Network Theorems using Matlab/ Simulink in the Designing of All Electrical Engineering Courses

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ABSTRACT
This paper describes the MATLAB/Simulink realization of the DC Network Theorems, namely Superposition, Thevenin's, Norton's and Maximum Power Transfer Theorems. These simulation models are developed as a part of a software laboratory to support and enhance all electrical engg. Courses at the faculty of electrical Engineering & Technology Integral University-Lucknow.

Keyword
Network Theorems; Education; Simulation Laboratory; Matlab/Simulink

1. INTRODUCTION
Computer modelling and simulation tools have been widely used to support and enhance electrical courses. MATLAB with its toolboxes such as Simulink [1] and SimPower System [2] is one of the most popular software tool packages used by educators, scholars & researchers to enhance teaching methodology along with advance learning trends. [3]. In an effort to restructure and modernize electrical courses at the faculty of Electrical Engineering Integral University-Lucknow-India, authors have developed Simulink models for network theorems experiments and successfully integrated them into all electrical engineering courses. A software laboratory has been designed to incorporate the simulation models into the Electronics & simulation laboratory section of the diploma course at Shahjahanpur campus. In order to have a complete set of simulation tools for all experiments of the field, the previously designed simulation laboratory should be extended to include some important software tools like PSpice, OrCAD, Labview KCIDE, Multisim & HFSS etc. The objective of this paper is to present simulation models of DC Network theorems. These models include Simulink models of four most common theorems , namely Superposition , Thevenin's, Norton's and Maximum power transfer Theorems. An Electric Network Experiment Toolbox (ENET) has been designed using MATLAB's graphical user interface programming to offer students all simulation models in a single and easy-to-use software package. The simulation models of DC Network theorems are integrated into extra-curricular activities in form of workshops & seminars to enhance the teaching and learning methodology of Network Theorems. This enhancement is achieved by using the simulation models of all lab experiments for various educational activities such apart of classroom demonstration, exercises, and assignments . It has been observed that with the help of simulation results they obtain, students increase their practical understanding beyond the understanding they gain from classroom lectures and textbooks.

2. CONCEPT OF NETWORK THEOREMS
The concept of a network theorem is a most common tool which is most similar to the geometry in which a relatively simple rule used to solve a problem, which is derived from a more intensive analysis from fundamental rules. At least hypothetically, any problem can be solved just by using the simple concept or theories pertaining to accuracy and fast error less analysis. Hence we need some shortcut methods in order to avoid procedural errors.In electric network analysis, the fundamental rules are Ohm's Law and Kirchhoff's Laws in which we can easily analyze any complex circuit without altering its original configuration. But for a large & complex circuit, this approach faces major disadvantage of tedious computation. Along with this many more problems can be solved under several conditions and various requirements.[7] In this new age, the area of application of circuits has led to an advancement of circuit systems from simple to complex. So in order to handle the complexity, engineers over the years have developed some theorems to simplify circuit analysis for those circuits whose parameters are constant i.e. linear circuits.[7] While the conventional laws may be applied for the analysis of any complex circuit, these theorems are the shortcut methods of analysis to make the calculations easier for any average learner.

Hence always we can check the validity, through empirical testing of any given network by setting up the circuits and calculating values using the old conventional methods through simultaneous equations of KCL & KVL versus the "new" i.e. by the theorems, to see whether the answers coincides or not.

Here we use the simulation of our experimental circuit and then we match it with the simulation model of theorems in order to match the results.

2.1 THEVENIN'S THEOREM
Thevenin's theorem is the equivalent generator theorem which is initially proposed by Hermann von Helmholtz in 1853. But the father of this Leon Charles Thevenin's, a French telegraph engineer proposed this theorem in 1883.

