

# Use of Scilab software as a didactic tool in electrical circuits laboratory practices

## *Utilización del software Scilab como herramienta didáctica en las prácticas de laboratorio de circuitos eléctricos*

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### ABSTRACT/ RESUMEN

The present work proposes a didactic tool to improve the teaching-learning process of Electric Circuits subjects, applying the problem-based learning method through laboratory practices, implemented in the free software Scilab. The foregoing is a consequence of the policy for the improvement of the continuous training process of Cuban professionals proposed by the Ministry of Higher Education. This is applied in the "E" study plan in the electrical engineering career at the Technological University of Havana, in which the essentiality of the contents constitutes a fundamental aspect to reduce training time and achieve higher levels of independence, motivation and role of the student; promoting autonomous, active, meaningful and collaborative learning. The results conclude that by carrying out the laboratory practices with the proposed methodology, it improves the learning results of the students.

**Keywords:** electrical circuits, ITC, Scilab, software, teaching-learning process.

El presente trabajo propone una herramienta didáctica para mejorar el proceso de enseñanza–aprendizaje de las asignaturas de Circuitos Eléctricos, aplicando el método de aprendizaje basado en problemas por medio de las prácticas de laboratorios, implementado en el software libre Scilab. Lo anterior es consecuencia de la política para el perfeccionamiento del proceso de formación continua de los profesionales cubanos propuesta por el Ministerio de Educación Superior. Esto se aplica en el plan de estudios “E” en la carrera de ingeniería eléctrica en la Universidad Tecnológica de la Habana, en el que la esencialidad de los contenidos constituye un aspecto fundamental para reducir el tiempo de formación y lograr mayores niveles de independencia, motivación y protagonismo del estudiante; potenciando el aprendizaje autónomo, activo, significativo y colaborativo. Los resultados concluyen que mediante la realización de las prácticas de laboratorios con la metodología propuesta mejora los resultados del aprendizaje de los estudiantes.

**Palabras clave:** circuitos eléctricos, proceso de enseñanza –aprendizaje, Scilab, software, TIC.

### INTRODUCTION

Starting in 2018, the Electrical Engineering career at the Technological University of Havana, CUJAE, began its curricular improvement, which, according to the Ministry of Higher Education, as a result of the exhaustive review of the training and development programs of Cuban professionals, and in correspondence with the new scenarios and complex conditions that are glimpsed for the next decades of the 21st century, a set of policies are proposed for the improvement of the continuous training process of these professionals, one of which expresses the following: "Improve undergraduate training in careers with a broad profile, refocusing them towards solving the general and frequent problems of the profession in the base link" [1]. In this new scenario, Information and Communication Technologies (ICT) are more important in achieving this goal, by enabling personalized and self-regulated learning in students, particularly in the use of free software in university education. According to reference [2], computational simulation and theoretical-experimental work are two activities of the teaching-learning process, which engineering students carry out in the laboratory and/or in the classroom, observing the effects; they analyze them to understand the impact of their actions in a particular context, they evaluate whether the same results could be reproduced in other scenarios or situations, establishing a connection between the abstract and reality. Simulations create an active and interactive learning environment, allowing students to explore the dynamics of processes.

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In correspondence with references [3-6], is considered that the use of ICT to obtain better results in the teaching-learning process constitutes an important element in today's Higher Education; specifically, simulation software is of great importance for carrying out laboratory practices, providing skills and, as a consequence, preparing students with the purpose of achieving university students with technical profiles capable of responding to the various problems that can be provided in the profession of engineering. For its part, reference [7] affirms that the pedagogical use of ICT in the curriculum helps to reinforce, deepen and socialize knowledge based on the role of the student as a constructor of knowledge and not as a receiver; and the role of the teacher as a counselor and guide through the interactivity of ICT. On the other side, the authors of the reference [8], emphasize that teaching and learning constitute a process, on whose quality the development of students depends, that they come to think and act with independence and initiative, that they seek solutions to problems, while listening, valuing and respecting the opinions of others and being able to work as a group.

