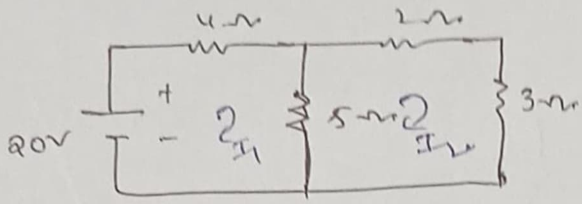
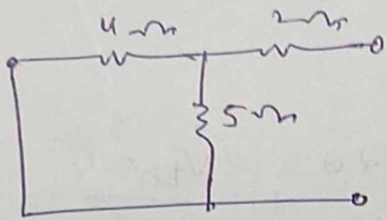
PART-A

M-2

① Determine the current flowing through 3 ohms resistor using Norton's theorem. If the circuit is as below.



Sol

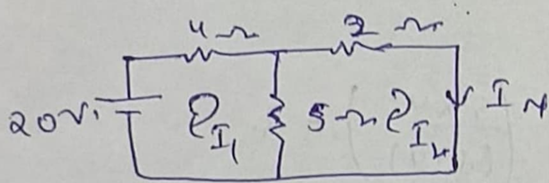


(1) To find R_N.

$$R_{eq} = \frac{5\times4}{5+4} = 2.2\,\Omega$$

$$R_N = 2.22 + 2 = 4.22\,\Omega$$

(2) To find I_N.



Mesh - I

$$-4I_1 - 5(I_1 - I_2) + 20 = 0$$

$$-4I_1 - 5I_1 + 5I_2 + 20 = 0$$

$$9I_1 - 5I_2 = 20 \quad \text{—(1)}$$

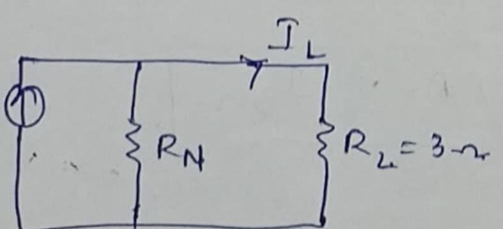
Mesh - II

$$-2I_2 + 5(I_1 - I_2) = 0$$

$$5I_1 - 7I_2 = 0 \quad \text{—(2)}$$

solve (1) & (2) → $I_1 = 3.68\,A$; $I_2 = 2.63\,A = I_N$

(3)

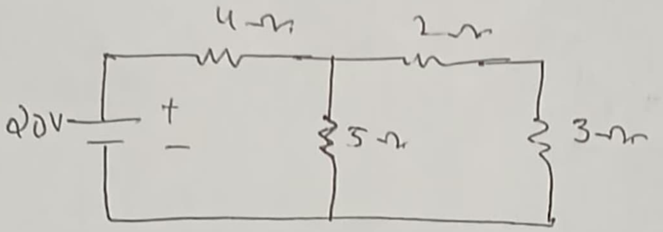


$$I_L = I_N \left(R_N / R_N + R_L \right)$$

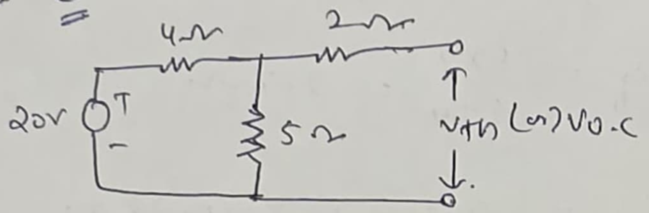
$$I_L = 2.63 \times \frac{4.22}{7.22}$$

$$\boxed{I_L = 1.53\,A = I_{3\Omega}}$$

(2) Determine the current flowing through 3 ohms resistor using thevenin's theorem. If the circuit is as below.



Sol (1) Calculation of V_{th}

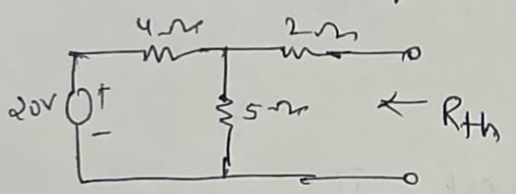


$$\frac{V_{th}-20}{4} + \frac{V_{th}-0}{5} = 0$$

$$9V_{th} = 100$$

$$\boxed{V_{th} = 11.1V}$$

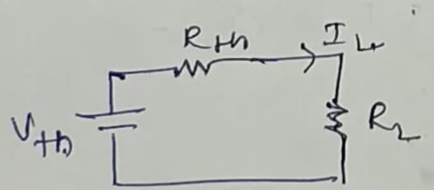
(2) Calculation of R_{th}



$$R_{th} = \left(\frac{5\times4}{(5+4)}\right) + 2.$$

$$\boxed{R_{th} = 4.2\,\Omega}$$

(3) Draw the equivalent circuit

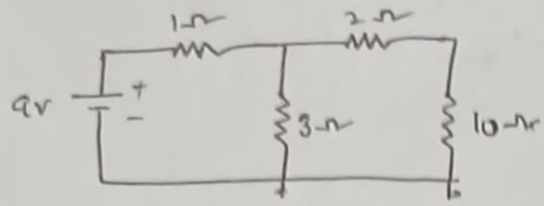


$$I_L = \frac{V_{th}}{R_{th}+R_L}$$

$$I_L = \frac{11.1}{4.22+3}$$

$$\boxed{I_L = 1.52A = I_{3\Omega}}$$

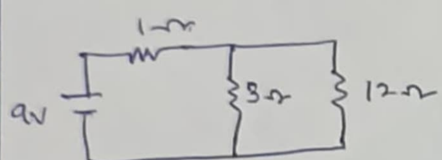
③ Find out the current flowing in $3\,\Omega$ resistor in the circuit shown in figure using reciprocity theorem.



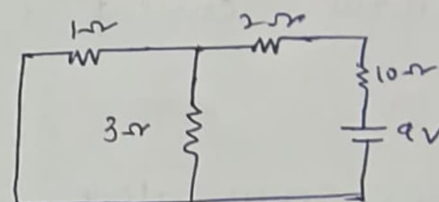
Sol: Reciprocity Theorem $\Rightarrow$ $\boxed{V/I_1 = V/I_2}$

$R_L = 3\,\Omega$

$$I_1 = I_T \times \frac{\text{opp Resistance (Ropp)}}{R_L + \text{Ropp}}$$



After Interchange



$R_{eq} = \left(\frac{12 \times 3}{12+3}\right) + 1 = 3.4\,\Omega$

$V = I_T R \Rightarrow 9 = I_T\,(3.4)$

$I_T = 2.69\,A$

$I_1 = 2.69 \times \frac{3}{15}$

$I_1 = 0.528\,A$

$V/I_1 = 17$

$R_{eq} = \left(\frac{3 \times 1}{3+1}\right) + 2 + 10 = 12.75\,\Omega$

$V = I_T R \Rightarrow 9 = I_T \times 12.75$

$I_T = 0.705\,A$

$I_2 = 0.705 \times \frac{3}{4}$

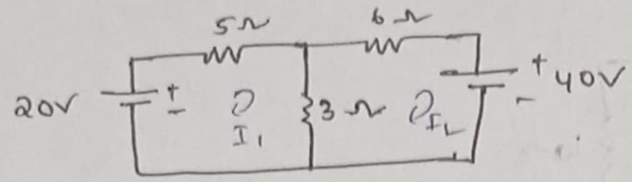
$I_2 = 0.52\,A$

$V/I_2 = 9/0.52 = 17\,V$

$\boxed{\therefore V/I_1 = V/I_2}$

$\boxed{\text{The current through } 3\,\Omega \text{ resistor is } 0.52\,A \quad (\because I_1 = I_2)}$

(5) Find out the current flowing in 3 Ω resistor in the circuit shown in figure using Superposition theorem.



Sol By mesh Analysis.

