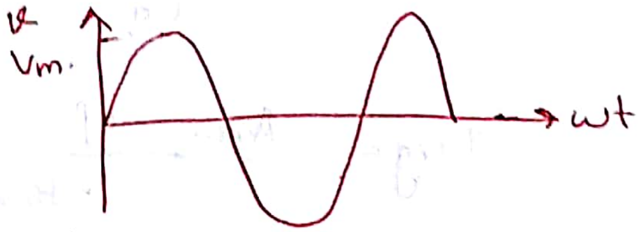
Sinusoidal alternating waveforms

1. Cycle :



2. Frequency : The no. of cycles in second.

3. Amplitude

4. Instantaneous value : - value at particular instant.

Average value "It is defined as steady direct current which transfers across any circuit, the same amount of charge as is transferred by the alternating current during same time.

Determination of Avg. value

1. Mid ordinate method

→ by taking arithmetic mean of ordinates at equal intervals

$$i_{av} = \frac{i_1 + i_2 + \cdots + i_n}{n}.$$

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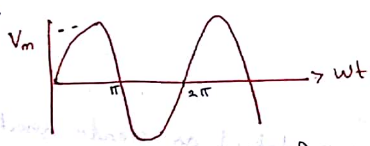
Analytical Method

Eq.

$$I_{avg} = \frac{\text{Area of first Repeating Cycle}}{\text{Base}}$$

* In case of symmetrical alternating current (sinusoidal), average value over complete cycle is zero. In such case avg. value is found by considering one half cycle only.

1.



$$V_{avg} = \frac{\text{Area of first half cycle of sine wave.}}{\text{Base}}$$

$$= \int_0^{\pi} \frac{V_m \sin wt}{\pi}\, dwt$$

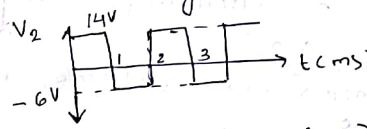
$$= \frac{V_m}{\pi} - \left[\cos wt\right]_0^{\pi} = \boxed{\frac{2V_m}{\pi}}$$

* Average value of symmetrical wave $= \dfrac{\text{Area of one alteration}}{\text{Base length.}}$

* Avg. value of unsymmetrical wave $= \dfrac{\text{Area over one cycle}}{\text{Base length.}}$

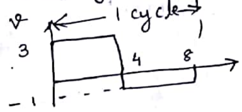
2]. Find the Average value of the waveform.

a)



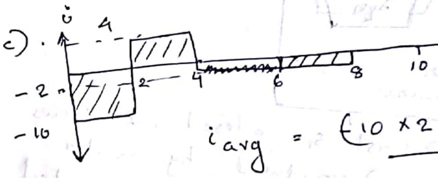
$$V_{2(avg)} = \frac{(14\times1) - (6\times1)}{2}\ \frac{\cancel{s}}{\cancel{s}} = \underline{\underline{4V}}.$$

b)



$$V_{avg} = \frac{12-4}{8} = \underline{\underline{1V}}.$$

c).



$$i_{avg} = \frac{(10\times2)+(4\times2)-(2\times2)}{10}$$

$$= \frac{-20+8-4}{10} = \underline{\underline{-1.6\,\text{A}}}$$

* Why sine waveform ?

1). In ac machines sinusoidal voltage.s and currents respectively produces least iron and copper losses for given output. The η is better.

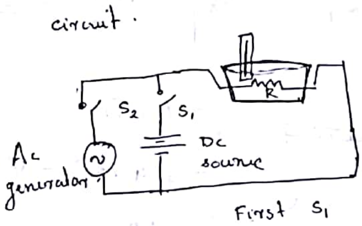
2) Sinusoidal voltage & currents produce less interference (noise) on telephone lines.

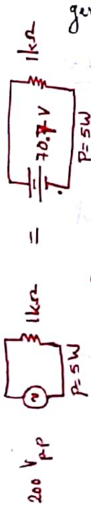
3) The sine waveform produces the least disturbance in electrical circuit and smoothest & efficient waveform.

RMS Value

An alternating voltage or current can be expressed in terms of (i) instaneous value. (ii) peak value. (iii) Rms value.

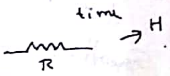
→ RMS value is based on it's heating effect of electric current in electric circuit.





First S_1 closed, I flows and heat (temp) produced by water determined by dc power dissipated in resistor b in the form of heat. Switch S_2 closed, S_1 open, Ac i/p varied untill temp reaches same as that of dc i/p.

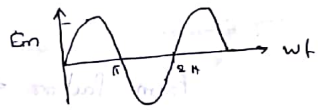
"Rms value is defined as that equivalent steady direct current which when flowing through a given resistance, for a given time produces the same amount of heat energy as produced by alternating current when flowing through the resistance for the same time"

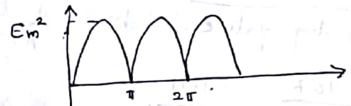


$$I_{rms} = \sqrt{\frac{i_1^2 + i_2^2 + \dots i_n^2}{n}}$$

$$\boxed{I_{rms}^2 = \frac{\text{Area under squared waveform or curve}}{\text{Base.}}}$$

1. Find the RMS value





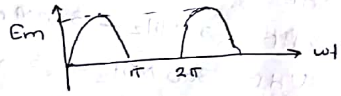
$$E_{rms}^2 = \frac{\int_0^{\pi} e^2 \, d(wt)}{\pi} = \frac{1}{\pi}\int_0^{\pi} Em^2 \sin^2 wt \, dwt$$

$$= \frac{Em^2}{\pi}\int_0^{\pi} \frac{[1 - \cos 2wt]}{2} = \frac{Em^2}{2\pi}\left[(\pi - 0) - (\sin 2wt)_0^{\pi}\right]$$

$$= \frac{Em^2}{2}.$$

$$\boxed{E_{rms} = \frac{Em}{\sqrt{2}}.} \quad ; \quad I_{rms} = \frac{I_m}{\sqrt{2}}.$$

2. Find rms, avg.



$$E_{avg} = \frac{1}{2\pi}\int_0^{\pi} Em \sin wt \, dwt$$

$$= \frac{Em}{2\pi} - [\cos wt]_0^{\pi} = \frac{Em}{2\pi} \times 2 = \underline{\underline{\frac{Em}{\pi}}}$$

$$E_{rms}^2 = \frac{1}{2\pi}\int_0^{\pi} Em^2 \sin^2 wt \, dwt$$

$$= \frac{Em^2}{2\pi}\int_0^{\pi}\left[\frac{1 - \cos 2wt}{2}\right]_0^{\pi}$$

$$= \frac{Em^2}{4\pi}[\pi - 0] = \frac{Em^2}{4}.$$

$$E_{rms} = \underline{\underline{\frac{Em}{2}}}$$

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Peak factor $= \dfrac{\text{Max. Value}}{\text{RMS value}}$.

sine wave $= \dfrac{V_m}{0.707\, V_m} = 1.412$.

Form factor $= \dfrac{\text{RMS value}}{\text{Avg. value}}$. ** Significance determines the sharpness of wave form

$= \dfrac{0.707}{0.637} = \underline{\underline{1.11}}$.

for square wave, rectangular wave form factor = 1

→ Frequency spectrum.

ELF –	30 Hz – 3 kHz	→ Extremely low freq
VLF –	3 kHz – 30 kHz	→ Very low freq.
LF –	30 kHz – 300 kHz	→ low freq.
MF –	300 kHz – 3 MHz	→ Medium freq.
HF –	3 MHz – 30 MHz	→ High freq.
VHF	30 MHz – 300 MHz	→ Very high freq.
UHF	300 MHz – 3 GHz	→ Ultra high freq.
SHF	3 GHz – 30 GHz	→ Super high freq.
EHF	30 GHz – 300 GHz	→ Extremely high freq.

RF

Audio freq.
15 Hz – 20 kHz

Radio freq → 3 kHz – 300 GHz.

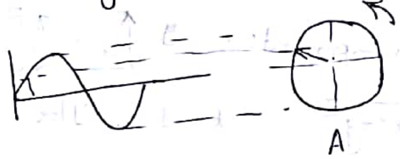
Micro wave → 300 MHz – 300 GHz

even 3 GHz – 300 GHz.

Wifi – 2.4 GHz – 2.56 GHz.

Phasor

A rotating vector is called a phasor.



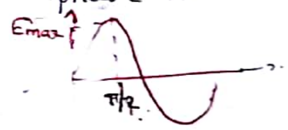
A sinusoidal alternating V or I can be represented by a line of definite length rotating in anticlock wise at constant angular velocity (ω).

Length of phasor = Max. value of alternating quantity.

phase and phase angle.

phase of an alternating quantity is the fraction of time period that has elapsed since it last passed from origin.

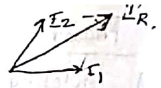
phase angle (ϕ) → equilent to phase in radians or degree.



Phase difference.

If 2 alternating quanties of same frequency, have different zero points; they are said to have a phase difference.

Addition of phasors



1. Parallelogram method.

2. Method of Components.

$R = \sqrt{x^2+y^2}$ $\tan\phi = y/x$

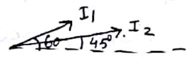
1 Two current represented by

$i_1 = 15 \sin(\omega t+\pi/3)$

$i_2 = 25 \sin(\omega t+\pi/4)$ are fed

to common conductor. Find total current.

Then find the energy loss in 10 hrs, if the circuit is provided with 2Ω resistance



$I_r = \sqrt{I_1^2+I_2^2} = \underline{39.9A}$

$\phi = \tan^{-1}\frac{30}{25.17} = 50.7^\circ$.

$I_{resultant} = 39.9\,(\sin(\omega t+50.7))^\circ$

$\frac{I_m}{\sqrt{2}} = I_{rms}$.

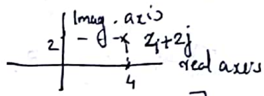
$H = I_{rms}^2 Rt$

$= \left(\frac{39.9}{\sqrt{2}}\right)^2 \times 2 \times 10\times60\times60$

$= \underline{57.31\times10^6}$. Joules

Operator j $j = \sqrt{-1}$

operator j when applied to a phasor E gives a new phasor jE, which is displaced by 90° in anticlockwise direction from E.



Complex No.

1. Rect. form $x + jy$.

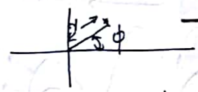
2. Trignometric form : $r[\cos\phi + j\sin\phi]$.

$r = \sqrt{x^2+y^2}$

$\phi = \tan^{-1} y/x$

3. Exponential form: $r\cdot e^{\pm j\phi}$

4. Polar form. $r < \pm\phi$.



44,45,

~~Operation.~~ or $r\angle\theta$ where $r = \sqrt{x^2+y^2}$

Division $\theta = \tan^{-1}y/x$

1. Convert $3+4j$ to polar $\rightarrow 5 < 53.13$

2. " $10 < 45^0$ to rectangular $\rightarrow 10\cos45 + j\,10\sin45$

$\rightarrow 7.07 + j7.07$

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Complex notation of AC.

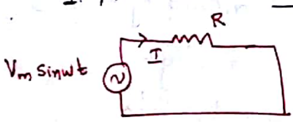
$V\angle\phi_1$

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

$X_L = j\omega L$.

Response of R, L, C elements to sinusoidal voltage

1. AC circuit contain R only



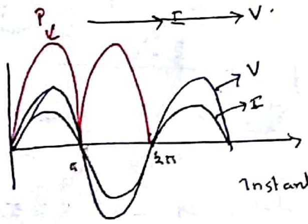
$V = IR$.

$V_m \sin\omega t = I\,R$

$I = \frac{V_m}{R}\sin\omega t = I_m \sin\omega t$

Phasor

or $\longrightarrow I$ $\longrightarrow V$



Instantaneous power $= V_m \sin\omega t \; I_m \sin\omega t$

Average Power over a complete cycle $= \frac{\text{Area under Curve}}{\text{Base.}} = \frac{\int_0^{\pi} V_m \sin\omega t \; I_m \sin\omega t \, dt}{\pi}$

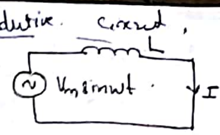
$= \frac{1}{\pi} V_m I_m \int_0^{\pi} \sin^2\omega t \, d\omega t$

$= \frac{V_m I_m}{2\pi} \int_0^{2\pi} [1-\cos 2\omega t]\, d\omega t = \frac{V_m I_m}{2\pi}[\pi.]$

$= \frac{V_m I_m}{2} = V_{rms} I_{rms}$

* Power is +ve, never zero. This means power is always absorbed in a resistive circuit and the same is dissipated as heat.

2. AC through purely inductive circuit,



$V = V_m \sin\omega t$

$= L\frac{di}{dt}$.

$\frac{di}{dt} = \frac{V_m}{L}\sin\omega t$

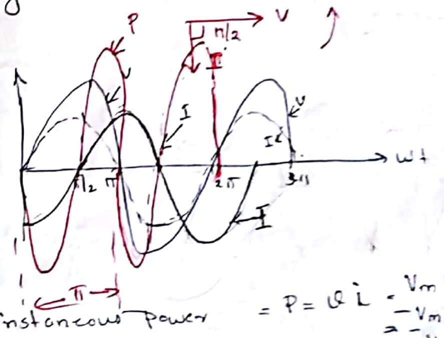
$\therefore i = \int \frac{V_m}{L}\sin\omega t \, dt = \frac{V_m}{L\omega}[-\cos\omega t]$.

$i = \frac{V_m}{L\omega}[\sin(\omega t - \pi/2)]$. ----> $\sin(\pi/2 - \omega t)$ $-(\sin(\pi/2-\omega t))$ $-\sin = \cos\omega t$

$I_{max} = \frac{V_m}{L\omega}$.

where $L\omega$, is called inductive reactance unit ohm.

$X_L = L\omega \rightarrow$ it is the opposition offered by inductance to alternating current flow.



Instantaneous power $= P = v\,i = V_m \sin\omega t \; I_m \sin(\omega t - \pi/2)$

$= -V_m I_m \sin\omega t \cos\omega t$

$= -\frac{V_m I_m}{2}\sin 2\omega t$

Average Power for a complete cycle. $c = \pi$

$= \frac{1}{\pi}\int_0^{\pi} -\frac{V_m I_m}{2}\sin 2\omega t \, d\omega t$

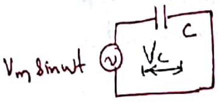
$= \frac{V_m I_m}{4\pi} \cdot 0 = 0$ ($\cos 0 - \cos 2\pi$)

Avg. power demand by pure inductive circuit is zero.

$\therefore$ Max. value of inst. power $= \frac{1}{2}V_m I_m$.

$= \frac{1}{\pi}\int_0^{\pi} V_m I_m \sin 2\omega t$ ($\cos 2\omega t$, $\cos 0$)

3. Ac through purely capacitive



$v_c = V = V_m \sin\omega t$

$v_c = Q/C = \int \frac{i\,dt}{C}$ $\qquad Q = CV$

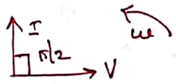
$\rightarrow i = \frac{dq}{dt}$

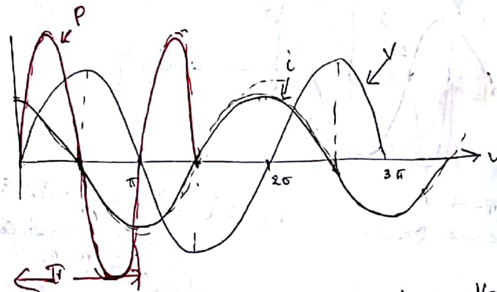
$= \frac{d}{dt}\left[V_m \cdot C \sin\omega t\right]$

$i = V_m C\omega \cos\omega t$

$i_c = \frac{V_m}{X_C} \sin(\omega t + \pi/2)$

$I = I_m \sin(\omega t + \pi/2)$





Instantaneous Power = $VC = V_m \sin\omega t \; I_m \cos\omega t = \frac{V_m I_m}{2} \sin 2\omega t$

Avg. power over whole cycle $= \frac{V_m I_m}{2} \int_0^{2\pi} \sin 2\omega t \, d\omega t$

$= 0$

Avg. power demand in purely capacitive circuit is zero.

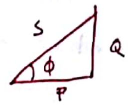
Max. value of inst power $\frac{V_m I_m}{2}$

$P_{avg} = \int_0^{\pi} \sin 2\omega t = \sin 2\pi - \sin 0 = 0$

Power Triangle

Active power → Power actually consumed in an AC circuit.

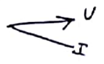
kW → $VI\cos\phi$



Power factor $\cos\phi = \frac{VI\cos\phi}{VI}$

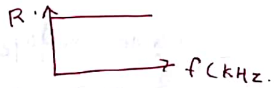
$= \frac{\text{Active Power}}{\text{Apparent Power}}$

- Cosine of angle b/w voltage & current in the circuit.

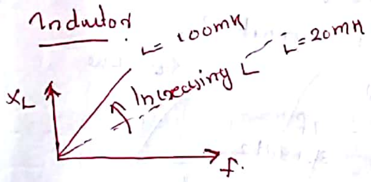


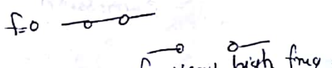
Frequency Response of Basic elements.

Resistor R



Inductor

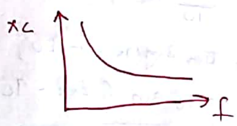




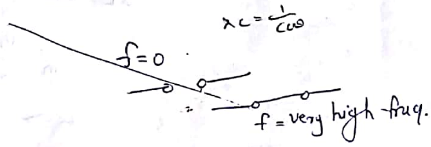
$X_L = L\omega$
$= L 2\pi f$

$I = V/X_L$

Capacitor



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



Impedance

"Ratio of phasor voltage to phasor Current as impedance"

Complex quantity having dimension of ohms. Impedance is not a phasor.

1\. Current through $100\mu F$ capacitor is given. Find expression for voltage across capacitor.

$i = 40 \sin(500t + 60^\circ)$.

$X_c = \frac{1}{wc} = \frac{1}{500 \times 100 \times 10^{-6}} = 20\Omega$.

C

$V_m = I_m X_c = 40 \times 20 = 800$ V.

$V = V_m \sin(wt - 90)$

$V(t) = 800 \sin(500t - 30)$.

2\. The voltage across 0.5 H coil is $v(t) = 100 \sin 20t$. What is the sinusoidal expression for current?

