Revista Científico Pedagógica
"Horizonte Pedagógico"

Pérez Martínez. Maykop
Artículo de investigación
Sección: Aula Abierta

Vol. 13, Año. 2024
ISSN-e: 2310-3637|RNPS-e: 2324-3647|RNSW: A-0872

Procedure for the resolution of general methods in electrical circuits using Scilab

Procedure for the resolution of general methods in electrical circuits using Scilab

Procedimiento para la resolución de los métodos generales en los circuitos eléctricos mediante Scilab

Recibido: 25/06/2024 | Aceptado: 20/08/2024 | Publicado: 06/09/2024

Maykop Pérez Martínez [1*]
Josnier Ramos Guardarrama [2]
Janette Santos Baranda [3]
Luis René Brizuela Bringuez [4]

[1*] Electrical Engineer, Master in Electrical Engineering, Assistant Professor, head of the Teaching Department and head of the Electrical Circuits Discipline, Faculty of Electrical Engineering, José Antonio Echeverría Technological University of Havana, Cujae. Cuba. PhD Student Doctorate in Engineering with a mention in Electrical Engineering, Universidad de Concepción, Chile. maykop1982@gmail.com ID ORCID https://orcid.org/0000-0003-3073-1675

[2] Electrical Engineer, Master in Electrical Engineering, Assistant Professor, José Antonio Echeverría Technological University of Havana, Cujae. Cuba. josnier@electrica.cujae.edu.cu ID ORCID https://orcid.org/0000-0002-8796-8481

[3] PhD in Pedagogical Sciences. Full Professor, director of the Reference Center for Advanced Education (CREA), José Antonio Echeverría Technological University of Havana, Cujae. Cuba. jsantos@tesla.cujae.edu.cu ID ORCID https://orcid.org/0000-0002-0225-5926

[4] Correspondent of the Inter Press Service Agency accredited in Havana. Cuba. luis4382@gmail.com ID ORCID https://orcid.org/0009-0008-8852-1017

Abstract:

Circuit analysis courses are essential in electrical engineering, as they enable students to understand and design complex electrical systems. These courses cover general methods for solving electrical circuits, including mesh and node methods, which allow students to model and simulate electrical behaviors. Additionally, the integration of Information and Communication Technologies (ICT) in the teaching-learning process has significantly improved the way these concepts are taught and learned. ICT enables the creation of interactive simulations, circuit visualizations, and data analysis, making it easier for students to understand and learn. These technologies are crucial for electrical engineering students to develop practical and theoretical skills to design and analyze complex electrical systems. The article aims to propose a tool using Scilab software that allows students to verify the analytical response of electrical circuits by applying node and mesh methods. During the research and design of the proposal, analytical-synthetic, inductive-deductive methods and systematization were employed. The main result is the recognition of the tool's utility in improving student self-learning and the teacher's role as a guide through interactivity. The proposal also verifies theoretical contents with practical ones, enabling students to engage in self-learning, collaborative learning, and self-assessment.

***Keywords*:** scilab; teaching-learning process; electrical circuits; branch; node.

Resumen:

Las asignaturas de circuitos eléctricos son fundamentales en la carrera de ingeniería eléctrica, ya *que permiten a los estudiantes comprender y diseñar sistemas eléctricos complejos. En estas asignaturas se imparten los métodos generales de resolución de los circuitos eléctricos, el método de las mallas y el de los nodos, que permiten a los estudiantes modelar y simular comportamientos eléctricos. Además, la incorporación de las Tecnologías de la Información y la Comunicación (TIC) en el proceso de enseñanza – aprendizaje ha mejorado significativamente la forma en que se enseñan y se aprenden estos conceptos. Las TIC permiten la creación de simulaciones interactivas, visualizaciones de circuitos y análisis de datos, lo que facilita la comprensión y el aprendizaje de los estudiantes, además son clave para que los estudiantes de ingeniería eléctrica formen habilidades prácticas y teóricas para diseñar y analizar sistemas eléctricos complejos. El objetivo del artículo es proponer una herramienta a partir de software Scilab que le permita al estudiante comprobar la respuesta analítica de los circuitos eléctricos aplicando los métodos generales de nodo y malla. Durante la investigación y diseño de la propuesta se emplearon los métodos analíticos – sintético, inductivo – deductivo y la sistematización. Como resultado principal se reconoce la utilidad de la herramienta para mejorar el autoaprendizaje de los estudiantes y el trabajo del profesor como orientador y guía mediante la interactividad, además con la propuesta se verifican los contenidos teóricos con los prácticos posibilitando a los estudiantes el autoaprendizaje, el aprendizaje colaborativo y la autoevaluación.*

Palabras clave: *Scilab; proceso de enseñanza – aprendizaje; circuitos eléctricos; malla; nodo.*

Introduction

The training of professional skills based on the development of theoretical and practical contents and knowledge is essential for the improvement of the teaching-learning process of electrical circuits in electrical engineering students.