Mesh - I : → $20 - 5I_1 - 3(I_1 - I_2) = 0$

$$8I_1 - 3I_2 = 20 \quad — (1)$$

Mesh - II → $6I_2 + 40 + 3(I_2 - I_1) = 0$

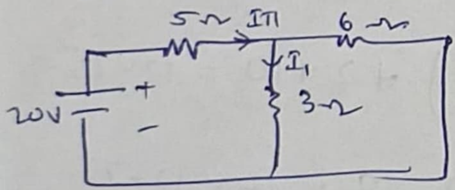
$$3I_1 - 9I_2 = 40 \quad — (2)$$

Solve (1) & (2) ; $I_1 = 0.95\,A$ and $|I_2| = +4.12\,A$

The total current $(I) = I_1 + I_2$

$$\boxed{I = 5.07\,A}$$

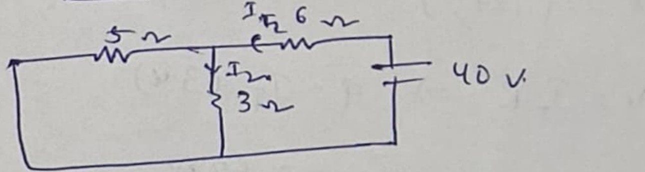
Consider 20V source alone



$$I_{T_1} = \frac{20}{5 + \left(\frac{6\times3}{6+3}\right)} = 2.85\,A$$

$$I_1 = I_{T_1} \times \frac{6}{5+3} = 2.14\,A$$

Consider 40V source alone



$$I_{T_2} = \frac{40}{6 + \left(\frac{5\times3}{5+3}\right)} = 5.07\,A$$

$$I_2 = I_{T_2} \times \frac{5}{6+3} = 2.81\,A$$

According to superposition theorem:

$$I = I_1 + I_2.$$

$$\boxed{I \simeq 4.95\,A}$$

(5) What is the necessity of interconnection windings in 3 phase supply. What is the co relation of star and delta connections in 3 phase supply system.

Ans **Necessity of inter connection windings in 3 phase supply:**

(1) Smaller in size.

(2) Constant output power.

(3) Easy in parallel operation.

(4) Good reliability.

(5) Inter connection of system is possible in star & delta.

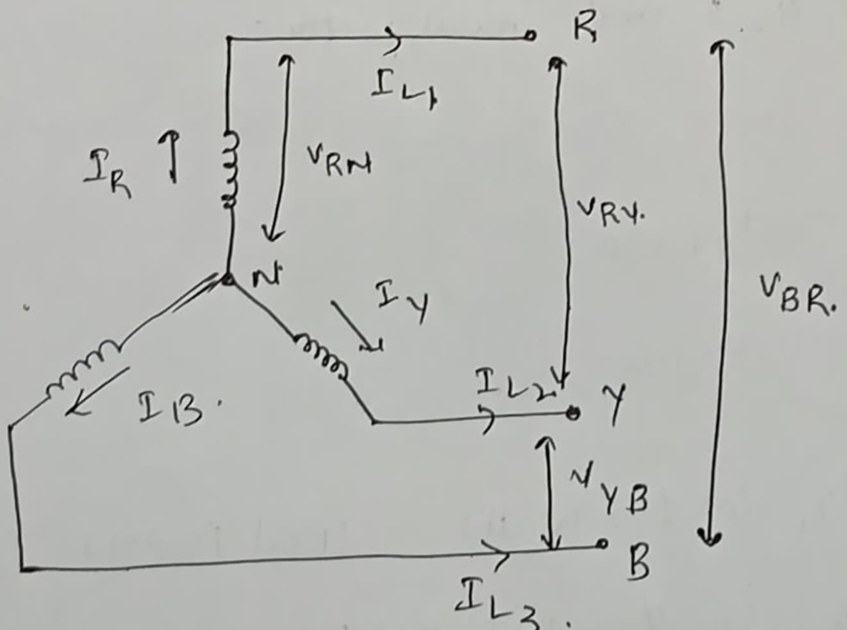
(6) Mutual phase ship between each phase is $120°$.

(1) **Star connection:**

$I_R, I_B, I_Y \rightarrow$ phase currents

$I_{L_1}, I_{L_2}, I_{L_3} \rightarrow$ line currents.

$\boxed{I_{phase} = I_{Line}}$

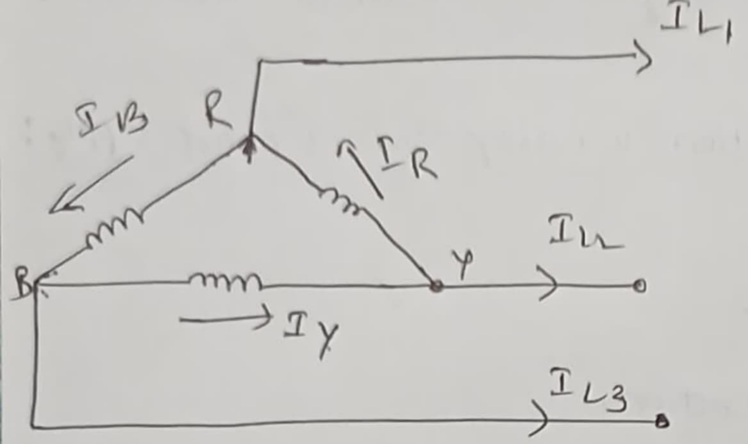


V_{RN}; V_{BN}; $V_{YN} \rightarrow$ phase voltages.

$\boxed{V_L = \sqrt{3}\, V_{ph}}$

V_{BR}; V_{BY}; $V_{RY} \rightarrow$ line voltages.

③ Delta connection:



$I_R, I_Y, I_B \rightarrow$ phase currents.

$I_{L1}, I_{L2}, I_{L3} \rightarrow$ line currents.

$$\boxed{I_L = \sqrt{3}\, I_{ph}.}$$

$V_R; V_Y; V_B \rightarrow$ phase voltages.

$V_{RY}; V_{YB}; V_{BR} \rightarrow$ line voltages.

$$\boxed{V_{ph} = V_{Line}.}$$

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⑦ Write the voltage and current relationships in 3 phase star connection supply. Also write the Expressions for; P, Q, S and power factor.

Sol (Diagram from above Question - refer before page).

* $I_{phase} = I_{Line}$

* $\sqrt{3}\, V_{phase} = V_{Line}$.

* $P = \sqrt{3}\, V_L I_L \cos\phi$ Watt's (Real Power)

* $Q = \sqrt{3}\, V_L I_L \sin\phi$ ~~KVR's~~ VAR's (Reactive Power)

* $S = \sqrt{3}\, V_L I_L$. VA (Apparent Power). Complex.

(8) Three loads, each of resistance of 30 are connected in star to a 415 V, 3 phase supply. Determine (a) the system phase voltage. (b) the phase current (c) the line current

Sol A '415V, 3 phase supply' means that 415 V is the line voltage. $\therefore V_L = 415V$.

$R_{ph} = 30\,\Omega$

Star connection.

(a) $V_{ph} = ?$; $V_L = \sqrt{3}\, V_{phase}$

$$V_{ph} = \frac{415}{\sqrt{3}} = 239.6V \text{ (or) } 240V.$$

(b) $I_{ph} = ?$; $I_{ph} = \frac{V_{ph}}{R_{ph}} = \frac{240}{30}$

$I_{ph} = 8A.$

(c) $I_L = ?$; $\because I_{ph} = I_L = 8\,A$

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(9) Write the voltage and current relationship in 3 phase delta connected supply. Also write the expressions for P, Q, S and power factor.

Ans (Diagram - Refer 6Q).

* $I_{Line} = \sqrt{3}\, I_{phase}$.
* $V_{phase} = V_{Line}$.
* $P = \sqrt{3}\, V_L I_L \cos\phi$ watt's (Real power).
* $Q = \sqrt{3}\, V_L I_L \sin\phi$ ~~KVR's~~ VAR's (Reactive power).
* $S = \sqrt{3}\, V_L I_L$ VA (Apparent power). Complex

(10) A 415V, 3 phase AC motor has a power output of 12.75 KW and operates at a power factor of 0.77 lagging and with an efficiency 85%. If the motor is delta connected. Determine (a) the power input (b) the line current (c) the phase current.