L

$L = 0.5H$ $\qquad X_L = Lw$.

$w = 20, \quad = 2\pi f$

$\therefore f = 3.18 Hz$

$X_L = Lw = 20 \times 0.5 = 10\Omega$.

$I_m = \frac{V_m}{X_L} = \frac{100}{10} = 10A$

since $L \rightarrow$ $I = I_m \sin(wt - 90)$

$= 10 \sin(20t - 90)$

3\. Current through 5Ω resistor is given $i(t) = 40 \sin(377t + 30^\circ)$. Find expression for voltage across resistor.

$V_m = 40 \times 5 = 200$ V

$v(t) = 200 \sin(377t + 30^\circ)$.

Average power.

$P = \frac{V_m I_m}{2} \cos\theta$

$P_{avg} = V_{rms} I_{rms} \cos\theta$ $\qquad \theta \rightarrow$ angle b/w v and i

1\. Find the average power dissipated in a network whose i/p I and V.

$i = 5 \sin(wt + 40^\circ)$

$v = 10 \sin(wt + 40)$.

Circuit is purely R.

$P = \frac{V_m I_m}{2}$. $= \frac{10 \times 5}{2} = 25$ W.

$= I_{rms}^2 R$.

$= \frac{V_{rms}^2}{R}$

2\. Determine power factor.

a) $i = 2 \sin(wt + 40^\circ)$

Load $\quad V = 50 \sin(wt - 20)$.

$(40 - -20)$

$pf = \cos\phi = \cos 60 = 0.5$ leading (current)

b). motor

$V = 120 \sin(wt + 80)$

$i = 50 \sin(wt + 30)$

$\cos\phi = \cos 50$

$= 0.64$. lagging.

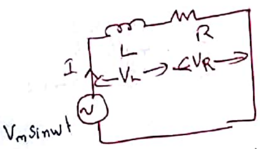
c). $P = 100$ W

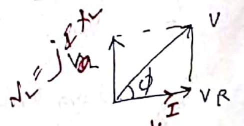
$V_{eff} = 20$ V

$I_{eff} = 5$ A

$\cos\phi$ ...

Ac through RL Circuit

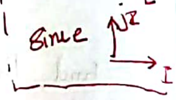




By KVL $V(t) = V_R + V_L$; $V = iR + jIX_L$

$v(t) = V_m \sin wt$

Since



Applied voltage

$V_R = IR$

$V_L = jIX_L$

$\bar{V} = \bar{V_R} + j\bar{V_L}$

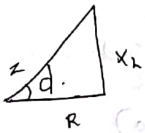
$\bar{V} = \bar{V_R} + j\bar{V_L}$

$= I[R + jX_L]$. $I = \frac{V}{R+jX_L} = \frac{V}{Z}$

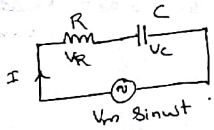
$I = \frac{V}{Z}$.

$|Z| = \sqrt{R^2 + X_L^2}$ $Z = R + jX_L$ is the impedance of Series RL circuit.

$\phi = \tan^{-1}\frac{V_L}{V_R} = \tan^{-1}\frac{X_L}{R}$.



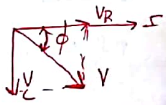
Ac through RC



$V(t) = V_R + V_C$

by KVL

$V = IR - jIX_C$



$j^3 = -j$

$V_R = IR$

$\vec{V_C} = -jIX_C$

$\bar{V} = \bar{V_R} - j\bar{V_C}$

$X_C = \frac{1}{wC} = \frac{1}{2\pi f C}$.

Applied voltage $V = \bar{V_R} + \bar{V_C} = IR - jIX_C = I(R - jX_C)$

$I = \frac{V}{R - jX_C} = \frac{V}{Z}$

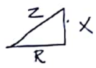
where $Z = R - jX_C$ is the impedance of circuit.

$|Z| = \sqrt{R^2 + X_C^2} = \sqrt{R^2 + \left(\frac{1}{Cw}\right)^2}$

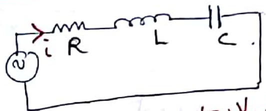
$\phi = \tan^{-1}\frac{V_C}{V}$.

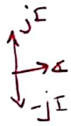
$= \tan^{-1}\left(\frac{\cancel{I}X_C}{\cancel{I}R}\right)$

$\therefore \cos\phi = R/Z$



Series RLC circuit



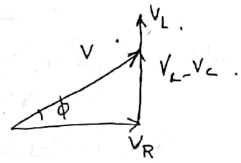


$V = V_R + V_L + V_C$

$= iR + jIX_L - jIX_C$

$= iR + jI(X_L - X_C)$

$V_L > V_C$ $|V| = I\sqrt{R^2 + (X_L - X_C)^2}$

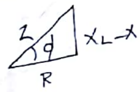


$\bar{V} = \bar{V_R} + j(\bar{V_L} - \bar{V_C})$

$V = \sqrt{V_R^2 + (V_L - V_C)^2}$

$= I\sqrt{R^2 + (X_L - X_C)^2}$

$I = \frac{V}{Z} = \frac{V}{\sqrt{R^2 + (X_L - X_C)^2}}$



$\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$

$V = V_m \sin wt$

$i = I_m \sin(wt \pm \phi)$.

$X_C > X_L \longrightarrow$ +ve sign

$X_L > X_C \longrightarrow$ −ve sign

$P = VI\cos\phi$.

$\cos\phi = \frac{R}{Z}$.

Admittance (Y)

It is the reciprocal of impedance.

It's unit is siemen or mho.

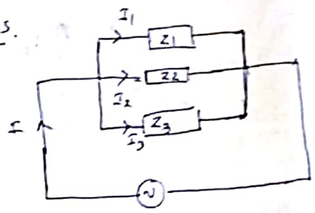
$$Y = \frac{1}{Z}$$

$$= \frac{1}{R+jX}$$

$$= \frac{R-jX}{R^2+X^2} = \underbrace{\frac{R}{R^2+X^2}}_{\text{Conductance}} - \underbrace{\frac{jX}{R^2+X^2}}_{\text{Sus...}}$$

In general $Y = G \pm jB$.

Parallel circuits.



$I = I_1 + I_2 + I_3$

$I_1 = \frac{V}{Z_1}$

$I_2 = \frac{V}{Z_2}$

$I_3 = \frac{V}{Z_3}$

Admittance $Y = \frac{1}{Z}$ mho.

$\therefore Y_1 = \frac{1}{Z_1} = \frac{I_1}{V}$

$\therefore I_1 = Y_1 V$

Similarly $I_2 = Y_2 V$

$I_3 = Y_3 V$

$\therefore I = I_1 + I_2 + I_3 = V[Y_1 + Y_2 + Y_3]$

$$\boxed{I = V\, Y_{equ}}$$

$Y_{equ} = Y_1 + Y_2 + Y_3$

Effect of freq. variation in RLC series circuit

$X_L = L\omega$

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

Resultant reactance → $X = X_L - X_C = 2\pi f L - \frac{1}{2\pi f C}$

if $X_L > X_C$, X is +ve

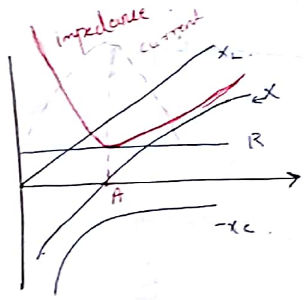
if $X_L < X_C$ X is -ve.

$|Z| = \sqrt{R^2 + (X_L - X_C)^2}$

$Z = \sqrt{R^2 + \left(2\pi f L - \frac{1}{2\pi f C}\right)^2}$

$X_L \rightarrow L\omega$ So X_L Vs f. straight line.

X_C $X_C \Rightarrow$ by rectangular hyperbola.



$Z = R + jX_e$

$X = X_L - X_C$.

At $A \Rightarrow X_L = X_C$. impedance. $X = 0$.

$I = V/X$ is max.

Effect of freq. variation in parallel circuit.

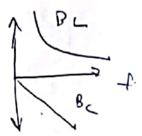
Inductive Susceptance $= \frac{1}{X_L} = \frac{1}{2\pi f L}$

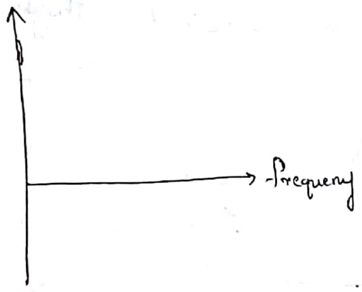
$X_L \propto f$

$B_L \propto \frac{1}{f}$

Capacitive susceptance $= \frac{-1}{X_C} = 2\pi f C$.

$B_C \propto f$.



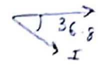


1) When AC voltage of 250V is applied across the circuit, the current in the circuit is found to be 25A. If the current is 0.8 p.f lagging, find impedance in the circuit.

$V = 250\ V$

$\cos\phi = 0.8$

$\phi = 36.86$



$|I| = 25A$

$\angle\phi = 36.86$.

$I = 25 \angle -36.86$

$$\boxed{\begin{aligned} x + jy &= r\angle\phi \\ \text{where } r &= \sqrt{x^2+y^2} \\ \phi &= \tan^{-1}(y/x) \end{aligned}}$$

$r\angle\phi = x + jy$

$x^2 + y^2 = r^2$

$\tan\phi =$

$\therefore = 25\cos\phi + j25\sin\phi$

$I = 20 - j14.99$

$Z = \frac{V}{I} = \frac{250}{20 - j15} = \underline{\underline{8 + 6j}}\ \Omega$

$|Z| = \underline{\underline{10\Omega}}$.

2) 100 A 100 Ω Resistor is in series with 120 μF capacitor, is connected to 230V, 50 Hz supply. Find (i) Circuit impedance (ii) current (iii) Pf. (iv) voltage across R.

$R = 100\ \Omega$ $\qquad f = 50\ Hz$

$C = 120 \times 10^{-6} F$

$X_C = \frac{1}{C\omega} = 26.5\ \Omega$

Impedance $Z = \sqrt{R^2 + X_C^2} = \underline{\underline{103.45\ \Omega}}$

$\phi = \tan^{-1} \frac{X_C}{R}$

$\phi = 14.84^0$

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

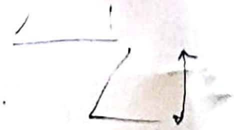
$= \frac{230}{103.45} = \underline{\underline{2.223\ A}}$

$I = 2.23\ \cancel{\angle 14.8}\ A$

$\cos\phi = 0.966$

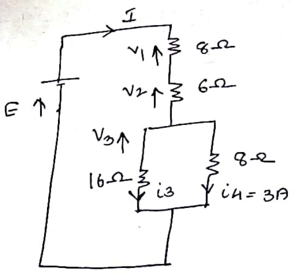
$V_R = IR = 222.3\ V$

$V_C = I X_C = \underline{\underline{58.90\ V}}$



<u>KCL and KVL</u>

1) Find supply current & Source emf



$V_3 = i_4 R_4$

$= 8 \times 3 = 24\ V$

$24 = i_3 \times 16$

$i_3 = \underline{\underline{1.5A}}$

$I = i_3 + i_4$

$= \underline{\underline{4.5A}}$

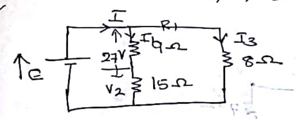
$V_1 = IR_1 = 4.5 \times 8 = \underline{\underline{36\ V}}$

$V_2 = IR_2 = 4.5 \times 6 = 27V$

by KVL

$E = V_1 + V_2 + V_3 = \underline{\underline{87V}}$

2) Determine I_1, E, I_3 and I.



$I_1 = \frac{V_1}{R_1} = \frac{27}{9} = 3A$

$V_2 = I_1 R_2\ 15 = \underline{\underline{45\ V}}$

$45 + 27V = E = \underline{\underline{72V}}$

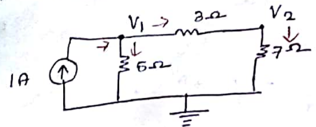
$I_3 = \frac{72}{8} = 9A$

$I = I_1 + I_3 = 3 + 9 = \underline{\underline{12A}}$

Mesh

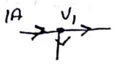
Nodal Analysis

1 Calculate V_1 V_2



Step1: V_1, V_2 : 2 nodes.

step2 : Assign current



Step3: Applying KCL at node 1

$$1\,A = \frac{V_1}{5} + \frac{V_1 - V_2}{3}$$

$$1 = V_1\left(\frac{1}{5}+\frac{1}{3}\right) - \frac{V_2}{3} \quad —(1)$$

$$1 = V_1\,\frac{8}{15} - \frac{V_2}{3}$$

node 2

$$\frac{V_2 - V_1}{3} = \frac{V_2}{7}$$

$$V_2\left[\frac{1}{3} - \frac{1}{7}\right] = \frac{V_1}{3} \quad —(2)$$

$$\left(1+\frac{1}{3}\right)V_2 = V_1\,\frac{8}{15} \quad —(a)$$

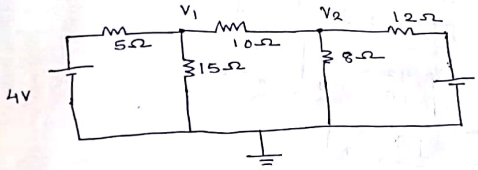
$$V_2 = V_1\,\frac{8}{15}$$

$$V_1\,\frac{2}{5}\left[\frac{4}{21}\right] = V_1$$

$$V_1 = \frac{10}{3}\,V.$$

$$V_2 = \frac{7}{3}\,V.$$

2. Using node voltage Calculate V_1 V_2 and calcul. current in 8Ω.



$V_1 = 2.88\,V$

$V_2 = 2.55\,V$

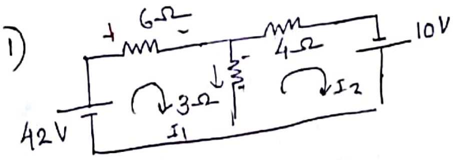
I in $8\Omega = \frac{V_2}{8} = 0.32A$

Nodal Analysis.

Scanned by CamScanner

Mesh - solution using matrix method

1)



$42 - 6I_1 - 3(I_1 - I_2) = 0$ —— (1)

$9I_1 - 3I_2 = 42$

$10 - 4I_2 - 3(I_2 - I_1) = 0$ —— 2

$+3I_1 - 7I_2 = -10$

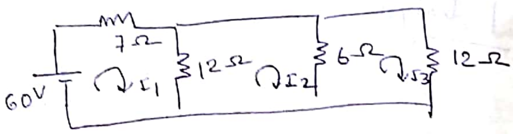
$-3I_1 + 7I_2 = 10$ —— (2)

$$\begin{bmatrix} 9 & -3 \\ -3 & 7 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 42 \\ 10 \end{bmatrix}$$

$$I_1 = \frac{\begin{vmatrix} 42 & -3 \\ 10 & 7 \end{vmatrix}}{\begin{vmatrix} 9 & -3 \\ -3 & 7 \end{vmatrix}} = 6A$$

$$I_2 = \frac{\begin{vmatrix} 9 & 42 \\ -3 & 10 \end{vmatrix}}{54} = \underline{4A}$$

2) Calculate current i_1, shown using mesh



$19I_1 - 12I_2 = 60$
$12I_1 - 18I_2 + 6I_3 = 0$

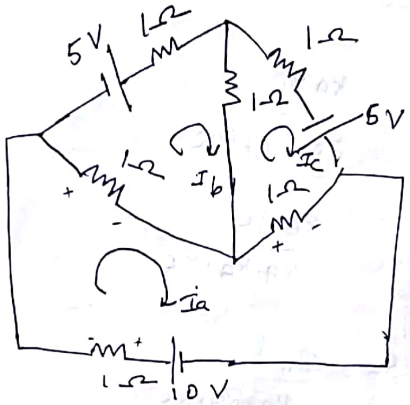
$6I_2 - 18I_3 = 0$

$$\begin{bmatrix} 19 & -12 & 0 \\ 12 & 18 & -6 \\ 0 & -6 & 18 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 60 \\ 0 \\ 0 \end{bmatrix}$$

$$I_1 = \begin{vmatrix} 60 & -12 & 0 \\ 0 & 18 & -6 \\ 0 & -6 & 18 \end{vmatrix} \div \begin{vmatrix} 19 & -12 & 0 \\ 12 & 18 & -6 \\ 0 & -6 & 18 \end{vmatrix}$$

$I_1 = \underline{6A}$

3.



