

Implementation and Assessment of Interactive Power Electronics Course

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Abstract: In recent years interactive web based courses has become very popular among teachers and more attention has been paid to it at universities. In this paper a web based interactive software has been designed and implemented to teach power electronics subject at undergraduate level in Shahrood University of Technology. The proposed course has seventeen parts based on power electronics syllabus in Iranian university. Each part includes a brief HTML text to explain circuit and necessary mathematical theory followed by Java applet to simulate circuit. It has been tried to prepare Java applets more attractive and easier to use compare to other available interactive software. Output is also available in forms of graphics and data that can be exported into spreadsheets programs like Excel for producing diagrams. The web-based interactive course was evaluated in offline use with a group of undergraduate students. Participants in the trials reported that the materials were engaging and assisted their learning about power electronics converter. This version of the course design was found effective in learning, and with further development, it may promises to be a powerful and flexible approach to supporting learning for students in power electronics courses.

Key-Words: -Interactive teaching, power electronics, Java applets, Web-based education.

1 Introduction

During last two decades, the rapid growth in the power electronics industry is caused an increased interest in teaching its fundamentals at the undergraduate and graduate levels in universities [1]-[4]. However power electronics teaching is challenging since the field is quite broad and includes fundamentals from a wide variety of areas of engineering such as control systems, magnetics, switching, semiconductor devices, and digital signal processing. There are many textbooks published in this field which have managed to overcome this challenge by reviewing material from prerequisite areas, as it is needed [5].

In power electronics subject, simulation is a perfect addition to some hardware experience gained in the laboratory. In advance to building a prototype the main functions of a power electronic system are simulated on the computer what generally does save a considerable amount of time and money [6]. Several programs, such as SPICE, SABER, CASPOC, SIMPLORER, for numerical simulation in power electronics are introduced and frequently used. These programs are easy to use and do show short simulation time and frequently used in university courses in addition to traditional lectures and practical exercises in the laboratory. There are

some drawbacks for using programs for numerical simulation as follows:

- These programs for numerical simulation do consume a large space on the computer's hard disk and are designed to be installed on the computer.
- Often a license is required in order to be allowed to run a simulation program.
- With always shorter time periods between hardware- and operating-system updates forced by the Information Technologies (IT) industry installing software becomes more and more frustrating for the user.

The other way of helping students and attracting students to power electronics subjects is using new technologies in power engineering teaching. Rapid changes of information technologies make this possible to provide students the efficient education in terms of time and costs [7]-[9].

In this paper after a brief review of web-based interactive teaching methods, a new web-based course of power electronics has been introduced. The main reason of this work is to help students in their effort to better understand the topics of power electronics and at the same time simulate the circuit and see the results. The effectiveness of the proposed package is evaluated and discussed in this paper.

2 Web-Based Teaching of Power Electronics

2.1 Employing Java Applets

Using IT in teaching can not only make studying more attractive to the student, but might make also teaching much easier and more effective. Especially in engineering courses like power electronics where complex technical problems have to be presented. The Internet does make education independent from a lecture room and a given lecture time. Furthermore, installation of a web-browser is standard on today's personal computers. If the course content along with necessary programs such as simulation and/or animation can be presented in the web-browser, there is no need for additional installations. Another advantage is independency of the program on the operating system when it runs in a web-browser.

Java which is a very popular programming language with syntax like C, makes this possible to run programs in web-browsers. It is object-orientated, and runs in a so-called virtual machine. Java has been written with emphasis on network programming and security, and is designed to run as a stand-alone application or, alternatively, inside a web browser. If the web-browser can't handle Java, so called plug-ins are available at no cost to add Java-ability. The Java programs running inside the web-browser are embedded in a HTML page and are called Java applets. As these Java applets have to be downloaded from the Internet, therefore the size of the simulation programs has to be kept as small as possible for keeping the downloading times short. Furthermore, the code in java applet has to be optimized in order to keep the simulation times short.

Although Java has not been designed to perform extensive numerical computations, it proved to be sufficient for circuit simulations and even simple calculation of electromagnetic field distributions as long as the programming is done carefully and with minimum computation time in mind [8].

