Study on Independent Experiment Model of Thevenin Theorem by Using DCAC Lab

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Abstract

This paper discusses the Study on the Independent Experiment Model of Thevenin Theorem by Using DCAC Lab which this theoretical was covered in the DET10013 Electrical Technology subject. This subject was taken by students in semester 1 and all the programme in the Electrical Engineering Department (JKE) it is compulsory. The lecturer presents the performance index requirements, self-learning experimentation for students, and the procedures for using the relevant instruments and meters. The students then independently design the experimental instruments and select them based on the requirements. The students engage in experimental activities involving the measurement of real quantities, the development of their experimental procedures, the recording of experimental data, and the use of advanced circuit simulation. They also can construct their circuits in the classroom and operate them as part of an experimental model. Experimental proof demonstrates that implementing a self-directed experimental teaching approach effectively stimulates students' enthusiasm, enhances their fundamental experimental skills, nurtures their comprehensive experimental aptitude and innovative experimental capabilities, and ultimately enhances the quality of subsequent related experimental courses.

Keywords **:** *Thevenin Theorem, DCAC Lab, Thevenin Voltage (VTH), Thevenin Resistance (RTH).*

I. INTRODUCTION

Thevenin Theorem is a fundamental lesson that should be included in the curriculum in higher engineering institutes. It provides a basis for studying additional vocational education. The teaching curriculum consists of two components: theory and experimentation. French telegraph engineer Léon Charles Thevenin (1857–1926) of the Posts of Telegraphs, the French national communications company at the time, is the inspiration for the name Thevenin's Theorem [1]. Ideal resistors and sources form a linear output voltage source at a pair of terminals. The Voltage and resistance of the ideal voltage source element are called the Thevenin voltage and resistance, respectively [2]. A voltage source Vin series with resistance can be used as a substitute for any linear network that includes resistances, dependent linear sources, and independent voltage and current sources. The Thevenin equivalent is the name given to the corresponding network. When no current is flowing into either terminal of the original network, the voltage is known as the open-circuit voltage or Voc. Thevenin resistance is the same as the original network's resistance R when dependent sources are not present; in this case, voltage and current are supplied by open and short circuits, respectively. It is not possible to regulate independent sources when they coexist with dependent ones. Rr = Voc lsc is the formula for resistance, with Isc representing the original networks short-circuit current. A source of current (or voltage) is connected to the terminals of the network when only the dependent sources are present. In this case, the Thevenin voltage is not defined [3]. Experimental teaching is a vital component of the educational process. The circuit course mainly focuses on confirmatory experiments, with subsequent emphasis on design and thorough experiments, by its characteristics. The primary objective of the basic confirmatory experiment is to reinforce students' comprehension of theoretical concepts and enhance their practical skills. This includes developing proficiency in using common electronic instruments and equipment, selecting appropriate components, measuring fundamental physical quantities, and troubleshooting common malfunctions.

Received: 02 March 2024
Revised: 21 March 2024
Accepted: 24 March 2024
Publisher: ICBE Publication

Constructing on the basic instruction in experimentation, the design experiment requires that students create a plan for the experimental procedure, choose appropriate devices and testing instruments based on the design objective, and independently. design experiments involving common unit circuits capable of performing fundamental functions. The exclusive implementation of an experimental teaching method significantly limits students' cognitive capacity and diminishes their motivation and passion for learning the subject. By integrating years of theoretical and experimental teaching experience and adjusting to the demands of the current teaching reform and system, the traditional teaching approach has been transformed. The experiment box serves as the fundamental platform, with the experimental circuit being standardised and modularized. This enables students to independently design their experimental circuits, select suitable instruments, and accurately measure physical quantities. The integration of the validating experiment and the design experiment enhances the students' practical skills and independent learning ability, and exemplifies the notion of "scientific, enlightening, and adaptable".

