INTERACTIVE JAVA APPLETS FOR POWER ELECTRONICS EDUCATION

Carlos A. Canesin[1], Flávio A. S. Gonçalves[2] and Leonardo P. Sampaio
São Paulo State University, UNESP – FEIS
Department of Electrical Engineering
15385-000 Ilha Solteira, SP – BRASIL
canesin@dee.feis.unesp.br[1], flavio@dee.feis.unesp.br[2]

***Abstract* –This paper presents interactive power electronics educational tools. These interactive tools make use of the benefits of Java language to provide a dynamic and interactive approach to simulate steady-state idealized rectifiers (uncontrolled and controlled; single-phase and three-phase). In addition, this paper discusses the development and the use of the Java applet programs to assist the teaching of basics rectifier power electronics circuits, and to serve as a first design tool for basics power electronics circuits in the experiments of the laboratories. In order to validate the developed interactive simulation applets, the results were confronted with results obtained from a well-known simulator package PSPICE.**

***Keywords* – E-learning, Java Applets, Power Electronics Teaching, Education Tool.**

I. INTRODUCTION

Education is one of the most important foundations for supporting the social development in a country. In the last decades, researchers have been trying the refinement of concepts/techniques and the development of new tools to support the improvement of the educational processes [1].

The traditional form of teaching presented in the classrooms can be complemented with the use of interactive systems based on computers. These systems can provide a learning environment with high quality leading to the improvement of the student's learning quality, and consequently the educator's productivity [2].

The evolution in the computers associated with the rapid emergence of the World Wide Web (WWW) and its associated tools have provided educators with a powerful and effective mechanism of information delivery. This environment can easily incorporate the latest hypermedia technologies (hypertexts, interactive simulations, videos/sounds, databases, remote instruments control) to compose and to manage educational courses, virtual laboratories and virtual classrooms [3, 4].

The main advantages of educational systems based on WWW are independence of time and space, a simple and familiar interface, due to methodology based on web browser, and conditions for simultaneous attendances [3-5].

Until few years ago, the teaching of power electronics circuits used to be based on methodologies where concepts were presented in a static way. However, these approaches are been supplemented with computer simulations and oriented object graphic tools, in order to illustrate in a dynamic and interactive way concepts usually difficult to reproduce in traditional classrooms through the explanation and static tools.

Provide the learning or teaching of a technical subject, mainly in power electronics area, is often complicated because there are a large number of possible reactions of a system in the presence of parameter changes. In this way, the dynamic system behavior can be explained much easier in many cases if these dynamics are presented in the interactive form through an interactive training environment. In addition, it enables the student to avoid a passive watching role at learning and pushes him to active participation in the learning process.

The circuit simulation packages became essential tools in several engineering courses, and strongly recommended for complementary and advanced circuit analysis, once they provide complex models with almost realistic behavior. Moreover, some of these approaches based on specific simulation packages require the software installation, and the student needs to learn first how to use the simulation tool before starts to study the desired topic. Usually, this task can become inefficient and confuse if the student is facing up with your first course using simulation packages [6-8].

On these last years, several researchers are looking for the development of distributed environment tools to assist the teaching of basic circuit systems with a high interaction level, and that can be executed in a easy and straight way. Thereby, Java is one of the most used platforms for the development of these tools, due to their intrinsic advantages [9-10].

In this context, most of the interactive tools are focused on "what-if" simulations based on moving bars to increase or decrease parameters of the circuits [10]. In other words, the circuit situations are performed without the use of real values for the circuit's parameters. Thus, the sense for real values is missed for the students, and it is well known that in this learning stage they are very important.

On the other hand, it is also important to give to the students a real world experience provided by laboratory experiments. The students can enjoy the real experiment and virtual simulation together if the laboratory experiments are supplemented with interactive simulations. The real experiment gives to the students a sense of practical testing, where they can see some effects (diode reverse recovery, switching losses, etc) not considered in the idealized models presented in the virtual simulation. Therefore, students can perform a relative comparison among lab-experiences and the theoretical concepts introduced in the classes provided on-line by the interactive simulations tools. [11]

In this context, this manuscript proposes several improved interactive Java applets, increasing the resources available for the WWW-HTML-based course in basic power electronics circuits, to be used both in the normal classes even the laboratory classes. The applets deal with the main aspects of the basic uncontrolled and controlled rectifiers and they can be used to calculate important parameters such as power factor, input current total harmonic distortion, root-means-square (rms) values, average and peak values and to provide a script file to be used in the simulator package PSPICE. [12]

