USAGE OF MATHEMATICAL TOOLS IN ELECTRICAL ENGINEERING

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***Abstract*:**

Use of mathematics in electrical and electronic engineering is very important thing. In this paper many application of mathematics in electrical and electronic engineering subject; this gives the method for solving the complicated circuit in simplest form. Many researchers think that it's hard to solve electrical and electronic engineering problems which required mathematics for some measure like resistor, inductor, capacitor, voltage and analysing circuits, which we have discussed in this note.

Keywords: Complex analysis, Impedance, Electric circuit, Nodal analysis, Superposition theory.

Introduction:

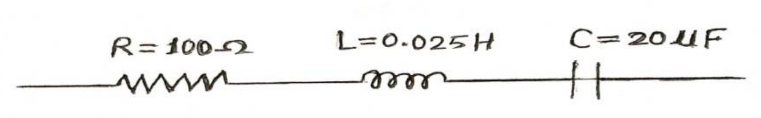
Mathematics is a big part of an engineer's daily work, including statistics, calculus, algebra, geometry, and trigonometry. In electrical engineering mathematics is used to analyse and design circuit, control system and communication network [3]. forever, engineering relies heavily on mathematical modelling and simulation technique to test and optimize design.

Mathematics is considered one of the most fundamental subjects that lay the foundation for many fields, including engineering. The importance of mathematics in these field cannot be overstated, as it provides the skills and knowledge necessary for problem solving analytic thinking and innovation. However, the level of importance of mathematics may vary based on the nature of discipline. Engineering is a field that involves the application of scientific principle to design, develop and maintain structure, machines, systems and processes. It is a broad field that encompasses many areas such as civil, mechanical, electrical, and chemical engineering among other. In engineering mathematics is used extensively for designing and analysing structures and machines. Without mathematics it would be impossible to design, develop and optimize the complex system and technologies that drive modern society.

Mathematics is used to find the complex number in electrical engineering [5]. In electrical circuit reactance is denoted by imaginary part e.g $Z = R + jX$, where R is real part which denoted pure resistance and jX denoted reactance. In electrical circuit two type of reactance are present i.e. inductive reactance and capacitive reactance. We can determine the reactance with the help of complex analysis and also we can solve complex circuit in easy way with the help of mathematical concept and we can solve the circuit in different method like Superposition Theorem [4], Thevenian Theorem, Norton's Theorem, Maximum Power Tensor Theorem and Tellgan Theorem. In transmission line we need total admittance present in the network. Advantage of calculation of admittance parameter, we improve efficiency of transmission line and regulated losses, we also find admittance parameter in generating station and distribution station.

Complex Analysis :

Complex analysis is used in Computer Science Engineering, Mechanical Engineering, Civil Engineering and Control System. Also, complex analysis are used in electrical and electronic engineering to define the alternating current (AC), concept of Impedance and in Fourier analysis they are used in the processing of radio, telephone, and video signals [5].Using complex analysis Impedance is an important technique for handling multi-component AC circuit. If a complex plane is used with resistance along the real axis then the reactance of the capacitor and inductor are treated as imaginary number. Complex analyses operate in the same way as the Impedance, providing the perfect tool to represent both the value and function of Impedance. The imaginary part represent the phase or delay of a sine wave.
We will consider an example to find the Impedance of a inductor, capacitor and resistor in series if frequency is 60Hz.



Solution: Given that, L= $0.025H, C = 20\mu F$, R=100Ω, F=60Hz

Impedance of an inductor (Z_L) will become, $Z_L = iwl = 9.42i\ \Omega$

Impedance of capacitor (Z_C) will becomes, $Z_C = \frac{1}{iwc} = -132.69i\ \Omega$

Impedance of resistor (Z_R) will be given that, $Z_R = 100\ \Omega$

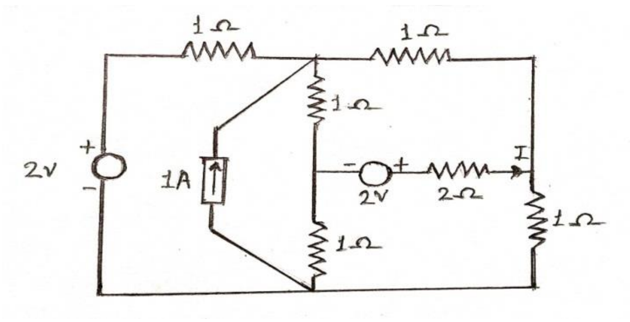
Now, we can write the Impedance of an Inductor, Capacitor and Resistor in series (Z) will becomes, $Z = 100 - 123.27i\ \Omega$

