

IMPLEMENTATION OF E-LEARNING PLATFORM FOR ELECTRICAL ENGINEERING

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ABSTRACT

Present engineering has to deal with increasingly complex systems. In particular, this is the case of electrical engineering. Though, this is obvious in microelectronics, also in the field of power systems the engineers have to design, operate and maintain highly complex systems such as power grids, energy converters and electrical drives. This is reflected in engineering education, where teachers try to communicate the many aspects of complex systems and where students try to learn and deal with this complexity. In this paper, a program of computer animations is discussed, that was originally and primarily designed for teachers and to be used during traditional lectures. It was found out however, that these animations could be very well used for self-study purposes provided a good instruction and clear assignments were given. The introduction of new technologies (e.g. ICT) into teaching of Electrical Engineering, and setting up and technical aspects of e-learning platform for Electrical Engineering are addressed in the paper.

KEYWORDS

Web-based learning, e-Learning, Electrical Engineering

INTRODUCTION

Present engineering has to deal with increasingly complex systems. In particular, this is the case in electrical engineering. Though this is obvious in microelectronics, also in the field of power, engineers have to design, operate and maintain highly complex systems such as power grids, energy converters and electrical drives. This is reflected in engineering education, where teachers try to communicate the many aspects of complex systems and where students try to learn and deal with this complexity. The introduction of new technologies (e.g. ICT) in teaching, though very promising at first glance may turn out to be counterproductive when the accent is on teaching, rather than learning. The same technologies may prove to be highly effective, if they are introduced to support the understanding and, consequently, handling and even designing of complex systems.

HISTORICAL DEVELOPMENT

Traditionally, in development of engineering education the key objective was to enable the teacher to convey knowledge and insight to the students. The main element was (and still often is) the lecture, where the teacher explains, gives examples, shows calculations, discuss mathematical derivations etc. The accent was on the oral communication, which was supported by on-line hand written messages using the blackboard and chalk. Due to the low speed of hand writing students had some (but often not enough) time to try and understand what was going on.

CHANGING DEMANDS

By the end of last century engineering educators began to realize, that the demands from industry had changed. There should be more emphasis in skills and (deep) understanding rather than knowledge.

This is reflected in the change in curricula (Petty, 1999) as well in the engineering criteria such as the ABET criteria (<http://www.abet.org>). These changes were largely discussed in the SEFI Annual Conference in Copenhagen (SEFI, 2001). For existing programmes, curricula and courses the shift from teacher to learner oriented education implies a redefinition of the objectives of education. Traditionally, the main objective was that the students acquired knowledge. The assessment was based on testing whether students could reproduce the acquired knowledge. Presently, the main objective of teaching is the development of student skills. This means that the teacher is a coach in the process of the students' development. Obviously, this has its implications on assessment, as has been discussed a.o. by (McDowell, 1999).

These actual objectives for a particular area/course should be derived from a reconsidered analysis. As an example: the original problem, defined as "it is difficult to explain the switching sequence and the consequent voltages and currents in a static converter" (teacher oriented) will be changed into "the student has difficulties in understanding the switching sequence and the consequent voltages and currents in a static converter" (student oriented). Obviously, a more detailed problem analysis is required. The educator has to carry out this analysis using as much information from students as possible. This will lead to requirements for a solution that has to be designed and implemented consequently. The final goal is to create an environment in which the defined problem is solved. Obviously, there are many boundary conditions that have to be taken into account such as>

- prior knowledge and skills,
- facilities,
- human: staff,
- material: laboratories, rooms, ICT-support systems,
- available time for students, both in terms of hours and of schedules.

This latter issue is becoming increasingly important. Nowadays, students often cannot follow courses simultaneously. Due to other activities, they want to devote time to their studies when it suits them individually. Therefore, any solution should allow for individual action, regardless when or where. Finally, eventual learning methods should be such that students indeed are able to learn and do assignments, in other words: an appropriate instruction in the learning material remains to be essential.