In this sense, Cerato & Gallino, (2018) affirm that the training of professional skills is essential for engineering students, as it allows them to develop the necessary capabilities to succeed in their professional field, as well as to apply theoretical knowledge to real situations, developing essential practical competencies for problem-solving in the field of engineering.

On the other hand, the training of professional skills promotes active and meaningful learning, where students engage more deeply with the content and develop critical and creative thinking. Beyond technical competencies, the development of professional skills contributes to the holistic development of the student, strengthening aspects such as autonomy, adaptability, and responsibility. It also enables greater student engagement with the social and business context, facilitating their integration and performance in the workforce.

It is important to highlight that electrical circuits subjects are an integral part of the degree, as they allow students to understand and design complex electrical systems. They are fundamental in the field of electrical engineering, as they enable students to comprehend and design intricate electrical systems.

In these subjects, basic concepts, elements, laws, general analysis methods, and fundamental theorems related to the analysis of electrical circuits are studied, stimulated by both direct current and single-phase and three-phase alternating current. This constitutes a basic theoretical and practical training necessary for their use in the electrical sector. Throughout the teaching-learning process, all the practical skills necessary for their use in the workplace and in other disciplines in later years are acquired, as well as the confrontation and verification of the theoretical foundation, providing students with a scientific method of work. Pérez, et al., (2022) The nodal and mesh analysis methods, according to González, (2017), are fundamental in the analysis and design of electrical circuits. These methods allow electrical engineers and electrical engineering students to understand and solve complex problems.

Nodal analysis is a method based on choosing node voltages as circuit variables. This method reduces the number of equations that need to be solved simultaneously, making the analysis of complex circuits easier. Nodal analysis is particularly useful when combined with Kirchhoff's laws, such as Kirchhoff's voltage law and Kirchhoff's current law.

On the other hand, mesh analysis is another fundamental method in solving electrical circuits. A mesh is a closed path formed by electrical components connected in series. Meshes are essential to ensure the continuous flow of current in a circuit and to identify and solve problems that may affect the current flow. Mesh analysis provides another general procedure for analyzing circuits by using mesh currents as circuit variables. The use of mesh currents, instead of element currents, as circuit variables is convenient and reduces the number of equations that must be solved simultaneously. Anaut et al., (2009) and Salazar et al., (2017).

There are many benefits that general methods for solving electrical circuits offer when solving a particular electrical circuit, among them are, according to Pérez, Vásquez, & Viloria, (2019), Gualotuña, et al.,(2020), and Cardero, et al., (2022), the following:

- **Circuit efficiency**: The use of meshes in an electrical circuit can increase its overall efficiency. By analyzing the currents and voltages in different parts of the circuit, we can identify any inefficiency or energy loss and make adjustments to improve the circuit's efficiency.
- **Current flow:** Meshes ensure the continuous flow of current in a circuit. By forming closed meshes, an uninterrupted path is created for the current to flow through the components connected in series. This is essential for the devices or loads connected to the circuit to function properly.
- **Error reduction:** Nodal and mesh analysis methods allow for the reduction of common errors when working with electrical circuits. By using these methods, we can quickly identify and solve any problems that may affect the current flow or the efficiency of the circuit.

On the other hand, Cañizares, et al., (2024) argue that Information and Communication Technologies (ICT) have revolutionized higher education in contemporary society. The incorporation of ICT in higher education has changed the ways of teaching and learning, and has had a significant impact on students' learning styles.

ICT has enriched the practice of the teaching-learning process for students, improving teaching skills and providing access to a wealth of online educational resources. Students can learn autonomously and explore topics of interest on their own. The teacher, on the other hand, takes on the role of a guide by supporting students in their teaching-learning process. Instead of being the sole provider of knowledge, the teacher becomes a facilitator and guide of learning, as ICT provides students with access to a wealth of online educational resources, enabling them to learn autonomously and explore topics of interest on their own.

Furthermore, ICT has contributed to social development and inclusion. In this regard, higher education has undergone changes and transformations in the dynamics of the teaching-learning process, which has allowed for the consolidation, among other aspects, of distance education, increasing accessibility and the quality of education.

Another important aspect is the development of virtual learning platforms, which have been a powerful tool for enhancing higher education. These platforms allow for the creation and development of complete courses on the web without the need for deep programming or graphic design knowledge.

