Analysis of magic table in completion of closed flow circuits

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Abstract. Problem of two-loop electric circuits is classified in the material that has a high degree of difficulty for students. Its completion requires several processes and a thorough analysis, translation of problem languages in mathematical language, applying concepts, and making algorithms. Electrical circuit material is often put into several tests which is implemented on university selection exams or national exam. In solving problems, students need a relatively long time. More effective and efficient methods are needed to solve the problem of two-loop electric circuits. The purpose of this research is to describe the Magic Table as a new solution in solving the electric current of a two-loop circuit more easily. The method used is the Ohm law concept and principle of simplifying Thevenin and Northon circuits, so that a replacement voltage is obtained to find the current strength in the circuit. This research analyzes several types of two-loop circuits with varying voltage and resistor sources. The results showed the calculation analysis using the magic table is easier and simpler than the elimination and substitution methods. With the application of simple concepts and algorithm, the Magic Table can be applied as a new solution to solving the problem of two-loop electric circuits.

1. Introduction

Physics is a science that has a big impact in the era of science and technology developments. Physics is also concerned on a collective knowledge, how to think, and conducting experiments to prove a theory under the purpose to develop a product is the required phase to be done in studying physics. According to the Indonesia Education Assessment Center 2019, the results of the National Examination 2019 high school level show that in science subjects the average value of Chemistry is 50.99, Biology 50.61, Physics 46.47, and Mathematics 39.33. From these data it can be seen that Physics ranks second lowest, so it can be indicated that there are still many students who have difficulty in solving physics problems. This can be caused by several factors, namely the mastery of weak concepts, and there is no critical thinking process to bring up creativity and innovation in solving physics problems, as well as students’ unpreparedness to accept learning to be done, so it is natural that physics is considered a difficult subject, complicated and requires more elaboration[1].

One of the many materials, Dynamic Electricity, is a material in physics that is considered to be difficult, this statement is supported by research [2] of the subject 214 students from 5 different schools, when they were given problems about Dynamic Electric especially in the sub-material of Kirchoff's law of electricity two loops, the percentage of student achievement ranges from 40% -50%, the percentage is still classified in the category of weak or low. The working method used so far, namely elimination and substitution requires a thorough level of analysis students are required to be
able to translate the problem language into mathematical language, apply the schema, and make an algorithm. Dynamic electricity deals with charges that move continuously in a circuit and are often referred to as electric currents. Kirchhoff’s Law is a sub material studied in Dynamic Electric, which discusses about algebraic sum of the currents into any junction is zero and the algebraic sum of potential in any loop, including those associated with emf’s and those of resistive elements, must equal zero[3]. Kirchhoff’s Law Meteri is often found in National Examination questions as well as Entrance Examination questions in Higher Education, with limited time, students are required to solve the problems given quickly and accurately. It can be ascertained that many students find it difficult to solve the problem of a closed loop electric current circuit, so a new method that is more effective and efficient is needed to solve the problem of a closed circuit electric current.

As an alternative solution to solve the problem of two-loop electric circuits, researchers developed a new method from an existing theory called Magic Table. The Magic Table method is the completion of a two-loop electric circuit by dividing the circuit into three parts which are then analyzed to obtain data arranged in a column and row so that it resembles a table, this method is based on Ohm’s Law principle which combines with the Thevenin and Norton theorem to change terminal port with voltage source becomes strong current[4]. From the combination of the two concepts, Ohm and Thevenen Norton, the value of the replacement voltage in the circuit could be obtained, then the value of the replacement voltage is used to find the value of the current strength at each branch in the circuit. It is hoped that with a simpler step, the Magic Table method, can help students solve the two-loop electric circuit problems more easily and quickly.

2. Method
This research is included in the type of basic research, which aims to find new solutions in solving the problem of two-loop electrical circuits using the magic table method based on existing theories [5]. The research will discuss how to analyze two-loop electrical circuits with Magic Tables. The development of the theory in this research is based on the Ohm's Law concept combined with the principle of simplifying the Theinvin and Norton series, so that be could generate the value of replacement voltage, when the value of replacement voltage is known, then the current power can be found in each circuit using Ohm's Law equation [6].

The following is a method of development using magic tables in a series of two circular electric circuits:

2.1 Principle of Thevenin's Norton theorem could be used to convert the voltage source into a current source with Ohm Law, then sum the algebraic currents in each section

\[ I_p = \frac{V}{R} \]  

2.2 Determine parallel risistor as Rresistor ekuivalen

\[ \frac{1}{R_e} = \frac{1}{R} + \frac{1}{R} + \frac{1}{R} \]  

2.3 Determine the replacement voltage in a circuit using Ohm’s law principle

\[ V_r = I_p \cdot R_e \]  

2.4 Determine the value of the current strength at each branch using Ohm's law principle

\[ I = \frac{\Delta V}{R} = \frac{|V_r - V_s|}{R} \]
The following are examples of problems in a two-loop electrical circuit with two voltage sources and three resistors in the circuit:

![Figure 1. Two-loop electrical circuits.](image)

The results of the analysis of sample problems in Figure 1. Using the Magic Table method are as follows:

![Figure 2. Analysis of the Magic Table method.](image)

The problem of the two-loop electric circuit in Figure 2. Generated data from each section included in the table is as follows:

| Description | Colomun 1 | Colomun 2 | Colomun 3 |
|-------------|-----------|-----------|-----------|
| $I^a$       | $I_{p1} = \frac{E_1}{R_1}$ | $I_{p2} = \frac{0}{R_3}$ | $I_{p3} = \frac{E_2}{R_2}$ |
|             | $I_p = \frac{E_1}{R_1} + \frac{0}{R_3} + \frac{E_2}{R_2}$ |                     |                     |
| $Re^b$      | $Re = \frac{R_1}{\frac{R_1}{R_1} + \frac{R_1}{R_2} + \frac{R_1}{R_3}}$ |                     |                     |
| $Vr^c$      | $Vr = I_p.Re$ |                     |                     |
| $I^d$       | $I_1 = \frac{\Delta V}{R_1}$ | $I_3 = \frac{\Delta V}{R_3}$ | $I_2 = \frac{\Delta V}{R_2}$ |

*a* Change the voltage source into a current source :

*b* Determine equivalent resistor

*c* Determine replacement voltage

*d* Determine the value of current in each branching

3. Results and discussion

The Magic Table is alternative solution to solve the problem of two-loop electric circuits. As we already know the conditions for the formation of a table is in the presence of rows and columns. What is meant by the tables in this study is to enter data from the results of the analysis carried out in a series, then arranged in a table to facilitate the process of analysis and mathematical calculations, so this method is called a Magic Table.
Using the results of the analysis method of the Magic Table described in Table 1. It will be applied in several examples of problems with variations in voltage sources and resistor values in the circuit as follows:

3.1 Problems with two voltage sources and three resistors in the circuit

![Figure 3](image3.png)

**Figure 3.** Loop circuit with two voltage source in the same direction.

The results of the analysis using the magic table method based on Figure 3. Above are as follows:

**Table 2.** Analysis circuit with two voltage source in the same direction using Magic Table.

| Description | column 1 | column 2 | column 3 |
|-------------|----------|----------|----------|
| \( I_p \)   | 1 A      | 0 A      | 1 A      |
| \( I_p = 1 + 0 + 1 = 2 A \) |
| \( R_e \)   | \( R_e = \frac{4}{1 + 1 + 2} = 1 \text{ ohm} \) |
| \( V_r \)   | \( V_r = 2 \cdot 1 = 2 \text{ v} \) |
| \( I \)     | \( I_1 = \frac{4 - 2}{4} = 0.5 A \) \( I_3 = \frac{2 - 0}{4} = 0.5 A \) \( I_2 = \frac{2 - 2}{2} = 0 A \) |

The data in Table 2. In column 2 is zero because the branch has no voltage source. In a voltage source circuit the value (+) is all due to having the same direction based on the loop direction agreement. So that the results of the analysis using the magic table obtained the results of the current strength at each branch are \( I_1 = 0.5 A, I_3 = 0.5 A, \) and \( I_2 = 0 A \). The truth of the value of the current strength can be compared with the results of calculations using the elimination method and substitution in Kirchoff’s law.

3.2 Problems with three voltage sources and three resistors in the circuit

![Figure 4](image4.png)

**Figure 4.** Loop circuit with three voltage source in the same direction.

The results of the analysis using the magic table method based on Figure 4. Above are as follows:

**Table 3.** Analysis three voltage source in the same direction using the Magic Table.

| Description | column 1 | column 2 | column 3 |
|-------------|----------|----------|----------|
| \( I_p \)   | 1 A      | 1 A      | 1.5 A    |
| \( I_p = 1 + 1 + 1.5 = 3.5 A \) |
\[ R_e = \frac{4}{1+2+1} = 1 \text{ ohm} \]

\[ V_r = 3.5 \cdot 1 = 3.5 \text{ v} \]

| \( I \) | \( I_1 = \frac{4 - 3.5}{4} = 0.125 \text{ A} \) | \( I_3 = \frac{3.5 - 2}{4} = 0.75 \text{ A} \) | \( I_2 = \frac{6 - 3.5}{2} = 0.625 \text{ A} \) |
|---|---|---|---|

The data in Table 3. It is known that each branch has a voltage source value so that there is no zero value, and the direction of the voltage source at each branch is the same (+). From the results of the analysis of the table method the results obtained are \( I_1 = 0.125 \text{ A} \), \( I_3 = 0.75 \text{ A} \), dan \( I_2 = 0.625 \text{ A} \).