ICTs require teachers to perform new functions and also require new methodologies and new approaches in the teaching-learning process. Achieving the integration of ICT in the teaching-learning process will depend on the ability of teachers to structure the learning environment in a non-traditional way, merge ICT with creative thinking and promote dynamic classes on a social level, stimulating learning. interactive, collaborative, autonomous and self-regulated. This implies knowing the diversity of tools, knowing how to select and use them properly for the appropriation of knowledge based on the different needs and profiles. Therefore, the use of the free software Scilab as a didactic tool in the improvement of the teaching-learning process from the development of the laboratory practices of the Electric Circuits subjects is very useful, on the one hand, due to the compatibility with the Windows and Linux operating systems and, which also contains packages and libraries that numerically solve equations and systems of ordinary differential equations, graphing the results obtained. Due to all the above, the objective of the article is to propose the free software Scilab as a didactic tool to improve the teaching-learning process of the subjects of Electrical Circuits, adapted to the contents that are taught in these subjects in the Department of Engineering. Electrical of the Technological University of Havana, CUJAE, for second year students.

## REFLECTION

Due to the importance that it presents for the Electrical Circuits subjects of developing a system of laboratory practices using the Scilab software and in correspondence with the declared objective, methods of the theoretical and empirical level are used. The method of the Analytical-synthetic theoretical level allowed to analyze, compare and confront the different literatures consulted and to reach conclusions in the theoretical plane from the potentialities of the free software Scilab to improve the teaching - learning process of the Electric Circuits subjects and their use in laboratory practices. As a method of the empirical level, the structured interview was applied to investigate the opinions of the students about the work developed with the Scilab software in the proposed laboratory practices, the population was composed of 56 second-year students of the Electrical Engineering career of the Technological University of Havana "José Antonio Echeverría", CUJAE.

For the processing and analysis of the information collected in the interviews, the calculation of absolute and relative frequencies was used as a mathematical-statistical method. The study began in the 2019-2020 academic year and has been given continuity in the current context characterized by the current epidemiological situation caused by COVID-19, all of which has made it possible to minimize the negative impact imposed by social isolation and technological costs associated with it to improve the PEA of the Electrical Circuits subjects without the need for attendance in laboratory practices. On the other hand, methodological meetings were development in the Discipline in which agreements were made aimed at determining and approving the laboratory practices to be developed with the Scilab software and the methodological guidelines for their execution. All this taking into account as a fundamental premise, according to the authors of the work [8], that ICTs do not transform learning by themselves or automatically generate educational innovation, but rather it is the method or didactic strategy used for their integration, together with to the planned exercises, those that promote one type or another of learning in the university student and with it their autonomy.

## RESULTS

Taking into account the most up-to-date references of recent years, both at the international and national levels, on the improvement of the teaching-learning process at the university level, among which the works of references [6, 9-12], which have directed their research around the new techniques in the teaching-learning process and the teaching methodologies used with the integration of Information and Communication Technologies in university education. And in addition to the work developed by the authors of the reference [8], in which the potentialities of free software Scilab adapted to the contents of the Electric Circuits subjects and that responds to current curricular changes are recognized, two laboratory practices are proposed to develop with the free software Scilab.

### Lab Practice 1

Title: Behavior of Direct Current and Alternating Current Electrical Circuits.

Topic: Laws and general methods that govern electrical circuits.

Objectives

Check through simulation:

- Behavior of circuit elements to DC and AC stimulus.
- Kirchoff's laws.

## Experiment

The equivalent circuit shown in figure 1, represents the monoliner of a simple electrical power system (EPS), composed of a generator, a transformer, a line, a motor and the load represented by its active and reactive power consumption.

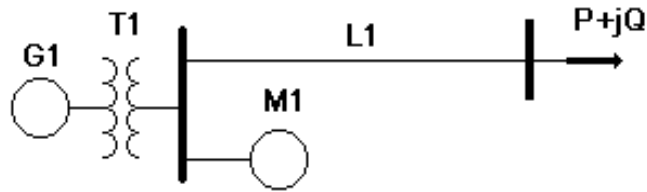


Fig. 1. Monoliner of a simple electrical power system

Starting from this monoliner, calculate through the studied Kirchhoff laws the values of the voltages and currents that will be measured by the instruments shown in figure 2, below, which represents the simplified circuit model of the system shown above. Simulate this circuit in Scilab.