In this context, (Fonseca, Barbieri, & Ferreira, 2019) suggest that the use of software tools like Scilab has proven to be an effective strategy to enhance the teaching-learning process of Electrical Circuits subjects by applying these general resolution methods.

On the other hand, (Gomez, Cabrera, & Robles, 2023) state that Scilab is a scientific programming and numerical analysis software widely used in teaching electrical circuits. Some of the main applications of Scilab in this context include:

- **Resolution of electrical circuit problems**: Scilab allows students to model and simulate the behavior of electrical circuits, applying analysis methods such as nodal and mesh analysis. This facilitates the understanding of theoretical concepts and the verification of results analytically.
- **Design and analysis of circuits**: Students can use Scilab to design and analyze different configurations of electrical circuits, evaluating the impact of changes in component parameters. This enables them to develop professional design skills.
- **Visualization and interactivity**: Scilab offers visualization tools that allow students to interact with electrical circuits, observing their behavior in real-time. This enhances the understanding of concepts and motivates students in their learning.

In this sense, the use of Scilab in electrical circuits subjects has shown various benefits, among which the following stand out:

- **Improvement of learning:** Students can compare theory with practice, which facilitates the understanding of concepts and the development of practical skills.
- **Promotion of self-learning**: Scilab allows students to conduct simulations and analyses autonomously, promoting self-regulated and collaborative learning.
- **Increased motivation:** The interactivity and visualization provided by Scilab enhances students' motivation for the subject and the field of electrical engineering.

Due to the aforementioned, the objective of this article is to propose a procedure for solving general methods in electrical circuits using Scilab, which will provide a tool for verifying the analytical solution when applying general methods in solving electrical circuits and thus improve the teaching-learning process of the subjects..

Materials and Methods

In order to achieve the objective of this research, it was necessary to verify existing theoretical studies and search for accumulated scientific knowledge regarding methodological and procedural applications for solving electrical circuits and the use of professional open-source software. The study was based on a descriptive qualitative methodology, utilizing documentary analysis methods and the systematization of documentary sources that serve as references for this work, particularly those that highlight the importance of integrating ICT to enhance the teaching-learning process with an emphasis on the open-source software Scilab. As a result of the methodological work and the capabilities of Scilab, a procedure was developed to verify the result of the analytical solution when applying general mesh and nodal methods in electrical circuits, as show in figure 1.

