Basic circuits analysis learning: a Coimbra University case study in the Electrical and Computers Engineering Department

P. M Faia
Department of Electrical Engineering and Computers - FCT,
University of Coimbra, Polo 2, Pinhal de Marrocos, 3030-290 Coimbra, Portugal.
faia@deec.uc.pt

***Abstract* - Teaching basic electrical circuits can be done using several approaches, being the one used by the classic authors, like Chirlian [1], the most common. However, independently of the used strategy, the success attained by the students in the Electrical Engineering Department, once they start learning this subject, is not as high as expected. A large number of factors can be related to this unexpected lack of success. This work will present the most recent effort made by the author using a more practical approach, such as the one used by Nilsson [2] (and so typically more popular between students), in order to increase students interest in the subject and that simultaneously resulted in an increased learning success rate.**

Keywords: teaching, electrical circuit's analysis, continuous evaluation method.

INTRODUCTION

Electrical engineers are involved in the creation and operation of a large number of systems built to serve society and human needs. The type of systems vary from those related to the production of energy, to the ones connected with the transportation of energy and also with the ones that deal with the consumption of energy (in many different fields such as our homes, transportation systems, industries just to mention some). Electrical engineering also plays a major role in the development of machines that are used to support human labour and productivity rates.

The design and production of this type of systems depends in part of the ability to construct mathematical and physical models of electrical components and systems, as well as models of interconnected components or systems: the mathematical models are supported by the electromagnetical field and circuit theory.

An engineering course has typically two primary objectives that go hand to hand. One is to impart quantitative information about systems and components, which reflect the current knowledge. A second involves the development of techniques of analysis and synthesis that are applicable to a large number of specific situations.

Students capable of thinking in terms of realistic number, that quantitatively describe a system under analysis, while at same time are able to focus their attention in the principles that underlie the system itself, will probably be in the best position do attain a successful career in world as competitive as it our owe and which is technologically changing very rapidly.

As practical engineers, people are asked to solve new problems: whether improving an existent system, or whether creating a new one, electrical engineers will be solving newer unsolved problems. However as future engineers, students are asked to devote most of their attention in the discussion of are solved problems: through the discussion of solved problems, students will be driven along a process of learning and training, which will later allow them to acquire the skills needed to solve future problems.

Others authors have already referred the increased success of continuous evaluations systems in students learning process [1-2]. Either using E-learning evaluation platforms, either using more traditional approaches, both intended to try to change the working habits of the students and optimize their efforts in their way for excellence.

TEACHING METHOD

Teaching basic electrical circuits can be done using several approaches, being the one used by the classic authors, like Chirlian [3], the most common. However, independently of the used strategy, the success attained by the students in the Electrical Engineering Department, once they start studying concepts concerning this theme, is not as high as expected. A large number of factors can be related to this unexpected lack of success. Among them, the author points out the following ones:

- First of all, the lack of motivation by the students to this theme: nowadays the technological achievements concerning electrical engineering to which the media give major importance are specially related with semiconductors, VLSI systems (Very Large Scale Integration systems) and their respective applications. However, behind those research based technological developments, reside, frequently, basic electrical engineering knowledge, such as basic electric quantities definition and basic circuits analysis, which is frequently unknown by most of the people, and particularly by the students.
- Secondly, the wide-ranging subjects included in the program of the discipline, implicates a long lasting effort by the students, during the all semester, in order to be fully prepared, when the final examination period

arrives. For a large number of students, that is not put in practice, limiting largely their apprenticing, and consequently their final results.

- For last, the absence of a laboratory component also limits the emphasis that could be given to the different subjects studied during the semester: let's not forget that engineering is an experimental science, and so any knowledge learning accompanied by experimental practice, is not only easier retained by the human knowledge system as also awakes curiosity feelings. The latter usually drives the individuals through a much more exhaustive learning and training path concerning the fundamental concepts and solving method's related to the under study theme.