II. LITERATURE REVIEW

There exist specific theorems that, when applied to electric networks, either simplify the network or make its analytical solution significantly easier. These theorems are also applicable to an alternating current (AC.) system, with the single variable being that impedances are substituted for the ohmic resistance that exists in a direct current (DC) system[4]. Circuit Analysis is used to simplify the circuit by using several theorems to monitor and analyse the overall circuit. One of the analysis theorems is the Thevenin Theorem. A commonly seen scenario where the Thevenin equivalent circuit consists solely of a passive resistor, it is also worth addressing the reverse case where Thevenin Voltage (Vth) is non-zero, but the resistor has a value of zero (or infinity). This example has the potential to be valuable in the development of optimal regulated voltage or current sources[5]. Frequently, in practical situations, there is a certain component in an electrical circuit that may be adjusted (commonly referred to as the load), while the other components remain constant. For instance, a common case involves connecting a household outlet terminal to several appliances, resulting in a fluctuating load. Whenever the variable element is modified, the complete circuit must undergo a comprehensive analysis once more. To circumvent this issue, Thevenin's theorem offers a methodology wherein the stationary portion of the circuit is substituted with an analogous circuit. Thevenin's theorem states that the linear circuit depicted in Figure 1(a) can be substituted with the circuit shown in Figure 1(b). The load depicted in Figure 1 can be either a solitary resistor or another interconnected circuit. The circuit adjacent to the terminals a-b in Figure 1(b) is referred to as the Thevenin equivalent circuit[6].

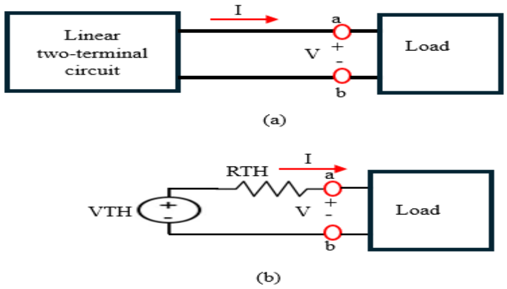

Figure 1 (a): Original Circuit (b): Thevenin equivalent circuit.

VTH refers to the voltage across the load terminals when there is no current flowing through them, whereas RTH represents the resistance at the terminals when all independent sources are off [7]. Figure 2(a) shows the actual circuit before applying the Thevenin theorem, which in the circuit will consist of a Load Resistor (RL). Meanwhile, Figure 2(b) shows the equivalent circuit after Thevenin Theorem is applied.

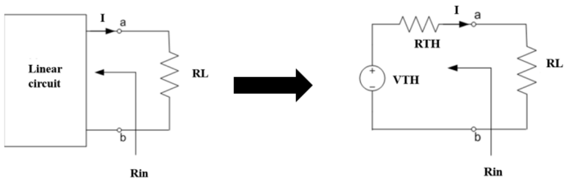

Figure 2 (a): Original Circuit (b): Thevenin equivalent circuit.

With consideration to any two terminals, a voltage source (Vr) (which is the open-circuit voltage) connected in series with the resistance between them can stand in for any linear network. Substituting the internal resistance of each device for its independent voltage and current sources yields the total resistance (Zyy).

Sources of voltage are considered short-circuited, while sources of current are considered open-circuited. Both Vr and Zyy are known as the

Received: 02 March 2024
Revised: 21 March 2024
Accepted: 24 March 2024
Publisher: ICBE Publication

Thevenin voltage and resistance, respectively [8]. This theorem applies to networks of batteries and resistors within the dashed lines, regardless of their complexity, under the condition that all elements adhere to a linear relationship between voltage and current. This applies to circuits that consist solely of batteries and resistors [9].

The step of solution Thevenin Theorem is referred to the step below according to Bird et al [10]:

i. Remove The Load Resistor (RL)
ii. Determine the Thevenin Voltage (VTH) across the break.
iii. Calculate the Thevenin Resistance (RTH) by shorting the circuit if the voltage source terminal is given and opening the circuit if the current source is given.
iv. Convert the circuit into a Thevenin Equivalent circuit with RL.
v. Calculate the value of load current (IL)

III. RESEARCH METHODOLOGY

The process of the teaching method is divided into 3 steps which consist of a selection of experiment contents, Implementation of the Teaching Method, and comparison of the theoretical and experimental results.

A. Selection of experiment contents

The circuit experiment is the first course in our electrical speciality, while the circuit theorem experiment is a basic course. For students, learning instrument use and skilful experiment operation are equally important. Implementing experimental techniques and routines helps them become qualified technicians. Teaching students basic theoretical design and calculation can be challenging to engage them in learning. Students are more interested in whether the study can successfully tackle practical issues. Educators often design different topics and teaching methods for the same knowledge point, resulting in varying experimental teaching effects. According to Ya-ning et al., experimental teaching content is linked to teaching objects. Different levels of students require varying teaching content [11]. For different teaching levels, the experimental content is divided into two parts which consist of a basic part and an improvement part. At a basic part, students need to know using the DCAC lab software which students can open the software and draw the selection circuit into the software. Figure 3 refers to the library of the components that students can use during the experiment [12]. There are many components that students can use during the experiment.

