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Electrical Field Simulation for Different Cases of Polymer Insulators Using FEM

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ABSTRACT

This paper describes the impact of the geometric characteristics of polymer insulators on the magnitude and distribution of electrical field across the polymer insulators. The procedure is based on finite element method numerical analysis. The selection of suitable polymer insulators has a significant impact on the insulation coordination of line and, consequently, on dielectric strengths, both inside and outside the insulator. This method is used to comparing of the performance characteristics for different polymer insulators in existing structures of them using Finite Element Method (FEM).
KEYWORDS: Electrical field, geometric, insulator, FEM, polymer.

1. INTRODUCTION

POLYMER insulators, which are being used increasingly for outdoor applications, have better characteristics than porcelain and glass types: they are lighter, have better contamination performance due to their surface hydrophobicity, possess higher impact strength, and so on [1].

The electric field (E-field) distribution on transmission class composite nonceramic insulators, alternatively called polymer or nonceramic insulators (NCIs), affects both the long and short term performance. In order to design and apply composite insulators effectively, a fundamental understanding of the E-field distribution and its effect on the insulator performance is needed [2]. So calculation of the electric field is required in the insulation design of HV electric power apparatus in order to reduce the size and to enhance the space utilization efficiency. In particular, electric field calculation has become indispensable tool. In [3] it have been developed a personal computer (PC) based electric field calculation system combined with CAD.

The document [2] was intended to provide an overview of the E-field distribution of composite insulators and the related issues. Hongwei Mei [4] investigated installing insulation jackets with different lengths on transmission line conductors to reduce the electric field strength on composite insulators. That paper presents the latest researches about field distribution for polymer insulators but unfortunately that is not complete and so there is need for further investigation about this issue with respect to different models.

This strengthens the requirements for higher reliability, compatibility, safety, long life, and minimal maintenance. The key role in every electrical element is played by the insulation elements. Ageing of their material and, consequently, their life-time depends mainly on the magnitudes of electric field they are exposed to [5].

For this reason, the presented study focuses on electrical field simulation for existing types of polymer insulators with respect to the geometric characteristics.

2. Electricalfieldissues

The E-field distribution on the surface of, and within composite insulators is a function of numerous parameters including applied voltage, insulator design, tower configuration, corona ring and hardware design, phase spacing, etc. The following discussion will provide generalized information that relates to the E-field distribution of most electrical applications.

There are three main regions of interest when considering the E-field distribution of composite insulators [2].

1) On the surface of, and in the air surrounding, the polymer weather-shed surface and surrounding the end-fitting seal.

2) Within the fiberglass rod and polymer rubber weather-shed material, as well as at the interfaces between these materials and the metal end fitting.

3) On the surface of, and in the air surrounding the metallic end fittings and attached corona rings.

If the E-field magnitude in any of these three regions exceeds critical values, excessively large magnitudes of, discharge activity can ensue, and the long or short term performance of the insulator may be affected. There is a direct relationship between the E-field distribution and the resulting discharge activity on and within composite insulators. The presence, location and magnitude of discharges are a function of the magnitude and direction of the local E-field.

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In general, the E-field magnitudes are larger close to the energized and grounded ends of a composite insulator. Typically the energized end is subjected to the highest field magnitudes. In some cases the position of highest E-field occurs adjacent to the end fittings, while in other cases it may occur within a short distance of the end fitting.

Numerous field observations and results from accelerated aging tests have shown that E-fields play a significant role in the degradation of polymer material. As such, the E-field is recognized as a significant factor in the aging mechanisms of NCIs [6].

3. Case study

Two polymer insulator-type specimens, having straight and alternate sheds, as typical samples from case studies were presented in Figures 1, 2. All the specimens were made of high-temperature vulcanized silicone rubber (HTV SiR) with alumina trihydrate (ATH: Al2O3•3H2O) filler contents of 50 parts per 100 by weight (pph). HTV SiR sheaths onto fiber-reinforced plastic (FRP) rods. Graphite discs, 31 mm in diameter and 5 mm in thickness, were screwed to both ends of each rod-type specimen using stainless steel hook screws. The insulator-type specimens were prepared by moulding HTV SiR onto the FRP rods. Moulding lines or parting lines were found on these insulator-type specimens. Each two pieces for individual specimen types were used in this investigation. These instances have been taken from [1]. But for further investigation, other models of polymer insulator have been chosen from [7] to extend the research for polymer insulator in a fog chamber (Figure 3).

