Computed voltage distribution in ZnO arrester under pollution by finite element method

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Abstract- **The voltage and electric field distribution in an arrester are very important for its long operation 15 kV with and without pollution. In order to clarify the influence of pollution severity condition on metal oxide surge arrester, the finite element method (FEM) compilation of the voltage distribution in the ZnO column varistors under different pollution layer conductivity (70µS, 20µS, 1nS) was employed.**

Keywords: ZnO arrester performance, Finite element method, voltage distribution, pollution

I. INTRODUCTION

Zinc oxide (ZnO) surge arresters have been used extensively in high voltage power systems for providing protection to the insulation in power apparatus against different forms of overvoltages. The life of these arresters is dependent on their steady state performance. It has been observed in practice that the voltage distribution in the arrester is quite non-uniform. As a result, the discs at the top are subjected to higher voltage than the remaining discs. This leads to a faster thermal ageing of the discs at the top. To overcome this problem efforts are generally made to make the voltage distribution as uniform as possible. Thus**,** the voltage and electric field distribution in an arrester are very important for its long operation performance.

Metal oxide surge arresters without gaps are continuously stressed at the system voltage. This leads to small leakage current levels flowing through the arrester elements. These currents are in the range of several microamps to several tens of microamps. Under steady state conditions the total leakage current is composed of a large capacitive component and a small resistive part, which leads to consider that the voltage distribution is mainly determined by the arrester capacitances [1, 5, 2]. Ideally, the potential gradient along the arrester should be uniform. The capacitance of each element can be determined approximately from the geometry and permittivity of each element, when neglecting the effect of stray fields. However, for a more accurate computation of the potential distribution and arrester capacitances (including stray capacitances), a field computation using a finite-element package is required [5].

In the present paper, the authors have used FEMLAB package [3] to compute the voltage and field distributions on a typical polymeric zinc-oxide surge arrester taking into account the pollution. Preliminary results for considered levels of pollution layer conductivity are presents and discussed.

II. ARRESTER MODEL

The surge arrester modelled in this work is a commercially available distribution polymeric housed distribution arrester rated at 15kV.

Fig. 1 shows the construction details of the arrester. The arrester polymeric housing is made of Ethylene Propylene Diene Monomer (EPDM), a synthetic hydrocarbon rubber with a relative permittivity ε_r = 3.9. In the housing, they are three zinc-oxide elements (60 < ε_r, < 1000) [4] are mounted in series between two aluminium-alloy terminal blocks. A permanent homogeneous resin and glass fibre bond (ε_r= 4.6) encases the element/terminal assembly to provide a high mechanical strength and a void-free dielectric interface at the walls of the zinc oxide elements [5]. In this work a relative permittivity ($\varepsilon_r=10^6$) of the metallised faces of the zinc-oxide elements was used.

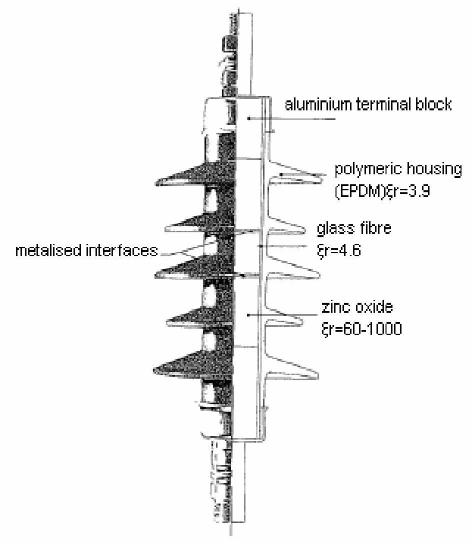

Fig. 1 Construction details of the modelled arrester
Reproduced from [5].

