

SOME CORRELATIONS BETWEEN CHARACTERISTICS, CALCULATION METHODS AND SOFTWARE APPLICATIONS FOR SIMULATION OF EFFECTS OF THE ELECTROMAGNETIC FIELD

Marius Lolea[1], Simona Dzitac[2], Eva Barla[3], Szabo Emeric[4], Creţ Petru[5], Andrea Minda[6]
[1] University of Oradea, mlolea@yahoo.com
[2] University of Oradea, simona.dzitac@gmail.com
[3] University of Oradea, ebarla@uoradea.ro
[4] University of Oradea, emeric.szabo@oradea.rdsnet.ro
[5] University of Oradea, pcret@uoradea.ro
[6] University “Eftimie Murgu” Reşiţa, a.minda@uem.ro

ABSTRACT: The paper presents a comparative analysis of the calculation methods of the electromagnetic field(EMF) parameters in relation to the possibilities of implementation in some software applications. The software applications referred to are generated either by developing numerical analysis and simulation algorithms using general software or by accessing modules designed to solve electromagnetic field problems within dedicated software products. Some correlations are made between the calculation of EMF's characteristic sizes and the possibilities for PC implementation, taking into account certain criteria such as the advantages or deficiencies of applying calculation models, the approximations and rendering of real phenomena, computational errors and calculating time etc. The examples of the paper are focused especially on numerical analysis solutions adapted to the components of electrical networks or equipments specific to the electric power domain.
KEYWORDS: electromagnetic field parameters, electric field strength, magnetic induction, EMF effects simulation

1. INTRODUCTION

The electromagnetic field (EMF) is omnipresent and has two categories of generating sources. Depending on these sources, EMF is natural and artificial or anthropogenic. The effects of EMF depending on the character of the spatial transmission and the characteristic parameters may be useful or harmful. Useful applications are those specific to medical treatments such as electrotherapy, X-ray radiographs, or cancer tumor destruction operations. Negative effects are those related to disturbances introduced into technical systems or damage to health by ionizing electromagnetic waves. The paper will deal with non-ionizing electromagnetic fields, that is, one that does not produce changes in the atomic or molecular structure of the substances.

The effects of the electromagnetic field on substances can be grouped into two broad categories: thermal and non-thermal. Among the categories of diseases on human health we specify [6], [9]: modification of the genetic material of the cell; alteration of gene expression; alteration of cellular structures; modifying calcium metabolism in the brain; decreased reproduction rate; modifying cell defense mechanisms; impaired immune system; diminishing skin resistance and altering protein in the skin; increasing lymphomas; generating other forms of cancer, including leukemia; activation of apoptosis; alteration of synapse metabolism in the brain; facilitating epilepsy seizures; disorders of heart rate and blood pressure; reducing cerebral blood flow; increasing the amount of mercury in the urine; increased proliferation of pathogenic bacteria; deregulation of melatonin secretion and circadian rhythm; insomnia, depression and anxiety; diminishing concentration etc. Some of these direct affections generate others. The physical effects on the biological tissue produced by the EMF can be explained by considering their electric and magnetic properties and the electronic schemes that can constitute the electromagnetic model of living cells [6]. Studies on the human body exposed to intense electromagnetic fields are not ethically and ethically agreed but various numerical computational models or research on models called ghosts are being developed [5]. There are value thresholds of characteristic sizes (CS) that separate the negative effects from the positive ones from the exposure of individuals to EMF. These are regulated as allowable values for the general population and operational personnel in the occupational environment, as is the case with the employees of the electrical grids [14], [15]. The negative effects of EMF produced in technical systems include disturbances in the use of telecommunication systems or damage to radio-TV broadcasts. Electromagnetic disturbances are transmitted in three different ways from source to receiver:

convection, conduction, and radiation [7]. The influence or interference of the useful signal is produced by means of electromagnetic couplings such as galvanic, inductive, capacitive and electromagnetic radiation. A schema for transmitting disturbances is shown in the following figure [10].

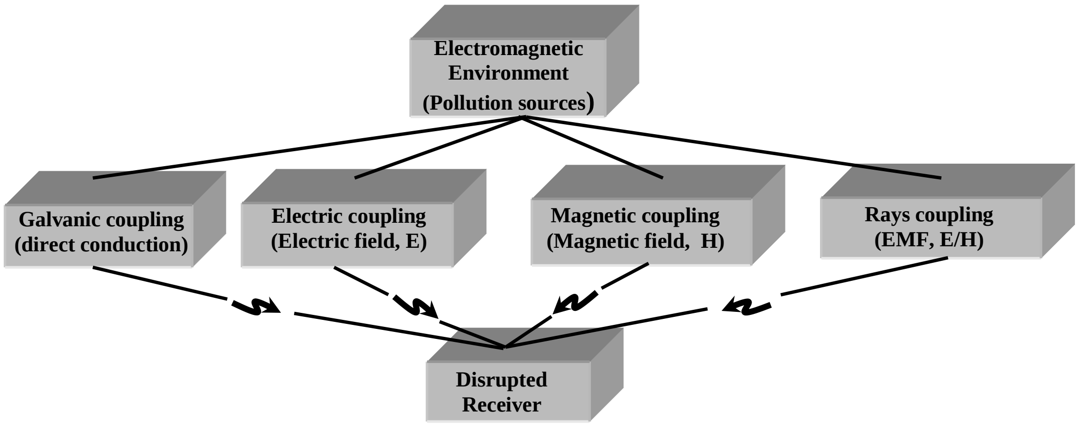

Figure 1. Mechanisms of coupling of electromagnetic interferences [10]

