Some Opportunities to Improve the Learning Process of Students Based on Computer Simulations

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Abstract—**The paper presents some opportunities for improving the quality of distance learning process of students, based on computer simulations. The considered examples illustrate simulations of electromagnetic processes and phenomena that cannot be studied in a real laboratory environment due to the Covid 19 pandemic. The aim is to facilitate the understanding of the material and significantly increases the possibility for self-learning process using FEM simulations of the studied phenomena.**

Keywords— learning process, computer simulations, electromagnetic phenomena

I. INTRODUCTION

Nowadays, computer simulations are becoming more widely used in the learning process of students. The reasons for this educational trend are determined by many factors mostly related with the requirements and organization of the learning process, as well as the attitudes of the young generation, which willingly perceives the information obtained in computer-assisted learning [1-3]. Such type of training is especially suitable in the distance learning. Experience from more than a year of distance learning (due to the Covid 19 pandemic) shows that it is necessary to make additional efforts in order to stimulate students' interest in the learning material. Computer simulations are a good opportunity to make the studied material more attractive for students and to improve the quality of the learning process [4-6]. Furthermore, the possibility to make simulations of processes and phenomena that cannot be studied in a real laboratory environment is especially useful and interesting in distance learning process. Moreover, in this pandemic situation there are cases, when this turns out to be the only opportunity to present the study material. The paper presents examples of computer simulations that help students better understand certain processes and phenomena studied in the basics of electrical engineering.

II. SPECIAL FEATURES OF THE PROBLEMS USED IN THE TRAINING PROCESS

Unfortunately, it is an indisputable fact that in the conditions of distance learning the students' interest in the learning process and in the studied material decreases. This, as already noted above, requires additional efforts and the introduction of new more attractive practices in the learning process in order to activate the desire of the students to learn new things. As modern young people, familiar with the work with computers, students willingly perceive computer

simulations of the studied processes and phenomena. However, in order to maintain this interest, the examples presented in the training need to have some specific features. The studied problems need to be:

- relatively simple and clearly defined;
- to have practical significance and application;
- very good visualization of the computer simulations of the studied processes;
- possibility to change some parameters: geometric, material properties, mode parameters, etc.

The presence of such features facilitates the understanding of the material and significantly increases the possibility for self-learning based on easy change of parameters and detailed analysis of the studied processes and phenomena.

III. EXAMPLES

The presented examples are related to the process of training in theoretical electrical engineering and computer simulations are based on modeling of the electromagnetic field distribution and subsequent determination of specific parameters and characteristics. The finite element method (FEM) and the program Quick Field 5.6 [7] are used for analysis and modeling of the electric and magnetic field distribution. It is particularly suitable for the learning process, as it offers a very good visualization of the field distribution and the determination of many parameters.

A. Mutual Inductance of Coaxial Coils

The example presents the determination of mutual inductance of two coaxial coils for different values of the distance D between them (Fig. 1). In the figure, all dimensions are given in millimeters. The relative magnetic permeability of air and copper conductor is $\mu_r = 1$.
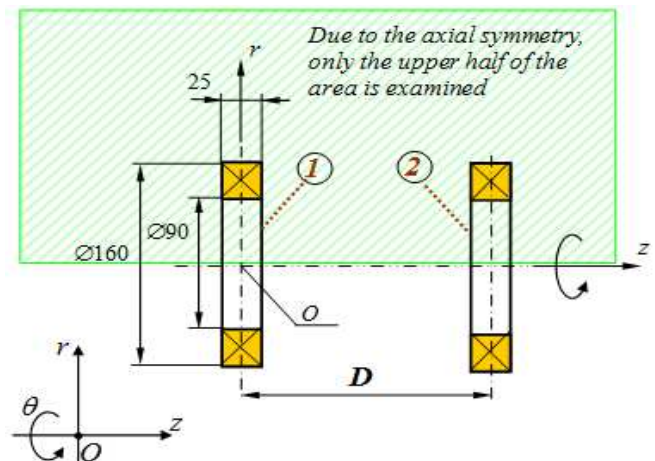

Fig. 1. Geometry of the studied area

The modeling of the magnetic field distribution and the determination of the mutual inductance has to be obtained for three values of the distance between the coils $D = \{70\text{mm}, 150\text{mm}, 210\text{mm}\}$.

The considered problem is magnetostatic. Taking into account the rotational symmetry of the system, it is appropriate to use cylindrical coordinate system. The problem can be solved as two-dimensional, axisymmetric in rOz plane (Fig. 1). In this case, the field exciter (the coil current) has a non-zero component only in the θ direction. Thus the magnetic vector potential used in the analysis of the magnetic field also has a non-zero component only on the same axis. The field distribution can be described by Poisson equation in cylindrical coordinate system:

$$\frac{\partial}{\partial r}\left[\frac{1}{r}\frac{\partial(rA_\theta)}{\partial r}\right] + \frac{\partial}{\partial z}\left[\frac{\partial A_\theta}{\partial z}\right] = -\mu J_\theta \qquad (1)$$

where J_θ and A_θ are respectively the components of the current density and of the magnetic vector potential in the azimuthal direction θ.

