NUMERICAL ANALYSES OF ELECTROMAGNETIC FIELDS IN HIGH VOLTAGE BUSHING AND IN ELECTROMAGNETIC FLOW METER

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ABSTRACT

The paper is divided into two parts. The first part is given to illustrate the previous work realized in the frame of diploma thesis. The topic of the thesis was "Numerical analyses of insulating system of electric device". There are the problem description, specification of performed simulations and some examples of computed results in the paper. The second part is dedicated to the present problem - electromagnetic flow meter. The physical processes in these devices are introduced in the first chapter. In the next chapter are discussed possibilities of numerical simulation of these devices and optimization of flow meters design. The description of performed electromagnetic analysis and results corresponds to the current state of author´s research.

KEYWORDS

Numerical analysis, numerical simulation, insulating system, electrostatic analysis, electromagnetic analysis, inductive flow meter

1. PART 1 – ELECTROSTATIC ANALYSES

1.1. Introduction

The solved problem was focused on the electric field analysis of insulation system in a high voltage electrical switchboard. The focus was mainly on a high voltage bushing used to pass the bus bars between two switchboard fields. In the insulation system can occur critical points with electric field of high intensity that affect the proper function of the system. The aim of these simulations was to estimate the location of critical points and their influence on the performance of the insulation of electrical equipment.

1.2. Analysis of electric device [1]

The goal of the work was to compute electrical stress inside the multi component insulation system of the compact switchboard system, which is operated at 17.5 kV voltage level. Resources and technical information for faithful simulation were provided by the manufacturer of the electrical equipment and insulating components. The ANSYS software was used for numerical calculation by the finite elements method. The task was considered in both two-dimensional and three-dimensional environment. The electrostatic problem was solved in steady state under following potentials loads:

$$U_{fm1} = \sqrt{2} \cdot U_n / \sqrt{3} \cdot \sin \pi/2 = 14.2\ kV \qquad (1)$$

$$U_{fm2} = U_{fm3} = -7.1\ kV \qquad (2)$$

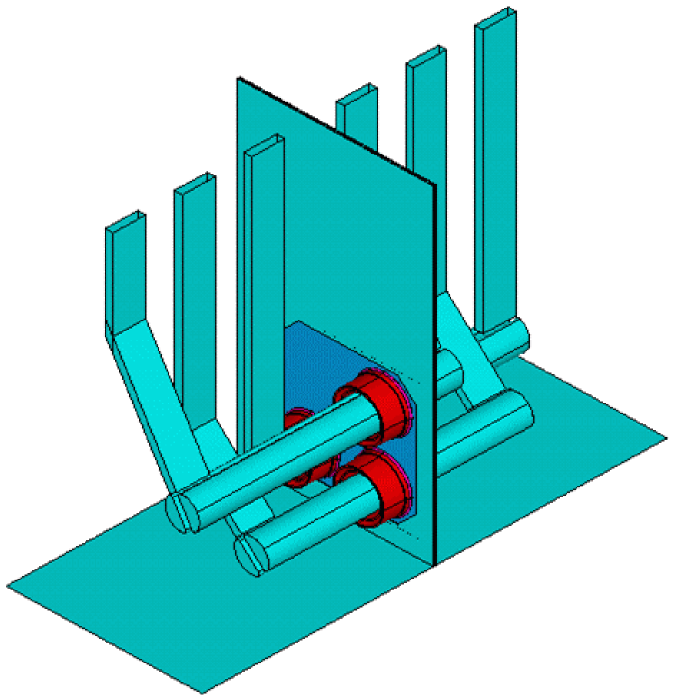

Figure 1 – Model - 3-phase configuration of two field switchboard [1]

3-phase system is mounted in the insulation system consisting of a neoprene lining, resin bushing and polyethylene insulation of bus bars. It is fastened with a rubber outer ring to the glass-reinforced plastic plate located between the fields of switchboard. Grounded walls have a zero potential.

