E-LEARNING IN EDUCATION OF ELECTRICAL DRIVES AND POWER ELECTRONICS: OPPORTUNITIES AND CHALLENGES

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Abstract. The paper presents an overview of the current state of development of e-Learning in Electrical Engineering with a special attention to the fields of Electrical Drives and Power Electronics. There is summarised philosophy at preparing the e-learning material, presented achieved results and pointed out some practical hints that should be considering at development of multimedia based e-learning modules. Based on a broad overview of the open Internet resources from fields of Electrical Drives and Power Electronics and taking into consideration the ideas presented recently at conferences and published in journals and own experiences, there are sketched challenges and ways of future development of e-learning in the presented fields.

Keywords. Education, Education Methodology, Education Tools, Teaching, Power Electronics, Electrical Drives, Motion Control, e-Learning

1. INTRODUCTION AND 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 there was (and still often is) the lecture in which the teacher explains, gives examples, shows calculations, discuss mathematical derivations, etc. The accent was put 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 they had some (but often not enough) time to try and understand what was going on.

With increasing complexity of the systems to be discussed (more dimensions, dynamical structures and mutual interactions of components/subsystems) the teacher began to feel hampered by the speed limitations of handwriting on the blackboard. They adopted the use of the overhead projector with great enthusiasm, since this enabled them to do a lot of the writing in the *preparatory phase of the lecture*. Also students appreciated this, since the, often unclear handwriting was replaced by well-structured and clearly readable notes. However, what was projected so easily was still hard to understand, in particular since the pace of dealing with subjects was increased.

A next problem for teachers was how to convey dynamical structures and interactions. The use of animations (inserted in PowerPoint presentations) seemed to be a solution. But again, from the students' point of view, the improvement was only partial. In [1] the positive and negative effects on teaching and learning of the different support system are summarised. It is shown that what is considered as an advantage for the teacher often turns out to be a disadvantage for student learning. The conclusion is, that in the design of the education the accent was on the teaching (particularly the preparation), which leads to beautiful lectures with a disappointing learning yield. What may be even more serious is, that students got de-motivated, since they felt themselves to be unsuited for subject, they experienced to be too difficult for them. The advance in the teaching method does not automatically yield better understanding. New advances in the teaching method allow to present more material in the same time period. The lectures often happen in the fast tempo with less time to comprehend (Fig.1).

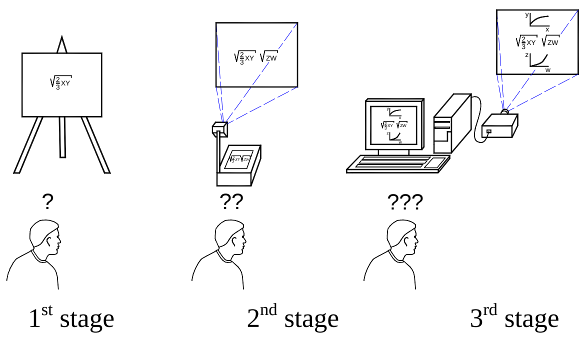

Fig. 1 Development of teaching methods

Obviously, the problems mentioned above have been identified. While maintaining *lectures* as the primary educational activity, *laboratory exercises* have been introduced. The introduction of electronic appliances (e.g. computers, networks with connected student laptops, etc.) has facilitated the introduction of interactive teaching and learning environments. Computer animations were developed so that students could more or less repeat the demonstrations as presented during lectures or even during

the lectures. Many different tools in fields of Electrical Drives and Power Electronics appeared recently as they are listed in the Appendix 1. Not all of them are fulfilling the strongest criteria requested for the e-learning tool. Also a proper balance between the all aspects of the education is an issue and question, which should be answered.
E-learning is a lot more than on-line learning. It is a sophisticated learning system that keeps the student skilled, provides just in time information and facilitates meaningful, directed collaboration.