EMF is characterized by specific physical sizes that have been set in accordance with the laws governing real electromagnetic phenomena. Evaluating of CS through is made by calculations or measurements. Generally, those EMF's parameters that can be easily measured can be calculated to establish errors and deviations between the results of the calculation methods and the real field values. On EMF components, electric fields and magnetic fields, the parameters that are commonly evaluated in various theoretical or practical applications are: the field strength E (V / m), the magnetic induction B (T) and the magnetic field strength H (A / m) .

The equation for the intensity of the electric field in case of two conducting and parallel, plates, ignoring edge effects, is[4]:

$$E = -\frac{V}{d} \quad (1)$$

Where, V is the potential difference, and d the distance, between the plates. The electric field owes from the positive plate to the negative, the opposite direction to the direction of increasing voltage. For a spatial spherical charge Q, the electric field strength at the radius r is given by relation[4]:

$$E = \frac{Q}{4\pi\varepsilon r} \quad (2)$$

Electric fields are linear vector fields and D is known as the electric flux density. They are related by4[]:

$$D = \varepsilon_0 \, \varepsilon_r \, E \quad (3)$$

Where, ε_0 is the permittivity of free space, and ε_r is the relative permittivity.

Magnetic H - and B - fields are two vector fields, often both referred to as the magnetic field. For linear materials, the related between the two quantities, is[4]:

$$B = \mu_0 \, \mu_r \, H \quad (4)$$

Where μ_0 is the permeability of free space and μ_r is the relative permeability. Obviously, more complex geometric structures lead to more complicated computational relations. The authors propose in this paper a theoretical adaptation of SWOT principles analysis consecrated in economy sciences, to the electromagnetic field issues. For this solution, criteria for analyzing solving methods are proposed as in Table 1.

Table 1. The first comparison criteria between methods

Crt. No.	General methods	Dedicated methods
1	Analogical	All devices
2	Numerical	Specific on domains
3	Graphical, analytical	Mixed

2. A REVIEW OF COMPUTATION EMF PARAMETHERS USING A DIFFERENT METHODS

For calculating the EMF sizes, it starts from its fundamental equations, and then seeks to obtain evaluation methods that ultimately lead to numerical results with the best accuracy correlated with the reality of physical phenomena. Numerous methods are known for determining the electrical and magnetic field characteristics. They are divided into numerical, analytical, graphical, graph-analytical and analogical methods [1, 3, 10, 8, 12, 13].

Analytical methods provide solutions that are expressed by certain known functions. Analytical solutions have the advantage of allowing qualitative interpretation of results. However, the number of configurations that can be approached with analytical methods is low. The main analytical methods are: elementary method, the method of integrating Poisson-Laplace equations by separating the variables, the electric imaging method, the complex variables functions - associated with the conformational transformations and the Green function method [4,10, 11,13].

Numeric methods can apply to any configuration, with an error that depends on the method used and field domain partitioning. The main numerical methods are: Finite difference method (FDM), Finite element method (FEM), Boundary elements method (BEM), Finite integration method (FIM), Charge simulation method (CSM), Monte Carlo method(MCM) etc [3,8, 10, 12].

The graphical methods are based on the plotting of the studied field, and the graphic - analytical method uses the approximation of the shape of the field lines by straight segments and circular arcs, or rarely elliptic arches. Analog methods use the representation of the electromagnetic field through fields of another nature [1]. In the context of the EMF, the basic criteria considered are: the destination of the methods, applicability, recommendations and prohibitions. A very widespread method is that of finite elements (FEM). The method is based on the division (mash) of the computing field in simple and regular forms, with the surface easy to compute. These elementary shapes can be triangular, rectangular, hexagonal or other types and are called finite elements [1], [3], [7], [10], [13]. An example of the application of the finite element method for a triangle composed of discrete surfaces of the triangular type, constructed and reproduced by graphs and manholes are shown in the figure 2.

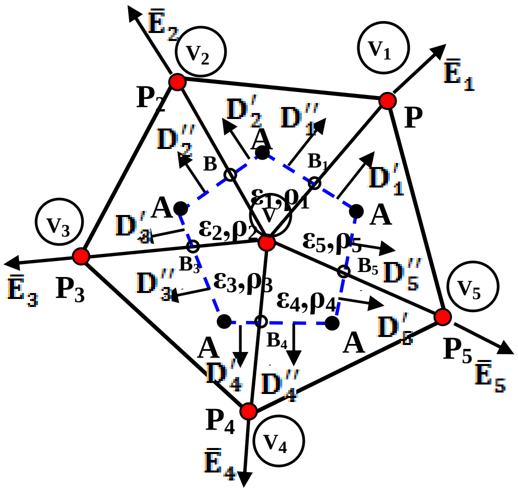

Figure 2. Principle of FEM for a triangular structures[13]

The intensity of the electric field in each sub-domain from Figure 2 is uniform and its components on the P_oP_1 direction can be calculated with the relations [13]:

$$E_1 = \frac{V_0 - V_1}{|P_0P_1|};\ E_2 = \frac{V_0 - V_1}{|P_0P_1|};\ E_3 = \frac{V_0 - V_1}{|P_0P_1|};\ E_4 = \frac{V_0 - V_1}{|P_0P_1|};\ E_5 = \frac{V_0 - V_1}{|P_0P_1|} \qquad (5)$$

By adapting the application of the method from Fig. 2 to the requirements of the ElecNet calculation program, the shape of the mesh (a) and the spatial distribution of the electrical potential V and E (b) will result, by direct choice, in the figure 3.

