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Average power.

Average power for whole cycle

$$P_{avg} = \frac{1}{2} V_m I_m \int_0^{2\pi} \sin 2\omega t . dt$$

$$= \frac{1}{2} V_m I_m \left[\frac{-\cos 2\omega t}{2\omega} \right]_0^{2\pi}$$

$$= 0$$

Therefore, the average demand of power from the supply = 0

power factor.

from eq^n (1) & (2) it is clear that

$$\phi = \pi/2$$

$$P.F. = \cos \phi$$
$$= \cos \pi/2$$

$$P.F. = 0 \text{ (leading)}.$$

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Que. A coil of resistance 10Ω; inductance 0.1 H is connected in a series with a capacitor or 150 μF. Across 200 V, 50 Hz supply. Calculate the following.

(1) Impedance (z)

(2) current

(3) power factor

(4) voltage across the coil = V_L

(5) V_R, V_L, and V_C

Sol:→ $L = 0.1$ $C = 150 \times 10^{-6}$ F.

$V = 200$ $f = 50$ $R = 10$.

$$X_L = \omega L = 2\pi f L = 2\pi \times 50 \times 0.1 = 2\pi \times 5$$
$$= 31.4\ \Omega$$

$$X_C = \frac{1}{\omega C} = \frac{1 \times 10^6}{2\pi \times 50 \times 150} = \frac{10000}{471} = 21.23\ \Omega$$

$$X_L > X_C$$

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

$$Z = \sqrt{(10)^2 + (31.4 - 21.23)^2}$$

$$Z = \sqrt{100 + 103.42}$$

$$Z = \sqrt{203.42} = 14.26\ \Omega$$

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

$$I = \frac{V}{Z} = \frac{200}{\sqrt{\cancel{203.92}}} \; 14.26$$

$$I_{rms} = 14.02\,A$$

$$i_M = \sqrt{2}\, i_{rms} = \sqrt{2} \times 14.02$$

power factor.

$$P.f = \frac{R}{Z} = \frac{10}{14.26} = 0.701$$

voltage across coil

$V_L = ?$

$$V_L = I X_L = (14.02)(31.4)$$

$$= 440.228\,V$$

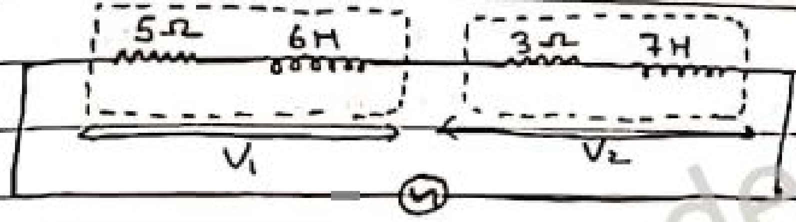
$$V_R = \cancel{10\Omega}\; IR = (14.02)(10) = 140.2\,V$$

$$V_C = I X_C = (14.02)(21.23)$$
$$= 297.6446\,V$$

Ques. Two coils are connected in series having the resistance of 5 & 3 Ω and inductances of 6 & 7 H connected in series applied voltage is 200V, 50 Hz calculate current & power factor

$= 140.2V$

Q. 2 coils are connected in series having the resistance of 5 and 3 ohms and inductances of 6 & 7 Henry connected in series applied voltage is 200 V 50 Hz calculate current and power factor for whole circuit voltage across each coil and power factor for each coil.



200V, 50Hz

Sol:- $R = 5 \& 3$

$L = 6 \& 7$

$V = 200V$

$F = 50Hz$

1st circuit

$Z = \sqrt{5^2 + 6^2}$

$Z = \sqrt{25+36}$

$Z_1 = \sqrt{61} = 7.81\ \Omega$

IInd circuit

$Z = \sqrt{3^2 + 7^2}$

$Z = \sqrt{9+49}$

$Z_2 = \sqrt{58} = 7.61\ \Omega$

$(X_L)_1 = 2\pi f L = 2\pi \times 50 \times 6 = 1884\ \Omega$

$(X_L)_2 = 2\pi f L = 2\pi \times 50 \times 7 = 2198$

$Req. = 5 + 3 = 8\ \Omega$

$Z_1 = \frac{V_1}{I} = \sqrt{R^2 + X_L^2} = \sqrt{5^2 + (1884)^2}$

$= \sqrt{3549481}$

$= 1884.0066$

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$$Z_2 = \frac{V_L}{I} = \sqrt{R_L^2 + X_{L}^2} = \sqrt{3^2 + (2198)^2}$$
$$= \sqrt{4831204+9}$$
$$= \sqrt{4831213}$$
$$= 2198.0020$$

$$Z_{eq} = Z_1 + Z_2 = 1884.0062 + 2198.0020$$
$$= 4082.008$$

$$I = \frac{V}{Z_{eq}} = \frac{200}{4082.008} = 0.048\ A$$

$$V_1 = IZ_1 = 0.048\,(1884.006) = 90.43\ V$$
$$V_2 = IZ_2 = 0.048\,(2198.002) = 105.5V$$

Power factor across whole circuit

$$\text{Power factor} = \frac{R}{Z} = \frac{R_{eq}}{Z_{eq}}$$

$$= \frac{8}{4082.008}$$

$$= 0.00195$$

Now power factor across

$$1^{st}\ \text{coil} = \frac{R_1}{Z_1} = \frac{5}{1884.006} = 0.0026$$

Power factor across 2^{nd} coil

$$\frac{R_2}{Z_2} = \frac{3}{2198.002} = 0.00136.$$

Parallel AC Circuits

1. Impedance (z)
It is the total opposition offered by AC circuit that may contain Inductance, capacitance and resistance to the alternating current when alternating voltage is applied across the circuit.

