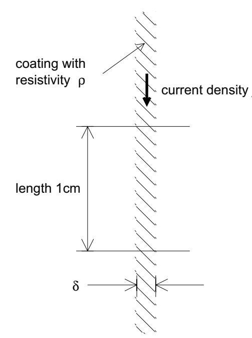

Figure 8: Power loss

For the 4cm sample the surface resistivity $(\frac{\rho}{\delta})$ is 4 times as much as for the 8cm sample, because the total coating resistance is according to figure 7 twice as high. Therefore at both samples the unit elements of the coating have the same power input.

$$P'_{8cm} = j^2_{8cm}(\frac{\rho}{\delta})_{8cm}$$

$$P'_{4cm} = (\frac{j_{8cm}}{2})^2 4(\frac{\rho}{\delta})_{8cm} = P'_{8cm}$$

This means that the coating temperature of both samples will be the same. The progression of the resistances of the samples develops similarly and the ratio remains constant.

The results for another sample with a higher resistance ($10^{11}\Omega$) are shown in figure 9. There is *no* change of the resistance over the test period, because the sample is not been heated. This means with a resistance of $10^{11}\Omega$ and more there is no influence of voltage and electric field stress, because the power input is not sufficient to heat the coating. The resistance of the coating remains constant with time.

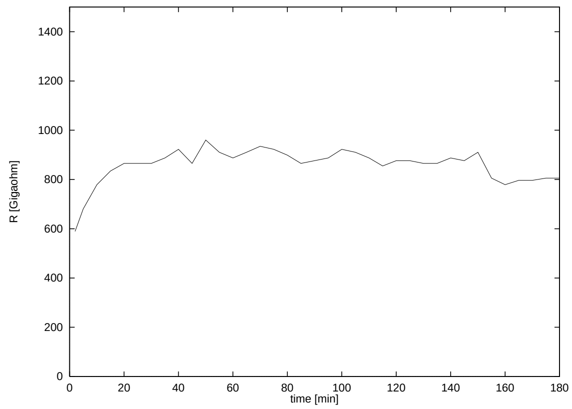

Figure 9: 3-hour test

6 Future Investigations

Future investigations will concern the behaviour of the coating under field stresses up to 100 kV/cm because for real GIS-systems such high field stresses are of interest.
Furthermore the coating has already been used on real 110 kV spacers for GIS. First results are similar to those for cylindrical samples. That indicates that the coating can successfully be applied in HVDC-GIS-systems. Additional investigations are necessary for its reliable application.
In real GIS-systems the inner conducter have temperatures up to 80^{o}C due to current heating. This has to be considered in future investigations.

7 Conclusions

High resistance surface coating of solid insulating components in highly stressed HVDC insulation systems have been investigated.

- The field distribution of HVDC insulation systems can be improved by using conductive surface coating.
- A special coating has been found, which can withstand an electrical field stress up to 30 kV/cm.
- This resistance can be varyied from $10^8 - 10^{14}\Omega$.
- The resistance is dependent on the temperature of the coating. With rising temperatures the resistance is decreasing.
- If a temperature increase due to power losses in the coating is avoided the resistance is independent on the voltage and electric field stress.
- In case of the used cylindrical sample a resistance of $10^{11}\Omega$ and more remains constant with time.

References

[1] F. Messerer, W. Boeck
Field optimization of a HVDC-GIS-Spacer
Annual Report CEIDP, Atlanta, 1998, Vol. I, pp. 15-18

[2] Z. Andjelic, B. Krstajic, S. Milojkovic, A. Blaszcyk, H. Steinbigler, M. Wohlmuth
Integral Methods for the Calculation of Electric Fields. Scientific Series of the International Bureau, Vol. 10, Forschungszentrum Jülich GmbH, Germany, 1992

[3] S. Chakravorti
Capacitive-Resistive Field Calculation around a HV Insulator using Boundary Element Method
10^{th} ISH Montreal, 1997, Vol.3 ,pp. 49-52

[4] Du Pont
ZELEC ECP
Electroconductive Powders

[5] M. Beyer, W. Boeck, K. Möller, W. Zaengl
Hochspannungstechnik
Springer Verlag, 1986

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