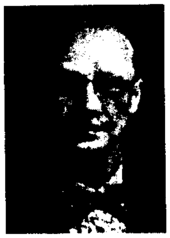
Teaching numerical techniques in electrical power engineering

Kay Hameyer and Ronnie Belmans



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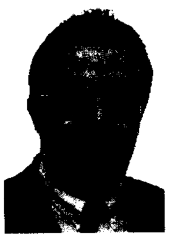

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Abstract **–The skills that should be tought to the engineering students are very complex and manifold. Learning is one of the hardest tasks to fulfil and thus, the university institutes have the duty to wake up enthusiasm in the student by choosing the right tools for teaching and knowledge transfer. The difficulty always is to choose an appropriate form to teach sophisticated and inherent very abstract subjects such as numerical techniques. Applied to power engineering problems a complex mathematical background and a deep physical understanding is recommended to be able to follow the courses and to collect the knowledge and experience for a successful later professional engineering carrier. In this paper the authors like to show their way of teaching the theory and application of numerical field computation methods in the power engineering division of the Katholieke Universiteit Leuven.**

Introduction

Basically, two streams in electrical engineering education can be followed: power and information technology. The technological progress in information techniques seems to be larger when compared to the power engineering sector. This implies and may give students the illusion that in the information technique more advanced and newer techniques are used to solve the specific problems in this engineering direction. It attracts undergraduates and explains the difference in the total number of students per academic year in most of the universities choosing for this engineering field and not for the power engineering education. However, at the Katholieke Universiteit over the last years a constant number of students per year in the power engineering division can be counted. By assuming a decreasing total number of electrical engineering students this means an increasing overall gradient for the power engineering division. The authors think that a main reason for this increasing gradient can be found by introducing new and modern methods and techniques to solve problems in classical subjects like electrical machines, high voltage and electro-heat to the students. Recent education tools such as multimedia computers and programs are used to support the individual learning capabilities of the students and are discussed in the paper as well.

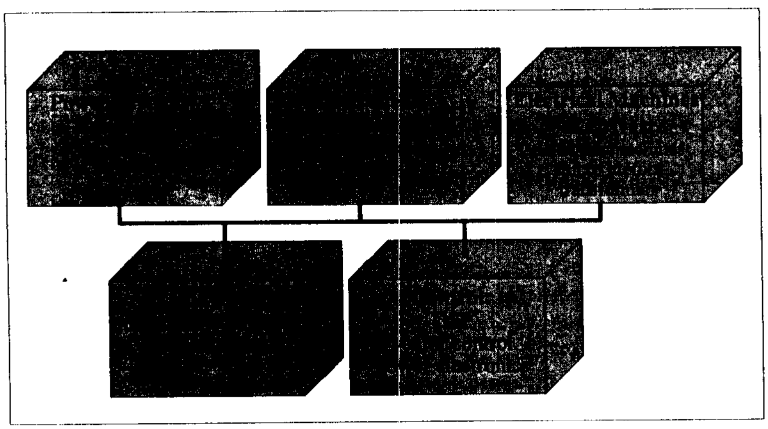


Fig. 1. Curriculum of the electrical power engineering students at the K.U. Leuven

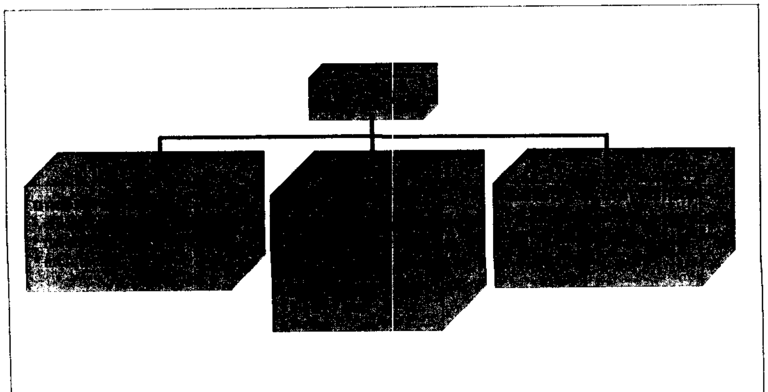


Fig. 2. Teaching activities ESAT - ELEN.

Close contacts between the university institute and industry are necessary to support the feeling of the students to work in a technical field of social importance. Parttime stays of students in industrial companies during lecture free periods are essential to enable the chance to see practical engineering problems and to judge with this practical knowledge how the university prepares the young engineer for the future. The classical subjects all power engineering students at the Katholieke Universiteit Leuven have to follow are (Fig. 1):

- power systems,
- electro heat and
- electrical machines and drives.

The listed subjects are not separated from each other. They have to be seen as a unit with the linking subjects such as CAD techniques and the control theory. With this link an interdisciplinary teaching is obtained. A strong link to the mechanical engineering department of the K.U.Leuven ensures that all items concerning the term energy are treated as complete as possible.