This Theorem is defined in terms of impedances and voltage sources for the fulfilment of its main purpose, to facilitate the analysis of linear networks of resistances and voltage sources.[5] In practice it is often found that a particular element in a circuit is variable i.e. load while the other elements are fixed. As a typical example, a household outlet terminal may be connected to different appliances constituting a variable load. Each time the variable element is changed, the entire circuit has to be analyzed all over again. To avoid this problem, Thevenin's theorem provides a technique by which the fixed part of the complex circuit is replaced by a simple

equivalent circuit.Thevenin's theorem states that a linear two-terminal circuit can be replaced by an equivalent circuit consisting of a voltage source VTh in series with a resistor RTh, where VTh is the open-circuit voltage at the terminals and RTh is the input or equivalent resistance at the terminals when the independent sources are turned off.[7]
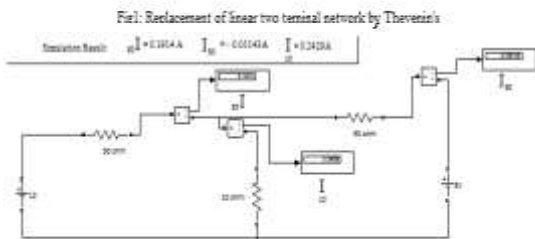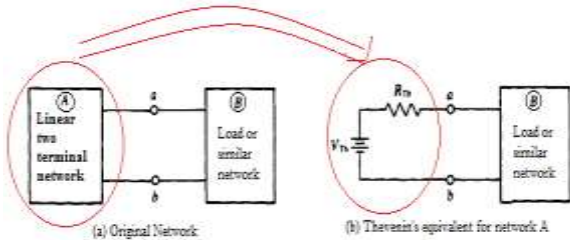

Fig1: Replacement of linear two terminal network by Thevenin's

Fig 3: Simulation of lab kit used for Superposition (for Current in each branch)
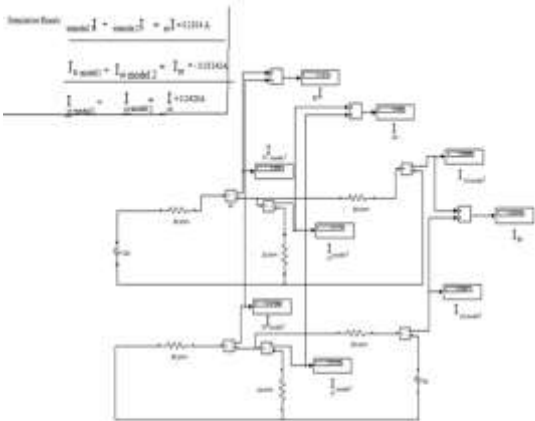
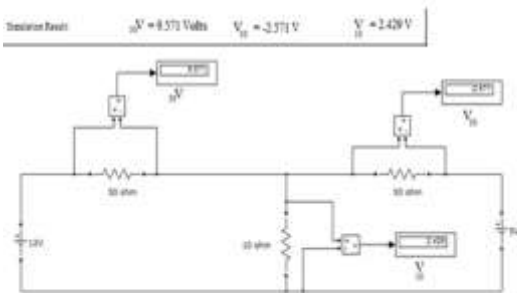Figure 4: Superposition Model (for Current in each branch)

Figure 5: Simulation of kit used for Superposition (for Voltage in each branch)

2.2 SUPERPOSITION THEOREM

 The idea of superposition rests on the linearity property. If a circuit has two or more independent sources, one way to determine the value of a specific variable voltage or current is to use nodal or mesh analysis by conventional method.

Another method is to determine the contribution of each independent source to the variable and then add them up. The latter approach is known as the superposition. Hence in the superposition theorem, the effect of each source will be determined independently, the number of networks to be analyzed will equal the number of sources. The total power delivered to a resistive element must be determined using the total current through or the total voltage across the element and cannot be determined by a simple sum of the power levels established by each source.

$$V_{model\ 1} + V_{model\ 2} = V_{original\ model} \quad \underline{\hspace{3cm}}$$
(1)

$$I_{model\ 1} + I_{model\ 2} = I_{original\ model} \quad \underline{\hspace{3cm}}$$
(2)

Multiply equation (1) & (2)

$$\{(V_{model\ 1} * I_{model1}) + (V_{model\ 2} * I_{model\ 2})\} + (V_{model\ 2} * I_{model\ 1}) + (V_{model\ 1} * I_{model\ 2}) = (V_{original\ model} * I_{original\ model})$$