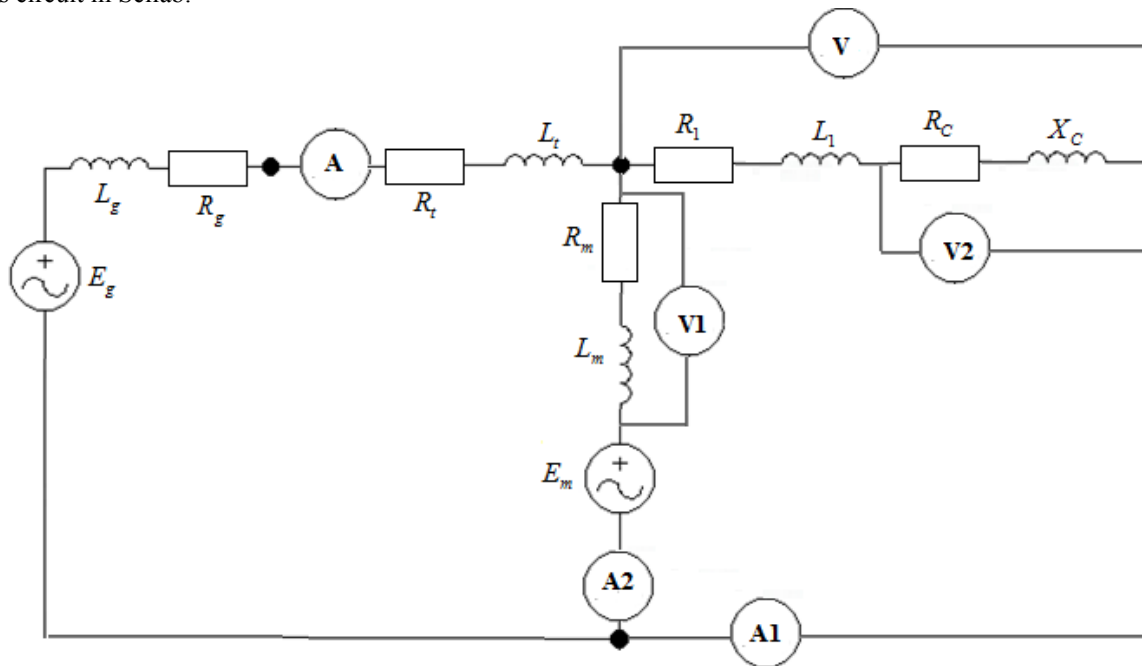


Fig. 2. Simplified circuit model of the simple electrical power system

Data:

$$\underline{E}_g = 4,16 \angle 60^\circ \text{ kV} \quad L_T = L_g = L_m = L_l = 0,053 \text{ H} \quad \underline{E}_m = 480 \angle 80^\circ \text{ V}$$

$$R_g = R_T = R_l = R_m = 1 \Omega \quad R_c = 100 \Omega \quad X_c = 50 \Omega \quad f = 60 \text{ Hz}$$

### Lab Practice 2

Title: Resolution of branched electrical circuits applying Ohm's law and Kirchhoff's laws. Phasor diagrams. Calculation of powers and power factor.

Topic: Laws and general methods that govern electrical circuits.

Objectives

- Verify through the simulation of simple electrical power systems the Ohm's Law and Kirchhoff's Laws.
- Make phasor diagrams of simple circuits.
- Calculate powers and power factor in simple electrical power systems.

### Experiment 1

In the following simple electrical power system shown in figure 3, a three-phase short circuit occurred across the terminals of transformer T2 on the 6,6 kV side. Calculate the short-circuit current in the 6,6 kV bus.

