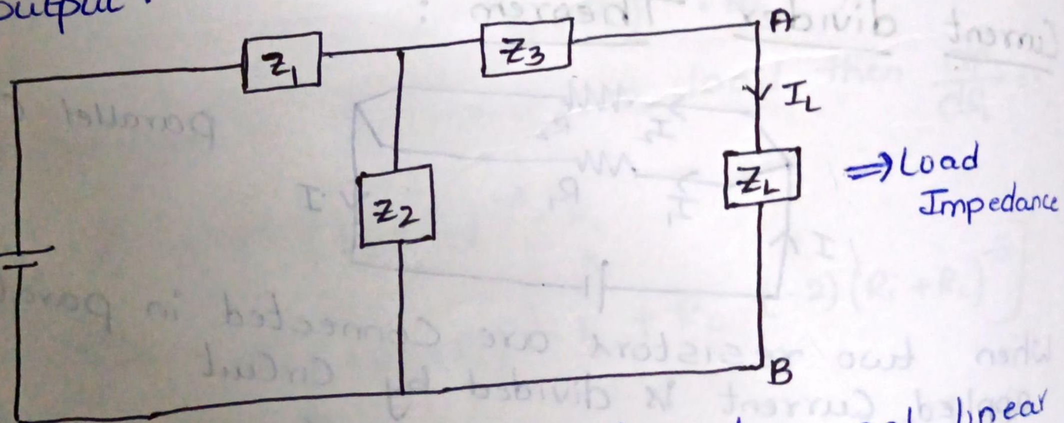
Norton's Theorem :-

Any Linear Active Network Containing parallel Linear Impedance and Voltage Sources Can be replaced by Nortan's equivalent Circuit.

⇒ the Nortan's equivalent Circuit Consists Norton's Constant Current Source (I_n) in parallel with Norton's Impedance

⇒ Norton's Impedance is the Resultant Impedance between output terminals (Apply chese param ga Vachedhi) & When all Voltage Sources Can be replaced by their Internal Impedances if any

⇒ Norton's Current is Current passing through the Short Circuited output.

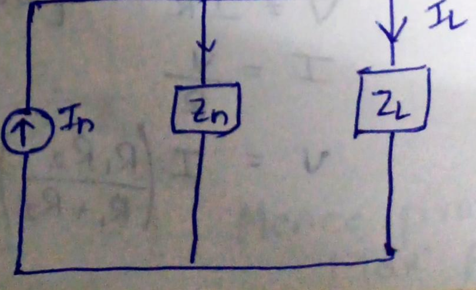


The above figure shows that the two terminal linear network it Consists a Voltage Source "E" Linear Impedances Z_1, Z_2, Z_3 & Z_L

⇒ The Z_L is Connected b/w A & B terminals we need to calculate the Current passing through the Z_L using Norton's theorem has follows.

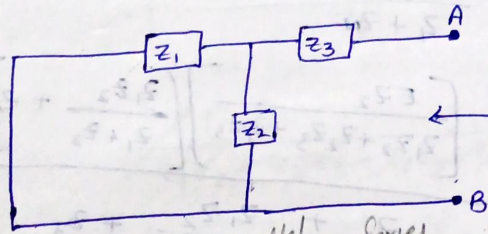
Norton's equivalent Circuit

I_n = Norton's Current



According to Norton's theorem the Norton's equivalent Circuit Consists the Norton's Constant Current Source (I_n) in parallel with Norton's Impedance (Z_n)

$$I_L = \frac{I_N Z_N}{Z_L + Z_N} \longrightarrow (1)$$ [As per Current divider theorem]