2. FROM TEACHING ORIENTED TOWARDS LEARNING ORIENTED EDUCATION

By the end of last century engineering educators began to realize, that the demands from industry changed. There should be more emphasis in skills and (deep) understanding rather than knowledge. Traditionally, the main objective of education consisted in acquiring knowledge by the students. 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 student knowledge development. Obviously, this has its implications on assessment, as has been discussed a.o. by McDOWELL [4].

3. PROBLEM ANALYSIS

A general problem in electrical engineering is the fact that it deals with rather abstract notions such as current, voltage, resistance, capacitance etc. These electrical quantities and phenomena are not directly observable and can only be made observable (usually: visible) by means of measurements. This is all the more so in the area of power electronics.

It has been found, that students who are faced with the principles of power electronics have problems in understanding and dealing with the high complexity of these systems. This complexity becomes evident by the high dimensionality and the dynamics of these systems. The main features of such systems are the large number of simultaneously occurring variables i.e. voltages and currents, 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.

Particularly apparent this becomes in three-phase systems. The systems become too complex; therefore at teaching a *step-down approach* is used. In the first step only the principles are explained and later the real world effects (stray effects, noise) are added. This is in agreement with philosophy of modelling.

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 only once or twice shows examples or animations. There remains a need for repetition and exercises. 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. 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.

4. REQUIREMENTS FOR E-LEARNING SOLUTION

On the basis of the problem analysis discussed above, it was identified that a possible solution at design of the learning support system should meet these criteria (that can be identified at most of the solutions listed in the Internet resources in the Appendix 1):

- 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 the systems of power electronics and electrical drives,
- 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 would face 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, independent of time and place,
- an appropriate instruction in the usage of the system should be provided,
- students should be 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.

Why the e-learning has already found its fixed position in education? Generally, we differ several main objectives there [11] (that can be found in most of the proposals of various e-learning projects):

- it increases the flexibility of the education in time and in place,
- it promotes the high quality and visual education at all levels starting form the vocational secondary schools up to the university level in the electrical engineering field,

- it supports the regular vocational trainings of the companies for the qualified engineers,
- it is especially suitable for education support of handicapped students.

5. RECENT EFFORTS

Recent efforts are summarized extensively in the reference [1] and are completed with some more results here. The URLs in the Appendix 1 contain interactive modules for power electronics, electrical drives and motion control, freely available at Internet for educational purposes. The count cannot be comprehensive (one could find also other resources on Internet satisfying the search criteria) but the presented web sites give a good basic overview about the state-of –art in the above-mentioned fields.

6. IMPLEMENTATION OF E-LEARNING PLATFORM FOR ELECTRICAL DRIVES AND POWER ELECTRONICS

The most important task at beginning of composing, design and development of a good e-learning material is its philosophy. This covers the appearance of the screens (environment), mutual linking and interlocking of the screens (screen flow), introducing animation and simulation tools, and finally, presenting a way of explanation and description of phenomena at the screen and other ideas.

Each good e-learning material for electrical engineering should evidently clarify the phenomena and variables that are not directly visible as pointed out in the chapter 3. In the fact nobody sees the current, voltage, but their consequences are apparent. This is why the good e-learning material contains animations to show the phenomena-component-circuit-system behaviour. The introduced interactivity brings a new dimension in the education there by showing and evaluating influence of a variable parameter. The parameter influence can be evaluated better from the interactive graph. A possibility to change a circuit/system parameter by shifting the slider or inserting the parameter value presents a presumption of the system analysis.

Further key point of a good e-learning material consists in way of theoretical explanation. It is not a simple question what amount of textual explanation is necessary to make the basics understand, but not too much to become boring. This fact depends on a purpose and target group, on the audience for which the e-learning material is prepared. These are reasons why it is difficult to find a “golden way” [11]:

- if the tools are utilized as a complementary part of the lectures at the university then the theory is mostly explained by the teacher, and the lecture notes, handouts can be used as the main source,
- short explanations in form of flowing windows appearing after any mouse activity (running over the picture, pushing buttons, etc) are usually also enough for the qualified engineers, who would like only to refresh or update their knowledge.
- much deeper theoretical explanations should be provided if the main objective is the distance learning, since the learners are expected to study most of the curriculum alone, after their work or on the weekends.

