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EFFICIENCY OF CABLE INSULATION CONTROL IN WEAK AND STRONG ELECTRIC FIELDS

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It is considered the efficiency of cable insulation control for monitoring of insulation quality with the electrospark control and the control of capacity and / or dielectric losses during cable manufacturing.

Key words:
Flaw of insulation, electrospark control, control of insulation capacity

Nowadays, cable manufacture is one of the most dynamically developing fields of industry. The quality of the cable product must be in compliance with regulatory documentation to provide reliable transmission path. The quality of cable insulation (continuity and external geometry) is one of the most important control-required parameters. This parameter is particularly significant for communication cables transmitting information.

According to the current regulatory documentation, epy control of cable insulation quality is carried out by electrospark and electrocapacity methods. The electrospark method is used for a strong electromagnetic field and insulation breakdowns are registrated during control. The electrocapacity method is used for a weak electromagnetic field. Changing in the capacitance is recorded. The method of electrocapacity control in a strong electric field was offered in previous papers.

To compare measurement efficiency carring out in a strong and weak electric fields it is necessary to explore the defect dimension affects to the capacitance in the both methods.

Measurement of capacitance in a strong electric field differs from that in a weak electric field because of the electrical breakdown. In case of the isolation thickness reduces more than the limit value it leads to electrical (and/or thermal) breakdown in a strong electric field, whereas in a weak electrical field this does not occur. As the capacitance does not depend on the voltage value, the defect dimension affects on capacitance is the same in both of the methods until the insulation thickness exceed the limit value. This statement does not work for "air pocket" defect because of the electrical discharge occurring if high test voltage is applied [2]. This phenomenon cannot be observed in a weak electric field.

Different dependencies have been obtained for a strong and weak electric fields during exploration of the "air pocket" defect dimension effect on the change in electrical capacitance.

For simplification an plate capacitor with anisotropic dielectric was used. The parallelepiped with *a*x*b*x*c* dimensions (height, length, width, respectively) is the model of the defect (Fig. 1).

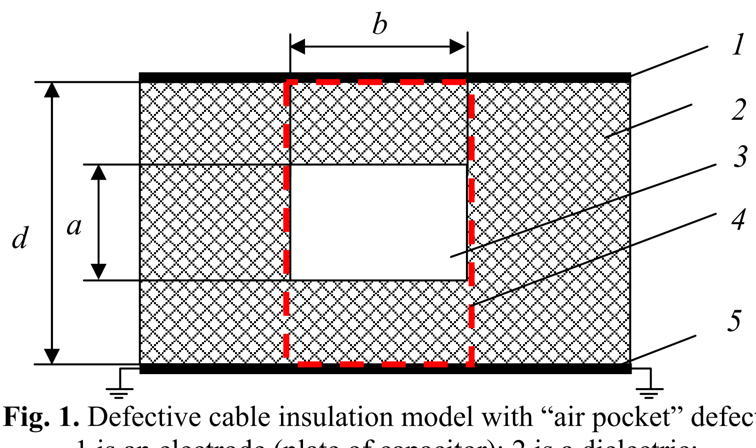

Fig. 1. Defective cable insulation model with "air pocket" defect:
1 is an electrode (plate of capacitor); 2 is a dielectric;
3 is "air pocket" (defect); 4 is the border of the defective insulation area 5 is a core (capacitor plate)

Electrical equivalent circuit of the defective insulation area with *d*x*b*x*c* dimensions is connect in series of the “air pocket capacity” (C_a) and the insulation capacity (C_i) with (*d*-*a*)x*b*x*c* dimensions. The final defective area capacitance (C_d) was found by with the formula of the electrical capacitance of the plate capacitor [2]:

$$C_d = \frac{C_a \cdot C_i}{C_a + C_i} = \frac{\varepsilon_0 \cdot \varepsilon_r^{\mathrm{a}} \cdot \varepsilon_r^{\mathrm{i}} \cdot b \cdot c}{\varepsilon_r^{\mathrm{a}} \cdot (d-a) + \varepsilon_r^{\mathrm{i}} \cdot a}, \tag{1}$$

where $\varepsilon_r^{\mathrm{i}}$ is insulation permittivity;

$\varepsilon_r^{\mathrm{a}}$ is air permittivity.

The formula (1) demonstrates the dependence of the final defective area capacitance on the defect dimension in a measuring in a weak electric field (Fig. 2**Ошибка! Источник ссылки не найден.**).

High intensity electric discharges occur in an “air pocket” defect in a strong electric field measuring and the defect area can be considered as a high conductive one (Fig. 3).

According to the mentioned, the function of the defective area capacity from the defect dimension is:

$$C_d = \varepsilon_0 \cdot \varepsilon_r^{\mathrm{i}} \cdot b \cdot c / (d-a) \tag{2}$$

The formulas (1) and (2) were analysed and the dependencies were found to be considerably different.

To verify the theoretically-obtained statement the insulation section model was made in software COMSOL Multiphysics as a plate capacitor with double-layer dielectric (PVC and air). The capacitance calculation was provided with the known formula $C = Q/U$ [1]. The charge (Q) was defined with the Gauss theorem in an integral form [1].

