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# MODELING OF PARTIAL DISCHARGES IN END CABLE MUFF FOR MEDIUM VOLTAGE

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## ABSTRACT

The cable muff for connecting of power cable for medium voltage is investigated. The distribution of electrical intensity in the cable insulation by extreme situations such as too great voltage and trial with increased voltage is considered. The stationary electrical field by finite element method is investigated. The electrical field intensity is searching by the electric scalar potential V. The zones where electrical intensity decrease and the electrical intensity is non-homogenous are indicated. The electrical field in the breaking zone of outer semi-conducting layer of cable insulation is a strongly non-homogeneous.

***Index Terms*** **–** Partial discharges, power cable, medium voltage, muff, modeling, finite element method, electrical potential, field intensity.

## 1. INTRODUCTION

The cable muff for connecting of power cable for medium voltage with other devices of power electrical substation such as transformers and breakers is considered.

The cable muff must ensure linear homogeneous distribution of electrical intensity in the cable end. If this condition is not implemented, then in the cable insulation can be a partial discharge [1].

The insulation lifetime of power cables is determined by several factors. One of the more important of these is the occurrence of partial discharge in the dielectric.

A various defects, such as voids, contaminants and electrical trees can cause a partial discharge in medium voltage power cable [2, 4]. The main XLPE insulation is very sensitive to partial discharges and will gradually degrade the insulation, eventually leading to major cable breakdown.

The distribution of electrical strength in the cable insulation by extreme situations such as too great voltage and trial with increased voltage is investigated.

## 2. ELECTROMAGNETIC MODEL

Cable muff must provide at the end of the cable to the electrical field intensity in the limit of the cable insulation standards and to ensure flawless operation of the work and test.

The cables of Medium Voltage MV (10 or 20 kV) are running in single phase execution [4].

The end muff of power cable 20 kV, insulated by polyethylene (XLPE) type SAXEKT is investigated. The design of end cable muff is shown in figure 1.

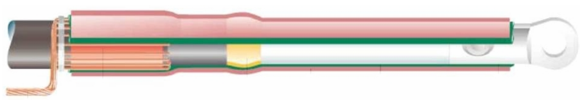

*Figure 1 Structure of end cable muff for medium voltage*

A model of the end cable muff for medium voltage for is shown on figure 2.

In Figure 2 are designated: 1 – aluminium conductor of cable; 2 - inner semi-conducting layer 3 - XLPE main insulation; 4 - Outer semi-conducting layer; 5 - copper screen; 6 – polymer cover of cable, 7- aluminium connection for high voltage; 8- inner thermoplastic insulation of the muff; 9 – outer cover of the muff; 10- low voltage (grounding) copper connection; 11- surrounding air.

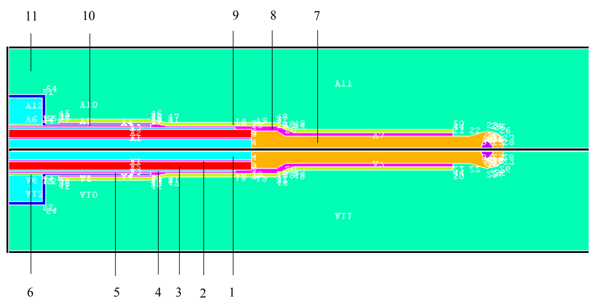


*Figure 2 Model of end cable muff for medium voltage*

In the single phase cable used in this muff, the conductor is stranded aluminium and the cable is concentric with inner and outer semi-conducting layers and the main (XLPE) insulation between the semi-conducting layers. The metallic shielding comprises helical copper strands and the overall cover is extruded polyvinyl chloride (PVC). This structure is shown in Figure 2. The semi-conducting layers are made of polyethylene or ethylene copolymer mixed with conductive carbon black [1, 4]. The semi-conducting layers are used to smooth out the electric stress enhancements at the conductor strands and thus prevent partial discharge activity at the interface between the conductor and the XLPE insulation of cable.

## 3. RESULTS OF ELECTROMAGNETIC MODELLING

The electrical field in the space between the conducting areas of the cable muff is searching by the electric scalar potential V. It satisfies the Laplace's equation [1, 4].

(1) $$\frac{\partial^2 V}{\partial_2 x} + \frac{\partial^2 V}{\partial_2 y} = 0$$

The stationary electrical field in the cable muff by finite element method [5] is investigated by extreme situations with too great voltage.