7. EXAMPLES

Due to space reason, only two typical examples are shown here. As the first example is from field of electrical drives (Fig. 2) and it shows time courses of AC drive typical variables – phase voltage of the motor, stator current, electrical torque and speed course. It can demonstrate frequency starting and direct connection to the pre-set frequency. The frequency is set by the orange colour slider.

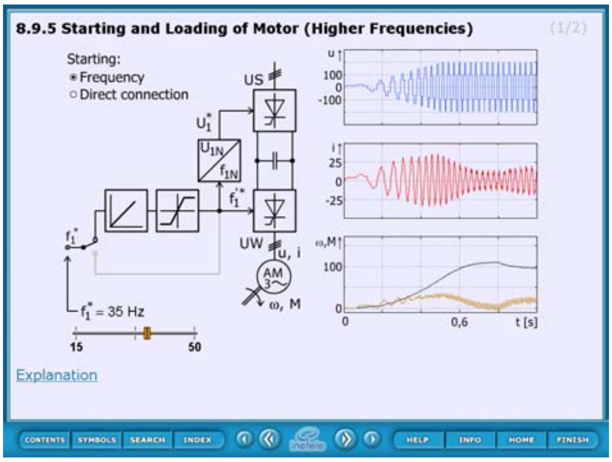

Fig. 2. AC drive with VSI performance - animation of drive behaviour in area of higher frequencies

This animation is made with specialized internet-based software - Macromedia Director. This software can develop interactive graphical user interfaces that are ease to use based on the mathematical description (what is more difficult) or on exchange of the figures based on position of the slider like shown here (the slider offers the interactivity). This solution is universal and the results are obtained regardless the complexity of the system. To create an interactive animation based on the mathematical description takes usually more programming skills, which are difficult to find by a teacher/trainer. 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.

Another example for illustration is from field power electronics. When studying a certain power electronic circuit, the first question of the student is always for the different current paths in dependency of the switching states and certain impressed currents and voltages. With traditional teaching the current paths are drawn using different colours into some figures of the power circuit, or the teacher presents slide-shows in the classroom. Here the approach of interactive animations is used. Different visualisation principles for explaining power electronic circuits are summarised in [16].

To illustrate the ideas mentioned above an example is shown here. The square wave generation principle shown in Fig. 3 is a basic switching strategy used for high power converters. The continuously running animation was replaced by a static one where the cursor (orange vertical line in the time diagram) that can be shifted in time by the lecturer. This solution gives a possibility to explain circuit behaviour

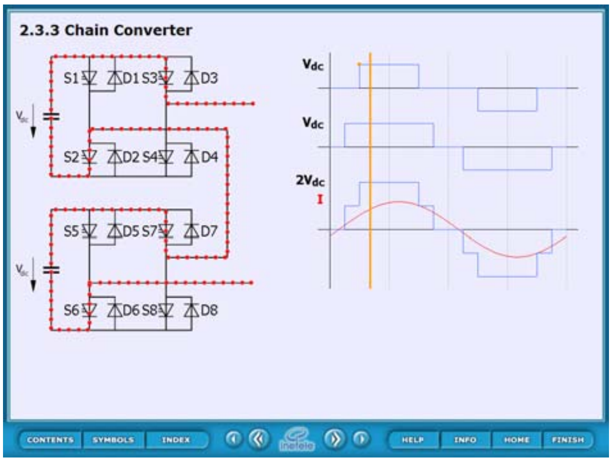

Fig. 3 A single-phase structure of an m-level cascade inverter

given by switching states of the power semiconductor devices in the required time instant. The chain circuit represents a straightforward approach to the realisation of a multi-level converter for use in high power applications without the need for magnetic combining circuitry and complex transformer arrangement. The main advantage of this approach is the well-defined operating environment for each three-level pole within a substantially isolated H-bridge circuit.