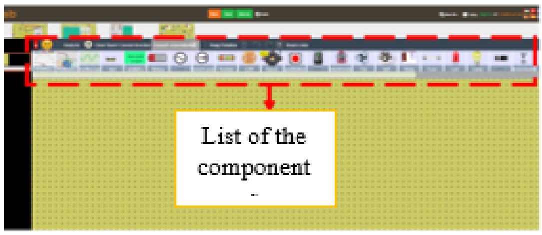

Figure 3: Layout of DCAC Lab

B. Implementation of the Teaching Method

At this phase, students will be guided on how to simulate the Thevenin Theorem by using DCAC LAB. The students will give the parameters to set. Based on the simulation students will get results such as the reading of Thevenin Resistance (RTH), Thevenin Voltage (VTH) and load current (IL). Figure 4 refers to the circuit that students need to draw in the DCAC software. This circuit is according to Hongyang et. Al which from the simulation the value of IL is needed to answer by considering the RL is equal to 10Ω.

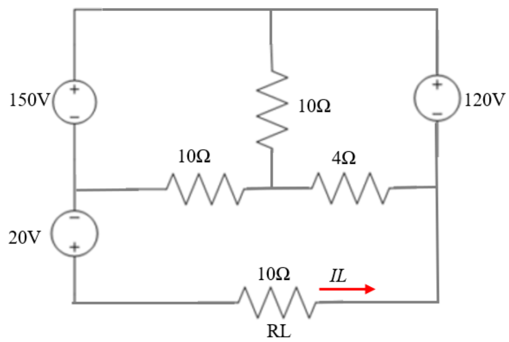

Figure 4: Experiment Circuit [13].

Based on Figure 5, the experimental circuit is constructed. From the circuit, students need to set up the value of the DC supply which consists of 150V, 120V and 20V. Besides this, students also need to set up the arrangement of the resistor with the accurate value.

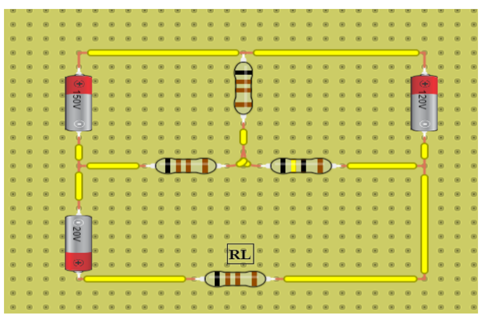

Figure 5: Experiment with the Circuit by using the DCAC lab.

Received: 02 March 2024
Revised: 21 March 2024
Accepted: 24 March 2024
Publisher: ICBE Publication

International Conference on Business Studies and Education (ICBE)
e-ISSN: 2785-9479

Now, the step to solve of Thevenin Theorem is used to solve this experiment. Firstly, the RL will be removed from the circuit and measure the VTH at the terminal break by using the voltmeter. Figure 6 shows how to measure the voltage.

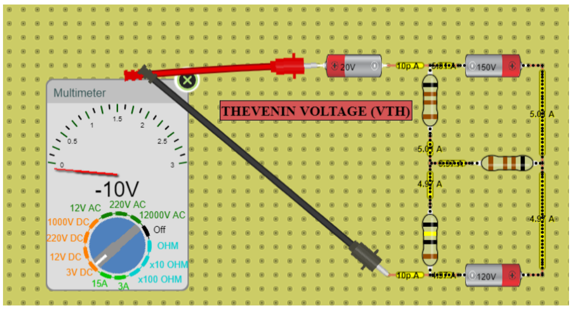

Figure 6: Experiment with the Circuit by using the DCAC lab.

The second step is to measure the RTH by taking out the voltage supply and shorting the terminal of the supply. It should be noted that the independent voltage source is deactivated. To deactivate an independent voltage source, it is necessary to substitute it with a short circuit. Similarly, to deactivate an independent current source, it needs to be replaced with an open circuit [14]. By using the ohm meter, the value of the RTH can be obtained. Figure 7 shows how to measure the RTH at the circuit.