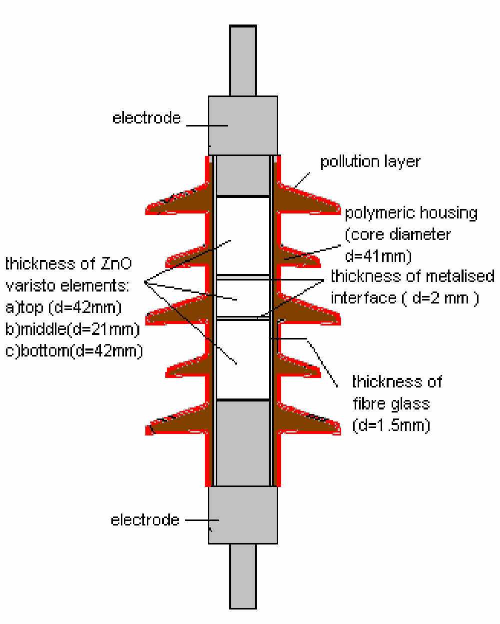

Fig. 2 Geometry model of 15kV MOA

III. GEOMETRY MODEL OF ARRESTER

Fig. 2 represents the Geometry model of 15kV ZnO surge arrester.The total height of the metal oxide arrester in this work is about 300mm, and the diameter of varistor disk is about 32mm.The total height of varistor disk column is about 105mm and The height of varistor disk column with two aluminum-alloy terminal blocks was about 168mm.the Inner diameter of polymeric housing was about 35mm and shed diameter large/small was about 111mm/88.2mm respectively. Then three of ZnO varistor elements are used with a relative permittivity $\varepsilon_{r\,(ZnO)} = 60$.

IV. BOUNDARY CONDITIONS

The relevant interface condition at interfaces between different media for this mode is

$$n2 \cdot (D1 - D2) = \rho_s \qquad (1)$$

In the absence of surface charges, this condition is fulfilled by the natural boundary condition

$$n \cdot \left[(\xi_0 V - P)_1 - (\xi_0 V - P)_2 \right] = -n \qquad (2)$$

$$(D1 - D2) = 0 \qquad (3)$$

The electric-potential boundary condition

$$V = V_0 \qquad (4)$$

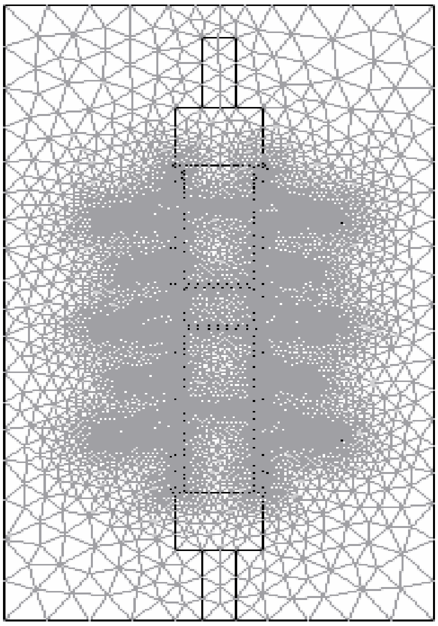

Fig. 3 Mesh with 36668 elements

Specifies the voltage at a boundary, which is the upper electrode in our modelled surge arrester. In this work electric-potential boundary of V_0=15000V.

The ground boundary condition (V = 0) is specifying zero potential, at the lower electrode of in our modelled arrester.

V. RESULTS AND ANALYSIS

According to the calculation model above, mesh is divided and boundary condition is given, by means of resolving and reprocessing. Fig. 4.a and fig. 4.b shows the results.

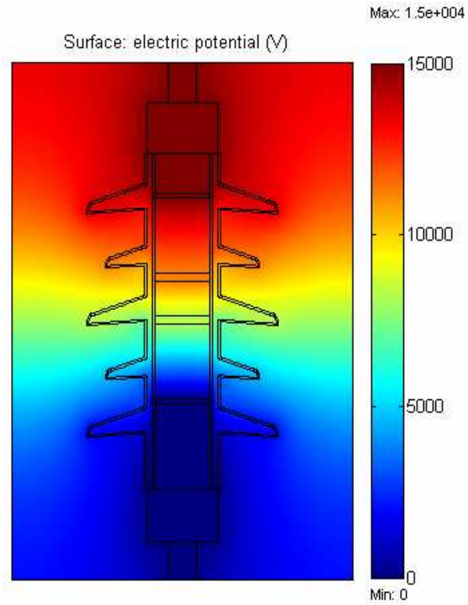

Fig. 4.a Electric potential distribution echogram with pollution at conductivity σ= 70μS