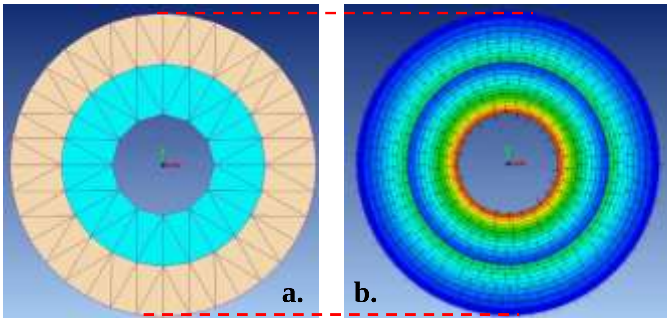

Figure 3. Simulation through ElecNet software[20]

Each numerical technique for EMF evaluation has its own merits and disavantages and it is not generally possible to prefer one technique over the others. In the case of the power transformer structure, it can be assumed that normally the 3D calculation of the electric field is applicable because there is no symmetry to ignore a dimension. Therefore, the numerical technique chosen must be able to model conducting or insulating layers [1, 3].

For example, FDM and FEM in the electric field computation have two disadvantages[1], [3]:

a) In determination of potential distribution using two methods, numerical derivative techniques must be used in order to obtain the electric field intensity. This has considerable error that leads to a large error in the electric field computation. In many cases, the field is required or the design of insulation of electrical equipment. Meanwhile, study of some phenomena such as electrical discharge is possible by electric field computation.

b) In order to prevent a large electric field and its drawbacks, the sharp edges on the different surfaces are avoided.

Therefore, the curved surfaces are often preferred. FDM and FEM have difficulty in modeling such curved surfaces; but CSM and BEM can be easily adapted for such cases. On the other hand, although FDM and FEM can theoretically compute 3D fields, there are many problems in dealing with this matter.One serious problem is 3D mesh generation and its modification to approach the required accuracy. Generally manual calculation is cumbersome and time consuming and also computer programming is really complicated.

Another difficulty is the large size of the coefficient matrix of the system of equations. In these methods number of equations is proportional to the memory required for computation while in other methods (CSM and BEM) this number is proportional with area of the boundary surfaces. It means that in FDM and FEM, the coefficient matrix has one more dimension than the coefficient matrix due to the other above-mentioned methods. Is necessary more memory and a high frequency of PC processors to reduce calculation time. Hence FDM and FEM may not be considered convenient techniques for electric field computation. MCM, at least in electric field computation, is not so common and has no considerable progress in recent years[1],[3].

However, at this time, applying this method to narrow-layer problems is very difficult. In spite of the simplicity of computer programming and high accuracy of the method, in computation of 3D electric fields having narrow layers CSM is confronted with a major difficulty. In this method it is necessary to consider charges within the mentioned layers such that they have enough distance from two sides of the layer[3].

It can also be said that BEM is able to modeling the 3D fields with some applications of the method for narrow layers. As shown in other papers [1], [3] BEM can be considered the most convenient technique for calculating the electric field inside the power transformers tank.

A very common ways to solver electric field strenght is to derive an equation for the capacitance between two conducting objects, usually two parallel plates, two concentric cylinders(figure 4- transversal section), or two concentric spheres.

Thus, the capacitance of the cylindrical capacitor assimilated to a single-phase cable with a radial field of length l in meters, can be calculated with the next relation [4]:

$$C = \frac{2\pi\varepsilon l}{\ln\frac{R}{r}} \qquad (3)$$

where: *ε* – is the dielectric permissibility of the cable insulation sheathi, in F/m; *r* – is the core ray, in mm; *R* – ray of external insulation, in mm.

For the single phase cable, the potential difference between the conductor and the sheath can be calculated with relation[4]:

$$V = \frac{q}{2\pi\varepsilon}\ln\frac{R}{r} \qquad (4)$$

And the intensity of the electric field at the distance x from the core will be[4]:

$$E_x = \frac{q}{2\pi\varepsilon x} \qquad (5)$$

The physical model of the energy cable is with capacitor shaped shown in Figure 4.