II. DEVELOPMENT AND ORGANIZATION OF JAVA APPLETS

The proposed Java applets were developed to assist power electronics education at undergraduate level in engineering course. The main goal of proposed Java applets is to produce an interactive visualization of simulations for idealized circuit of power electronics in steady state, which are used as an instructional tool embedded in a WWW-HTML-based course in the classes and in the laboratories. Therefore, the results of simulation processes in steady-state may be visually presented to learner in real time, illustrating important concepts that are difficult to realize in a traditional classes and laboratories.

The graphical user interface (GUI) for the simulation applets were designed with four distinct sectors, as shown in Fig. 1, with the purpose of allows the student to go through menu options to change circuit's parameters, run and view simulation results in an easy and straight way.

The sectors that can initiate new simulations are denominated actives, and the others are passives. The passive sectors provide the feedback information to the student through waveforms and calculated values.

The sectors 1 and 2 are active; where the student can specify all circuit parameters and select the desired component of the circuit to perform the requested simulation analysis. Essentially, the student can set the load type (R or R-L) and its magnitudes, amplitude and frequency of the input voltage, and the fire angle in the case of the controlled rectifiers.

The sectors 3 and 4 are passive sectors. In the sector 3 are shown the voltage and current waveforms for the selected circuit component in the sector 2. The main circuit variables are online calculated and showed in the sector 4.

Additionally, if inconsistent values are specified by the students in the simulation options, the simulation applets perform warnings in the passive sectors informing the type of errors.

III. DEVELOPED JAVA APPLETS

Currently, the available interactive circuit simulations include:

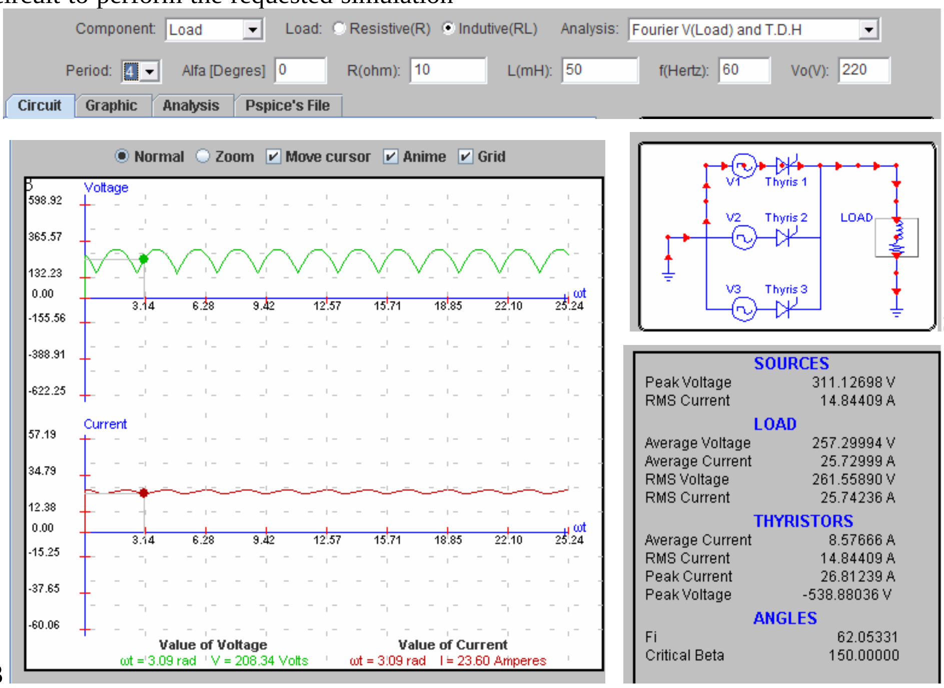
A. Uncontrolled Rectifiers (Idealized Circuits)

- *Single-Phase:* half-wave diode rectifier, half-wave diode rectifier with freewheeling diode, full-wave center-tapped diode rectifier, full-wave full-bridge diode rectifier;
- *Three-phase:* three-pulse diode rectifier, six-pulse full-bridge diode rectifier.

