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Using MULTISIM software as a replacement or supplement for physical labs

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BRIEF

Abstract

MULTISIM is a computer simulation software that among other things simulates the performance of electric circuits. The article presented here demonstrates using MULTISIM as an educational tool to enhance student learning process by discussing the use of MULTISIM for teaching basic electrical circuits consisting of analysis of Series-Parallel Circuits, Superposition Theory, Thevenin Theory and Norton Theory. The traditional textbooks only demonstrate the final result of a circuit analysis using MULTISIM. However, the article presented here discusses using the software as an aid to check the intermediate steps of hand calculation techniques that must be used if no computer software were being used. By using the mixed approach of using a hand calculation technique and MULTISIM, the students have the opportunity to verify the accuracy of every step of the process which will improve their learning and will allow them to find and correct their own errors. The added student self-reliance is especially useful in a Distance Learning course.

Keywords: MULTISIM, Superposition Theory, Thevenin Theory, Norton Theory, Hardware Descriptive Language

1 Introduction and Related Work

Textbooks and conference articles have numerous examples of using MULTISIM software for circuit analysis [1] [2] [3] [4] [5] [6]. However, they only demonstrate the final result of a circuit analysis using MULTISIM. The approach described in the article presented here is more detailed and unique from a teaching point of view by using the software as an aid in verifying and if necessary correcting the hand calculation steps when using Superposition, Thevenin and Norton techniques.

A case study was performed at Northwestern University that showed there were no significant differences in student understanding between a simulated introductory electrical engineering technology laboratory and a traditional hardware based laboratory. This is critical since accreditation of an Engineering Technology program requires laboratory components associated with most subject matters [7]. Hall confirms the conclusion reached at Northwestern that computer simulation is a suitable replacement/addition to traditional hardware based laboratories [8].

Extensive attempts have been made to include computer simulation as a part of the students' laboratory experiments and these attempts are not limited to electronics laboratories [9]. For example, there are numerous possible Controls Engineering applications using MULTISIM [10, 11]. There are other software (for example MATLAB) that can extensively be used as replacing/supplementing Electronics and Controls laboratories [12–16].

2 Combining Hand Calculations and MULTISIM to enhance understanding

The various Series-Parallel circuit analysis techniques consist of reducing circuits until basic Ohm's law can be applied. A more detailed use of MULTISIM is an effective educational tool for verifying

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the accuracy of the various reduction techniques at every step of the process. Highlights of techniques related to Superposition, Thevenin and Norton techniques used in both lectures and labs follow. Actual lab instructions and theoretical descriptions provided to students are far more detailed than the summaries presented in the article presented here.

When a circuit has more than one power source, the technique that can best be initially understood by students is to find the currents from each power source independent of all other sources and then adding them up algebraically. Students practiced this technique with circuits similar to the one shown in Figure 1. In Figure 1, currents that would have resulted if each power source were applied individually are displayed. Figure 2 is the MULTISIM simulation of the total currents for the circuit of Figure 1. Verifying the equality of the algebraic sum of currents from the two power sources shown in Figure 1 and the total currents simulated in Figure 2are part of the lab exercise.