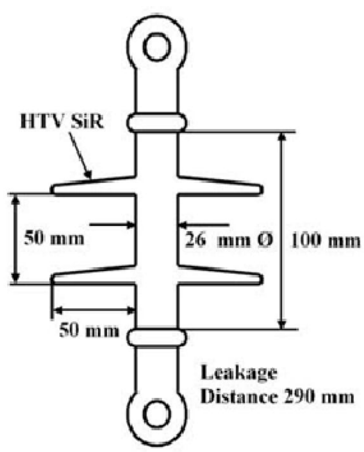

Figure 1: Straight shed mode for polymer insulator that has been selected as 1th case study

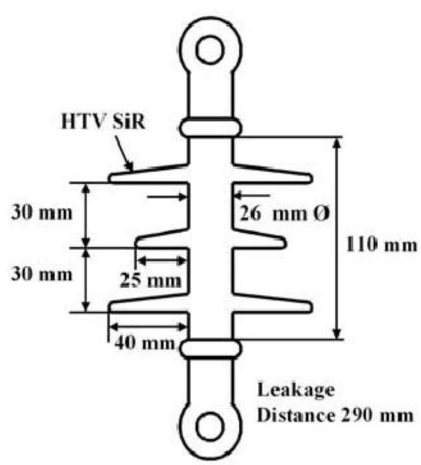

Figure 2: Alternate shed mode for polymer insulator that has been selected as 2th case study

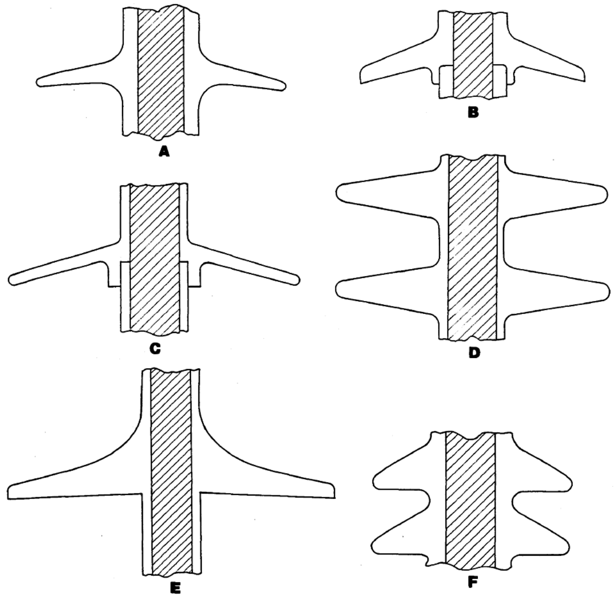

Figure 3: Other modes of polymer insulator that have been selected for simulation as 2-7th case studies

4. SIMULATION AND RESULTS

The application of appropriately designed insulators can be used to reduce the maximum E-field magnitudes and move the position of the maximum E-field away from the end-fitting (as the end-fitting seal is considered critical). The geometric properties have a significant influence on the E-field. In this section the results for presented insulators will be showed (Figures 4-10). Models are simulated by FEM in 2D axial symmetry module.

