International Journal of Precious Engineering Research and Applications (IJPERA)
www.ijpera.com ISSN: 2456-2734,
Volume 4, Issue 3 (May-June) 2019), PP. 05-08

Thevenin analysis of alternating current R-C circuit for teaching and learning of electric circuit subject

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ABSTRACT: *The paper presents the calculated and simulated of R-C alternating current (ac) circuit solved by using Thevenin method used for electric circuit subject. A MATLAB-Simulink (R2017b) was used for simulation purposes. A selected value of R-C ac circuit is developed for calculation and simulation, respectively. The simulation results of Vth and Zth using Simulink achieved lower percentage error Vth (0.102%) Zth (0.524% and 0.106%). The result showed simulated of Thevenin equivalent circuit is consistent with the calculated value with small error percentage. The first method of calculation of Zth achieved best result with the lowest percentage error of 0.106%. The result showed the successfully simulation by Simulink for Thevenin voltage and Thevenin impedance.*

KEYWORDS:*Simulink, Thevenin impedance, Thevenin voltage.*

DATE OF SUBMISSION: 15-07-2019 DATE OF ACCEPTANCE: 31-07-2019

I. INTRODUCTION

Thevenin's theorem is the powerful theorem to simplify a complex circuit by an equivalent Thevenin voltage (Vth) in series connection with an equivalent impedance or Thevenin impedance (Zth). In the case of alternating current (a-c) sources of resistor, capacitor (R-C) circuit, the Vth is obtained at open circuited terminals where the load has been removed from the circuit. In addition, the Thevenin impedance, Zth is the total impedance looking from the terminal of load that has been removed. Note that, all independent ac sources exist in the circuit are set to be zero (any current source removed from the circuit while direct current voltage source also removed from the circuit but replaced by wire) [1-5]. The calculated of Thevenin voltage and impedance is again connected in series with the terminal load (a and b). If terminals a and b are connected to one another, the current flowing from a to b will be Vth/Zth. This means that Zth could be calculated as Vth divided by the short-circuit current between A and B when they are connected. In circuit theory terms, the theorem allows any one-port network to be reduced to a single voltage source and single impedance [1-5].

Thevenin's theorem can be used to convert any circuit's sources and impedances to a Thevenin equivalent; use of the theorem may in some cases be more convenient than use of Kirchhoff's circuit laws [6-12]. However, in this study, we study the technique how to construct the R-C ac circuit using Simulink approach. The result of Thevenin equivalent circuit is compared to the calculation approach. The comparison study of Thevenin equivalent circuit using Simulink approach has rarely been reported

II. METHODOLOGIES

2.1 Calculated Approach

The ac circuit used for analysed Thevenin equivalent circuit is shown in Fig. 1. Impedances (4 and 5 and -5j Ω), independent ac voltage and current of -2j V and 12A, respectively are constructed for calculation and simulation study. There are two calculation methods used. In first calculation method, the Zth are calculated between terminal a-b as shown in Fig. 1 by setting the turning off all ac independent source in the R-C ac circuit. This is done by removing ac voltage and replacing it with wire while and ac current is removing from the circuit. The result is 3 parallel combination impedances of 4, 5, and -5j Ω series with 4 Ω. By through calculation process, Zth is (5.8555-0.8246j) or 5.9133<-8.016^{o} Ω.

For obtain Vth, the calculated open circuit voltage between terminal voltage is the Vth. The detail of calculated Vth is followed: In order 4, 5 and -5j Ω impedances are in parallel, the ac voltage of -2j V must be transformed into ac current source by using ohm's law. The transform result of ac current of is -0.5j A. The parallel impedances of 4, 5 and -5j Ω are simplified to (1.8555-0.8246j) Ω. Since two ac current sources with the same direction are in parallel, the total of ac current source is 11.5j A. The Vth is obtained by transform the 11.5j A and (1.8555-0.8246j) Ω which result to (9.4829-21.3383j) V since the voltage drop across 4 and (1.8555-0.8246j) Ω series impedances are zero volt.