PROBLEM ANALYSIS

A general problem in electrical engineering is the fact that it deals with rather abstract notions such as resistance, capacitance, inductance, etc. and non-visible electrical quantities as current, voltage, magnetic flux, etc. The electrical quantities and phenomena, that are not directly observable, can only be made observable (here usually: visible) by means of measurements.

It has been found, that students who are faced with the principles of fundamentals of electrical circuits have problems in understanding and dealing with the more complex systems. This complexity becomes evident by the high dimensionality and the introducing the dynamics of these systems. Large number of simultaneously occurring variables i.e. voltages and currents present the main feature of such systems, in particular:

- the way they vary with time,
- their polarities,
- their mutual dependency (in particular the causal relations),
- their relation to the state of the circuit.

The students, who do not understand completely principles of basic electrical circuits and their prompt application, have big problems at more complex circuits, like three-phase systems or power electronics circuits. The most important is to understand physical phenomena and behaviour of the circuits and based on them, their mathematic description is considerably easier to compile.

Teachers may clearly discuss all the phenomena involved during lectures. However, even if computer animations are used, students cannot grasp the details in a short time, since the teacher shows examples or animations only once or twice. There remains a need for repetition and exercises and to find out influence of changeable parameters of the system to the result.

As a side problem, students tend to get de-motivated by this complexity. This leads to the undesirable situation, that the discrepancy between the number of students in electronic power engineering and the demands from industry for engineers in this field is increased.

REQUIREMENTS FOR A SOLUTION

On the basis of the problem analysis discussed above, it was identified that a possible solution should meet the criteria:

- a learning support system should be developed in such a way that it allows students to acquire a possibly deep insight into the complex and dynamic interactions of a number of parameters in power electronic systems,
- the focus of learning should be on the electrical phenomena themselves and not on the problems inherent in measurements,
- the learning support system should be structured in such way that it is faced with increased complexity (hierarchical approach),
- due to the multi-dimensional character of the systems, a high degree of interactivity should be provided e.g. if simulations or computer-animations are used, students should have the possibility to freeze the time or even reverse the time so as to study the causal relation between different phenomena and states of the circuit under study,
- the system should give a qualitative impression of level of different quantities,
- the learning support system should be accessible, independently of time and place,
- appropriate instructions in the usage of the system should be provided,
- students should get motivated to study these systems in more detail, so as to become skilled in designing such systems themselves,
- the system should allow for self-assessment of student learning,
- the system should allow for including assignments as well as individual assessments.

After some considerations it was decided to develop a number of computer animations showing in a systematic and consistent way the interactions of switching states, currents and voltages of different circuits. Systematic and consistent in this case means, that currents and voltages (both polarity and values) are displayed in the same way in all animations. The animations allow for a high degree of interactions with the user. The animations can be run either via an internet link or using a CD-ROM. Assignments and assessment can be done over the Internet. A limited number of lectures are given. The main role of these lectures is the introduction of the backgrounds of power electronics and the usage of the computer animations.

What is to be explained by the animations in the e-learning modules for electrical engineering- typical features of the topics:

- basic laws in EE (electrostatic, electromagnetic and electrical circuits),
- electromagnetic laws and their applications,
- behaviour of basic electronic and power electronics switching devices,
- behaviour of electronic circuits themselves,
- switching and behaviour of power electronic circuits of various complexity (power converters of the following types: DC/DC, DC/AC, AC/DC, AC/AC),
- electromechanical conversion of energy (interactivity between electrical and mechanical circuits),
- block diagrams (explaining subsystems connections, control systems),
- more complex and advanced topics that present combination of above described themes.

DESIGNING OF EDUCATIONAL INFRASTRUCTURE FOR ELECTRICAL ENGINEERING

The interactive animations are intended to be a basic supported educational material:

- for explanation in lectures (to explain the most important parts) and simultaneously
- as a study material (requiring a detailed workout of the topics).

From view of appearance of the learning materials each described utilisation requires a special access to design. The proposed structure of the interactive learning materials consists of: 1) main screens and of 2) subordinated (linked, secondary) screens. Meaning of the screens and properties are explained in the Table 1. The secondary screens are called from the main screen by a button.

Table 1. Properties of the main and secondary screens.