This work will present the most recent efforts made by the author using a more practical approach, such as the one used by Chirlian and Nilsson [4] (and so typically not so popular between the majority of our students), in order to increase student's interest in the theme and that simultaneously resulted in an increased learning success rate. The above authors refer the use of an approach based on problem solving and already stated, through the systematic discussion of solved problems, students will be driven along a process of learning and training, which will later allow them to acquire the skills needed to solve future problems. The current experience indented to demonstrate to our students the advantage of such systematic approach to the success of Electrical circuits theory learning.

Whichever author is looked and used as guide for the preparation and planning of the electrical circuit basic theory discipline in our Department, the basic subjects to be studied will be essentially the same.

So, similarly as in books from various authors [4-6], the program of the discipline look's to the following main topics:

- Electrical quantities (voltage and current); Ohm and Kirchhoff Law's; Energy and power definitions; Circuit elements: resistances, inductances and capacitors.
- Electrical equivalent circuits: voltage and current dividers and delta-wye and wye-delta impedance transformations; Power sources transformation; Thévenin, Norton and Superposition Fundamental Theorems.
- Natural and Step response of RL, RC and RLC circuits (series and parallel).
- Sinusoidal steady-state analysis: sinusoidal power sources and sinusoidal response of the basic passive elements; the phasor and passive elements in the phasor domain; Kirchhoff law's in the phasor domain; Electrical equivalent circuits, voltage and current dividers, and delta-wye and wye-delta transformation in the phasor domain. Power sources transformation and Thévenin, Norton and Superposition Fundamental Theorems in the phasor domain. Sinusoidal steady-state power calculations: real and reactive; Complex power calculation.
- Balanced three-phase voltages. Balanced three-phase circuits: analysis of wye-wye, wye-delta, delta-wye and delta-delta circuits; Power calculations in three-phase circuits.

In the Electrical and Computers Engineering Department of the Faculty of Sciences and Technology of the University of Coimbra (FCT-UC), teaching basic electrical circuit analysis theory is usually done by means of a set of theoretical and practical classes that students can attend during the semester, and where they will learn fundamental concepts and train exercises solving concerning the above topics. Theoretical classes are used to introduce to the students the diverse fundamental concepts and solving method's associated to circuit's analysis. During practical classes, teachers propose and help students to solve different type of problems regarding the topics of the course, and that where previously presented to them in the theoretical classes.

However those theoretical and practical classes attendance is non obligatory, and so some of the students tend to not frequently assist to the classes, especially to the theoretical ones. This immediately imposes limited practical class's progress. In addition, some of those students also do not attend to practical classes as regularly as they should. As consequence a significant number of those same students do not practise problem solving regularly, during the semester, leaving all the work to just nearby the final exam date. Examination period is short, during which there are two final written exams (Normal and Recourse Exams): however each one of the students has not only the basis circuit's analysis exam to respond to. Consequently exercises solving period is much shorter, and perhaps not as intense, than needed: for some of those students the obtained skills will not be enough and will not let them feel comfortable and prepared for general life problem solving.

For more then a dozen years, the author has experienced teaching basic circuit analysis theory and practise. For is accumulated experience, he has gained the sense that only with intensive and repeated exercises solving, students will get confidence and will be prepared for answering any real practical problem demand.

During the last semester, for the practical course of basic electrical circuits and system analysis a non obligatory evaluation method, but continuous, has been proposed to the students of the Department of Electrical Engineering and Computers, DEEC, of the Faculty of Sciences and Technology of University of Coimbra.

Students could make an option: instead of being evaluated at the end of semester only based on a final written exam, they could be evaluated along the semester, and then answer only to a part of the final written exam (for this proposal, the exam only counted as 75% of the final result of the discipline). The continuous evaluation during the semester consisted of 5 exercises, proposed to the students, that where due to be solved on a defined time of the class length. Even more, the students were not obliged to make an option between evaluation systems automatically, at the beginning of the semester: they could solve the proposed exercises and afterwards, based on the exercises classification, if they were not satisfied with the obtained

results, they choose to be evaluated only based on the final written exam.