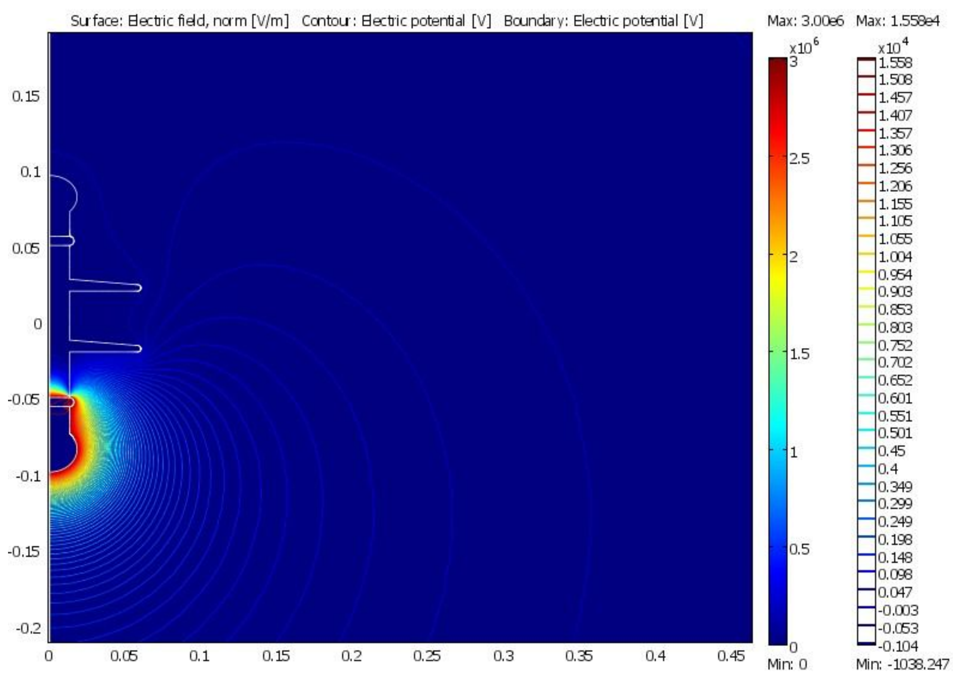

Figure 4: Electrical field distribution and electrical potential contour for 1th case of polymer insulator

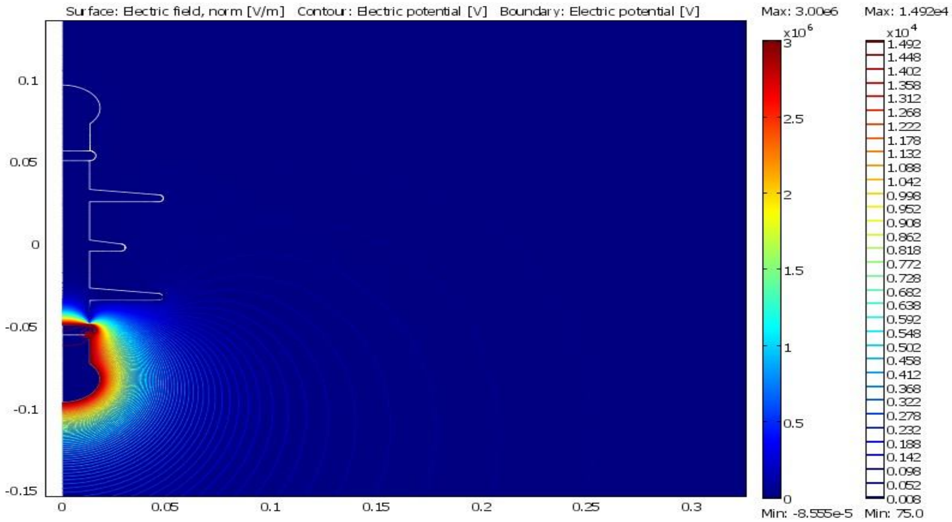

Figure 5: Electrical field distribution and electrical potential contour for 2th case of polymer insulator

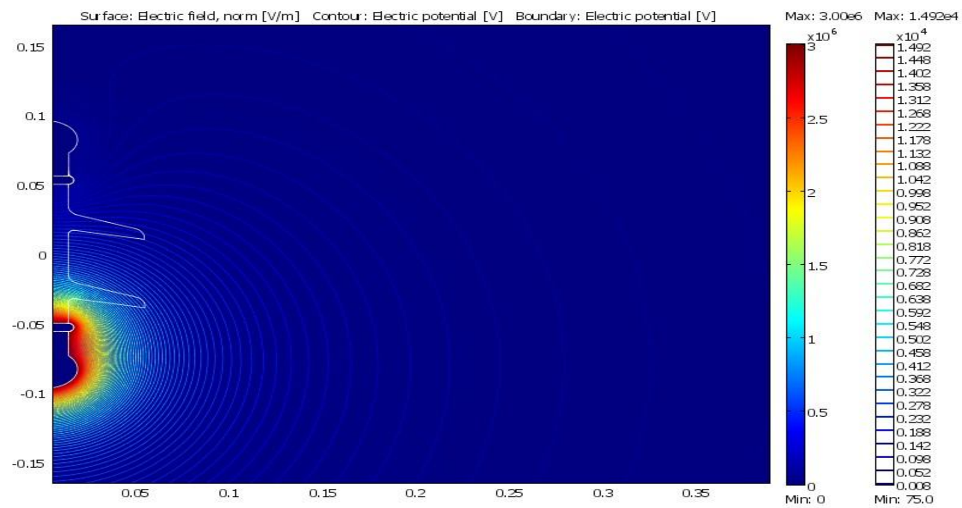

Figure 6: Electrical field distribution and electrical potential contour for 3th case of polymer insulator