Purpose for	Characteristics (contents of the screens)	Features of multimedia representation
Lectures	<ul style="list-style-type: none"> • Used for projecting at the screen during lecture in the lecture hall: • Principal diagrams, schemes • Interactive screens • Animations • Large letters • Few texts • Brief information (basic division, etc.) • Fundamental (key) knowledge • Basic equations 	<ul style="list-style-type: none"> • To use the main (primary) screens • The main screens must be attractive • Try to ensure that each main screen has to contain animations, interactive graphs • It will contain links to subordinated screen(s), where appropriate (to explain details of subsystems in the main screen) • Each screen should be designed as a whole, without necessity to use shifter to get to the next part (i.e. all must be shown in one screen – in case of using the same screen size like designed). • Approx. number of the main screens is listed in the project proposal
self-study	<ul style="list-style-type: none"> • Used for reading by a student sitting at the computer • Smaller letters • Full information about the presented matter – detailed explanation (longer texts, figures from the main screen, decomposed into parts where appropriate, phases of animations, etc.) • All equations - full derivations of equations • Questions to answer 	<ul style="list-style-type: none"> • The linked subordinated (secondary) screen(s) will be called from the main screen by agreed icons, or by hyperlinks • There can be several linked screens to the main screen but usually the one is enough (use this feature in exceptional case only) • Each subordinated screen can spread over several screens and the scrollbar is used for navigation

Main features of the interactive screens:

- animations (electrostatic, magnetic and electromagnetic fields, voltages and current paths),
- interactive static graphs - static characteristics with changeable parameters,
- animations (electromechanical conversion of energy),
- dynamic properties (time responses, frequency characteristics),
- block diagrams and animations of subsystems,
- virtual reality.

The division described in Table 1 will enable to utilise the educational multimedia material twice - for both purposes (teaching and learning). Graphical representation of two realised variants is in Figure 2. The main screens (satisfied requirements for the lecturing – containing key information and large letters) are linked with the secondary screens (that are suitable for self learning - with full information is

shown). If necessary, the simple flow of main can be completed by another supported screen to the main screen (see M.Screen 2a in Figure 2b), to explain some details at the lecturing, etc.

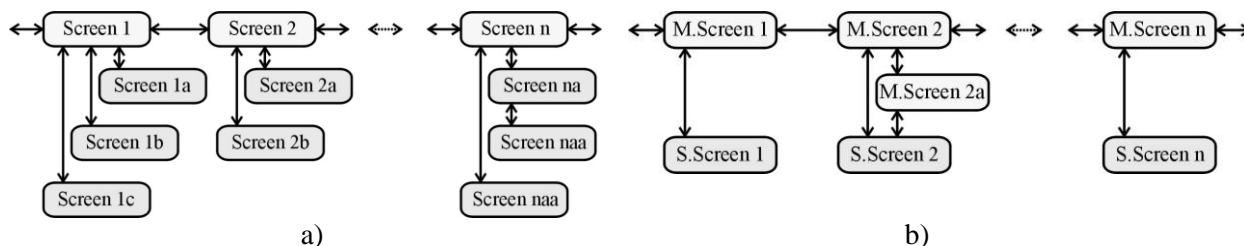


Figure 1. Chosen forked structure of main screens (numbered as 1, 2, 3, ...) and supported – secondary screen (numbered as 1a, 1b, 1c, 2a, ...)

What concerns the modules and their contents; we divided the electrical engineering subjects into five groups. They are:

- (1) Fundamentals of El. Engineering (electromagnetic and electrostatic fields, DC and AC circuits);
- (2) Electrical Machines (static – transformers and rotating ones)
- (3) Electronics, Power Electronics, Applications and Influence of Power Electronic Converters
- (4) Electrical Drives, Controlled Drives, Application of Drives; Mechatronic Systems, Robotics
- (5) Specialised SW in Electrical Engineering.

In framework of the INETELE project (2002) altogether 22 modules are being developed that cover most of the electrical engineering fields.