B. Controlled Rectifiers (Idealized Circuits)

- *Single-Phase:* half-wave thyristor rectifier, full-wave center-tapped thyristor rectifier, full-wave full-bridge thyristor rectifier;
- *Three-Phase:* three-pulse thyristor rectifier, six-pulse full-bridge thyristor rectifier.

The Figures 2 until 5 show a couple of rectifier's simulations performed using the proposed interactive simulation tools with the intention of tool features exemplification.



Sector 1
Sector 2
Sector 3
Sector 4

Fig. 1 – Graphical User Interface designed for the simulation applets.

One can verify in these educational tools that students are allowed to vary the circuit's parameters and examine instantly the effect of these changes on the main circuit's variables. Thus, the output current and voltage waveforms, as well as another rms, average and peak circuit values, can be investigated in the simulation applets for different input parameters, as is shown in Fig. 2.

Moreover, the proposed improved simulation applets features also include the Fourier analysis option for some specified circuit variables, animation mode showing the operational stages and the current flow paths, waveform zoom tool with cursor option, abacus mode where the students can select the rectifier operation point through normalized graphics, and Pspice option where the simulation script regarding the interactive simulation is provided using the Pspice standard.

Figure 3 shows an example illustrating the option "move cursor", when this option is selected and the red point regarding the current waveform position dragged and moved by the mouse, the actual amplitudes of current and voltage are shown in the bottom of section 3 and the selected current flow is shown in the picture of the power circuit in the sector 2. The current flow is visualized by moving colored red arrows and the students can pass through all the topological stages of analyzed rectifier topology. Other option available is the "anime mode" that provide the same information regarding the topological stages but in an automatic way as an animation.

For the three-phase interactive simulation tools, a Fourier analysis can be performed using the input current through one of the voltage sources, or the current and voltage across the load. In accordance with Fig. 4, the Fourier analysis results are presented in a table format, where the harmonic content is depicted through each component order and their associated amplitudes in peak values, frequency, and the phases in degrees. Moreover, the power factor (P.F.) and total harmonic distortion (T.H.D.) for the input current can be also calculated.

In order to validate the developed simulation models, the results were confronted with the results obtained from a well-know simulator package PSPICE, where the rectifiers' circuits were created employing idealized models for the semiconductors and simulated using the script file provided by the java application, as is shown in the example of Fig. 5.

Figure 6 shows the comparison for the results regarding the Three-phase six-pulse full-bridge controlled rectifier. In accordance with the difference between the results obtained, the simulation applet performed an error relatively small, and it has proved to be reasonably accurate taking in account the simplicity of the utilized algorithms.

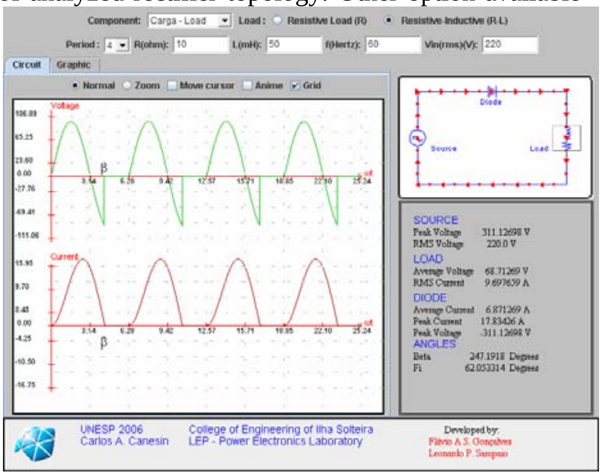


Fig. 2 - Single-phase half-wave uncontrolled rectifier: waveforms for the resistive-inductive load.

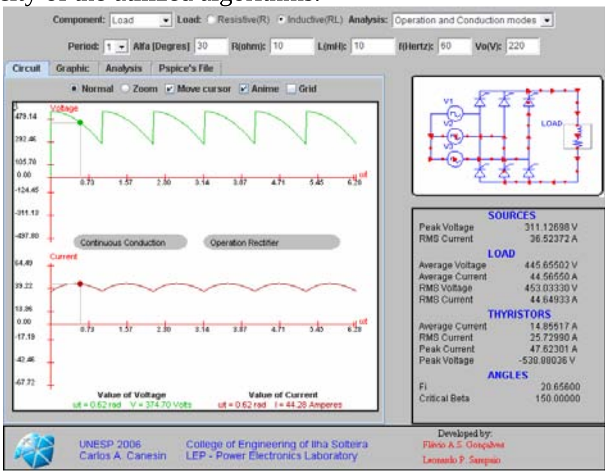


Fig. 3 - Three-phase six-pulse full-bridge controlled rectifier, operational stages and cursor example.