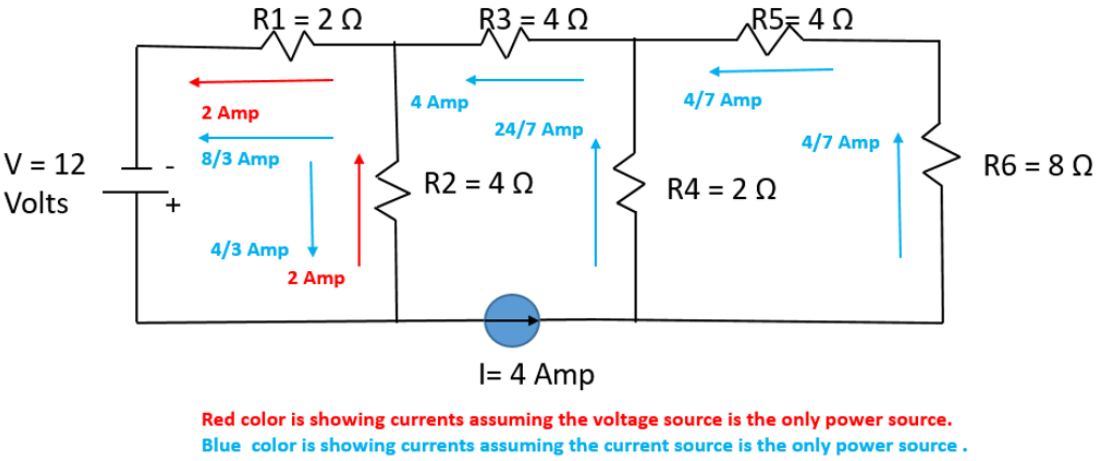

Figure 1. Illustration of circuit with two power sources and resulting currents from each power source by assuming each power source is applied individually

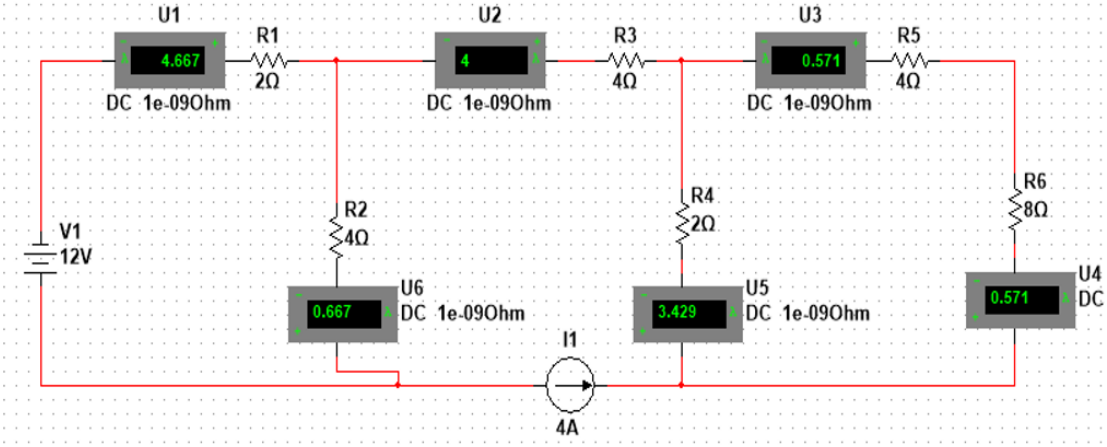

Figure 2. Simulation of the circuit of Figure 1 in MULTISIM.

According to Thevenin Theory a circuit is replaced with an equivalent circuit consisting of a resistor and voltage. Students practiced Thevenin's Theory on circuits similar to the one shown in Figure 3. The circuit was replaced by the equivalent circuit of Figure 4 where the current through R6 could be calculated by an application of Ohm's law.

In order to calculate Thevenin Voltage (VTH) for Figure 3, R6 should be removed from the circuit, and two open terminals A and B added in its place as shown in Figure 5. The voltage across the two open terminals is VTH. VTH can be calculated by classical circuit analysis techniques and/or

determined by using MUTLISIM. Figure 6 is a MULTISIM simulation that shows the voltage across open terminals A and B of Figure 5.

Figure 7 shows the circuit for calculating Thevenin resistance (RTH). RTH is the resistance from the point of view of A and B when all the voltage sources are shorted and the current source is opened. RTH can be calculated by classical circuit analysis techniques and/or determined using MULTISIM. Figure 8 is the MULTISIM simulation of resistance measurement of Figure 7.

All the intermediate steps involved in the manual calculation of VTH and RTH can also be verified by MULTISIM as a means of reinforcing the concepts.