Sol
$\eta = 85\%$; power factor $= 0.77$; O/P power $= 12.75$ KW
$V_L = 415$

(a) $\eta = \dfrac{\text{o/p power}}{\text{i/p power}} \times 100 \Rightarrow \dfrac{85}{100} = \dfrac{12.75 \times 1000}{\text{i/p power}} \cancel{\times 100}$ KW

$\boxed{\text{i/p power} = 15000\,W = 15\,KW}$

(b) Power $= \sqrt{3}\, V_L\, I_L \cos\phi$ $\qquad I_L = ?$

$I_L = \dfrac{15000}{\sqrt{3} \times 415 \times 0.77}$

$\boxed{I_L = 27.10\,A.}$

(c) Delta ; $I_L = \sqrt{3}\, I_{phase}$

$I_{ph} = \dfrac{27.10}{\sqrt{3}}$

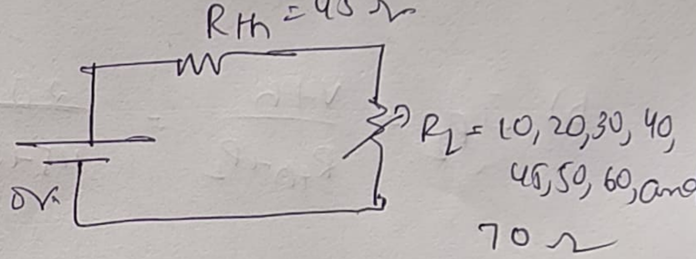
$\boxed{I_{ph} = 15.65\,A.}$

4m left

(4) In a Series circuits source resistance is 45 ohms and load resistor is R_L with. 20V DC Supply. If R_L is variable of resistances 10, 20, 30, 40, 45, 50, 60, 70 ohms respectively. Calculate for what resistance of load maximum power transferred, maximum power value, current and voltage drops in each case.

Ans Maximum power transfer Theorem condition is

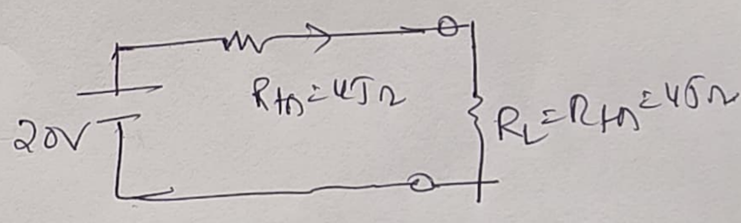
when $R_{th} = R_L$.



$$I_{R_L} = \frac{V_{th}}{R_{th} + R_L}$$

$$\Rightarrow \frac{20}{45+45} = \frac{20}{90}$$

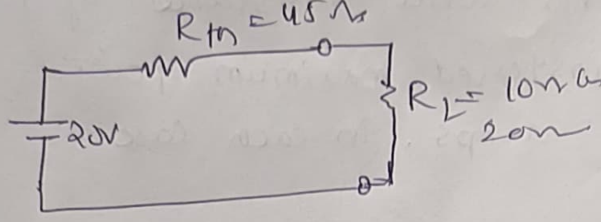
$$= 2/9 \text{ Amp.}$$



$$P_{max} = \frac{V_{th}^2}{4R_{th}} = \frac{20 \times 20}{4 \times 45} = \frac{20}{9} \text{ watts.}$$

voltage at maximum power transfer condition is 10V (50% of supply voltage & Efficiency is only 50%).

This theorem is not applicable to power systems where Mega watts of power is transfered



a) $I_{R_L} = \dfrac{V_{th}}{R_{th} + R_L} = \dfrac{20}{45+10} = \dfrac{20}{55} = 0.3636$ Amp

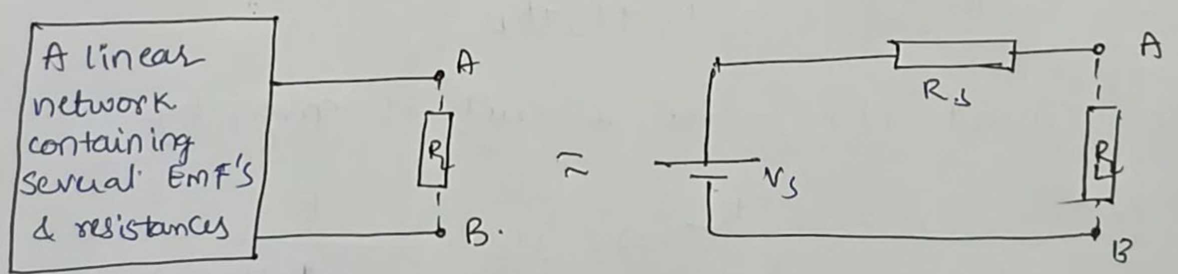
b) $I_{R_L} = \dfrac{V_{th}}{R_{th} + R_L} = \dfrac{20}{45+20} = \dfrac{20}{65} = 0.3076$ Amp

PART- B

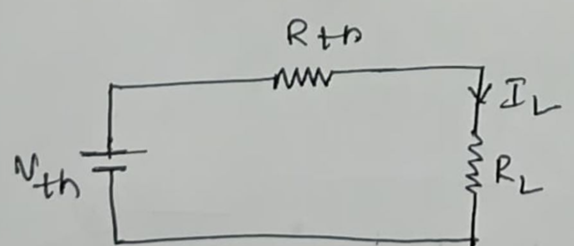
(1) State Thevenin's Theorem. Prove Thevenin's Theorem.
(2) Explain the steps in calculating the Thevenin's voltage
(3)
(4) and also to determine the equivalent circuit while applying
(6)
(16) Thevenin's Theorem to DC network. Explain with an example for DC excitation. State the theorem applications & limitations.

Ans: **Thevenin's theorem;**

Statement: "Any linear, bilateral network (AC or DC) containing several number of voltage sources, current sources and resistances can be replaced by an equivalent network of having a single voltage source called Thevenin's voltage (V_{th}) and a single resistance called Thevenin's resistance (R_{th})."

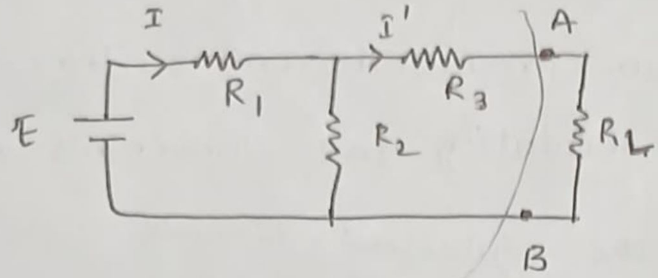


Equivalent circuit diagram:



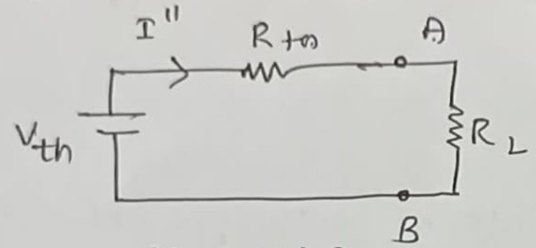
$$I_L = \frac{V_{th}}{R_{th}+R_L}$$

Proof: Consider the network as shown below



circuit(1)

The equivalent circuit is given by.



Circuit(2)

From circuit (1); The effective resistance of the network is R_3 and R_L are in series and this combination is parallel to R_2 and which in turn is in series with R_1.

$$R_{eff} = R_1 + \frac{R_2(R_3+R_L)}{R_2+R_3+R_L} \quad \text{—} \ (1)$$

The current (I) in the circuit is given by

$$I = \frac{E}{R_{eff}} \Rightarrow I = \frac{E}{R_1 + \frac{R_2(R_3+R_L)}{R_2+R_3+R_L}}$$

or

$$I = \frac{E(R_2+R_3+R_L)}{R_1R_2+R_1R_3+R_1R_L+R_2R_3+R_2R_L} \quad \text{—} \ (2)$$

The current through load resistance (I') is found by using branch current method.

$$I' = \frac{I R_2}{R_2+R_3+R_L} \quad \text{—} \ (3)$$

Substituting for I from ① & ③

$$I' = \frac{E(R_2 + R_3 + R_L) \cdot R_2}{(R_1R_2 + R_2R_3 + R_3R_1 + R_1R_L + R_2R_L)(R_2 + R_3 + R_L)}$$

$$I' = \frac{E R_2}{R_1R_2 + R_2R_3 + R_3R_1 + R_1R_L + R_2R_L} \quad \text{— (4)}$$

Thevenin's voltage $V_{th} = \dfrac{E R_2}{R_1 + R_2}$ — (5)

(By Nodal analysis $\dfrac{V_{th} - E}{R_1} + \dfrac{V_{th} - 0}{R_2} = 0$

Thevenin's resistance $R_{th} = R_3 + \dfrac{R_1 R_2}{R_1 + R_2}$. — (6)

Consider the equivalent circuit ②. The current I'' in the equivalent circuit is $I'' = \dfrac{V_{th}}{R_{th} + R_L}$ — (7)

Substitute (5) & (6) in (7)

$$I'' = \frac{\left(\frac{E R_2}{R_1 + R_2}\right)}{R_3 + \frac{R_1R_2}{R_1 + R_2} + R_L} = \frac{E R_2}{R_1R_2 + R_2R_3 + R_3R_1 + R_1R_L + R_2R_L} \quad \text{— (8)}$$

From eq (4) & (8), it is observed that $I' = I''$.