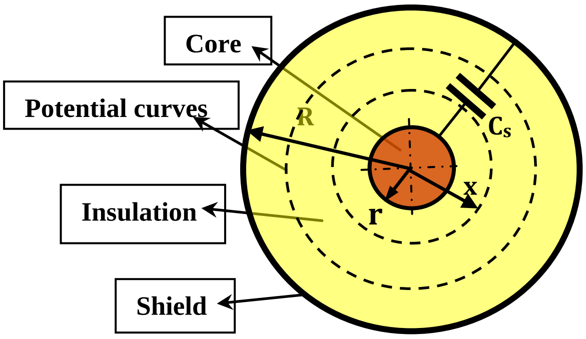

Figure 4. Power cable section adapted by [3]

To facilitate access to information on EMF effects and also to provide the possibility of viewing simple calculation methods of EMF characteristic dimensions existing on the Internet, the authors created the website www.electromagnetism.ro

Figure 5. Web-site access interface [16]

Figure 5 presents the interface of the developed web-site. Explaining a few menu button functions is as follows:

- Function "HOME" – offers general information about website;
- Function "THEORY" – gives information about the Theory of theoretical characteristic of EMF parameters: physical law, definite sizes, measure units etc;
- Function "LEGISLATION" offers the possibilities of download about basic regulations which involves the limits values of characteristic sizes of EMF etc;
- Function "CALCULATE" offers the possibilities to calculate the parameters of EMF;
- Function "ELECTROMAGNETIC MAP" indicates a link to the application with distribution and parameters of EMF public sources in Oradea town teritorry.

3. SIMULATION OF EMF EFFECTS. A FEW SOFTWARE PRODUCTS

The need to increase the precision of computation and the difficulty of calculus time or the complexity of equations requires the computerized approach to electromagnetic field problems. In this context, the opportunity and the principles of PC simulation are presented in this paragraph. Any numerical technique for electric field evaluation has its own merits and drawbacks and it is not generally possible to prefer one technique over the others. Each technique to calculate the electric and magnetic field has its own merits and drawbacks and one technique cannot be generally preferred to others. Based on the proposed problem, the most convenient technique must be selected. For example, the different numerical techniques, so far used for the electric field analysis, are briefly reviewed and the most convenient technique is then suggested for electric field evaluation within the interior space of power transformers.Computer-assisted analysis of electromagnetic field problems involves three preliminary operations [2],[11],[12], namely:

a. Physical modeling - in which essential physical phenomena are identified, explicitly neglected are those that are not significant and the physical magnitudes characteristic of the essential phenomena are identified. On this occasion, the field of electromagnetic field considered in the studied study is determined and the approximations and idealizations of geometric and temporal nature, material or field sources are made.

b. Mathematical modeling - in which the equations describing the essential phenomena are written and the mathematical structures by which the physical quantities are represented, as well as the domains of definition of the functions or operators intervening in the equations are identified. Mathematical modeling should be based on theorems that guarantee correct formulation of the problem and which ensure the uniqueness, existence and stability of the solution. For a rigorous mathematical formulation of a field problem, it is necessary to determine the functional framework, respectively the field and the code of each function that intervenes in the respective problem, either as a date or as a solution, as well as the class of functions (space) involved. In short, the mathematical description should be made: the scope of the problem, the material properties, the field sources and the solution. To define exactly the scope of the problem, the first operation consists in choosing a suitable coordinate system. The next step is to define the space-time domain. The scope can be bordered or not. In the case of the model, the scope of calculation can be considered to be bordered and the problem is referred to as a closed border or "internal problem". For an unlimited domain, the problem is called an open boundary or an "external problem". In determining the mathematical model of the physical domain expressed in the coordinate system chosen, not only the boundaries of the boundary of the computing domain, but also those specific to the separation surfaces between sub-domains with different physical properties, intervene. The next step is to define the material properties given that they can be of several types: linear / nonlinear, isotropic / anisotropic, etc. A computing domain may be complex and composed of more distinct regions characterized by properties of composite material.

c. **Numerical modeling** - follows the mashing(discreet resolution) of the computing field to solve the field problem, which implies the approximation of the continuous spaces in which are defined the functions describing the spatial-temporal variations of the physical quantities involved in the study through discrete, finite spaces as well as the meshing operators intervening in the field-specific equations studied. The spatial discrepancy of the computing domain is executed automatically, being embedded in the various software packages. Numerical modeling aims to solve the problem with the finite computer resources a computer offers. This step involves the approximation of the continuous spaces of functions describing the spatial-temporal variations of the physical quantities, by discrete spaces, the finite dimensional, as well as the mashing of the operators intervening in the field equations. There are several ways in which this approximation can be made according to the numerical method used. Many software programs have been developed for each of these methods. After completing these three specific stages, the studied problem reaches a form that can be dealt with by the computation program, thus finally obtaining the numerical solution of the direct problem. The complete computer assisted analysis process ultimately involves validating the numerical solution. One of the main criteria for developing a software product dedicated to EMF problems is that of electromagnetic wave frequencies. Another criterion is that of the field of application in terms of power and destination of equipment models: electronics, power systems, electro- thermals domain etc. Also, the electric and magnetic field regime requires the creation of specially allocated software modules. Last but not least, the destination of the software application according to the type of system analyzed is another criterion: technical sites and biological systems. For each criterion or category listed, identifying and analyzing all existing software is virtually impossible. That's because their number is very high worldwide. But, based on CELM's destination and regimes, the authors of the paper make a brief analysis of the identified programs as follows:

- For EMF simulation produced by electrical grids, with industrial frequency analysis, the most known and used programs are EFC 400, SEMCAD X or CDEGS. An example for EMF simulation for a power substation (PSS), from power system using EFC 400 software, is shown in figure 6.
- For electric and magnetic field simulation produced by electrical and electronic apparatus with static and stationary regime analysis, some of the most known and used software programs are: Elecnet, Magnet, Maxwell or Comsol Multiphisics.

