Simulation of the Electric Field on High Voltage Insulators using the Finite Element Method

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Abstract— The paper presents a study into the potentials and electric field distribution on insulator strings, which are used for suspension of overhead transmission lines of 400kV and are stressed by power frequency voltage. The investigated insulator strings are used by the Public Power Corporation of Greece in high voltage transmission networks. The Finite Element Analysis (FEA) program OPERA was used to carry out the electric analysis on the insulators. Two types of insulator strings were investigated, the first using porcelain and the second using glass as the insulating material. A comparative analysis of these insulators is presented.

I. Introduction

The insulators, which are used for the suspension of overhead transmission lines, constitute one of the most important parts of the transmission lines as flashover effects in polluted insulators can cause the breakdown of a transmission network. The electric field distribution within and around high voltage insulators is a very important aspect of the design of the insulators. Also the knowledge of the electric field could be useful for the detection of defects in insulators [1].

Several methods have been developed for the computation of electric fields and potential along an insulator string [2, 3]. In this paper, the electric field and potential distribution around and inside the insulator when it is stressed by power frequency voltage is examined using OPERA, which is a suite of programs for two and three dimensional electromagnetic field ana1ysis [2]. The software package uses the finite element method to solve the partia1 differential equations that describe the behaviour of fields.

II. Electric Field and Potential Formulation

The electric field intensity **E** is given by [4]:

$$\mathbf{E} = -\nabla V \tag{1}$$

The divergence of the electric flux density **D** is related to the charge density ρ:

$$\nabla \mathbf{D} = \rho \tag{2}$$

Combining equations (1) and (2) and introducing the dielectric permittivity tensor ε ($\mathbf{D} = \varepsilon \mathbf{E}$) arises the usual Poisson's equation description of the electrostatic potential:

$$\nabla \cdot \varepsilon \nabla V = -\rho \tag{3}$$

A similar equation arises for current flow problems,

$$\nabla \cdot \sigma \nabla V = 0 \tag{4}$$

where σ is the conductivity, and $\mathbf{J} = \sigma \mathbf{E}$.

The paper will discuss the limitations of an electrostatic solution for this class of problem and present results from alternative formulations that account for the conducting and dielectric properties of the materials. In its simplest form, a combined solution would involve an initial solution of the current flow problem, the output of which is used as a boundary condition for the electrostatic problem. This combination of the two solvers is shown to improve the simulation results and reduce the simulation error to a satisfactory point.

III. Results and Discussion

The paper discusses the application of two and three dimensional FEA for the modeling of the insulators, as well as the solution formulations appropriate for this class of problem. The axi-symmetry of the problem is destroyed by the existence of excited and ground conductors which must be included in the three-dimensional model to correctly represent the problem. A comparison between results from two and three dimensional analysis of the insulator strings is presented.

Cap-and-pin insulator string structures, which are used for the suspension of 400kV overhead transmission lines, are simulated. In order to construct a model that provides accurate results, the conducting and dielectric properties of the materials must both be accounted for. The simulation results show that the part of the insulator string nearer the conductor is more highly stressed.

Fig. 1 indicates one comparison of the electric field distribution along porcelain and glass insulator strings.

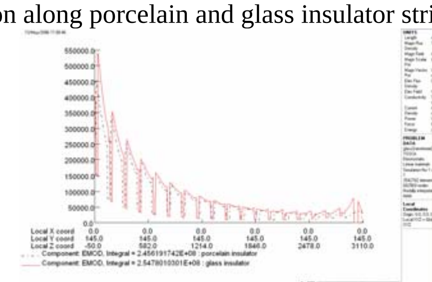

Fig. 1. Electric field along porcelain and glass insulator string.

IV. References

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