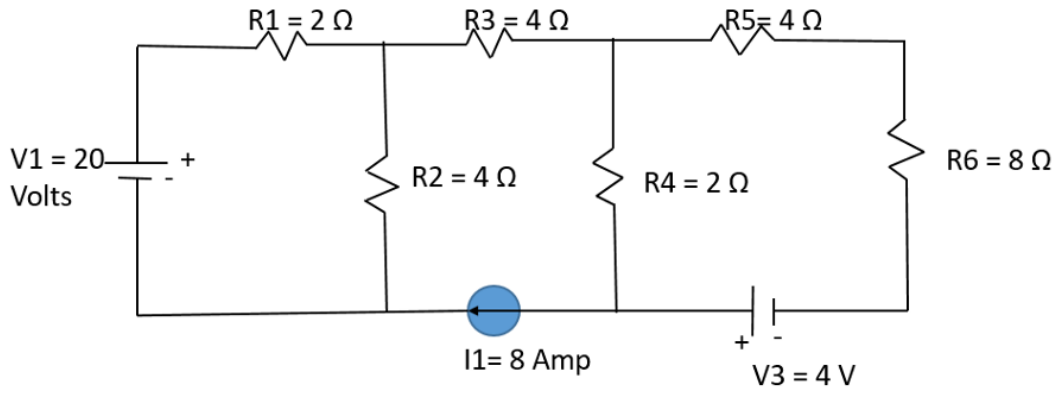

Figure 3. Circuit to be analyzed by Norton and Thevenin theorem.

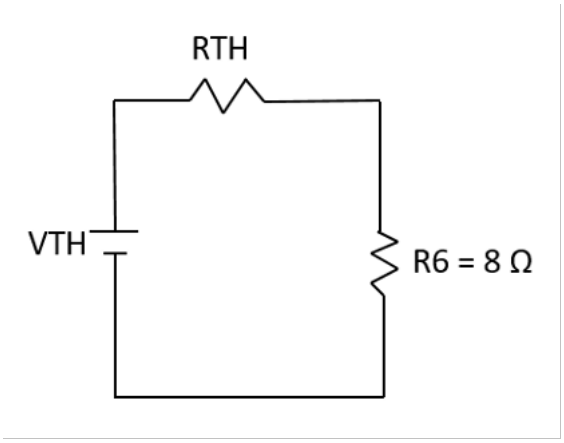

Figure 4. Equivalent Thevenin circuit of the Figure 3 circuit.

Norton's Theory enables a complex circuit to be replaced with a simplified circuit consisting of a resistor and a current. Let as assume that it is desired to find the current through R6 of the circuit of Figure 3 using Norton Theorem. The circuit can then be replaced by the Norton circuit of figure 9. In order to calculate Norton current, R6 should be shorted and two terminals added instead of R6. The current through where R6 was is the Norton Current (NI). Figure 10 illustrates the concept. In Figure 10, the current through nodes A & B is NI.

Norton resistance (RN) is determined the same way Thevenin resistance is determined. Figure 7 shows the circuit used for calculating RN. All the intermediate steps involved in the manual calculation of RN and NI can also be verified by MULTISIM as a means of reinforcing the concepts. MULTISIM simulations for Norton techniques can be performed similar to the simulations presented earlier.

Student reaction & assessment of the technique:

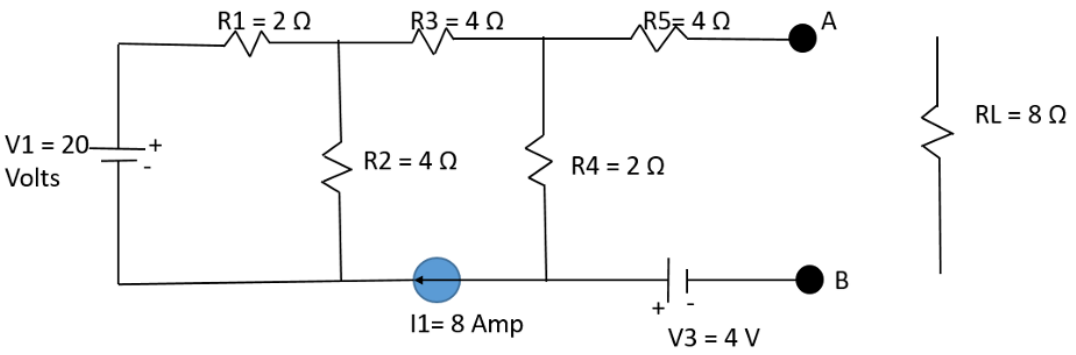

Figure 5. Voltage across open terminals A and B is VTH.