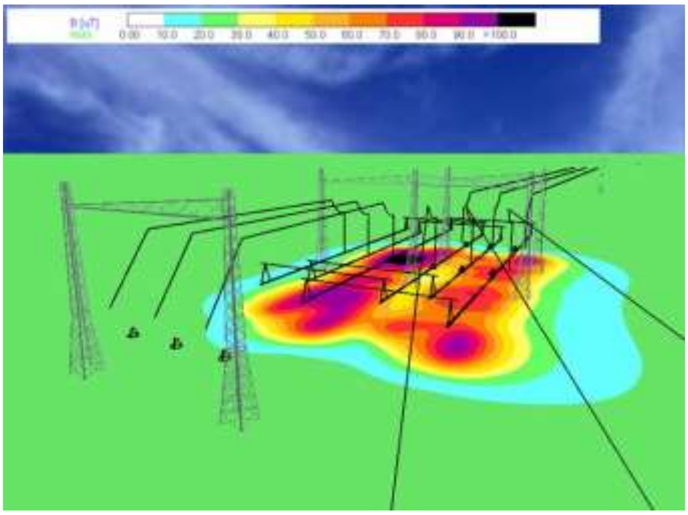

Figure 6. EFC 400 simulation of EMF for a PSS [17]

For EMF high frequencies simulation including effect about biological systems, the following programs are better known: HFFS, CST microwaves Studio, Radia Electromagnetic Pollution (REMP), Quick field or BiozSim. Images with solutions of simulation in REMP and CST products are shown in figures 7 and 8. Live organisms generally cannot be directly subjected to EMF action, and simulation software applications must be developed in correlation with certain electrical and magnetic characteristics of tissues. Simulations are often performed by data acquisition using sensors mounted on mats of materials that mimic the shape and electromagnetic characteristics of human body.

The Radia Software offers multiple possibilities to the user because it has solutions both in locating sources on a real map taken from Google-Earth and evaluating the territorial spread of the electromagnetic pollution area.

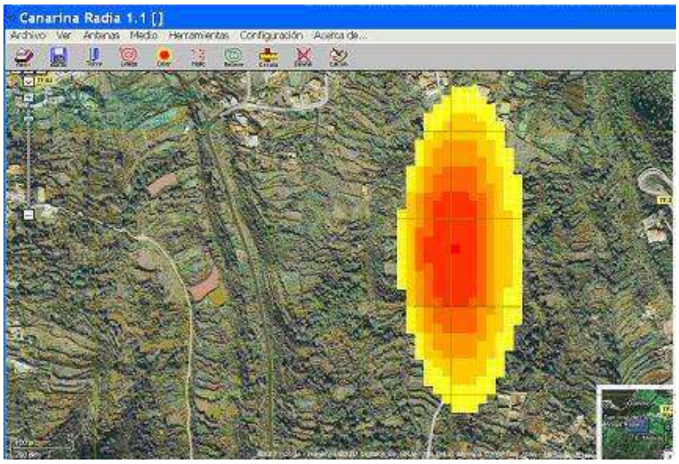

Figure 7. An example of image in Radia EMF Pollution software simulation [18]

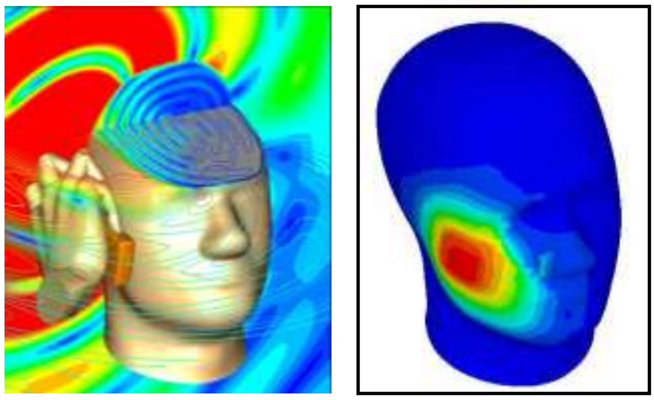

Figure 8. Human head examples simulation [19]

Figure 8 shows the EMF lines and the heating of the head tissue obtained by simulation with CST Microwave Studio [19].

Using the model from paragraph 2, for calculating the field strength of power cables, the authors developed a software application in Visual Basic called LEC Proxicel. The logic diagram of the application and the computing interface are shown in Figures 9 and 10.