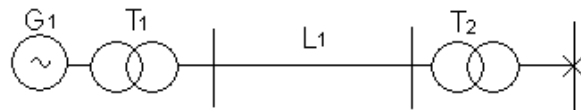


Fig. 3. Representation of a simple electrical power system experiment 1

Data:

Transformer 2:	Transformer 1:	Generator:	Line 1:
$S_n = 60 \text{ MVA}$	$S_n = 75 \text{ MVA}$	$S_n = 100 \text{ MVA}$	
110 / 6,6 kV	6,6 / 110 kV	$U_n = 6,6 \text{ kV}$	$X = 0,5 \Omega / \text{km}$
$X = 20 \%$	$X = 15 \%$	$X = 10 \%$	$l = 40 \text{ km}$

### Experiment 2

Suppose that in the electrical power system of experiment 1, a generator identical to generator 1 connected to the primary of T2 was increased, as shown in figure 4. In your opinion, what will happen to the short-circuit current, does it increase or decrease? In what percentage? Explain.

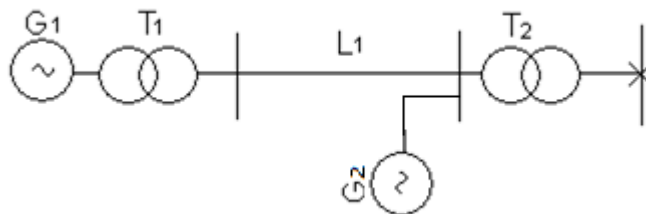


Fig. 4. Representation of a simple electrical power system experiment 2

### Experiment 3

In the simple electrical power system represented in figure 5, it is desired to obtain the following magnitudes.

- Current through the line, generator and through the loads assuming that these can be represented as  $Z_{C1}=Z_{C2}=0,018432+j0,09216 \Omega$
- Line voltage drop
- Power losses in the line due to joule effect
- Active, reactive, apparent, complex apparent power, power factor of both loads separately and together.
- Power factor of the generator.

Data:

Transformer 2:	Transformer 1:	Generator:	Line 1:
$S_n = 60 \text{ MVA}$	$S_n = 75 \text{ MVA}$	$S_n = 100 \text{ MVA}$	
110 / 6,6 kV	6,6 / 110 kV	$U_n = 6,6 \text{ kV}$	$X = 0,5 \Omega / \text{km}$
$X = 20 \%$	$X = 15 \%$	$X = 10 \%$	$l = 40 \text{ km}$

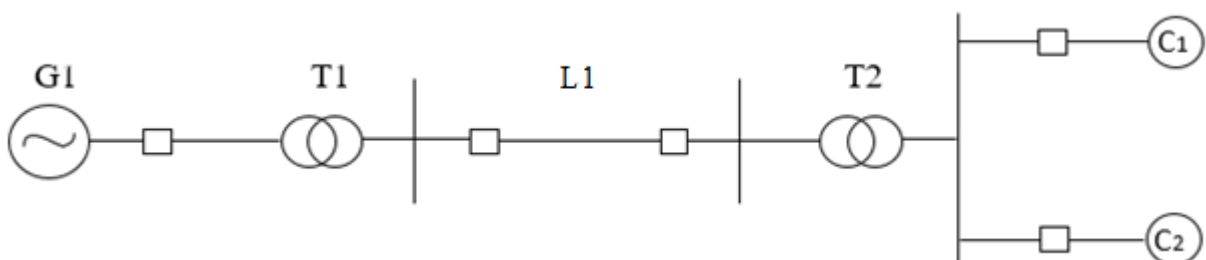


Fig. 5. Representation of a simple electrical power system experiment 3

### Solution of the laboratory practice proposal # 1 Using the Scilab software

As an example, laboratory practice # 1 is solved, for the construction of the model of the proposed laboratory practice, the Xcos graphic environment was used, in figure 6, the block diagram implemented in the Scilab software is shown.