8. FUTURE CHALLENGES AND OPPORTUNITES: E-LEARNING AND VIRTUAL LABORATORIES

E-learning has introduced a new access to engineering subjects learning: by using interactive animation and simulation it enables to create *interactive training environment* helping partly to replace laboratories: (performing little experiments and system analysis).

However the danger is that instead of deep understanding and physical background, the students could memorize visualized results or at complicated animations without previous explanation they could feel like sitting in a theatre and passive watching the running animations. The described tools therefore cannot perform to stand alone education and must be part of *complete curricula*.

These new challenges for e-learning can offer the solutions:

- most of the interactive tools are focused on *"what-if" simulations* based on moving bars to increase or decrease parameters of the circuits. In other words, the circuit situations are performed without the use of real values for the circuit's parameters. The sense for real values is hereby very important.
- based on knowledge of components properties and subsystems behaviour *to perform synthesis* of the final system and to design the new system based on real (produced) components.
- to introduce a possibility of *evaluation and judgments* about the merits of ideas, verifying value of evidence, recognizing subjectivity. The key words here are: to conclude, criticize, decide, defend, determine, evaluate, dispute, judge, justify, compare, rate, recommend, agree, appraise, prioritize, assess, estimate, deduct.
- to introduce an active way of e-learning towards project oriented learning. Instead of using a short problem as a tool to deliver information and knowledge, a larger scope project should be used. It is well suited to the engineering disciplines and the way engineers in the industry work and therefore, it is considered as an attractive way to approach teaching and learning.
- it is important to give to the students a real world experience. However to build an experiment is expensive and it is impossible for an educational institute to have the complete scale of experiments. The hardware experiment should therefore be redesigned such that they also can be accessed in the Web and possibly integrated in e-learning. It must be a real electro technical experiment conducted in the laboratory but remotely controlled and monitored by e-learning web-based tools. The appearance of the measurement instrument, the electronic components and many more factors such as lay-out can be experienced.
- electrical drives and power electronic themselves deal with practical utilisation of the knowledge. Finally, each circuit/system composed on their base should work and be useful. Introducing pictures form practical realisation and short movies (e.g. actuating of the power electronic converter or operation of a drive in industrial environment) gives evidence on application of the analysed phenomena. This is reason why a good e-learning material has to contain as much as possible evidences on practical realisation and application of power converters and electrical drives.

Some other opportunities and challenges, which should be addressed, are in [20]:

- <u>Packaging and integration</u> as well as electromechanical systems would require new curriculum and e-learning approaches as the technologies mature.
- <u>Energy storage, energy management and intelligent systems</u> will play a very important role and must be integrated in the curriculum.
- As we move from the device and circuit level to the system level we must not forget how new semiconductors based on wide band-gap technology will affect the way power electronics are designed, built and integrated with other systems and be ready to change the curriculum as required.
- <u>Artificial intelligence</u> and further <u>integration of control, monitoring and diagnostics functions</u> to get self-healing

devices and systems would unfoundedly change the way the curriculum is organized.

Global expertise and knowledge management systems could be leveraged and networks can be built to assist industry and graduates in the years after graduation for keeping up with developments.
The next step in development of e-learning consists in virtual laboratories [1]. Utilizing the recent achievements in the ICT it becomes possible to build up them, extending the availability of the laboratory resources via high-speed networks. Users from remote locations can perform experiments, collect experimental data and analyze the results in the same manner as if they were carried out in a local laboratory.

The concept of virtual laboratories fits very well to the e-learning. They will probably have an important role in the future, because they integrate the technical, financial and human resources by sharing data, information, documents, multimedia means, etc., that is, *the knowledge-base*. The virtual laboratories should be utilized as auxiliary parts of the education or, in contrary, they could constitute "virtual universities", where students and teachers would be "virtual" (located at different points of the word and communicate with each other via different telecommunication channels, using chat rooms, internet phones, etc.). In this case, the laboratory measurements would be completed in the virtual laboratories.