Due to some security reasons, web-browsers like internet explorer do not permit to store simulation results of Java applets on the local hard disk. This security restriction is applied to prevent hackers to spread viruses in form of Java applets through internet and destroying the reputation of Java as a safe network language. One simple solution for this restriction is to provide the simulation results in form of columns and rows as text that can be copied and pasted into spreadsheet programs such as Excel for producing diagrams and reports.

2.2 Current Status of Web-Based Interactive Teaching of Power Electronics

As explained in previous part, interactive teaching by employing Java applets mainly take advantages of the simple usage, easy distribution and compatibility with the Internet. In power electronic teaching, Ramaswamy has developed an interactive web-based homepage which is based on embedding the Java-applets into HTML text [9]. Java applets are inserted in very detailed text instead of circuit diagrams and figures, where students can set circuit parameters and start a simulation and immediately see the resulting currents and voltages.

Interactive Power Electronics Seminar (iPES) [6], [8] has been developed at the ETH Zurich and is used in the introductory course on power electronics. IPES is a collection of Java applets which are used in addition to conventional teaching in the classroom in order to support the students with getting familiar with new concepts and basic circuits in power electronics. Its emphasis is on interactive animation not on simulations. The students can change various parameters with the mouse and watch the system's reaction immediately. The iPES Java applets are presented with a minimum of text which is about how to change parameters of the applet.

3 Proposed Web-Based Course

Proposed web-based interactive software is developed to teach undergraduate power electronics course in Iranian universities. It is prepared based on power electronics syllabus and has seventeen parts categorized in four major sections listed in the following [10]:

- 1) AC to DC diode rectifiers
 - Basic single-phase diode rectifier with
 - Single-phase full bridge diode rectifier with resistive load
 - Single-phase line commutated full bridge diode rectifier with constant output current
 - Single-phase full bridge diode rectifier with a filter capacitor
 - Three-phase full bridge diode rectifier with resistive load
 - Three-phase line commutated full bridge diode rectifier with constant output current
- 2) AC to DC controlled rectifiers
 - Basic single-phase controlled rectifier
 - Single-phase full bridge half-controlled rectifier with inductive load
 - Single-phase line commutated full bridge controlled rectifier with constant output current

- Three-phase full bridge half-controlled rectifier with inductive load
 - Three-phase line commutated full bridge controlled rectifier with constant output current
- 3) DC to DC converters (Choppers)
- Buck converter
 - Boost converter
 - Buck-boost converter
 - Cuk converter
- 4) DC to AC inverters
- Single-phase inverter
 - Three-phase inverter

Each part includes HTML text to briefly explain circuit and necessary mathematical theory followed by Java applet to simulate circuit. It has been tried to prepare Java applets more attractive and easier to use compare to other available interactive software. Fig. 1 shows a screen caption of a Java applet sample. All applets offer the possibility of a manipulation of system and load parameters with the mouse via a graphical user interface. The Java applets do the simulation immediately and by selecting the waveforms, simulation results will be shown. By moving the red vertical line (by mouse) switch condition and current direction on the circuit will be shown by red dots. At the same time necessary output values like output voltages or currents will be shown on the right hand side. If Applet-viewer is used, output results can be exported to a data file which may be opened by spreadsheets programs like Excel for producing

diagrams and writing reports. Otherwise, the simulation results should be provide in form of columns and rows as text which then can be copied and pasted into data file.

The main advantages of the developed software compare to the previously proposed softwares are as follows:

- a) Flexibility of circuit parameter changes (e.g. load, circuit and input power supply parameters)
- b) Ability to choose the output waveform to show
- c) Ability to save the output results in a data file (when using Applet-viewer)

4 Some Examples

In this section a few examples of proposed web-based interactive power electronics are given in detail.

4.1 Single-Phase Full Bridge Diode Rectifier

The single-phase full bridge diode rectifiers with different conditions can be simulated. Fig. 2 shows simulation result when bridge diode rectifier is connected to load with a capacitor as a filter.