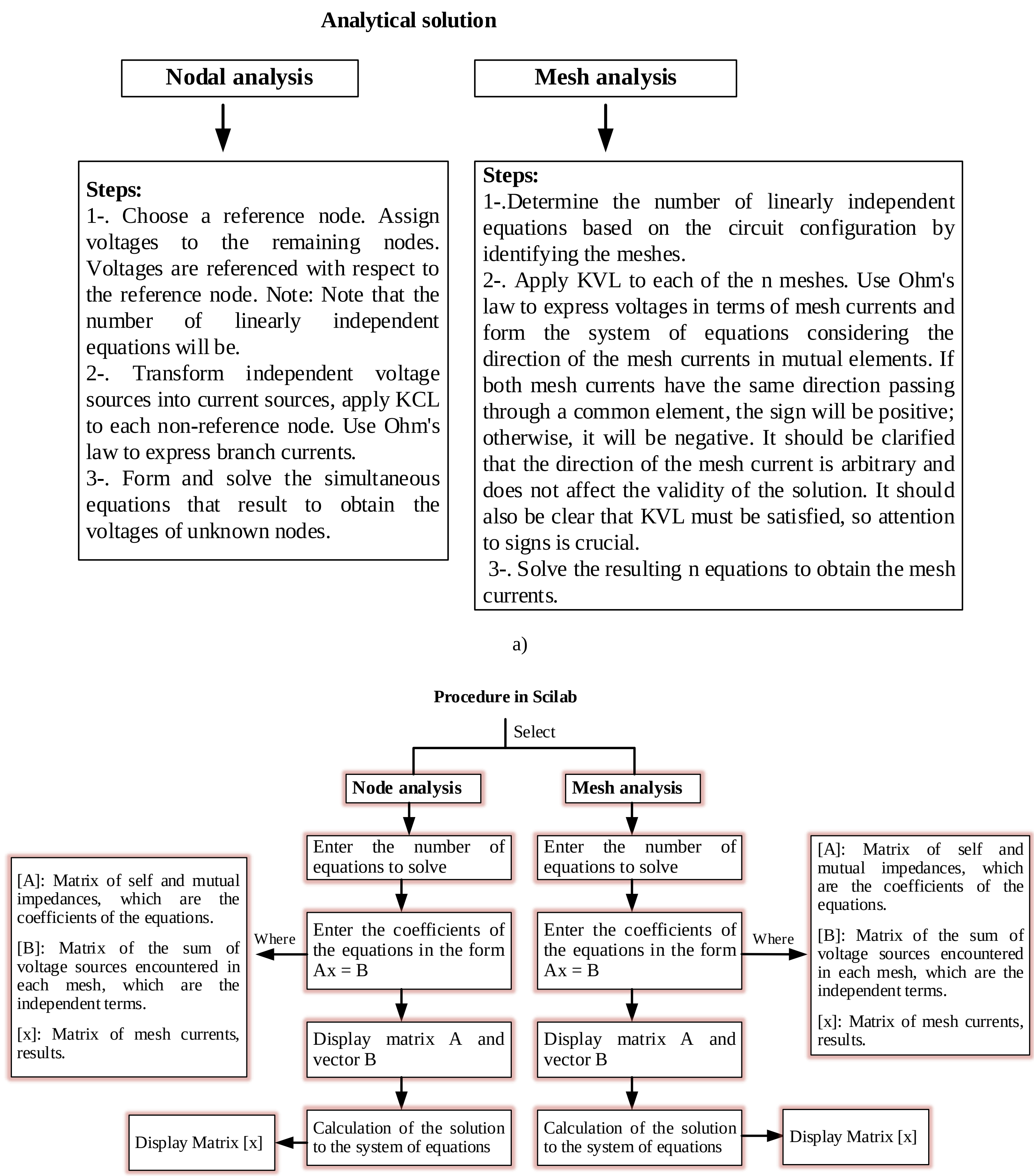

Fig. 1. a) Procedure for the analytical resolution of the nodal and mesh methods.
b) Procedure in Scilab for the resolution of the nodal and mesh methods.
(Source: Own elaboration)

Results and Discussion

In order to present the proposed procedure, two practical class exercises were solved together with the students, one using the nodal method and the other using the mesh method, to then verify their results using Scilab. The code developed in the Scilab script is shown below in figure 2.

```
disp('Select the method to use:')
disp('1. Mesh method')
disp('2. Nodal method')
method = input('Enter the number corresponding to the selected method: ');
if method == 1 then
   // Mesh method
   disp('You have selected the Mesh method.')
disp('Mesh method - Solving systems of equations')
disp('----------------------------------------------------------')
n = input('Enter the number of equations to solve: ');
A = zeros(n, n);
B = zeros(n, 1);
disp('Enter the coefficients of the equations in the form Ax = B:')
for i = 1:n
   for j = 1:n
      A(i, j) = input(sprintf('Enter the coefficient a(%d,%d): ', i, j));
   end
   B(i) = input(sprintf('Enter the independent term b(%d): ', i));
end
disp('The matrix A is:')
disp(A)
disp('The vector B is:')
disp(B)
x = A \ B;
disp('The solution of the system of equations is:')
disp(x)
elseif method == 2 then
   // Nodal method
   disp('You have selected the Nodal method.')
disp('Nodal method - Solving systems of equations')
disp('----------------------------------------------------------')
n = input('Enter the number of equations to solve: ');
A = zeros(n, n);
B = zeros(n, 1);
disp('Enter the coefficients of the equations in the form Ax = B:')
for i = 1:n
   for j = 1:n
      A(i, j) = input(sprintf('Enter the coefficient a(%d,%d): ', i, j));
   end
   B(i) = input(sprintf('Enter the independent term b(%d): ', i));
end
disp('The matrix A is:')
disp(A)
disp('The vector B is:')
disp(B)
x = A \ B;
disp('The solution of the system of equations is:')
disp(x)
else
   disp('Invalid option. Please select 1 or 2.')
end
```

Fig. 2. Code in the Scilab Script that allows the application of the nodal and mesh methods to an electrical circuit. (Source: Own elaboration)

Exercise proposed by the nodal method

Calculate the voltages at points 1 and 2 in the circuit shown in figure 3, applying the nodal method.

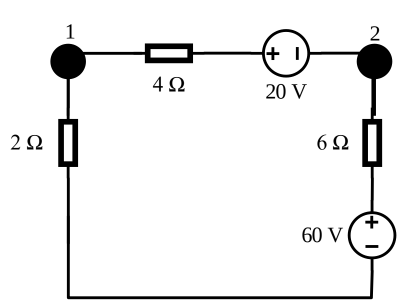

Fig. 3. Electrical circuit to be solved by the nodal method. (Source: Own elaboration)

Solution

The procedure for the nodal method described in Figure 1 in the Materials and Methods section will be applied for the solution. figure 4 shows the steps followed to obtain the voltages at points 1 and 2, as well as the equivalent circuits at each of them.