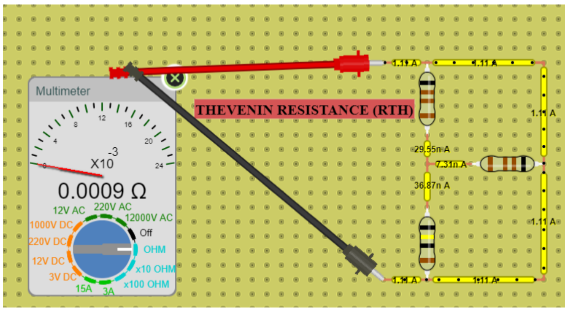

Figure 7: Measuring of RTH.

After the value of VTH and RTH is obtained. The equivalent circuit of Thevenin Theorem is constructed according to Figure 8 which the circuit only consists of VTH as a supply source, series connection between RTH and RL. From this circuit, the measuring of IL can be obtained.

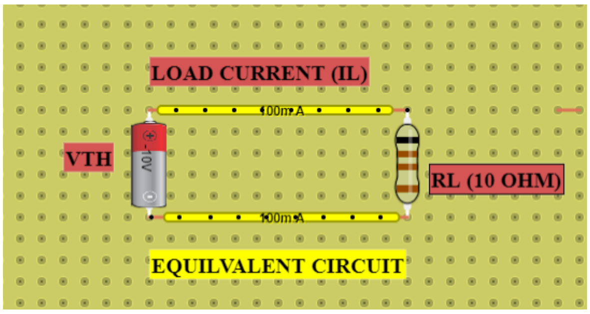

Figure 8: Thevenin Theorem Equivalent circuit

C. Comparison of the theoretical and experimental results

Finally, at this phase, students will compare the simulation results with calculations before doing the hands-on during the practical classes. During the practical sessions, students will able to conduct and construct the circuit easily by following the procedure during the simulation.

V. RESULT AND DISCUSSION

A. Theoretical solution

By referring to Figure 4, remove the RL from the circuit. Figure 9 refers to the circuit after removing RL and based on the circuit the VTH is calculated. To calculate the value of VTH the node or mesh to be used. According to Rubido et al, If inputs and outputs change frequently, such as when a voltage generator's cathode and anode are moved from one node to another, nodal and mesh methods become inefficient for recalculating voltage drops across the network. This switching is common in supply-demand networks and modern power-grid impedance network circuit models [15].

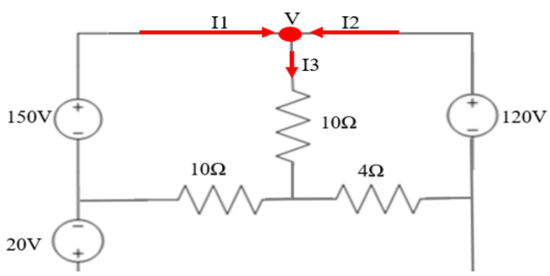

Figure 9: Circuit without RL

Received: 02 March 2024
Revised: 21 March 2024
Accepted: 24 March 2024
Publisher: ICBE Publication

By using Node analysis, calculate the voltage drop at node V and calculate the value of I1 and I2. After that, calculate the voltage drop between V1 and V2 across the10Ω and 4Ω according to Figure 10. Lastly, the VTH will be determined.

$$\frac{150-V}{10}-\frac{V}{10}+\frac{120-V}{4}=0$$

$$15-0.1V-0.1V+30-0.25V=0$$

$$-0.45V+45=0$$

$$0.45V=45$$

$$V=\frac{45}{0.45}=100V$$

$$I1=\frac{150-100}{10}=5A$$

$$I2=\frac{120-100}{4}=5A$$

$$V1=I1(10)=(5)(10)=10V$$

$$V2=I2(4)=(5)(4)=20V$$

$$20+VTH-V2+V1=0$$

$$20+VTH-20+10=0$$

$$VTH=-10V$$

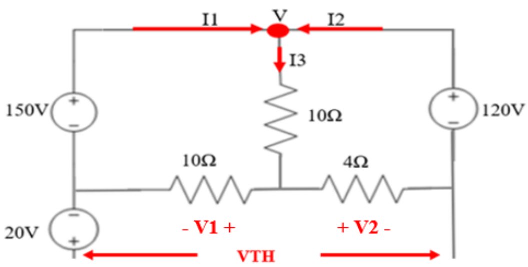

Figure 10 : Circuit without VTH

After the value of VTH is calculated, according to Figure 11, remove all the voltage sources and short all the terminals to calculate the RTH. RTH equals zero because there is a short circuit between loop 1 and loop 2. The Thévenin resistance is calculated by dividing the voltage of the Thévenin, which is also known as the open-circuit voltage, by the voltage of the short-circuit [16].

