Teaching numerical techniques in electrical power engineering

Kay Hameyer and Ronnie Belmans

Abstract — The skills that should be taught to the engineering students are very complex and manifold. Learning is one of the hardest tasks to fulfill 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 career. 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 this 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.

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. Part-time 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 engineers 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 integra-
A strong link to the mechanical engineering department of the K.U. Leuven ensures that all items concerning the medium 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 SAT (1-3). An annual course on electromagnetic fields, given for engineers out of industry, is one attempt to fill this gap in the field of practical laboratory sessions.

Starting with the 3rd academic year, students 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 where the students are working with commercial FEM program packages. The numerical processes considered in the classroom are the solution of complex, nonlinear problems using computers and the visualization of the results on the computer screen.

The methodology of the step by step approach of computer assisted teaching, performed at the K.U. Leuven, is as follows. Here, the students have to measure the currents induced by an induction motor and the inductances of very simple magnetic circuits. In the following academic years, more complex tasks are demanded, such as simulations of induction machines or electromagnetic fields.

For better insight into the behavior of physical systems and to make the field solutions of induction machines understandable, the students are working with a multimedia software program 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, is as follows. Here, the students have to measure the currents induced by an induction motor and the inductances of very simple magnetic circuits. In the following academic years, more complex tasks are demanded, such as simulations of induction machines or electromagnetic fields.

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 electronic devices 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 possibility to access easy information at anytime from nearly every place in the world via the Internet is increasing as well. As a reaction to ensure equal opportunities, the Katholieke Universiteit Leuven is renting students their own PCs for a subsidized fee. As a consequence, the university teaching staff has to offer possibilities to include the students into the lectures and laboratory sessions. Therefore, the abbreviation CAE 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 difficulty: a splitting between high level, the knowledge on matrix level, intermediate level and basic skills. Understanding of the function of the method, must be performed to teach 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.

In general, universities have a triple duty:

- transfer of knowledge to the society
- placing scientific services at the society’s disposal
- research

All mentioned points are linked to teaching. The transfer of knowledge is mainly done by instructing students from undergraduate to the doctoral 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 triple duty, it is necessary to split into three levels of difficulty and this is didactically straightforward 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 1. 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...
<table>
<thead>
<tr>
<th>method</th>
<th>principle of discretization</th>
<th>geometry</th>
<th>nonlinearities</th>
<th>computational costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEM</td>
<td>extremely flexible</td>
<td>possible</td>
<td>high</td>
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</tr>
<tr>
<td>FDM</td>
<td>inflexible</td>
<td>possible</td>
<td>high</td>
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</tr>
<tr>
<td>BEM</td>
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<td>troublesome</td>
<td>high</td>
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<td>MEC</td>
<td>specific geometries</td>
<td>possible</td>
<td>very low</td>
<td></td>
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<tr>
<td>PMM</td>
<td>simple geometries</td>
<td>by constant low factors</td>
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Tab 2: Field computation methods. FEM - finite element method, FDM - finite difference method, BEM - boundary element method, MEC - magentic equivalent circuit, PMM - poro 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 the 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 the corresponding 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]. Also 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 overcoming 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 obtained. Now the numerical problems and all neglects 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 homogeneous curriculum for electrical power engineering students at the Katholieke Universiteit Leuven in Belgium.

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**References**

1. [1] INDUSTRY TUTOR
   - [http://www.extraknowledge.com/elektroelektro](http://www.extraknowledge.com/elektroelektro)

**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.

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