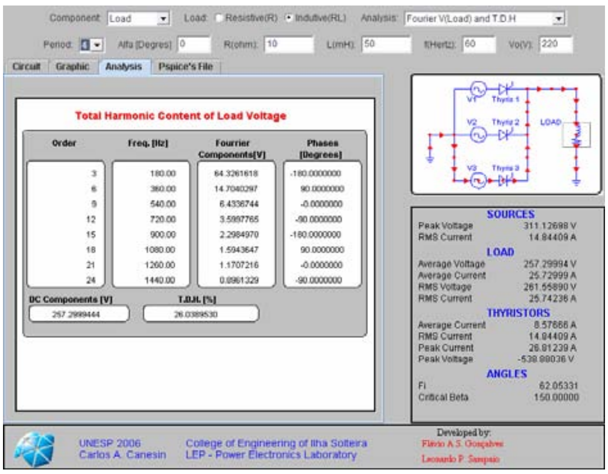


Fig. 4 - Three-phase three-pulse controlled rectifier, harmonic analysis of load voltage example.

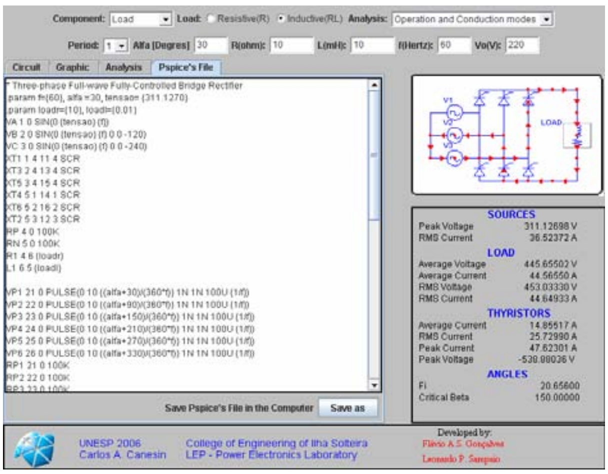
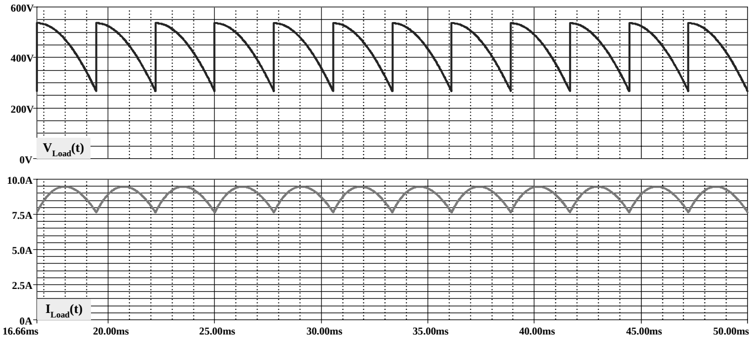
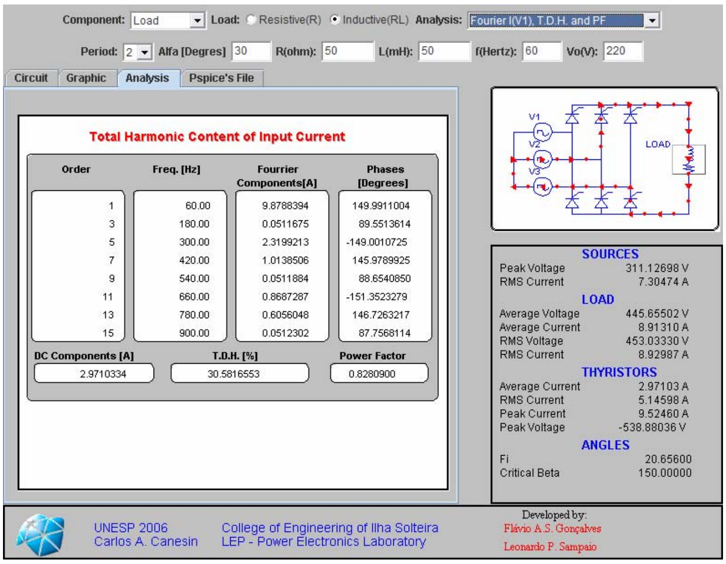


Fig. 5 - Three-phase six-pulse full-bridge controlled rectifier, Pspice script example.