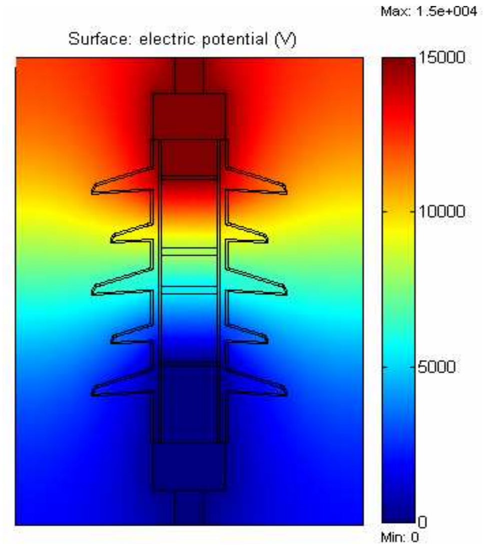

Fig. 4.b Electric potential distribution echogram without pollution

Fig.5 and Fig.6 shows potential contours for complete surge arrester structure with a permittivity ε_r = 60 for the zinc oxide under clean and pollution condition respectively with the help of the FEMLAB software

The potential contours for complete surge arrester structure without pollution was uniform, but with pollution was non uniform. For $\varepsilon_{r\ (ZnO)}$ = 60, the per-unit potential values of 0.53and 0.36 were obtained on the upper and lower metallised interfaces of the ZnO varistors column, respectively.

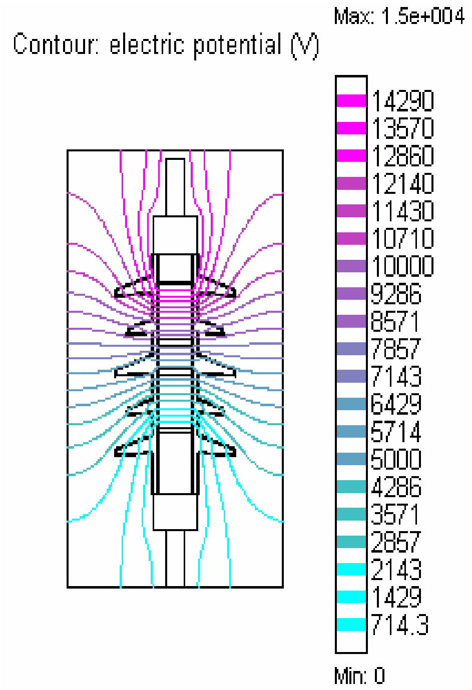

Fig. 5 Potential contours for 15kV ZnO surge arrester without pollution (clean)

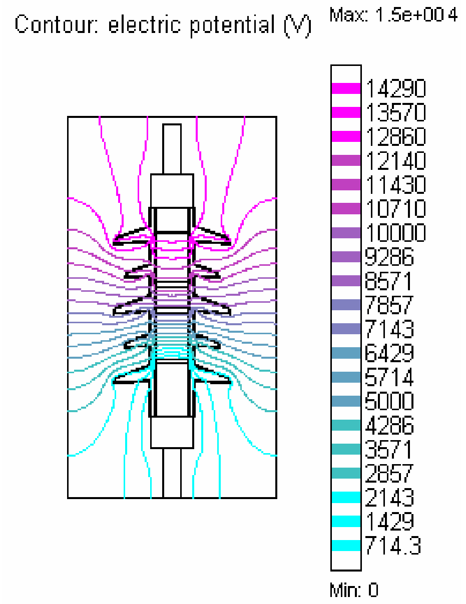

Fig. 6 Potential contours for 15kV ZnO surge arrester with pollution at conductivity σ= 70µS

Table I represents the comparing of results of the per_unit potential values on the upper and lower metallised interfaces respectively, using the FEM computed method with the results obtained in [5].