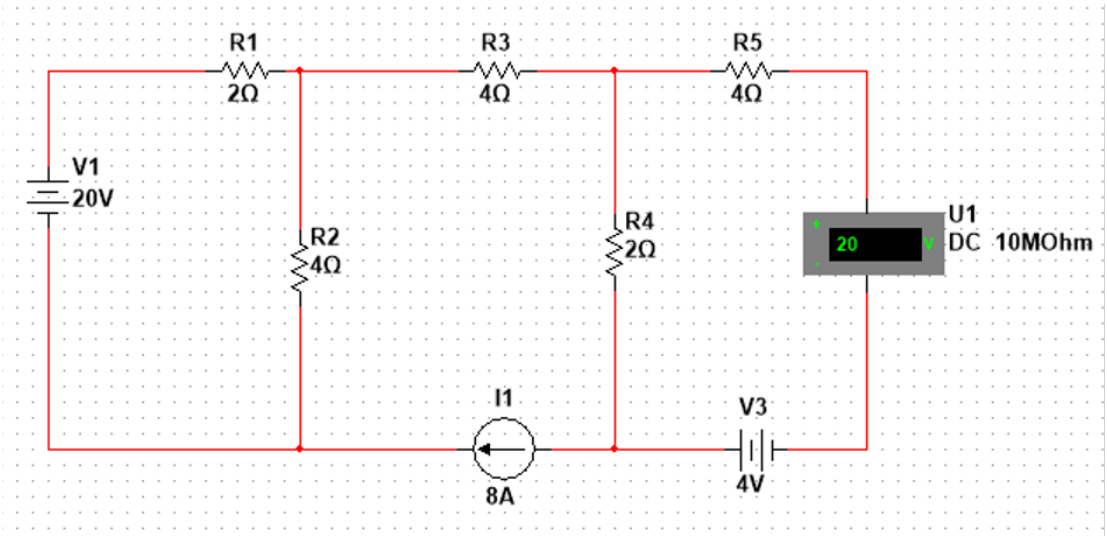

Figure 6. MULTISIM simulation of the voltage measurement across terminals A and B of the Figure 5 circuit.

End of the semester comments from the students were positive. The following are paraphrased highlights of students comments:

- I had difficulty with the laboratory concepts because classes were canceled due to Covid pandemic. Once the detailed lab instructions containing step by step instructions became available, simulated Superposition lab experiments became easier to understand, and I was able to relate them to the online lecture content.
- I had difficulty with the steps required to perform the Superposition analysis technique. Once suggestions and examples were available in the online lectures regarding the use of MULTISIM for performing/checking the intermediate steps, I began to understand the concepts[1]
- The hybrid use of the software was a good replacement for lack of traditional class interaction.

[1] There were similar positive student comments about other topics such as Thevenin and Norton theories.