(a) Pspice Waveforms



(b) Simulation Applet

Magnitude	Applets	Pspice 9.1	Error (%)
DC Component	0 A	0.0 A	0
Component Order 1	9.8790 A	9.803 A	0.76
Component Order 3	0.0508 A	0.0528 A	3.78
Component Order 5	2.3187 A	2.340 A	0.91
Component Order 7	1.0197 A	0.978 A	4.26
Phase (Degrees)	**Applets**	**Pspice 9.1**	**Error (%)**
Component Order 1	149.605	150.1	0.33
Component Order 3	88.166	86.90	1.46
Component Order 5	-150.615	-148.6	1.36
Component Order 7	142.175	146.9	3.22
T.H.D and P.F	**Applets**	**Pspice 9.1**	**Error (%)**
T.H.D. [%]	30.5764	29.524	3.56
Power Factor	0.825	0.831	0.72

(c) Input current and Power Factor Analysis

Component	Applets	Pspice 9.1	Error (%)
Source V_1			
RMS Current	7.3048 A	7.2835 A	0.29
Load			
Average Voltage	445.650V	443.56 V	0.47
Average Current	8.9130 A	8.8786 A	0.39
RMS Voltage	452.430 V	450.992 V	0.32
RMS Current	8.9298 A	8.8962 A	0.38
Thyristors			
Peak Current	9.5244 A	9.4825 A	0.45
Average Current	2.9710 A	2.9221 A	1.68
RMS Current	5.1459 A	5.0870 A	1.16
Peak Voltage	-538.858 V	-537.66 V	0.22

(d) Main Voltages and Current Analysis

Fig. 6 - Three-phase six-pulse full-bridge controlled rectifier: Pspice Results versus Java Applet results.

IV. LABORATORY SET-UP EXAMPLE

The experiments are developed using a laboratory set-up including digital multimeters, digital oscilloscope, didactic rectifier modules from DEGEM Systems, and a microcomputer with internet connection, as shown in Fig. 7.

In this context, through experimental analysis of a specific rectifier structure, the students can compare and analyze the experimental results and obtained experimental waveforms, in relation to simulated results obtained from the proposed Java applets, as shown in Fig. 8. Consequently, students can develop an accuracy conclusion for the experiments, through a complete analysis between the idealized simulated circuits and the real experiments, confirming and proving the concepts developed in the classes.

Finally, in the example shown in Fig.8 students can note the thyristor forward voltage drop during the interval when the thyristor operates in the on state, and thyristor commutation-angle, that reduces the average value of the load voltage.