Hence

$$(V_{model\ 1} * I_{model1}) + (V_{model\ 2} * I_{model\ 2}) \neq (V_{original\ model} * I_{original\ model})$$

$$P_{model\ 1} + P_{model2} \neq P_{original\ model}$$

The superposition principle states that the voltage across (or current through) an element in a linear circuit is the algebraic sum of the voltages across (or currents through) that element due to each independent source acting alone. This statement is true only for voltage & current but not for power.[6]
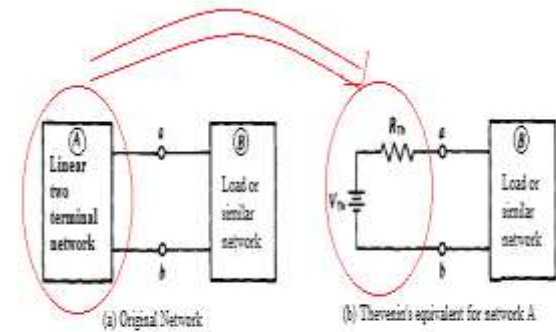
2.3 NORTON'S THEOREM

Fig1: Replacement of linear two terminal network by Thevenin's

E. L. Norton, an American engineer at Bell Telephone Laboratories, proposed a theorem similar to Thevenin's theorem in 1926, about 43 years after Thevenin's published his theorem.Norton's theorem states that a linear two-terminal circuit can be replaced by an equivalent circuit consisting of a current source IN in parallel with a resistor RN, where IN is the short-circuit current through the terminals and RN is the input or equivalent resistance at the terminals when the independent sources are turned off.[6]

3. MATLAB/SIMULINK ANALYSIS AND RESULT MATCHING OF DC NETWORK THEOREMS

Now by taking the help of lab apparatus as an object we present the Simulink models of these four theorems for DC network are presented along with its numerical
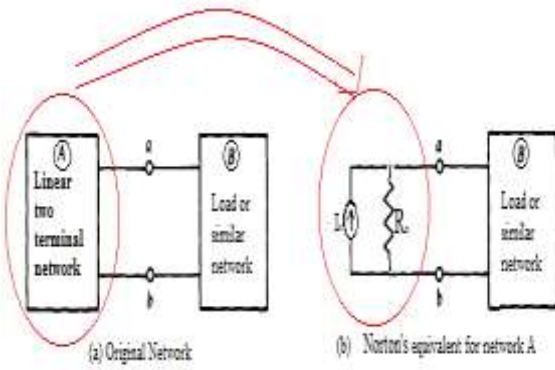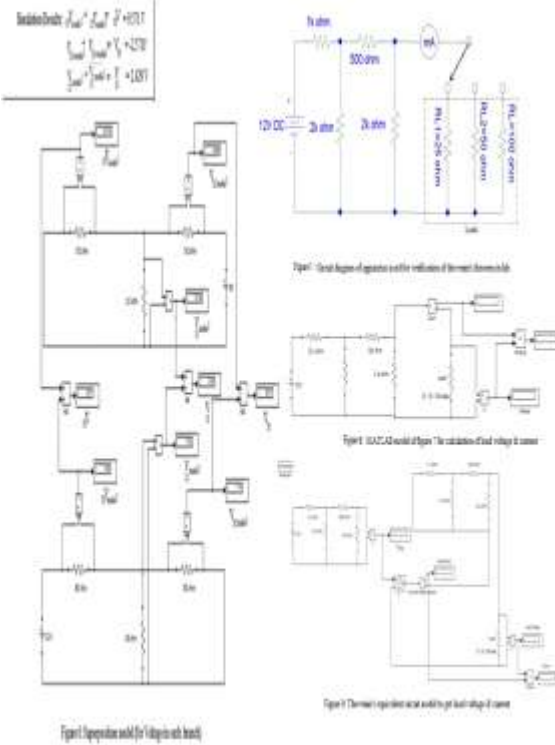
(a) Original Network   (b) Norton's equivalent for network A

Fig2: Replacement of linear two terminal network by Norton's Theorem

Figure4: Superposition model (for Voltage in each branch)