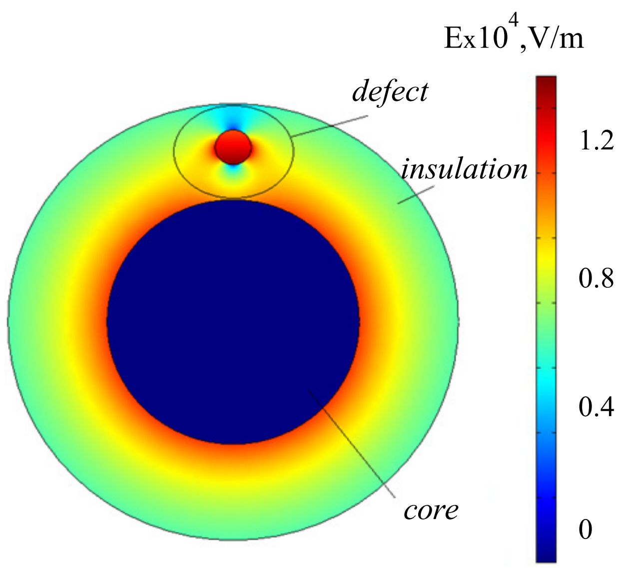

Fig. 2. Tension distribution in cable in a weak electric fields (insulation defect “air pocket”)

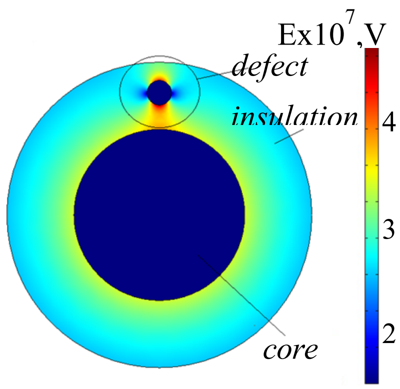

Fig. 3. Tension distribution in cable in a strong electric fields (insulation defect “air pocket”)

According to the dependences lines plotted in Fig. 4 it can be pointed out that the dependencies in weak and strong fields are different: the defect capacity slightly decreases with increasing of the defect dimension in a weak electric field, however this function exponentially increases in a strong electric field.

To define the change in insulation section capacity the coefficient with a defect (C_d) and without it (C_0) (sensitivity) is introduced an additional sign k:

$k = C_0 / C_d$ for a strong electric fields measuring;

$k = C_d / C_0$ for a weak electric fields measuring.

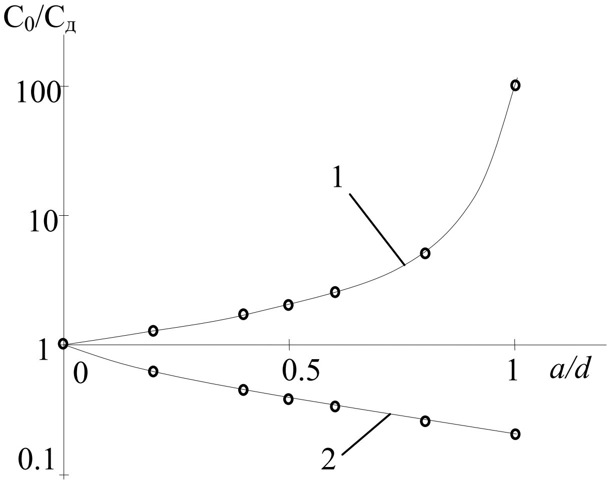

Fig. 2. Dependence of relative capacitance on a relative defect dimension in strong (1) and weak (2) electric fields

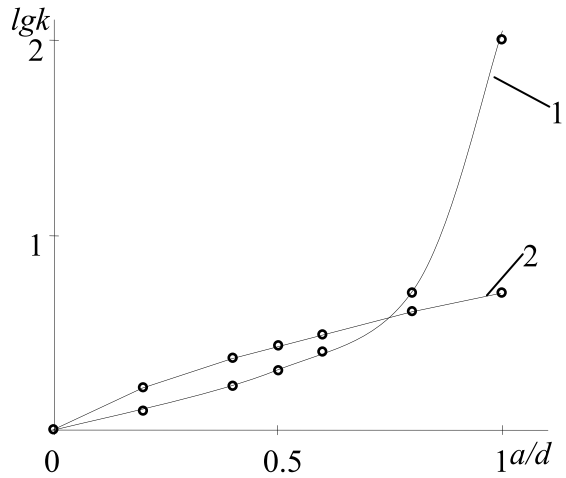

Fig. 3. Dependence of measuring sensitive on a relative defect dimension in strong (1) and weak (2) electric fields

The analysis of the obtained values revealed that higher sensitivity of measuring in weak electric field in comparison with the sensitivity measured in a strong electric field until the defect dimension does not exceed 70 % from defect-free insulation (Fig.5). If the defect is large in size, measurement sensitivity is higher in a strong electric field and this increase exponentially.

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