Source zero chetham

open Circuit
Load Resistance Remove chetham

parallel Series

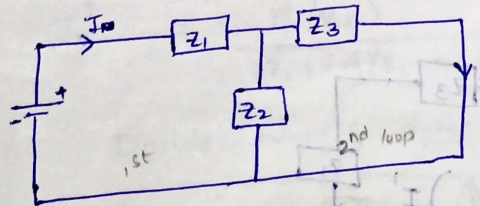
$$Z_N = (Z_1 \| Z_2) + Z_3$$

$$Z_N = \frac{Z_1 Z_2}{Z_1 + Z_2} + Z_3 \longrightarrow (2)$$

$\frac{1}{Z_N} \rightarrow \frac{1}{Z_1} + \frac{1}{Z_2}$

As per Norton's

<u>Norton's Current</u>



$I_{SC} = I_N \rightarrow$ Norton's Current
Short circuit current

$I = \frac{V}{R} = \frac{E}{Z}$

Z = Total Impedance

parallel

$$= (Z_2 \| Z_3) + Z_1$$

$$= \frac{Z_2 Z_3}{Z_2 + Z_3} + Z_1$$

$\frac{1}{Z_2} + \frac{1}{Z_3}$

[I_{SC} only flow in Z_2 & Z_3 loop]
2nd loop Short Circuit

$$\boxed{Z = \frac{Z_2 Z_3 + Z_1 Z_2 + Z_1 Z_3}{Z_2 + Z_3}}$$

Total Current $I = \frac{E}{Z}$

$$\boxed{I = \frac{E(Z_2 + Z_3)}{Z_2 Z_3 + Z_1 Z_2 + Z_1 Z_3}}$$

Norton's Current $\Leftarrow$ (3)

$$I_N = \frac{I Z_2}{Z_2 + Z_3}$$

Across Z_2 & Z_3
(2nd loop only Short circuit)

$$= \frac{E(Z_2 + Z_3)}{Z_1 Z_2 + Z_2 Z_3 + Z_1 Z_3}\left(\frac{Z_2}{Z_2 + Z_3}\right)$$

$$\boxed{I_N = \frac{E Z_2}{Z_1 Z_2 + Z_2 Z_3 + Z_1 Z_3}} \longrightarrow ③$$

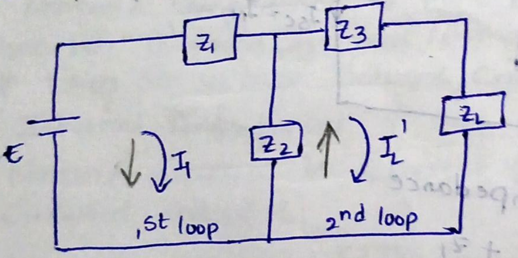
Sub ② + ③ in eq-①

$$I_L = \frac{I_N \cdot Z_N}{Z_L + Z_N}$$

$$= \frac{\left[\frac{E Z_2}{Z_1 Z_2 + Z_2 Z_3 + Z_1 Z_3}\right]\left[\frac{Z_1 Z_2}{Z_1 + Z_2} + Z_3\right]}{Z_L + \frac{Z_1 Z_2}{Z_1 + Z_2} + Z_3}$$

$$\boxed{I_L' = \frac{E Z_2 / Z_1 + Z_2}{Z_L + Z_3 + \frac{Z_1 Z_2}{Z_1 + Z_2}}}$$

proof: As per KVL



Apply KVL to 1st Loop

$$E = I_1 Z_1 + Z_2 (I_1 - I_L')$$

$$= I_1 Z_1 + I_1 Z_2 - I_L' Z_2$$

$$= I_1 (Z_1 + Z_2) - I_L' Z_2 \longrightarrow ①$$

Apply KVL to 2nd Loop

$$0 = I_L' Z_3 + Z_L I_L' + Z_2 (I_L' - I_1)$$

$$= I_L' Z_3 + I_L' Z_L + I_L' Z_2 - I_1 Z_2$$

$$= I_L' (Z_2 + Z_3 + Z_L) - I_1 Z_2$$

$$I_1 = \frac{I_L' (Z_2 + Z_3 + Z_L)}{Z_2} \longrightarrow ③$$

Sub I_1 value in eq (1)