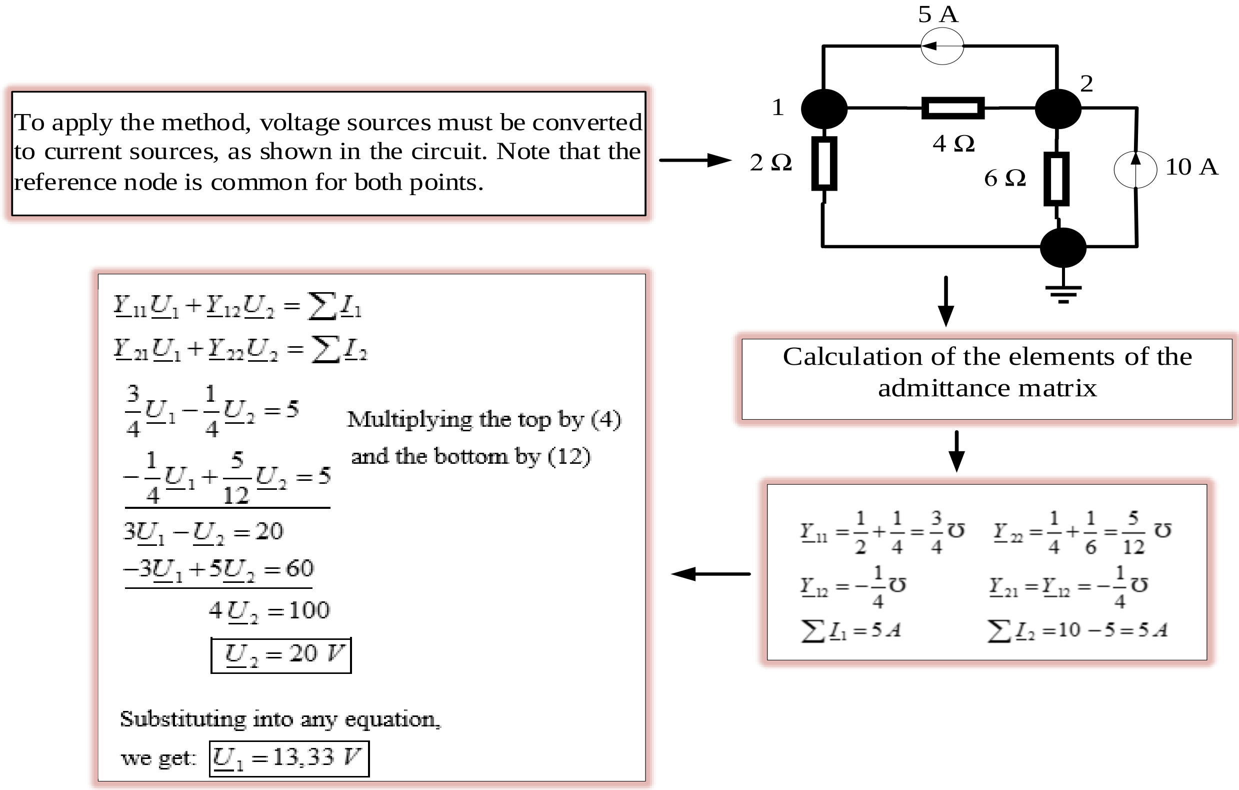

Fig. 4. Analytical result using the nodal method for the proposed electrical circuit. (Source: Own elaboration)

Now, to verify the proposed tool in the procedure, the process will be carried out as shown in figure 5, illustrating the Scilab software prompt when running the script. As can be seen, the voltage values match for both methods, demonstrating the utility of the proposed tool, allowing students to verify their analytical results through circuit simulation.

```
--> exec('C:\Users\Maykop Pérez Mtnez\Desktop\script_ingles.sce', -1)
  "Select the method to use:"
  "1. Mesh method"
  "2. Nodal method"
Enter the number corresponding to the selected method: 2
  "You have selected the Nodal method."
  "Nodal method - Solving systems of equations"
  "------------------------------------------------------------"
Enter the number of equations to solve: 2
  "Enter the coefficients of the equations in the form Ax = B:"
Enter the coefficient a(1,1): 3/4
Enter the coefficient a(1,2): -1/4
Enter the independent term b(1): 5
Enter the coefficient a(2,1): -1/4
Enter the coefficient a(2,2): 5/12
Enter the independent term b(2): 5
  "The matrix A is:"
   0.75  -0.25
  -0.25   0.4166667
  "The vector B is:"
   5.
   5.
  "The solution of the system of equations is:"
   13.333333
   20.
```

Fig. 5. Result using Scilab of the nodal method for the proposed electrical circuit. (Source: Own elaboration)

Exercise proposed by the mesh method

For the circuit shown in Figure 6, determine the mesh currents as indicated using the corresponding method.