RESULTS AND DISCUSSION

As stated, in the Coimbra University a basic electrical engineering circuits analysis, as a practical teaching component, consisting in practical classes, were teacher proposes and helps students to solve different type of problems related with the issues that are related to the course.

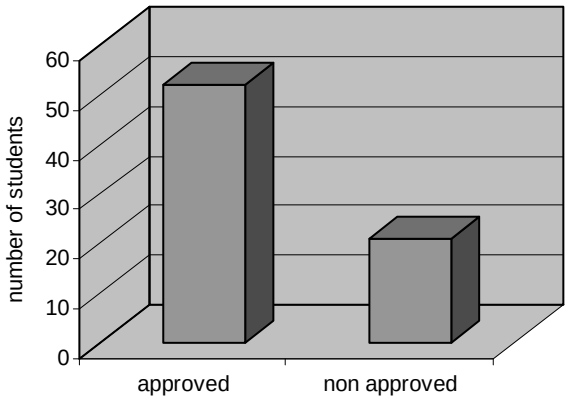

FIGURE 1 – NUMBER OF STUDENTS APPROVED AND NOT APPROVED, THAT HAVE PRESENTED THEMSELVES TO THE FINAL EXAM, DURING THE FIRST EXAMINATION PERIOD, AND THAT MADE THE OPTION TO BE EVALUATED CONTINUOUSLY.

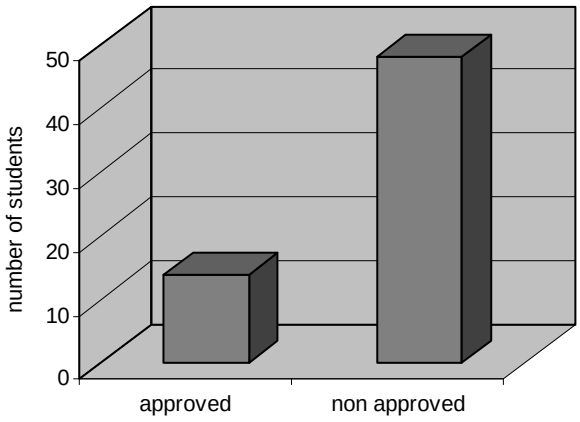

FIGURE 2 – NUMBER OF STUDENTS APPROVED AND NOT APPROVED, THAT HAVE PRESENTED THEMSELVES TO THE FINAL EXAM, DURING THE FIRST EXAMINATION PERIOD, AND THAT MADE THE OPTION TO BE EVALUATED ONLY BASED ON THE FINAL EXAM.

Since it was a first time experience, the suggested continuous evaluation process was non obligatory, as stated before. In consequence, and as expected, a large number of students tried to profit and benefit from the experience.
The rules were clear. During the regular practical classes, a total of five, non warned, exercises would be proposed to the students. Each one of them would be classified in a scale up to 20. In order for a student to be dispensed from answering to a quarter of the final written exam, the average of the proposed exercises, during the semester, should be higher than 14: 78 from a total of 107 initially interested students have achieved that goal. Several reasons can be pointed out for explaining the remaining 29 failure (and so that had to be evaluated obligatory by means of only a final written exam):

- Students are not obliged to assist practical classes, and so they could miss one or more proposed exercises.
- Unsatisfactory results obtained in one of the exercises could conduct students to decide to quit the continuous system evaluation method. However the total number of students dispensed from a quarter of the final exam was very significant, when compared with the number of students that have initially submitted to the continuous evaluation system.