$$E = \frac{I_L'(Z_2+Z_3+Z_L)(Z_1+Z_2)}{Z_2} - I_L' Z_2$$

$$= I_L'\left[\frac{(Z_1+Z_2)(Z_2+Z_3+Z_L)}{Z_2} - Z_2\right]$$

$$= I_L'\left[\frac{(Z_1+Z_2)(Z_2+Z_3+Z_L) - Z_2^2}{Z_2}\right]$$

$$\cancel{I_L' = \frac{E(Z_2)}{Z_1Z_2 + Z_2Z_3 + Z_1Z_3 + Z_1Z_L}}$$

$$= I_L'\left[\frac{(Z_1+Z_2)(Z_3+Z_L) + Z_1Z_2 + Z_2^2 - Z_2^2}{Z_2}\right]$$

$$E = I_L'\left[\frac{(Z_1+Z_2)(Z_3+Z_L) + Z_1Z_2}{Z_2}\right]$$

$$I_L' = \frac{E(Z_2)}{(Z_1+Z_2)(Z_3+Z_L) + Z_1Z_2}$$

Divide Num & deno with (Z_1+Z_2)

$$\boxed{I_L' = \frac{\dfrac{E\,Z_2}{Z_1+Z_2}}{Z_L + Z_3 + \dfrac{Z_1Z_2}{Z_1+Z_2}}}$$

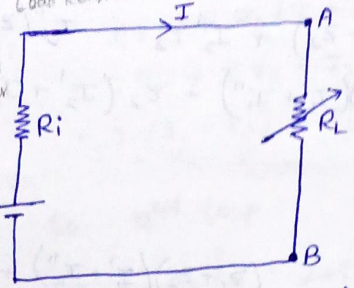
$$\therefore I_L = I_L'$$

Hence proved

Maximum power transform theorem :-

In an Active Network the Maximum power delivered to la. load when the Internal Resistance of Source or Network is equals to Load Resistance

output lo unnadhi Load Resistance
Internal Resistance = Load R
then Maximum power
power = V × I
$V = IR$



$R_i \rightarrow$ Resistor
$R_L \rightarrow$ Load Resistance

power is taken across A & B terminal (R_L)

In this active Network R_i is the Internal Resistance of Source and R_L is the Load Resistance

Total Resistance $R = R_i + R_L$

Current passing through the circuit $I = \frac{E}{R_i + R_L}$

power delivered to the load

$$P = V \times I \qquad \because V = IR$$
$$= IR \times I$$
$$= I^2 R_L$$
[$R = R_L$ because power is taken across A & B (R_L)]

$$P = \left[\frac{E}{R_i + R_L}\right]^2 \cdot R_L$$

$$P = E^2 (R_i + R_L)^{-2} \cdot R_L$$

When maximum power delivered to load then $\frac{dp}{dR_L} = 0$

$$P = E^2 \underset{u}{(R_i + R_L)^{-2}} \cdot \underset{v}{R_L}$$

$$\frac{dp}{dR_L} = E^2 \left[(R_i + R_L)^{-2} \cdot 1 + R_L (-2)(R_i + R_L)^{-3} \right]$$

$$= E^2 \left[(R_i + R_L)^{-2} - 2 (R_i + R_L)^{-3} \cdot R_L \right] = 0$$

$E^2 \neq 0$; $R_i + R_L \neq 0$ [Applied Source So $\neq 0$]

$$E^2 \left[(R_i + R_L)^{-2} \left(1 - 2 (R_i + R_L)^{-1} \cdot R_L \right) \right) = 0$$

$$1 - 2 (R_i + R_L)^{-1} \cdot R_L = 0$$

$$1 = \frac{2 R_L}{R_i + R_L}$$

$$R_i + R_L = 2 R_L$$

$$\boxed{R_i = R_L}$$

Hence proved
Max power is delivered

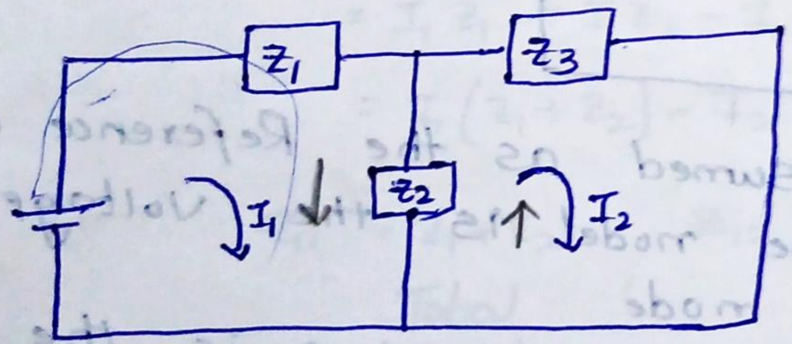
Reciprocity Theorem :-

Statement: Any Active Linear network Contains Linear Impedances, If EMF is Applied in the first Loop then the Current passing through the second loop is equals to Current flowing through the first loop when the Same Source Acting in the Second Loop