Hence, thevenin's theorem is verified.

Steps in Calculating the Thevenin's voltage and thevenin's resistance:

Step - 1: Replace all sources by their internal resistance (voltage sources are replaced by short circuit and current sources are replaced by open circuit).

Step - 2: Find the equivalent resistance R_{th} across the open circuited load resistance.

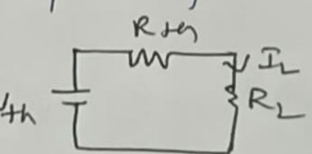
Step - 3: Find the open circuit voltage (V_{oc}) or thevenin's voltage (V_{th}).

Step - 4: Remove the load resistance.

Step - 5: Find the thevenin's voltage (V_{th}) across the load terminal.

Step - 6: Draw the thevenin's equivalent circuit and find the load current (I_L) by using the formulae

$$I_L = \frac{V_{th}}{R_{th} + R_L}$$



Applications: ① Used in the analysis of power systems.

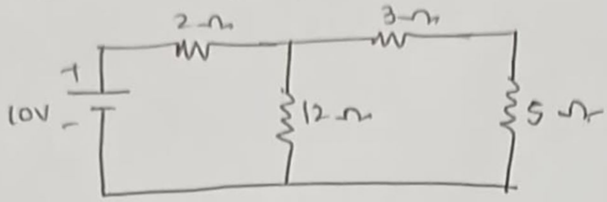
② Used in source modelling and resistance measurement in Wheatstone bridge.

Limitations: ① Not applicable to Unilateral networks.

② Not applicable to the circuits consisting of non-linear elements.

③ The power dissipation of the thevenin's equivalent is not identical to the power dissipation of the real system.

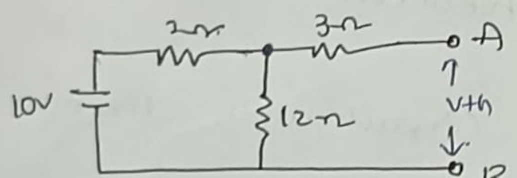
Example : By using Thevenin's theorem, determine the current through 5 Ω resistor as shown in below figure.



Sol Step-1: Since, the question asked to determine the current through 5 Ω resistor. We get into a conclusion that,

Load resistance $= R_L = 5\,\Omega$.

Step-2: Open the branch of 5 Ω resistor. Calculate the thevenin's voltage (V_{th}).



By Nodal analysis

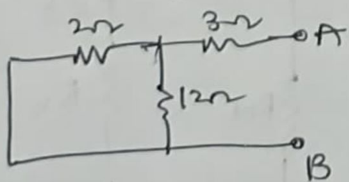
$$\frac{V_{th}-10}{2} + \frac{V_{th}-0}{12} = 0$$

$$6V_{th} - 60 + V_{th} = 0.$$

$$7V_{th} = 60$$

$$\boxed{V_{th} = 8.571V}$$

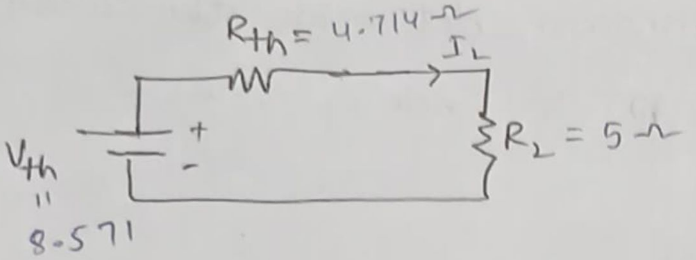
Step-3: To find the thevenin's resistance, short circuit the voltage source.



$$R_{eq} = \left(\frac{2\times12}{2+12}\right) + 3$$

$$R_{eq} = 4.714\,\Omega = R_{th}.$$

Step-4: Draw the Thevenin equivalent circuit and find the load current.



$$I_L = \frac{V_{th}}{R_{th} + R_L}$$

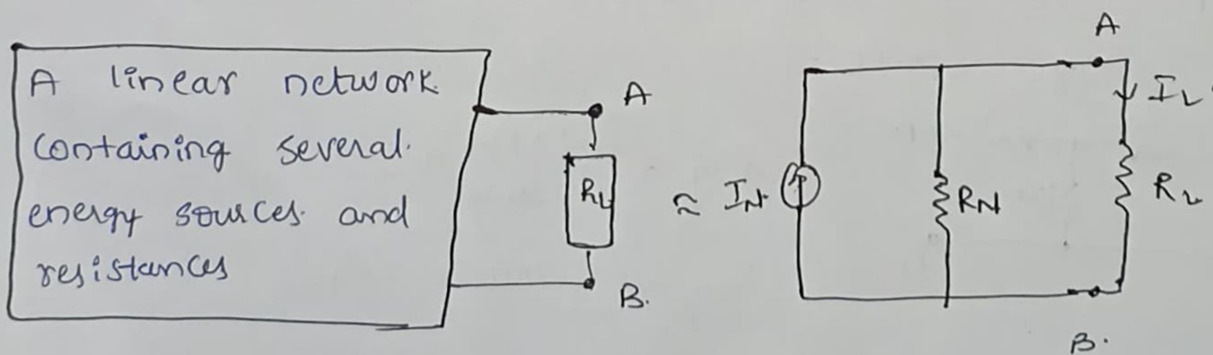
$$(I)_{5\Omega} = \frac{8.571}{(4.714+5)} = \frac{8.571}{9.714} = 0.882\ A$$

$\boxed{\therefore \text{ The current through } 5\Omega \text{ resistor is } 0.882\ A}$

(17) Mention and verify Norton's theorem with an example for DC excitation.

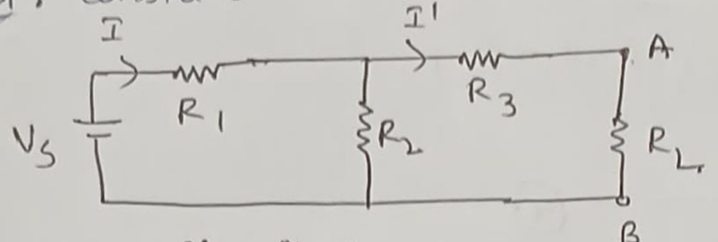
(14) Describe the Norton's equivalent circuit with their importance.

Ans Statement: "Any linear, Bilateral network (AC or DC) containing several voltages, currents and resistances can be replaced by just one current source (I_N) with a parallel resistance (R_N)."



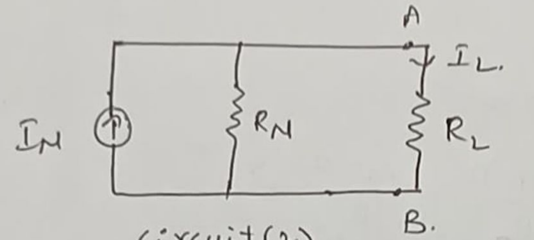
$$\boxed{I_L = I_N \frac{R_N}{(R_N + R_L)}}$$

Proof: Consider the network as shown below.



Circuit (1)

The equivalent circuit is given by,



Circuit (2)

From circuit (1): The Effective resistance of the network is R_3 and R_L are in series and this combination is parallel to R_2 and which in turn is in series with R_1.

$$R_{eff} = R_1 + \frac{R_2(R_3+R_L)}{R_2+R_3+R_L} \quad — ①$$

The current (I) in the circuit is given by $I = \frac{V_S}{R_{eff}}$

$$I = \frac{V_S}{R_1 + \frac{R_2(R_3+R_L)}{R_2+R_3+R_L}}$$

or

$$I = \frac{V_S (R_2+R_3+R_L)}{R_1R_2 + R_2R_3 + R_3R_1 + R_1R_L + R_2R_L} \quad — ②$$

The current through load resistance (I') is found by using branch current method.