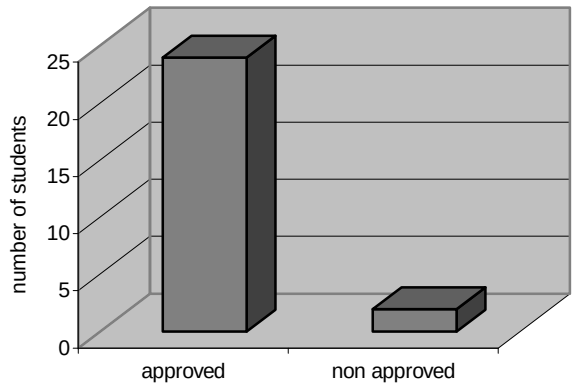

FIGURE 3 – NUMBER OF STUDENTS APPROVED AND NOT APPROVED, THAT HAVE PRESENTED THEMSELVES TO THE FINAL EXAM, DURING THE SECOND EXAMINATION PERIOD, AND THAT MADE THE OPTION TO BE EVALUATED CONTINUOUSLY.

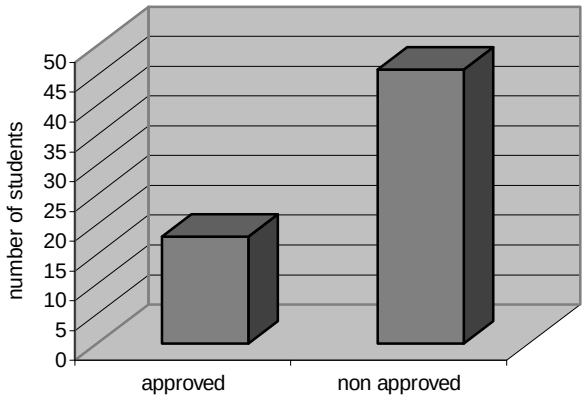

FIGURE 4 – NUMBER OF STUDENTS APPROVED AND NOT APPROVED, THAT HAVE PRESENTED THEMSELVES TO THE FINAL EXAM, DURING THE SECOND EXAMINATION PERIOD, AND THAT MADE THE OPTION TO BE EVALUATED ONLY BASED ON THE FINAL EXAM.

But as desired, the final success could only be discussed after the final exam's examination period.

To the first regular period of examination, the number of students that have presented themselves to the final written exam, were 134 (Normal exam). From those 73

belonged to the group of students that had agreed to be evaluated continuously during the semester, while the remaining 58 made the choice of being evaluated only by means of the final exam.

The results can be seen in figures 1 and 2. From them the author can retain that the number of approved and non approved students in both proposed evaluation systems is largely different. While in the continuous procedure 52 of a total of 73 students have achieved success (approximately 71% final course approval success rate), in the final written exam only evaluation procedure, merely 14 of a total of 62 students have reached the same objective (approximately 22% final course approval success rate). From the presented results, the author can state that:

- Nevertheless being a first time experience, it seems very clear that it should be repeated regularly.
- The continuous system seems to create in the students a learning strategy and planning that encourages them to practice and train problem solving during the semester, instead of making a nearby exam only practice study: as consequence of the distributed effort the final course success is more than 3 times.

These conclusions are further supported after analysing the results from the second period of examination.

To the second regular period of examination, the number of students that have presented themselves to the final exam, were 90 (Recourse exam). From those 26 belonged to the group of students that had agreed to be evaluated continuously during the semester, while the remaining 64 made the choice of being evaluated only by means of the final exam.

The results can be seen in figures 3 and 4. From them the author can conclude that the number of approved and non approved students in both proposed evaluation systems is once again different.

While in the continuous procedure 24 of a total of 26 students have achieved success (approximately 92% final course approval success rate), in the final written exam only evaluation procedure, just 18 of a total of 64 students have reached the same objective (approximately 28% final course approval success rate).

TABLE 1
TOTAL NUMBER OF STUDENTS APPROVED AND NOT APPROVED, THAT HAVE PRESENTED THEMSELVES TO THE FINAL EXAM, DURING THE BOTH EXAMINATION PERIODS, EVALUATED BASED ON THE CONTINUOS METHOD AND ON THE FINAL EXAM ONLY METHOD

	APPROVED	NON APPROVED
CONTINUOUS METHOD	76	2
FINAL EXAM	32	56

From the just presented results, concerning this second written exam, the author can reinforce the already exposed ideas concerning the analysis of the Normal exam: nevertheless being a first time experience, it seems very clear that it should be repeated regularly, since this continuous system apparently creates in the students a learning strategy and planning that encourages them to practice and train problem solving during the semester, instead of making a nearby exam only practise study. As consequence of the distributed effort made by the students that have been evaluated using the continuous system, their final course evaluation success is more than 3 times higher than the remaining ones.