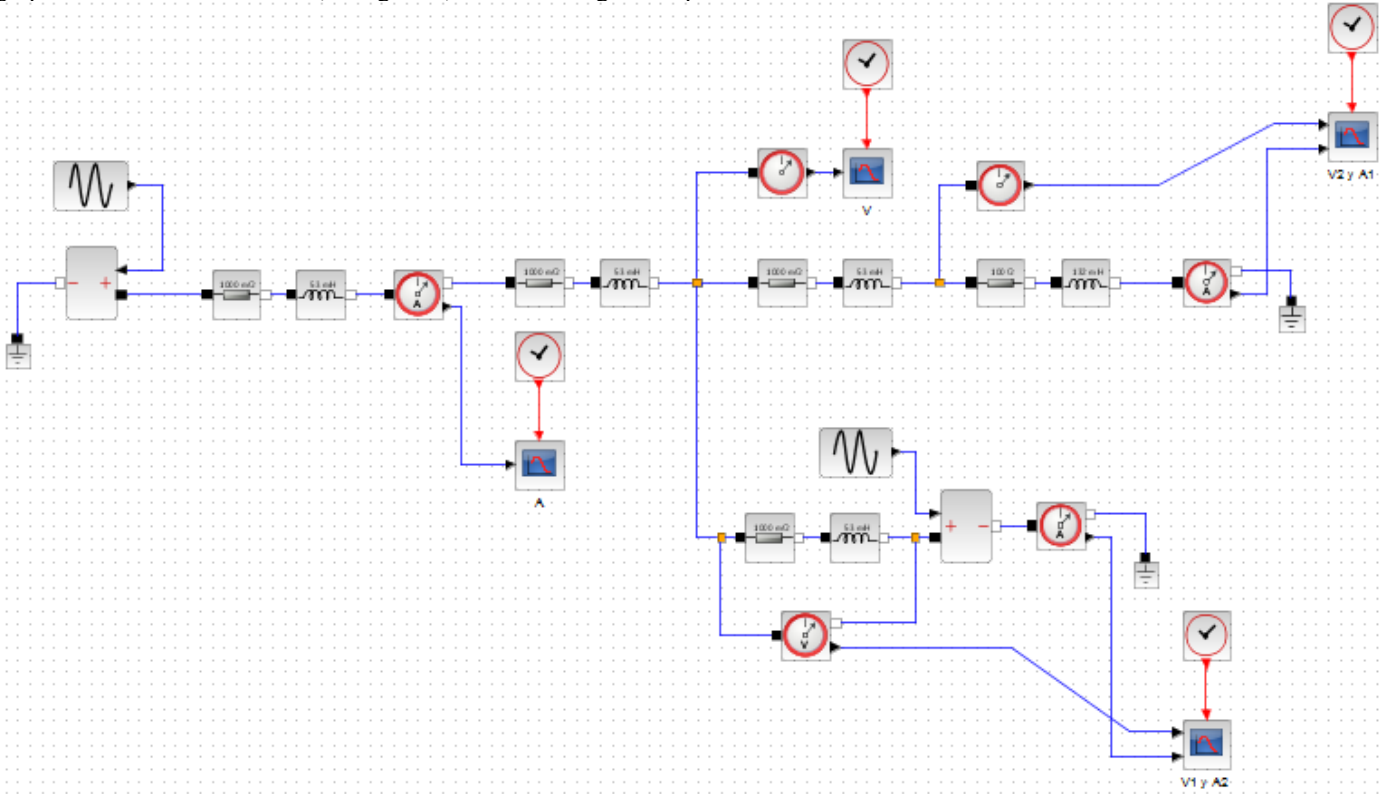


Fig. 6. Block diagram of the solution of lab #1

The results of the waveforms measured by the instruments are shown in figures 7, 8 and 9, respectively.