9. CONCLUSIONS

Rapid development of ICT technologies caused development of e-learning educational (internet based) materials. Based on their philosophy and purpose of utilisation they are suitable for learning, teaching or for the both purposes. A lot of e-learning materials have appeared in last years, the evidence of which can be found in special sessions on education at the conferences from field of ED & PE from on e-learning or at the specialised conferences on education.

The presented paper gives an overview of the present state of development of e-learning materials in field for electrical drives and power electronics and tries to show some hints to design a proper materials optimised from view of purpose of its utilisation. It does not deal with the e-learning standards that give a framework but they cannot cover all needs specified by the user.

An overview of free available educational resources on internet creates a valuable part of the paper. Based on the overview the authors drafted new challenges and ways of the future development in the filed of e-learning for electrical engineering.

The authors have got reach experiences during development of the e-learning modules in framework of the Leonardo da Vinci educational project INETELE [19] with the web site: www.tuke.sk/inetele in framework of which a set of 22 modules utilising all described features and possibilities was developed.
Due to limited possibilities at paper publishing (the static screens only) and restricted space, here we limited ourselves for description the main principles. The main features of the developed materials will be presented "in natura" during the lecture.

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The opinions expressed by the authors do not necessarily reflect the position of the European Community, nor does it involve any responsibility on its part. Achievements in the INETELE project can be followed at the web site: www.tuke.sk/inetele.

APPENDIX 1

http://www.ipes.ethz.ch

The results achieved by J. Kolar and U. Drofenik at the *Swiss Federal Institute of Technology Zurich (CH)* are widely known and it can be said that they performed a pioneering work. In the recent years the number of the available interactive animations has been continuously increased. The web site offers interactive tools in the fields of: signal theory in power electronics, theory of three phase systems, DC-DC converters, several types of diode and thyristor rectifiers with different supply and load conditions, DC drives, power factor correctors, resonant converters, one and three phase converters, matrix converters, Vienna rectifier, thermal problems in power electronics, heat transfer models, fundamentals of electric and magnetic fields, etc. At the implementation, HTML and Java applets were applied. The tools are freely downloaded in eight languages: English, Dutch, German, Japanese, Korean, Chinese, French, Spanish, and extension to other European languages is expectable.

http://www.tuke.sk/inetele

The *Technical University of Kosice* coordinated a project on "Interactive and Unified E-Based Education and Training for Electrical Engineering" (INETELE). The authors of the contribution have played key roles in co-coordinating and technical advising of the project. 22 modules with interactive features were developed, starting from fundamentals of electrical engineering and electrical machines, through electronics, power electronics and its applications, to electrical drives, controlled drives, motion control and mechatronic systems. The set is completed by the modules on utilisation of specialised SW (for CAD and simulation) in electrical engineering. The modules satisfy both the needs for lecturing and for self-learning which is realized by introducing an hierarchy of the screens: (a) main screens with hey ideas (for lectures) and (b) secondary screens containing full explanation (for self-learning). The set of the modules was prepared in English and translated into the Czech/Slovak language, and several modules are in the German language.

http://thayer.dartmouth.edu/other/3Dcircuits/ animations/index.shtml

There is a particular feature of the electricity and electronic circuits, namely that the quantities (voltage, current, flux, etc.) are usually not directly perceptible, only through some measuring equipment. At the design of the animations usually one of the most complicated tasks is to visualize the most important electric quantities and characteristics. A new idea can be found on the home page of the *Thayer School of Engineering at Dartmouth College, USA.* The novelty of the animations is that instead of using the conventional 2D representations, they apply 3D ones. The role of the third (z) axis is to present the voltage changes in the circuit. HTML and animated gif pictures were developed. The content is divided into two parts: electronic circuit animations (like operational amplifier, comparator and Schmitt-trigger circuits) and power circuit animations (e.g. a simple diode rectifier, a bridge rectifier and a half-wave rectifier). In addition, a 3D circuit animation toolbox for MATLAB can be downloaded to open door for constituting new circuit animations. All the explanations are available in English language.