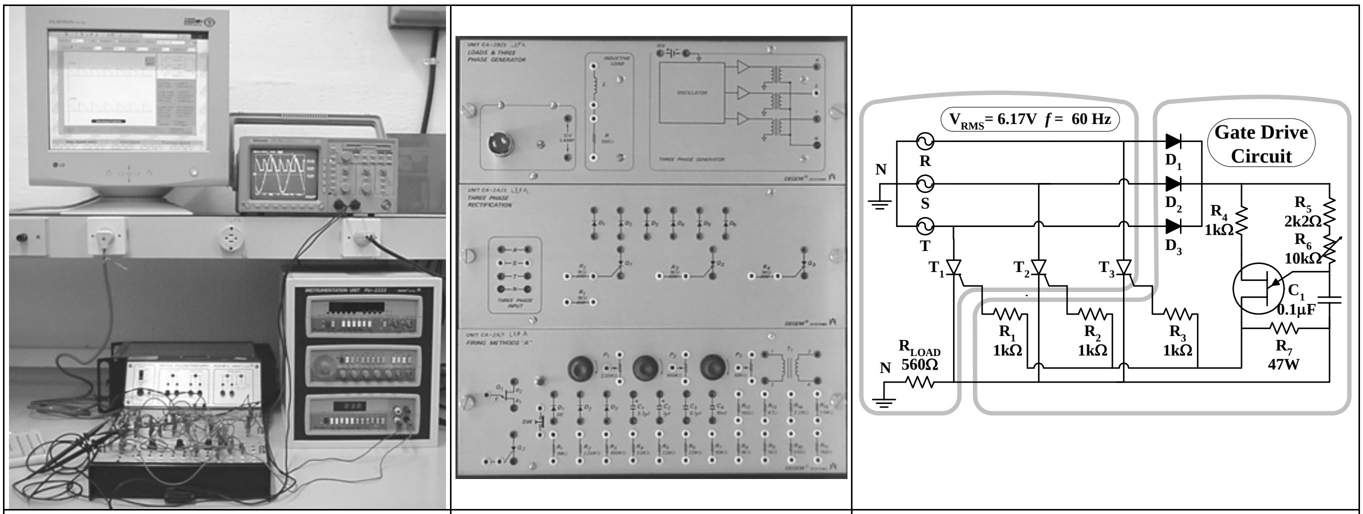
V. CONCLUSIONS

This paper presented JAVA applets for a WWW-HTML-based course in power electronics also applied in power electronics labs.

The information technologies bring us new perspectives for education, further on the technologies themselves, but also on the philosophy, and strategies of instruction and learning, allowing significant changes on many aspects of undergraduate education. Java applets provide a powerful and flexible way to deliver interactive content to students. In particular, the interactive simulations allow anyone to gain new insight into the behavior of basic rectifiers learning.

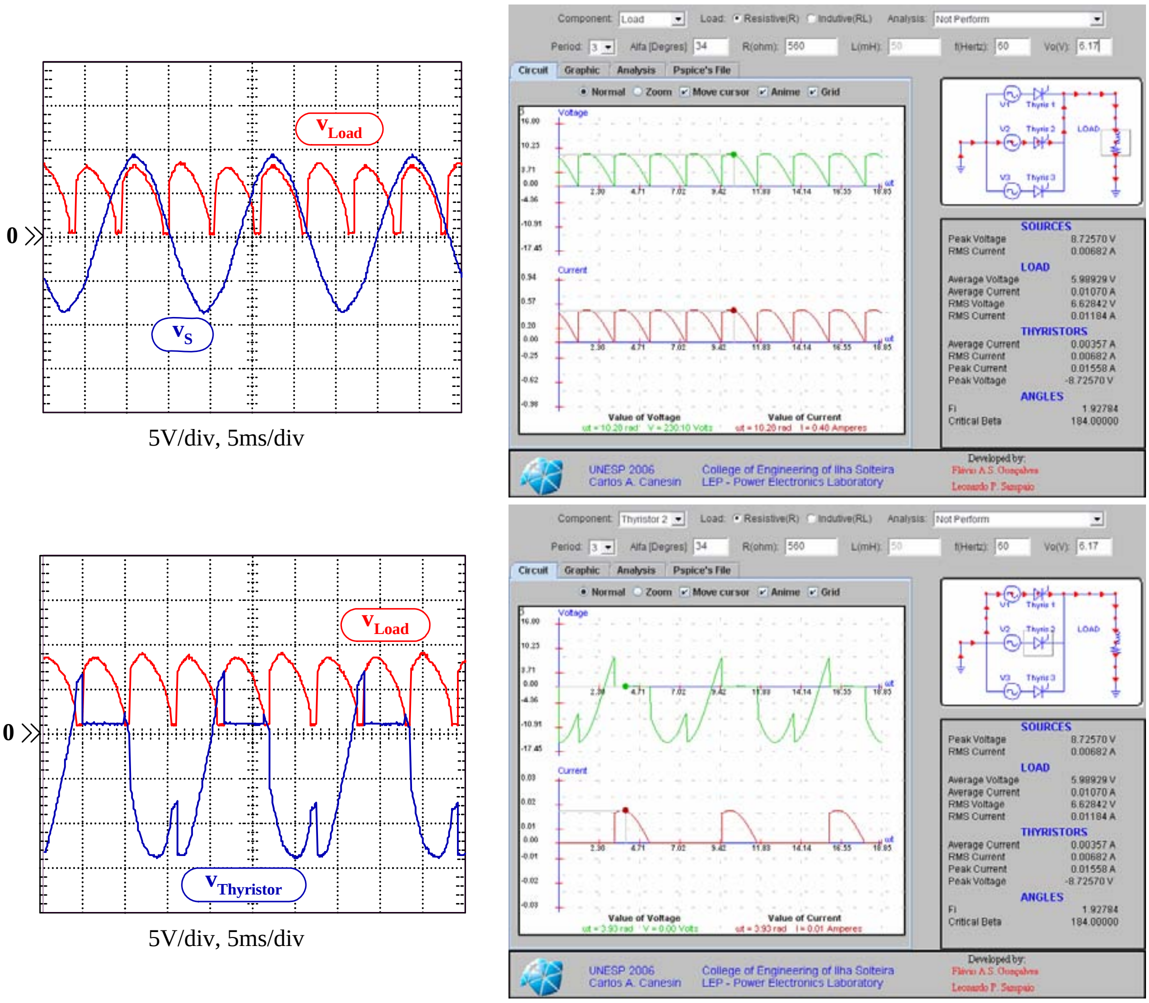
In this context, it was observed an important increase in the student's desire to learn the content of the power electronics course, when the proposed JAVA tools were included in the traditional classes, resulting in an important improvement of apprenticeship, due to the increase of student's motivation, and the increase in the student's abilities to comprehend the behavior of several rectifier circuits.