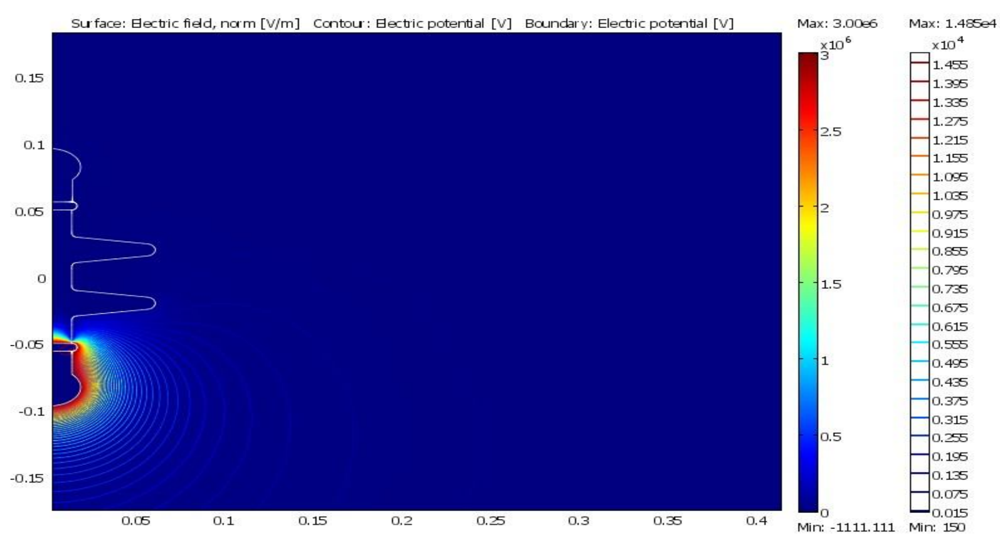

Figure 7: Electrical field distribution and electrical potential contour for 4th case of polymer insulator

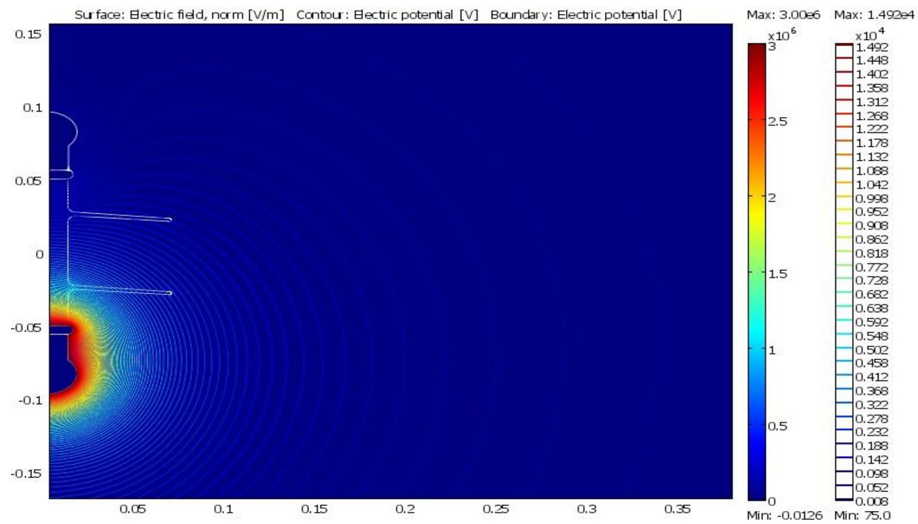

Figure 8: Electrical field distribution and electrical potential contour for 5th case of polymer insulator