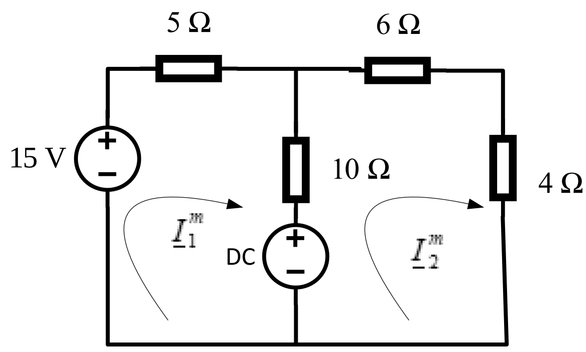

Fig. 6. Electrical circuit to be solved by the mesh method. (Source: Own elaboration)

Solution

Similarly, to the previous case, the procedure for the mesh method described in Figure 1 in the Materials and Methods section will be applied for the solution. Figure 7 shows the steps followed to obtain the mesh currents.

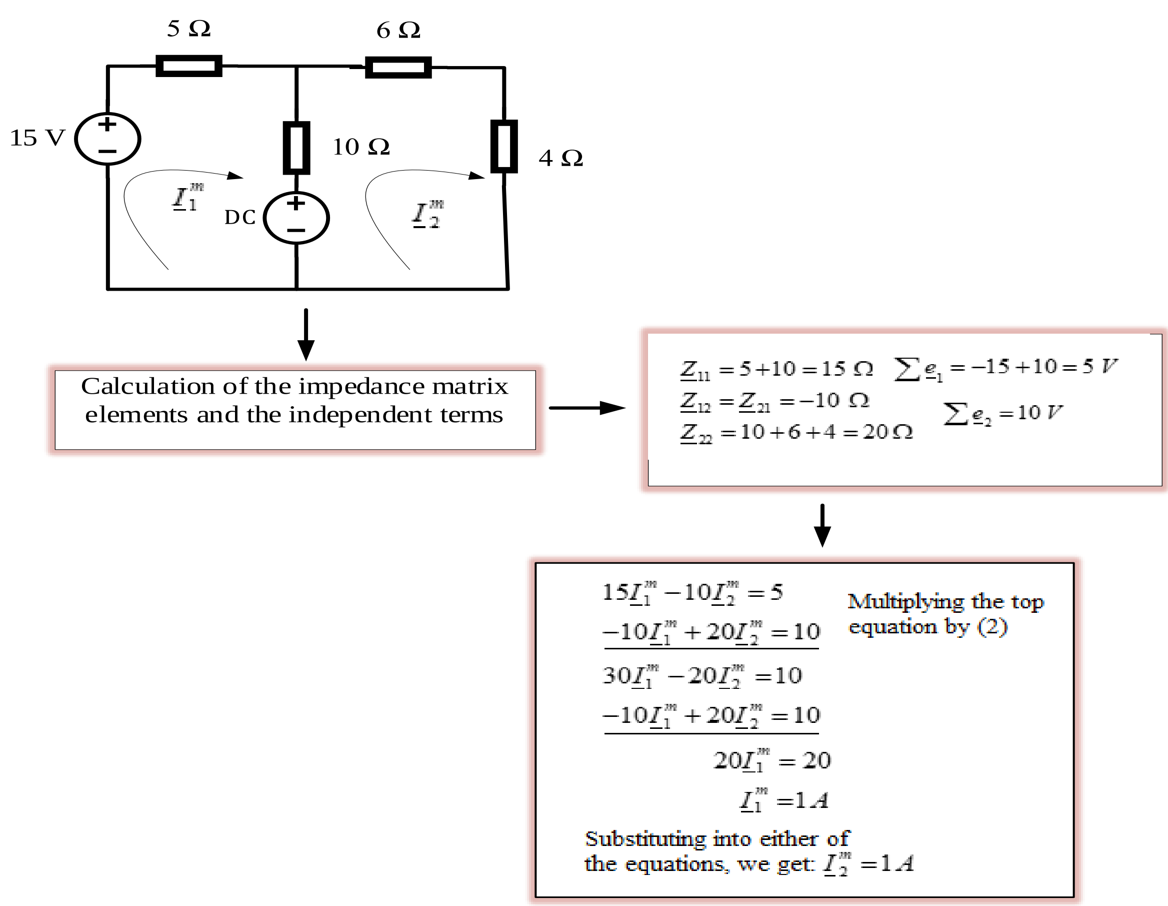

Fig. 7. Analytical result using the mesh method for the proposed electrical circuit. (Source: Own elaboration)

To verify the proposed tool in the procedure, the process will be carried out as shown in figure 8, which illustrates the Scilab software prompt when running the script. As can be seen, the mesh current values match for both methods, demonstrating the utility of the proposed tool, allowing students to verify their analytical results through circuit simulation.

