Effect of Impurities on Electric Field Distribution in HV XLPE Insulation

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ABSTRACT

Nowadays, the majority of underground HV/EHV cables are XLPE insulated. When dealing with XLPE, special care should be taken to insure an impurity-free product since these contaminations will cause localized stresses that will deteriorate the insulation leading to failure.

In this paper, we will be able to accurately identify and simulate, using image processing and FEM, the exact values of the localized stresses which will give you a strong base for further analysis of their effect.

KEYWORDS

XLPE, impurity, contamination, void, localized stress, HV/EHV, Gmsh, GetDP, Matlab.

INTRODUCTION

The electric field distribution within insulation in the absence of any contaminant is well known and dependent on the voltage level, diameter over conductor shield, diameter over insulation and distance of the desired point from conductor shield [1]. We get maximum electric stress when the distance is equal to the conductor shield diameter i.e. nearest insulation point to the conductor. The electric stress level is the same on each equipotential line inside the insulation.

In the presence of any void, impurity or contamination, electric stress distribution in insulation is disturbed especially around and inside the contamination. These disturbances and variations in stress level depend on the material, shape, and size of impurity. In theory and literature, large sizes containing sharp edges are the most dangerous. But none of them have specified this risky stress level that is reached in a specific real case measured in V/mm.

Many papers have simulated using FEM the electric stress disturbance due to a circular shape contamination inside XLPE, which does not reflect the actual situation since in real life, we won't get a 100% circular shape void or impurity. Thus, these simulations are irrelevant for the objective of knowing exactly what's happening in the surrounding and inside the impurity.

To be able to precisely simulate the real life case, a microscopic picture of the impurity shall be taken, and then image processing of this picture shall be performed to detect the boundaries, followed by an electrostatics simulation using FEM to compute electric stresses.

CASE STUDY

Throughout this paper and for comparison purpose, we will study the electric stress distribution of both healthy and contaminated XLPE insulation. Cable under consideration has the following details:

- 1x1200 mm^2, Cu conductor, 76/132 kV
- Diameter over conductor shield is 47.0 mm
- XLPE thickness is 21.6 mm
- Material of impurity is $CaCO_3$ (non-conductive)

STRESSES IN HEALTHY XLPE

Two methods of calculating these stresses will be used. First using mathematical approach, and second using FEM tools, Gmsh [2] and GetDP [3].

For the first method, stresses are calculated by the following formula:

$$E_x = \frac{V}{x \log_e\left(\frac{R}{r}\right)} \qquad [1]$$

Where,

x is the radius from the center of conductor in [mm]
E_x is the stress at radius x in [V/mm]
V is the phase to ground voltage in [V]
R is the radius over insulation in [mm]
r is the radius under insulation in [mm]

Maximum stress is obtained when x = r, i.e. at the conductor shield and insulation interface.
Minimum stress is obtained when x = R, i.e. at the insulation and insulation shield interface.

After performing the calculation, we get,

- E_{max} = 4961 V/mm
- E_{min} = 2585 V/mm

For the second method, stresses are calculated by solving the following Laplace's equation [refer to [4] for derivation] describing the electric field

$$\nabla^2 V = 0 \qquad [2]$$

In a previous step, Gmsh was used to draw the cable.

The results are presented in **Figure 1**

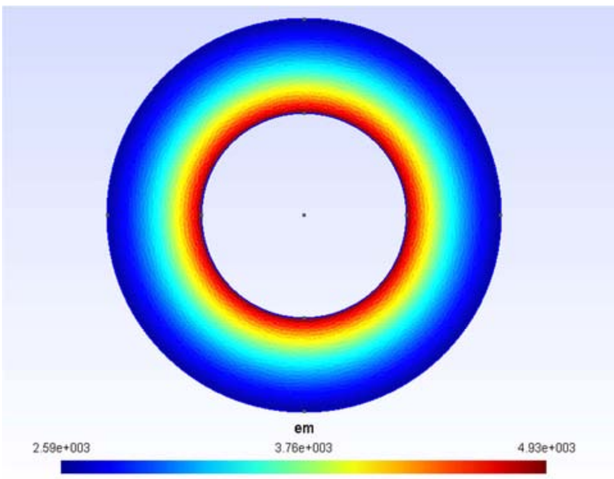

Figure 1: Electric field levels of healthy XLPE