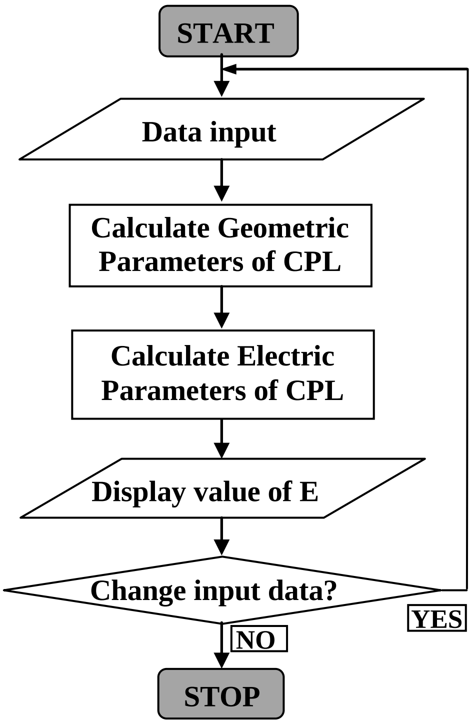

Figure 9. Logic diagram

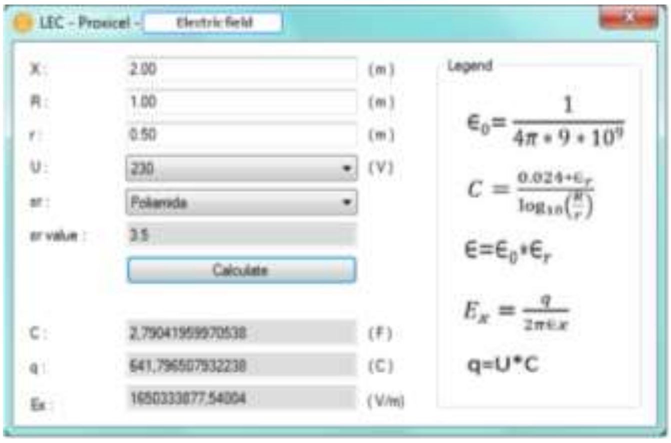

Figure 10. LEC - Proxicel interface with setup example

4. A FEW CORELATIONS BETWEEN EMF PARAMETERS, CALCULUS METHODS AND SOFWARE SIMULATIONS

Although comparative analyzes of various computational methods have been performed by specialists [1],[2],[3], [7], [13] etc. The evolution of the computing technique and the increased complexity of the electrical installations require their periodic resumption.

Therefore, a supplement to the conclusions of the specialized analyzes on the methods and models of calculating the parameters of the electromagnetic field or the elaboration of other analytical criteria was considered appropriate. At the same time, the number of analyzed methods is higher compared to other works published by different authors. All these aspects are obviously adapted to the trends of the present times. The choice of a numerical method of calculating the magnetic field depends on many parameters: the structure of the field and the shape of the electric and magnetic field, the required calculation accuracy, the complexity of the program, the duration of the data input and the running of the calculation program etc [1][12].

It is rather difficult to establish a calculation method that presents a number of advantages over other methods, since the criteria for choice depend, first of all, on the nature of the problem (shape and complexity of electrodes, dielectric characteristics, domain structure: closed or open), but also by the habit of using a given method by a person. However, it is useful to perform a comparative analysis of the numerical calculation methods of the electric field, because in the case of high voltage installations and equipment, the use of certain methods is preferable. To this end, reference will be made mainly to the methods FDM, FEM, MEC (method of electric charges) and MEI (method of electrical images) and partly at MCM. Variable methods have less use in high tension techniques. Many of the calculation methods apply to both the electric field and the magnetic field. Depending on the regime in which the EMF components are determined, the calculation methods can be divided into two categories: domain methods (FDM, FEM, MCM) and surface methods (MEC, MEI)[1][3]. Methods that specifically refer in this paper are for to the field electric field calculation. These methods have developed the first for calculating the magnetic field strength, and then applied to the electric field [1].

Interest in the use of these methods in the calculation of the electric field has declined lately because the precision in determining the field strength of an electrode is lower than in surface methods. Indeed, when using, for example, MEF, the determination of the solution is based on the minimization of energy in that field that does not have a direct correspondence with electrostatic laws, for example with Coulomb's Law. Unlike this method, MEC and MEI use potential and field coefficients that derive directly from electrostatic laws and, consequently, satisfy the Laplace equation.

Calculating the field strength of electrodes with FDM or FEM requires several steps. In a first step, a certain distribution of potential for the electrodes considered is taken, potential coefficients are calculated, and, consequently, the electrical charge of these electrodes is determined [1]. With the help of the previously determined potential coefficients, the potential of the electrodes can be calculated according to their load. Next, the calculation is repeated by considering the potential of all electrodes.

The Finite Difference Method (FDM) can also be applied to the stationary magnetic field. If the magnetic field problem is formulated with a scalar potential, then the forms for the electrostatic field can be used [1]. The essential difference to the electrostatic problem lies in the fact that when there is a current distribution in the field, the use of an auxiliary field that takes over the rotor of the initially assumed field causes a field filling with magnetization loads (spatial loads). Unlike electrostatic problems, where potentials are usually given on certain surfaces, where superficial distributions of electrical charges will occur, which do not explicitly intervene in solving, and in the field there are no electric load distributions.