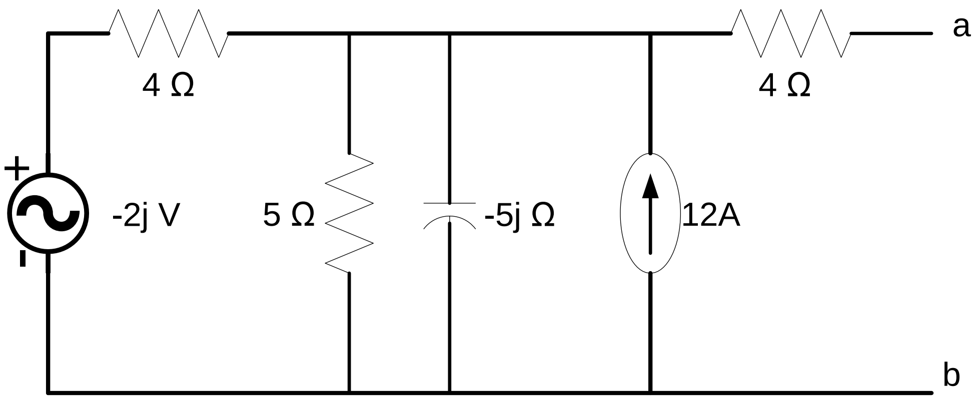

FIG. 1. THE R-C AC CIRCUIT ANALYZED FOR THEVENIN METHOD

Other second calculation method to obtain Z_{th} is by setting the voltage 1 V and the unknown current i A at terminal a-b as shown in Fig. 2. In addition, any independent ac sources in R-C ac circuit must be turn off (current remove from the circuit, while ac voltage replace with wire). This will produce three impedances in parallel (4//5//-5j) Ω. The total of parallel impedance is (1.855-0.825j) Ω. The total impedance (Z_{total}) is obtained by adding it with other series 4 Ω impedance which is (5.855-0.825j) Ω or in phasor form is (5.913<-8.0201o) Ω. The calculated ac current i ($i=-V/Z_{total}$) is 0.169<-171.979^o A.

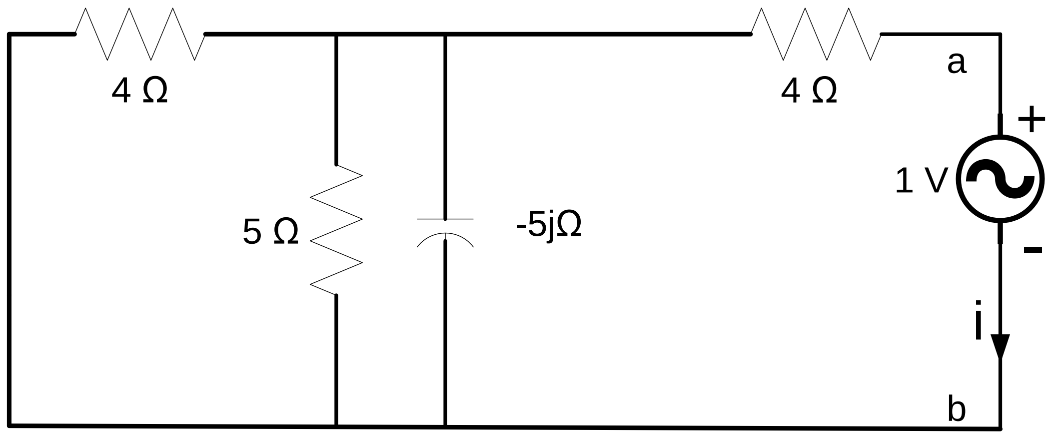

FIG. 2. THE R-C AC CIRCUIT ANALYZED BY SECOND CALCULATION METHOD

2.2 Simulink Approach

The MATLAB R2017b package software is used for Simulink simulation [14-15]. The component of R-C ac circuit is constructed in Simulink as shown in Fig. 3. The component power gui is attached in simulation to display the result of ac voltage (Vth) and ac current, respectively. The Z_{th} on the other hand is obtained by calculated those variables (the ac voltage and ac current using Ohm law). The detail simulation and calculation Thevenin voltage and impedance from both approaches are compared and further discussed in section 3 (Results and Discussions).