http://www.ckk.chalmers.se/people/magnax/elkraft/ Engelsk/start/index.html

The *Centre for Digital Media and Higher Education, Chalmers University of Technology (S)* with a close cooperation with the *Göteborg University* offer solutions that utilize the possibilities connected with digital media in research and education. Relating to the power electronics field, the home page helps in the visualization of electric machines, power electronics and drive. The power electronics part contains interactive animations of rectifiers and step-down dc-dc converter. The other part presents principles on the electro-magnetic field theory and their utilization at electric machines. It also shows the construction and basic operation of DC machines, synchronous and induction machines. It is welcome that several animations of the electric machines are supplemented by practical (industrial) solutions. The selectable languages are Swedish and English.

http://www.isep.pw.edu.pl/ICG/vlab/

Development of a Virtual Laboratory of Power Electronics has recently been started in Poland at the *Warsaw University of Technology (PL)* by M. P. Kazmierkowsky and R. Bracha. According to the current standing, the home page offers Web based interactive tools for teaching Pulse Width Modulation (PWM) techniques of three-phase bridge converters. The theory is shortly summarized on an HTML surface in either English or Polish language. The interactive animations are available in Java Applets.

http://www.sia.co.jp/~icass/index.html

Home page of the *Shukagawa Internet Association (J)* offers Java-based interactive animations for explaining the current and voltage sharing among resistors connected in parallel and in series, respectively; furthermore it explains the behaviour of resistors, inductors and capacitors in one phase networks. The basic series and parallel RL, RC and RLC circuits are also investigated. The animations are completed with the basic equations necessary to solve similar examples. Unfortunately the text is included only in Japanese language, although equations and figures are quite understandable and interactive schemes work.

http://www.lei.ucl.ac.be/multimedia/eLEE/

According to the statement of the home page "*Association for promotion of e-Learning tools for Electrical Engineering*", ("*e-LEE Association*") its aim is to promote and evaluate the multimedia learning tools for the engineering teaching, more specifically for electrical engineering". The association was created following the initiative of four universities, the *Laboratoire d'Electrotechnique et d'Instrumentation Université Catholique de Louvain, Belgique*; *Hautes Etudes d'Ingénieur Lille, France; Instituto Superior Técnico Lisbonne, Portugal* and *Facultatea de Electromecanic Universitatea din Craiova, România*. They provide tutorials for the electric circuit theory, power electronics, electrical machines and renewable energies. The homepage offers curriculum downloadable in pdf format and some interactive animations implemented in Java. To verify the knowledge, problems and test-like questions with selectable answers can also be found. The principal language of the homepage is French, however some parts can be read is English, Portuguese, and Romanian.

http://services.eng.uts.edu.au/~venkat/pehtml/contents.htm

This page belonging to the *University of Technology, Sydney, AU* offers Java Applet based interactive power electronics content together with English explanation text. The following topics are included: Simple diode circuits, Simple SCR circuits, Fully controlled 1-phase SCR bridge rectifier, Fully controlled 3-phase SCR bridge rectifier, Semi-controlled rectifier circuits, and Switch mode power supply. There are some useful e-learning tools, although the page has not been updated since 1999, therefore the recent multimedia technologies are not utilized.

http://Schmidt-Walter.fbe.fh-darmstadt.de/smps_e/smps_e.html

The homepage is made by the *Department of Electrical Engineering and Computer Technology, Fachhochschule Darmstadt, University of Applied Science (D)*. Its main purpose is to give insight into the operation and design of the switch-mode power supplies. The basic buck, boost and buck & boost converters, the forward and push-pull converters, furthermore power factor pre-regulator circuit are incorporated. The tools make the necessary calculations and draw the most important wave-forms with the characteristic steady-state values, based upon the input data provided by the user. It also helps in the selection of the best suitable coil. The Java based tools are available in English and German languages.