The intensity of the electric field introduces as function of the scalar electric potential through dependencies [3]

(2) $$\vec{E} = -gradV$$

The Analysis of the electric field in cable muff is done numerically, using finite element method. In this event equation (2) has the form

(3) $$\{E\} = -\nabla \{N\}^T \{V_e\},$$

where $\{N\}$ are functions of the form, $\{V_e\}$ is the scalar electric potential in nodes of finite element mesh and index $^T$ means transposition.

The corresponding border conditions are: the potentials of conducting core of cable and high voltage connection (phase electrode) is 60000 V and shield of the cable and low voltage connection muff (ground electrode) is 0 V.

The type of the finite element mesh in investigation area is shown on figure 3.

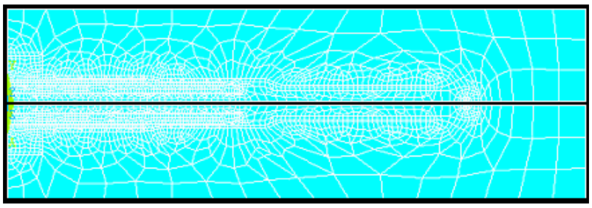

*Figure 3 Finite element mesh*

Investigation structure has symmetry and problem is axis-symmetric, because cable and cable muff have a cylindrical form.

So the result of analysis only in upper half of the investigation area of cable insulation is limited.

First the scalar electric potentials in nodes are computed.

The result of distribution of electric potential in cable muff in figure 4 is shown.

The part of the outer semi-conducting layer is removed in preparing the cable for connecting to cable coupling.

This led to a change in the distribution of electrical field in cable insulation.

Result of voltage distribution in the zone of breaking of outer semi-conducting layer in figure 5 is represented. This is zone with high gradient of voltage.

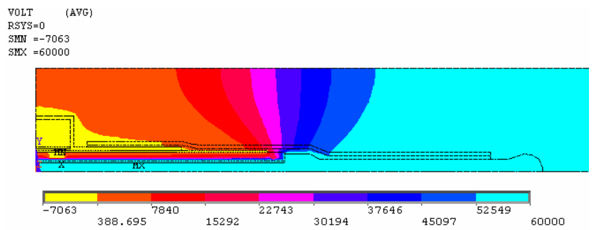


*Figure 4 Distribution of potential in end cable muff for medium voltage*

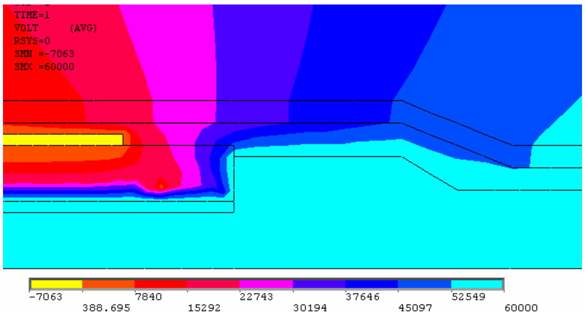


*Figure 5 Distribution of potential in the zone of breaking of outer semi-conducting layer of cable insulation*

In the next stage the electric field intensity through dependence (3) is calculated.

The x-component of electrical intensity in the zone of breaking of outer semi-conducting layer of cable insulation is represented in figure 6.

The values of the intensity of electrical field are quite large at the end of the main cable insulation and the inner layer of the muff insulation.

The y-component of electrical intensity in the zone of breaking of outer semi-conducting layer of cable insulation is represented in Figure 7.

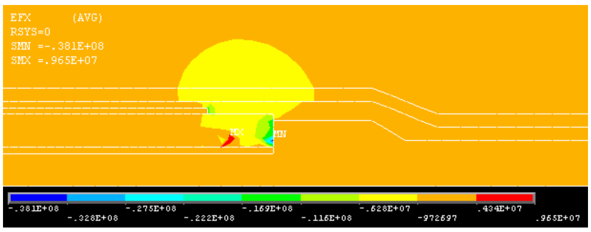


*Figure 6 X-component of electrical intensity in the zone of breaking of outer semi-conducting layer*