Furthermore, courses developed and given for engineers from industry can be found in the teaching program of the division ESAT - ELEN (Fig. 2). An annual course on electromagnetic fields, given for engineers out of industry, is one attempt and effort to train engineers in a complex item such as numerical field computation theoretically and in practical laboratory sessions.

Starting with the 3rd academic year the students from electrical energy at the K.U.Leuven are following theoretical lectures and laboratory sessions supporting basic knowledge of numerical techniques. In particular, the finite element method (FEM) is introduced. The numerical sessions take place in front of workstations. The students are working with commercial FEM program packages and the numerical parts are always followed by a practical laboratory session. Here, the students have to measure the beforehand computed results such as currents, induced voltage and inductances of very simple magnetic circuits. In the following 4th academic year more complex tasks are demanded such as computations of dc machines or asynchronous induction machines. For a better inside of the physical behavior and to make the field solutions of induction machines understandable a multimedia software program is for the students available and distributed via the Internet. The methodology of the step by step approach of computer assisted teaching, performed at the K.U.Leuven, to transfer the knowledge of the complex numerical field computation techniques are discussed here.

The well known abbreviation CAE (computer aided engineering) is regularly used to describe engineering techniques aided by digital computers. Thus, activities of industrial or university engineers to solve design problems or calculate and predict the behavior of physical technical products such as electromechanical energy converters are part of this definition. Due to constantly decreasing prices of standard computers hardware and software, powerful PC's now can be found in nearly every student-household. The possibilities to access easily information at anytime from nearly every place in the world via the Internet are increasing as well. As a reaction and to ensure the equal opportunities the Katholieke Universiteit Leuven is renting students hard and software by a subsidized fee. As a consequence, the university teaching staff has to offer possibilities to include computer-aid into the lectures and laboratory sessions. Therefore, the new abbreviation CAT can now be used for Computer Assisted Teaching.

A Step by Step Approach

The authors do understand the here discussed methodology in teaching as a step by step approach. The complex knowledge of numerical techniques can be transferred on different levels of difficulties. A splitting between high level, the knowledge on matrix level, intermediate and basic skills, understanding of the function of the method, must be performed to reach and succeed in teaching different target groups. Students of the different fields of engineering science and already in industry working engineers are the target groups that have to be reached.

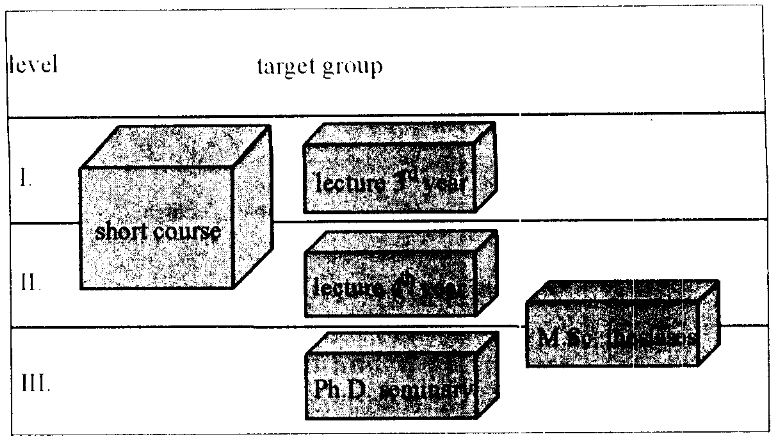


Fig. 3: Target groups and related level of teaching difficulty.

level	target group	aim
I	a) undergraduates 3rd year b) engineers out of industry	• basic theoretical knowledge of numerical field computation methods • capability to solve simple standard electromagnetic static and time-harmonic field problems in 2D
II	c) undergraduates 4th year d) (partly) engineers out of industry	• advanced theoretical knowledge of numerical field computation already on matrix level • numerical optimization algorithms • design theories and methodologies • capability to solve more complex field simulation tasks in 2D and simple problems in 3D
III	e) Ph.D. students f) programmer	• extended theoretical knowledge on matrix and program level • knowledge of data structures • capability of handling data to obtain own solution algorithms • programming own software routines • capability to solve advanced 3D problems

Tab. 1: Aims and steps in teaching computational magnetics.

In general, universities have a threefold duty:

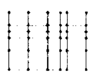
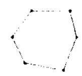
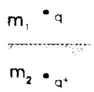
- transfer of knowledge to the society
- placing scientific service at the society's disposal
- research

All the mentioned points are linked to teaching. The transfer of knowledge is mainly done by instructing students from undergraduate to the doctorate level. The training of engineers from industry by giving annual short courses can be linked to the first two points of the list. Research finally influences the content of the teaching material and contributes to the first point as well. To fulfill the threefold duty, it is necessary to split into three levels of difficulty and this is didactically straight forward as well (Fig. 3).