3.1 VOLTAGE IN EACH BRANCH
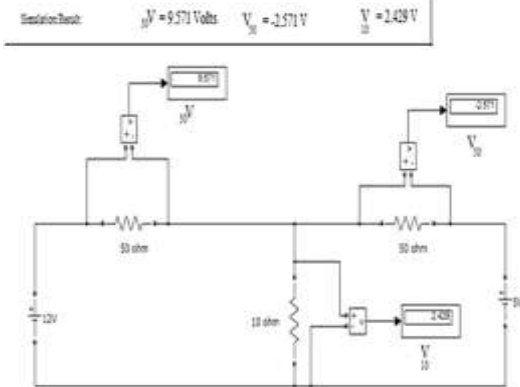
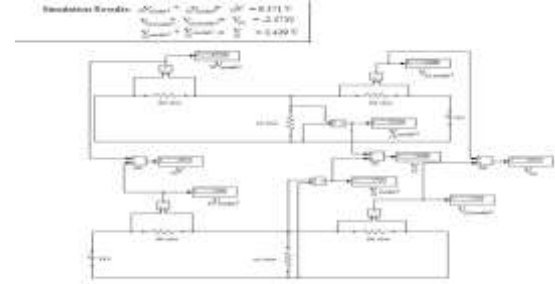Figure 5: Simulation of kit used for Superposition (for Voltage in each branch)

Figure 6: Superposition model (for Voltage in each branch)
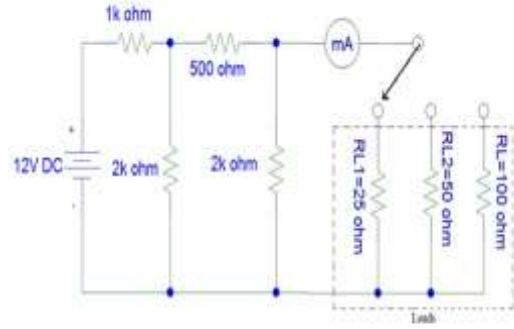
3.2 THEVENIN'S THEOREM

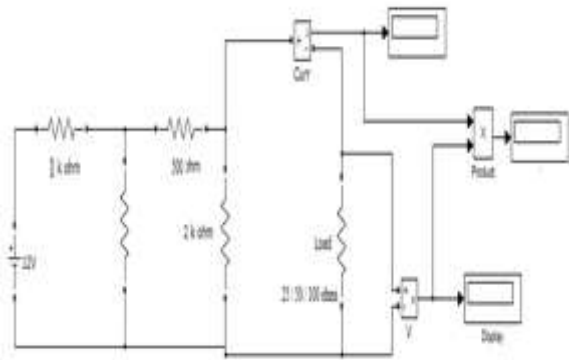Figure7 : Circuit diagram of apparatus used for verification of thevenin's theorem in lab

Figure 8: MATLAB model of figure 7 for calculation of load voltage & current

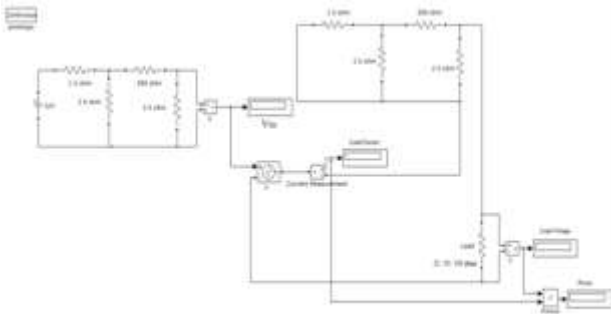| At Load	= 25 ohms	= 50 ohms	= 100 ohms
Load Voltage	165.8 mV	321.1 mV	603.8 mV
Load Current	6.632 mA	6.421 mA	6.038 mA
Load Power	1.1 mW	2.062 mW	3.645 mW

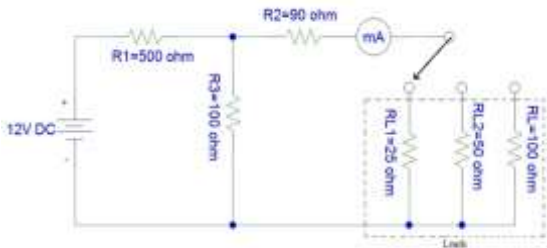Figure 9: Thevenin's equivalent circuit model to get load voltage & current