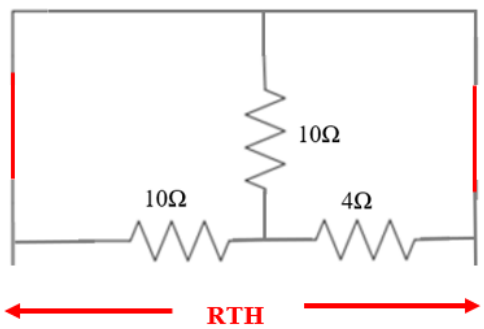

Figure 10 : Circuit without VTH

Based on Figure 11, the value of IL can be determined by using the formula of Ohm law which Ohm's law relates potential difference and electric current. Current flows through most conductors proportionally to voltage [17]. The algebraic expression states that voltage (V) is the product of current (I) and resistance (R). By employing algebraic techniques, we can manipulate this equation into two distinct variations, enabling us to solve for the variables I and R individually [18]. So, based on the calculation, the value of IL is equal to -1A.

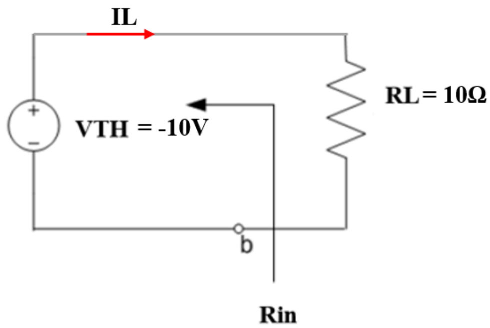

Figure 11: Equivalent circuit of Thevenin Theorem

$$IL=\frac{V}{R}=\frac{-10}{10}=-1A$$

A. Comparison between calculation and simulation results.

Table 1 shows the comparison result between the calculation and simulation of the Thevenin Theorem Circuit. Both results show the same answer. A small tolerance indicates a significant difference between the actual and measured resistance values. The measurement instruments used, like ohmmeters and voltmeters, had their internal resistance, which marginally impacted the outcome, adding to the small tolerance. Without considering the instrument and the actual resistor value, the precise value was determined using a theoretical approach. Therefore, the value has a small tolerance of around 5% [19]. When compared to the traditional experimental mode, the independent mode stands out due to its unique characteristics involving creative structure, compelling content, and strong narrative coherence. The topic of discussion can be categorised into three different aspects [20]:

1) The experimental content chosen is the typical classic circuit theorem, which has replaced previous methods of experimental verification and shifted towards experimental design. This change has increased the difficulty of the verification experiment.

Received: 02 March 2024
Revised: 21 March 2024
Accepted: 24 March 2024
Publisher: ICBE Publication

2) The students are taught the principles of experiments, instructions for using instruments, and how to independently design experimental circuits as required by the experiment. The circuit structure and parameters are self-governing. This approach enhances students' motivation to learn and their enthusiasm for experimentation, prevents students from simply copying data, enhances students' ability to identify and rectify common fundamental errors, improves their foundational experimental skills, deepens their understanding of theoretical knowledge, and enables students to apply knowledge from textbooks to practical circuitry. It establishes a robust experimental basis for future design through encompassing and autonomous experiments.

3) The level is unique. The advanced experimental content design accommodates diverse teaching objectives by catering to specific requirements. Effectively instruct students based on their abilities.

Table 1: Result between calculation and simulation

No	Calculation	Simulation
VTH	-10V	-10V
RTH	0Ω	0.0009Ω
IL	-1A	-1A

VI. CONCLUSION

In this study, we compared theoretical and practical results for a direct current resistive circuit that uses a range of positive voltages, from 150 V to 20 V. Results revealed measured and computed values for the Thevenin voltage, resistance, and load current. There is consistency between the theoretically calculated and measured values of the Thevenin voltage and resistance. In addition, the teaching methods allow students to fully engage in their learning experience and apply theoretical concepts through simulation and practical exercises.

ACKNOWLEDGMENT

Sincere express of appreciation to Polytechnic Ungku Omar for funding this paper.

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Received: 02 March 2024
Revised: 21 March 2024
Accepted: 24 March 2024
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Received: 02 March 2024
Revised: 21 March 2024
Accepted: 24 March 2024
Publisher: ICBE Publication