proportional

Voltage

Linear Active - Voltage Current



Currents in opp direction

proof :-

Apply KVL to 1st Loop $\quad I_1' = I_2$

$$E = I_1 Z_1 + Z_2(I_1 - I_2)$$
$$= I_1 Z_1 + I_1 Z_2 - I_2 Z_2$$
$$= I_1(Z_1 + Z_2) - I_2 Z_2 \longrightarrow (1)$$

Apply KVL to 2nd Loop

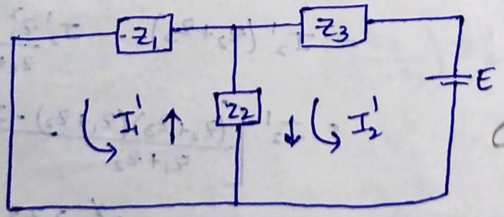
$$0 = I_2 Z_3 + Z_2(I_2 - I_1)$$
$$= I_2 Z_3 + I_2 Z_2 - I_1 Z_2$$
$$= I_2(Z_2 + Z_3) - I_1 Z_2 \longrightarrow (2)$$

$$I_2(Z_2 + Z_3) = I_1 Z_2$$
$$I_1 = \frac{I_2(Z_2 + Z_3)}{Z_2} \longrightarrow (3)$$

Sub (3) in (1)

$$E = I_1(Z_1 + Z_2) - I_2 Z_2$$
$$= \frac{I_2(Z_2 + Z_3)(Z_1 + Z_2)}{Z_2} - I_2 Z_2$$
$$= \frac{(I_2 Z_2 + I_2 Z_3)(Z_1 + Z_2) - I_2 Z_2^2}{Z_2}$$
$$= \frac{I_2 Z_2 Z_1 + \cancel{I_2 Z_2^2} + I_2 Z_1 Z_3 + I_2 Z_2 Z_3 - \cancel{I_2 Z_2^2}}{Z_2}$$
$$= \frac{I_2(Z_1 Z_2 + Z_2 Z_3 + Z_1 Z_3)}{Z_2}$$

$$\boxed{I_2 = \frac{E Z_2}{Z_1 Z_2 + Z_2 Z_3 + Z_1 Z_3}}$$



Currents in opp Direction

Apply KVL to 1st loop

$$0 = I_1' Z_1 + (I_1' - I_2') Z_2$$
$$= I_1' Z_1 + I_1' Z_2 - I_2' Z_2$$
$$= I_1'(Z_1 + Z_2) - I_2' Z_2$$
$$I_2' = \frac{I_1'(Z_1 + Z_2)}{Z_2} \longrightarrow (4)$$

$$E = I_2' Z_3 + Z_2(I_2' - I_1')$$

$$= I_2' Z_3 + I_2' Z_2 - I_1' Z_2$$

$$E = I_2'(Z_2 + Z_3) - I_1' Z_2 \longrightarrow ⑤$$

Sub eq 4 in ⑤

$$E = I_2'(Z_2 + Z_3) - I_1' Z_2$$

$$= \frac{I_1'(Z_1 + Z_2)(Z_2 + Z_3)}{Z_2} - I_1' Z_2$$

$$= \frac{(I_1' Z_1 + I_1' Z_2)(Z_2 + Z_3) - I_1' Z_2^2}{Z_2}$$

$$= \frac{I_1' Z_1 Z_2 + I_1' Z_1 Z_3 + \cancel{I_1' Z_2^2} + I_1' Z_2 Z_3 - \cancel{I_1' Z_2^2}}{Z_2}$$