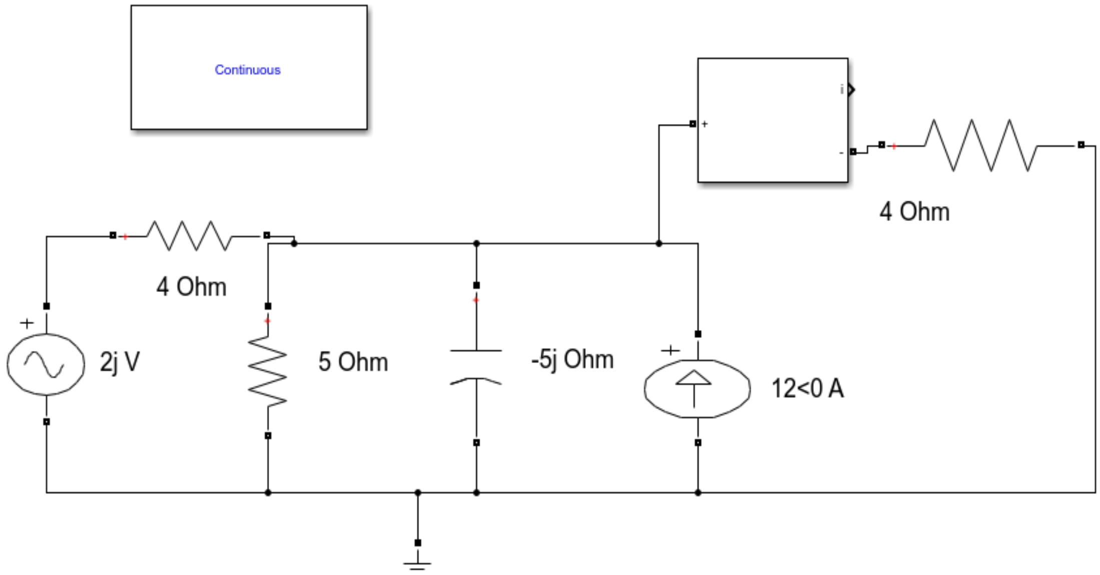

FIG.3 THE SIMULINK OF R-C AC CIRCUIT FOR ANALYZING THEVENIN EQUIVALENT CIRCUIT

III. RESULTS AND DISCUSSIONS

The Simulink result of ac voltage and ac current measurement is shown in Fig. 4. There are 3 measurement values indicate in Fig. 4. The measurement 1 indicate the ac voltage which represents the value of Vth as shown in Table 1. The first ac current measurement is used for obtaining Z_{th} using ohm law (Z_{th}=V/I) and the result is tabulated as first method of measurement as shown in Table 1. This simulation result is used as comparison with first method of calculation. The second measurement current is the ac current used for determining Z_{th} and the result is tabulated as second method of measurement as shown in Table 1. This simulation result is used as comparison with second method of calculation.