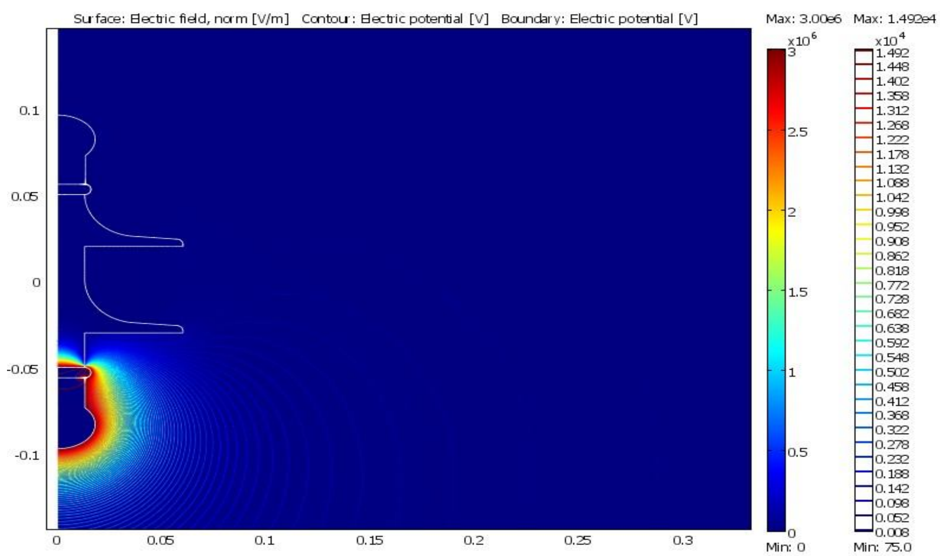

Figure 9: Electrical field distribution and electrical potential contour for 6th case of polymer insulator

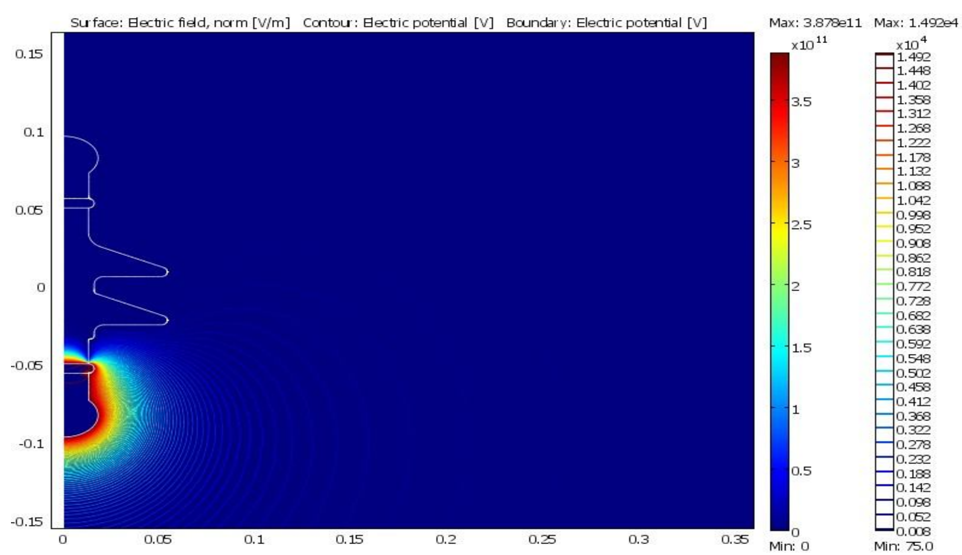

Figure 10: Electrical field distribution and electrical potential contour for 7th case of polymer insulator

5. Conclusion

The E-field distribution on composite insulators is nonlinear with the regions close to the energized end normally being subjected to the highest magnitudes. For most applications, the dominant direction of the E-field is along the axis of the insulator. The E-field distribution influences the presence and magnitude of discharge activity within and on the surface of the dielectric material, as well as discharge activity from the metal end fittings. Internal and external discharge activity needs to be considered when considering maximum allowable fields.

Field magnitudes on the rubber surfaces of composite insulator sheath sections may vary considerably depending on the design, configuration and application. The electrical stresses can be reduced using appropriate geometry design. Therefore the optimization design for designing of polymer insulators is very important that discussed in this paper and employed for different models.

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