OR

It is the complex summation of resistance and reactance it's unit is ohm's so it can be written as :-

$$z = R + jX$$

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

when $X_L > X_C$

$$z = \sqrt{R^2 + (X_C - X_L)^2} \quad (X_C > X_L)$$

2. Reactance (X)
This is the opposition offered by inductance and capacitance to the current when AC voltage is applied to the circuit. It

is given in ohm's

That may be of two type

1) Inductive reactance

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

2) Capacitive reactance

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

3. Admitance (Y) :-

It is the easiness to flow of alternating current provided by AC circuit when alternating voltage is applied across the circuit. It can also defined as the reciprocal of Impedance.

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

Unit = Ω^{-1}, ℧ (mho) simens.

4. Quality factor: (Q factor)

Q factor is the reciprocal of power factor of the coil. It is the figure of merit.

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that means. It should be as large as possible for any coil (combination of resistance and inductance).

$$Q = \frac{1}{\cos\phi} = \frac{Z}{R}$$

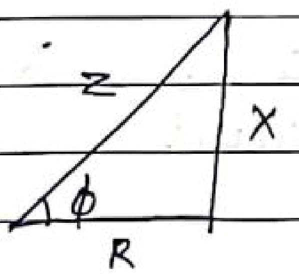
$$\frac{Z}{R} = \frac{\sqrt{R^2 + X_L^2}}{R}$$

If, $R <<< X_L$

$$Q = \frac{X_L}{R} = \frac{\omega L}{R}$$

5. Impedance triangle :-

It is the right angle triangle as shown in figure



$$Z = \sqrt{R^2 + X^2}$$

where,

ϕ = power factor angle.

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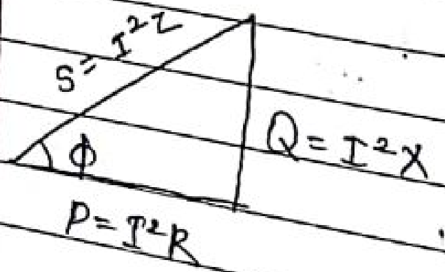
S – active power
P – reactive power
Q – Apparaent power.

6. Power triangle

All the three powers S, P & Q can be represent in a triangle called the power triangle.



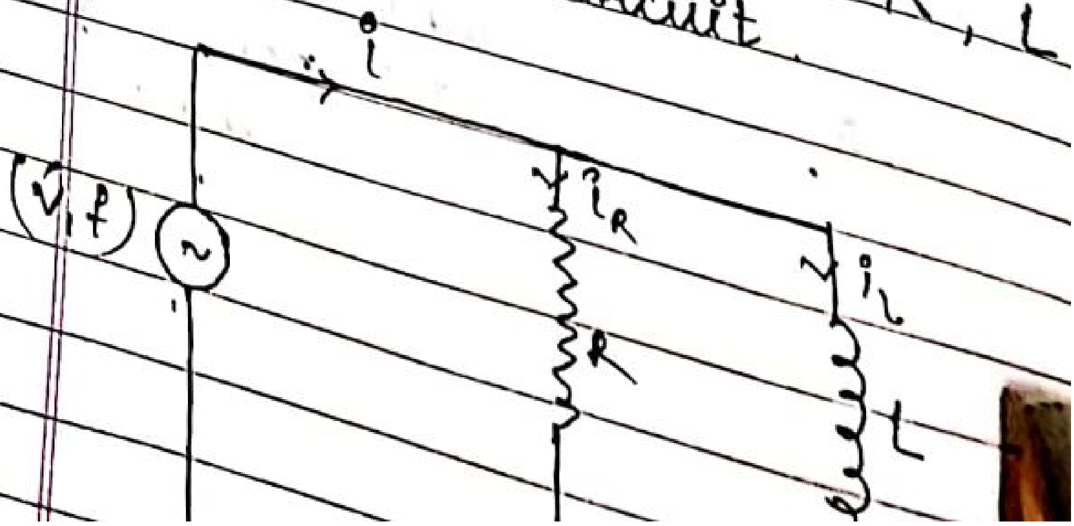
$$S = \sqrt{P^2 + Q^2}$$

$$\phi = \tan^{-1} \frac{Q}{P}$$

where,

ϕ = angle of power

(1-φ) single phase AC parallel circuit for R, L



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An alternating voltage v of frequency f is applied across a parallel combination of a resistance and inductance where,

V = r.m.s value of applied voltage

i = r.m.s value of applied current

i_R = current flowing through the resistance $= V/R$

i_L = current flowing through the inductance $= V/X_L$

since, resistance and inductance are connected in parallel therefore the voltage across both of them is same. that's why it is convinient to take voltage as reference phasor.

For resistance, current is in the same phase with voltage.

For inductance current is lagging the voltage by $\pi/2$

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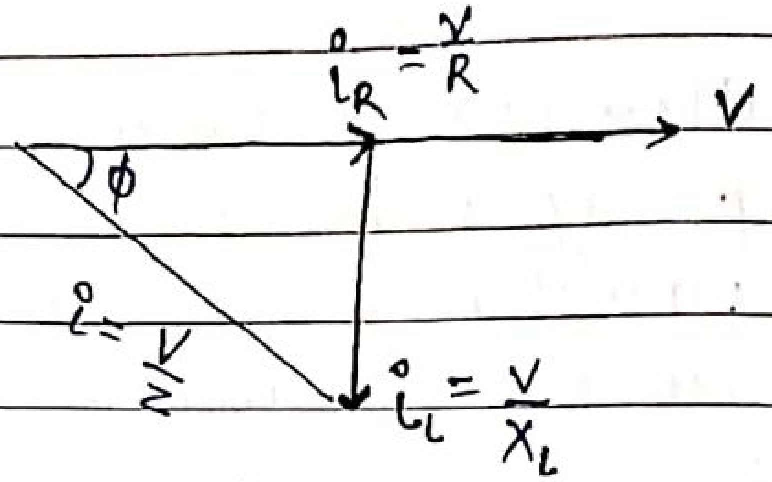


By applying pythagorus theorem.

