types of electric-power machines used general electromechanical converter matrix , typical patterns — double-wound transformer in transient regimes, direct-current starts, single-phase sinchronous generator in instantaneously short circuit, induction ransient regimes (computer-aided tests).

ılinear mathematical models of electric-power machines with lumped paramerers (40 e application of the equation systems with magnetic flux linkage derivatives and ırrent ones, matrixes of static and dynamic varied inductances,the methods of circuit saturation registration, typical patterns — direct-current generator in self- implisit-pole sinchronous generator in asymmetry short-circuit, synchronous in different continuous duties, induction motor in different continuous duties -aided tests).

athematical models of electric-power machines with distribuited parameters (16 ıe magnetic field calculation and equations of electromagnetic connections, cal simulation of electric-power machines with magnetic field calculations in egimes (compulsator - compensated pulsed alternator), mathematical simulation of wer machines with magnetic field calculations in continuous duties (salient-pole

omputer - aided tests (MS-DOS) for practical training (menu: theory, practice tasks, ting etc.) are presented in Russian and in English. The computer - aided test on cal simulation of implicit - pole synchronous generator in asymmetry short circuit s a detailed example.

4. COMPUTER - AIDED TEST

ıter-aided test is intended for mathematical simulation of implicit - pole synchronous A digital model can be used for transient analysis of an isolated two - phase ıs generator operating in sudden asymmetrical short - circuits. It is supposed that the ıdings are absent. The rotational speed is assumed to be constant as well.

matical simulation of the synchronous generator in sudden asymmetrical short- erformed in the reciprocal moving reference axes frame. To obtain the differential of the synchronous generator the differential equations of the general ıanical converter in matrix form are used.

ıg static and dynamic inductances are calculated using flux path saturation curves. It ıphasized that saturation curves of main flux path and leakage flux path must be ed analitically.

tep of numarical integrating the differential equations containing the time rates of ux linkages the currents are obtained by iterative computating the non-linear set of ıagnetic connection equations.

he developed mathematical model one can predict the influence of generators on asymmetrical transients (one phase is being closed when flux leakage maximum phase is open). Special attention must be paid to investigating the flash on and overvoltage phenomenon.

ıits system with basis nominal static saturated mutual inductance is recommended parameters and initial field current of synchronous generator are initial data for the ıl simulation.

LINKING CIRCUIT ANALYSIS AND FIELD CALCULATIONS IN ELECTRICAL ENGINEERING TEACHING.

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Abstract: Classical electrical engineering teaching devotes a lot of time to circuit analysis. In recent years the importance of numerical field analysis has grown. The subject of CAD in electromagnetism has been introduced in different basic courses on electricity. The students often regard both topics to be separate treatments of similar subjects. Using different practical applications, it is shown how both techniques may be linked, leaving the student with a system approach, rather than an idea of two calculation techniques. Three simple examples are given to illustrate this approach, treating all passive elements of circuits. The first is a parallel plate capacitor. The link between the internal electric field, the material characteristics and the dimensions is shown, as is the importance of the stray flux. The second example deals with the analysis of an iron cored coil containing an air gap. Here special attention is paid to the influence of saturation on the behaviour and on the importance of the correct definition of the global quantities as the inductance in a non-linear system. As a last example resistances are discussed, both in dc applications and in ac systems. In the latter case, the influence of the skin effect is important.

1. INTRODUCTIONS

Classical electrical engineering teaching devotes a lot of time to circuit analysis [1,2,3]. The parameters of common circuit elements are inductance L, capacitance C and resistance R. Analytical, often very simplifying formulae are used to link the parameters with the physical dimensions of the components. Material parameters are supposed to be homogeneous, constant and linear. The geometry is reduced to its elementary proportions and no details are provided.

In order to overcome these assumptions and limitations, numerical field analysis techniques are used in combination with Computer Aided Design methods at the input and the output [4,5,6]. They allow the detailed calculation of the electric field strength and the magnetic flux density, accounting for the correct material characteristics and the exact geometry. However, a link with circuit components is seldom available. The link with circuit theory is not provided and in some universities both approaches to this problem (circuits and fields) are taught in different courses. Students do not understand the links and have the impression that the same subject is treated twice.

In order to overcome this discrepancy between circuits and fields, a general approach is developed in which the students are confronted with the components in both ways and where they are shown how both approaches may be linked.