$$= \frac{I_1'(Z_1 Z_2 + Z_2 Z_3 + Z_1 Z_3)}{Z_2}$$

$$\boxed{I_1' = \frac{E Z_2}{Z_1 Z_2 + Z_2 Z_3 + Z_1 Z_3}}$$

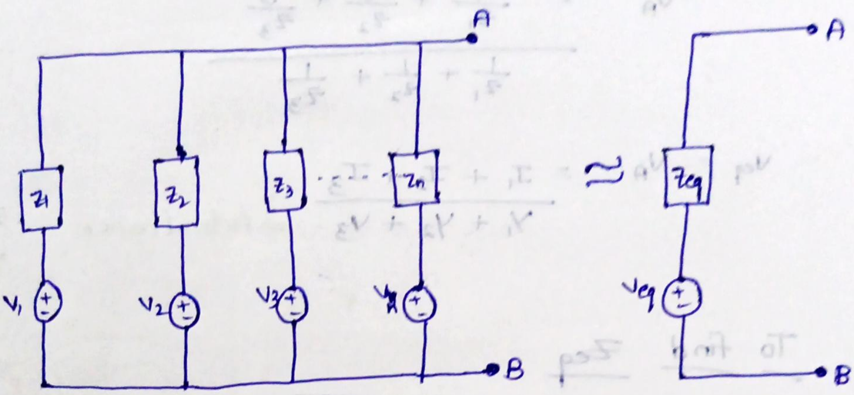
$$\therefore \boxed{I_1' = I_2}$$

Hence proved

Milliman's Theorem :-

Milliman's theorem states that a network containing no of voltage sources having series impedances are connected in parallel then such a network can be reduced to a single network containing one voltage source and impedance.

Consider a network shown in figure



Where

$I = \frac{V}{R}$

$$V_{eq} = \frac{\frac{V_1}{Z_1} + \frac{V_2}{Z_2} + \frac{V_3}{Z_3} + \cdots \frac{V_n}{Z_n}}{\frac{1}{Z_1} + \frac{1}{Z_2} + \frac{1}{Z_3} + \cdots \frac{1}{Z_n}}$$

$Z = \frac{V}{I}$

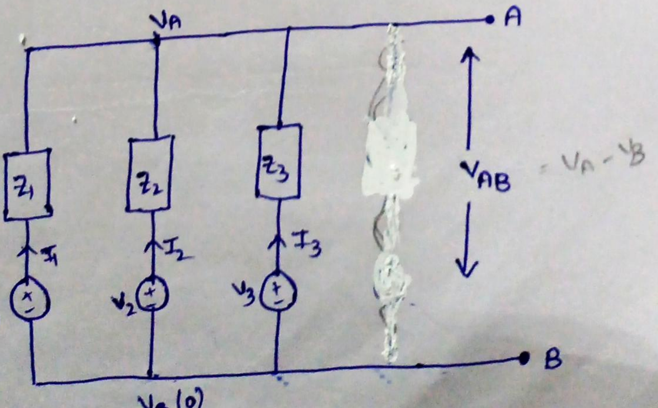
Y = Admittance $= \frac{1}{Z} = \frac{I}{V}$

parallel $\frac{1}{R_1} + \frac{1}{R_2}$

$$V_{eq} = \frac{I_1 + I_2 + I_3 + \cdots + I_n}{Y_1 + Y_2 + Y_3 + \cdots Y_n}$$

$$V_{eq} = \frac{\sum_{i=1}^{n} I_i}{\sum_{i=1}^{n} Y}, \quad Z_{eq} = \frac{1}{Z_1} + \frac{1}{Z_2} + \cdots \frac{1}{Z_n}$$

proof



V_B (0)

Ground (Reference Node) = 0

Apply KCL at node

$$I_1 + I_2 + I_3 = 0$$

$V = IR$

$I = \frac{V}{R \to Z} \Rightarrow \frac{V}{Z}$ $V \to$ Potential diff

$$\frac{V_A - V_1}{Z_1} + \frac{V_A - V_2}{Z_2} + \frac{V_A - V_3}{Z_3} = 0$$

$$V_A\left(\frac{1}{Z_1} + \frac{1}{Z_2} + \frac{1}{Z_3}\right) - \left(\frac{V_1}{Z_1} + \frac{V_2}{Z_2} + \frac{V_3}{Z_3}\right) = 0$$