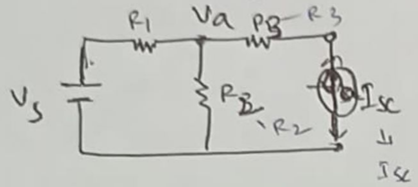
$$I' = \frac{I R_2}{R_2+R_3+R_L} \quad — ③$$

Substitute ② in ③

$$I' = \frac{V_s\,(R_2 + R_3 + R_L) \cdot R_2}{(R_1R_2 + R_2R_3 + R_3R_1 + R_1R_L + R_2R_L)\,(R_2 + R_3 + R_L)}$$

$$I' = \frac{V_s\,R_2}{R_1R_2 + R_2R_3 + R_3R_1 + R_1R_L + R_2R_L} \quad \text{— (4)}$$

Source voltage (V_s) - ?



By nodal analysis;

$$\frac{V_a - V_s}{R_1} + \frac{V_a - 0}{R_2} + \frac{V_a - 0}{R_3} = 0$$

$$\frac{V_a}{R_1} + \frac{V_a}{R_3} + \frac{V_a}{R_2} - \frac{V_s}{R_1} = 0$$

$$V_a\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right) = \frac{V_s}{R_1}$$

$$V_a\left(\frac{R_1R_2 + R_2R_3 + R_3R_1}{R_2R_3}\right) = V_s$$

$$V_a = \frac{V_s\,(R_2R_3)}{R_1R_2 + R_2R_3 + R_3R_1}$$

$$I_{sc} \text{ (Nortons current)} = \frac{V_a}{R_3}$$

$$I_{sc} = \frac{V_s\,R_2}{R_1R_2 + R_2R_3 + R_3R_1} = I_N \quad \text{— (5)}$$

Norton's resistance; $R_N = R_3 + \dfrac{R_1R_2}{R_1 + R_2}$ — (6)

Consider the equivalent circuit (2). The current I_L in the circuit is given by $I_L = I_N\left(\dfrac{R_N}{R_N + R_L}\right)$ — (7)

Substitute (5) & (6) in (7)

$$I_L = \frac{V_S R_2}{R_1R_2+R_2R_3+R_3R_1} \times \frac{\left(\frac{R_1R_2+R_2R_3+R_3R_1}{R_1+R_2}\right) \times}{\left(\frac{R_1R_2+R_2R_3+R_3R_1}{R_1+R_2}\right)+R_L}$$

$$I_L = \frac{V_S R_2}{R_1R_2+\cancel{R_2R_3+R_3R_1}} \times \frac{\cancel{R_1R_2+R_2R_3+R_3R_1}}{\cancel{R_1+R_2}} \times \frac{\cancel{R_1+R_2}}{R_1R_2+R_2R_3+R_3R_1+R_1R_L+R_2R_L}$$

$$I_L = \frac{V_S R_2}{R_1R_2+R_2R_3+R_3R_1+R_1R_2+R_2R_L} \quad -(8)$$

From eq (4) & (8), it is observed that $I_L = I'$

Hence, Nortons theorem is verified.

Steps in calculating the load current in the equivalent circuit:

Step - 1: Find the Norton's resistance (R_N).

Step - 2: Replace all sources by their internal resistance (voltage sources are replaced by short circuit and current sources are replaced by open circuit).

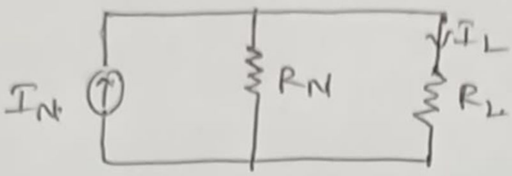
Step - 3: Findout equivalent resistance R_N across the open circuited load resistance.

Step - 4: Find out short circuit current I_{SC} (or) Nortons current I_N.

Step - 5: Remove the load resistance with a short circuit.

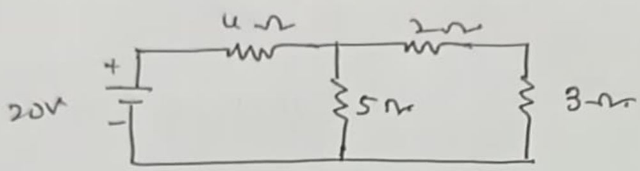
Step - 6: Find the Norton's current I_N across the load terminal.

Step - 7: Draw the Norton's equivalent circuit.

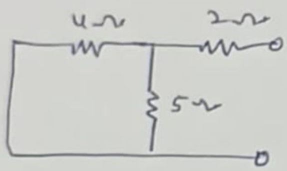


$$I_L = I_N \frac{R_N}{R_N + R_L}.$$

Example: Calculate the current flowing through 3 Ω resistor using Norton's theorem.



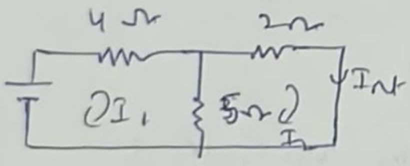
Sol



Step - 1: Find R_N

$$R_N = \left(\frac{5 \times 4}{5+4}\right) + 2 = 4.22\ \Omega$$

Step - 2: Find I_N



Ist mesh: $9I_1 - 5I_2 = 20$ — (1)

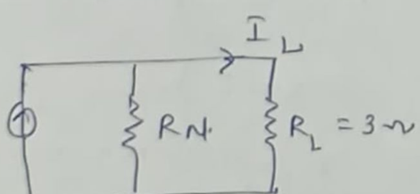
IInd mesh: $5I_1 - 7I_2 = 0$ — (2)

Solve (1) & (2)

$I_1 = 3.68\,A$; $I_2 = 2.63\,A$.

$$\boxed{I_N = I_2 = 2.63\,A}$$

Step - 3: Find I_L



$$I_L = I_N \times \frac{R_N}{R_N + R_L}$$

$$I_L = 2.63 \times \frac{4.22}{7.22}$$

$$\boxed{I_L = 1.53\,A}$$

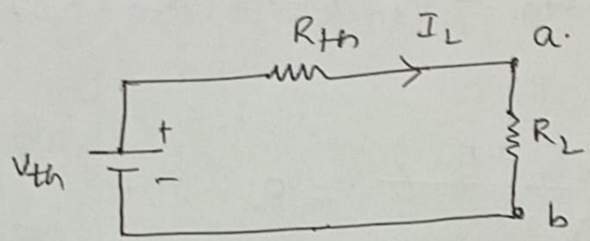
∴ The current through 3 Ω resistor is 1.53A

(5) State and verify maximum power transfer theorem with
(10) an Example for DC excitation and also prove the following
(15) Case : load resistance is equal to the source resistance.

Ans: **Maximum power transfer theorem :**

Statement : "In any linear, bilateral network a load will receive maximum power from the source when the load resistance is equal Exactly to the thevenin's resistance of the network."

Proof : consider the circuit (equivalent) from the thevenin's theorem.