This figure includes the time behaviors of input/output currents and voltages and other important values. When the red vertical line dragged and moved by the mouse, the actual selected current flow is shown in the picture of the power circuit. The current flow is visualized by moving colored points. Students often face difficulties in understanding why the output voltage of such a

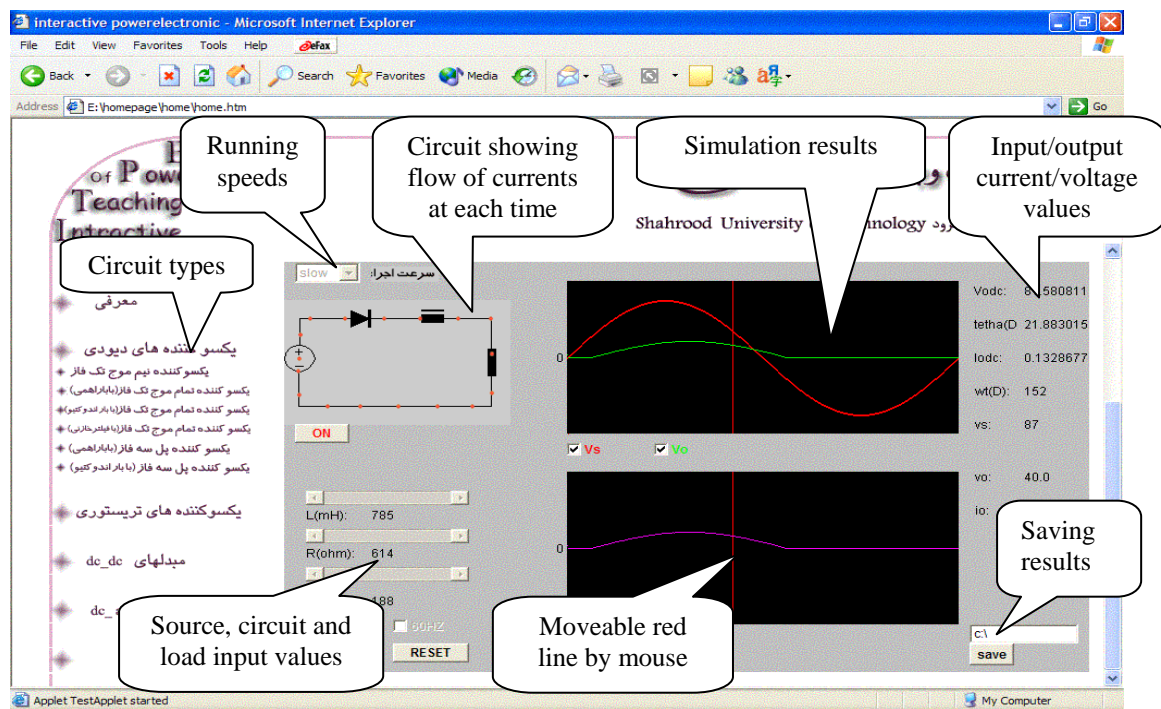


Fig. 1: A sample of Java applet

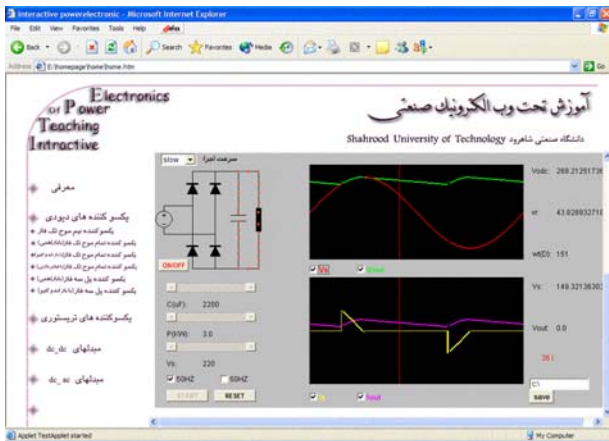


Fig. 2: Single-phase diode bridge rectifier supplying a filtered capacitor load

system is said to be approximately constant. Here, by simply changing the capacitor value in the power circuit and running the simulation, new voltage and current waveforms are calculated and shown shortly. This makes it very easy to understand why increased capacitance results in more and more "constant" output voltage while the input current is forming sharp peaks.