Figure 10:Circuit diagram of apparatus used for verification of   Norton's theorem in lab
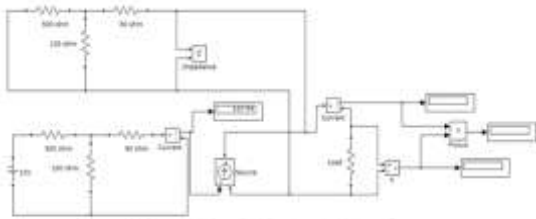
3.3 Norton's Theorem:

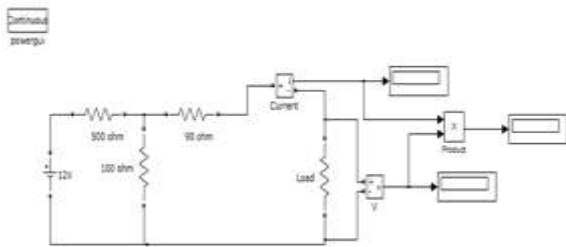Figure 12: Norton's equivalent circuit model to get load voltage & current

Figure 11: MATLAB model of figure10for calculation of load voltage & current

At Load	= 25 ohms	= 50 ohms	= 100 ohms
Load Voltage	252.1 mV	447.8 mV	731.7 mV
Load Current	10.08 mA	8.995 mA	7.317 mA
Load Power	2.542 mW	4.01 mW	5.354 mW

3.4 Maximum Power Transfer Theorem:

Figure 13: Circuit diagram of apparatus used for verification of maximum power transfer theorm

| At R1=50 ohm		At R1=100 ohm		At R1=150 ohm	
Load R (in ohms)	Load Power (in watt)	Load R (in ohms)	Load Power (in watt)	Load R (in ohms)	Load Power (in watt)
10	0.4000	50	0.3200	100	0.2304
20	0.5878	60	0.3375	110	0.2343
30	0.6750	70	0.3488	120	0.2370
40	0.7111	80	0.3556	130	0.2388
50	0.7200	90	0.3590	140	0.2397
60	0.7140	100	0.3600	150	0.2400
70	0.7000	110	0.3592	160	0.2398
80	0.6817	120	0.3570	170	0.2391
90	0.6612	130	0.3539	180	0.2380
100	0.6400	140	0.3500	190	0.2367
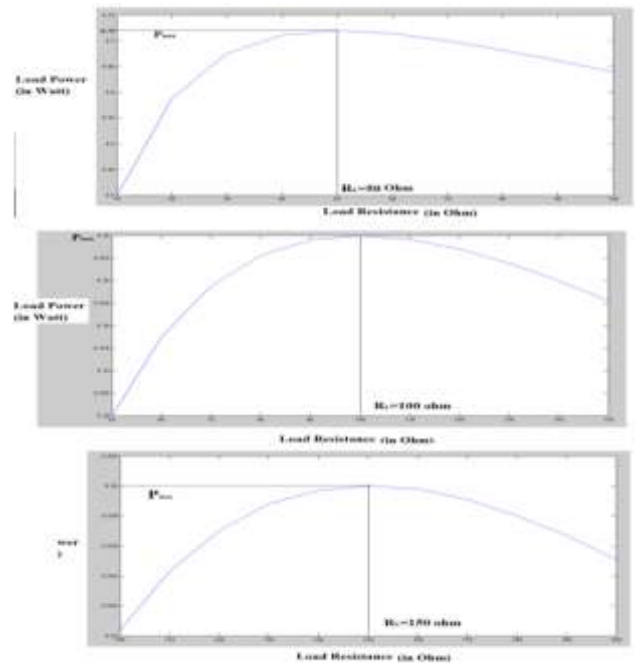
Figure 14: Graphical plots for maximum power transfer theorem

4. THE EDUCATIONAL USE OF THE MODELS

This section describes how the proposed Simulink models of all laboratory networks used in lab used in a diploma & degree level electrical engineering courses, at the faculty of electrical engineering Integral University, Lucknow.

