Experiment – 2

Verification of Circuit Theorems

1. **Objective**: The main objectives of the experiment is to verify The most common theorems used in solutions of the direct current (DC) circuits and the alternating current circuits (AC). Theorems are.
2. Superposition theorem,
3. Thevenin theorem,
4. Norton theorem.
5. **Theory:**

 In electrical circuits, the sources and the loads can be connected in series, parallel or mixed. Ohm and Kirchhoff laws are valid in all the solution methods of electrical circuits. There are some practical methods derived from Ohm's and Kirchhoff's laws in the analysis of the electrical circuits. These methods are called the "circuit theorems".

The circuit theorems are used in solutions of the direct current (DC) circuits and the alternative current circuits (AC).

The most common ones of the circuit theorems are as follows.

1- Superposition theorem, 2- Thevenin theorem, 3- Norton theorem.

The theorems shown above will be discussed respectively.

**2.1 SUPERPOSITION THEOREM**

 The superposition theorem is used in circuits having multiple sources in order to find the voltage at a junction point. While analyzing the circuit, in each step only one of the sources is considered and the rest of the sources are killed (voltage sources are short circuited and the current sources are open circuited). Let's determine the voltage at the A junction point in the circuit of Figure 1 with respect to the ground.

 The circuit in Figure 1 is basically a voltage divider. Firstly, let's find the effect of the E1 source on the circuit. For this purpose, the E2 source is removed from the circuit and its terminals are short circuited.



Figure 1

Considering Figure 2, the voltage is across the "R2" pins. As this voltage is created by E1, we call this voltage E1A and let's determine this voltage using voltage division method.



Figure 2



This time, let's kill E1 to find the effect of E2 on the circuit. To kill E1, we remove it and short circuit its terminals.



Figure 3

We call the voltage at the A point "E2A" as it is created by E2. Let's again determine this voltage using voltage division method.



The voltage of the A point with respect to the ground is the summation of these two voltages. Calling this voltage the superposition voltage and denote as "EP", we find:



In this circuit, the two sources are connected in order to increase the voltage drop on the load. If the polarities of one of the sources are reversed, then the voltage on the load is decreased.

**2.2 THEVENIN THEOREM**

 One of the most common methods used in the analysis of the electrical circuits is the Thevenin Theorem. Using this method, no matter how complicated the electrical circuit is, it can be converted to a single voltage source "ETh" and a resistor "RTh" serially connected to it.



Figure 4

The "ETh" voltage in Figure 4 is the open circuit voltage of the "A" and "B" points. RTh is the equivalent resistance between A and B points when the source is killed. This simple circuit illustration is called the "Thevenin equivalent circuit". The circuit analysis can easily be done after the equivalent circuit is constructed.



Figure 5

TO determine the voltage across the load resistor in Figure 5 using the Thevenin Theorem. The voltage across the terminals of the "R2" resistor is the open circuit voltage at the "A" and the "B" points. At the same time, this is the Thevenin voltage, ETh.

 

The open circuit is seen in Figure 6. Let's calculate this voltage using voltage division.

 

In order to find the Thevenin resistance (RTh) of the circuit, the source is removed from the circuit and its terminals are short circuited. At this point, the resistance at the "A" and the "B" points is the Thevenin Resistance, "RTh".

In Figure 7, the R1 and the R2 resistors are parallel to each other. The equivalent resistance of the parallel two resistors can most easily be found by multiplying two values and then dividing the result to the sum of the resistances.

 

  

 Figure 6 Figure 7

The Thevenin Equivalent of the circuit is seen in Figure 8. As seen, till this point the load has not yet been used. At this point, the load is connected to the Thevenin circuit and the voltage on the load, "EL" and the current passing through the load, "IL" are determined. In Figure 9, the RTh and the RL resistors are in series. Therefore the circuit current flows through the load.

  

 Figure 8 Figure 9



The voltage at the load terminals is determined with the voltage division method.



The voltage at the load ends can more practically be found with the Ohm's law.

 EL=IL\*RL =0,3\*24 = 7,2 Volts.

* 1. **Norton Theorem**: One of the most common methods used in the analysis of the electrical circuits is the Norton Theorem. Using this method, no matter how complicated the electrical circuit is, it can be converted to a single current source, "IN", and a resistor, "RN", connected to it in parallel.



Figure 10

IN current in Figure 10 is the current passing when the "A" and "B" points are short circuited. RN resistance is the resistance seen looking through the "A" and "B" points. The representation of the electrical circuit in this manner is called the "Norton Equivalent Circuit". Then, solution of the circuit can easily be done.



Figure 11

Let's determine the current passing through the load resistor in Figure11 using the Norton Theorem. In order to convert the circuit to the Norton Equivalent Circuit, the load resistor is removed from the circuit and its terminals are short circuited. Then the Norton current "IN" is found.



 Figure 12A Figure 12B

When the A and B points are short circuited, the R2 resistor will have no effect on the circuit. This situation is seen in Figure 12B. The Norton current "IN" is found using the Ohm's law.

 

The source is removed from the circuit in order to find the Norton Resistance, RN. The pins of the circuit connected to the source are short circuited and the resistance between "A" and "B" points is calculated.

 Figure 13 

In Figure 13, R1 and R2 are parallel resistors. The overall resistance of the circuit is "RN".

 

After the Norton current and the Norton resistance are found, the "Norton equivalent circuit" can be drawn.