$\cancel{i =}$

$$i = \sqrt{i_R^2 + i_L^2}$$

$$i = \sqrt{\left(\frac{V}{R}\right)^2 + \left(\frac{V}{X_L}\right)^2}$$

$$i = V\sqrt{\left(\frac{1}{R}\right)^2 + \left(\frac{1}{X_L}\right)^2}$$

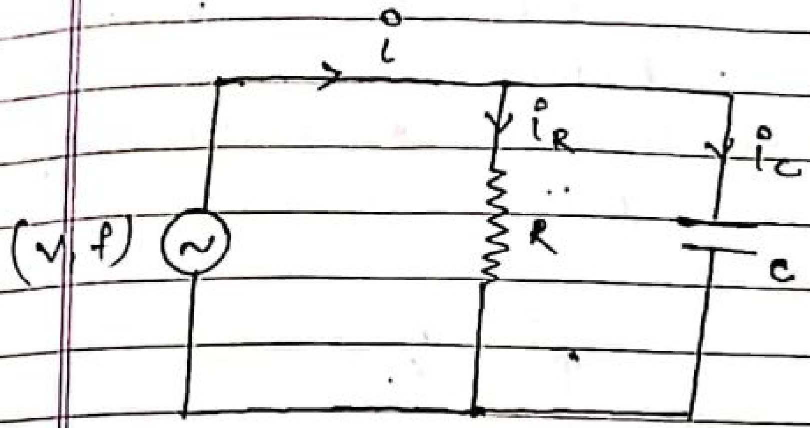
$$\frac{i}{V} = \frac{1}{Z} = y = \sqrt{\left(\frac{1}{R}\right)^2 + \left(\frac{1}{X_L}\right)^2}$$

power factor. $= \cos\phi$

$$= \frac{i_R}{i} = \frac{V/R}{V/Z} = \frac{Z}{R}$$

$$\boxed{P.F. = \cos\phi = \frac{Z}{R}}$$

1-ϕ AC for parallel RC circuit.



An alternating voltage V of frequency f is applied across a parallel combination of resistance and capacitance

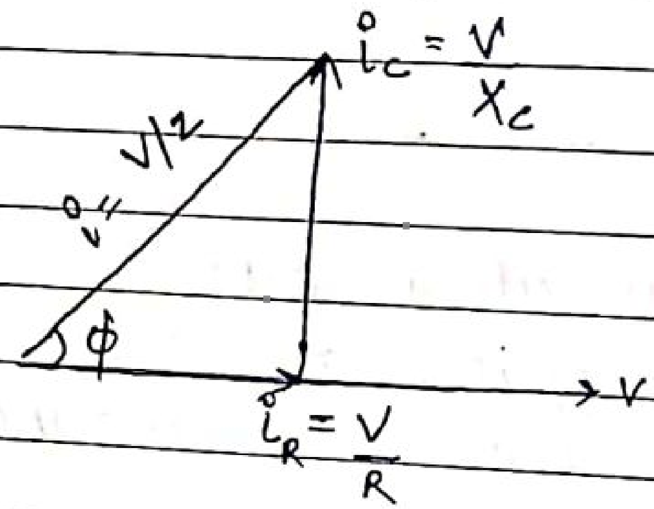
V = r.m.s value of applied voltage
i = r.m.s value of applied current.
i_R = current flowing across resistance
$= \frac{V}{R}$

i_C = current flowing across capacitance
$= \frac{V}{X_C}$

Since, the resistance and capacitance are connected in parallel therefore the voltage across both of them is same that's why it is convinient to take voltage as reference phasor.

for R → current will be the same phase wi[th] voltage.

for C → current leads the v[oltage] by $\pi/2$.



By applying pythagorus theor[em]

$$i = \sqrt{i_R^2 + i_C^2}$$

$$i = \sqrt{\left(\frac{V}{R}\right)^2 + \left(\frac{V}{X_C}\right)^2}$$

$$i = V\sqrt{\left(\frac{1}{R}\right)^2 + \left(\frac{1}{X_C}\right)^2}$$

$$\frac{i}{V} = \frac{1}{Z} = Y = \sqrt{\left(\frac{1}{R}\right)^2 + \left(\frac{1}{X_C}\right)^2}$$

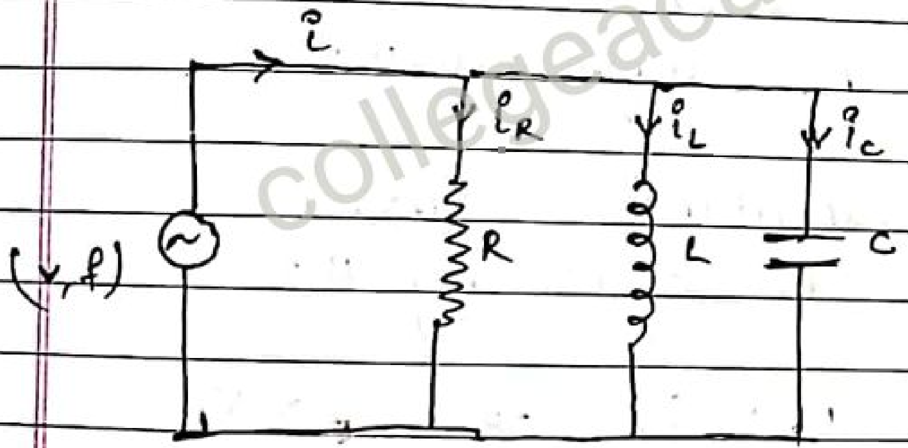
Power factor

$$P.F = \cos\phi$$

$$P.F. = \frac{i_R}{i} = \frac{\frac{V}{R}}{\frac{V}{Z}} = \frac{Z}{R}$$

$$\boxed{P.F. = \cos\phi = \frac{Z}{R}}$$

1-ϕ AC for parallel RLC circuit



An alternating voltage v of frequency f is applied across the parallel combination of resistance, inductance and capacitance. since all are connected in the parallel that's why voltage will be same same for all. and it is convinient to take voltage as reference for phasor.