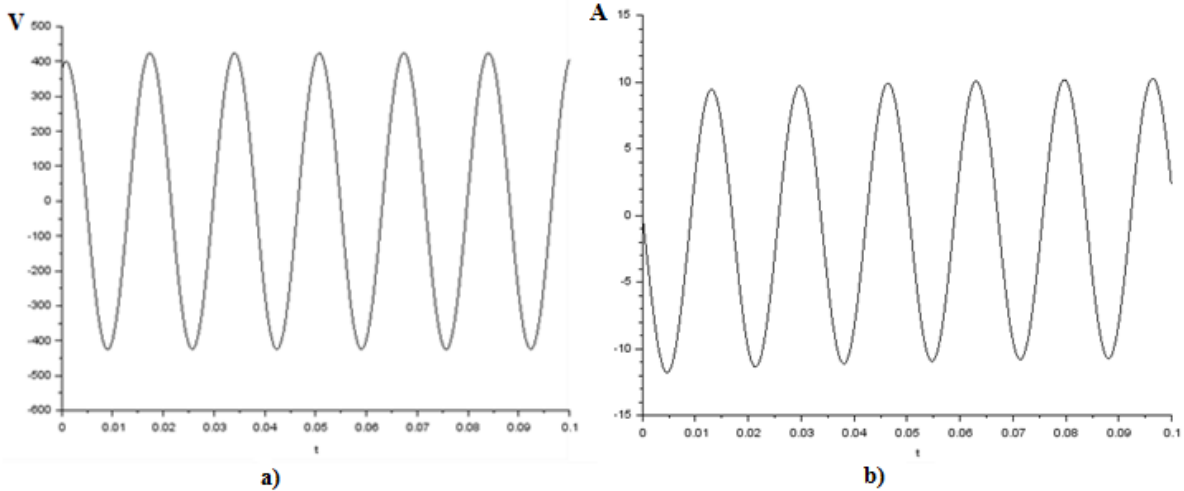


Fig. 7. Waveforms a) of the voltmeter "V" and b) of the ammeter "A" of laboratory practice #1

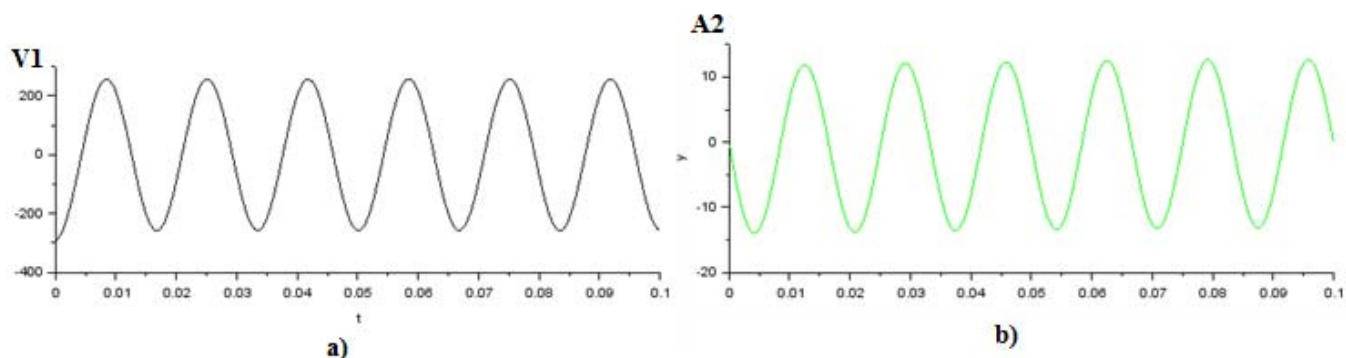


Fig. 8. Waveforms a) of the voltmeter “V1” and b) ammeter “A2” of laboratory practice #1

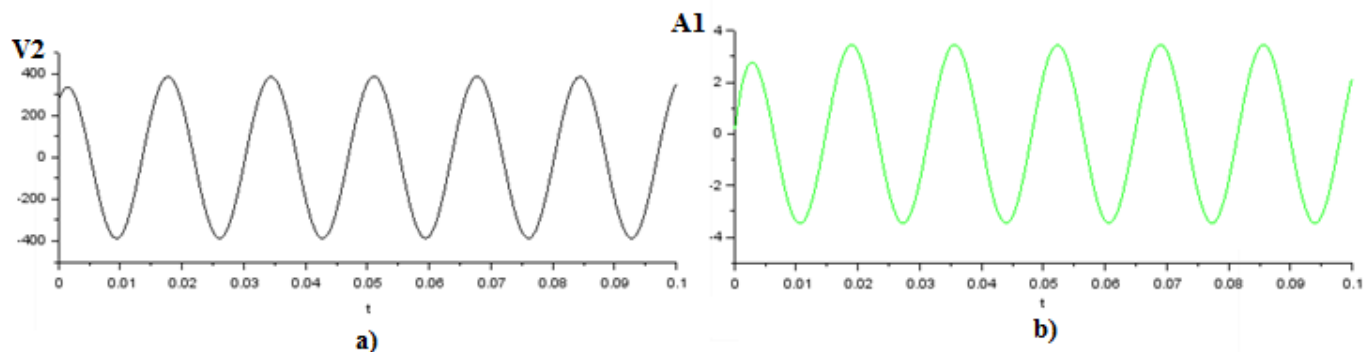


Fig. 9. Waveforms a) voltmeter “V2” and b) ammeter “A1” from laboratory practice #1