2. CAPACITANCE

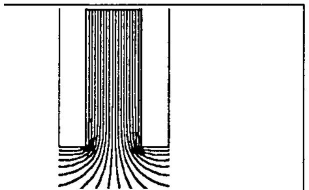
The capacitance of a parallel plate capacitor is given by

$$C = \frac{\varepsilon A}{d} \tag{1}$$

h ε is the permittivity of the material between the plates. A is the area of the plates and istance between them. (1) assumes that the electric field is confined to the area of the In practice this is not correct as may seen in Fig. 1 showing the electric field between allel circular plates. This is an axisymmetric problem. The area of the plates is 78.5 cm^2 n). From the finite element solution, the capacitance may be found using the integration lectrical energy as coming out of the post-processor of the finite element solution

$$W_e = \frac{CU^2}{2} = \int w_e dV = \int \frac{\varepsilon E^2}{2} dV \qquad (2)$$

acitance as a function of the distance is shown on Fig. 2. The top curve is the analytical The higher the distance, the more important the influence of the leakage around the or and thus the more both curves diverge.



apacitance with equipotential lines (d=2 cm)

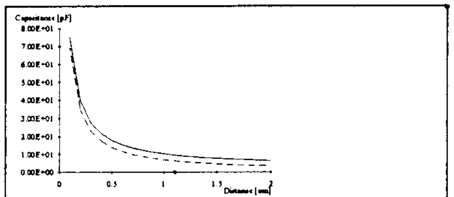


Fig. 2 Capacitance as a function of the distance between the plates for the analytical and the numerical solution

3. INDUCTANCE

uctance of an E-cored coil is given by

$$L = N^2 \frac{\mu_o A}{d} \qquad (3)$$

permeability of the free space, N is the number of turns of the coil, A is the area of the and d the air gap width. The permeability of the iron is supposed to be infinite. nore, the spreading of the flux in the air gap is not accounted for. The problem is an x-etry, supposed to be infinitely long. The non-linearity of the core material is taken into ration. The flux density distribution is calculated. In this non-linear situation, it is no ossible to give a single definition of the inductance. The values coming out of the flux differ from those found from the stored energy. Furthermore, the stored magnetic s no longer uniquely defined, as the history of the non-linear material is important. For lculations, the following definition is used:

$$W_m = \frac{LI^2}{2} = \int w_m dV = \iiint\limits_V \int\limits_0^B (H.dB) dV \qquad (4)$$

hows the flux density distribution in the E-cored coil. Fig. 4 gives the comparison the inductance found from the analytical formulation and the finite element solution. n-linear behaviour is obvious in the finite element solution. The inductance first s as the iron comes out of saturation and then decreases as the analytical solution.

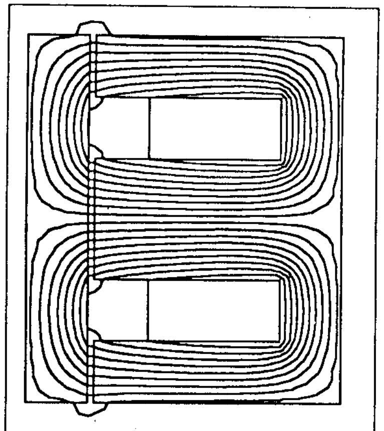


Fig. 3 Flux lines of the coil with an air gap of 3 cm

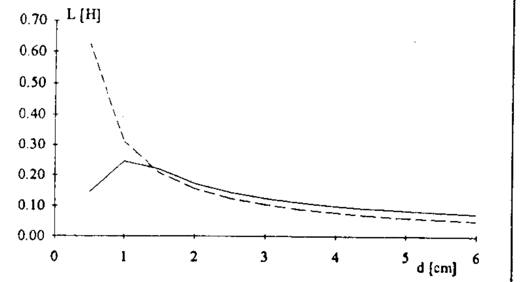


Fig. 4 Analytical and numerically obtained value for the coil

4. RESISTANCE

The dc resistance is defined as the voltage drop along a conductor when a given current is passing through it. However, problems occur when the current density changes along the resistor's length due to the non-uniformity of the cross section. Such a situation occurs in so-called trimming resistances. The equipotential lines, that are perpendicular to the current density, are shown on fig. 5, while the resistance as a function of the depth of the cut is given in fig. 6. Clearly, it is not possible to have a reasonable analytical approach to this situation. The relation between resistance value and depth of the cut is far from linear.