$I_a = 7.5A$

$I_b = 6.25A$

$i_c = 6.25A$

$10 - I_a - (I_a - I_b) - (I_a - I_c) = 0$

$10 - 3I_a + I_b + I_c = 0$ —— (1)

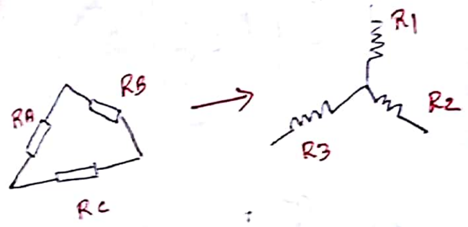
$5 - I_b - (I_b - I_c) - (I_b - I_a) = 0$

$5 - 3I_b + I_c + I_a = 0$ —— (2)

$5 - I_c - (I_c - I_a) - (I_c - I_b) = 0$

$5 - 3I_c + I_a + I_b = 0$ —— (3)

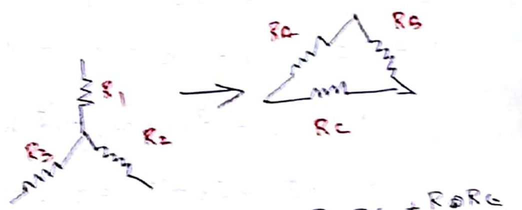
Star - Delta 787



$$R_1 = \frac{R_A R_B}{R_A + R_B + R_C}$$

$$R_2 = \frac{R_B R_C}{R_A + R_B + R_C}$$

$$R_3 = \frac{R_A R_C}{R_A + R_B + R_C}$$

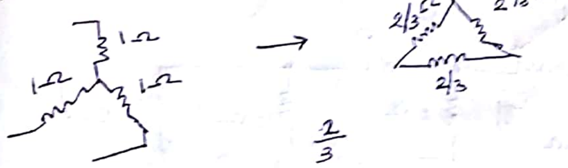


$$R_A = \frac{R_1 R_2 + R_2 R_3 + R_3 R_1}{R_2}$$

$$R_B = \frac{R_1 R_2 + R_2 R_3 + R_3 R_1}{R_3}$$

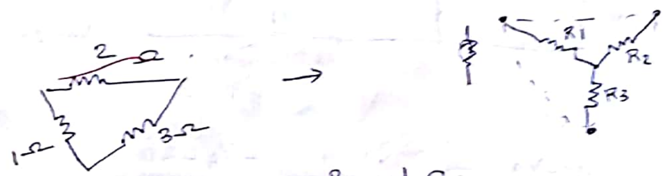
$$R_C = \frac{R_1 R_2 + R_2 R_3 + R_3 R_1}{R_1}$$

1. Convert



$\frac{2}{3}$

2)

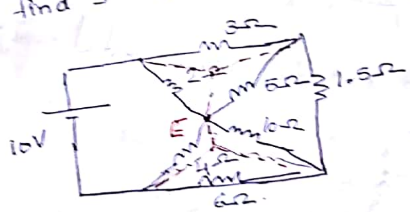


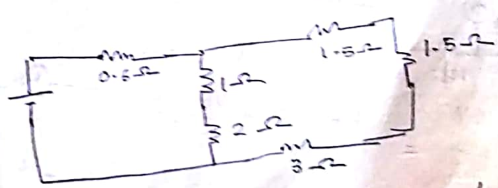
$$R_1 = \frac{2}{6} = \frac{1}{3}\,\Omega$$

$$R_2 = \frac{(2\times 3)}{6} = 1\,\Omega$$

$$R_3 = \frac{3\times 1}{6} = \frac{1}{2}\,\Omega$$

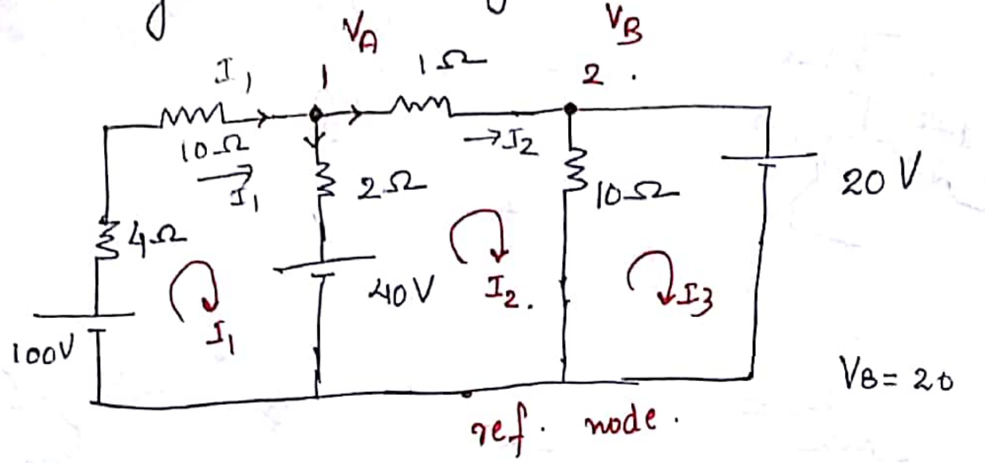
1. Using delta - star transformation find I drawn





$$I = 10/5.5 = 2.63\,A$$

1. Using nodal analysis find I_1 and I_2.



$V_B = 20$

I_1

$$\frac{100-V_A}{14} = \frac{V_A-40}{2} + \frac{V_A-20}{1}$$

$$100 - V_A = 7V_A - 280 + 14V_A - 280$$

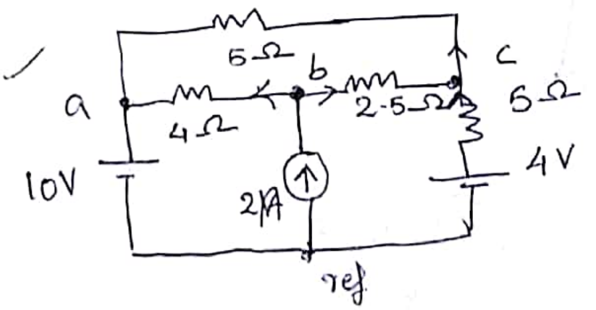
$$660 = 22V_A$$

$$V_A = \frac{660}{22} = 30V$$

$$I_1 = \frac{100-V_A}{14} = \frac{\cancel{60}\ 70}{14} = 5A$$

$$I_2 = \frac{V_A - 20}{1} = \cancel{80}\ 10A$$

2. Determine V_b and V_c using nodal analysis



$V_a = 10V$

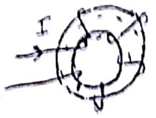
At b, $2 = \frac{V_b-10}{4} + \frac{V_b-V_c}{2.5}$ — (1)

At c ; $\frac{4-V_c}{5} + \frac{V_b-V_c}{2.5} = \frac{V_c-10}{5}$ — (2)

$\frac{mmf}{AT}$ NI 18.

Magnetic circuit

The complete closed loop, path followed by any group of magnetic flux lines is reffered to as a magnetic circuit.



One of the simplest form of magnetic circuit is the ring as shown.

where the steel ring provides the space in which magnetic flux is created. Most rings are made like anchor rings in that their cross section is circular - such rings called toroid.

$\underline{mmf} = NI$ Ampere turns.

Magnetic field strength $\boxed{H = \frac{NI}{l}}$

$B = \phi/\text{area}$.

$\mu_0 = \frac{B}{H}$ unit henry/m H/m.

$\mu_0 = 4\pi \times 10^{-7}\, H/m$

Reluctance: $S = \frac{mmf}{flux} = \frac{NI}{B \times \text{area}} \quad \frac{Hl}{}$

$= \frac{l}{\mu_0 \mu_r A}$

$\boxed{S = \frac{l}{\mu_0 \mu_r A}}$ AT/wb

Permeance $= \frac{1}{\text{reluctance}} = \frac{\phi}{mmf}$.

1. A mild steel ring having cross-sectional area $500\,mm^2$ and mean circumference 400 mm has a coil of 200 turns wound uniformly around it. Calculate

Give $\mu_r = 380$

a) reluctance

b) current required to produce flux 800 μwb.

$S = \frac{l}{\text{area} \times \mu_0 \times \mu_r} = \frac{0.4}{500 \times 10^{-6} \times 4\pi \times 10^{-7} \times 380}$

$= 1.68 \times 10^{6}$ AT/wb.

$H = \frac{B}{\mu_0 \mu_r}$ $H \times l = mmf$.

b) $= \underline{6.7\,A}$.

Permeability - The ability of a material to conduct magnetic flux through it. (μ) unit H/m (henry/meter)

2) A flux of 0.04 wb is produced in a solenoid of axial length 25 cm with 500 turns carrying a current of 4A. Find reluctance of magnetic circuit?

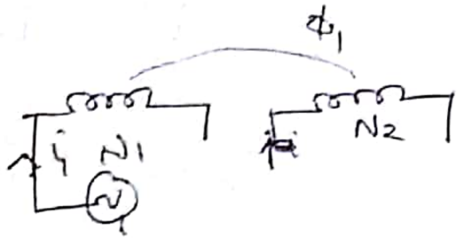
$\phi = 0.04$ wb

$S = \frac{mmf}{\phi} = \frac{NI}{\phi} = \frac{500 \times 4}{0.04}$

$= 50{,}000$ AT/wb

$$L = \frac{N_1 \phi_1}{I_1}$$

$$M = \frac{N_2 \phi}{I_1}$$



- Coupling
- Coupling Coefficient

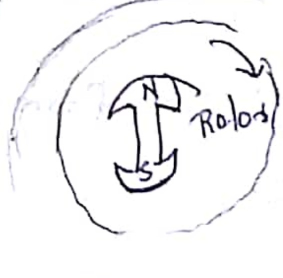
$$k = \frac{M}{\sqrt{L_1 L_2}}$$

Generation of alternating voltages

An alternating voltage may be generated

(i) by Rotating a coil at constant angular velocity in a uniform magnetic field

(ii). by rotating mag. field at cons. angular velocity with in stationary coil



1. Find RMS value

$i = 10 + 10 \sin\theta$

$$I_{rms} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} i^2 \, d\theta}$$

$$= \sqrt{\frac{1}{2\pi}\int_0^{2\pi} (10+10\sin\theta)^2 \, d\theta}$$

$$= \sqrt{\frac{100}{2\pi}\int_0^{2\pi} (1+\sin\theta)^2 \, d\theta}$$

$$= \sqrt{\frac{50}{\pi}\left[\theta - 2\cos\theta + \frac{\theta}{2} - \frac{\sin 2\theta}{4}\right]_0^{2\pi}}$$

$$= \sqrt{\frac{50}{\pi}(2\pi + \pi)}$$

$$= \sqrt{150} = \underline{12.247A}$$

18.2) Determine rms value, Avg

$$I_{rms} = \sqrt{\frac{(10^2 \times 2)}{3}} = 8.16\,A$$

$$I_{av} = \frac{10^2 \times 2}{3} = 6.67A$$

$$\text{form} = \frac{I_{rms}}{I_{av}} = \frac{8.16}{6.67} = 1.2$$

1. In an AC circuit consisting of 2 elements in series, the equations of voltage and current are given by $e = 50 \sin(2000t - 25)$ and $i = 8(\sin 2000t + 5)$. Calculate the frequency, Pf. and values of circuit constants.

$\omega = 2\pi f = 2000$

$$f = \frac{2000}{2\pi} = 318.3\,Hz$$

Angle b/w e and i $= 25 + 5 = 30°$

$Pf = \cos 30 = \frac{\sqrt{3}}{2} = 0.866$ leading (since i leading)

$E_m = 50\,V$ $\quad I_{rms} = \frac{8}{\sqrt{2}} = 5.65A$

$$E_{rms} = \frac{50}{\sqrt{2}} = 35.35\,V$$

Impedance $Z = \frac{E_{rms}}{V_{rms}} = 6.25\Omega$

$$Z = \text{phasor}\ \frac{E_{rms}}{V_{rms}}$$

$$= \frac{50\angle -25}{8\angle +5}$$

$$= \underline{6.25\angle -30\,\Omega}$$

$Z = 5.41 - 3.125j$

$R = 5.41\Omega$

$X_C = 3.12\Omega = \frac{1}{C\omega}$

$C = 1.60 \times 10^{-4}\,F$

$= \underline{0.16\,mF}$

Advantage of 3ϕ system over (1ϕ s/m)

1. o/p of 3ϕ machine generating electricity is more than the o/p of a single phase machine of same size.
2. The 3ϕ inductions motors are self starting. For 1ϕ motors. a separate starting winding is required.
3. 3ϕ power transmission is more economical.
4. Pf. of 3ϕ system is better than 1ϕ systems.
5. 1ϕ power supply can also be obtained from a 3ϕ supply.
6. The inst power in a 1ϕ system is fluctuating with time giving rise to noisy performance of 1ϕ motors. The power op is steady.
7. For rectification of AC into dc, o/p voltage becomes less fluctuating

Power measurement using 2 wattmeter reading

$$\boxed{\begin{array}{l} W_1+W_2 \rightarrow 3\phi \text{ Power.} \\ W_1-W_2 = \sqrt{3}\, V_{ph} I_{ph} \cos\phi \\ \therefore \phi = \tan^{-1} \sqrt{3}\dfrac{(W_1-W_2)}{W_1+W_2} \end{array}}$$

~~$W_1 = \phi V_{ph} I_{ph}$~~

$$\boxed{\begin{array}{l} W_1 = V_L I_L \cos(30 \mp \phi) \\ W_2 = V_L I_L \cos(30 + \phi) \end{array}}$$

case i) At upf. $\phi = 0$.

$W_1 = W_2$. equal & +ve

2). $\cos\phi = 0.5$ $\phi = 60$ $W_1 = V_L I_L \cos 30$

$W_2 = 0$,

3) when $\phi > 60$ W_2 will be -ve reading., W_1 will give +ve reading

4) when $\phi = 90$ when load is purely inductive or capacitive.

$W_1 = V_L I_L \cos 60$

$W_2 = V_L I_L \cos(120)$ $\cos(90+30)$

$= -V_L I_L \sin 30$

Both wattmeter reading. equal but opposite

Total Power = 0.

$W_1 = -W_2$

1. Draw the connection diag. for 2 w/m method. The load Connected was 30kW at 0.7 Pf lagging. Find reading of each wattmeter

$$W_1 + W_2 = 30 \text{ kW}$$

$$\phi = 45.57^\circ \text{ lagging}$$

$$\sqrt{3} V_L I_L \cos\phi = 30 \text{ kw}$$

$$V_L I_L = 24743.58 \text{ VA}$$

$$= \underline{\underline{24.743 \text{ kVA}}}$$

$$W_1 = V_L I_L \cos(30-\phi)$$

$$W_2 = V_L I_L \cos(30+\phi)$$

$$W_1 = 24.743 \times 10^3 \cos(30-45.57)$$

$$= 23.835 \text{ kw}$$

$$W_2 = 6.165 \text{ k.W}$$

$$W_1 + W_2 = \underline{\underline{30 \text{ kw}}}$$

2. A 3ϕ balanced load connected across a 3ϕ, 400V ac supply draws a line current of 10A. Two w/m are used to measure i/p power. Ratio of w/m reading is 2:1. find readings of 2 w/m?

1. A balanced 3ϕ star-connected load of 8+j6 Ω/per phase is supplied by 400V 3ϕ supply. Calculate I_L, Pf, P, Q ?

$V_{ph} = 230.94$ V

$I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{230.94}{8+6j} = \cancel{18.4}$ $23.09\angle -36.8$

Pf = 0.8006 lagging.

Active Power = $\sqrt{3} V_L I_L \cos\phi$

= 12.776 kw.

Reactive power = $\sqrt{3} V_L I_L \sin\phi$

= 9.627 kVAR.

2. The input power to a 3ϕ m/c was measured by 2 wlm method. The readings were 5.2 kW and -1.7 kw and the line voltage was 400 V. Calculate P, Pf, I_L ?

$W_1 = \sqrt{3} V_L I_L \cos(30-\phi)$.

$W_2 = V_L I_L \cos(30+\phi)$

$\tan\phi = \sqrt{3}\left[\frac{5.2+1.7}{5.2-1.7}\right]$

5.2 - 1.7 = 3.5

$\phi = 73.67^\circ$

Pf = $\cos\phi$ = 0.28

$I_L = \frac{W_1}{V_L \cos(30-\phi)} = \frac{5200}{400 \times \cos}$

= 17.99

* Substation. → principles of power system. V.K mehta

11 kv → HV → LV → Consumer

At some places in the line of power system, it may be desirable to convert large quantities of ac power to dc power. eg: for traction, electroplation. This job is again performed by a suitable apparatus called substation. It is clear that equipment needed in a substation will depend upon service requirement.

Substation: "The assembly of apparatus used to change some characteristics of electric supply (eg: voltage, ac to dc, freq. pf etc) is called a substation."

Substation are important part of substation. The continuity of supply depends to a considerable extent upon the successful operation of substation. The following imp. points which must be kept in view while laying out a substation;

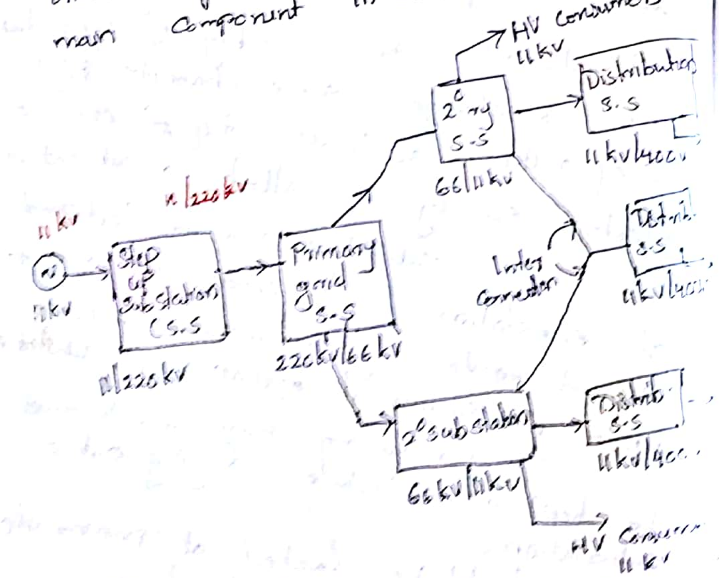
1) It should be located at proper site.
2) " provide safe & reliable arrangement.

It should be easily operated ... ...ing
It should involve min. capital cost

→ For beyond 66 kV, equipment is installed out door; so outdoor substation is used.

→ pole mounted substation → cheapest substation for voltages not exceeding 11 kV (or 33 kV)

→ The majority of substation are transformer substation (→ they are concerned with changing of voltage level of electric supply. Receive power at some voltage & delivers power at the other voltage. Transformer will be the main component in such substation



Equipments in a transformer substation

1. Bus bars
'Cu' or 'Al' bars (generally rectangular cross section) and operate at constant voltage. The incoming and outgoing lines in a substation are connected to the bus bars.

2. Insulators
They serve 2 purposes
→ a) Support the conductors (or bus bars)
→ b) Confine the current to the conductors.
→ Porcelain (used for manfu. of insulators)
several type of insulators are used
a) Pin type
b) suspension type
c) post insulator etc.

3. Isolating switches
In substation, it is often desired to disconnect a part of S/m for general maintance and repairs. This is accomplished by an isolating switch or isolators; it is designed to open a circuit under no load. i.e. isolator switches are operated only when the lines in which they are connected carry no current

4. Circuit Breaker : It is an equipment which can open or close a circuit under normal as well as fault condition. CB is designed to operate a) manually (or by remote control)

b) automatically under fault condition (For this relay is used with CB)

5. Power transformers : are used in a substation to step up or step down the voltage.

6. Instrument transformers

a) CT → step up transformer

1^0 → one or more turns thick wire connected in series with line

2^0 → large no of fine wires.

Rating : 100/5 A

b) PT or voltage transformer → step down transformer.