Since the problem is in open domain, a buffer air zone is introduced in the region of consideration, along the boundaries of which a zero boundary condition is imposed.

The problem has been solved for each of the variants of the distance D using FEM and the QuickField program. Fig. 2 shows the finite element mesh of the investigated region for the variant $D = 210$ mm.
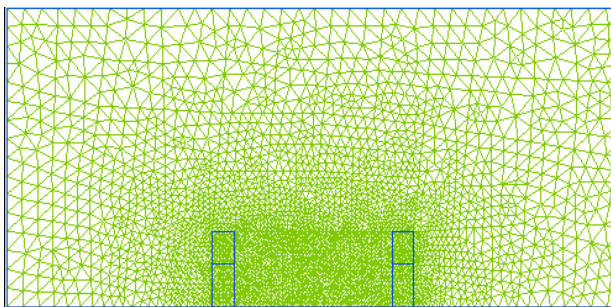

Fig. 2. Finite element mesh with 3553 nodes for the variant $D = 210$ mm.

As a result of the computer simulation, the three variants are considered and for each of them the following results are determined:

- the map of magnetic flux density distribution (Fig. 3);
- the map of magnetic field strength distribution (Fig. 4);
- field values at any point in the field (Fig. 5);
- magnetic flux Φ_{21} created by the coil 1 and coupled with the turns of coil 2 (Table I);
- mutual inductance M of the two coaxial cylindrical coils (Table I).

The computer simulation allows the use of an integral calculator for determination of specific integral characteristics and parameters. Fig. 6 is an illustration of the possibility of determination of the magnetic flux and coil inductance.
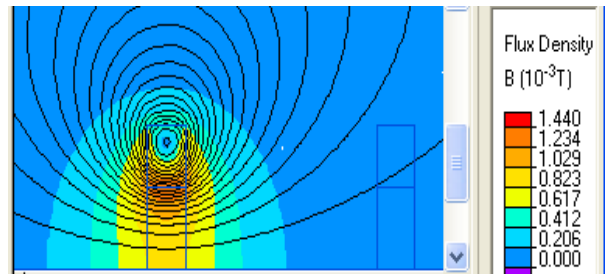

Fig. 3. Magnetic flux density distribution for $D = 150$mm
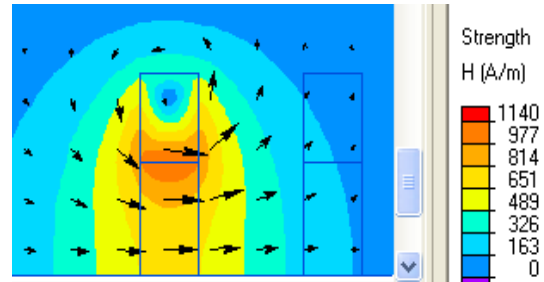

Fig. 4. Magnetic field strength distribution for $D = 70$ mm
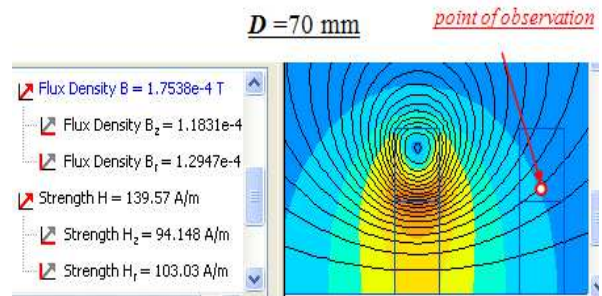

Fig. 5. Field values at specified point of observation.
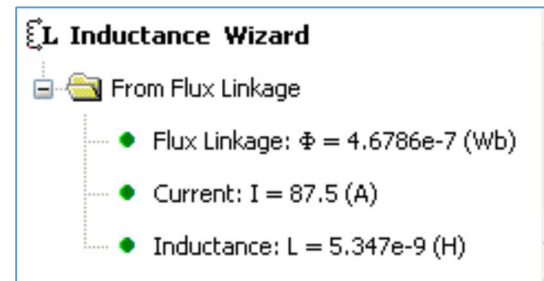

Fig. 6. Determination of the magnetic flux and coil inductance.