In polar form: $Z = 158.72\ \Delta\ -50.93^{\circ}\ \Omega$

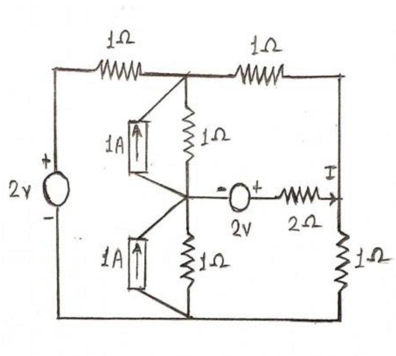
In exponential form: Z=$158.7e^{-50.93i}$ Ω.

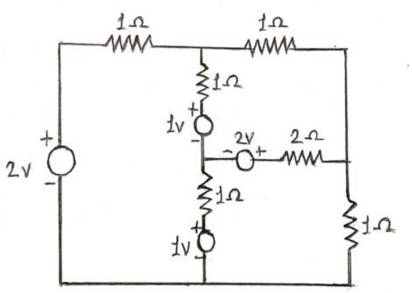
Network system :

Computer networks [4] include communication, resource, sharing, remote access, e-commerce, education, and entertainment. Example of network in our daily life is wireless connection into mobile phone network, personal computer, telephone line, modem and other network connection. We need to calculate to different parameter for proper management of different type of network like LAN, WAN, PAN and MAN. Electronic circuit consist electrical component such as resistor, capacitor and inductor with combination in the form of network and these device based on current reading, voltage reading and power reading, need to find the current and voltage. We will consider the example to find the current through 1Ω resistance for the following circuit.



Solution: By using I-shift rule we can redraw the given network

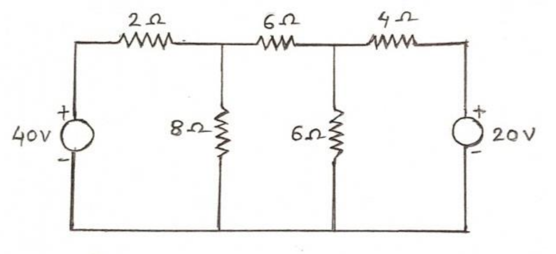




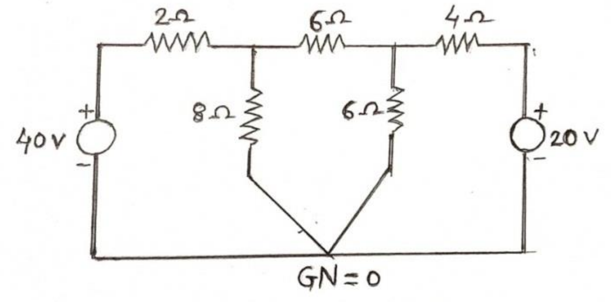
By converting current source into voltage source
Apply KVL in loop1: $3I_1 - I_2 - I_3 = 0$ ------(1)
Apply KVL in loop:$-I_1 + 4I_2 - 2I_3 = -1$ ------(2)
Apply KVL in loop3: $-I_1 - 2I_2 + 4I_3 = 3$ ------(3)
Solving the above system of equation, provides the following current, all determine in amperes
$I_1 = 0.499A$, $I_2 = 0.416A$, $I_3 = 1.083A$
The current flowing through 1Ω resistor is $0.083\ A$

Nodal analysis :

Nodal analysis is mathematical method to analyse circuit in terms of voltage drops between nodes in a circuit diagram. Nodal analysis produces a compact set of equation of the network which can be solved using linear algebra. The node voltage method is best for voltage source because every voltage source connected to the reference node reduces the equations to be solved [1]. Basically, Mesh analysis is applicable for planer network and Nodal is applicable for both planer network and non-planer network. Hence nodal analysis is preferred over mesh analysis then we can solve the mesh analysis problem to the nodal analysis method for the following circuit and calculated the voltage.