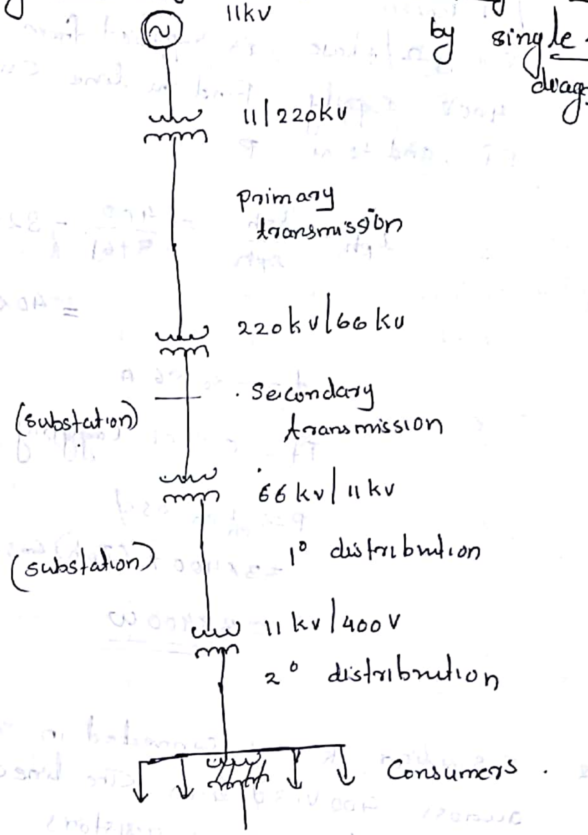
eg: 66kv/110v.

7. Metering & indicating instruments.

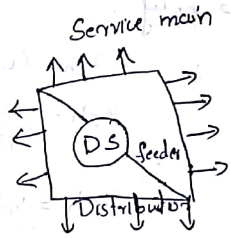
eg: v/m, A/m, energy meters

8) Miscellaneous equipment :
→ Fuse, carrier-current equipment, substation auxiliary supplies

Layout of typical ac Power supply scheme by single line diagram



Secondary distribution — It consists of feeder distributor and service main.



A balanced Δ connec...
$8+6j\,\Omega$/phase is supplied from 400V supply. Find the line current, pf, and total P.

$$I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{400}{8+6j} = 32-24j$$

$$= 40\angle -36.86$$

$\phi = -36.86$ A

Pf = 0.8001 lagging.

$P = 3V_{ph}I_{ph}\cos\phi$

$= 3\times 400 \times (I_{ph})\cos\phi$

$= 38400$ W

2. 3 similiar R are connected in star across 400 V, 3φ lines. The line current is 10A. If the same resistors are connected in Δ across same supply calculate current drawn from the supply.

In λ, $I_{ph} = I_L = 10A$

$V_{ph} = \frac{400}{\sqrt{3}}$

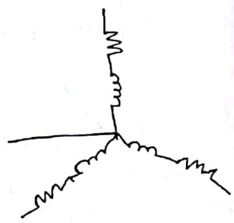
$Z_{ph} = \frac{V_{ph}}{I_{ph}} = 23.09\,\Omega$

In Δ, $V_{ph} = 400V = V_L$

$$I_{ph} = \frac{V_{ph}}{R} = \frac{400}{23.09} = 10\sqrt{3}$$

$I_L = \sqrt{3}I_{ph} = 30A$

3. 3 similiar indutive coils are connected in λ to a 3φ, 4wire, 415V, 50Hz supply. The line current is 4A at pf = 0.6 lagging. Calculate the resistance and L of coil?



$V_L = 415V$

$V_{ph} = \frac{V_L}{\sqrt{3}}$

$|I_L| = 4A = I_{ph}$

$$Z_{ph} = \frac{239.6}{4\angle 53.13} = \frac{V_{ph}}{I_{ph}}$$

$= 59\angle 53.13$

$\cos\phi = R/Z$

$I = |I_L|\angle -\phi$

$\phi = \cos^{-1}(0.6)$

$= 4\angle -53.13$

$= 53.13°$

$Z = R + jX_L = 35.4 + 47.19j$

$R = 35.4\,\Omega$

$\omega = 2\pi f = 100\pi$

$X_L = 47.19 = L\omega$

$L = 0.15$ H

4. A 3ϕ, Δ Connected has a p.f 0·8 lag and power Consumed by it is 4.35 kW. Calculate Current drawn from supply.

7·56.

$V_{ph} = V_L = \underline{415\,V}$

$P = \sqrt{3} V_L I_L \cos\phi$

$I_L = \dfrac{4350}{415 \times 0{\cdot}8 \times \sqrt{3}}$

$= \underline{7.56\ A}$

DC transmission

1) chandrapur to padghe (mumbai)
– 1500 MW at ±500 kV

2) rihand to delhi

3) talchal to kolar

Transformed

Losses -

a) Core losses or Iron losses.
→ Eddy current $K_e f^2 B_m^2 t^2$ watts/m³
→ hysteresis losses $K_h f B_m^{1.6}$ w/m³

b) Copper losses.

$I_1^2 R_1^2 + I_2^2 R_2$.

Construction of transformer

1. Core is made of Si. steel which has low hysteresis loss and high permeability. Core is laminated in order to reduce eddy current loss.

2. Instead of placing 1° on one limb and 2° on the other it is a usual practice to wind one-half of each winding on one limb. This ensure tight coupling b/w the 2 windings. Consequently leakage flux is considerably reduced.

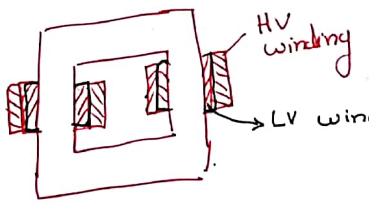
Types of transformers

a. Core type

b. Shell type.

Core type

– windings surrounds the core.

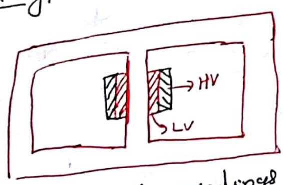


Windings are placed around each limb.

Shell type transformer

text electrical machines by V.K Mehta.

Core surrounds winding



Both the windings are placed around the central limb

→ Core type for H.V (voltage > 11kV) and small o/p

shell type suitable for L.V and high o/p (voltage less than 11 kV)

3ϕ transformer 3ϕ transformer

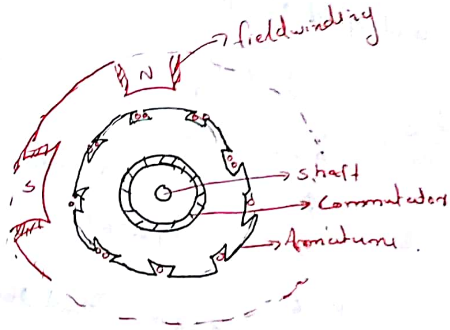
In 3ϕ s/m 3ϕ transformer is used to ~~generate~~ transmit electric power. 3 phase voltages are raised or lowered by means of 3ϕ transformers.

DC Machines.

Construction

stator: stationary part of a m/c.

Rotor: This part is free to rotate and normally inner part of machine.



Find the useful flux per pole on no load of a 250V, 6 pole shunt motor having wave connected arm. winding with 110 turns. The armature resistance including brush is 0.2. The arm. current is 13.3 A at no load speed of 908 rpm.

$$E_g = \frac{\phi Z N P}{60 A}$$

$A = 2$ (wave)

$E_g = V - i_a R_a = 250 - (13.3 \times 0.2)$

$= 247.36 V$

$P = 6$

$Z = 110 \times 2 = 220$ Conductors

$$\therefore \phi = \frac{E_g \times 60 \times A}{Z N P}$$

$$= \frac{247 \times 60 \times 2}{220 \times 908 \times 6} = 24.8 mWb$$

Machines

3ϕ Induction motor

Universal motor

Can operate on the supply on ac supply at approximately the same speed and output. It is smaller version of dc series motor, suitably modified for operation on ac supply.

$P \rightarrow 5W - 200W$

$N \rightarrow 6000 - 8000$ rpm

Construction: is similar to that of a dc series motor

• Necessity of earthing

By earthing we mean a metallic connection of the body to the earth (Considered to be at zero potential) for the saftey of human body from shocks.

All metallic covers of machines, starter or sheathing of wiring, etc are generally dead but can become alive due to failure of insulation or bad workmanship. When a person touches such part of machine or installation, gets a serious shock. To avoid from such severe shocks, all the metallic covers and frames of machines are earthed.

A good earthing should have very low resistance and easily allow the leakage current through it.

• Systems of earthing.

1. Pipe earthing

In this method a galvanised iron (GI) pipe ~~of~~ (38mm dia (1½")) ~~(½")~~ 12 mm diameter (6½") 2m length having holes on it's surface ~~and~~ is buried vertically in the wet earth to work as an earth electrode. The lower end of pipe is made ~~tappered~~ tapered to make driving easy

If soil is dry then the length of pipe varies ~~from 2m to~~ 2.75m.

The depth to which GI pipe should be embedded depends upon the moisture ~~of~~ in the soil. It should be normally be 4.75 m, but this is not a hard and fast rule.

Another (GI) pipe of 19mm diameter and of sufficient length is connected to the earth electrode through a reducing socket. A funnel having a wire mesh is provided at the top of 19 mm diameter ~~PR~~. During summer season water is poured in the funnel for maintaing earth connection in good ~~connection~~. Condition. The funnel is enclosed in a concrete box with a cover fitted with a hinge.

The earth pipe is surrounded by ~~10~~ 15 cm (6") thick alternate layers of salt and charcoal powder. The reason for adding the salt is that it attracts the moisture from the soil. Charcol Retains the moisture near the earth electrode which decreases the earth resistance. The GI earth wire (earth continuity Conductor) of suitable size to carry the fault current safely is ~~Conne~~ Connected to 19mm dia pipe. Further the earth continuity conductor is brought to main switch, distribution box and individual machines for earthing.

Plate earthing

In this system earthing pit is dug in the ground until sufficient moisture is available in the soil. (3m) approx. Then GI or Cu plate is connected to the earth continuity conductor

GI plate 60cm × 60cm × 6.35 mm

and for Cu plate 60 cm × 60cm × 3.16 mm

This plate is placed at the bottom of pit and is covered with 15 cm thick alternative layers of salt and charcoal.

→ "MCB provides overload protection fuse offer short circuit protection only".

→ * For low protective fault current pipe earthing used. large protective fault current plate electrodes are used.

Condnit Wiring

3 types of Condnit wiring

a) Concealed Conduit
b) Surface Conduit
c) flexible conduit wiring

Metal halide lamp

It is an electric lamp producing light by an electric arc through a gaseous mixture of Mercury and metal halides (Compounds of metals with Bromine or Iodine).

Tariff It is the rate at which electrical energy is supplied to consumers. Tariff includes cost of power generation, transmission and profit to the power company.

Consumers → a) Domestic
b) Commercial → shops
c) Industrial (manufact. unit).

Lowest ratings of Tariffs are given to residential and highest rate for industrial consumers.

Tariff divided into 2 parts
Fixed charge for supply of energy to your premises; the variable charge for the amount of energy used.

Types of Tariff

1. Uniform Tariff / Simple Tariff
— Here there is fixed rate per unit of energy consumed.
In this tariff, the price charge per unit of energy consumption is constant. and the price of tariff does not vary with no. of units of energy consumed.

2. Differential Tariff
Price / unit of energy varies with consumption.
During peak time tariff high
" low during low energy consumption
• This helps a balance the rate at which power is used and created.

Objectives of Tariff
1. It should compensate the cost of generation of power.
2. Its " " transmission & distribution and maintenance
3. " operation cost

cost

Traffic unit	RS
0 - 50	2.8
51 - 100	3.2
101 - 150	4.2
151 - 200	5.8
201 - 250	7

Power Consumers : Consumers of electricity are called as power consumers

HT consumers :
Large consumers, electric traction systems, large housing colony, air port etc, taking electric connection at 11 kV to 33 kV are called high tension consumers.

eg: Domestic HT : Bulk supply for residential colonies.

- Commercial HT for bigger offices, film studios, etc

- Industrial HT : for heavy & industries.

- Agriculture HT : large farms or estate.

LT Consumers
In india Low tension (LT) voltage (supply) is 400V for 3ϕ connection and 230V for 1ϕ connection.
Consumers of electricity using low tension voltage are called LT consumers.

eg: Most small scale consumers like houses, shops, offices.

Domestic LT — most individual residential connection.

Commercial LT - Small shops and offices

Industrial LT - Small manufacturing units.

Agriculture LT : - Small farms and estate.

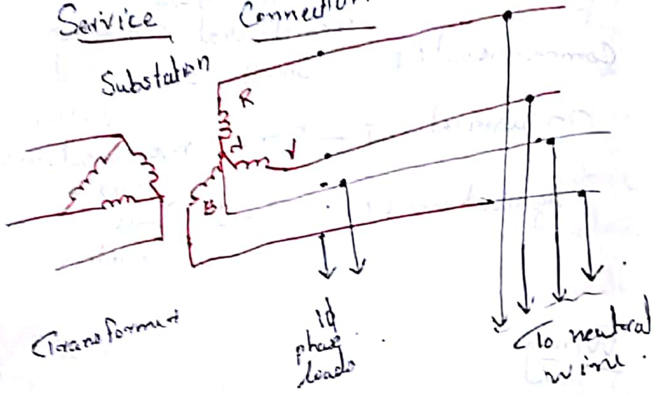
Wiring

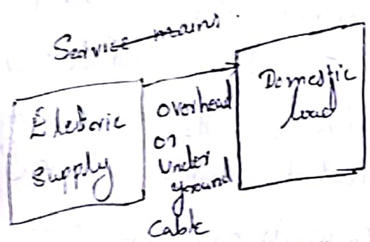
Conduit wiring consists of PVC wires taken through either steel conduit pipes or through PVC conduit. Conduits are run over surface of walls and ceiling or are concealed under masonary work.
When conduits are run over the surface of walls, the wiring is called surface conduit wiring.
When the conduits are run inside the walls → concealed conduit wiring

Surface conduit wiring is used in factories for installation of heavy motors & other electrical equipment

Scanned by CamScanner

Service Connection





Typical effects of electric shock currents on humans

50 Hz Current	effect
0-1 mA	No sensation
0-3 mA	mild sensation
3-5 mA	pain or annoyance
5-10 mA	Painful shock
10-15 mA	Local Muscle contraction
30-50 mA	Breathing difficult
50-100 mA	Ventricular fibrillation
100-200 mA	of heart certain

Fuse

It is a small piece of wire connected in b/w 2 terminals mounted insulated base and connected in series with the circuit. It is the simplest form of protection and used for protecting low voltage equipment against overloads or short circuit.

Fuse carry the normal working current safely without over heating, and during fault (overload / S.C) it gets heated upto melting point rapidly.

Materials normally used: tin, lead (Pb), silver (Ag), Zn, Al, Cu etc.

For small value of current (< 15 A) alloy of tin (63%) and lead (37%) is used.

for (>15) greater than 15 A, silver is found to be quite satisfactory as a fuse material because it is not subjected to oxidation and it's oxides are unstable.

Draw back. Relatively high cost. So tin-lead used for low range current.

Fuse: Used to protect electrical equipment from over loads & short circuit.

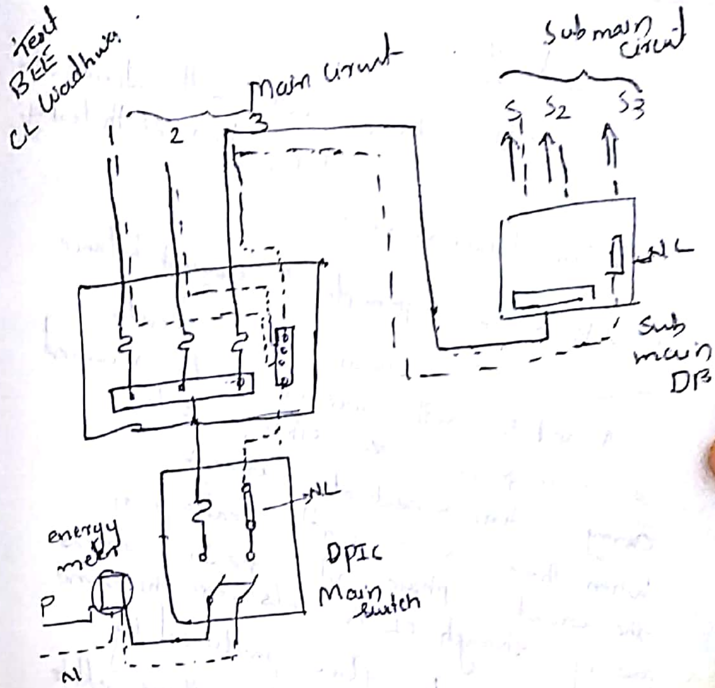
Fuse rating: It is the value of current which when flows through the element, does not melt it.

$$\text{Fusing factor} = \frac{\text{Min. fusing current}}{\text{Fuse rating}}$$

; greater than unity

Distribution board

The cable from electric utility is connected to energy meter first before taking any other connection. From the load terminals of energy meter it is taken to distribution through DPIC (Double pole iron clad switch).



1. A 6 pole 3ϕ, 50 Hz I/M.

$\left(? \; N_s = \frac{120f}{P} = 1000 \text{ rpm}\right)$

Rotor current makes 120 complete cycle per minute.

$f_r = \cancel{60} \; \frac{120}{60} = 2\,Hz$

find slip and Ns.

$\cancel{\text{for } s}$ $f_r = sf$

$s = \frac{f_r}{f} = \frac{2}{50}$

$= 4\%$

ELCB

. protective device, which will automatically trip; when earth leakage

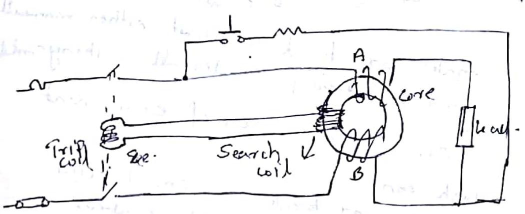
. Also known as RCCB.

. Works on principle of current balance.

There are 2 coils A and B with same no. of turns wound on a magnetic core. These coils carry phase & neutral current.

When there is no earth leakage in the circuit phase and neutral currents passing through ELCB coils are the same and the magnetic flux produced by coils are in opposite direction, there will be no net flux in the core.

But when there is an earth leakage, the phase and neutral currents will be different and therefore a net magnetic flux will be available in the core. This cut activate flux induces a voltage in search coil wound on the core and activates the trip circuit.



C

Circuit breakers. (CB)

A circuit breaker can make or break a circuit either manually or automatically under all working condition

CB is a piece of equipment which can

(i) make or break a circuit either manully or by remote control under normal conditions.