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r.m.s value of

V = applied voltage

i = r.m.s value of applied current

$\frac{V}{R}$ = i_R = current through the resistan

$\frac{V}{X_L}$ = i_L = current through the inducto

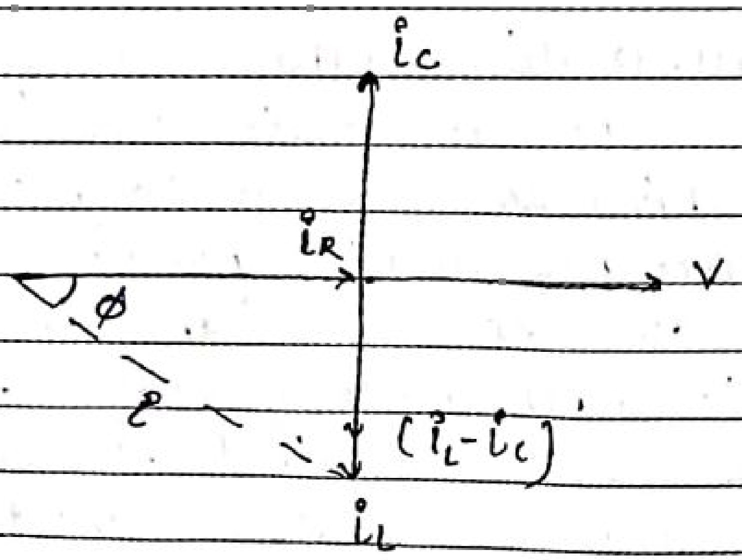
$\frac{V}{X_C}$ = i_C = current through the capacit

for resistance → current is in the same phase with voltage.

for Inductance → current laggs the voltage by $\pi/2$.

for capacitance → current leads the voltage by $\pi/2$

case 2:- $i_L > i_C$ OR $X_C > X_L$



since i_L and i_C are in direct opposition and $i_L > i_C$

therefor. their resultant $i_L - i_C$ can be given in the direction of i_L.

By pythagorus theorem

$$i = \sqrt{(i_R)^2 + (i_L - x_C)^2}$$

$$i = \sqrt{\left(\frac{V}{R}\right)^2 + \left(\frac{V}{X_L} - \frac{V}{X_C}\right)^2}$$

$$i = V\sqrt{\left(\frac{1}{R}\right)^2 + \left(\frac{1}{X_L} - \frac{1}{X_C}\right)^2}$$

$$\frac{i}{V} = \frac{1}{Z} = Y = \sqrt{\left(\frac{1}{R}\right)^2 + \left(\frac{1}{X_L} - \frac{1}{X_C}\right)^2}$$

Power factor.

$$P.F. = \cos\phi$$

$$= \frac{i_R}{i} = \frac{\frac{V}{R}}{\frac{V}{Z}}$$

$$\boxed{P.F. = \cos\phi = \frac{Z}{R}}$$

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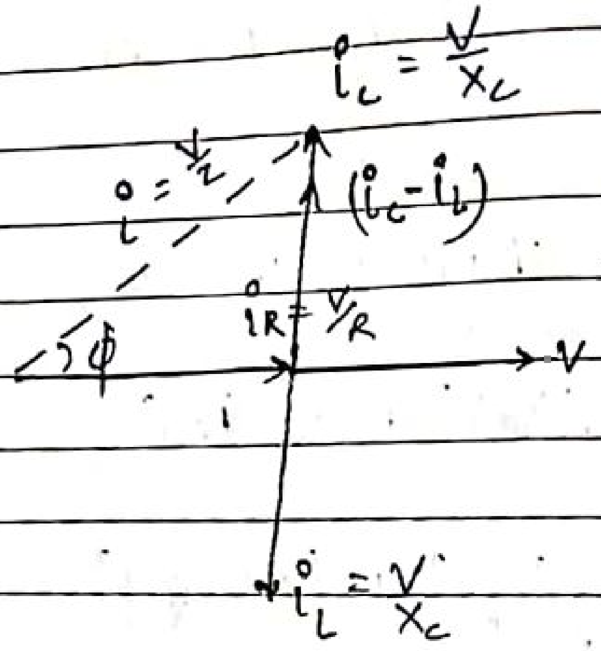
case II :— $i_c > i_L$ OR $X_L > X_C$



since i_c and i_L are in direct opposition and $i_c > i_L$ therefore their resultant $i_c - i_L$ can be given in the direction of i_c

By pythagoras theorem

$$i = \sqrt{(i_R)^2 + (i_c - i_L)^2}$$

$$i = \sqrt{\left(\frac{V}{R}\right)^2 + \left(\frac{V}{X_C} - \frac{V}{X_L}\right)^2}$$

$$i = V\sqrt{\left(\frac{1}{R}\right)^2 + \left(\frac{1}{X_c} - \frac{1}{X_L}\right)^2}$$

$$\frac{i}{V} = \frac{1}{Z} = Y = \sqrt{\left(\frac{1}{R}\right)^2 + \left(\frac{1}{X_c} - \frac{1}{X_L}\right)^2}$$