4.2 Three-Phase Line Commutated Full Bridge Controlled Rectifier

In proposed software some basic semi/full controlled rectifier circuits are available. In this section, as an example, the three-phase line commutated full bridge controlled rectifier is discussed in detail. Basically, five different values can be defined as input for this circuit, including firing angle, output current and source inductance, voltage and frequency. Fig. 3 shows simulation results for three-phase line commutated thyristor converter in inverter modes. The vertical red line can be dragged and moved by the mouse and shows the actual state

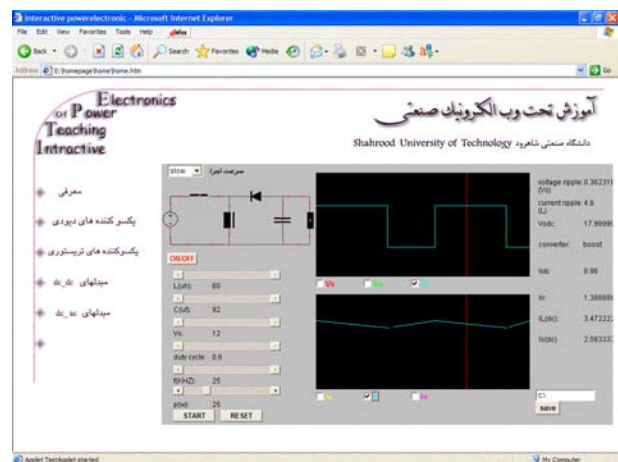


Fig. 3: Three-phase line commutated bridge converter in inverter mode

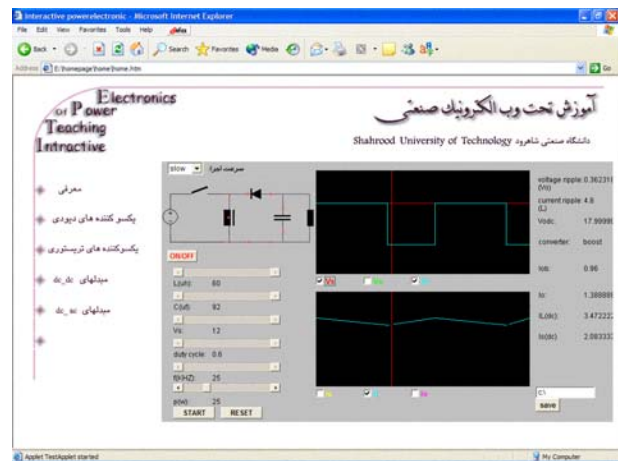
of the current flow in the power circuit. At the same time the values of output DC voltage, commutation angle, and conducting thyristors are shown on right-hand side of the Java applet. In summary, on a single web page all current-, voltage- and load-conditions of the quite complex three-phase full bridge thyristor converter can be demonstrated effectively.

4.3 Buck-Boost Converter

For explaining the operating behaviors of a buck-boost converter it is necessary to show the current path in dependence of the state of the power switch. Fig. 4 shows Java applet for the buck-boost converter. Six input parameters are values of inductance, capacitance, source voltage, switch duty cycle, output power and switching frequency. After running the applet, interested voltage and current waveform can be selected. As explained in previous sections, by moving the red line the actual current path is marked by moving colored dots and the visual representation of the power switch will be shown in power circuit as given in Fig. 4(a) for the



(a)



(b)

Fig. 4: Buck-boost converter when switch is (a) on state (b) off state

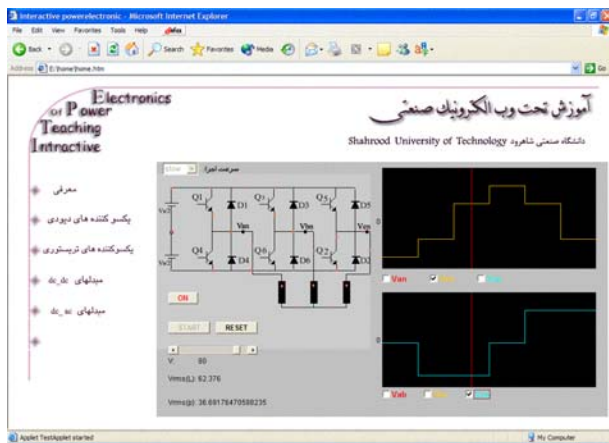


Fig. 5: Three-phase inverter applet

on state and Fig. 4(b) for the off state. Values of voltage and current ripples, output voltage, input and output current and mode of conversion (buck or boost) are given on right-hand side of applet.

4.4 Three-Phase Inverter

Fig. 5 shows the Java applet of the three-phase voltage- source inverter. Input value for this circuit is source voltage as the output voltage in VSI does not depend on the load. After running the applet to see the waveforms, interested phase and line voltages can be selected. By moving the vertical red line the current path and its direction is marked by moving colored dots. RMS values of output phase and line voltages are given in applet.