(ii) break a circuit automatically under fault conditions.

(iii) make a circuit either manually or by remote control under fault conditions.

V.K mehta

power system

operating principle

Consist of a fixed and moving contacts.

Under normal working condition (and these contacts remain closed and will not open automatically until unless slm becomes faulty

When a fault occurs the trip coil of CB get energised and moving contacts are pulled apart by some mechanism.

• Circuit :

Non-Linear Circuit : The circuit whose parameters change with application of voltage or current

Linear : Parameters are Constant

Bilateral circuit : it's properties are same in either direction.

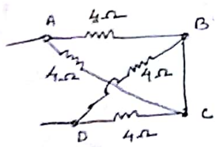
eg: Transmission line

Unilateral circuit: properties changes with direction of its operation

eg: Diode

Node : It is a junction in a circuit where 2 or more circuit elements are connected together.

1. Calculate R b/w P and Q .

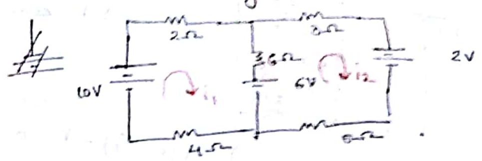


$2 + 2 = 4\Omega$

D. B

Mesh analysis

1. Find current through 6Ω ?



$10 - 2I_1 - 6(I_1 - I_2) - 6 - 4I_1 = 0$

$4 + 6I_2 - 12I_1 = 0$

$\cancel{3I_1 - I_2}$

$2 + 3I_2 - 6I_1 = 0$

$6I_1 - 3I_2 = 2$ —— 1

$6(I_1 - I_2) + 6 - 3I_2 - 2 - 5I_2 = 0$

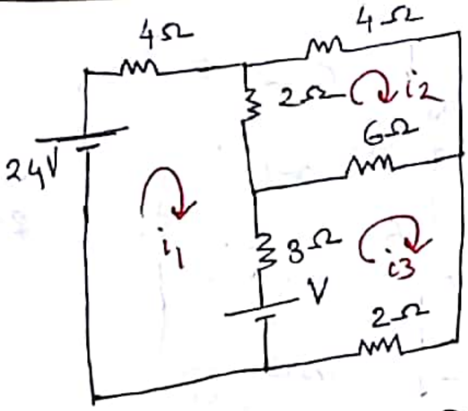
$6I_1 - 14I_2 + 4 = 0$

$3I_1 - 7I_2 = -2$ —— 2

check $I_1 = \frac{20}{33}$ A

$I_1 - I_2 = \frac{2}{33}$

2)



Determine such that I_1 will be zero

$I_1 = 0$

$$24 - 4I_1 - 2(I_1 - I_2) - 3(I_1 - I_3) - V = 0$$

$$24 - V + 2I_2 + 3I_3 = 0 \quad \text{— (1)}$$

In mesh (2)

$$-4I_2 - 6(I_2 - I_3) - 2(I_2 - I_1) = 0$$

$$\cancel{-4I_2} - 12I_2 + 6I_3 = 0$$

$$2I_2 = I_3 \quad \text{— (2)}$$

In mesh (3)

$$-3(I_3 - I_1) - 2I_3 - 6(I_3 - I_2) + V = 0$$

$$-11I_3 + 6I_2 + V = 0$$

$$V = 11I_3 - 6I_2 \quad \text{— (3)}$$

from equ (2)

sub in equ (3)

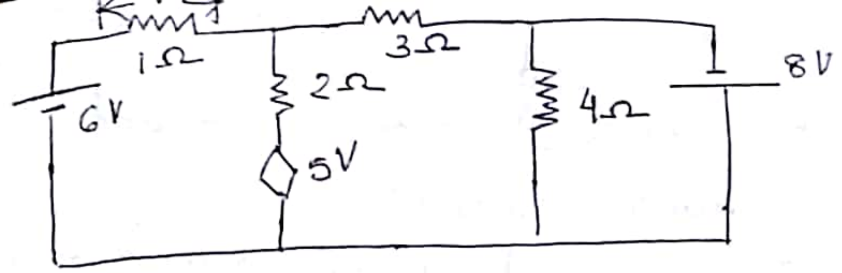
$$V = 11I_3 - 3I_3 = 8I_3 \quad \text{— (a)}$$

Put equ (2) in equ (1)

$$24 - V + \cancel{2}I_3 + 3I_3 = 0$$

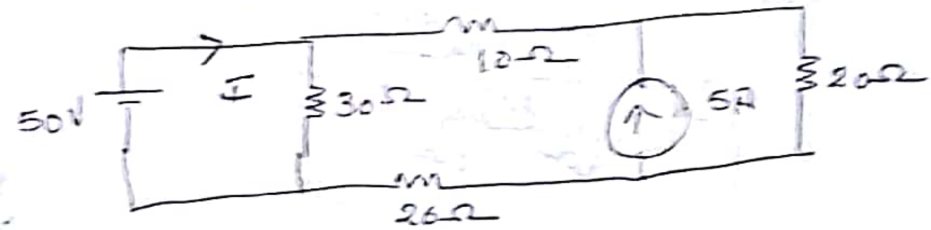
$$24 - V + 4I_3 = 0$$

$$V = 24 + 4I_3 \quad \text{— (b)}$$

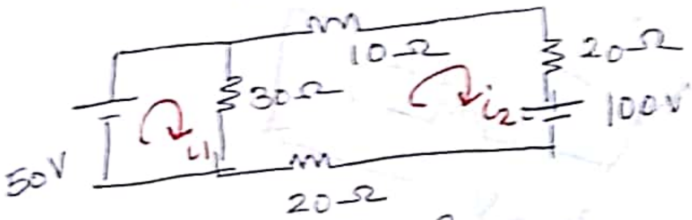


1Ω
3Ω
8V
6V
2Ω
4Ω
5V

Find current in 10Ω Resistor



; using source transformation;



$$50 - 30[I_1 - I_2] = 0$$

$$+30I_1 \mp 30I_2 = 50 \quad \text{—— ①}$$

In mesh 2;

$$-50I_2 \mp 30(I_2 - I_1) - 100 = 0$$

~~30~~ I_2

$$30I_1 - 80I_2 = 100 \quad \text{—— ②}$$

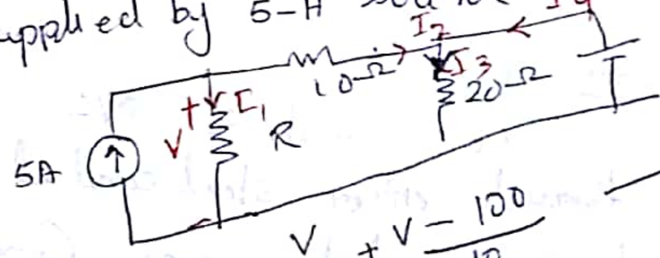
$$\cancel{100} - 50I_2 = 50$$

② − ①

$$I_2 = -1\,A$$

I_2.

2. Find the value of R in the circuit such that power supplied by 100V source to network is same as power supplied by 5-A source



R = 20Ω

At node 1: $5 = \frac{V}{R} + \frac{V - 100}{10}$ —— ②

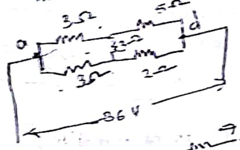
At node 2: $\frac{100 - V}{10} + I_4 = \frac{100}{20} = 5$

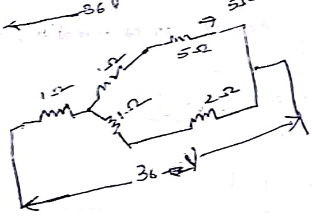
$100 I_4 = 5V$

For equal power

∴ $R = 20\Omega$.

Find the current in 5Ω resistor





6 | 3

$\frac{15}{9}$

$R_{eq} = 3\Omega$

$I_{total} = \frac{36}{3} = 12A$

$I_{in\ 5\Omega} = 12 \times \frac{3}{9} = 4A$

System of Wiring

Various types

1. Cleat wiring
2. Wood casing wiring
3. batten wiring
4. Conduit Wiring.

Conduit Wiring

It consist of PVC wires taken through either steel conduit pipes or through PVC conduit pipes. Conduits are run over the surface of walls, the wiring is called surface conduit wiring.

When the conduits are run inside the walls, the wiring is called ~~surface~~ Concealed conduit wiring.

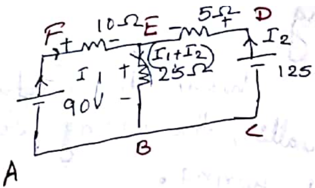
Surface conduit wiring is used in factories for installation of heavy motors and other electrical equipment. The system is water proof and replacement of deffective wires is easy.

In concealed conduit wiring, a chase or groove is cut on the wall to place conduit pipes.

In case of building under construction the chase should be provided on the wall and ceilings for laying the conduit pipes before plastering of walls and ceiling done. Suitable inspection boxes are provided to permit the inspection and replacement of wires, if necessary.

Concealed conduit wiring is almost all modern residential, Commercial and public building. ~~The appearance of buildings from~~

KVL



$-10I_1 - 25(I_1+I_2)$

$+90 = 0$

$-35I_1 - 25I_2 = -90$ —— 1

$35I_1 + 25I_2 = 90$

$5I_2 - 125 + 25(I_1+I_2) = 0$ —— 2

$+25I_1 + 30I_2 = 125$

$$\begin{bmatrix} 35 & 25 \\ 25 & 30 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 90 \\ 125 \end{bmatrix}$$

$I_1 = -1A$

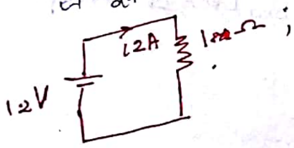
$I_2 = 5A$

→ Voltage source

The term voltage source is used to describe a source of energy which establishes a potential difference across its terminal.

eg: batteries, dc generators, alternators.

Ideal voltage source (Const. Volt. Source) is one that maintains a constant terminal voltage, no matter how much current is drawn.

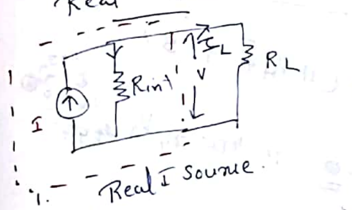


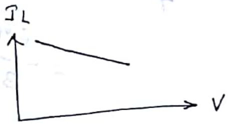
ideal current source,

It will supply the same current to any resistance (load) connected across its terminals.

eg: solar cells

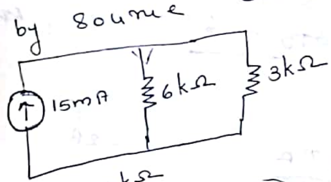
Real Current Source

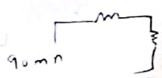


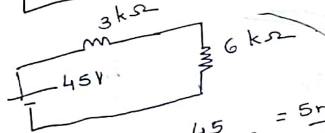


$I_L = I - \frac{V}{R_{int}}$

1. Find the current in 6kΩ resistor by source conversion;



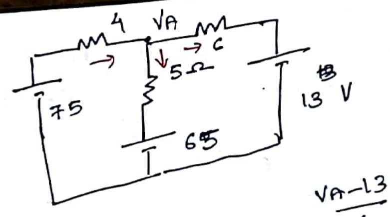




$I = \frac{45}{9\times10^3} = 5mA$

2.

1. find I through 5Ω



$$\frac{75-V_A}{4} = \frac{V_A-65}{5} + \frac{V_A-13}{6}$$

$$= \frac{6V_A - 390 + 5V_A - 65}{30}$$

$$-30V_A + 2250 = 4(11V_A - 455)$$

$$+2250 + 1820 = 74 V_A$$

$$V_A = 55\,V$$

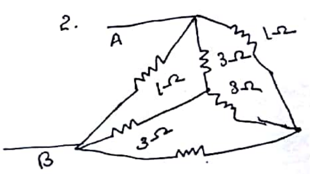
$$i_5 = \frac{55 - 65}{5} = \frac{-10}{5} = -2$$

$i_5 = -2A$

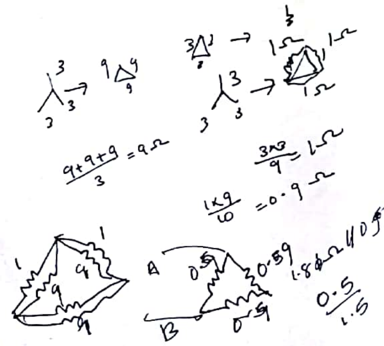
So $\uparrow i_5$ 2A

$$\frac{75-V_A}{4} = V_A$$

2.



$$\frac{9+9+9}{3} = 9\Omega \qquad \frac{3\times3}{9} = 1\Omega \qquad \frac{1\times9}{10} = 0.9\Omega$$

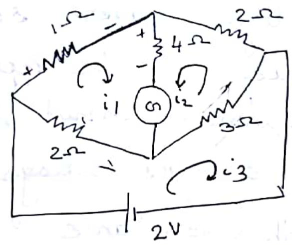


$$\frac{0.5}{1.5}$$

$$\frac{1.8\times0.9}{2.7} = \frac{0.162}{2.7}$$

$$= \frac{1.62}{2.7} = 0.6\Omega$$

3.



1st $-i_1 - 4(i_1+i_2) - 2(i_1 - i_3) = 0$

$-7i_1 - 4i_2 + 2i_3 = 0$ —— ①

2nd Mesh; $-2i_2 - 4(i_2+i_1) - 3(i_2+i_3) = 0$

$-4i_1 - 9i_2 - 3i_3 = 0$ —— ②

3rd → $-3(i_3+i_2) + 2 - 2(i_3 - i_1) = 0$

$+2i_1 - 3i_2 - 5i_3 = -2$ —— ③

$i_1 = 0.065$

$i_2 = 0.141$

$i_3 = 0.5108$

$i_1 + i_2 = 0.206$

$i_1 = 0.157706\,A$

$i_2 = 0.151832$

$i_3 = 0.24070$

$i_1 + i_2 = 0.0228\,A$

$i_1 = 0.6818$

$i_2 = -0.6590$

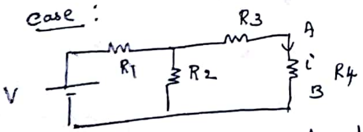
$i_1 + i_2 = 0.0228\,A$

Thevenin's Theorem

"Any 2 terminal linear bilateral network having a number of voltage, current sources and resistance can be replaced by a simple equivalent circuit ~~havi~~ consisting of a single voltage source in series with a resistance."

- The value of voltage source = open circuit voltage across two terminals of network
- Resistance = equivalent resistance measured b/w terminals with all the energy sources are replaced with their internal resistance.

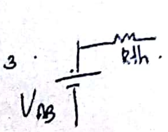
case : Find i



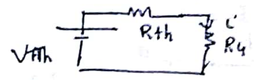
steps 1. Replace that branch element

2. 

Find V_{AB}, R_{Th}.

3. 

4. Again join removed branch & find i



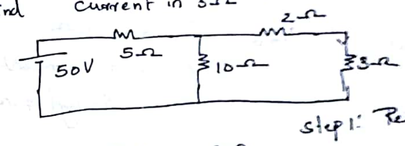
$$i = \frac{V_{th}}{R_{Th} + R_4}$$

To find R_{th}

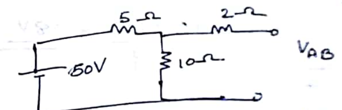
→ Short circuit, voltage source.

→ open circuit, current source.

1. Find current in 3Ω ; Use Thevenin's theorem.



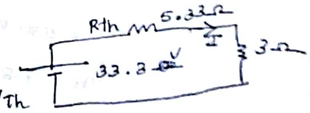
step 1: Remove 3Ω.



$$V_{Th} = V_{AB} = 50 \times \frac{10}{15} = 33.3\,V$$

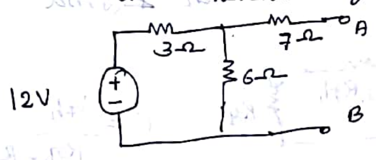
$$R_{AB} = 2 + \frac{5 \times 10}{15} = \underline{5.33\,\Omega}$$

~~Redr~~ Again Connect 3Ω to Thevenin circuit & find I.

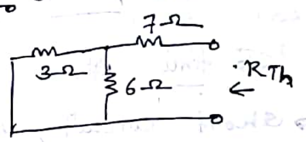


$$I = \frac{33.3}{8.33} = \underline{4\,A}$$

2. Find Thevenin equivalent



Rth →

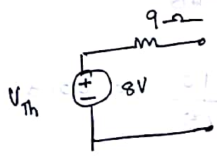


$(3 \parallel 6)$ series to 7Ω

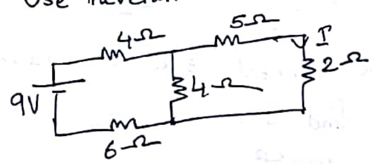
$R_{th} = 9\Omega$

$V_{AB} = V_{across\ 6\Omega}$ (Since no current through 7Ω)

$= \frac{12 \times 6}{9} = 8V$



3. Use thevenin theorem find I in 2Ω.



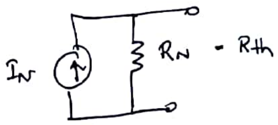
$V_{Th} = 2.571\ V$

$R_{Th} = 7.857$

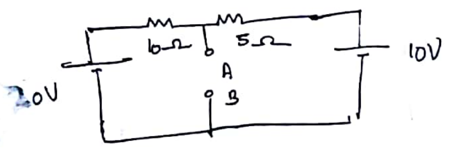
$I = 260.8\ mA$

Norton's Theorem

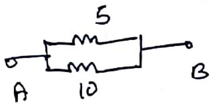
Any 2 terminal linear network with current source, voltage & resistance can be replaced by an equivalent circuit consisting of a current source in parallel with resistance.