 Figure 14 

Then, the load resistor is connected to the Norton equivalent circuit and solution is done.

 Figure 15 

The branch currents in Figure 15 are calculated using current division method. The current division method is a practical method that is also derived from the Ohm's and the Kirchhoff's laws. This method resembles the voltage division method.

 

In the formulas, the code of the branch current and the resistor codes at the numerator are reversed. That is because that the current and the resistance values are inversely proportional. The voltage at the load ends are found using the Ohm's law.

 EL=IL \*RL =IL \*24 = 0,6 \*24 =14,4 Volts.

1. **EXPERIMENTAL PROCEDURE:**

3.1 **ANALYZING THE SUPERPOSITION THEOREM**

Connect the Y-0016/004 module to its place. Before making the circuit connections, give energy to the set and adjust the power supply voltage to 12V. Cut off the energy of the set. Make the circuit connection as in

Figure 16, so that you can see the effect of E1 only on the circuit. Give energy to the circuit.



**Figure 16**

1- As the voltage seen in the voltmeter is created by E1, it is the E1A voltage. Read and note this voltage.

The voltage on the voltmeter is E1A =

2- Mathematically determine the E1A voltage. Compare the voltages that you calculated and measured.

 

Is the voltage you calculated is the same as the voltage you read on the voltmeter?

3- Make the circuit connection as in Figure 17 so that you can see the effect of E2 only on the circuit.



Figure 17

4- As the voltage seen in the voltmeter is created by E2, it is the E2A voltage. Read and note this voltage.

The voltage on the voltmeter is E2A=

5- Mathematically determine the E2A voltage. Compare the voltages that you calculated and measured.

 

 =

Is the voltage you calculated is the same as the voltage you read on the voltmeter?

6- Connect the circuit as in Figure 18 in order to see the effects of both the sources on the circuit.



 **Figure 18**

7- The voltage seen on the voltmeter is called the superposition voltage (EP). Read and note this voltage.

The superposition voltage is EP=

8- Mathematically calculate the superposition voltage. Compare the voltage that you calculated and the one you measured.

EP=E1A + E2A =

Is the voltage we calculated is the same as the voltage we read on the voltmeter?

9- If we see a mismatch between the value calculated and the value read, what can be the reason for this?

The possible mismatches are because of

* 1. **ANALYZING THE THEVENIN THEOREM**
1. Connect the Y-0016/004 module to its place. Before making the circuit connections, give energy to the set and adjust the power supply voltage to 6V. Cut off the energy of the set. Make the circuit connection as in Figure 19 Give energy to the circuit.



**Figure 19**

2. What is the voltage seen on the voltmeter in Figure 19 called? Read and note this voltage.

The voltage seen on the voltmeter is the " ".

 This voltage is ETh =

1. Mathematically calculate the Thevenin voltage. Compare the values that you calculated and you measured.



Is the values are the same?.

1. Remove the voltmeter and the "E" source from the circuit. Short circuit the source sockets in the circuit. At this moment, measure the resistance of the R2 resistor using an ohmmeter. What is this resistance called? Read and note the value seen on the ohmmeter.

The resistance is the " ".

The value of this resistance is RTh =

1. Mathematically calculate the Thevenin resistance. Compare the values that you calculated and you measured.



Is the values that are calculated and measured are the same?

1. Construct the Thevenin Equivalent of the circuit with the values you found.

Figure 20

1. Make the circuit connections as in Figure 21. Read and note the voltage on the load and the current passing through the load.



Figure 21

The voltage across the load terminals is EL= Volt.

 The current passing through the load is IL= mA.

1. Mathematically calculate the voltage on the load and the current passing through the load from the circuit in figure 20. Compare the values you measured and you calculated.





Is the values we calculated and the one we measured are the same?

9- If we see a mismatch between the value calculated and the value read, what can be the reason for this?

The possible mismatches are because of the tolerances of the resistors.

* 1. **ANALYZING THE NORTON THEOREM**

 Connect the Y-0016/004 module to its place. Before making the circuit connections, give energy to the set and adjust the power supply voltage to 6V. Cut off the energy of the set. Make the circuit connection as in Figure 22. Give energy to the circuit.

Figure 22

1- What is the current seen on the ammeter in Figure 22 called? Read and note this current.

The current on the ammeter is called the " ".

This current is IN=

2- Mathematically calculate the Norton current. Compare the values you calculated and measured.

 

 Is the values that are read and calculated are the same?

3- Remove the ammeter and the source from the circuit. Short circuit A1 and the source sockets in the circuit. Open the short circuit across the terminals of the R2 resistor. Read the resistance across the R2 resistor using an ohmmeter. What is this resistor called? Note the resistance seen on the ohmmeter..

The resistance we read is the “ “

. This resistance is RN=

4- Mathematically calculate the Norton resistance. Compare the values you calculated and read on the ohmmeter.



 Is the values that are read and calculated are the same?

5- Draw the Norton equivalent circuit with the values found.

Figure 23

6- Make the circuit connections as in Figure 24. Read and note the voltage on the load and the current passing through the load.

**Fig. 24**

The current passing through the load is IL =

The voltage across the load EL =

7- Mathematically calculate the current passing through the load and the voltage on the load. Compare the values you calculated and measured.





7- If we see a mismatch between the value calculated and the value read, what can be the reason for this?

The possible mismatches are because of

1. Discussion.
2. Answer all question given through the procedure.
3. What was your conclusion? Stae your comments. .