### General aspects of laboratory practices

The method used in carrying out the laboratory practices was problem-based learning, which allowed to enhance and/or improve the autonomous, active, significant and collaborative learning of the students. With the use of this method, the role of the teacher changes to that of a tutor or counselor who guides the teaching-learning process of the students in the development of laboratory practices. For the development of the laboratory practices, with the aim of promoting collaborative learning, the students formed similar groups of up to five members.

Each laboratory practice corresponded to a problem of the real profession adapted to the contents of the electrical circuit's subjects and in line with the professional model proposed in the "E" curriculum. In addition, the student is provided with didactic materials and scientific articles that serve as tutorials on the use and configuration of the free software Scilab, reflected in the research carried out by references [2, 8, 13-14].

Laboratory practices according to this approach aim to integrate the contents taught in the classroom, through lectures and practical classes, to problematic situations of the profession in order to develop skills with measurement instruments and interpretation of results. In this way, students can observe the effects of the different elements that make up electrical power systems in the face of different stimulus, analyze them to understand the impact of their operation in a particular context, and evaluate whether the same results could be reproduced in other scenarios or situations, establishing a connection between the abstract and reality. Simulations create an active and interactive learning environment, allowing students to explore the dynamics of processes.

After carrying out the laboratory, each team must prepare a laboratory report which, in correspondence with the work [15], has the following characteristics:

- Cover page with the name of the subject, number and title of the laboratory, the names of the students, the number of the list, the group and the date.
- abstract
- Introduction.
- Scientific problem.
- Object of Research.
- General objectives.
- Specific objectives.
- Hypothesis.
- Development with data and results tables, figures, etc.
- Conclusions.
- Bibliography consulted to prepare the report
- Attachments, if deemed necessary.

To develop the different points of the laboratory report, students must consult the textbooks of the Electrical Circuits subjects, the teacher as tutor and guide of the teaching-learning process, their work group and the theoretical concepts acquired in other subjects.

## DISCUSSION

To analyze the results of the application of the proposed laboratory practices with the Scilab software, a sample was taken for the interviews of 56 second-year students who took the subjects of Electrical Circuits in the period 2020 -2021, which represents 80% of the total enrollment, of the career of electrical engineering at the Technological University of Havana, CUJAE.

The form that served as a guide for conducting the interview was structured as follows:

**Question No. 1.** In your opinion, do you consider that the laboratory practices proposed with the software helped you to reinforce the theoretical contents?

The answers to this question are shown in table 1.

**Table 1.** Results of Question No 1

Answers	Frequency	%
Yes	53	94,6
No	2	3,6
To some extent	1	1,8
Total	56	100

**Analysis and interpretation:** Are observed that 94,6% of the interviewed students consider that the laboratory practices proposed with the free software Scilab helped them to understand the theoretical contents taught in the conferences, which translates into a good relationship between theory and practice in the proposal, improving the teaching-learning process of the Electric Circuits subjects.

**Question No. 2.** In your opinion, did the use of the Scilab software in the proposed practices help you acquire skills in performing electrical measurements?

The responses to this question are shown in table 2.

**Table 2.** Results of Question No 2

Answers	Frequency	%
Yes	55	98,2
No	1	1,8
To some extent	0	-
Total	56	100

**Analysis and interpretation:** 98,2% of the student's state that with the use of the software they acquired skills regarding the realization of the different variables to be measured in the electrical systems, and also the connection of the measuring instruments, an aspect that enhances student learning in electrical measurements and raises motivation and interest in the career.