### 3.3 Problems with two opposite voltage sources and three resistors in the circuit

![Figure 5. Loop circuit with two opposite voltage source.](image)

The results of the analysis using the magic table method based on Figure 5. Above are as follows:

| Description | colomun 1 | colomun 2 | colomun 3 |
|-------------|----------|----------|----------|
| \( I_p \)   | 4 A      | 0 A      | 4.8 A    |
| \( I_1 = \frac{12 + 0.774}{3} = 4.258 \text{ A} \) | \( I_3 = \frac{0 + 0.774}{2} = 0.387 \text{ A} \) | \( I_2 = \frac{-0.774 + 24}{5} = 4.645 \text{ A} \) |

The data in Table 4. It is known that in column section 2 the value is zero, but the voltage sources are (+) and (-) this is due to the difference in the direction of the loop in the circuit. \( I_1 = 4.258 \text{ A} \), \( I_3 = 0.387 \text{ A} \), dan \( I_2 = 4.645 \text{ A} \).

### 3.4 Problems with two directions of different voltage sources and 4 resistors in a series arranged in series

![Figure 6. Loop circuit with two opposite voltage and four resistors.](image)

The results of the analysis using the magic table method based on Figure 6. Above, because it has a series resistor, it must first add up \( R_s = R_3 + R_4 = 8 \text{ Ohms} \), as follows:
Table 5. Analysis circuit with two opposite voltage and four resistors using the Magic Table.

| Description | columna 1          | columna 2          | columna 3          |
|-------------|--------------------|--------------------|--------------------|
| $I_p$       | 1.66 $AA$          | 0 $A$              | 1.25 $A$           |
|             | $I_p = 1.66 + 0 - 1.25 = 0.41A$ |
| $R_e$       | $R_e = \frac{8}{2.66 + 1.33 + 1} = 1.6$ ohm |
| $V_r$       | $V_r = 0.41 \times 1.6 = 0.666 \nu$ |
| $I$         | $I_1 = \frac{5 - 0.666}{3} = 1.44A$ | $I_3 = \frac{0 - 0.666}{6} = 0.111A$ | $I_2 = \frac{10 - 0.666}{3} = 1.33A$ |

The data in Table 5. In column 2 is almost the same as the first problem which is zero because the branch has no voltage source. However, voltage sources are valued (+) and (-) because they have different directions based on the loop direction agreement. So from the results of the analysis using the magic table, the results of the current strength at each branch are $I_1 = 1.44A$, $I_3 = 0.111A$, and $I_2 = 1.33A$. It is necessary to know in advance in using MagicTable, that the direction of the voltage source and the largest resistor value in the circuit are factors that are very important. This is because the difference in the direction of the voltage source in the circuit will produce a value (+) or (-) according to the loop direction agreement. If the loop moves from negative to positive then the emf source will be valued (+) and vice versa. Positive or negative values in the emf source will affect the value of the strong current. Besides that the largest resistor value in the circuit will be used as a numerator to determine the parallel resistor value [7].

The application of the MagicTable method if used in a two-loop electric circuit type with a more complex resistor arrangement as arranged in series or parallel in each branching, or arrangement of voltage sources in the opposite direction. To determine the equivalent resistor value in the MagicTable method must consist of three resistor parts or one in each branching, so that when the number of resistors exceeds three in a circuit, it must be calculated beforehand whether the resistors are arranged in series or parallel in the branching. Whereas the variation of the voltage source in the MagicTable method must be based on the principle of the loop direction flowing in the circuit.

Based on some literature and the author's experience that the completion of the two-loop electric circuit using the method of substitution elimination, will experience difficulties. This is because students are required to be able to translate problem languages into mathematical language, apply concepts, and make algorithm. After all, the process in working on the problem using a method of elimination of substitution long enough to include, thorough analysis of the circuit, analyzing the direction of the current and the direction of each loop, then translates the direction of the loop in the circuit into Kirchhoff's law equation, then eliminates and substitutes to get the magnitude of the current strength at each branch [8]. So that the process is quite long and accompanied by a complex analysis, it is certain that in solving a problem students will experience difficulties and require a relatively long time. So as to make it easier to solve the problem of two-loop electrical circuits, the Magic Table method is developed, with this method of solving the problem only need to analyze simply by dividing the circuit first into three parts, then with the help of the table, values can be divided into each column, so we get a substitute current and equivalent resistor to be substituted in Ohm's law so that the replacement voltage value can be known, then the voltage value is used to find the strength of the current at each branching. Because the analysis needed in this method is quite simple, and the steps are
more concise, work will simplify and increase time efficiency for students when working on two-loop electrical circuit problems.

4. Conclusion
The Magic Table method is a new way of solving two loop electrical circuit problems, this method uses division into three circuits, then an analysis is carried out to obtain data to be entered into the table. Ohm's law and Thvenin's Norton theorem are used as basic principles in developing theories. The problem of two-loop electrical circuits using the Magic Table method will make it easier for students, because the analysis required is simpler. Besides that the steps in the work are more concise so that it helps students to increase the time efficiency needed in solving problem.

Acknowledgment
The authors would like to thank the lecturer for his guidance and support to create this article. The author also thank the support of ICCGANT 2019.

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