Study on Electric Field Variation of Bubble within Transformer Oil under Various Electrode Geometries Using COMSOL Multiphysics

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ABSTRACT

Bubbles form in liquid insulation systems as a result of the effects of many thermal, mechanical and environmental factors. The researchers proved that bubbles pose a risk to the transformer insulation system. The geometry of the internal parts of the transformer controls the electric field distribution, the bubbles in the transformer oil are subject to this field. Any alteration in this field leads to a change in the local field of the bubble, potentially resulting in the occurrence of partial discharge. Transformer oil contains bubbles of varying shapes, sizes, and quantities, which can interact with one another. This paper presents a study of electric field variation using the finite element method (FEM) based COMSOL multi-physics simulation tool to determine the effects of the size and shape of an air bubble and its position concerning three types of electric fields (uniform, quasi-uniform, non-uniform) on the distribution of the electric field inside it, as well as the reciprocal effect of two air bubbles if they are close to each other. The results reveal that the bubble size and shape have an impact on the electric field inside it. Moreover, a mutual interaction between two nearby bubbles is noticed. In addition, the electrode geometry and the location of the bubble relative to the high-voltage electrode are two significant factors that influence the local electric field of the bubble.

Keywords: Transformer oil, Electric field, Comsol multi-physics.

1 Introduction

The transformer is the most crucial and expensive part of high-voltage power system. transformer oil plays the role of insulation between the internal components of the transformer and contributes to the dissipation of heat generated during its work [1]. During operation, the transformer is subjected to a variety of conditions and internal and external stresses, including thermal, mechanical, and environmental stresses. These stresses cause changes and deterioration in the insulation system. Several studies have shown that there are several factors involved in bubbles formation in transformer oils, including temperature, moisture, vibration, and discharge [2]. The distribution of the electric field in the presence of bubbles is a significant indicator of the occurrence of discharge. In this work, we study the effect of the shape and the size of an air bubble in relation to the direction of electric field on the intensity of the electric field inside it, as well as the reciprocal effect of two air bubbles when they approach each other horizontally and vertically, in addition to the importance of the effect of the location of an air bubble in its three forms (sphere, horizontal ellipse, vertical ellipse) under the influence of several types of electrode geometry (plane to plane, sphere to plane, needle to plane).

2 Methodology

In the current study, we use the finite element method, which is a numerical method for precisely resolving problems of various physical types. The electrostatic model from the AC/DC module uses the finite element approach and is implemented by the COMSOL Multi-physics software version 5.5 [3].

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3 Results and Discussion

Figure 1 displays the effect of bubble and electrode characteristics on the electric field. Each of these characteristics mentioned in Figure 1 showed varying effects on the value of the electric field inside the bubble, thus affect the occurrence of partial discharge.

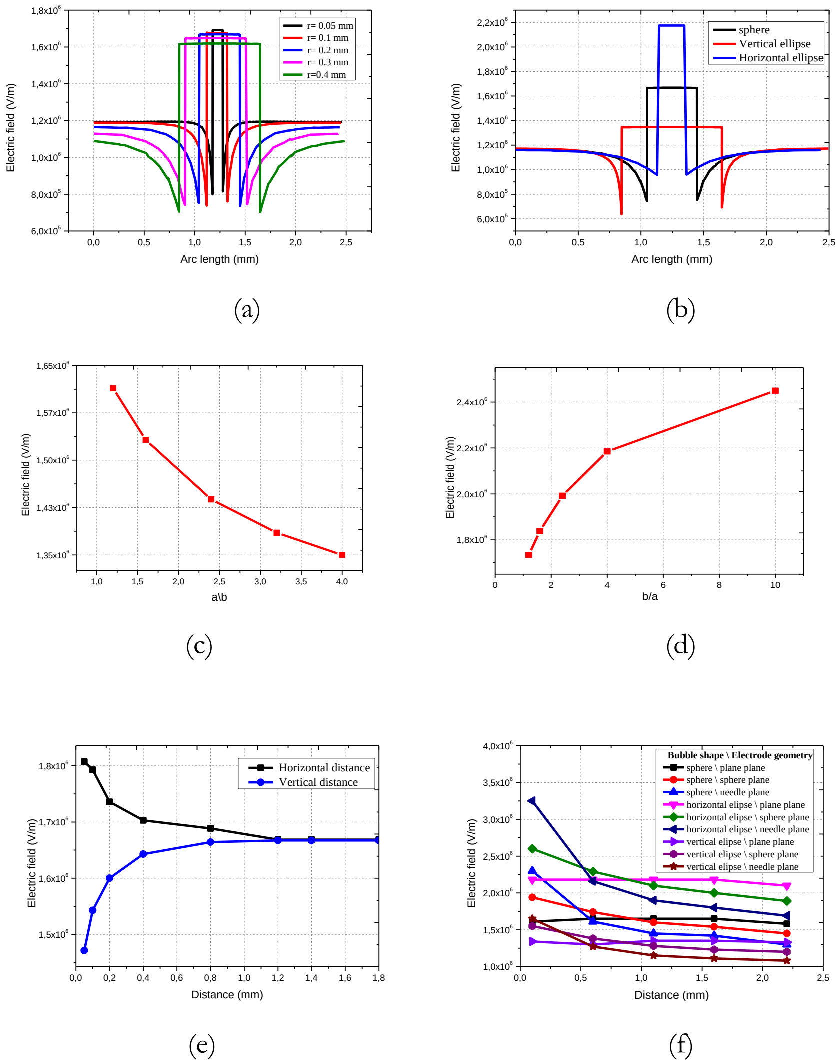

Figure 1: *Variation of the electric field with respect to (a) Bubble size (b) Bubble shape (c) Vertical elongation of bubble (d) Horizontal elongation of bubble (e) Distance between two bubbles (f) Distance between the bubble and high-voltage electrode on various electrode geometries*

4 Conclusion

One of the principal causes of partial discharge inside the bubble is an increase in the internal electric field. The obtained results show that the electric field inside a bubble and its size are inversely related, in addition to that the elliptical shape of the bubble perpendicular to the lines of the electric field is considered the most dangerous compared to other shapes. Furthermore, the elongation of the bubble perpendicular to the electric field leads to an increase in the electric field inside it, and in the case of two bubbles, they exchange influence among them, whenever the distance between them changes by less than six times the diameter of the bubble. Moreover, the influence of electrode geometry and the type of electric field applied is clear, the needle to plane electrode is the most unfavourable type of electrode when bubble is in contact with the high-voltage electrode. In the case of the non-uniform and quasi-uniform electric field, the farther the

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bubble is from the high-voltage electrode, the electric field inside it decreases. Contrary to the uniform field, the internal electric field of the bubble does not change no matter how its location changes. These results can be relied upon when studying the voids in solid insulators.

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