1.3. Numerical simulation

The task was divided into several parts, which were treated separately in order to achieve good results of numerical simulation. The 2D task focused on one bus bar with bushing was analyzed in detail with very good discretization scheme, but without influence of other bus bars. The 3D task involves complex switchboard geometry but it was limited in discretization, regarding huge computational requirements. The sample of the 2D analysis is shown on figure 2.

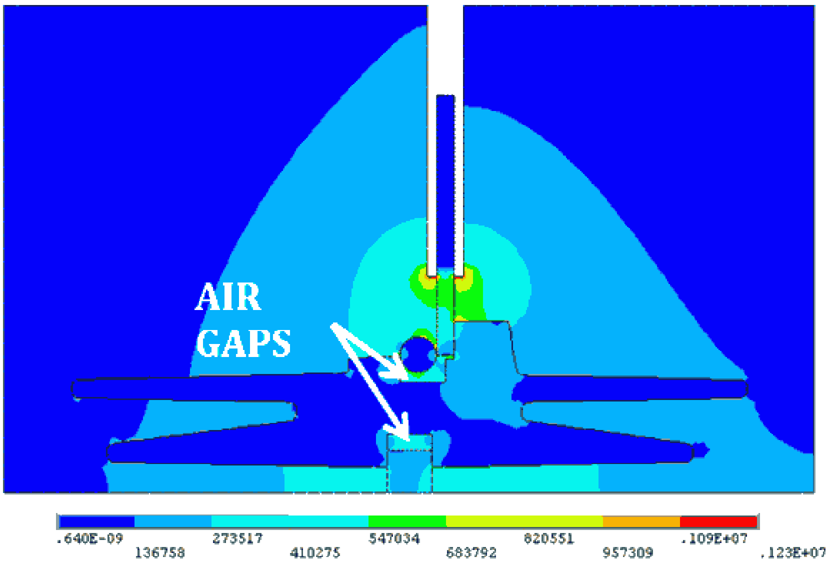

Figure 2 – Simulations in 2D - Section of bushings [1]

Figure 2 and 3 illustrate the distribution of the electric field in the bushing cross sections. There ca be seen void spaces that represent air gaps between bushing components and switchboard wall. These areas are exposed to highest values of intensity of electric field and therefore higher risk of partial discharges ignition. To achieve low intensity of electric field and elimination of these critical areas it is important to remove sharp edges and properly design position of components loaded by different potential.

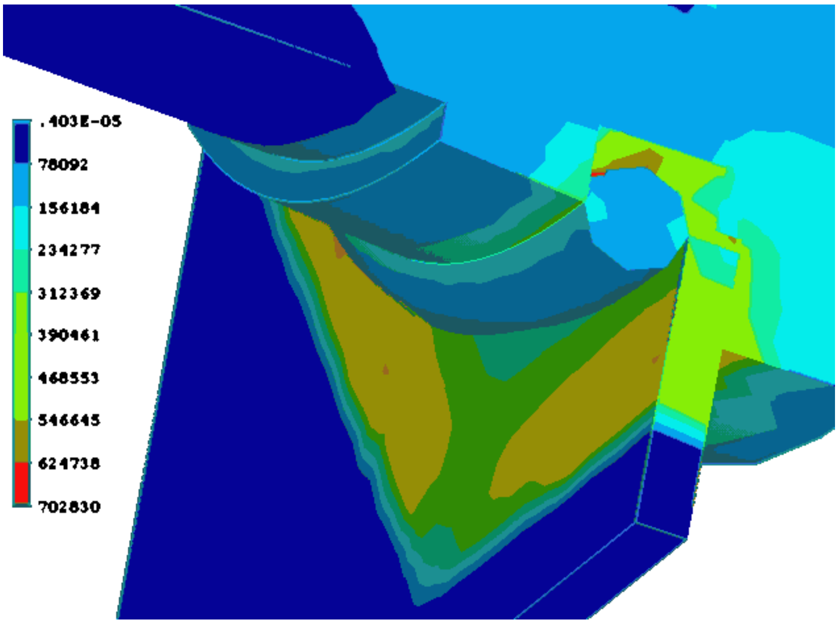

Figure 3 – Simulation in 3D - Section of bushings [1]