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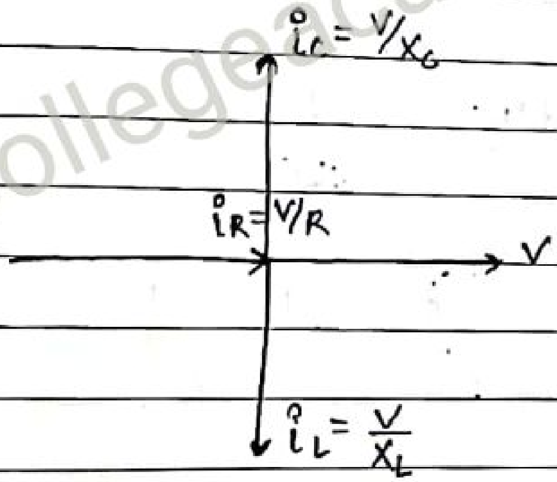
Power factor

$$P.F. = \cos\phi$$

$$= \frac{i_R}{i} = \frac{V/R}{V/Z}$$

$$\boxed{P.F. = \cos\phi = \frac{Z}{R}}$$

Case III :- $i_C = i_L$ OR $X_L = X_C$



By applying pythagorus theorem

$$i = \sqrt{(i_R)^2}$$

$$i = \sqrt{\left(\frac{V}{R}\right)^2}$$

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

$$\frac{i}{V} = \frac{1}{Z} = Y = \frac{1}{R}$$

This is called as resonance condition

$$X_L = X_C$$

$$\omega L = \cancel{\omega C}\ \frac{1}{\omega C}$$

$$2\pi f L = \frac{1}{2\pi f C}$$

$$(2\pi f)^2 LC = 1$$

$$2\pi f^2 = \frac{1}{\sqrt{LC}}$$

$$\boxed{f = \frac{1}{2\pi\sqrt{LC}}}$$

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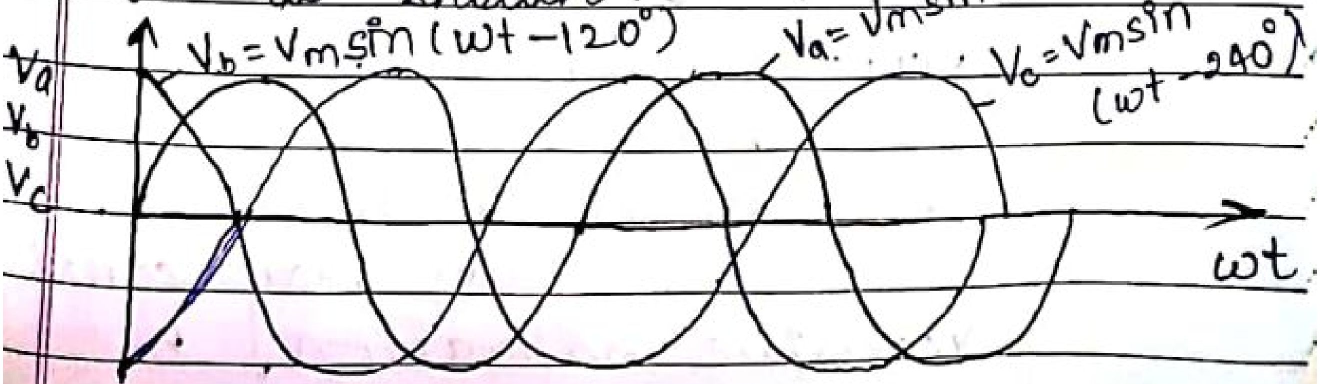
3-ϕ AC circuit :-

1) Single phase (1-ϕ) supply system is satisfactory for domestic applications like light, fans and heating, etc But for industrial applications and large size electrical drives Single phase system has many limitations

2) Hence polyphase system (2-ϕ, 3-ϕ, 6-ϕ, etc) are used in electrical engineering

3) But for generation, transmission, distribution and utilization of electrical power a 3-ϕ system has been universally adopted.

A set of 3, 1-ϕ sinosuidal (voltage or current) of the same frequency and magnitude but have a progressive phase difference of 120° or $2\pi/3$ radians electrical balanced 3-ϕ voltage or current are as shown.



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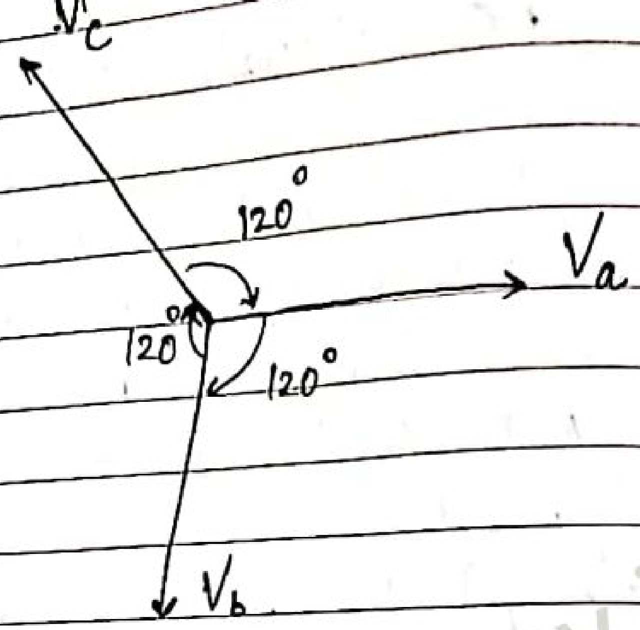

$V_a = V_m \sin \omega t$
$V_b = V_m \sin (\omega t - 120°)$
$V_c = V_m \sin (\omega t - 240°)$

3-ϕ voltage and their instantaneous values.