Solution:



Apply KCL to V_1: $19v_1 - 4v_2 = 480$ --------(4)

Apply KCL to V_2: $-2v_1 + 7v_2 = 60$ --------(5)

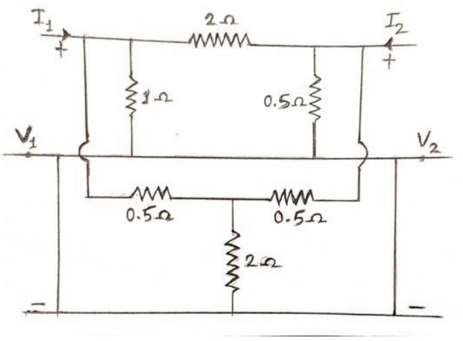
For calculating the v_1 and v_2 value from equation (4) and (5) by using Cramer's rule,

v_1=28.8 V and v_2= 16.8 V

Parallel-Inter connection network :

Interconnection network are used to connect nodes where nodes can be single processors, or group of processors, to other nodes interconnection network can be categorised on the basis of their topology [2] parallel computing is used of multiple processing elements simultaneously for solving any problem. A network allows exchange of data between processors in the parallel system in two ways. Direct connection network and indirect connection network [6].

We can consider the example, to find the current in following circuit.



Solution: By using Y-parameter

This network can be considered as a parallel combination of two networkN_1 and N_2,

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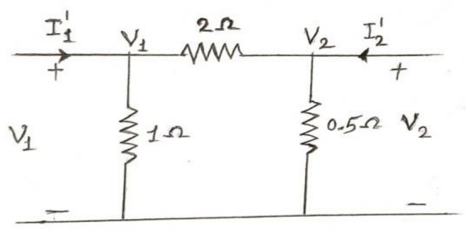
Find y-parameter for network N_1



Apply KCL at node 1: $I_1' = \frac{3}{2}v_1 - \frac{1}{2}v_2$ -----(1)

Apply KCL at node 2: $I_2' = -\frac{1}{2}v_1 + \frac{5}{2}v_2$ -----(2)

Now, Y-parameter for node1 is given by, $\begin{bmatrix} y_{11}' & y_{12}' \\ y_{21}' & y_{22}' \end{bmatrix} = \begin{bmatrix} \frac{3}{2} & \frac{-1}{2} \\ \frac{-1}{2} & \frac{5}{2} \end{bmatrix}$ ------(3)
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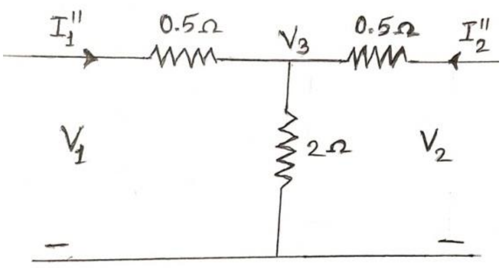
Also, find Y-parameter for network N_2,



Apply KCL at node 3: $I_1'' + I_2'' = \frac{v_3}{2}$ ----(4)

i.e. $I_1'' = 2v_1 - 2v_3$ and $I_2'' = 2v_2 - 2v_3$ ----(5)

Equation (4),we get, $v_3 = \frac{4}{9}v_1 + \frac{4}{9}v_2$ ----(6)

Equation (5) gives, $I_1'' = \frac{10}{9}v_1 - \frac{8}{9}v_2$ -----(7)

Equation (6) gives, $I_2'' = -\frac{8}{9}v_1 + \frac{10}{9}v_2$ -----(8)

Now, Y-parameter for node 2 is given by, $\begin{bmatrix} y_{11}'' & y_{12}'' \\ y_{21}'' & y_{22}'' \end{bmatrix} = \begin{bmatrix} \frac{10}{9} & \frac{-8}{9} \\ \frac{-8}{9} & \frac{10}{9} \end{bmatrix}$ -----(9)
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From equation (3) and (7), we get $\begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix} = \begin{bmatrix} \frac{47}{18} & \frac{-25}{18} \\ \frac{-25}{18} & \frac{65}{18} \end{bmatrix}$

This is Y parameter in a given circuit with the help of y parameter we can find the current for given circuit. From equation (1) and (2), we get