2. PART 2 – ELECTROMAGNETIC FLOW METERS ANALYSES

2.1. Principle of the electromagnetic flow meter

Magnetic flow meters are instruments dedicated for measurement of passing volume per time. Flow meters based on electromagnetic principle are widely used in many industrial fields [2]. The performed analyses are focused on the electromagnetic flow meters for liquids especially water flow meters. The flow meters are based on interactions between electromagnetic field and flowing fluid. The principle exploits Michael Faraday's law of electromagnetic induction for a moving conductor in a magnetic field:

$$U_i = B \cdot l \cdot v \; [V; T, m, m \cdot s^{-1}] \qquad (3)$$

Flowing conductive fluid represents a moving conductor in this case. Direction of the movement should be perpendicular to the magnetic field. The resulting induced voltage on the sensing electrodes corresponds to the flow rate [Fig.4].

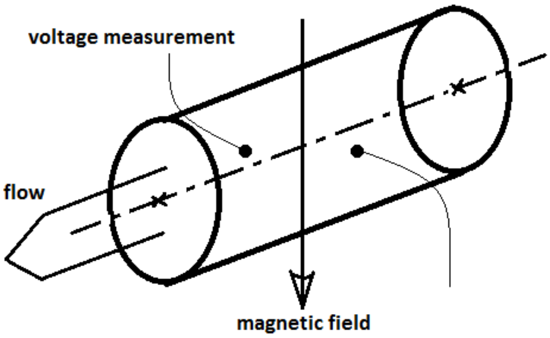

Figure 4 – Principle of electromagnetic flow meters

Measuring device consists of two main parts – primary sensor and secondary converter. Primary sensor is a modified part of the pipe with an insulated inner surface. The pair of sensing electrodes is placed opposite to each other along the perimeter and perpendicular to the magnetic field excitation. Electric current flowing through coils or permanent magnets excitation are the conventional signal sources. The converter provides energizing for sensor and performs signal processing. It offers functions of liquid batching control, detection of empty piping, internal meter status diagnostics, automatic counter cleaning and selection of flow units in data visualization.

2.2. Optimization opportunities

It is obvious that inductive sensing principle posses certain limitations. Constraining conditions are determined by liquid properties – the lowest measurable conductivity of liquid is at least 0.1 $\mu S \cdot m^{-1}$. Effects of hydraulic failure and problems of pipeline shape are the extensive chapter. In addition to these external influences belong interferences and noises that distort the measurement accuracy. Equipment must be suitably adapted or resistant to interference.

The proper selection and adjustment of these devices are also important economic aspects. The main characteristics that determine the cost and additional operating costs are based on these requirements:

- energy consumption, reliability of operation, sensitivity to fouling, failure rate, durability, etc.

Although the main requirements listed above are based on fluid properties and the environment influences their satisfaction can be achieved by optimizing the sensor arrangement. It is necessary to focus on more sophisticated solution of input parameters and processing of output signal.

In addition to arrangement, the flow meters are characterized by sampling systems (alternate current sampling, direct current pulses sampling, combination of AC and DC). An ideal situation, the output signal from flow meter is a square wave whose amplitude is proportional to the velocity of flow. The signal that comes from flow meter is usually noisy. Conventional techniques are not effective enough in dealing with noisy situations. Therefore this issue is defined as the specific topic of research.

2.3. Problem analysis

The aim of the first stage is to analyze the practical arrangement of primary elements of flow meters without fluid flow consideration. In this case, the task is simplified to simulation of magnetic field. Input excitation resp. electric current is considered as steady or transient with the waveforms based on the experimental results.

The simplest method is based on magnetic flux analytical calculation, which does not consider the spatial field distribution. The more detailed method is the finite element analysis. The numerical method can be easily extended to situations which are complicated flow profile, fluid properties and boundary conditions. Numerical analyses involve more extensive computation. The well known ANSYS computational software is suitable for this task.

Electromagnetic analyses allow simulations in 2D and 3D environment, depending on simplification of the flow meter design and solved problem.

2.4. Static and transient magnetic analysis

Static magnetic analyses do not consider time dependent effects such as eddy currents. Magnetic fields are computed in steady state under excitation of direct electric current or permanent magnets [6].