http://www.machines.cg.ac.yu/index.htm

This link contains useful, multimedia-rich e-learning content relating to the electric machines. The curriculum was prepared in the frame of a Tempus Joint European Project with the participation of the *University of Manchester, UK; University of Montenegro, Yugoslavia, Politecnico de Torino, Italy* and *Technical University of Kosice, Slovakia*. The main topics are transformers, DC motor-generator, induction machines, synchronous machines, brushless machines, stepper motor, reluctance drive, actuators, linear motors, heating and cooling, bridge-inverters, etc. The interactive animations were designed dexterously, making the understanding of the machine principles much easier. Interactive animations were prepared using the Macromedia Flash technology. The content is available in English language. The project partners decided to print a supporting book for the teaching material.

http://www.batarseh.org

College of Engineering and Computer Science University of Central Florida Orlando, USA has developed the Web Based Textbook on Power Electronics containing interactive applets for 29 power electronics circuits.

Phase two will focus on closed loop response and dynamic modelling, and phase three will emphasize on the system design of power electronic circuits.

http://www.dee.feis.unesp.br/gradua/elepot/gojava.html

São Paulo State University offers the www Course in Power Electronics Currently, the available interactive circuit simulations include: Uncontrolled Rectifiers (Idealized Circuits) Controlled Rectifiers (Idealized Circuits). The full text is in Portuguese and only the applets are in English.

http://www.marvel.uni-bremen.de/

University of Bremen, Laboratory for Art, Work, Technology (artecLab) coordinated the project MARVEL (Virtual Laboratory in Mechatronics: Access to Remote and Virtual e-Learning) in framework of which they implemented and evaluated e-learning environments for Mechatronics in Vocational and Professional Training. The main objective of MARVEL is to use real world in virtual learning environments. The students are allowed ubiquitous online access to physical workshops and laboratory facilities from remote places.

The main application areas covered by MARVEL are mechatronics, solar energy labs, robot training and electronics. The consortium consists of the following virtual laboratories: Full-scale solar heating plant and laboratory at Technical College II Delmenhorst (D), The HTI solar energy e-learning laboratory (CY), Robot Training Lab at ZENON (GR), Marvel Remote Workshop at West Lothian College (Scotland), Mechatronics Mixed Reality Web Service (deriveServer) at artecLab (D), FEUP's Remote Lab for electronics Design & Test (PT), Remote Control of Mechatronic Systems - Haute Ecole Valaisanne (F).

http://virtual.cvut.cz/dynlab/

Czech Technical University Prague coordinated a project where the main aim was to develop and disseminate an innovative Web Based Course on dynamics and control of multidisciplinary engineering systems. This course presents a novel approach to modelling allowing the integration of various engineering disciplines using a unified approach. It is supported by DYNAST simulator freely available for use across the internet. The course provides an extensive range of interactively solvable examples and virtual reality experiments. The course contains parts from modelling and simulation of electrical and electronic systems, power electronics, electromechanical systems (electrical drives), control systems and mechanical systems. There is a rich collection of solved examples.

http://www.softintegration.com/webservices/control/

This Web service for interactive control system design and analysis is part of Ch Control System Toolkit (offered free for academic use), which supports most classical and modern control techniques through object-oriented programming based on a control class. This Web-based system can be used for modelling, design, and analysis of continuous-time or discrete-time linear time-invariant (LTI) control systems. A control system can be modelled in the form of transfer functions, zero-pole-gain, or state-space.

http://www.bolton.ac.uk/mind/content-subject.html
Staff of *Universität Paderborn (D)* in cooperation with *University of Bolton Institute (UK), University of Northumbria (UK) and Politecnico di Torino (I)* developed selected chapters from the courses on Applications of Microelectronics to Electrical Drives, Motor Drives, Control and on Sensors Systems. The web pages are static but due to large figures they are suitable for presentation during lectures. The module on Intelligent Power Modules is completed by datasheets of the semiconductor devices of several manufacturers.