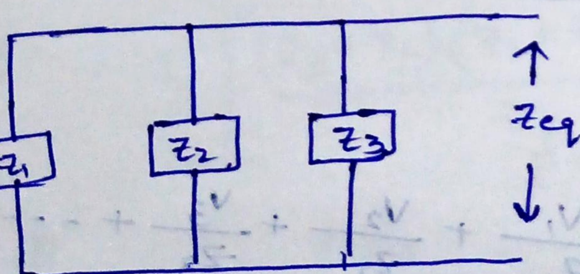
$$V_A = \frac{\frac{V_1}{Z_1} + \frac{V_2}{Z_2} + \frac{V_3}{Z_3}}{\frac{1}{Z_1} + \frac{1}{Z_2} + \frac{1}{Z_3}}$$

$$V_{eq} = V_A = \frac{I_1 + I_2 + I_3}{Y_1 + Y_2 + Y_3}$$ $\Rightarrow$ Admittance

$Z = \frac{V}{I}$

$Y = \frac{I}{V}$

<u>To find</u> <u>Z_{eq}</u>



They are in parallel

$$\frac{1}{Z} = \frac{1}{Z_1} + \frac{1}{Z_2} + \frac{1}{Z_3}$$

$$\frac{Z_2Z_3 + Z_1Z_3 + Z_1Z_2}{Z_1Z_2Z_3}$$

$$\boxed{Z_{eq} = \frac{1}{\frac{1}{Z_1} + \frac{1}{Z_2} + \frac{1}{Z_3}}}$$

$$Z = \frac{Z_1Z_2Z_3}{Z_1Z_2 + Z_2Z_3 + Z_1Z_3}$$

passive Networks

Circuit :- A circuit is a closed path through which an electric current either flows or Intend to flow
try

Electrical Network: The Combination of various electronic Components Connected in any manner is called as electrical Network
close/open

passive Network: If a network Contains circuit elements (components) without any Source that is Voltage (or) Current Source

Active Network: If a network Contains Circuit elements with energy source is called as Active Network.
Voltage (or) Current

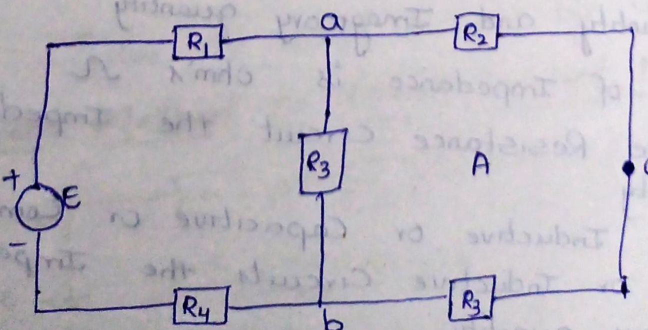
⇒ They are two types of Active Networks
1. Linear Active Network
2. Non linear Active Network

Linear Active Network : A Network is Said to be linear when Currents in all branches linearly proportional to driving Voltage. (Apply chesma Voltage ∝ Current)

Non-Linear Network: A Network is Said to be Non-linear when Currents in all branches Non-linearly proportional to driving Voltage.

Integrated Circuit : Semi Conductor Circuit with silicon chip

Node:- The Junction points where the elements in a network meet Such as the points a and b



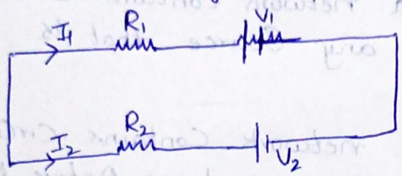
Branch :- An element joining two nodes such as a to b is called a Branch.

Loop :- Any cloosed path in a network such as abcd is called a loop.