1. Determine Norton's equivalent

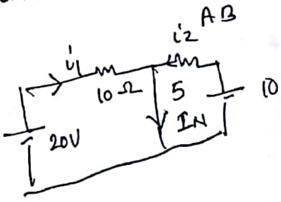


$R_N = R_{th}$ short voltage source



$R_N = \frac{50}{15} = \frac{10}{3} = 3.33\Omega$

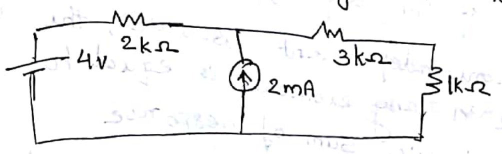
I_N = short circuit current through AB



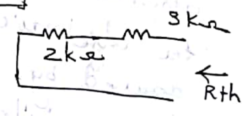
$I_N = i_1 + i_2$

$= \frac{20}{10} + \frac{10}{5} = 4A$

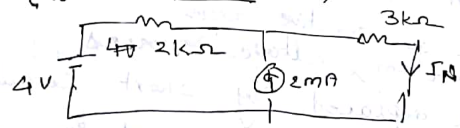
1. Find Norton equivalent circuit for the networks faced by 1 kΩ resistor



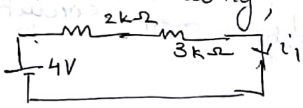
Rth = 5kΩ



To find I_N, use superposition

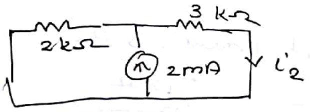


When 4V alone acting;



$i_1 = \frac{4}{5\times10^3} = \frac{4}{5}$ mA

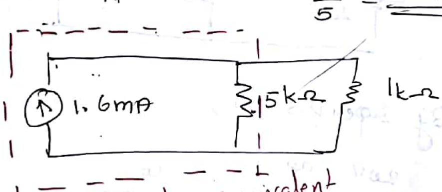
When 2mA alone acting;



$i_2 = 2 \cdot \frac{2}{5}$

$= \frac{4}{5}$ mA

$\therefore i_N = i_1 + i_2 = \frac{8}{5} = 1.6$ mA



Norton equivalent

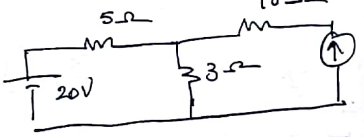
Superposition theorem

"In any linear n/w containing 2 or more independent sources, the response in any element is equal to the algebraic sum of response caused by individual sources acting alone, while the other sources are non operative."

Source non operative means

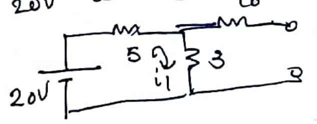
→ ~~To problem~~ voltage sources are replaced by short circuits, and independent current sources replaced by open circuit".

1. Find current through 3Ω



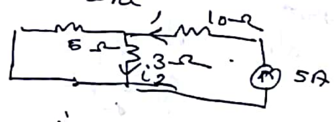
By superposition,

20V alone



$i_1 = \frac{20}{8} = 2.5A$

when 5A alone:



$\cancel{i_2 = 5A \cdot 5 \times 8}$

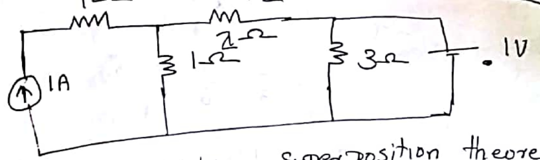
$i_2 = 5 \times \frac{5}{8}$ (current division rule)

$= 3.125A$

By superposition:

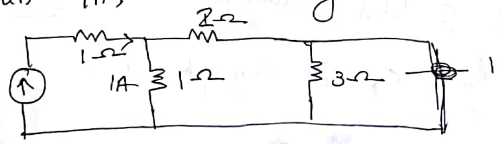
Total current $i = \Sigma i_1 + i_2$

$= \underline{5.625}$



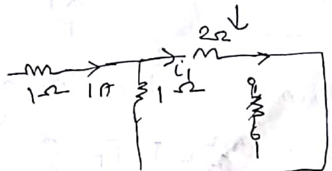
1) find I using superposition theorem?

when 1A, source acting,



so ineffective

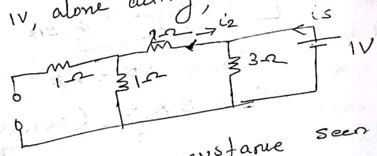
3Ω will act as short circuit



current through 2Ω

$i_1 = 1 \cdot \frac{1}{3} = \frac{1}{3}A$

When 1V alone acting;



Total resistance seen from 1V,

$3\Omega \parallel 3\Omega$
$= 1.5\Omega$

$I_s = \frac{1}{1.5} = 0.66A$ $\quad \frac{3}{2}$

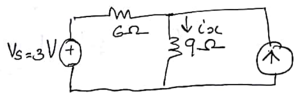
$-I_2 = I_s \times \frac{3}{6}$

$= \frac{2}{3} \times \frac{3}{6} = \frac{1}{3}$

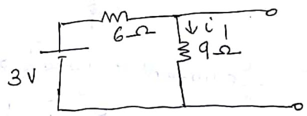
$I_2 = -1/3$

So total current $= 1/3 - 1/3 = 0$

3. Find current through 9Ω.

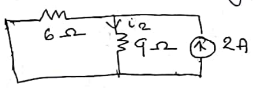


When 3V alone acting;



$i_1 = \frac{3}{15} = \frac{1}{5}$

When 2A alone acting;



$i_2 = \frac{2 \times 6}{15} = \frac{4}{5}$

∴ So $i_x = i_1 + i_2 = \underline{1A}$

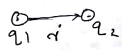
Coloumb's law

This law states that like charges repel and opposite charges attract, with a force proportional to product of charges and inversly proportional to square of distance b/w them.

$F = k_e \frac{q_1 q_2}{r^2} = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2}$

$k_e = 8.99 \times 10^9 \ Nm^2/C^{-2}$

$\varepsilon_0 = 8.85 \times 10^{-12}$.



Electric field strength ⇒ $E = F/q$.
$= V/m$

electric flux density $D = \varepsilon E$

charge density built up on a test capacitor and given in units of coloumbs/square meter

$E = F/q =$

$D = \varepsilon E$ $\qquad F = \frac{q_1 q_2}{4\pi\varepsilon_0 r^2}$

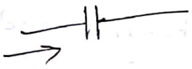
$E = \frac{q_1}{4\pi\varepsilon_0 r^2}$

$D = \varepsilon E = \frac{q}{4\pi R^2}$

Capacitance $= Q/V$

$E = \frac{1}{2}CV^2$ $\qquad$ ~~$Q = cV$~~

$Q = CV$



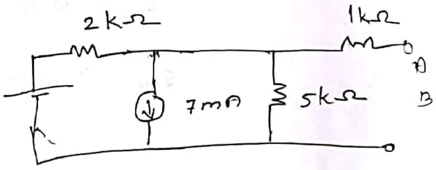
~~$1/4\pi\varepsilon$~~ $1/X_C$

$i = c\frac{dV}{dt}$

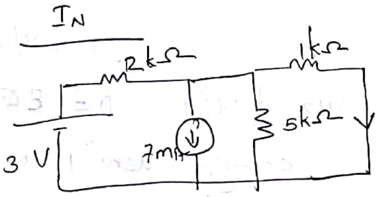
→ open circuit to dc.

$c = \frac{A\varepsilon_0}{d}$ farad

Determine Thevenin & Norton, equivalents

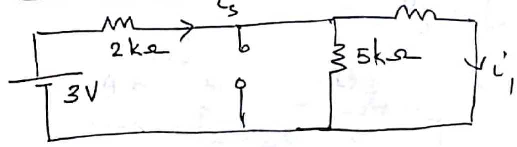


I_N



To find I_N apply super position theorem;

Due to 3V alone;



$i_s = \frac{3}{2+(1\|5)} = \frac{V}{R}$

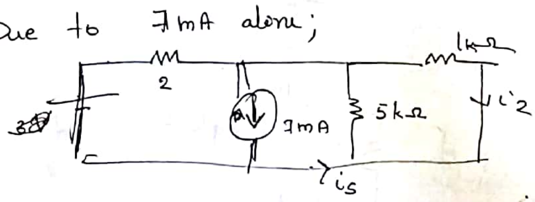
$= \frac{3\times 6}{17} = \frac{18}{17}$

$\frac{5}{6}+2 = \frac{17}{6}$

$i_1 = i_s \times \frac{5}{6}$

$= \frac{18}{17}\times\frac{5}{6} = \frac{15}{17}$ A

Due to 7mA alone;



$i_s = \frac{7\times 2}{17/6}\times 10^{-3}$ (Current division rule)

$= \frac{7\times 2 \times 6}{17}\times 10^{-3}$

$\frac{5}{6}+2 = \frac{17}{6}$

$= \frac{14\times 6}{17}\times 10^{-3}$

$i_2 = -\frac{\left(\frac{14\times 6}{17}\right)\cdot 5}{6}\times 10^{-3}$ Current division rule.

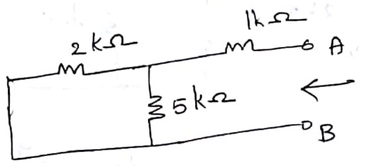
$= \frac{14\times 5}{17} = \frac{-70}{17}\times 10^{-3}$

$i_N = i_1 + i_2 = \frac{15}{17} - \frac{70}{17}$

$= \frac{-55}{17}\times 10^{-3}$

$= -3.235$ mA

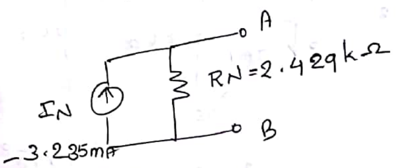
To find R_N



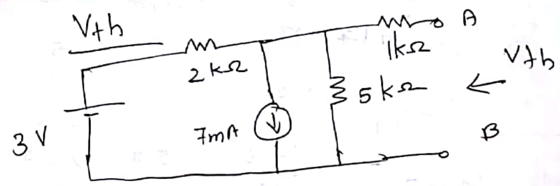
$(2 \parallel 5) + 1$

$\frac{10}{7} + 1 = \frac{17}{7}$ kΩ

$R_N = \underline{2.429\ k\Omega}$



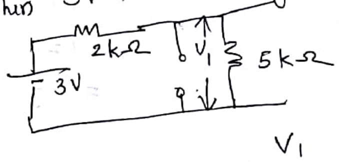
$\underline{V_{th}}$



$V_{th} = V_{across}$ 5 kΩ

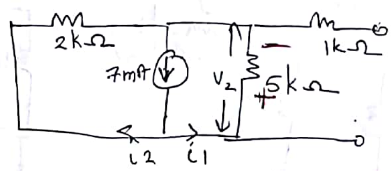
Apply super position;

When 3V alone acting



$V_1 \quad 3 \times \frac{5}{7} = \frac{15}{7}$ V

∴ When 9mA alone acting;



$i_1 = (9 \times 10^{-3}) \cdot \frac{2}{7}$ → Current division rule

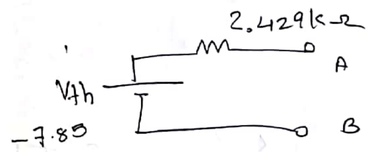
$= 2$ mA

∴ $V_2 = i_1 \times 5$ kΩ

$= \underline{-10\ V}$

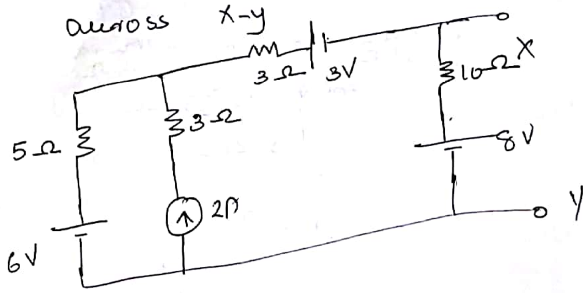
∴ $V_{th} = V_1 + V_2$

$= \frac{15}{7} - 10 = \underline{-7.85\ V}$

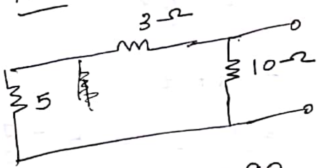


u.q

Obtain Thevenin's equivalent circuit across X-y



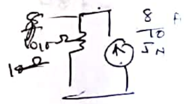
Rth



$\frac{8 \times 10}{18} = \frac{80}{18} = \frac{40}{9} = 4.44\,\Omega$

Vth.

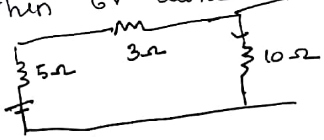
Voltage across X Y



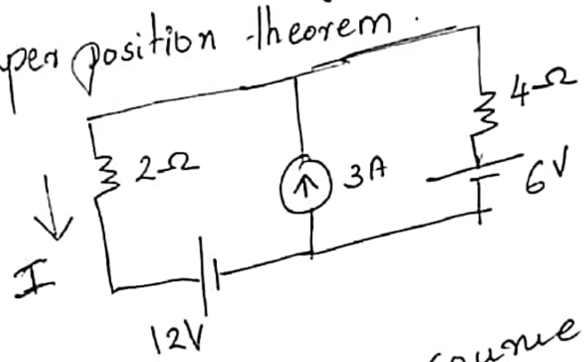
$= 8V + V_{across}\ 10\Omega$

Current through 10Ω Use superposition theorem.

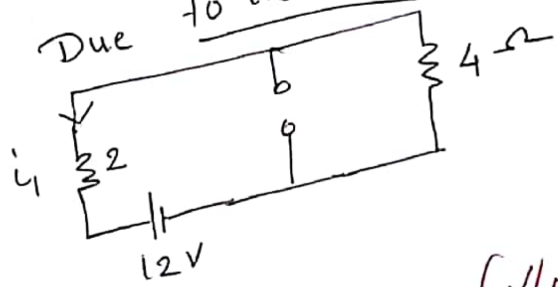
When 6V alone



2. Find current through 2Ω, using super position theorem.



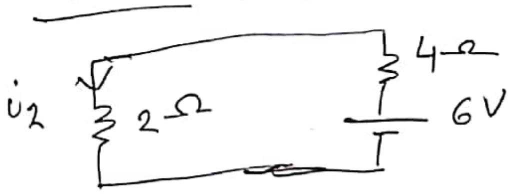
Due to 12 V source,



$$i_1 = \frac{12}{6} = \underline{\underline{2A}}$$

(∵ V/R)

Due to 6V source,

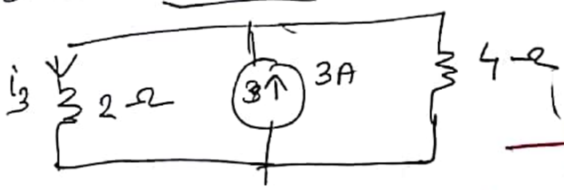


$i = V/R$

$$i_2 = \frac{6}{6} = 1A$$

(∵ V/R)

Due to 3A source;



Current division rule

$$i_3 = 3 \times \frac{4}{6} = 2A$$

$$i = i_1 + i_2 + i_3$$

$$= \underline{\underline{5A}}$$

$V_R = (19.74 \angle 80.5)\,(1 \angle 0)$
$= 19.74 V \angle 80.5^\circ$

$V_C = I_S \cdot Z_2$
$= (19.74 \angle 80)\,(6\Omega \angle -90)$
$= 118.44 \angle -9.46^\circ$.

$\therefore\ I_C = \frac{V_C}{Z_C} = \frac{V_C}{2 \angle -90} = 59.2 A \angle 80.5$

Complex no. Conversion b/w forms.

Rectangular to polar

$r = \sqrt{x^2+y^2}$

$\theta = \tan^{-1} y/x$

Rectangular	polar form
$x+jy$	$r \angle \theta$

polar to rectangular

$x = r \cos\alpha$

$y = r \sin\alpha$

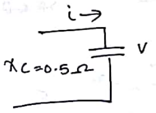
1. Convert $10 \angle 230$

$x = 10 \cos 230$, $y = 10 \sin 230$

$x+jy = -6.42 - j7.6$

Series & llel ac Circuits

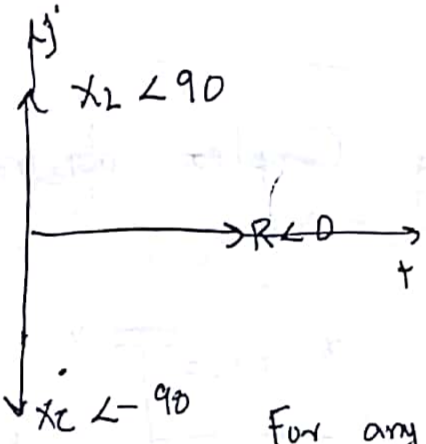
1. Using Complex algebra, find the voltage v



$i = 6 \sin(\omega t - 60)^\circ$.

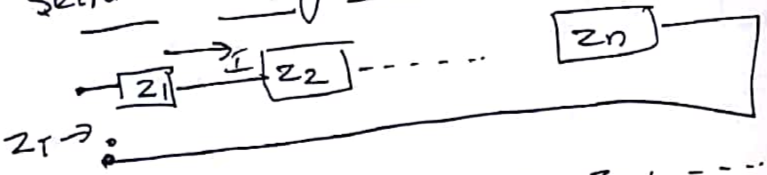
$V = I Z_C = I \angle \theta\ (X_C \angle -90)$.

Impedance diagram.



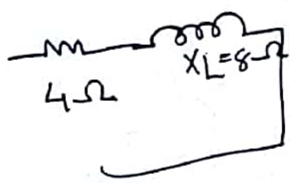
For any n/w the resistance will always appear on the +ve real axis; X_L on +ve imaginary axis, ~~&~~ X_C on -ve imaginary axis. The result is an "impedance diagram" that can reflect the individual & total impedance levels of an ac n/w.