Advantages of 3-ϕ system over 1-ϕ system.

1). Power in a single phase (1-ϕ) system is pulsating this is tollerable in lightening and small motor loads of domestic applications. But for large industrial motors this may cause accessive vibration beyond constant power → balance load.

the tolerable limits.

2) In 3-ϕ system total power delivered is constant if the load is balance hence, 3-ϕ system is highly desirable for power loads.

3) for the same size output of 3-ϕ motor is 1.5 times the output of 1-ϕ motor

4) 1-ϕ motors are not ~~self~~ self-starting they need special arrangements for starting, whereas all types of 3-ϕ motors are self starting except ~~Except~~ synchronous motor.

5) Efficiency and power factor of 3-ϕ motors are better as compared to single phase (1-ϕ) motors.

6) 3-ϕ system is more capable and reliable as compared to single phase (1-ϕ) system.

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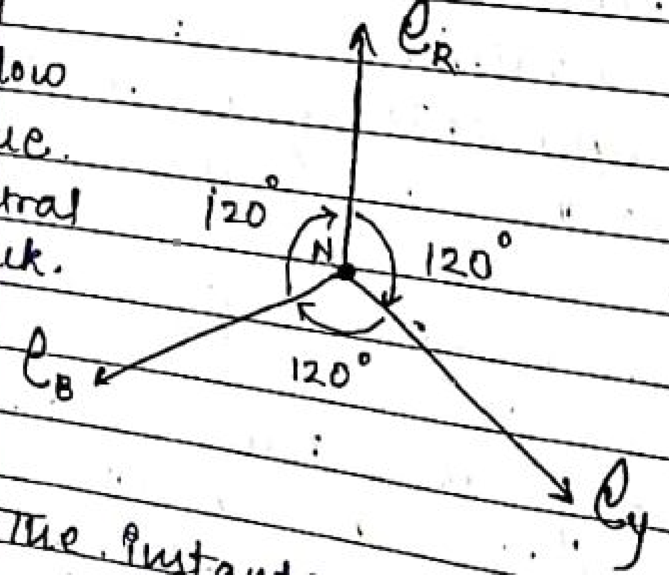
Parallel operation of 3-ϕ alternators is simple as compared to 1-ϕ alternator

Relationship b/w star & De

3-ϕ system :-

It is the combination of three single voltages of equ magnitude and frequency separated by 120° phase differe

R - red
Y - yellow
B - Blue.
N - Neutral
Black.



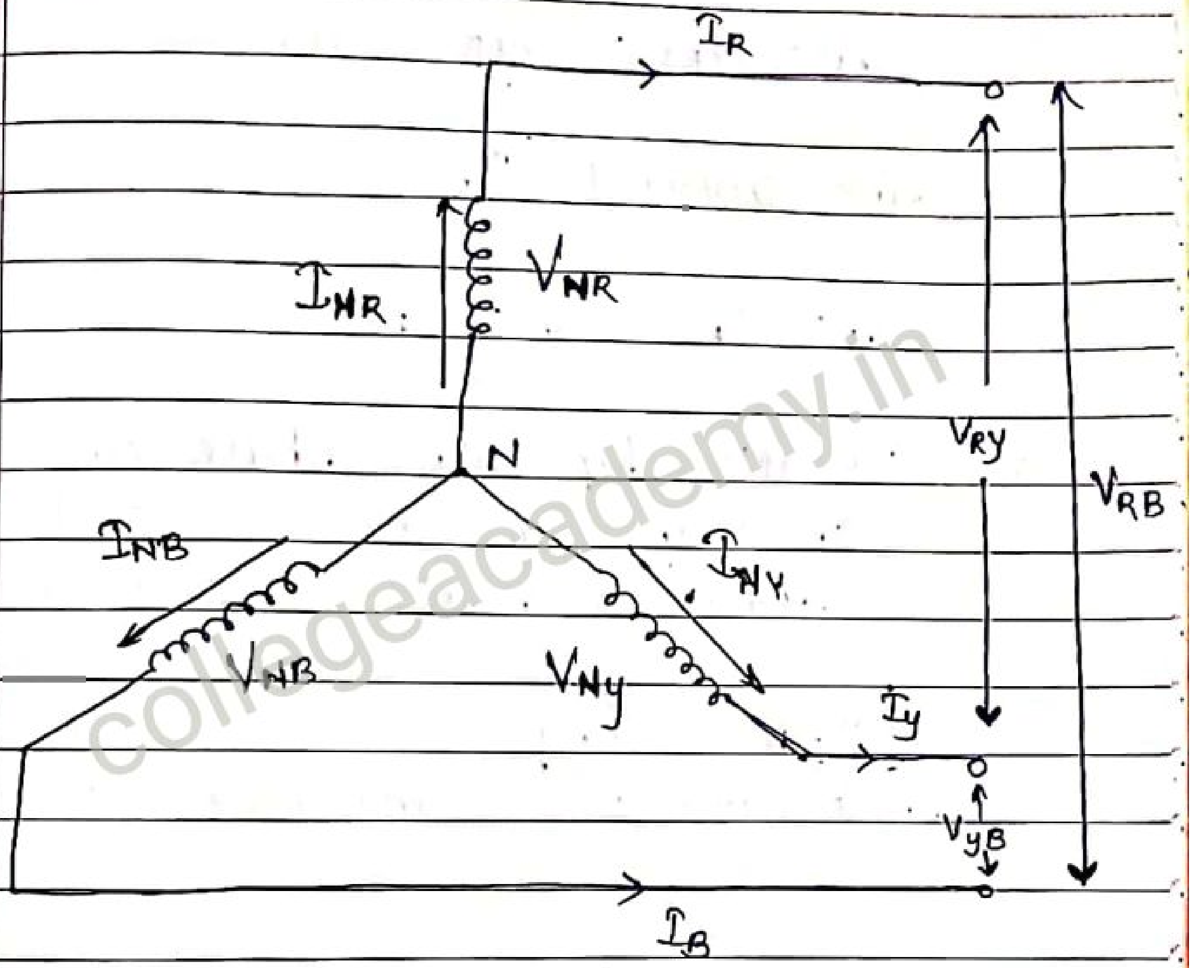
The instantaneous values of three voltages generated by three coils is given as