The current in the equivalent circuit is

$$I_L = \frac{V_{th}}{R_{th} + R_L}$$

we know that; power delivered to the load resistance

$$P = I_L^2 R_L$$

$$P = \left(\frac{V_{th}}{R_{th}+R_L}\right)^2 R_L \quad \text{— (1)}$$

To determine the value of R_L for maximum power to be transferred to the load, we have to set the first derivative of the above equation with respect to R_L and equals to zero's i.e,

$$\frac{dP}{dR_L} = 0$$

$$\frac{d}{dR_L}\left(\left(\frac{V_{th}}{R_{th}+R_L}\right)^2 R_L\right) = 0.$$

By $\frac{d}{dx}(u/v) \Rightarrow \frac{vu' - uv'}{v^2}$

$$\frac{1}{((R_{th}+R_L)^2)^2}\left((R_{th}+R_L)^2 \cdot \frac{d}{dR_L}(V_{th}^2 R_L) - V_{Th}^2 R_L \cdot \frac{d}{dR_L}(R_{th}+R_L)^2\right) = 0$$

$$\frac{1}{(R_{th}+R_L)^4}\left\{(R_{th}+R_L)^2 V_{th}^2 - V_{th}^2 R_L \cdot 2(R_{th}+R_L)\right\} = 0.$$

$$\frac{V_{th}^2 (R_{th}+R_L - 2R_L)}{(R_{th}+R_L)^3} = 0.$$

$$V_{th}^2 (R_{th} - R_L) = 0.$$

$$R_{th} - R_L = 0$$

$$\boxed{R_{th} = R_L}$$

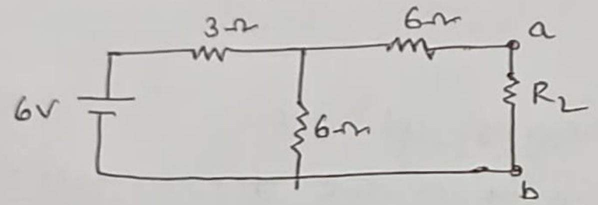
Therefore, from ① $P_{max} = \frac{V_{th}^2}{(2R_{th})^2} \cdot R_{th}.$

$$\boxed{P_{max} = \frac{V_{th}^2}{4R_{th}}}$$

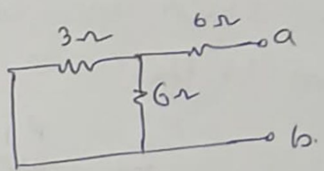
Expressions for maximum power transfer theorem :

When ; $\boxed{R_{th} = R_L}$ then $\boxed{P_{max} = \frac{V_{th}^2}{4 R_{th}}}$

Example: Calculate the value of R_L for maximum power to R_L and Calculate the power delivered under these conditions for the network of the figure shown below.

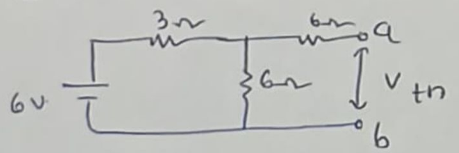


Sol: ① Find the R_{th}.



$R_{th} = (3 \| 6) + 6 = 8\,\Omega = R_L$

② To find V_{th}.



$$\frac{V_{th} - 6}{3} + \frac{V_{th} - 0}{6} = 0$$

$$3 V_{th} = 12$$

$$V_{th} = \underline{4V}$$

from maximum power transfer theorem ;

$$P_{max} = \frac{V_{th}^2}{4R_{th} \cancel{+R_L}} = \frac{4 \times 4}{4 \times 8}$$

$$P_{max} = \underline{0.5 \text{ W}}$$

$\boxed{\therefore \text{ The maximum Power delivered is } 0.5 \text{ W}}$

(15) Mention and prove reciprocity theorem with an example of DC excitation.

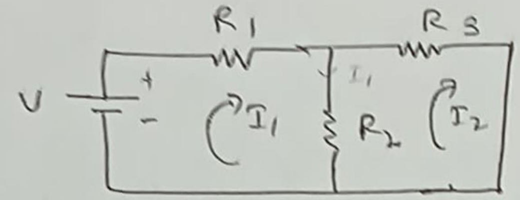
Ans

RECIPROCITY THEOREM:

Statement: In any linear, bilateral, single source network, the ratio of input to output is constant even when their positions are interchanged.

Proof:

Case-1: Consider the networks as shown in below figure (1) in which the source of emf 'E' in the first mesh. Let the current in the first and second mesh be I_1 and I_2 respectively.



Mesh-I:

$$I_1 R_1 + I_1 R_2 - I_2 R_2 = V$$

$$I_1 (R_1 + R_2) - I_2 R_2 = V \quad \text{--- (1)}$$

Mesh-II:

$$I_2 R_3 + R_2 (I_2 - I_1) = 0$$

$$I_2 (R_2 + R_3) - I_1 R_2 = 0$$

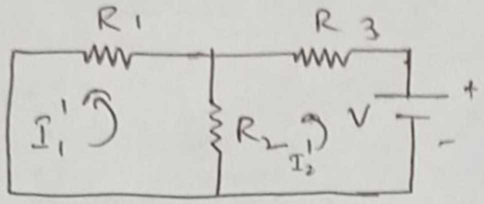
$$I_1 = \frac{I_2 (R_2 + R_3)}{R_2} \quad \text{--- (2)}$$

Substitute (2) in (1);

$$\frac{I_2 (R_1 + R_2)(R_2 + R_3)}{R_2} - I_2 R_2 = V$$

$$I_2 = \frac{V R_2}{\left((R_1 + R_2)(R_2 + R_3) - R_2^2\right)} \quad \text{--- (3)}$$

Case - 2: Consider the network as shown in figure below in which the source of emf in the second mesh. The current in the first and second mesh be I_1' and I_2' respectively.



Mesh - I: ~~$I_1' R_1 + I_1' (R_2 - I R_2) = 0$~~ $I_1' R_1 + (I_1' - I_2') R_2 = 0$

$$I_1' R_1 + I_1' R_2 - I_2' R_2 = 0$$

$$I_2' = \frac{I_1'(R_1 + R_2)}{R_2} \quad \text{—(5)}$$

Mesh - II: $I_2' R_2 + I_2' R_3 - I_1' R_2 = V$

$$V = I_2'(R_2 + R_3) - I_1' R_2 \quad \text{—(6)}$$

Substitute (6) in (5)

$$V \Rightarrow \frac{I_1'(R_1 + R_2)(R_2 + R_3)}{R_2} - I_1' R_2$$

$$V = \frac{I_1'\left((R_1 + R_2)(R_2 + R_3) - R_2^2\right)}{R_2}$$

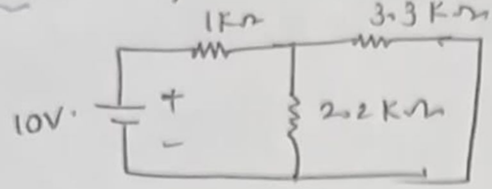
$$I_1' = \frac{V R_2}{\left((R_1 + R_2)(R_2 + R_3) - R_2^2\right)} \quad \text{—(6)}$$

Compare eq (5) & (6); we have.

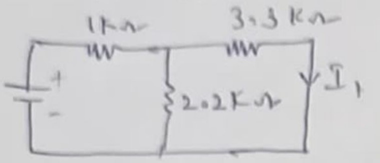
$$I_2 = I_1'$$

which proves the reciprocity theorem.

Example: Verify the reciprocity theorem for the given network



Sol Case - 1



$$I_T = \frac{10}{R_T} = \frac{10}{1+\left(\frac{2.2\times3.3}{2.2+3.3}\right)} = 4.31\,mA.$$

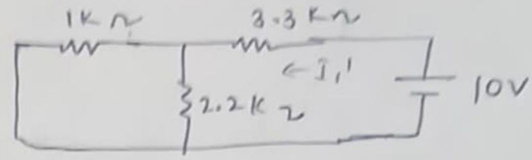
$$I_1 = I_T \times \frac{2.2}{(2.2+3.3)}$$

$$I_1 = 4.31 \times \frac{2.2}{5.5}$$

$$I_1 = 1.724\,mA.$$

$$\frac{V}{I_1} = \frac{10}{1.724} = 5.8\,K\Omega$$

Case - 2 :



$$I_T' = \frac{10}{R_T'} = \frac{10}{3.3+\left(\frac{1\times2.2}{1+2.2}\right)}$$

$$I_T' = \frac{10}{3.98\times10^3} = 2.507\,mA.$$

$$I_2 = I_T' \times \frac{2.2}{(2.2+1)}$$

$$I_2 = 1.723\,mA$$

$$\frac{V}{I_2} = \frac{10}{1.723} = 5.8\,K\Omega.$$

$$\boxed{\therefore \frac{V}{I_1} = \frac{V}{I_2}}$$

Hence proved.

(7) Define the following terms.

(i) phase (ii) Line (iii) Neutral

(iv) phase voltage and current (v) Line voltage and current.

Ans (i) Phase : ~~Phase is the position of a point in time on a cycle of a wave form. One complete cycle is called the phase~~ (or) The three components comprising a three phase source or load are called phases.

(ii) Line : The conductors connected to the three points of a three phase source or load are called lines.