5 Interactive Course Evaluations

This software is being developed to assist in the education of students in the complexities of the power electronics circuits and aims to increase the level of their understanding. Due to some limitation, first version of prepared course materials copied in a CD and delivered to participant students. In order to assess the students' reaction to the use of the package a questionnaire is prepared. The survey of the course obtained for the 20 Likert scale items on the questionnaire from approximately 15 participants in 2005–2006. They completed the evaluation questionnaire at the end of their session. Table 1 summarizes the results Items for which the numbers are underlined were negatively phrased and have been reversing scored to assist in the interpretation of ratings. The table shows the number of responses recorded for each point on the scale together with median ratings.

User response to the materials was generally positive. Students reacted very favorably to the presentation of the materials (items 10, 11, 13 and

19) and perceived them as highly relevant to their professional preparation (items 2, 3, 4, 6 and 7).

Item 20 was the only item for which the median score (2.0) indicated an overall negative reaction to the materials. Three items (12, 14 and 16) had median scores of 3.0. Items 12 and 20 referred to operating instructions and operational difficulties. Because of delays in preparation of the prototype and the limited availability of the students, the trial was conducted with a version in which the interface was incomplete and only very limited operating instructions were included. Not all of the sample responses to tasks had been incorporated in the prototype and the response to item 14 was consistent with this.

There are some strengths of using developed package in teaching power electronic course which may attract more students to power electronic course. It has an advantage over traditional teaching in that it can permit a degree of user control that allows a user to take different values and see the results. It is suited to simulations of power electronics circuits which enable visualization and better understanding of complex, dynamic or inaccessible processes, in a form which students can access all necessary results.

6 Conclusions

This paper reported a web-based interactive teaching which is prepared for power electronics course in Iranian universities. Other approaches, such as animated and/or media-extended slide-shows, numerical circuit simulation, web-based content and simulation in power electronics are discussed in paper. The proposed web-based course is prepared by Java applets for interactive animation and simulations with an easy to use graphical interface.

Simulation examples have shown that prepared material is flexible in use and could be employed in addition to conventional teaching. Interactive animation is very efficient for studying because students are actively involved. It also simplifies the studying of the basics of power electronics for students. A survey of participants has been done at the end of the class. Overall, the survey results confirmed that the course was positive and prepared package is flexible in use and could be employed in addition to conventional teaching.

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Table 1: User evaluation data for the prototype trial (N= 15)

No	Item	Strongly Disagree 1	Disagree 2	Null 3	Agree 4	Strongly Agree 5	Median
1	I was enthusiastic about using the package as a part of my study	1	1	3	5	5	4.0
2	The problem presented in this package was NOT closely related to the everyday experience of teaching	7	8	0	0	0	4.0
3	The problem presented in this package was relevant to the power electronics course	0	0	0	6	9	5.0
4	Using this package did NOT help to increase my confidence for making professional decisions	2	9	4	0	0	4.0
5	Using this package helped to improve my knowledge	0	0	3	12	0	4.0
6	Working with this package did NOT help me to prepare better for future work	5	9	1	0	0	4.0
7	Using this package helped to improve my understanding of converters	0	0	3	8	4	4.0
8	Using this package increased my confidence for dealing with related issues in laboratory	0	0	4	11	0	4.0
9	In my opinion this type of package is a very effective learning tool	0	0	0	9	6	4.0
10	The quality of the sound on this package is very good	0	0	0	8	7	4.0
11	The visual quality of this package is very good	0	0	0	8	7	4.0
12	The operating instructions included on the package were sufficient to allow me to use it effectively	1	6	3	5	0	3.0
13	The textual materials on the package were of high quality	0	0	2	10	3	4.0
14	There was NOT adequate feedback for the tasks on the package	1	5	7	1	2	3.0
15	The problem on the package progressed in a logical fashion	0	3	0	12	0	4.0
16	Navigation through the package was NOT difficult	0	5	3	4	3	3.0
17	Sufficient time was allowed to work through the tasks	0	2	1	10	2	4.0
18	The resources on the package were difficult to access	1	9	3	2	0	4.0
19	Colors used in the package interface were suitable	0	0	0	11	4	4.0
20	There were NO difficulties in operating the software	2	9	1	3	0	2.0

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