In the finite difference method, the system of differential equations or partial derivatives valid for any point of the analysis domain is transformed into a system of equations valid only for certain points of the domain, points defining the domain meshing network. The main drawback of this method is the use of a rectangular meshing mesh network. So its use on contouring or curved surfaces introduces a number of difficulties and computing fireworks. At the same time, there are numerous problems of stability and solution convergence, which determines the specific conditions of occurrence and their avoidance for each class of problems. For the magnetic field problem formulated with the help of the magnetic vector potential, the finite difference method apply only in particular cases when the potential vector has only one component and the problem is solved in a plan. In this case, either the approximation of the LPL or the combined differential and integral form can be used. In the latter case, by divided central differences, the components of the magnetic field are perpendicular to the sides [1].

The finite integral method applied to static electric two-dimensional fields can also be applied to other types of static or stationary fields based on the analogy of the corresponding fields, studied in terms of a scalar potential such as the magneto-static field, the pseudo-stationary electro-kinetic field, the thermal field or stationary electrochemical field [1].

The Monte Carlo method (MCM) is particularly useful for installations and structures with three-dimensional geometries, where it is necessary to determine the potential and intensity of the electric field only in a limited region of interest [1]. An example is the structure made up of a window of the high-voltage line pole through which a conductor or a conductor assembly passes. It follows from the above that for the calculation of the potential and the electric field strength in the case of high voltage installations, MEC and MEI are preferred, with the observation that for three-dimensional structures MCM may have advantages. Both MEC and MEI methods are more general in solving electrical field problems than FDM and EMF. MEC and MEI may consider different limit conditions as they allow for the calculation of potential and field strength in closed or open domains. At the same time, it should be mentioned that MEC is not effective enough for low-size electrodes or for multiple dielectric structures [1]. Both MEC and MEI can solve, without too much difficulty, the determination of the electric field in the presence of space loads; it should be noted that the distribution of these tasks does not create difficulties in solving the problem, since they can be represented by linear, superficial and volume structures. The advantage of MEI is that the solution is obtained directly in the form of the distribution of the electric field strength on the surface of the electrode. Also, MEI is more appropriate for three-dimensional electric fields. Parallel to the determination of the electric field by solving the corresponding integral equations, new methods of using MEI have been developed by representing spatial loads using triangular structures or by resorting to Fourier series development of superficial electrical charge density[1].

An analysis criterion for the calculation of the electric field is the time needed to solve the problem. The use of MEC is especially recommended if the continuity, shape and position of equivalent tasks can be established. This method is easy to apply, particularly in the case of a structure made of electrodes of relatively simple form. The calculation error, depending on the complexity of the structure, may be no more than (5÷10 %) [1]. Thus MEC is preferable to other methods in the case of a conductor system because the potential at their surface is determined with sufficient precision, considering that the electric charge is located in the conductor axis. Consequently, in the case of a high voltage overhead power line, the calculation of the field strength is the most appropriate method of equivalent load [1].

The method of the border elements has, over the equivalent tasks, the advantage of higher calculation accuracy. At the same time, in the case of more complex structures, it is preferable because it requires a shorter training period and because it leads more directly to the solution of the problem [1]. The comparisons in this paragraph have been made both on the basis of the authors' findings and on the issues identified by other authors.

For example, FDM in the time domain has the following advantages [1]:

- Maxwell's equations can be mashing very easily;
- The meshing equations are solved sequentially, being easy to implement on a numerical calculation system;
- The method can apply to problems involving complex structures that would be very difficult to solve by analytics or other numerical methods;
- Being a time-based analysis method, it offers transient mode solutions directly, and can then easily transform the time domain solution into the frequency domain. This way you can get the frequency behavior of different devices.

The method can be applied for the analysis of non-homogeneous media with loss, anisotropic, dispersive and variable in time, which gives it a net advantage over other methods which do not have such a wide use spectrum. For simulations in which the analyzed region has infinite stretch, frontal absorption conditions are applied to the planes that delimit the molded region, flat due to the truncation of space. This method has several disadvantages including:

- ✓ False field reflections may occur at the ends of the field under consideration (because of algorithm);
- ✓ Numerical dispersion of the solution may occur due to the fact that meshing is not done in infinitely small steps.

The main disadvantage of the method is, in case of complex problems, the high computing time and the need for large memory space. As with other methods, however, some of these disadvantages can be minimized. In the case of electrical equipment and networks, the situations for which the intensity of the electric and magnetic field is to be determined are very numerous and varied [1].

Parallel to the calculation of the electric field strength, for example, it is also possible to establish the necessary measures to improve the distribution of the electric field along an insulating structure or in a capped installation. For each situation we analyze what is the most appropriate calculation method, which also depends in part on the specialization in a certain area of the numerical method of the computing engineer. Of the above mentioned, there is a great variety of cases that may occur in the calculation of the electric field strength or the voltage distribution in case of high voltage power installations. For this reason, the calculation for a relatively small number of cases considered to be of greater interest will be presented under this paragraph. Among the presented methods, the method of integral equations and the method of equivalent tasks shall be used, the use of these methods being wider.

FEM is a method that can provide high precision, provided that the number of computing points and implicitly written equations to find unknowns is greater. This is why it is one of the most used methods in PC assisted modeling and simulation, both for the assessment of the specific quantities of electric and magnetic field [1].