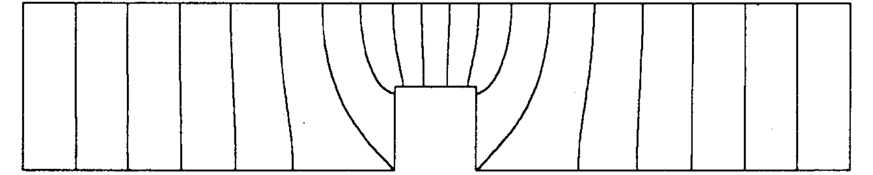


Fig. 5 Current density lines in a trimming resistance

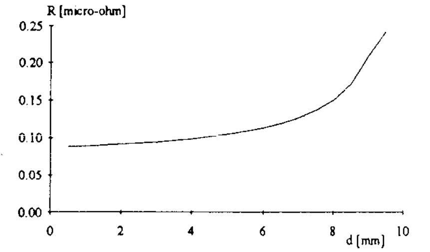


Fig. 6 Resistance as a function of the depth of the cut

If a solid conductor is supplied with an ac current, the current density is not evenly distributed over its surface. Due to skin effect, the current density is higher at the surface. This increases the overall resistance and decreases the inductance. If the return conductor is close, the proximity effect is important: the symmetrical distribution of the current density is no longer valid, which may yield an increase or decrease of resistance or inductance. The link between both parameters, resistance and inductance is given by the ium of active and reactive power:

$$P = RI^2 \qquad Q = \omega LI^2 \qquad (5)$$

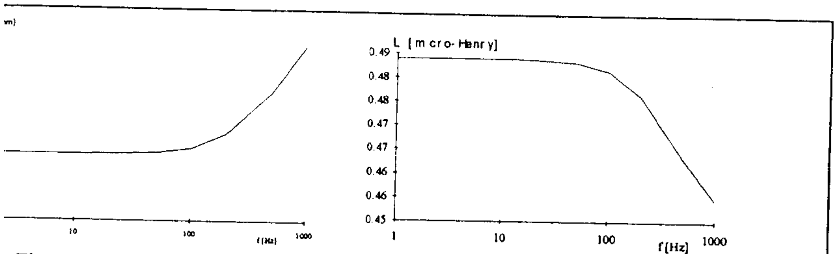


Fig. 7 Resistance (left) and inductance (right) as a function of the frequency

5. CONCLUSIONS

e finite element solution coupled with CAD techniques at input and output is a very and powerful analysis tool in modern electromagnetics. However, students are trained in circuit design. The extraction of the global parameters from the solution yields the een both approaches. In this way, the students get the impression to be faced with an olution to one problem: how to obtain the global parameters out of the geometry of a ather than two separate approaches to one problem, i.e. the circuit parameters at the and the field solution at the other.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

on J.W.: "Electric circuits," Addison Wesley Publishing Company, Reading achusetts, U.S.A.

s T.J.: "Circuit calculations," Newnes, A Butterworth-Heinemann Book, 1992

r S.A.: "Electric circuit analysis," Prentice Hall International Editions, 1987

ner D.A., Silvester PP.: "Computer Aided Design in Magnetics," Springer Verlag, -Heidelberg-New York-Toronto, 1986

nadière J.C., Coulomb J.L.: "Finite element methods in CAD," Springer-Verlag York, Inc., 1987

.: "Numerische Methoden in der Berechnung elektromagnetischer Felder," Springer ich, 1994, Berlin-Heidelberg-New York

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EVALUATION OF FIRST YEAR STUDENTS' UNDERSTANDING OF SIMPLE ELECTRIC CIRCUITS

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Abstract: This paper reports an investigation of the performance of first year students in the Electrical and Computer Engineering Department. The diagnostic test was administered to a sample of 80 students at the beginning and at the end of the course of the Introduction in Electric Measurements.
The aim of the research was the evaluation of the students' knowledge about the circuits at the entry level and the assimilation of the course at the final stage of the lecture. Furthermore an attempt was made for the evaluation of their understanding of simple circuit's performance, their ability to make correct predictions about measurements and the distinction between a theoretical and an actual model of the circuits.

1. INTRODUCTION

Before commencing with Network Analysis, students attend an introductory course on measuring instruments (multimeter, oscilloscope, function generator, DC- and AC-signals) and basic measuring circuits and methods. The course of the Introduction to Electrical Measurements of the Electrical and Computer Engineering curriculum incorporates classroom and mainly laboratory introductory experience for first semester students. The main purpose is the familiarization of the students with the basic electrical instruments and the revision of their basic knowledge about electricity. Every year about 100 students attend the course, which consists of three parts that run in parallel: lecturing, tutoring on next lab and labs.
The course was introduced at an application oriented level a few years ago, and then repeatedly revisited with successively greater levels of detail and theoretical sophistication. Each revision was the result of study department's needs, the students' performance in oral examinations and the evaluation of a number of surveys. The results of a such survey are discussed in this report.
Similar work has been reported in recent years on students' understanding of ideas about simple electric circuits. A large scale survey of students' ability with electricity has been carried out by the Assessment of Performance Unit in five European countries [1]. Related papers also reports on the findings of similar study to investigate student's, at age of 15, understanding of the behavior of simple circuits consisting of two resistors connected in series and the potential divider [2] and questions dealing with parallel circuits [3]. Papers [4] and [5] are referred to similar attempts for improvement in laboratory, first courses in Electrical Engineering.

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