Measurement and Verification of the Voltage Distribution on High Voltage Insulators

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Abstract— The paper presents a study into the potential and electric field distribution along an insulator string, which is used for the suspension of 150 kV overhead transmission lines. In order to calculate the voltage distribution, a model of the insulator string was set up using OPERA, an electromagnetic analysis program based on the Finite Elements method. Simulation results have been compared with experiments which were successfully conducted in the High Voltage Laboratory of the National Technical University of Athens. The experimental procedure is also presented in the paper and discrepancies between simulated results and experiment and discussed.

I. Introduction

Insulator strings are used for the suspension of overhead transmission lines. Stray capacitances between insulators and of each insulator in the insulator string with respect to the high voltage conductor as well as to earth are developed. These capacitances have different values for different positions of the insulators in the string. Due to the stray capacitances existing between the insulator discs, the conductor and the ground, the voltage distribution along the insulators is not uniform. Hence, the insulators nearer the conductor are more highly stressed.

In this paper, the field and potential variation in a porcelain insulator string is investigated. Simulation results obtained using OPERA-2d and 3d are compared with experiment.

II. Experimental Apparatus

The aim of the experiments was the study of the voltage distribution along an insulator string. The investigated insulator string that consists of ten porcelain insulators of the cap-and-pin type is used for the suspension of 150kV overhead transmission lines. The test setup is shown in Fig. 1.

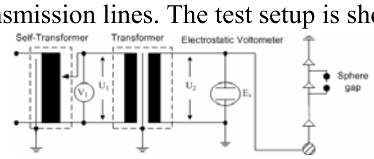

Fig. 1. Experimental set-up.

A 110V/55kV transformer is fed through a 230V self-transformer. The high voltage U_2 is measured using an electrostatic voltmeter E_v [1]. In parallel with the *i*-insulator is connected a sphere gap. By increasing the voltage U_2, the sphere gap critical voltage U_d is being reached. The percentage of the voltage P_i that is applied in the *i*-insulator, is given by

$$P_i = \frac{U_d}{U_{2i}} \cdot 100\% \quad (1)$$

Moving the sphere gap in each of the ten insulators and calculating the rates P_i for each insulator the critical voltage of the sphere gap is calculated by the equation

$$\sum_{i=1}^{10} P_i = U_d \cdot \sum_{i=1}^{10} \frac{1}{U_{2i}} = 1 \quad (2)$$

III. Simulation

OPERA, a Finite Element Analysis program for two and three dimensional electromagnetic design, was used to analyse fields and potentials along the insulator string. Two main sources of error from the simulation needed to be considered: Although the main insulator geometry is axi-symmetric (and could therefore be modeled using OPERA-2d) the complete structure was in essence 3-dimensional, owing to the presence of the excited and earth conductors. In addition, conventional methods for the modeling of the insulator strings using an Electrostatics solver would not suffice – the model needed to account for the conductivity of the insulator components. The paper will discuss how these issues were addressed: The OPERA-3d model included the insulator string structure (including the porcelain, cement and iron components) as well as part of the conductor, in order to correctly represent the real setup and hence accurately compute the potential distribution. Special solvers and procedures were also adopted within OPERA to account for the conducting and dielectric properties of the materials. OPERA-2d and 3d results will be compared in the paper.

IV. Results

Fig. 2 shows the first experimental and simulated results of the voltage distribution on each insulator. Fifteen series of experiments have been carried out and the average value and the standard deviation have been calculated. A very good agreement has been ascertained, by comparing the results of the experiments with those of the simulation.

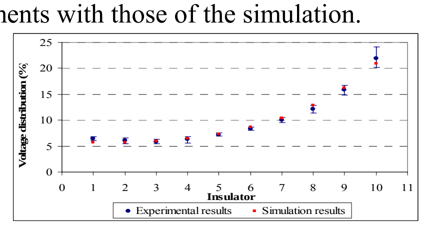

Fig. 2. Comparison between experimental and simulation results.

V. References

[1] IEC 60060-1, "High voltage test technique, Part 1: General Definitions and test requirements", November 1989.