Numerical Simulation of the High-Voltage Cable Sleeve Operation for 110 kV

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***Abstract*— Vulnerable area of a high-voltage cable lines is the linking of two cables, connecting of which are carried out using cable sleeve. The main reason of failure of the cable sleeves is a violation of the basic insulation. Currently, the main element of the high-voltage sleeves is the stress cone, which uses a capacitive method of reducing unevenness of an electric field. The numerical simulation of the high voltage sleeve was fulfilled for the cable 110 kV using finite element method. The electric and thermal fields were analysed. The most probable zones of electric breakdown in the structure of the investigated sleeve have identified as a result of numerical studies. The optimal geometric and physical parameters of the stress cone were determined also. The use of computer simulation has enabled to save time on designing and creating a prototype.**

Keywords—cable sleeve; high-voltage; electrical cables; numerical simulation; electric field

I. Introduction

Development and production of cable fittings is one of the priorities of modern cable technology. The place of cutting, where there is infringement of the basic cable insulation, is one of the most vulnerable places in the cable line. Statistics of damage to cable lines in China for the last 10 years shows that 63% of the injuries have on the cable sleeves [1]. So now the actual problem is to increase reliability and improve operational characteristics of the coupling through optimization of its design.

Currently the capacitive method [2-3], implemented in a specially formed two-component elastomeric element – the so-called stress cone is using for control the electric field in the cable in high voltage terminating and couplings. In this work the stress cone of the coupling was considered only. Because all the key elements and the hazardous areas of terminating sleeve are presented in the coupling.

I. Basic principles

The aim of this work is the optimization of the design of the stress cone of the coupling by means of computer simulations based on the finite element method [4-5]. The main constructural elements of the high-voltage coupling studied are shown in the Fig. 1. Part of the stress cone of the coupling includes: a main insulating body and the deflector. The basic material of element is the ethylene propylene rubber. The conductive filler is added into the material of the deflector. To solve this problem we use a combination of the two means (geometric and refractive) capacitive control method of an electric field. The computer simulations using specialized software "ElcutProfessional" was carried out to optimize the balance between physical and geometrical parameters, reliability and cost of the hight-voltage sleeve. The optimization procedure was performed on the following parameters:

- The value of the relative permittivity ε of the insulating main body
- Length of high voltage electrode
- The distance between the high voltage electrode and deflector
- The conductivity of the high-voltage electrode

The results obtained are presented below.

II. The results of the computer simulation

The dependences of the electric field in critical zones, in which these changes have the greatest impact, were found by sequential variation of each parameter.

The electric field strength is inversely proportional to ε of the insulating main body. Therefore, when determining the optimum values of the dielectric constant should take into account changes in the physical properties of the material.

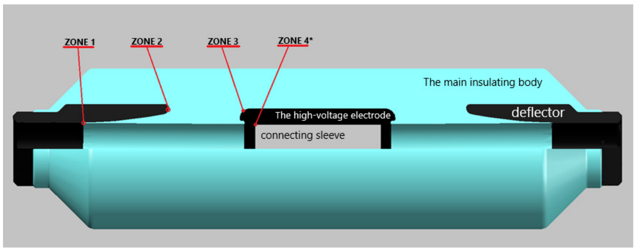

Fig. 1. Elements of the design of the stress cone and the critical zones of the electric field: 1 – (Zone 1) the border of the shield over the polymeric insulation of the cable and the deflector, 2 – (Zone 2) the edge of the deflector, 3 – (Zone 3) the edge of the high-voltage electrode, 4 – (Zone 4) the edge of the connecting sleeve (if the edge of the sleeve comes over the high-voltage electrode), 5 – the main insulating body, 6 – deflector, 7 – the high-voltage electrode.