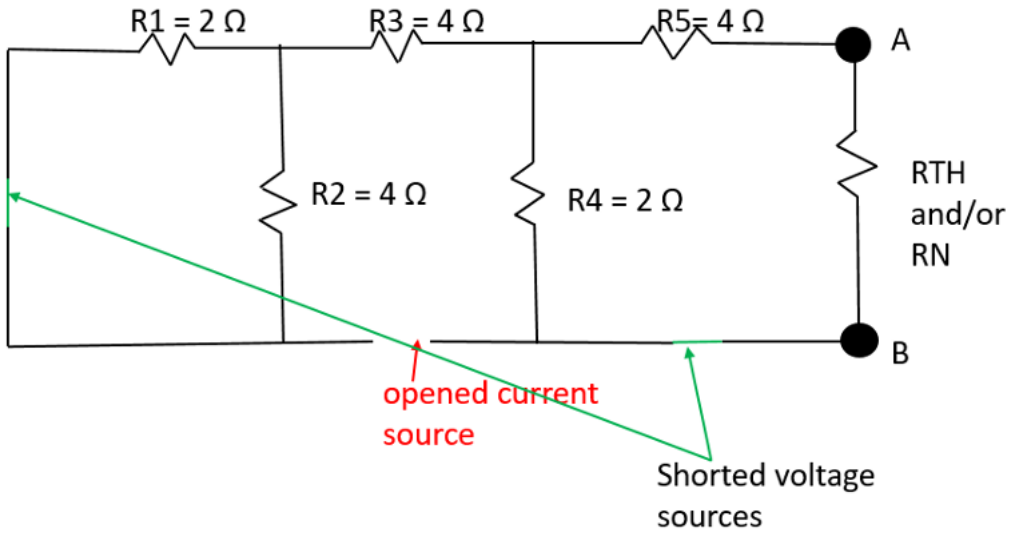

Figure 7. The total resistance across A and B is Thevenin Resistance (RTH) and/or Norton Resistance (RN)