This suggested course is electrical engg-oriented course that offers the simulation of both AC & DC network models using simpower.For the electrical analysis, the topics covered by the course structure should contain networks, power electronics, power system, switchgear & machine etc. [10]. After the study of the above circuit model, student can be familiar with

the software tools used in electrical engineering, as presented in the above demonstration of superposition theorem (fig. X), Thevenin'stheorem(Fig.X), Norton's theorem(Fig.X) & the maximum power transfer theorem (Fig.X) under the wide range of developed area of electrical network as an initial step.After the demonstration, students are asked to obtain the model of any circuit for different theorems in order to match the results.for each theorem, compare the result with the simulation output obtained by the conventional method. Hence they can familiar with all the practical aspect summery taken from lecture, lab work & simulation work. Students through this exercise should have a basic understanding of the MATLAB/Simulink & its tools.Moreover, after having enough experiences with these simulation models, the following exercises are assigned to students: Obtain the result of voltage, current & power in each branch of the given circuit. Then develop the model of super position, Thevenin's, Norton's & maximum power transfer theorem, also match all the result.

Table 1. Experimental Analysis of Theorem Table
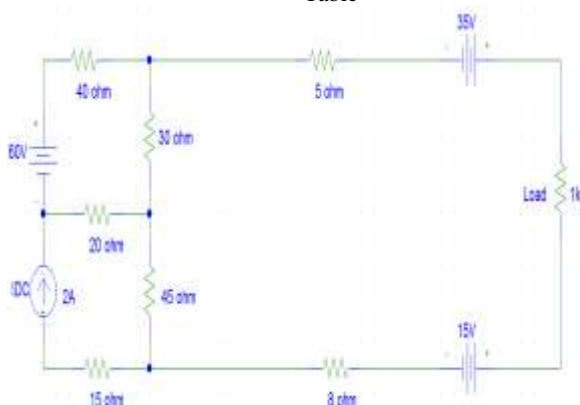
The simulation result clearly shows that result remains same in each analysis either by conventional methods through KCL & KVL or by advance methods of different network theorems. Such simulation exercises help students develop concepts and skills in network analysis and their applications in various DC & AC electrical systems.The use of the proposed simulation models was assessed both formally with student evaluations and informally from discussions with students. Since the models were introduced to all students within a course. The student response to the use of the models has been very positive. The majority of students indicate that having a tool that is easy to use allows them to comprehend different network analysis.Students increase their understanding of DC & AC circuit with their analysis beyond the understanding they gain from classroom lectures and textbooks. They especially appreciate the integrative teaching approach that combines traditional approaches, are supported by simulation models. Students suggest that MATLAB and Simulink/SimPower Systems should be integrated into other electrical and electronics courses as well. Moreover, with the extensive use of simulation models, students have become familiar with the widely used numerical simulation environment ofMATLAB, which they will be able to use subsequently for their senior design projects or research.

5. CONCLUSION
Simulation models of DC network theorems have been developed using MATLAB/Simulink. It has been shown that proposed simulation models correctly explain DC network theorems. Furthermore, Simulink models have been successfully integrated into all electrical engineering courses as a part of the software laboratory in electronics & simulation lab. The teaching of DC network theorems has been developed using the simulation models. Simulated examples are directly taken from lab apparatus which will help students to increase their understanding of DC network theorems &its fundamentals. Future work will involve further development of simulation models to include network analysis of electrical & electronics not only in DC but also in AC.

6. REFERENCES
[1] SIMULINK, Model-based and system-based design, using Simulink, MathWorks Inc., Natick, MA, 2000.

[2] SimPowerSystems for use with Simulink, user's guide, MathWorks Inc., Natick, MA, 2002.

[3] Mostafa.A. M. Fellani, Daw.E. Abaid, Using MATLAB/ Simulink in the designing of Undergraduate Electric Machinery Courses International Journal of Computer and Information Technology (ISSN: 2279 – 0764) Volume 02– Issue 05, September 2013

[4] BACK TO BASICS, IEEE SPECTRUM, March 1990 Brittain, J.E.Spectrum, IEEE (Volume:27 , Issue: 3) March 1990

[5] Electric networks fundamentals, 3rded., WCB/McGraw-Hill, New York, 1998.

[6] Charles K. Alexander & Matthew N. O. Sadiku, Fundamentals of Electric Circuits, 5th ed., WCB/McGraw-Hill, New York, 2013.