Series configuration

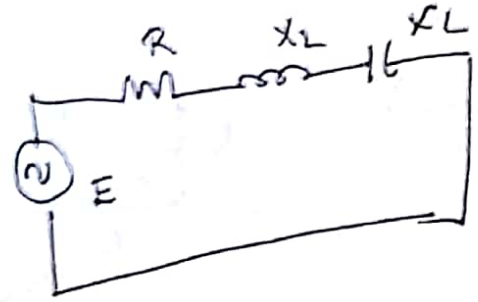


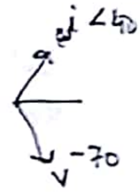
$$Z_T = Z_1 + Z_2 + \cdots + Z_n$$

Over all properties of series ac circuits are the same as those for dc circuits.



$$Z_T = R\angle 0 + X_L \angle 90$$
$$= R + jX_L$$
$$= 4 + j8\,\Omega$$
$$= 8.9 \angle 63.43$$

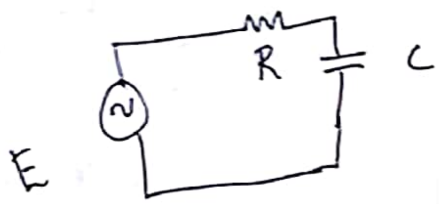
2) 



$$V_R = \frac{E \cdot Z_R}{Z_R + Z_L + Z_C}$$

$$V_L = \frac{Z_L \cdot E}{Z_R + Z_L + Z_C}$$

Freq. response of RC n/w



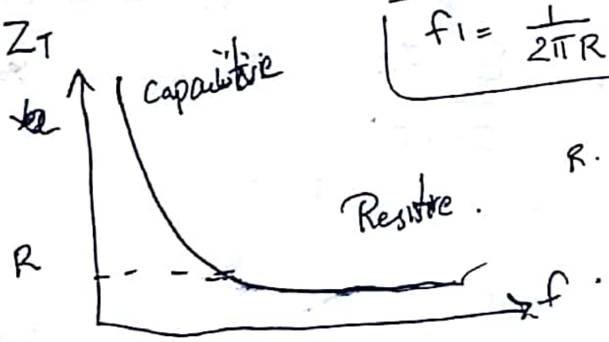
f = 0 to 20KHz

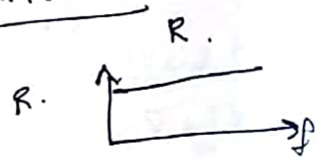
At low f X_C will high so impedance will be capacitive in nature. At high freq. X_C will drop below R and the n/w will shift towards one of a purely resistive nature.

The freq. at which $X_C = R$ can be determined by f_1

$$X_C = \frac{1}{2\pi f_1 C} = R$$

$$\boxed{f_1 = \frac{1}{2\pi RC}}$$

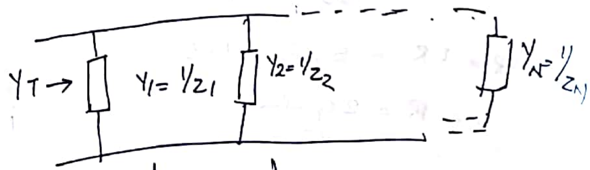




Admittance $Y = 1/Z$.

unit Seimens

Admittance is a measure of how well an ac circuit will admit or allow current to flow in the circuit.

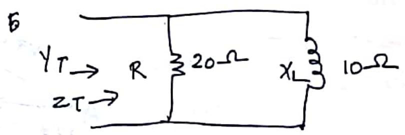


parallel ac n/w.

$$Y_T = Y_1 + Y_2 + \cdots + Y_n.$$

→ Reciprocal of reactance $(1/X)$ is called susceptance.

1.



Find
1. $Z_{i/p}$
2. $Y_{i/p}$

$$Y_R = \frac{1}{R} = \frac{1}{20\Omega} = 0.05.$$

$$Y_L = \frac{1}{X_L \angle 90}$$

$$= \frac{1}{10} \angle -90$$

$$= 0.1 \angle -90 = -j0.1 \text{ S}$$

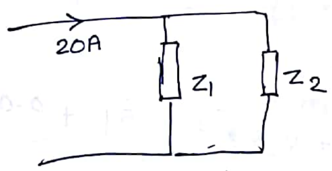
$$Y_{i/p} = Y_R + Y_L$$

$$= 0.05 - j0.1 \; ℧$$

$$Z_{i/p} = \frac{1}{Y_{i/p}} = 8.93\Omega \angle 63.43°$$

U.Q

1. Two circuits, the impedances of which are given by $Z_1 = (15 + j10)\Omega$ and $Z_2 = (8 - j6)\Omega$ connected in ||el. If the total current supplied is 20A, what is the power taken by each branch.

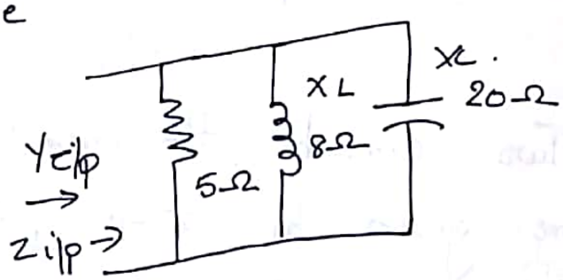


$$P = I_1^2 R_1 \qquad P_2 = I_2^2 R_2$$

$$I_1 = \frac{I \cdot Z_2}{Z_1 + Z_2} = 20 \cdot \frac{(8 - j6)}{23 + 4j}$$

$$I_2 = \frac{I \cdot Z_1}{Z_1 + Z_2} = \frac{20(15 + j10)}{23 + 4j}$$

2. Find i/p impedance and admittance



$$Y_{i/p} = \frac{1}{5} + \frac{1}{8j} \cancel{+} - \frac{1}{20j}$$

$$= \cancel{\tfrac{1}{5}} \cancel{+}\ 0.2 + 0.125 \angle \bar{90}$$

$$\cancel{+}\ \cancel{+}\ 0.05 \angle 90$$

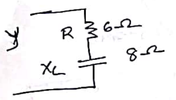
$$= 0.2 \cancel{+} - 0.125j + 0.05j$$

$$= 0.2 - 0.075j$$

$$Z_{i/p} = \frac{1}{Y_{i/p}} = 4.383 + 1.64j$$

$$= \underline{\underline{4.68 \angle 20^\circ}}$$

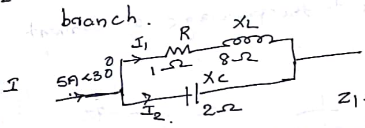
1. Find admittance



$Z = R - jX_c = 6 - 8j$

$Y = \frac{1}{Z} = 0.06 + 0.08j$

2. Find current through each parallel branch.



$Z_1 = 1 + 8j$

$Z_2 = -2j$

$I_1 = \frac{I \cdot Z_2}{Z_1 + Z_2}$

$= \frac{(5\angle 30)(-2j)}{1+6j} = \underline{\underline{1.64A \angle -140^\circ}}$

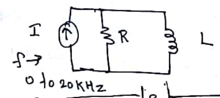
$I_2 = \frac{I \cdot Z_1}{Z_1 + Z_2}$

$= \frac{(5\angle 30)(1+8j)}{1+6j}$

$= \underline{\underline{6.62A \angle 32^\circ}}$

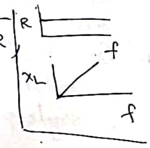
Freq. response of parallel elements

✓ parallel RL n/w

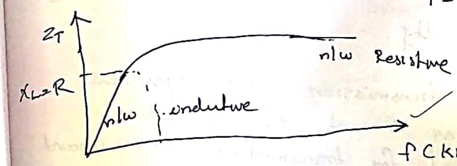


At low freq. X_L is very small compared to R

So low freq. n/w will be primarily inductive



$Z_T = \frac{R \cdot jX_L}{R + jX_L}$



3ϕ power is common form of electrical power & popular method of electric power transmission and distribution. ~~This is due to~~;

Adv. of 3ϕ power over 1ϕ power are

1. For a given size of frame, 3ϕ generator or motor has greater o/p than that of a single phase generator.

2. 3ϕ g/r work in Parallel without any difficulty.

3. 3ϕ transmission line requires lesser amount of conductor material for transmitting same amount of power over a 1ϕ line.

4. 3ϕ m/r posses uniform torque; where as 1ϕ m/r possess a pulsating torque.

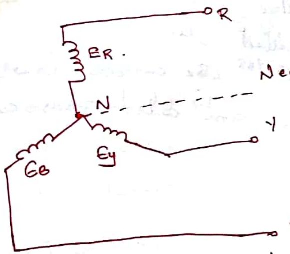
5. Polyphase induction m/r are self starting where as 1ϕ ac m/r are not self starting.

Methods of connection of 3ϕ s/m

2 methods of interconnecting the 3 phases

1. Star: Connection

Similiar ends of 3ϕ phases are joined together with in the alternator and 3 lines are run from free ends as shown.

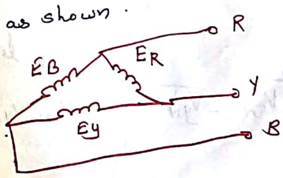


If a neutral conductor is present, it is called 3ϕ, 4 wire system.

→ 3ϕ, 4 wire system used in industrial & large consumers.

2. Delta Connection

Dissimiliar ends of phases are joined to form a closed mesh and 3 lines are run from junction Points as shown.



Analysis - star Connection.

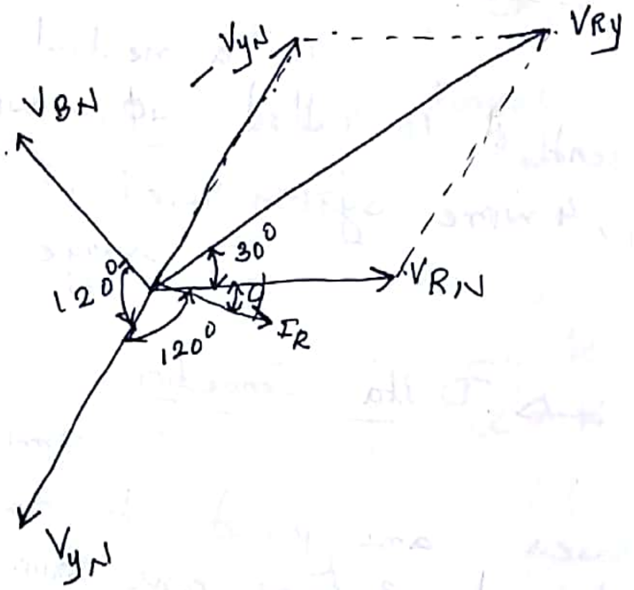
Similar ends of 3 phases are joined together to form a common junction 'N' called star or neutral point

V_{ph} → voltage b/w any line & neutral point ie voltage across each winding

eg: V_{RN}, V_{YN}

V_L → voltage b/w any 2 lines. are called line voltage.

eg: V_{RY}, V_{YB}, V_{BR} The currents flowing in phases are called phase current



V_{Ry} line voltage

$\overline{V_{Ry}} = \overline{V_{RN}} - \overline{V_{YN}}$

V_{RN}, V_{YN} phase voltage.

Adv. of star

1. $V_{ph} = V_L/\sqrt{3}$

In an alternator induced emf $\propto$ no. of turns.

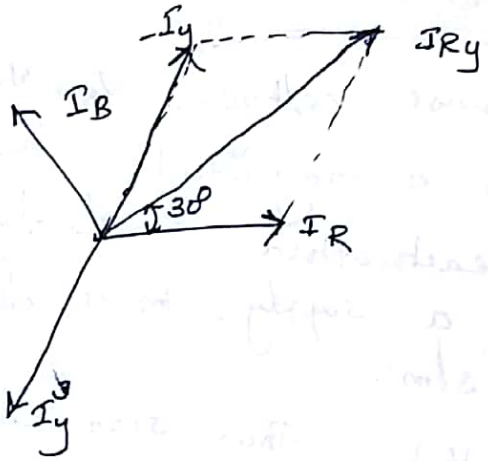
So star connected alternator has require lesser no. of turns.

2. For the same line voltage. star connected alternator will require lesser amount of insulation.

3. Two levels of voltage

4. In star earthing of neutral permits use of relay.

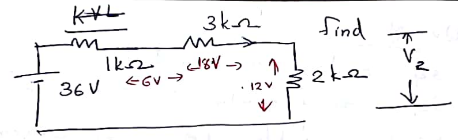
Delta or Mesh



$$I_{Ry} = \sqrt{I_R^2 + I_y^2 + 2 I_R I_y \cos 60}$$

$$\boxed{\begin{array}{c} I_L = \sqrt{3}\, I_{ph} \\ V_L = V_{ph} \end{array}}$$

~~H.A~~ ~~KVL~~

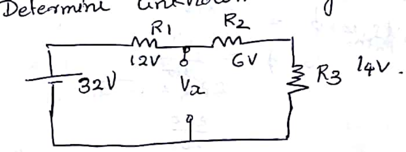
1. 

find V_2

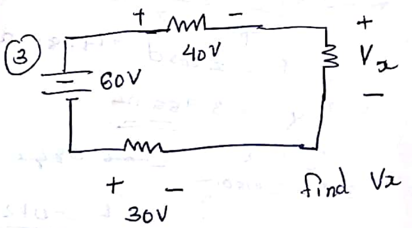
$I = V/R_{eq} = \frac{36}{6k\Omega} = \underline{6mA}$

$V_2 = \underline{12V}$

Determine unknown voltage



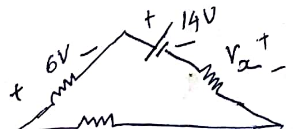
$V_x = 6V + 14V = 20V.$



find $V_x = ?$

$60 - 40 - V_x + 30 = 0$

$V_x = \underline{50V}$

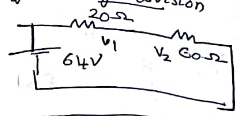
4. 

$V_x = ?$

$-6 - 14 - V_x + 2 = 0$

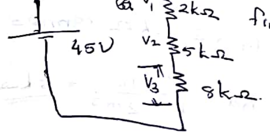
$V_x = \underline{-18V}$

Voltage division

5. 

$V_1 = 16V$

$V_2 = \underline{48V}.$

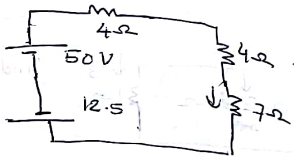
6. 

find V_3 ?

$V_3 = 45 \cdot \frac{8}{15}$

$= \underline{24V}$

$V_1 = 6V$

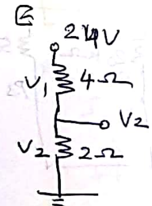
7. 

find I and $V_{across\ 7\Omega}$?

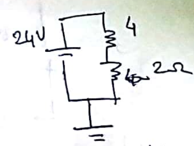
$I = \frac{37.5}{15} = \underline{2.5A}$

$V_{7\Omega} = (2.5 \times 7) = IR = \underline{17.5V}$

$\boxed{\text{Voltage } V_{ab} = V_a - V_b}$ In general double subscription notation

8. 

find V_1 & V_2 ?

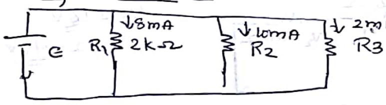


$V_1 = 16V, V_2 = \underline{8V}$

Scanned by CamScanner

Current division

1.



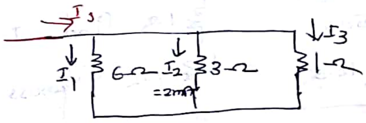
find R_3.

$I_{total} = 20mA$

$\cancel{E = (20mA \times R_{eq})}$ $E = 2k\Omega \times 8mA = 16\,V$

$R_3 = \frac{V}{I} = \frac{16}{2mA} = 8k\Omega$

2.



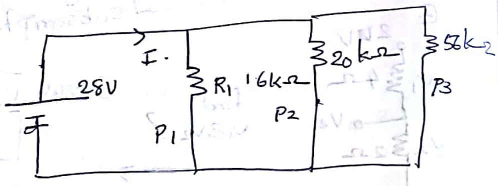
Find I_s ?

$I_1 = \frac{I_2}{2} = 1mA$ (since R twice)

$I_3 = 3 I_2 = 6mA$

$I_s = 9mA$

3



$R_T = 1.44\,k\Omega$

$I = \frac{28}{R_T}$
$= 19.44mA$

$I_1 = \frac{28}{R_1}$

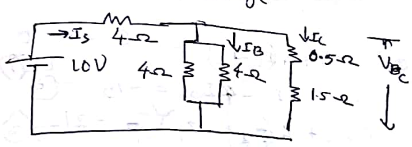
$P_1 = I^2 R_1 = 490mW$

$P_2 = I_2^2 R_2 = (1.4mA)^2\, 20\,k\Omega$
$= 39.2\,mW$

$P_3 = \frac{V^2}{R_3} = 14mW.$

$P_{total} = 543.\,mW.$

1. Determine I_B, voltage



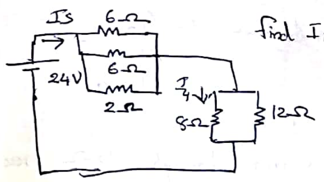
$R_{total} = 5\Omega$

$I_s = \frac{10}{5} = 2A$

$I_B = I_C = 1A$

$V_L = IR$
$= 1 \times 2 = 2V$

2.



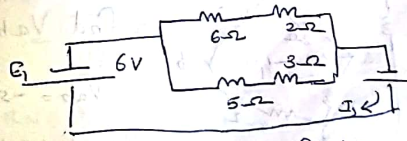
find I_4 = ?

$R_{total} = 6\Omega$

$I_s = \frac{24}{6} = 4A$

$I_4 = \frac{4 \times 12}{20} = \frac{12}{5} = 2.4A$

3.

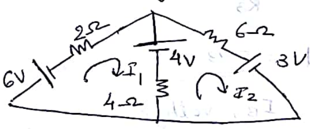


And I_s.

$I_s = \cancel{3A}\ 3A$

Mesh analysis

1. find I in 4Ω resistor



$2I_1 + 4(I_1 - I_2) = -6 - 4 = -10$

$6I_1 - 4I_2 = -10$ — (1)

$6I_2 + 4(I_2 - I_1) = -~~8~~1$ — (2)

$-4I_1 + 10I_2 = 1$ — (5)

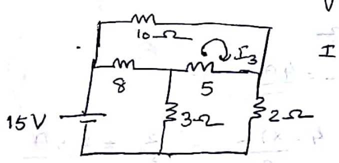
$I_1 = -2.18A$

$I_2 = -0.77A$

I through $4\Omega = (I_1 - I_2)$

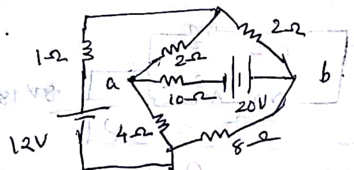
$= -1.41A$

2. Find current through 10Ω resistor



$I_3 = 1.22A$

3. find Vab



$V_{ab} = -5.52$

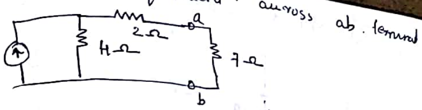
$V_a = 4.48V$

$V_b = 10V$

I_1 (cw) = 2.37A

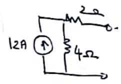
I_2 (cw) = −0.20

1. Find Thevenin equivalent across ab terminal

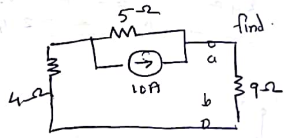


Rth → ~~13Ω~~ 6Ω

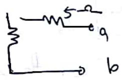
Vth → 12×4 = 48V



2. find Norton equivalent

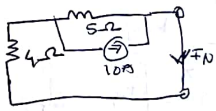


RN →



→ 9Ω

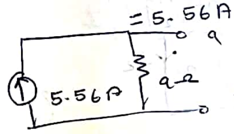
IN



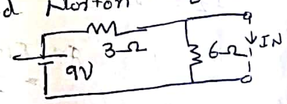
$I_N = \frac{10 \cdot 5}{9} = \frac{50}{9}$

Current division rule.