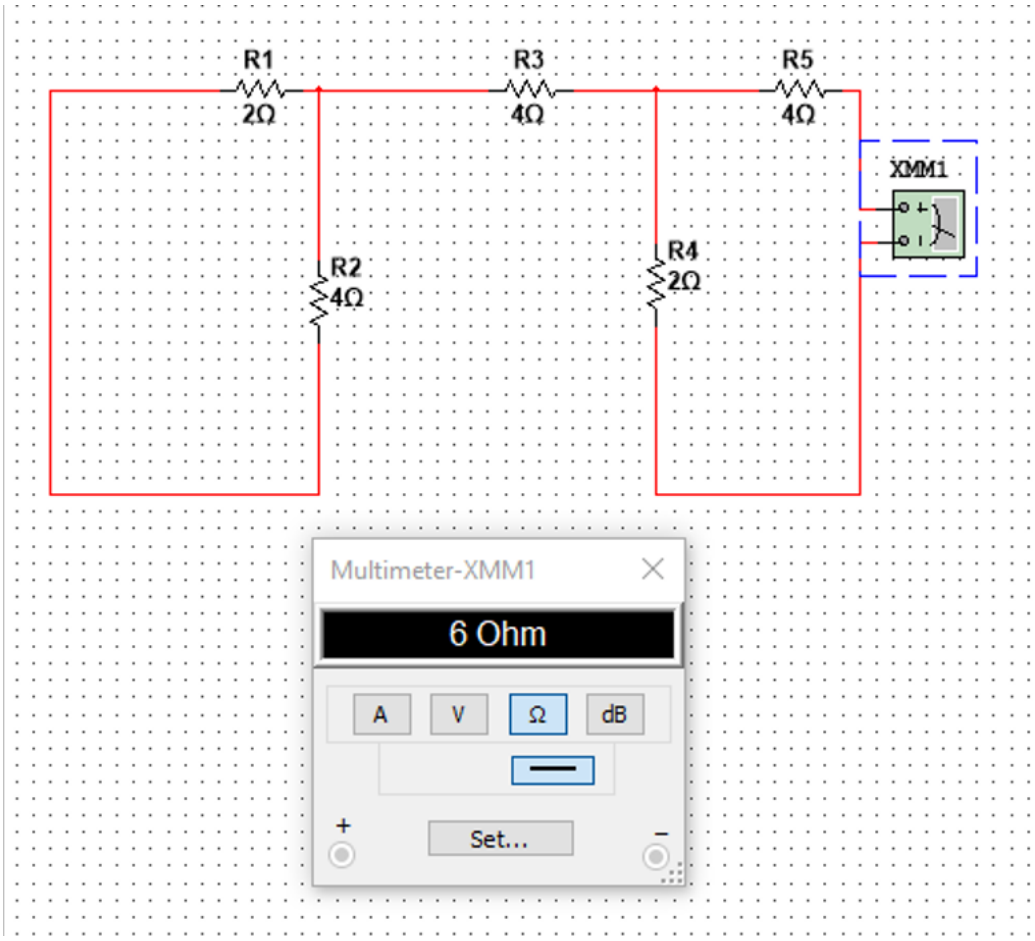

Figure 8. MULTISIM simulation of resistance measurement across terminals A and B of the Figure 7 circuit.

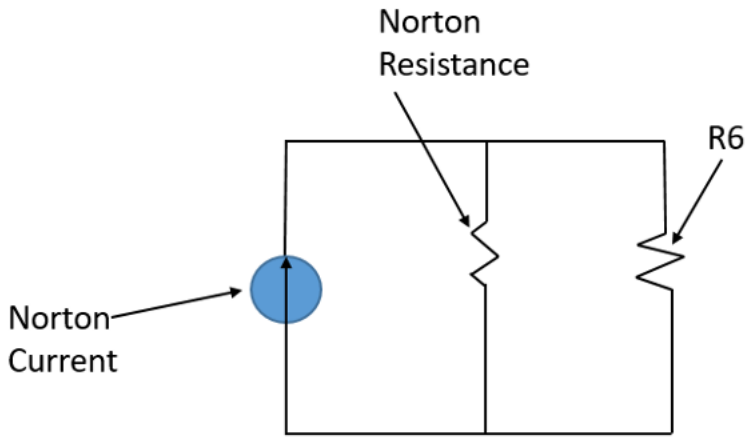

Figure 9. Norton equivalent circuit of the Figure 5 circuit,

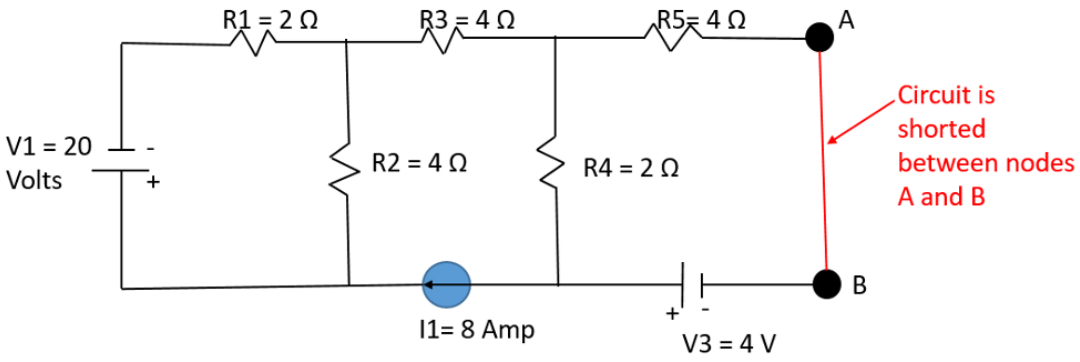

Figure 10. Current through A & B is the Norton Current (NI)

3 Conclusion & summary

In the current article, examples of the enhanced and unique use of MULTISIM software to enhance teaching Superposition, Thevenin and Norton Theories are presented. **The uniqueness of the approach stems from the fact that the software was used to check the validity of the intermediate classical calculation techniques.**

The analysis techniques are not technically complicated. However, that is precisely the point of the presented article. The techniques are suitable as teaching aids for students that are just beginning to learn electrical engineering concepts. The methods described in the current article were developed and used by necessity due to Covid 19 pandemic that forced the electronics lab at the author's institution into a 100% online format.

However, as the literature review shows, MULTISIM can be used across a spectrum of teaching levels and subject matters. The author will continue using these techniques after the pandemic ends and classes are held in the traditional lecture/lab format.

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