UNIFIED ENVIROMENT

Final version of all modules is in a unified graphical environment. This environment includes:

- accompany (introductory) page to the module (project title, title of the module, logos, mention about the project, copyright, links to other modules),
- basic layout of the screen (in form of typical examples),
- using of unified menu for management within the module (buttons)
- unified structure of the text (basic layout of the screen following several typical forms),
- using of unified symbols (IEEE standards), sizes of letters, diagrams and graphs,
- using of interactive changing of the graphs' parameters by: (1) slider, (2) numerical value,
- interactive changing of other parameters (by size of a device - e.g. by length of the resistor)
- unified control for graphs allowing zooming, shifting the co-ordinating axes (movement across the graph), inserting the crosshair, its movement and reading the co-ordinations, direct printing of the graph and its saving to clipboard for further processing,
- possibility to utilise linked screens to the main screens (subordinating screens) and hypertext links,
- animations according to the authors' requirement.

The screen in the bottom contains a bar with buttons for navigation within the module:



with the explanation of the buttons shown in Table 2.

DESIGNED INTERACTIVE ANIMATIONS

Accessibility

The learning support system should be accessible, independent of time and place and therefore the used learning software tool in the designed interactive animations must be independent from the operating

system of the computer, without complicated installing of software and plug-ins and which can be available via Internet, too. Macromedia and HTML are a perfect choice for all requirements.

Table 2. Explanation of the buttons at the user screen

	Displays contents of the multimedia module. After select of chapter, window will be closed
	Displays list of symbols used in the multimedia module with their explanation
	Displays index of keywords of the multimedia module
	Shows previous/next chapter of the multimedia module
	Shows previous/next screen (only within the same chapter/subchapter)
	Displays help screen
	Shows main (home) screen of the multimedia module
	It contains: 1) Information about the project, 2) Project partners, 3) Brief description of module, 4) References to other modules, 5) References (to the module), 6) Copyright disclaimer notice

User Interaction

The multi dimensional character of the system requires studying the causal relations between different phenomena and states of the circuit. There are many examples of e-learning tools, where the viewer watches the explanation as a cartoon or movie. Here conversely a high degree of interactivity is requested and many parameters are to be changed. These are e.g. polarity of the voltages, currents, states of the different switches and time sequence. The interactive quantities must be clearly identified. Any action (change in the interactive quantities) has an influence on the rest of the animation. This way the learning system can be used to solve small engineering problems. This is a next step in the education and yields a better understanding of the system.

Finally, the designed learning system allows freezing the behaviour in time, changing interactively the parameters and going back in time and behaviour.

EXAMPLES

Due to space reason, only two typical examples are shown here. As the first example a voltage source inverter animation is given (Figure 2).

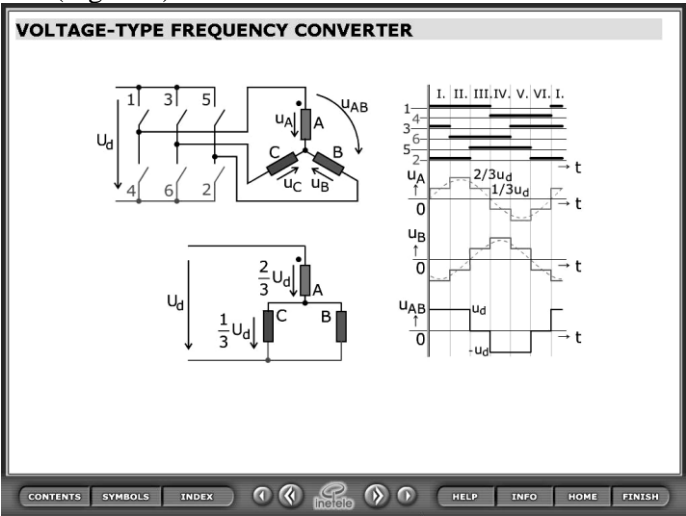


Figure 2. Animation of voltage source inverter (VSI)

This animation is made with specialized internet-based software - Macromedia Director. This software can develop interactive graphical user interfaces that are ease to use. The equations describing converter dynamics are also written in Macromedia where a simple numerical integration is performed or pre-solved equations are visualized. However to create such an interactive animation takes usually more programming skills which are difficult to find by an electrical engineer. The role of the user is limited to the predefined action and settings. On the other side such animations are usually on the very high graphical level. The orange cursor offers the interactivity and different states of a converter can be hereby set up (in the fact, the orange colour in our modules was chosen to identify object possessing interactivity/animation properties).