TABLE I. RESULTS FOR THE THREE VARIANTS

Results obtained from simulations		
Distance D mm	Flux linkage Φ_{21} Wb.10^{-6}	Mutual inductance M H.10^{-9}
70	2,21	25,3
150	0,47	5,3
210	0,21	2,1

B. *Study of Electrostatic Field by Means of Electrolytic Tank*

The example presents computer simulations, corresponding to the laboratory setup in which the

electrostatic field is studied by means of electrolytic tank (Fig. 7).

The aim of the laboratory exercise is experimental and numerical study of electrostatic field, based on the analogy between electrostatic field and electric field of direct currents. The use of this analogy allows determination of some quantities and parameters in electrostatic field, based on an experimental study of electric field excited by direct currents. In this lab, the electrostatic field generated by a two-wire long air line with a square cross-section of the conductors (Fig. 7a) is studied with the help of electrolytic tank with two electrodes in it of the same cross section (Fig. 7b).

The students have to investigate experimentally the electric field produced in a tank with electrolyte in which two electrodes with different potentials have been posed.

The example demonstrates the possibilities of computer modelling of the field and determination of the field parameters and characteristics for different variants of positions, shapes of the electrodes and applied voltage.
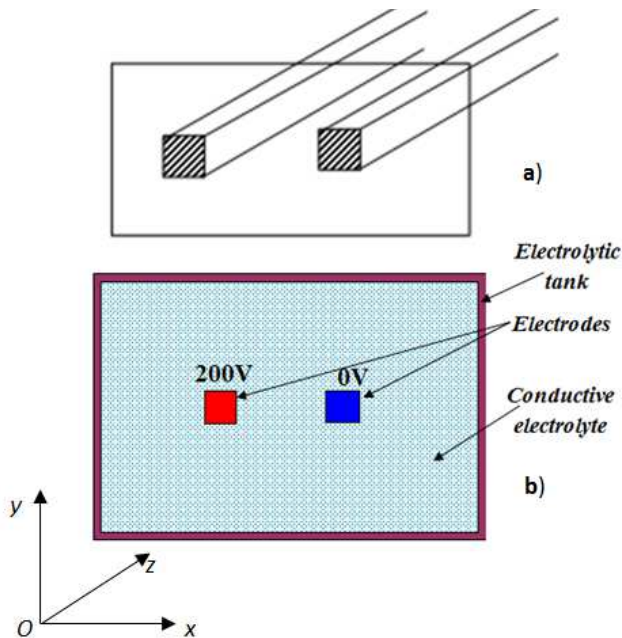

Fig. 7. Study of electrostatic field by means of electrolytic tank.

The considered problem is electrostatic. It can be analyzed as two-dimensional, plane parallel in xOy plane (Fig. 7). Mathematical formulation of the task is based on the electric scalar potential and the electric field distribution can be described by Laplace equation:

$$\frac{\partial^2 V_\varepsilon}{\partial x^2} + \frac{\partial^2 V_\varepsilon}{\partial y^2} = 0 \qquad (2)$$

The analysis of electrostatic field is carried out when zero boundary conditions $V_\varepsilon = 0$ are accepted on the walls of the electrolytic tank.

The problem has been solved using FEM and the QuickField program. Fig. 8 shows the finite element mesh with 3677 nodes.
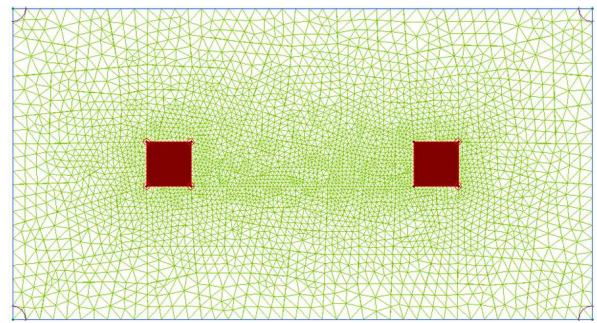

Fig. 8. Finite element mesh for the electrolytic tank problem.

As a result of the computer simulation are determined:

- the map of electric scalar potential distribution (Fig. 9);
- the map of electric field strength distribution (Fig. 10);
- electric field quantities at specified point of observation (Fig. 11);
- field distribution along a specified line of observation (Fig. 12);
- the electrode capacitance (Fig. 13) and energy of the system (Fig. 14).

Electric scalar potential distribution in the area between the conductors is presented in Fig. 9.
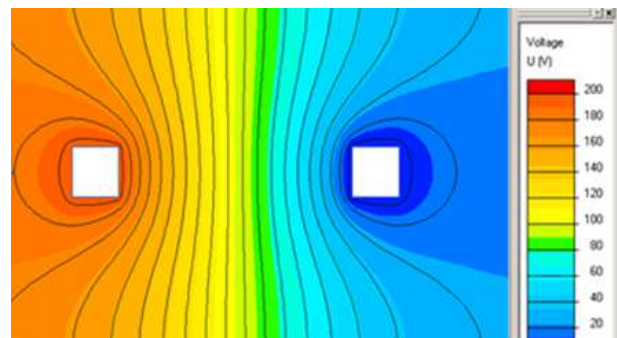

Fig. 9. Electric scalar potential distribution.