**Question No. 3.** In your opinion, did carrying out the proposed laboratory practices as a team help you exchange knowledge and skills with your classmates?

The answers to this question are shown in table 3.

**Table 3.** Results of Question No 3

Answers	Frequency	%
Yes	50	89,2
No	3	5,4
To some extent	3	5,4
Total	56	100

**Analysis and interpretation:** 89,2% of the students emphasize that the formation of teams to carry out the proposed laboratory practices with the Scilab software helped them to exchange information regarding the use and implementation of the models in the software. As well as the study of the different models of the elements that make up electrical power systems applied to electrical circuits to understand their operation. This result shows that the formation of teams in carrying out the laboratory practices enhances the collaborative learning of the students, especially when problem situations of the profession are applied.

From the analysis of the results of the interview carried out, after putting into practice the virtual laboratories exposed here, it is confirmed that these help to understand how the theoretical contents are integrated with the practical ones, that is, a theory-practice link was achieved, which helped to improve the teaching-learning process, in addition, collaborative learning was enhanced from problem-based learning.

To contrast the results that have been obtained in the development of the teaching-learning process of the Electric Circuits subjects with the implementation of the proposed laboratory practices, the teaching results of the 2014-2015 courses were compared to 2018-2019 with the 2019-2020 course at the Technological University of Havana “José Antonio Echeverría”, CUJAE, after implementing the practices proposed here.

The result was a 23% increase in students passing midterm exams for the 2019-2020 academic year compared to the other academic years from 2014-2015 to 2018-2019, as shown in figure 10; which shows that the implementation of this type of exercise enhances the improvement of the teaching-learning process of the subjects of Electrical Circuits.

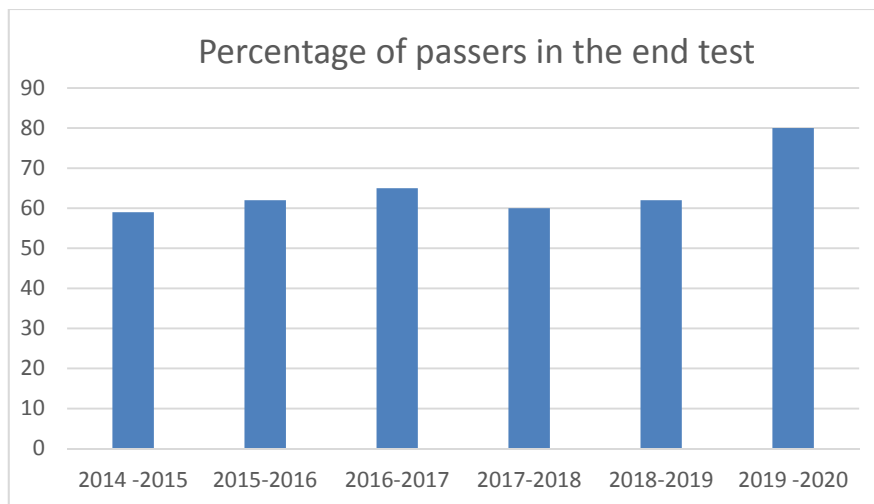


Fig. 10. Comparison of the academic courses of the electrical circuits subjects

## CONCLUSIONS

The above analysis leads us to think about the need to achieve a harmonic integration of ICTs in the curriculum, it is necessary to make them part of the curriculum as a whole. That is why the methodological work that is developed in the subjects of Electrical Circuits in the Electrical Engineering career promotes the use of Scilab software as an educational resource that enables experimentation through the application of the problem-based method, which has led to an improvement in the promotion of the subjects.

The Scilab software is characterized by being an educational resource that achieves a high degree of motivation and turns out to be useful for the learning of second-year students of the Electrical Engineering career in the subject of Electrical Circuits, with greater emphasis on the current context. determined by the convulsive health situation of confinement conditioned by COVID-19, which in turn minimizes the negative impact imposed by social isolation and the technological costs associated with it, particularly non-attendance in laboratories.

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## CONFLICT OF INTERESTS

The authors declare that there are no conflicts of interest

## CONTRIBUTION OF THE AUTHORS

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