The use of a general simulation tool is the only way to allow students to go deeply inside the operating of a device and to understand the dynamic interactions between parameters. The difficulty is to developed sufficient attractive problems, which first give the idea to play with the simulation, and second which teach concepts difficult to understand by other ways. In the INETELE project (INETELE, 2002), the choice has been done to use CASPOC (www.caspoc.com), a general simulation tool of Power Electronics and Electrical Drives.

The example presented here illustrates the operating of SRM drive (Figure 3). The use of simulation gives the possibility to understand many different points.

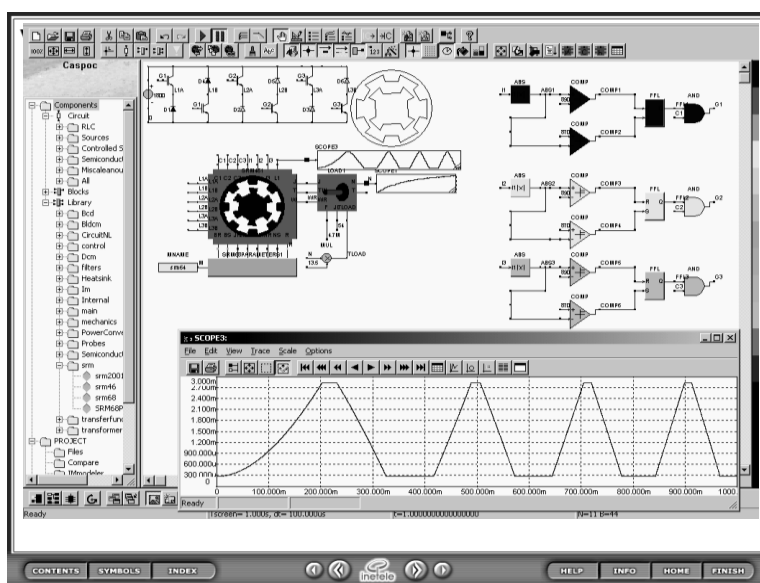


Figure 3. CASPOC simulation of a SRM drive

CONCLUSIONS

Here we presented basic philosophy that the developer of interactive multimedia module meets when designing a set of the modules from field of engineering. Design and development of multimedia interactive e-learning modules requires considerably higher effort like design and development of classic static texts. Regardless this effort and skills with computer processing, the most important is task of the principal philosophy of the modules (esp. in case when more modules have to be in an unified environment) and suitable presentation of the matters using multimedia features. The module developer has not only to be familiar with learning procedures of the student – to foresight his reactions and learning procedures, but he must possess considerable imagination, innovation in utilization and discovering of new advances at explanation the phenomena and last but not least, to have artistic feeling for the final product – layout of the screens.

The developed modules from field of electrical engineering feature by unified environment and thanks to division in the main and secondary screens they are suitable both for lectures and for self-study. Except of main and secondary screens there also are other features like hypertext references, list of used symbols, keywords, contents, questions for knowledge testing, etc. The last development in this field except of finishing works on modules comprises a direct involvement of the programme for digital simulation into the user's environment in order to enable the learner to change all parameters of the system (Fedák, 2003). This will really give strong learning tools that, the authors believe, will contribute to the slogan: „learning by playing“.

In framework of the project: Interactive e-Learning in Electrical Engineering “INETELE”, (2002), we have developed the whole series of the e-learning modules covering basic fields of electrical engineering. We already presented most of the modules in verification courses held for undergraduates in the academic year 2004/05. Practical experiences show considerable increase of their interest about presented matter. Utilising interactive feature we were able to demonstrate system responses in various working points and to evaluate influence of changeable parameters to the system behaviour. Performed tests prove that the students got deeper knowledge about the studied systems and interactivity described in the contribution reflected in increase of their analytical thinking.

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