$= 5.56A$



3. find Norton equivalent



$R_N = \frac{3 \times 6}{9} = 2\Omega$

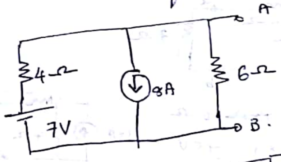
I_N

IN

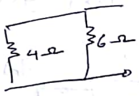
6Ω, inactive, since shorted.

$I_N = \frac{9}{3} = 3A$

1. Find Norton equivalent.



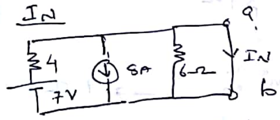
R_N



$R_N = \frac{24}{10}$

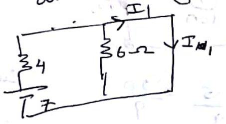
$= 2.4\Omega$

I_N



Use super position theorem

when 7V alone acting



$I_1 = \frac{7}{4}$

since 6Ω, short circuited.

when, 8A alone acting;

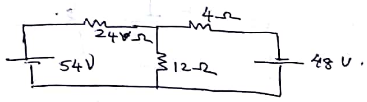
$I_2 = -8A$

$I_N = I_1 + I_2$

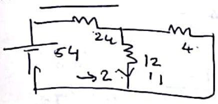
$= -6.25$

$\uparrow 6.25A$.

1. Use super position to find I trough 12Ω



when 54V alone



$R_{eq} = \frac{12 \times 4}{16} + 24$

$= 3 + 24 = 27\Omega$

$I_s = \frac{54}{27} = 2A$

$I_1 = 2 \times \frac{4}{16}$

$= 0.5A$

when 48V alone

$R_{eq} = 4 + 8 = 12\Omega$

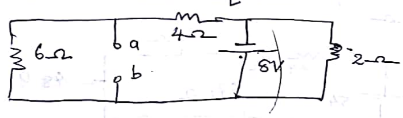
$I_s = \frac{48}{12} = 4A$

$I_2 = \frac{4 \times 24}{36} = \frac{24}{9} = 2.67A$

$I_{12\Omega} = I_1 - I_2$

or $I_2 - I_1 = 2.17A$ upwards. ↑

1. Find Thevenin equivalent.

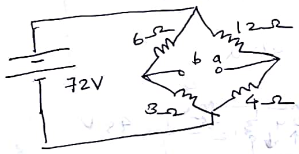


V_{th} $R_{th} \rightarrow 6\Omega \parallel 4\Omega$

$R_{th} = \underline{2.4\Omega}$

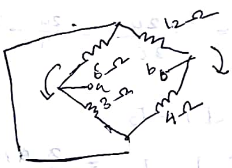
$V_{th} = \frac{8 \times 6}{10} = \underline{4.8V} = V_{ab}$. voltage division.

2.



Find V_{th}.

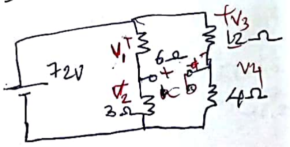
$R_{th} = \cancel{7\Omega \parallel 18\Omega}$



6Ω || 3Ω and
12Ω || 4Ω
2Ω and 3Ω
series

$R_{th} = 2+3 = 5\Omega$

V_{th}.



$V_1 = \frac{72 \times 6}{9} = 48V$

$V_2 = \frac{72 \times 3}{9} = 24V$

$V_{th} = V_3 - V_1$, Apply KVL V_1 $-V_3+V_{th}=0$, $V_{th}=V_3-V_1$

$V_3 = 72 \times \frac{12}{16} = \cancel{54V}$ $\underline{54V}$

$\therefore V_{th} = V_3 - V_1$
$= 54 - 48 = \underline{6V}$

Magnetic circuits.

1. A magnetic field is produced by a coil of 300 turns which is wound on a closed iron ring. The ring has a cross-section of $20cm^2$ & mean length of 120cm. Permeability of iron is 800. If the current in the coil is 10A. Find Energy stored in the magnetic field?

$E = \frac{1}{2} L I^2$ $L = \frac{N\phi}{I}$

$L = \frac{N^2}{S}$ $= \frac{N}{I}\left(\frac{mmf}{S}\right)$

$S = \frac{l}{\mu_0 \mu_r a} = \frac{120 \times 10^{-2}}{4\pi \times 10^{-7} \times 800 \times 20 \times 10^{-4}}$ $L = \frac{N}{I} \cdot \frac{NI}{S} = \frac{N^2}{S}$

$S = 596831$ AT/wb

$L = \underline{0.15H}$

$e = \frac{1}{2} L I^2 = \underline{7.539 J}$

2017 U.Q

1. Apparent power drawn by an ac circuit 10kVA, active → 8 kw find Pf and ?

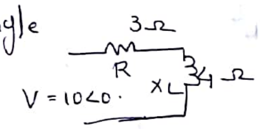
$x = \sqrt{10^2 - 8^2} = 6kVA$ 10kVA, 8kw, ϕ

$Pf = \cos\phi = \frac{8}{10} = 0.8$

2. Two impedance $z_1 = 6+j8\ \Omega$ and $Z_2 = 8-j6\ \Omega$ are connected in Parallel across 100 V supply.

Power triangle

1

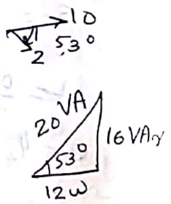


Find Active power ?

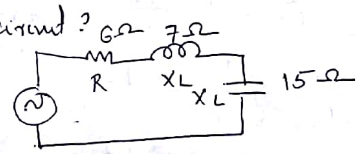
$I = \frac{V}{Z} = \frac{10\angle 0}{3+j4} = 1.2 - 1.6j = 2\angle -53^\circ$ A

$P = VI\cos\phi$

$= 10 \times 2 \times \cos 53 = \underline{12\ \omega}$



2. Find Power factor of the given circuit ?



$I = \frac{V}{R+j(X_L - X_C)} = \frac{100}{6-8j} = 6+8j$

$= 10\angle 53^\circ$

$Pf = \cos 53^\circ = 0.601$ leading

Active power $VI\cos\phi = ~~10~~ ~~661\omega~~$ $100 \times 10 \times \cos 53$

$= \underline{601\,W}$

3. An electrical device is rated 5 kVA, 100 V at 0.6 pf lag find Z ?

$I = \frac{5000}{100} = \underline{50\,A}$

$\phi = \cos^{-1}(0.6)$

$Z = \frac{E}{I} = \frac{100}{50\angle -53^\circ}$

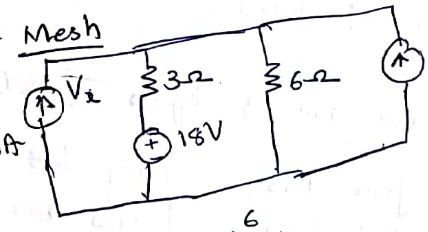
lag so −ve, ϕ

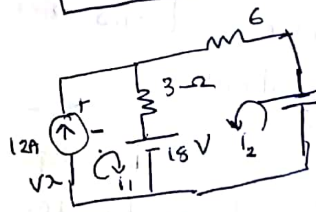
$= \underline{2\,\Omega \angle 53^\circ}$

. Mesh

. Find V_x using mesh ?

1.





72 − 18

54

$V_x =$

$I_2 = 2A$.

$I_2 = 6A$

$V_x = 18$

V_x, u_1

$I_1 = \underline{12A}$

$V_x = 18$

$-V_x + 3(I_1+I_2) - 18 = 0$ — (1)

$V_x - 36 + 3I_2 - 18 = 0$

$V_x + 3I_2 + 54 = 0$ — (a)

$V_x + 3(I_2+I_1) - 18 = 0$ $I_2 = 6A$

$-36 + 6I_2 + 3(I_2+I_1) - 18 = 0$

$36 + 9I_2 - 36 - 18$

$9I_2 = 18$

$I_2 = \underline{2\,A}$

−12 V

$V_x =$
$= -18+6$

Types of generators
classified according to the way in which their fields are excited.

1. Seperately excited

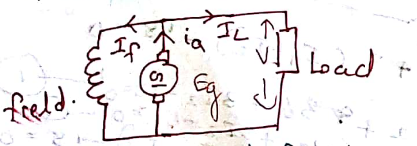
field magnet are energised from an independent external dc source

2. Self excited generators

field magnets are energised by the current produced by the generators themselves.

There are 3 types of self excited ~~dc~~ generators, according to the manner in which their field coils are connected to the armature.

a. shunt wound



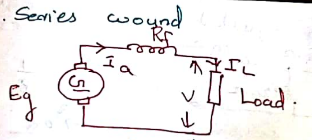
~~$I_L = I$~~

$I_a = I_f + I_L$

$V = E_g - I_a R_a$

: used for charging batteries because their terminal voltages are almost constant.

b. Series wound

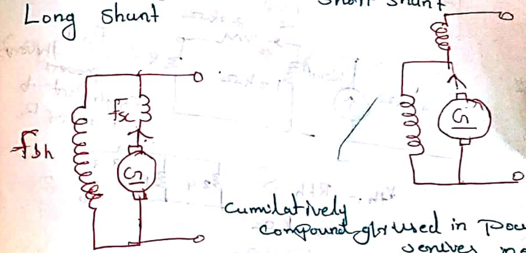


$I_a = I_L$

They are not used for power supply because of their rising characteristics. It is used as boosters in certain types of distribution systems particularly in railway service.

c. Compound wound

Long shunt | Short shunt



cumilatively compound gtr used in power services in electric railways.

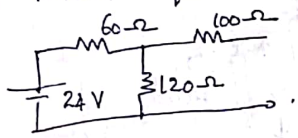
diff. compound used in arc welding.

Motor applications

1. Series — $T \propto I_a$. It is used when huge starting torque required for accelarating heavy masses such as hoists and electric trains.

2. Shunt motor : Due to constant speed, suitable for driving shafts, machine tools, lathes, wood-working machine

1. Find Thevenin Equivalent



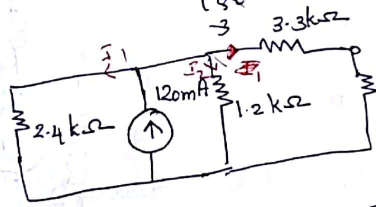
$\frac{1}{80} + \frac{1}{120}$

R_{th} = $\frac{60 \times 120}{60 + 120}$ = $\frac{270Q}{180}$ = $\frac{90}{6}$ = ~~15Ω~~

= 40 Ω

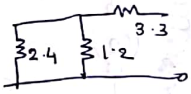
R_{th} = 40 + ~~60~~ 100 = 140 Ω

V_{th} = $\frac{24 \times 120}{180}$ = 16V



Find thevenin ~~power~~ equivalent to Resistor R.

V_{th} - R_{th} ⇒



~~= 0.8kΩ~~

R_{th} = 0.8 + 3.3 = 4.1 kΩ

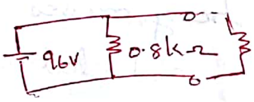
V_{th} = V. across 1.2kΩ

= $I_2 \times 1.2 \times 10^3$

$I_2 = \frac{120 \times 10^{-3} \times 2.4 \times 10^3}{3.6 \times 10^3}$

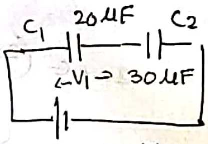
= 80mA.

V_{th} = 96V



Capacitors

1. Two Capacitor A, B having capacitance 20μF, 30μF are connected in series to a 600V dc supply. Determine potential difference across each capacitor.



$C_{eq} = \frac{20 \times 30}{20 + 30}$

= 12 μF

Q = CV
'C' in series.

∴ Q remains same ~~in~~ since

$Q_{total} = C_{eq} \times 600$

= 7200 μC.

~~V_1~~ = $Q_{total} \cdot \frac{C_2}{C_1 + C_2}$

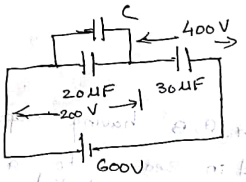
V_2 : $Q = C_1 V_1 = C_2 V_2$

$7200 \times 10^{-6} = 20 \times 10^{-6} \times V_1$

$V_1 = 360$

$V_2 = 240$

→ If a 3rd capacitor 'c' is connected in parallel with A and it is then found that the potential difference across B is 400 V. Calculate capacitance of C and energy stored in it.



~~$C_{eq} = 20\mu F + C$~~

~~$Q = C_{eq} V$~~ $Q = CV$

~~$20 + C$~~ $(20\mu F + C)\, 200 = (30 \times 10^{-6}) \times 400$

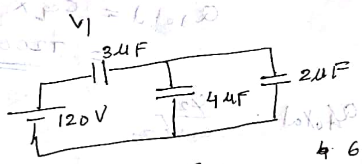
$(20 \times 10^{-6}) + C = 60 \times 10^{-6}$

$\underline{C = 40 \mu F}$

E stored $\frac{1}{2} CV^2 = \frac{1}{2} \times 40 \times 10^{-6} \times 200^2$

$= \underline{0.8 J}$

2



~~4~~ 6 μF ~~d~~ serves with 3 μF

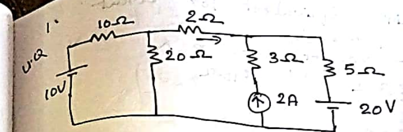
$C_{total} = \frac{6 \times 3}{6+3} = \underline{2 \mu F}$

$Q_{total} = CV = 120 \times 2 \times 10^{-6}$
$= 240 \mu C.$

$V_1 = \frac{Q_1}{C_1} = \frac{240 \times 10^{-6}}{3 \times 10^{-6}}$.

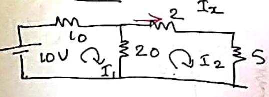
$Q = 240 \mu c$

1.



Find voltage across 2Ω using superposition

When 10V alone



$-10I_1 + 10 - 20(I_1 - I_2) = 0$

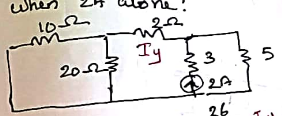
$-30I_1 + 20I_2 + 10 = 0$ ⟶ (1)

IInd mesh $-7I_2 - 20(I_2 - I_1) = 0$

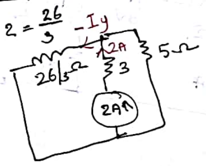
$+20I_1 - 27I_2 = 0$ ⟶ (2)

$I_2 = \frac{20}{41} = I_x$

When 2A alone:



$2 + \frac{20 \times 10}{30} = \frac{200}{30} + 2 = \frac{26}{3}$

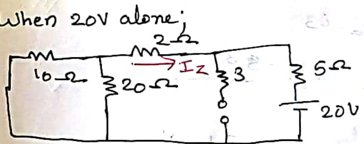


current division;

$I_y = -\left(2 \cdot \frac{5}{\frac{26}{3} + 5}\right)$

$= \frac{10}{41} \times 3 = -\left(\frac{30}{41}\right)$

When 20V alone;



$R_{total} = \frac{20}{3} + 7 = \frac{41}{3}$

$I_{total} = \frac{20}{R_{total}} = \frac{20 \times 3}{41} = \frac{60}{41}$

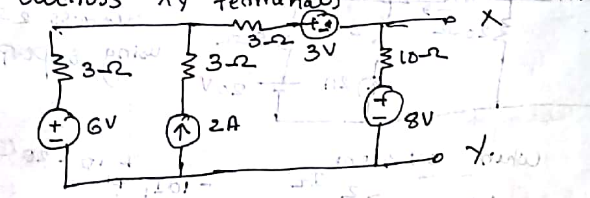
$I_z = -\frac{60}{41}$

∴ Current through 2Ω $= I_x + I_y + I_z = \frac{20}{41} - \frac{30}{41} - \frac{60}{41}$

$= \frac{-70}{41}$ ∴ so $\frac{70A}{41}$ ←

$\therefore V_{2\Omega} = \frac{2 \times -70}{41} = \frac{-140}{41} = -3.41 V$

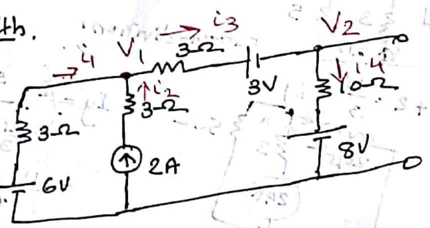
1. Obtain Thevenin's Equivalent for circuit across xy terminals



V_{Th} R_{th}

$6\Omega \parallel 10\Omega \quad \frac{60}{16} = \frac{15}{4} = 3.75\Omega$

V_{th}.



At V_1 KCL

$i_1 + i_2 = i_3$

$\frac{-6+V_1}{3} + 2 = \frac{V_1 - 3 - V_2}{3}$

$2 - \frac{V_1}{3} + 2 - \frac{V_1}{3} = 1 - \frac{V_2}{3}$

$-\frac{2V_1}{3} = -5 - \frac{V_2}{3}$

$2V_1 = 15 - V_2$

$2V_1 + V_2 = 15$ — (1)

At V_2 : KCL

$i_3 + i_4 = 0$

$(3) - V_1 + \frac{V_2 - 8}{10} = 0$

$\frac{V_2 + 3 + V_1}{3} = \frac{V_2 - 8}{10}$

$+\frac{V_2}{3} + 1 - \frac{V_1}{3} + \frac{V_2}{10} - \frac{8}{10} = 0$

$[+V_2 + 3 - V_1]\, 10 = -3V_2 + 24$

$+30 - 10V_1 = -13V_2 + 24$

$-10V_1 + 13V_2 = -6$ — (2)

$V_1 = 5.58$ V

$V_2 = 3.83$ V

$0.667V_1 - 0.33V_2 = 5$

$-0.33V_1 + 0.433V_2 = -0.2$

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