Vol. 13, Año. 2024
ISSN-e: 2310-3637|RNPS-e: 2324-3647|RNSW: A-0872


```
--> exec('C:\Users\Maykop Pérez Mtnez\Desktop\script_ingles.sce', -1)
 "Select the method to use:"
 "1. Mesh method"
 "2. Nodal method"
Enter the number corresponding to the selected method: 1
 "You have selected the Mesh method."
 "Mesh method - Solving systems of equations"
 "---------------------------------------------------"
Enter the number of equations to solve: 2
 "Enter the coefficients of the equations in the form Ax = B:"
Enter the coefficient a(1,1): 15
Enter the coefficient a(1,2): -10
Enter the independent term b(1): 5
Enter the coefficient a(2,1): -10
Enter the coefficient a(2,2): 20
Enter the independent term b(2): 10
 "The matrix A is:"
  15.  -10.
 -10.   20.
 "The vector B is:"
  5.
  10.

 "The solution of the system of equations is:"

  1.
  1.
```

Fig. 8. Result using Scilab of the mesh method for the proposed electrical circuit. (Source: Own elaboration)

In order to evaluate the usefulness of the proposal, a structured interview was conducted with a sample of 30 students who took the Electrical Circuits I course in 2024. Three fundamental aspects were assessed: development of self-learning, verification of theoretical contents with practical ones, development of practical skills. Figure 9 shows the results.

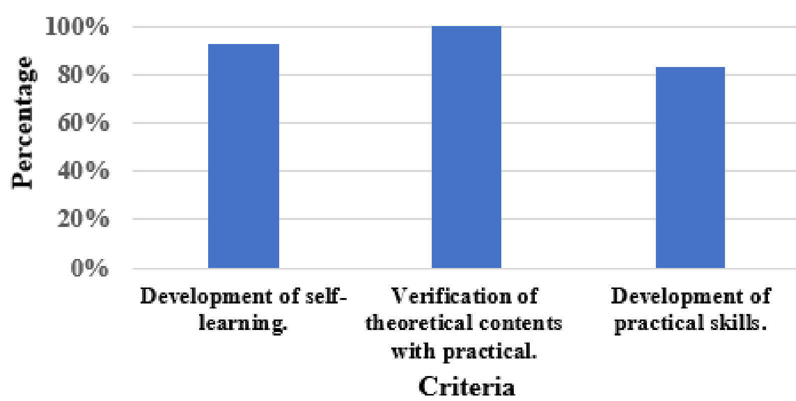

Fig. 11. Results of the applied interviews. (Source: Own elaboration)

From the comparison of the results, it can be interpreted that through the proposed procedure based on the tool developed in Scilab, the teaching-learning process of the Electrical Circuits subject was improved. As observed, 93,3% of the interviewed students claim that they developed self-learning. On the other hand, 100% emphasize that the tool developed with Scilab software ensures a proper connection between theoretical and practical content when applying the node and mesh methods to an electrical circuit. Additionally, 83,3% agree that they developed practical skills, reinforcing their theoretical and practical knowledge.

Conclusions

The use of Scilab software in the subjects of Electric Circuits and the procedure proposed here has proven to be an effective strategy to improve the teaching-learning process in the training of electrical engineering students, specifically in the application of the nodal method and the mesh method.

Scilab allows students to solve problems, design and analyze electrical circuits, as well as visualize their behavior interactively, which facilitates the understanding of theoretical concepts and the development of practical skills.

On the other hand, ICT has had a significant impact on higher education. They have improved student learning practices, enhanced teaching skills, and provided access to a wealth of educational resources. It is important that higher education institutions integrate digital competency training into their curriculum and promote the proper and effective use of ICT to maximize its benefits.

Bibliographic References

Anaut, D., di Mauro, G., Meschino, G., & Suárez, J. (2009). Optimización de Redes Eléctricas Mediante la Aplicación de Algoritmos Genéticos. *Información Tecnológica, 20*(4), 137-148. DOI: 10.1612/inf.tecnol.4089it.08

Cañizares , E., Ferrer , G., Espinosa, N., & Guillen, E. (2024). Estilos de aprendizaje y Tecnologías de la Información y la Comunicación en la Educación Superior. *Edumecentro, 16*, 1 - 17. Recuperado el 2024, de http://scielo.sld.cu/pdf/edu/v16/2077-2874-edu-16-e2631.pdf