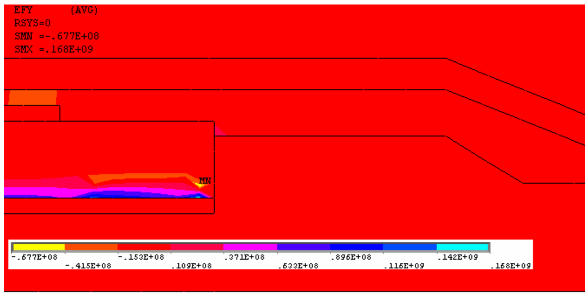


*Figure 7 Y-component of electrical intensity in the zone of breaking of outer semi-conducting layer*

Largest values of electric intensity are obtained in the main insulation of the cable in the area of interruption of semi-conducting layer.

The picture of the electric intensity vector is shown in figure 8.

The electrical field is relatively evenly along the cable insulation.

However, in the areas of connection of the coupling of the electrodes (high voltage and ground) electrical field is non-homogeneous.

The vector field of electrical intensity in the zone of cable insulation in the place of ground electrode is represented in figure 9.

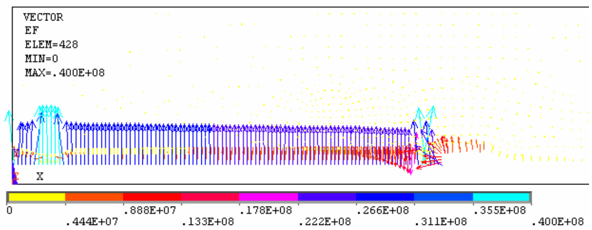


*Figure8 Vector field of electrical intensity in end cable muff*

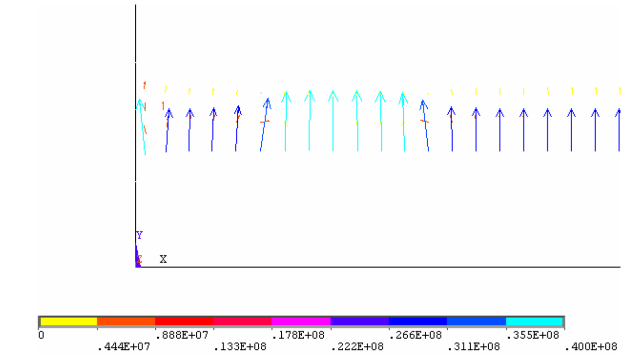

*Figure9 Vector field in the area of connection of ground electrode*

The values of electrical intensity in this zone of ground electrode are 1.5 times greater than the intensity of the field in an area over along the main cable insulation.

The vector field of electrical intensity in the zone of breaking of outer semi-conducting layer of cable insulation is represented in figure 10.

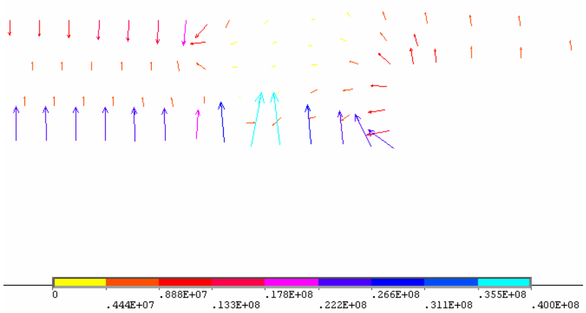

*Figure10 Vector field in area of connection in high voltage electrode*

In the area of connection of the high voltage electrode the electrical field is a strongly non-homogeneous and non-radial.

The values of electrical intensity in this zone are approximately 2 times greater than the intensity of the field in an area over along the main cable insulation.

Then in the cable insulation in these 2 zones, especially in the area of interruption of semi-conducting layer can be a partial discharge.

## 4. CONCLUSION

The cable muff for connecting of power cable for medium voltage is investigated.

The distribution of electrical strength is represented. The zones, in which electrical strength decrease and the electrical strength is non-homogenous are indicated. These zones are the place of high voltage electrode and ground electrode.

Based on the distribution of electrical strength, we can foresee the appearance of partial discharges in the cable insulation and eventually this can leading to major cable breakdown.

In the area of interruption of semi-conducting layer the partial discharge may affect the level of insulation of cables and greatly reduce its durability.

Partial discharges in solid insulation can generate electrical signals with frequencies up to several hundred MHz .

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