(iii) Neutral: A current carrying conductor that carries the unbalanced current in 3 phase systems, and is intentionally connected to the ground.

(iv) phase voltage; The voltage across the phase winding is called the phase voltage.

Phase currents: The current across the phase winding is called the phase currents.

(v) Line voltage: the voltage between the 2 lines are called as line voltages.

line currents: The current between the 2 lines are called as line currents.

---

(8) Define 3phase system. write the advantages of 3phase
(13) system over 1phase system?

Ans 3 phase System: The three phase system is an economical way of bulk power transmission over long distances and for distribution. The three phase system consists of a three phase voltage source connected to a three phase load by means of transformers and transmission lines.

→ They are usually connected in two kind of connections

a) star connection.

b) Delta connection.

Advantages of 3_phase Systems:

1. Smaller in size.
2. Constant output power.
3. Easy in parallel operation.
4. Good reliability.
5. Interconnection of system is possible in star and delta.
6. mutual faceship between each phase is 120°.

---

(9) What is phase Sequence. How many number of possible Phase Sequence for a 3 phase AC system?

(19) Explain its significance. What is the difference between RYB phase sequence and RBY phase sequence.

Ans Phase Sequence: It is the order in which the three phases of a three-phase system reach their peak values.

→ phase sequence can be either clockwise or counterclockwise, depending upon the direction of rotation of the phasor diagram.

For Ex: ① If phase A reaches its peak before phase B, and phase B reaches it peak before phase C, then the phase sequence is ABC.

② If phase C reaches its peak before phase B, and phase B reaches it peak before Phase A, then the phase sequence is CBA.

Significance of phase sequence:

① Phase sequence is critical to the performance and safety of three-phase systems. If not done correctly, a 3 phase motor may rotate in the wrong direction, potentially damaging equipment or causing accidents.

② Additionally, a three phase transformer may have reversed polarity leading to short circuits or over voltages.

③ Lastely, a three phase load may have a low power factor, resulting in reduced efficiency and increased losses of the system.

* The number of possible phase sequence for a 3 phase AC system is two (02).

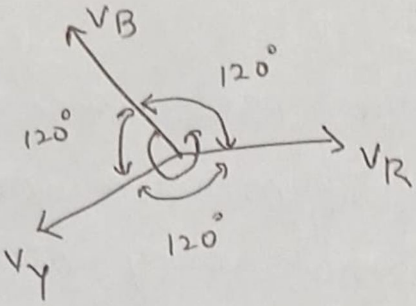
* Consider the R, Y and B be the three phases of the supply system, then the possible phase sequences are RYB and RBY corresponding to the two possible directions of alternator connection.

Difference between RYB phase sequence and RBY Phase Sequence:

→ Basic difference is in the direction of phasors.

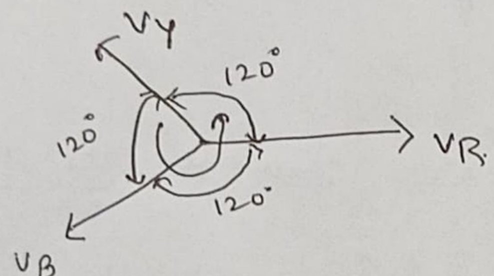
→ They are opposite in direction as they are vector quantities.

→ RYB is considered as a positive sequence, and RBY is a negative sequence supply.



positive sequence - RYB.

The phase sequence can be taken as RYB if R attains its maximum value first with respect to the reference in anti clockwise direction followed by Y phase 120° later, and B phase 240° later than the R phase.



Negative sequence - RBY.

The phase sequence can be taken as RBY if R ~~attains~~ followed by B phase is at 120° later and Y phase is at 240° later than the R phase.

(10) Define Balance load. Comparisions of Star and Delta connections of 3 phase circuit.

Ans: Balance load: In a three-phase system the power factors and the phase current or line currents of the 3 phase are equal then that load is called Balanced load.

Comparisions of star and Delta connections of 3 phase circuits:

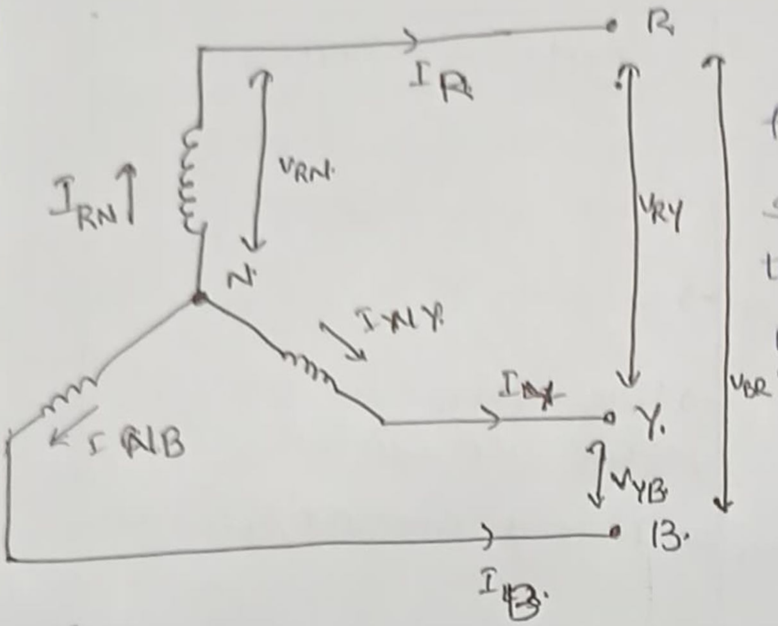
4 wire connection (4th wire optional in some cases)

always 3 wired connection.

Star connection	Delta connection
→ Line current and phase current are same.	→ line current & phase current are different
→ In star connection; $I_{Li} = I_{ph}$.	→ In delta connection; $I_{Li} = \sqrt{3} I_{ph}$
→ Line voltage and phase voltage are different.	→ line voltage and phase voltage are same.
→ In star connection; $V_{Li} = \sqrt{3} V_{ph}$	→ In delta connection, $V_{Li} = V_{ph}$.
→ Used in both transmission and distribution networks.	→ Used in distribution networks only.
→ used for long distances, since insulation required is less.	→ used for shorter distances only.
→ often used in application which require less starting current	→ often used in application which require high starting torque.
→ The common point of the star connection is called Neutral or start point.	→ There is no neutral in delta connection.

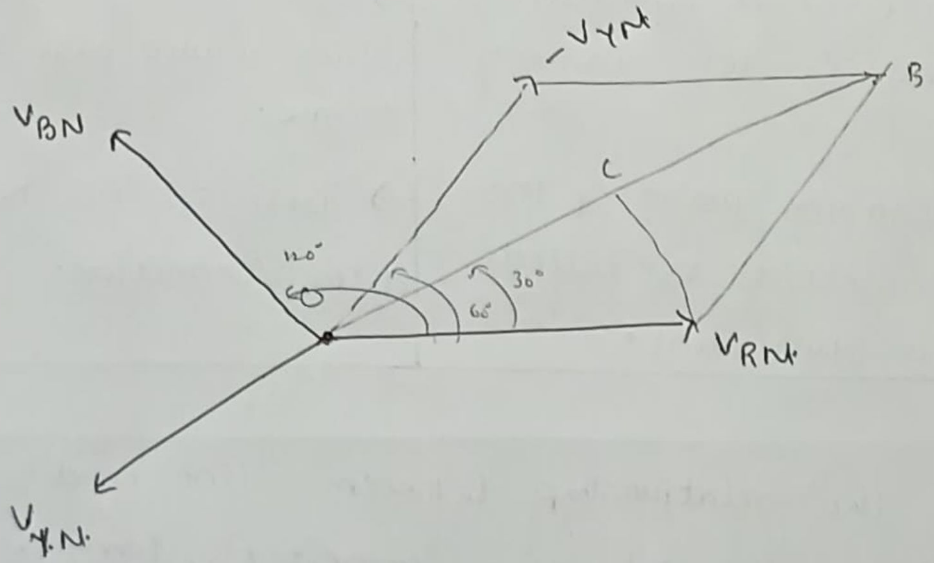
20) Derive the relationship between line and phase quantities in a 3 phase balanced, star connected system and delta connected system and draw phasor diagram.