TABLE I

COMPARING OF RESULTS

Voltage distribution	Voltage at upper metallised interface (per unit)	Voltage at lower metallised interface (per unit)
Using FEM computed method	0.53	0.36
Obtained in [5].	0.55	0.37

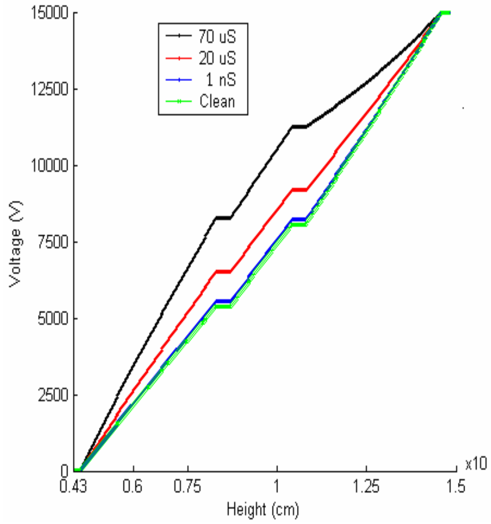

Fig. 7 Voltage distribution along ZnO varistors of arrester

V.1. Voltage distribution studies under polluted conditions.

Three levels of pollution layer conductivity are considered for the study, assuming uniform deposition: pollution level at conductivity σ= 70µS, σ =20µS and σ =1nS. Fig. 7 show the results. The voltage distribution is non uniform only for pollution levels at conductivity σ= 70µS and σ =20µS, so the voltage distribution remain non uniform for a wetting pollution layer deposit in the housing of arrester.

The fig.8 showed the voltage distribution along external layer of the polymeric housing for different severity of the pollution layer (σ= 70µS, σ=20µS) with a permittivity (ε_r =650, ε_r =18) [6], respectively and clean layer. The pollution severity depends on the environmental conditions in the location where the surge arresters are employed.

In general, the external layer of arrester in clean environmental a very high resistance and the potential distribution along the arrester is linear. But when the external layer of the arrester is contaminated and in moisture ambient, the pollution layer on the polymeric housing attains some conductivity, and the resistance decrease for some orders of magnitude. So the voltage distribution of MOA inside (ZnO varistors elements) and outside (pollution layer on the polymeric housing) is uneven, the consequence is the voltage to same varistors are too high.

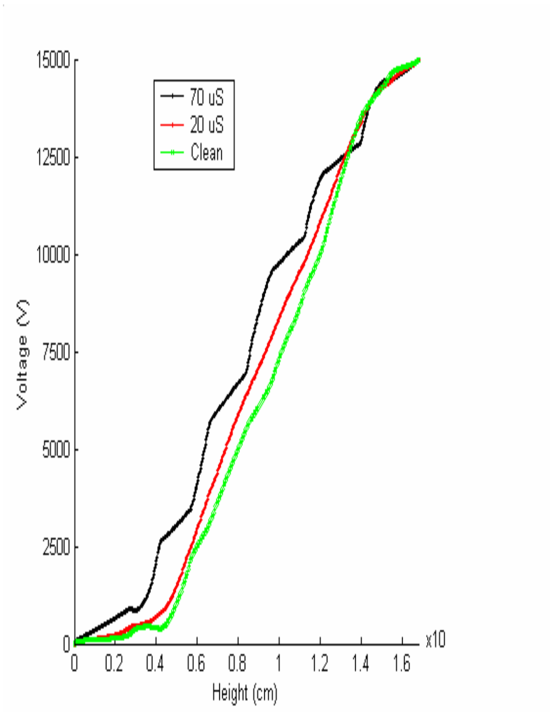

Fig. 8 Voltage distributions along external layer of the polymeric housing of ZnO arrester.

VI. CONCLUSION AND FUTURE WORK

In order to clarify the influence on the zinc oxide varistors elements (ZnO) under pollution severity Condition in the metal oxide surge arrester. The finite element method (FEM) compilation of the voltage distribution in the ZnO column varistors under different pollution layer conductivity (70µS, 20µS, 1nS) was employed. The obtained results are very promising As a result, the voltage distribution remain non uniform for a wetting pollution layer deposit in the housing of arrester.

In future work a full equivalent capacitance network, which takes into account the ZnO material properties and the stray capacitances to the floating electrodes, could be derived. This will provide a circuit based method for the simulation arrester steady state performance. This approach may give an accurate representation of the voltage distribution in the arrester under power frequency voltage. For the case of fog conditions, pollution layers on the arrester housing will become conducting and could result in a significant redistribution of the voltage. The method of computation of the equivalent network may be used for example to simulate the effects of the capacitive coupling to polluted layers on the arrester housing. Such a condition is of real concern and has been known to unfavourably stress the arrester.

VII. REFERENCES

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