Mesh :- The Space that, the loop encloses is called a Mesh

Kirchoff's Current law :- The Algebric Sum of Currents ~~node~~ points meet at a point (Node) is Zero

Kirchoff's Voltage law. The Algebric Sum of voltage drop is equal to the EMF's of the Resistance of Current



$V = IR$

$V_1 + V_2 = I_1R_1 + I_2R_2$

Impedance(z) :- $Z = \frac{V}{I}$ $\Rightarrow$ If only Resistor in Circuit the z is Real ; If there exist Capicitor, Inductor etc then z has Complex Constants then j or i are parameters of z

Admittance :- $Y = \frac{I}{V}$

Series Combination :- $R = R_1 + R_2 + R_3$

Current flows same, Voltage divider

parallel Combination :- $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

Voltage flow same, Current divider (different)

Impedance :- Ratio of Voltage and Current

$$Z = \frac{V}{I}$$

$\Rightarrow$ The Impedance is the Complex quantity and it Consists of Real quantity and Imaginary quantity

units of Impedance is "ohm's" Ω

$\Rightarrow$ for a pure Resistance Circuit the Impedance is Real quantity

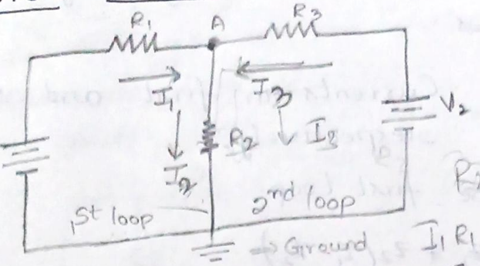
$\Rightarrow$ for a pure Inductive or Capacitive or Combination of Capacitive or Inductive Circuits the Impedance is Imaginary quantity

$\Rightarrow$ When the Circuit Containing resistive and Inductive the Impedance is Complex quantity

$X_C = \frac{1}{\omega C}$

$X_L = \omega L$

Branch Current method :-



Junct → cur
loop → vol

$R_2 (I_2 + I_3)$

$I_1 R_1 + R_2 (I_2 + I_3)$

$I_1 R_1$

At node → Current Law

At Loop → Voltage Law

At node point A

$I_1 + I_3 - I_2 = 0 \longrightarrow ①$

If V_1 is not there then $I_1 R_1 + I_2 R_2 = 0$

1st loop $V_1 = I_1 R_1 + I_2 R_2$

2nd loop $V_2 = I_3 R_3 + I_2 R_2$

$V_1 - V_2 \quad I_1 R_1 - I_3 R_3$

⇒ The first and most straight forward network analysis technique is called the branch current method.

⇒ In this method we assume directions of currents in a network then write equations describing their relationship to each other through kirchoff's and ohm's Law. (V=IR)

⇒ once we have one equation for every unknown current we can solve the simultaneous equations and determine all currents and all voltage drops in the network.

At node point A, Apply KCL

$I_1 + I_3 - I_2 = 0 \longrightarrow ①$

Apply KVL to 1st Loop

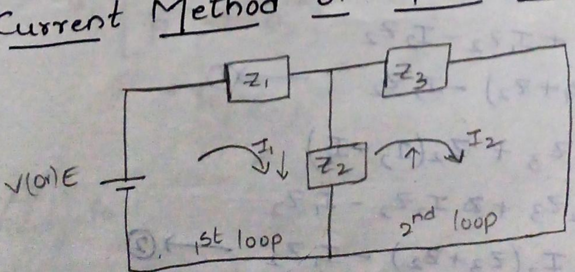
$V_1 = I_1 R_1 + I_2 R_2 \longrightarrow ②$

Apply KVL to 2nd Loop

$V_2 = I_3 R_3 + I_2 R_2 \longrightarrow ③$

Solve the above 3 eqn's by using elimination Method

Loop Current Method or Mesh Current Method :



opposite in direction (1st - 2nd)
At 1st loop

⇒ In loop current method the unknown currents are assumed to be flowing around the closed loop in the network and write the voltage eqn in a Closed loop as follows

Let us Assume the Currents in first and Second Loops are I_1 & I_2 respectively

Apply KVL to the first Loop

$$E = I_1 Z_1 + Z_2(I_1 - I_2)$$
$$= I_1 Z_1 + I_1 Z_2 - I_2 Z_2$$
$$= I_1(Z_1+Z_2) - I_2 Z_2 \longrightarrow (1)$$