Ans: Star connected System:



Consider the beside figure, where 'N' is the star or Neutral point. The three conductors named R, Y and B run from the remaining three free terminals say. Here I_R, I_Y and I_B are the line currents. I_{RN}, I_{BN}, I_{YN} are the phase currents. In addition to this, V_{RN}, V_{BN} and V_{YN} are phase voltages and V_{BR}, V_{YB}, V_{RY} are the line voltages. As the system is balanced, we need to draw the phasor diagram.

RYB.



$(V_{RY} = V_{YB} = V_{BR} = V_{Li})$.

Now; $V_{RN} = V_{YN} = V_{BN} = V_{ph}$ (in magnitude)

Tracing the loop NRYN, $\bar{V}_{RY} = \bar{V}_{NY} - \bar{V}_{NR}$ (vector difference)

$\therefore \bar{V}_{RY} = \bar{V}_{NY} - \bar{V}_{NR}$

$$|V_{RY}| = \sqrt{V_{NY}^2 + V_{NR}^2 + 2(V_{NY})(V_{NR})\cos 60^\circ}$$

$$|V_{RY}| = \sqrt{V_{ph}^2 + V_{ph}^2 + 2V_{ph}^2 \times \frac{1}{2}}$$

$$|V_{Li}| = \sqrt{3V_{ph}^2}$$

$$\boxed{V_{Li} = \sqrt{3}\, V_{ph}}$$

Similarly, $V_{YB} = V_{BN} - V_{YN}$ (or) $V_{Li} = \sqrt{3}\, V_{ph}$.

$V_{BR} = V_{RN} - V_{BN}$ (or) $V_{Li} = \sqrt{3}\, V_{ph}$.

Hence, in star connection; line voltage is square root 3 times of phase voltage.

As far as for, line current and phase currents, the same current flows through the phase winding as well as in the line conductor as it is connected in series with phase winding.

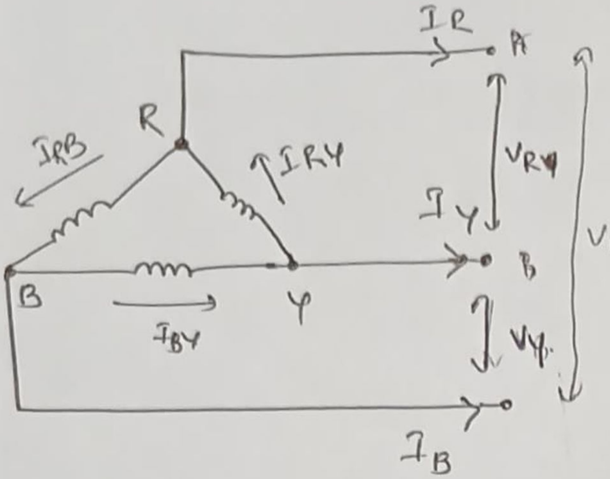
$\therefore I_{RN} = I_R$; $I_{YN} = I_Y$; $I_{BN} = I_B$

where; I_{RN}, I_{YN}, I_{BN} are phase currents and I_R, I_Y and I_B are line currents.

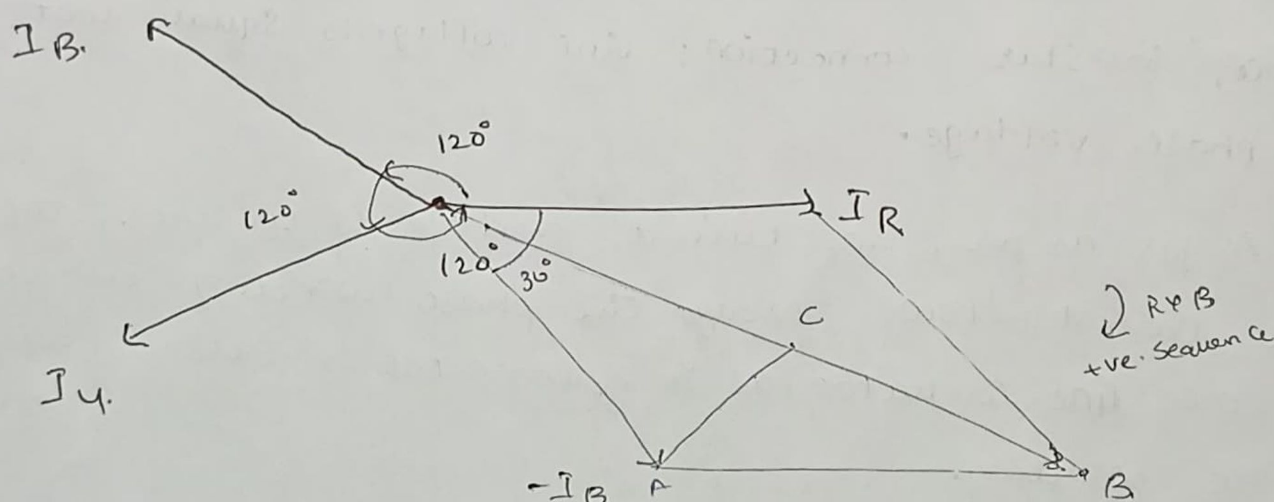
$$\boxed{I_{Li} = I_{ph}}$$

Hence in star connection, line currents is same as the phase current.

Delta Connected:



Consider the beside figure, where it is connected in RYB Sequence. The three conductors R, Y and B are running from the three junctions known as line conductors. Say V_{RY}, V_{YB} and V_{BR} are ~~line~~ Phase voltages and V_R, V_Y and V_B are line voltages. In addition to this; I_R, I_Y and I_B are line currents and I_{RB}, I_{RY} and I_{BY} are phase currents. As it is in the balanced system, we need to draw phasor diagram.



~~$\bar{I}_{RB} = \bar{I}_{YB} - \bar{I}_{YR}$ (vector difference)~~.

By KCL;

$$\bar{I}_{RY} = \bar{I}_R + \bar{I}_{RB}$$

$$\bar{I}_R = \bar{I}_{RY} - \bar{I}_{RB}$$

$$|I_R| = \sqrt{(I_{RY})^2 + (I_{RB})^2 + 2(I_{RY})(I_{RB})\cos 60^\circ}$$

$$I_L = \sqrt{I_{ph}^2 + I_{ph}^2 + 2 (I_{ph})^2 \cdot \frac{1}{2}}$$

$$I_L = \sqrt{3 I_{ph}^2}$$

$$\boxed{I_L = \sqrt{3}\, I_{ph}}$$

Similarly; $\bar{I}_Y = \bar{I}_{RY} + \bar{I}_{BY}$ (or) $I_L = \sqrt{3}\, I_{ph}$

$\bar{I}_B = \bar{I}_{RB} + \bar{I}_{BY}$ (or) $I_L = \sqrt{3}\, I_{ph}$.

Hence in delta connection, Line current is square root 3 times of the phase current.

As far as concern for ~~currents~~ voltages; the voltage across terminals. R and B is same across the end point terminal of R and B. Therefore;

$V_{RB} = V_B \Rightarrow \boxed{V_{ph} = V_L}$

Similarly; $V_{BY} = V_Y$ and $V_{YR} = V_R$.

The phase voltages are

$$V_{RB} = V_{BY} = V_{YR} = V_{ph}.$$

The line voltages are

$$V_R = V_Y = V_B = V_{line}.$$

Hence in delta connection, line voltage is equal to the phase voltage.

(1) Define the statement of below theorems

(i) Thevenins theorem: "Any linear, bilateral network containing Several no. of voltage Sources, current sources and resistances Can be replaced by an equivalent network of having a Single voltage Source called thevenins voltage (V_{th}) and a single resistance called thevenins resistance (R_{th})."

(ii) Superposition theorem: Any linear, bilateral and passive network if it consist of multiple Sources the response in a particular branch is the algebraic sum of responses when one Source is acting individually remaining Sources are deactivated.

(iii) Norton's theorem: Any linear, bilateral network containing Several voltages, currents. and resistances Can be replaced by just one current Source (I_N) with a parallel resistance (R_N).

(iv) Reciprocity theorem: In any linear, bilateral, single Source network, the ratio of input to output is constant even when their positions are interchanged.

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Maximum power transfer theorem: In any linear, bilateral network, a load will receive maximum power from the source when the load resistance is exactly equal to the thevenin's resistance of the network.