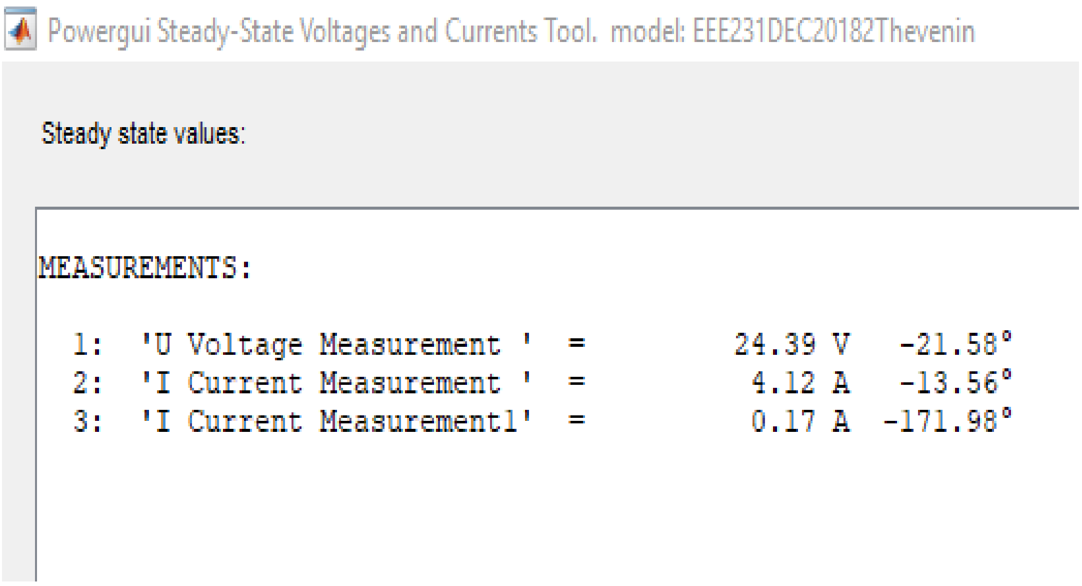

FIG.4 THE SIMULINK RESULT OF AC VOLTAGE AND CURRENT DISPLAYED BY POWER GUI

The simulated result (0.17<-171.89o A) is consistent with the theoretical result value (0.169<-171.979o A) indicate, the successfully of simulation process. The result observes, the calculation value of ac current is almost similar with Simulink method with very small error percentage of approximately -0.059%.Table 1 shows the calculated and simulated result of Thevenin voltage and impedance, respectively. The calculated and simulated result of Zth are obtained by first and second method of calculation. In first method of calculation Zth is obtained by divide Vth with ac current measurement I (2: Measurement Fig. 4) while second method calculation of Z_{th} is divide the 1V by ac current I (3: Measurement in Fig. 4). The simulation result of Z_{th} by first method of measurement indicates the value is comparable with theoretical method with only 0.106%

percentage error, confirmed the measurement method is correct. Small percentage error indicates the small difference value of simulated impedance comparing with the exact value of impedance. The same simulated result of Vth is consistent with theoretical result with percentage error of 0.102%. However, it is observed that, the percentage error of Z_{th} by second method is higher than first method correlated to the first method is more accurate than the second method to determine the Z_{th}. The reason is probably due to, the second method involved the ac current in the measurement. Small changes of current will influence the Z_{th} since $Z_{th}= V_{th}/I$.
Another factor that contribute to the small tolerance is the limitation of power gui had internal resistance which slightly affect the result [2-4]. The exact value by theoretical approach did not affected by those factors since it represents the ideal value of impedance. Hence the value has some small error percentage.

TABLE 1THE CALCULATED AND SIMULATED RESULT OF THEVENIN

CALCULATION		SIMULATION	PERCENTAGE ERROR (%)
V_{th} (V)	24.414<-21.405	24.389< -21.58^o	-0.102
Z_{th} (Ω): 1)FIRST METHOD	5.9133<-8.016^o	5.9196<-8.02^o	0.106
2)SECOND METHOD	5.9133<-8.0201^o	5.8823<-8.02^o	-0.524

IV. CONCLUSION

The paper discussed the calculated and simulated Thevenin equivalent circuit on R-C ac circuit. The result showed simulated of Thevenin equivalent circuit is consistent with the calculated value with small error percentage. The first method of calculation of Z_{th} achieved the lowest percentage error of 0.106%. The simulation results of Vth and Z_{th} using Simulink achieved lower percentage error. The comparison between simulation results and the calculated result, can help students and lecturers in teaching and learning of Electric Circuit subject.

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