http://www.yaskawa.com/site/Training.nsf/training/DrivesELearningModule.html
Yaskawa Electric Corporation with branches throughout the world, belongs to the world's largest manufacturer of AC inverters, servo motors and drives and machine controllers provides not only products based on the concept of "Mechatronics" but also the technical knowledge and support to fulfill each customer's needs. Yaksawa's key technologies are in the following three fields: Motion control Robotics automation, System engineering
Yaskawa Technical Training Services of the Yaskawa Electric America, Inc. recognizes recent trends and has created e-learning modules (eLMs) to train its customers on its variable speed drive products. eLMs that explain a wide variety of drive topics can be simply downloaded from this website. The purpose of an AC Drives eLM is not to replace Yaskawa variable speed drives training seminars but to compliment them, by giving the student another choice for drives training - by small specific training lessons (each eLM takes about 30 minutes to complete) so that the students to complete their job in the short term. Yaskawa eLMs are modular in nature and pinpoint specific topics. Up to now they developed 26 eLMs.

List of topics of the selected YASKAWA modules
(a simplified overview for illustration only; the web site contains exact titles and their size)

- Troubleshoooting and Preventative Maintenance
- Braking Methods
- Network Communications (Overview of Ethernet Modbus TCP/IP, its Configuring and DriveWizard)
- Profibus for Yaskawa Drives
- Motor and Drive Basics
- DriveWizard for Yaskawa Drives
  Part 1: Download, Install and Connect
  Part 2: Using the Program
- Building Automation Networks
- Torque Control Configuration
- Introducing the G7 Inverter, its New Functions
- New Open Loop Vector Torque Control
- Motor Tuning Calculations
- Features and Benefits of the P7 Drive

APPENDIX 2

LIST OF THE INETELE PROJECT MODULES

(Interactive and Unified E-Based Education
and Training in Electrical Engineering)

od	Title	Authors
1.1	Basics of Electrical Engineering	H. Weiss
1.2	Electrical Measurement Methodology	H. Weiss
2.1	Basic Principles of Electrical Machines	H. Weiss
2.2	Transformers	M. Kostelný, J. Kanuch
2.3	DC Machines	C. Ondrusek
2.4	AC Machines	J. Kudla, R. Miksiewicz
3.1	Practical Electronics	H. Weiss
3.2	Power Semiconductor Devices	J. Dudrík
3.3	Power Electronics	B. Davat, P. Bauer P. van Duijsen
3.4	Control in Power Electronics	I. Nagy, R.K. Járdán
3.5	Power Electronic Applications Electrical Power Systems	P. Bauer
3.6	Harmonic Treatment in Industrial Power Systems	S. Manias
3.7	Electromagnetic Compatibility	S. Manias
4.1	Electrical Drives	V. Fedák, J. Žilková, J. Timko,
.2	Controlled Electrical Drives – beginner's course	H. Weiss
.2	Controlled Electrical Drives – advance course	L. Zboray
4.3	Motion Control	P. Korondi
4.4	Automotive Electrical Systems I., II	V. Hájek., F. Ďurovský, V.Maxim
4.5	Mechatronic Systems	V. Fedák, J. Fetyko
4.6	Telematic Systems and Robotics	P. Korondi
5.1	Automatic Design and Projecting ir EE	H. Kuchyňková, Ž. Ferková
5.2	Simulation of Power Electronics	P. van Duijsen, P. Bauer
5.3	FEM in CAD of Electromechanical and Electromagnetic Devices	B. Davat, J. Kudla, Ž. Ferková

Note: Coloured here are shown five groups of the INETELE modules:
1st group: Electrical Engineering Fundamentals
2nd group: Electrical Machines
3rd group: Electronics and Power Electronics
4th group: Electro-Mechanical Systems, Motion Control, and Mechatronics
5th group: CAD and Applied SW in Electrical Engineering