$V_1 = \frac{5}{7}I_1' + \frac{1}{7}I_2'$ and $V_2 = \frac{1}{7}I_1' + \frac{3}{7}I_2'$

For both equation we get, $\begin{bmatrix} I_{11}' & I_{12}' \\ I_{21}' & I_{22}' \end{bmatrix} = \begin{bmatrix} \frac{5}{7} & \frac{1}{7} \\ \frac{1}{7} & \frac{3}{7} \end{bmatrix}$ ------(10)

Similarly, from equation (7) and (8), we get

$V_1 = \frac{5}{2} I_1" + 2I_2"$ and $V_2 = 2I_1" + \frac{5}{2} I_2"$

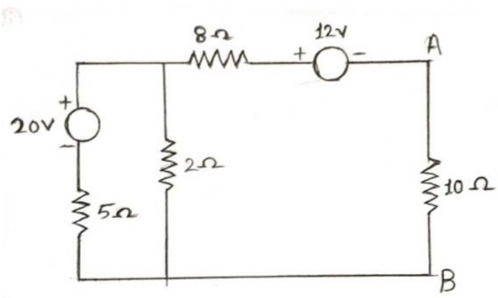
For both equation, we get, $\begin{bmatrix} I_{11}" & I_{12}" \\ I_{21}" & I_{22}" \end{bmatrix} = \begin{bmatrix} \frac{5}{2} & 2 \\ 2 & \frac{5}{2} \end{bmatrix}$ ------(11)

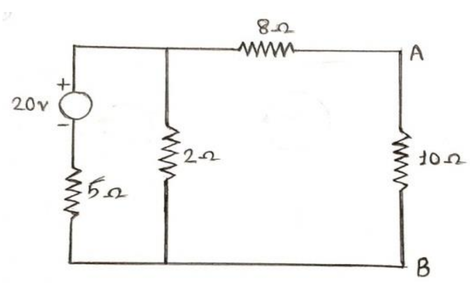
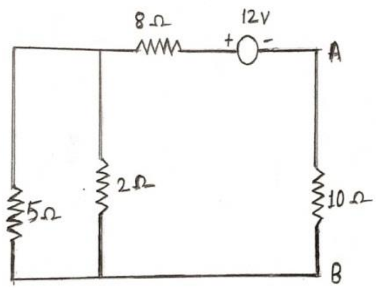
From equation (10) and (11), gives the current for the given circuit (node1 and node2)

$$\begin{bmatrix} I_{11} & I_{12} \\ I_{21} & I_{22} \end{bmatrix} = \begin{bmatrix} \frac{45}{14} & \frac{15}{7} \\ \frac{15}{7} & \frac{41}{4} \end{bmatrix}$$

Superposition Theorem :

Superposition theorem is to eliminate all, but one source of power within a network at a time. We use series and parallel circuit analysis technique to determine voltage drops and current within the modified network for each power source separately. It is used to converting any circuit into its Norton's equivalent. The theorem is applicable linear network and not applicable to power, because it is non-linear quantity. We can consider the example, to evaluate the current through 10Ω resistor for the circuit.



Step 1: consider the 20V source	Step 2: Consider 12V source
 Apply KVL by loop 1: $7I_1' - 2I_2' = 20$ -----(1) Apply KVL by loop 2: $-2I_1' + I_2' = 0$ -----(2)	 Apply KVL at loop 1: $7I_1" - 2I_2" = 0$ -----(3)

By solving above system then the current is given by, $I_2' = 0.2941\ A$	Apply KVL at loop 2: $-2I_1'' + 20I_2'' = -12$ ----(4) By solving the above system then the current is given by, $I_2'' = -0.6176A$ Now the current flowing through 10Ω resistor is $-0.3235\ A$

Conclusion:

In this paper, various type of application of mathematical tools in electrical and electronic engineering field has been shown. The various type of applications of mathematical problems have taken from real life. Nodal analysis uses Kirchhoff's current law to calculate the voltage at each node in an equation. Electric and electronic engineers can solve any complex electrical network by using different methods like Superposition Theorem, Thevenian Theorem, Norton's theorem, Maximum Power Tensor Theorem and Tellgan Theorem with convenient method.

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