$Z_{11} = Z_1 + Z_2$ Total Impedance in first loop

$Z_{12} = Z_2$ = Common Impedance b/w first & Second Loop

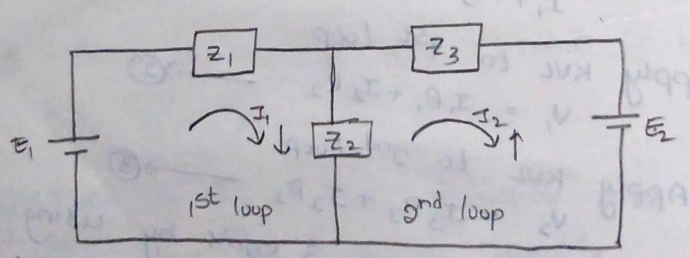
Apply KVL to the Second Loop

$$0 = I_2 Z_3 + Z_2(I_2 - I_1)$$
$$= I_2 Z_3 + I_2 Z_2 - I_1 Z_2$$
$$0 = I_2(Z_2 + Z_3) - I_1 Z_2 \longrightarrow (2)$$
$$= -I_1 Z_2 + I_2(Z_2+Z_3) \longrightarrow (2)$$

$Z_{21} = Z_2$ Common Impedance b/w 1st & 2nd loop

$Z_{22} = Z_2 + Z_3$ = Total Impedance in the second loop

$$\begin{bmatrix} E \\ 0 \end{bmatrix} = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix}$$

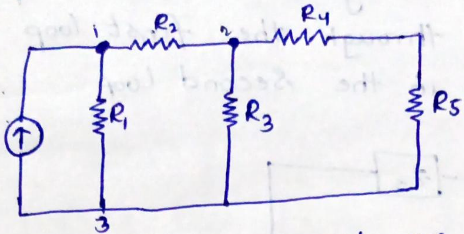


$$E_1 = I_1 Z_1 + Z_2(I_1 - I_2)$$
$$= I_1 Z_1 + I_1 Z_2 - I_2 Z_2$$
$$= I_1(Z_1+Z_2) - I_2 Z_2 \longrightarrow (1)$$

$$E_2 = I_2 Z_3 + Z_2(I_2 - I_1)$$
$$= I_2 Z_3 + I_2 Z_2 - I_1 Z_2$$
$$= I_2(Z_3+Z_2) - I_1 Z_2 \longrightarrow (2)$$

Nodal Analysis :-

The Node voltage is the voltage of a given node with respect to one particular node called the Reference node which are assume at zero potential.

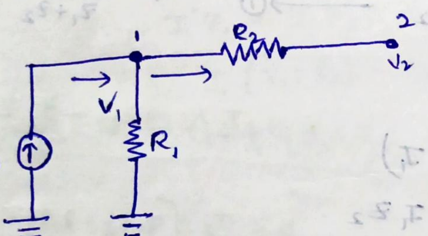


⇒ The node 3 is assumed as the Reference node.

⇒ The voltage at the node1 is the voltage at that node w.r.t the node

⇒ Similarly the voltage as the node 2 is the voltage at that node w.r.t the node - 3

Apply kirchoff's current law as the node 3 the current leaving the current entering is equal to



Entering Current = leaving Current

$I = \frac{V}{R}$

$$I_1 = \frac{V_1}{R_1} + \frac{V_1 - V_2}{R_2}$$

⇒ potential difference b/w points Node 1 Consider Chettunnam kanuka $V_1 - V_2$

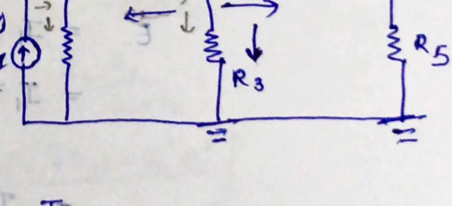
Here V_1 and V_2 are the voltages at node 1 & 2

At node 2, the current entering is equal to the current leaving

node 2 Consider chettunnam kanuka $V_2 - V_1$ ⇓ R_2 are Resistor two nodes points ki madyalo vundhi

$$\frac{V_2 - V_1}{R_2} + \frac{V_2}{R_3} + \frac{V_2}{R_4 + R_5} = 0$$

only node 2 ki link



Arranging the above eqn

$$V_1\left[\frac{1}{R_1} + \frac{1}{R_2}\right] - V_2\left[\frac{1}{R_2}\right] = I_1$$

$$-V_1\left[\frac{1}{R_1}\right] + V_2\left[\frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4 + R_5}\right] = 0$$