The aims of the three level structure used at the K.U.Leuven, with other words the three steps in teaching students in magnetics, are collected in Table I. A short course in 'CAD in magnetics' is given annually to interested engineers from industry and other universities.

Level I

In a first step to enter the level I, the target group has to be prepared. Here, it is explained where the numerical field

method	principle of discretization	geometry approximation	non-linearities	computational costs
FEM		extremely flexible	possible	high
FDM		inflexible	possible	high
BEM		extremely flexible	trouble-some	high
MEC		specific geometries	possible	very low
PMM		simple geometries	by constant factors	low

Tab. 2: Field computation methods. FEM - finite element method. FDM - finite difference method, BEM - boundary element method, MEC - magnetic equivalent circuit, PMM - point matching method

computation has its place. Therefore, advantages and disadvantages of classical analytical models of the field approximation have to be treated as well as the various pure numerical methods (Table II). This step is accompanied by studying the working principles of electromechanical energy converters to transfer a feeling to the students of how a field behaves and with which range of magnitude. Among the lectures about electrical machines the students can work at a computer with a multimedia tool to understand the working principles of an induction machine before they start to solve its associated field problems. The multimedia software tool is developed by the group at the K.U.Leuven and distributed via the Internet and can be downloaded by the students at any time [1]. A secondary effect is obtained by distributing the software in this way and letting the undergraduates work with it. Even nowadays, there are students not used to work at a computer and they are loosing the fear of this device that always seems to be right.

To support the understanding of the physical behavior of the technical devices treated in the lecture and the methods to calculate them, practical CAD sessions at the computer are obliged. Here, simple 2D computations are performed using the FEM. Examples are chosen to point out the connection between analytical, numerical and measurements in particular.

Level II

After the entry level a basic understanding of the physical device and its numerical treatment can be insinuated. Now the numerical problems and all neglections assumed are part of the lecture. More and more numerical details are illuminated. Simple 3D computations are performed in the CAD sessions to demonstrate the differences to the 2D approximation. Other methods combined with the FEM such as optimization algorithms are introduced in this level as well.

Level III

The last step of this 4 year lasting program is reserved for the doctorate level. The theory of the method is given on the matrix and program organization level. Here, special problems such as error estimation, mesh adaptation techniques, solver strategies etc. are treated. The capabilities in coding own parts in field computation programs are trained.

Conclusions

A CAT program is described which, always carefully updated, successfully runs for a couple of years already. During several stays at universities in different countries such as Great Britain, Canada, Germany, Algeria and Brazil the authors collected experiences in teaching such complex subjects to put together in an homogene curriculum for electrical power engineering students art the Katholieke Universiteit Leuven in Belgium.

Acknowledgment

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References:

[1] INDUCTUTOR
http://www.esat.kuleuven.ac.be/elen/elen.html,
K.U.Leuven, ESAT / ELEN, multimedia tool, 1995

Biographies

Kay Hameyer received the M.S. degree in electrical engineering in 1986 from University of Hannover, Germany. He received the Ph.D. degree from University of Technology Berlin, Germany, 1992.

From 1986 to 1988 he worked with the Robert Bosch GmbH in Stuttgart, Germany, as a design engineer for permanent magnet servo motors. In 1988 he became a member of the staff at the University of Technology Berlin, Germany. From 1993 to March 1994, he held a HCM-CEAM fellowship financed by the European Community at the Katholieke Universiteit Leuven, Belgium. Currently he is professor for numerical field computations with the K.U.Leuven and a senior researcher with the F.W.O.-V. in Belgium, teaching CAE in electrical engineering and electrical machines.

Ronnie J. M. Belmans received the M.S. degree in electrical engineering in 1979 and the Ph.D. in 1984, both from the Katholieke Universiteit Leuven, Belgium, the special Doctorate in 1989 and the Habilitierung in 1993, both from the RWTH Aachen, Germany.

Currently, he is a full professor with the K.U. Leuven, teaching electrical machines and CAD in magnetics. His research interests include electrical machine design (permanent magnet and induction machines), computer aided engineering and vibrations and audible noises in electrical machines. He was the director of the NATO Advanced Research Workshop on Vibrations and Audible Noise in Alternating Current Machines (August 1986). He was with the Laboratory for Electrical Machines of the RWTH Aachen, Germany, as a Von Humboldt Fellow (October 1988-September 1989). From October 1989 to September 1990, he was visiting professor at the McMaster University, Hamilton, ON., Canada. He obtained the chair of the Anglo-Belgian Society at the London University for the year 1995-1996.

Dr. Belmans is a member of the IEE (U.K.), the International Compumag Society and the Koninklijke Vlaamse Ingenieursvereniging (KVIV).