One of the outcomes of these tasks depends on the properties of such materials. There is the simplest example of a part of computational grid on the Figure 5. The task was solved as steady state simulation of a simplified 2D model.

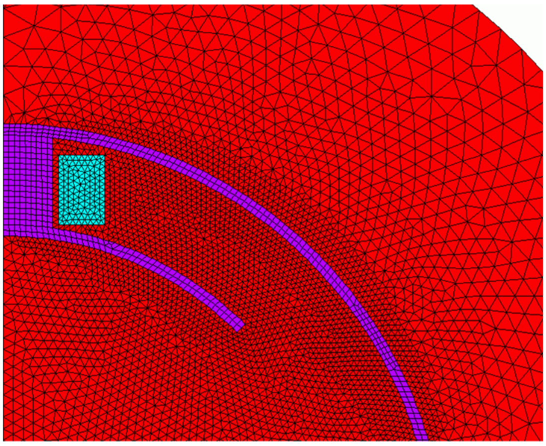

Figure 5 – 2D model – Magnetic flow meter

Several first simulation examples are shown on the Figure 6. The illustrated units and scale do not represent exact levels. Copies of the screen are only illustrative.

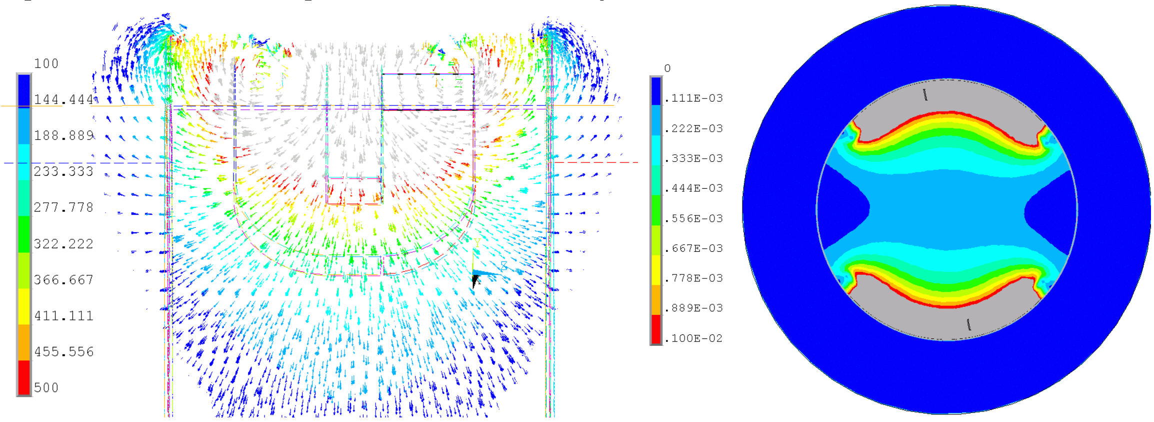

Figure 6 – Simulation examples – Magnetic field distribution

Transient magnetic analysis is a technique for calculating magnetic fields that vary over time. The results of transient simulation are influenced by eddy currents which are induced in conductive materials with respect to changes of magnetic field. As the consequence of the eddy currents can be evaluated power losses. The transient analysis procedure includes the following: build the model, apply loads and obtain a solution, and then review the results. The procedure will be repeated with varying conditions to obtain coherent results during each step.

Application of numerical analyses and their results for optimization of flow meter design are tasks for further research.

3. CONCLUSIONS

The simulation of electrostatic field is briefly mentioned as an example in the first part of the paper. There were no preconditions that the present system under normally conditions reach such a critical point where the danger of flashover discharge is predictable. The highest computed electric field intensity reaches less than 0.9 kV / mm. However, lower level of discretization does not represent real extremes. Therefore local peaks of intensity have to be expected higher in a real system.

The second part of the paper is an overview of theoretical background of electromagnetic flow meters, present state of numerical simulations and a plan of future research. The future research involves phase with practical measurements and numerical simulations focused on steady state and transient simulations of electromagnetic fields. The computed results will be compared with experimental data.

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