The modeling of the electric field strength distribution in the studied region has been illustrated in Fig. 10.
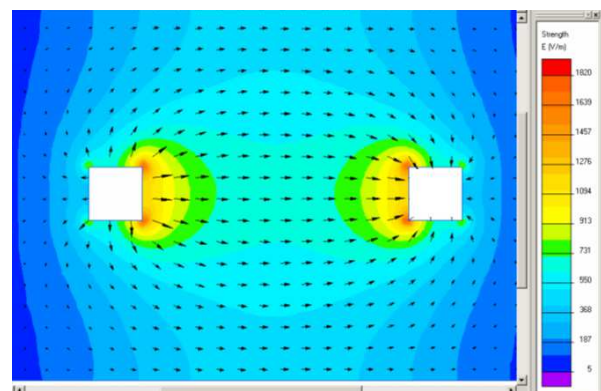

Fig. 10. Electric field strength distribution in the electrolytic tank

The computer simulation also allows the determination of the field vectors at specific points, as well as its distribution along a specified line of observation.

The determination of electric field quantities at specified point of observation is shown in Fig. 11. For the point with fixed coordinates $x = 0$, $y = 0$, the potential $V = 100$ V and the field strength $E = 645$ V/m are determined.
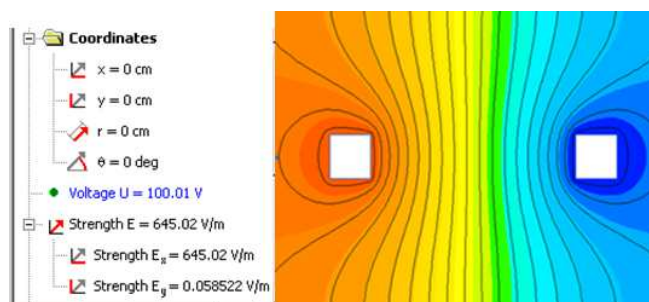

Fig. 11. Determination of field quantities at a point with fixed coordinates.

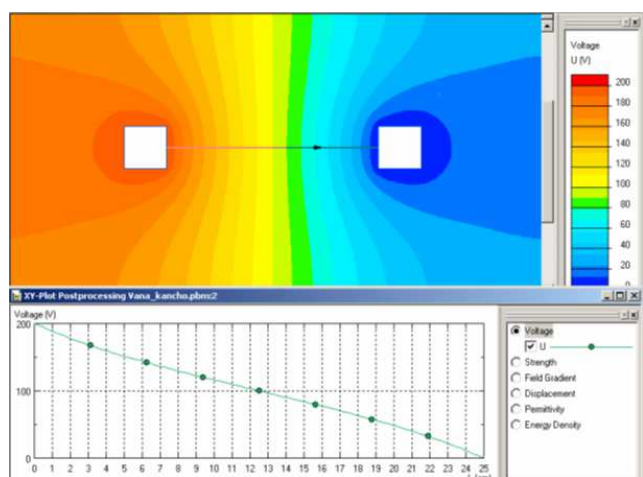The distribution of the electric potential along the observed line is shown in Fig. 12.

Fig. 12. Electric potential distribution along a specified line of observation.

The modeling of the electric field strength distribution and determination of the electrode capacitance in two ways (by the energy W and using the charge Q) are shown in Fig. 13.
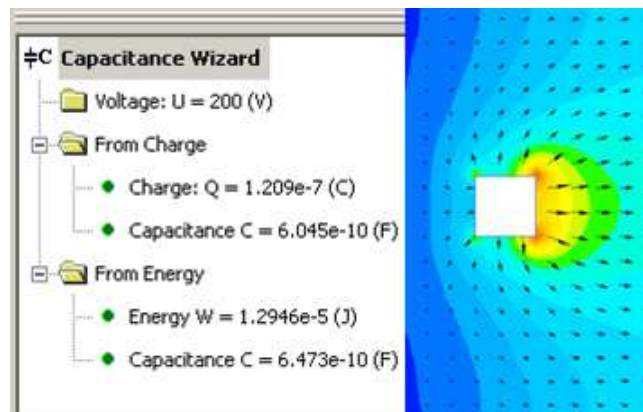

Fig. 13. Determination of the energy of the system and electrode capacitance.

CONCLUSION

The computer simulations based on modeling of electromagnetic field distribution in combination with the possibility for easy change of the parameters and excellent visualization of the field distribution activates student attention and provokes greater interest in the distance learning process.

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