In table 1, the author summarises the data concerning both final exams, which is also represented in the graphics of figures 5 and 6.

From the final compiled information, represented in those figures, where information from both final exams is present, the author states that:

- The total number of students that have obtained final approval on both exams is higher than the reproved one (108 versus 58).
- Nevertheless being a first time experience, it seems very clear that it should be repeated regularly. However, the main reason for the success, seems to be entirely associated with the continuous evaluation system: the number of total approved students evaluated using the continuous system is more than 2 times higher than the number of approved students evaluated only based on the final written exams. Reciprocally, the number of reproved students is almost incomparable: only 2 that were evaluated using continuous system against 56 evaluated using only final exams.

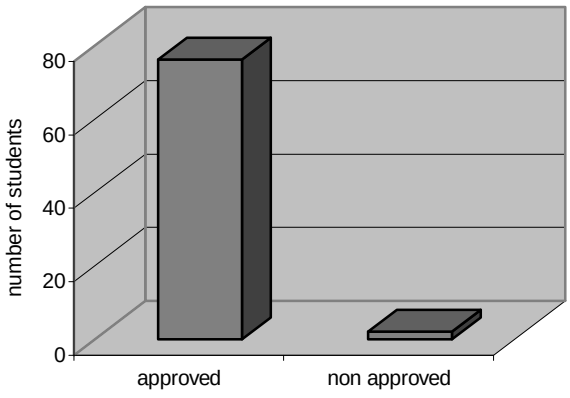

FIGURE 5 – TOTAL NUMBER OF STUDENTS APPROVED AND NOT APPROVED, THAT HAVE PRESENTED THEMSELVES TO THE FINAL EXAM, DURING THE BOTH EXAMINATION PERIOD, AND THAT MADE THE OPTION TO BE EVALUATED CONTINUOUSLY.

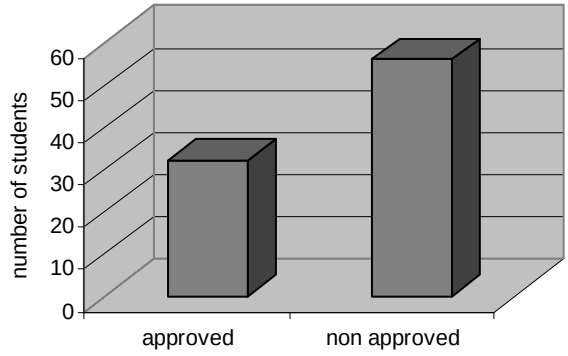

FIGURE 6 – TOTAL NUMBER OF STUDENTS APPROVED AND NOT APPROVED, THAT HAVE PRESENTED THEMSELVES TO THE FINAL EXAM, DURING THE BOTH EXAMINATION PERIOD, AND THAT MADE THE OPTION TO BE EVALUATED ONLY BASED ON THE FINAL EXAM.

CONCLUSIONS

From the present study here presented, which resulted from a first time experience proposed to the students for evaluating basic electrical circuit's analysis discipline effort, the author concludes that:

- The continuous evaluation systems seems to be a tool to further exploit and to be suggested to the students for evaluating their effort during the semester: it looks as if it encourages the students to distribute their learning effort and practice training skills, with evident increased evaluation success, by the end of the semester: the number of approved students is more than two times higher, while the number of reproved students is amazingly smaller.
- However this experience should be carried repeatedly, not only with this discipline, as also with others, in the Electrical and Computers Engineering Department, before the obtained results can be claimed as absolutely conclusive, and the success of the continuous system be declared effective.

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