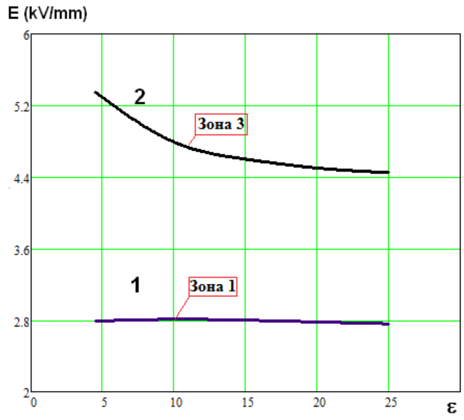

Fig. 2. The dependence of the electric field *E* in the critical area 1 and 3 on the value ε of the main insulating body: 1 – Zone 1, 2 – Zone 2.

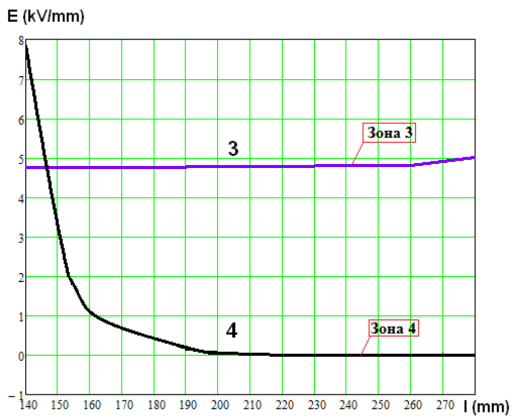

Fig. 3. The dependence of the electric field *E* in the critical area 3 and 4 on the length of high voltage electrode: 3 – Zone 3, 4 – Zone 4.

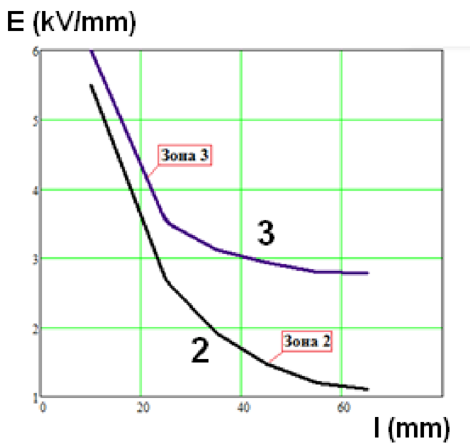

Fig. 4. The dependence of the electric field *E* in the critical area 2 and 3 on the distance between length of high voltage electrode and deflector: 2 – Zone 2, 3 – Zone 3.

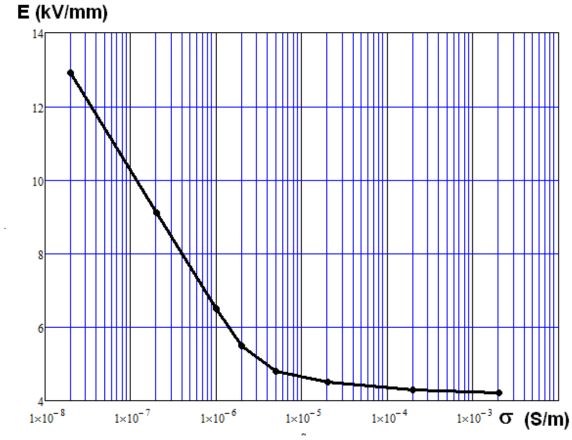

Fig. 5. The dependence of the electric field *E* on conductivity of high voltage electrode for zone 3.

IV. Conclusions

Using the numerical simulation was defined as optimal parameters following values of the high-voltage stress cone:

- length of the high voltage electrode is 190 mm
- distance between the high voltage electrode and the deflector is 65 mm
- sufficient conductivity of the material of the deflector is 0.0002 S/m; the increase in conductivity over the specified value is impractical because does not reduce the strength of the electric field.

Considered the design optimization of electrical high voltage sleeves does not account for the complexity of its production and installation. Further work should be devoted to the problem of simplifying the construction of the sleeve that is replacement structure consisting of two elements into a single element structure.

References

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