5. DISCUSSION

Some of the methods presented can be easily implemented in software applications created individually using general PC utility programs such as Matlab, Mathematica, Turbo Pascal or Visual Basic. Due to the simplicity of the calculation method and the low claims on the introduced calculation errors, this type of application does not require much programming knowledge from the user. Only a minimal understanding of how to operate with general software is required.

The use of software specifically dedicated to the numerical solution of EMF problems does not require increased user attention and, depending on the EMF knowledge previously acquired, also varies the time spent learning how to use the program. This category of users can embrace the first. Creating dedicated software requires special computer skills, extensive knowledge of mathematics and physics, or collaborating with EMF specialists. This approach is specific to a third category of users.

Through the additional comments that made, the authors complete analyzes taken by other specialists, whose statements were briefly presented in this paper. The review part of the paper was based in particular on exposures and quotes from [1] and [3].

6. CONCLUSIONS

Due to the claims regarding the precision of the EMF specific assessment sizes, in the case of the exposure of living beings or the effects on the technical systems, an appropriate correlation between the categories of specialists involved and the applied methods is necessary.

Assessment by calculation of the electric field sizes is important from the following points of view:

- The distribution of electrical potentials that render the configuration of the electric field lines in a certain space;
- Establishing areas of possible overflows and penetrations of electrical insulation;
- Establishing the distribution of the electric field and the possibility of highlighting the areas of maximum unevenness within the installations where possible insulation faults could occur;
- The possibility of establishing the areas of the step tensions on the electric landings route with the implicit avoidance of possible accidents by overcoming the admissible ground voltage drops etc.

Also, calculating the quantities of the magnetic field is important from the following points of view:

- Provides the possibility of establishing areas with intensive magnetic fields and the causes of their occurrence in close connection with defective currents;
- The distribution of magnetic potentials gives the configuration of the magnetic field lines in a certain area;
- Establishment of areas in installations on the path of passage of the load currents around which magnetic fields are produced;
- Highlighting potential areas of electric current intensification due to imperfect contacts, where magnetic field increases occur.

7. REFERENCES

1. Drăgan G, *Tehnica tensiunilor înalte*, Vol. I , Editura Tehnică, Bucureşti(1996);
2. Fireţeanu V., Popa Monica,Tudorache T, *Modelarea numerică în studiul şi concepția dispozitivelor electrotehnice*, Ed. Matrix Rom, Bucureşti(2004);
3. Jawad Faiz, M. Ojaghi, *Instructive Review of Computation of Electric Fields using Different Numerical Techniques*, Int. J. Engng Ed. Vol. 18, No. 3, pp. 344÷356, Tempus publications, (2002);
4. Mocanu C. I, *Teoria câmpului electromagnetic*, Editura Didactică şi Pedagogică, Bucureşti, (1981);
5. Morega Mihaela, Covrig M , *Modele analitice pentru estimarea nivelului de expunere a organismelor la câmp magnetic de foarte joasă frecvenţă*, Rev. EEA Electrotehnica, vol. 44, nr. 1-2, pg. 18-22(1996);
6. Morega Mihaela, *Bioelectromagnetism*, Editura Matrix Rom , București(1999);
7. Moraru A, *Bazele Electrotehnicii*, *Teoria Câmpului Electromagnetic*, Edit. MatrixRom, ISBN 973-685-343-8, Bucureşti, (2002);
8. Moraru A, *Complemente de teoria câmpului electromagnetic*, Editura MatrixRom, București, (2003);
9. Păunescu Gabriela, *Câmpul electromagnetic. Studii asupra posibilelor efecte ale câmpului electromagnetic asupra sănătății*, www.infoscola.webgarden.ro, ISBN 978 – 973-0- 07974- 6, (2010);
10. Schwab A., Kurner W, *Compatibilitate Electromagnetică*, Editura AGIR, București, (2013);
11. Tomescu Anca, Tomescu I.B.L., Tomescu F.M, *Electrotehnică. Sisteme electromagnetice, Calculul câmpului electromagnetic,* Ed. MatrixRom, București,(2008);
12. Vîrjoghe Otilia, Enescu Diana, Stan M.F, Căciulă Ion, *Modelarea numerică a câmpului electromagnetic și a câmpului termic*, Editura Bibliotecha, Târgoviște, (2008);
13. Voicu N, Constantinescu L. Mirela, Gavrilă Delia, *Teoria câmpului electromagnetic, Elemente de teorie,* Editura MatrixRom, Bucuresti, (2005);
14. *** Directiva 35/UE a Parlamentului european și a Consiliului european din 26 iunie 2013 privind cerințele minime de sănătate și securitate referitoare la expunerea lucrătorilor la riscuri generate de agenții fizici;
15. *** Hotărâre Nr. 520/2016 din 20 iulie 2016 privind cerinţele minime de securitate şi sănătate referitoare la expunerea lucrătorilor la riscuri generate de câmpuri electromagnetice , Emisă de Guvernul României şi publicată în MO nr. 576 din 28 iulie 2016;
16. *** www.electromagnetism.ro;
17. *** www.narda-sts.com;
18. ***http://www.canarina.com/radiasoftwareenglish.pdf;
19. *** www.cst.com/products/cstmws
20. *** https://www.infolytica.com