In addition, the use of these proposed tools during the traditional laboratory experiences provide for the students conditions to perform an online comparison analysis among lab-experiences and the theoretical concepts developed in the classes. The resultant approach is very efficient for education because the students are actively involved, once it allows an interactive and attractive learning system.



(a) Experimental Set-up | (b) DEGEM Experimental Board | (c) Circuitry of the experiment

Fig. 7 – Experimental Set-up Example.



(a) Experimental results from oscilloscope (b) Simulation results from microcomputer using the proposed tool

Component Load	Applets	Experimental	Error (%)
Average Voltage	5.98 V	5.62 V	6.4
RMS Voltage	6.62 V	6.12 V	8.2

(C) Load Voltage Analysis

Fig. 8 – Comparisons among experimental and simulation results.

REFERENCES

[1] G. Hwang, “A Tutoring Strategy Supporting System For Distance Learning On Computer Networks”, IEEE Trans. Educ., vol. 42, no. 4, 1999, CD-Rom Folder.

[2] G. Bengu and W. Swart, “A Computer-Aided, Total Quality Approach To Manufacturing Education In Engineering”, IEEE Trans. Educ., vol. 39, no. 3, pp.415-422, 1996.

[3] H. A. Latchman, C. Salzmann, D. Gillet and H. Bouzekri, “Information Technology Enhanced Learning In Distance And Conventional Education”, IEEE Trans. Educ., vol. 42, no. 4, pp.247-254, 2000.

[4] A. A. Renshaw, J. H. Reinbel, C. A. Zukowski, K. Penn, R. O. McClintock and M. B. Friedman, “An Assessment Of Online Engineering Design Problem Presentation Strategies”, IEEE Trans. Educ., vol. 43, no. 2, pp.83-91, 2000.

[5] M. Chirico, F. Giudici, A. Sappia and A. M. Scapolla, “The real experiment execution approach to networking courseware”, IEEE Trans. Educ., vol. 40, no. 4, pp. 297, 1997.

[6] L. P. Huelsman, “An Advanced Modern Course On Circuit Theory”, IEEE Trans. Educ., vol. 29, no. 3, pp.166-172, 1986.

[7] D. W. Hart, “Circuit Simulation As An Aid In Teaching The Principles Of Power Electronics”, IEEE Trans. Educ., vol. 36, no. 1, pp.10-16, 1993.

[8] I. Chamas and A. El Nokali, “Automated Pspice Simulation as an Effective Design Tool in Teaching Power Electronics”, IEEE Trans. Educ., vol. 47, no. 3, pp. 415-421, 2004.

[9] V. Ramaswamy, “The online text on power electronics”, available:http://services.eng.uts.edu.au/~venkat/pe_html/peintro.htm.

[10] U. Drofenik and J. W. Kolar, “Interactive Power Electronics Seminar (iPES)-a Web-Based Introductory Power Electronics Course Employing Java Applets”, in Proceedings of the 2002 IEEE Power Electronics Specialists Conference, pp.443-448.

[11] C. Fernández, 0. Garcia, J.A.Cobos, J. Uceda, “Self-learning Laboratory Set-up For Teaching Power Electronics Combining Simulations And Measurements”, in Proceedings of the 2002 IEEE Power Electronics Specialists Conference, pp.449-454.

[12] F. A. S. Gonçalves and C. A. Canesin, “Java Applets for a WWW-HTML-based Course in Power electronics”, in Proceedings of the 2001 IEEE Power Electronics Specialists Conference, pp. 85-91.