Cardero , C., Salazar , F., Castro, T., Jaime, G., Cervantes, O., & Barrero, F. (2022). Reconfiguración multiobjetivo en sistemas de distribución primaria con presencia de generación distribuida. *Ingeniare. Revista chilena de ingeniería, 30*(3), 592-601. DOI: http://dx.doi.org/10.4067/S0718-33052022000300592

Cerato, A. I., & Gallino, M. (2018). Competencias genéricas en carreras de ingeniería. *Ciencia y Tecnología , 18*(2), 83 - 94. Recuperado el 2024, de https://dspace.palermo.edu/ojs/index.php/cyt/article/view/58/40

Fonseca, d. O., Barbieri, L., & Ferreira, C. (2019). Experimentando con Arduino y Scilab: propagación de calor en una barra metálica. *Revista Brasileira de Ensino de Física, 41*(4). DOI: https://doi.org/10.1590/1806-9126-RBEF-2018-0356

Gomez, R., Cabrera, D., & Robles, P. (2023). Estudio para la localización de fallas en sistemas de distribución eléctricas. *Ingenius. Revista de Ciencia y Tecnología*. DOI: https://doi.org/10.17163/ings.n30.2023.06

González, H. (2017). Implementación de circuitos eléctricos para facilitar el aprendizaje de sistemas algebraicos lineales. *Revista Iberoamericana para la Investigación y el Desarrollo Educativo, 7* (14), 1 - 12. DOI: http://dx.doi.org/10.23913/ride.v7i14.272

Gualotuña, R., Ramírez, J., Lucio, M., Granda, N., & Quilumba, F. (2020). Estimación de los Parámetros Eléctricos de una Línea de Transmisión Trifásica a Escala de Laboratorio a Partir de Mediciones de Transitorios de Voltaje. *Revista Técnica "energía", 16*(2), 9–18. DOI: https://doi.org/10.37116/revistaenergia.v16.n2.2020.348

Pérez, M. M., Ramos, G. J., Santos, B. J., Santos, F. A., Silvério, F. R., & Ayllón, F. E. (2022). *Propuestas metodológicas para el plan de estudios E de las asignaturas de circuitos eléctricos. Revista Ingeniería Energética, Vol. 43, No. 3, ISSN 1815-5901.* Recuperado el 2023, de https://rie.cujae.edu.cu/index.php/RIE/article/view/695/847

Pérez, R., Vásquez, C., & Viloria, A. (2019). *Métodos de localización de fallas en sistemas eléctricos de distribución con presencia de generación distribuida.* Quito, Ecuador: INGA ORTEGA, E., ed. Aplicaciones e innovación de la ingeniería en ciencia y tecnología. Editorial Abya-ISBN: 978-9978-10-491-0. DOI: https://doi.org/10.7476/9789978104910.0004.

Salazar, F., de la Fé, D., & Torres, G. (2017). Reconfiguración multiobjetivo en sistemas de distribución primaria de energía. *Ingeniare. Revista chilena de ingeniería*, *25*(2), 196-204. DOI: http://dx.doi.org/10.4067/S0718-33052017000200196

Contribución de los autores

No.	Roles de la contribución	Autor 1	Autor 2	Autor 3	Autor 4
1.	Conceptualización:	90%	4%	4%	2%
2.	Curación de datos:	70%	10%	10%	10%
3.	Análisis formal:	70%	5%	10%	15%
4.	Investigación:	70%	10%	10%	10%
5.	Metodología:	85%	5%	5%	5%
6.	Software:	80%	10%	5%	5%
7.	Validación:	80%	10%	5%	5%
8.	Visualización:	80%	10%	5%	5%
9.	Redacción – borrador original:	70%	10%	20%	20%
10.	Redacción – revisión y edición:	80%	10%	10%	10%

Declaración de originalidad y conflictos de interés

El/los autor/es declara/n que el artículo: **Procedimiento para la resolución de los métodos generales en los circuitos eléctricos mediante Scilab**

Que el artículo es inédito, derivado de investigaciones y no está postulando para su publicación en ninguna otra revista simultáneamente.

- Que se acepta tanto la revisión por pares ciegos como las posibles correcciones del artículo que deban hacerse tras comunicarle/s la oportuna disconformidad con ciertos aspectos pertinentes en su artículo.
- Que en el caso de ser aceptado el artículo, hará/n las oportunas correcciones en el tiempo que se estipule.
- No existen compromisos ni obligaciones financieras con organismos estatales ni privados que puedan afectar el contenido, resultados o conclusiones de la presente publicación.

A continuación, presento los nombres y firmas de los autores, que certifican la aprobación y conformidad con el artículo enviado.

Autores

Maykop Pérez Martínez

Josnier Ramos Guardarrama

Janette Santos Baranda

Luis René Brizuela Bringuez