$e_R = E_m \sin \omega t$

$e_Y = E_m \sin (\omega t - 120°)$

$e_B = E_m \sin (\omega t$

3-ϕ star connection :-



$V_{NB}, V_{NR}, V_{Ny} \Rightarrow$ phase voltage
$V_{RY}, V_{RB}, V_{YB} \Rightarrow$ line voltage

phase voltage (V_{ph})

$$V_{ph} = V_{NR} = V_{Ny} = V_{NB}$$

phase current (I_{ph})

$$I_{ph} = I_{NR} = I_{NY} = I_{NB}$$

Line voltage (V_L)

$V_L = V_{RY} = V_{YB} = V_{BR}$

Line current (I_L)

$I_L = I_R = I_Y = I_B$

Relationship b/w phase current and line current for 3-ϕ star connection is given a

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

phase current = line current

Relationship b/w phase voltage and line voltage for 3-ϕ star connection is given as :

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

3-ϕ power for star connection

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

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

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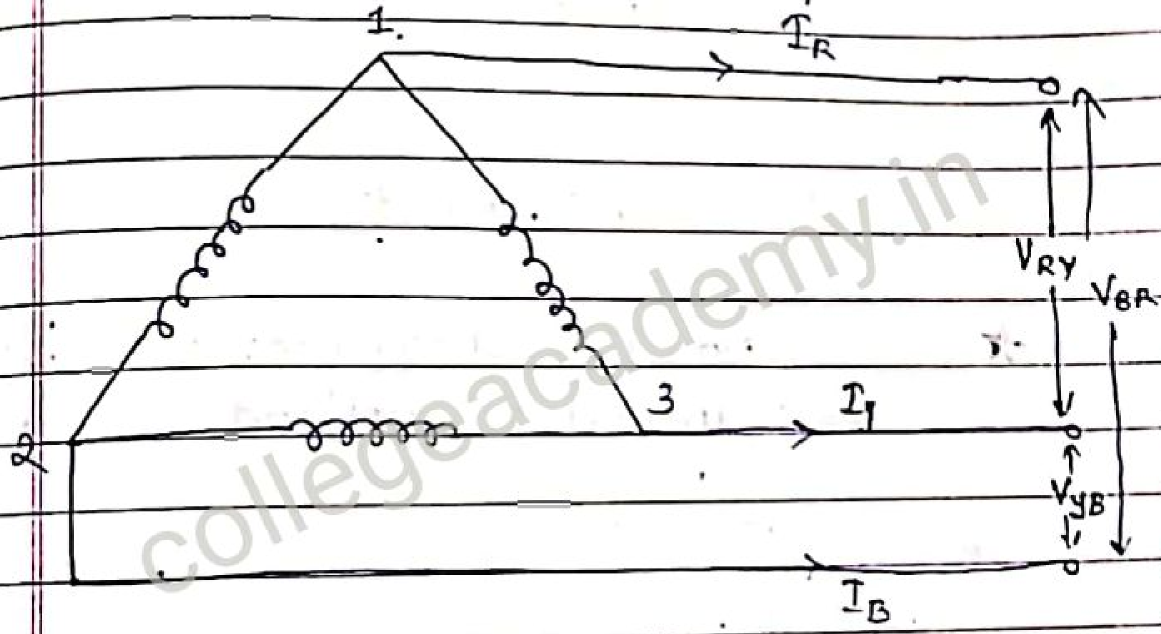
$$\boxed{P = \sqrt{3}\, V_L I_L \cos\phi}$$

3-ϕ Delta Connection



Relationship b/w line voltage and phase voltage in delta connection is

$$\therefore \boxed{V_{ph} = V_L}$$

Relationship b/w line current and phase current in delta connection is

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

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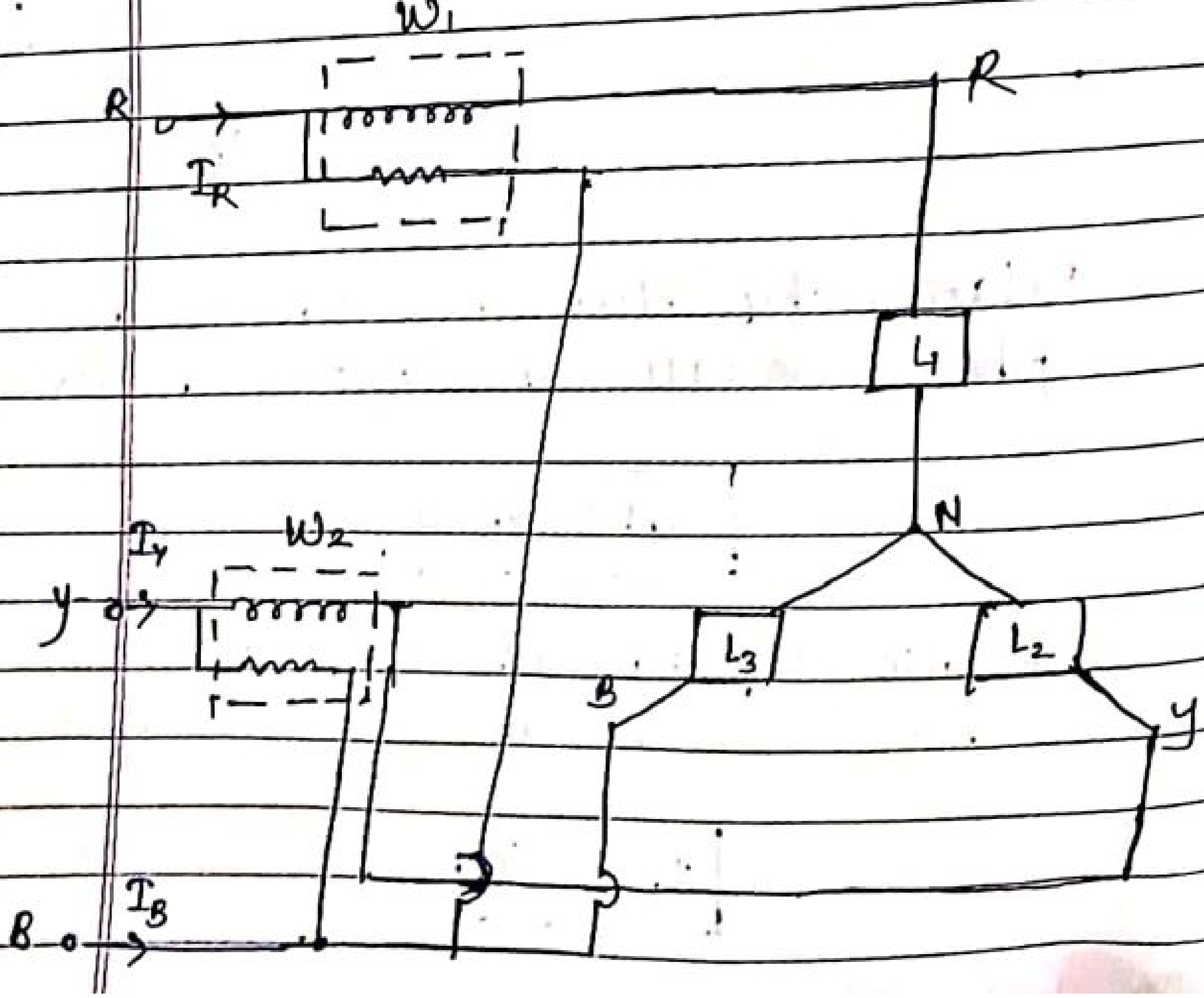
3-ϕ power in Delta connection

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

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

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

★ 3-ϕ power measurement by 2-watt metre method.



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1) The current coils of 2-watt meters are connected in any two lines while the pressure coil of each watt metre is connected between it's own current coil terminal and the other one without a current coil

2) In the given arrangement current coils of watt meters (W_1 & W_2) are inserted in the lines R and Y

3) whereas pressure coils of watt-meters W_1 and W_2 are connected between RB for 1-watt meter and YB for other watt meter.

4) consider the R.M.S. values indicated by I_R, V_{RY}, etc. whereas instantaneous values are indicated by i_r, v_{ry}, etc

5) The connections are same for star or delta connected load it can be shown that when 2-wattmeters are connected in this way the algebraic sum of 2-wattmeter readings gives the

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total power decipated in the 3-ϕ total circuit.

If W_1 and W_2 are the two wattmeter readings, then total power is

$$W = W_1 + W_2 \quad (3\text{-}\phi \text{ power})$$

6) It is important to note that watt-meter gives average value

$W = I_c V_{pc} \cos(I_c \wedge V_{pc})$.

$$W = I_c V_{pc} \cos(I_c \wedge V_{pc})$$

if I_c and V_{pc} are r.m.s values of current through the current coil and voltage across the pressure coil.

And instantaneously wattmeter reads just the product of instantaneous values of current of current coil and voltage across pressure coil.

$$W_{ins} = i_c \times V_{pc}$$

According to connections instantaneously W_1 and ...

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will show the following readings.

$$W_1 = i_r \times V_{rb}$$

$$W_2 = i_y \times V_{yb}$$

where,

V_{rb}, V_{yb}, V_b are instantaneous values of phase voltages of

Therefore substituting the values of W_1 and W_2

$$W_1 = i_r \times (V_r - V_b)$$
$$W_2 = i_y \times (V_y - V_b)$$

$\therefore$

$$W_1 + W_2 = i_r (V_r - V_b) + i_y (V_y - V_b)$$

$$W_1 + W_2 = i_r V_r - i_r V_b + i_y V_y - i_y V_b$$

$$W_1 + W_2 = i_r V_r + i_y V_y - (i_r + i_y) V_b \quad \text{(1)}$$

Now according to KCL to neutral point.

$$i_r + i_y + i_b = 0$$

$$i_r + i_y = -i_b$$

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put the value of $i_r + i_y$ in eq

$$w_1 + w_2 = i_r V_r + i_y V_y + i_b V_b .$$

As V_r, V_y, V_b are instantaneous values of phase voltages and i_r, i_y, i_b are instantaneous values of line currents which are same as phase current since load is star connected.

$$w_1 + w_2 = P_R + P_y + P_B .$$

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where, P_R, P_y, ~~R_B~~ P_B are instantaneous values of Power consumed by each phase of the load.

Hence at any instant two-wattmeter reading always gives the instantaneous total power consumed by 3-ϕ load. since the connections are same for star and delta. Therefore by 2-wattmeter method we can measure total power through the load. (Balanced or unbalanced) for the star or delta connections