3ϕ AC   Module - 4   9

(In 1ϕ s/m 2 wires are suffice for transmitting voltage to load i.e motor (P-N))

Introduction :→ Any electrical equipment such as motor, generator, transformer, a rectifier having only one winding is called a 1ϕ system

→ if No of of Armature windings are increased it becomes polyphase system

→ A two phase generator has two windings displaced by 90 & produces 2-phase voltage means 2-phase having equal voltage

→ Similarly 3-phase generator has 3 winding carries equal voltage & displaced by 120° & it is popularly used.

→ The generation, transmission & utilization of Electric power are carried out by 3-ϕ system

Advantages of 3ϕ system :-

1) 3-ϕ apparatus is more efficient than a 1ϕ phase apparatus
(i) 3ϕ machine gives a higher o/p than 1ϕ machine

2) For the same capacity, 3ϕ apparatus costs less than 1ϕ Apparatus.
(i) voltage regulation in 3ϕ system is better than that in 1ϕ supply

3) Size of 3ϕ Apparatus is smaller in size than the size of 1ϕ Apparatus of same capacity & hence requires less material for construction

4) 3ϕ motors produces uniform torque whereas the torque produced by 1ϕ motor is pulsating

5) 3ϕ motors are self starting whereas 1ϕ phase motor are not self starting.

6) Power factor of 1ϕ motors is poor than 3ϕ motors of same rating

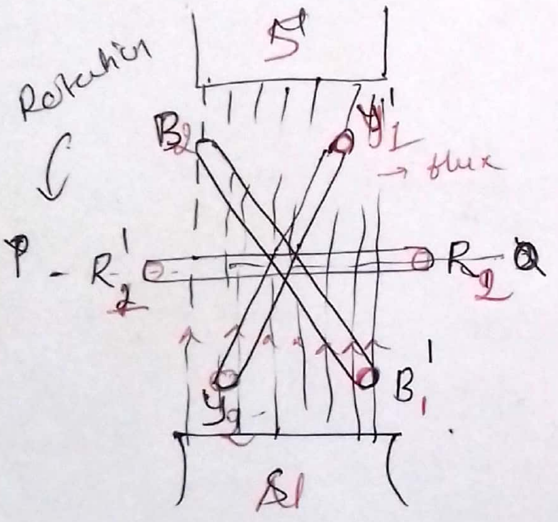
7) Instantaneous power of 3ϕ is constant whereas it is fluctuating in 1ϕ. this fluctuating power causes vibration in motor.

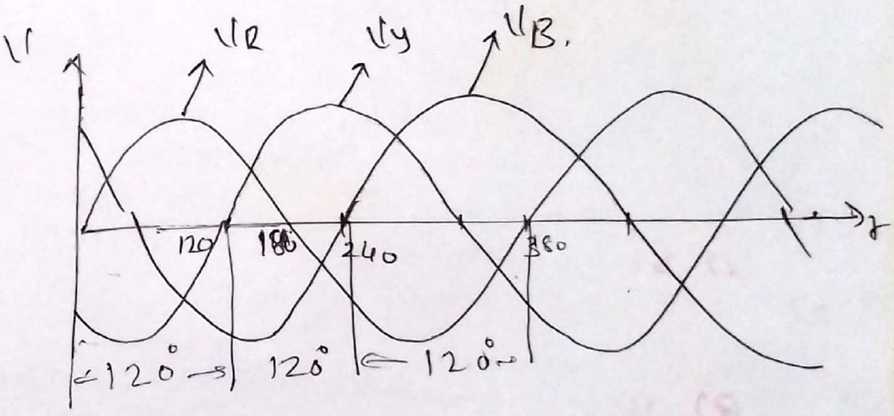
8) In case of start system 2 - different voltages can obtained. one b/w lines & other b/w line & phase whereas 1 ϕ only one voltage can be obtained.

Generation of 3ϕ AC - ~~Supply~~ Voltage :-

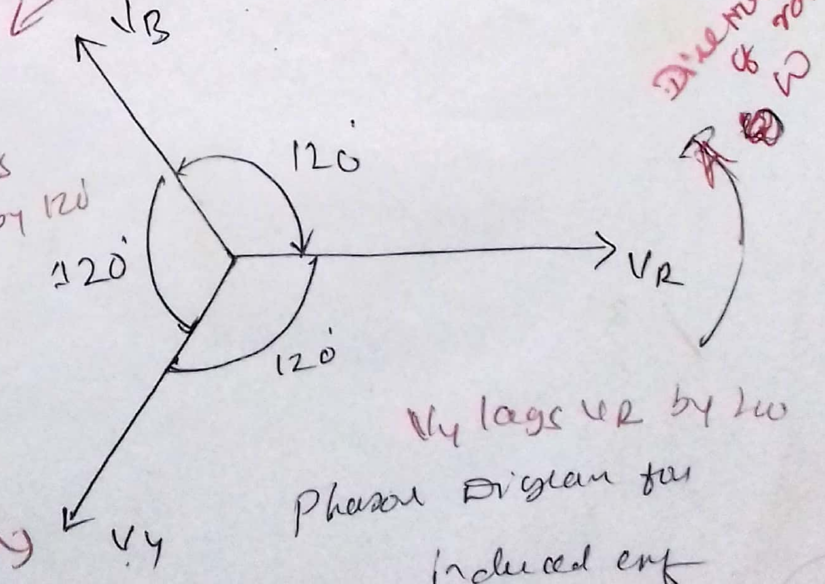
In 3ϕ system there are ~~3 windings~~ 3 - equal voltages of same frequency but phase displaced ~~from one~~ another by 120° electrical.
Those voltages are produced by 3ϕ generator which ~~has~~ has 3 - identical winding. when these windings are rotated in a magnetic field, emf induced in winding. or phase

These emf are same magnitude & frequency but phase displacement will be 120°





3-ϕ waveform



Phasor Diagram for induced emf

(a) Let VR, Vy, & VB are 3 independent voltages induced in coils R1 R2, Y1 Y2 & B1 - B2

→ When coil R_1R_2 is in the position PQ as shown below & is increasing in +ve direction this is indicated by V_R as shown in waveform.

→ Coil Y_1Y_2 is 120° electrically behind R_1R_2. The emf induced in this coil is -ve & is approaching -ve value as shown in V_y waveform.

→ Similarly coil B_1B_2 is electrically 240° behind R_1R_2 & 120° behind Y_1Y_2

→ Therefore emf induced in 3-coils are of same magnitude & frequency but 120° electrically from each other

From the phasor diagram V_R is assumed to be reference voltage & is zero for the instant as shown. At same instant V_y is displaced by 120° & will follow V_R, while V_B is ahead of V_R by 120°

$$V_R = V_m \sin\omega t$$

$$V_Y = V_m \sin(\omega t - 120°)$$

$$V_B = V_m \sin(\omega t - 240°)$$
$$= V_m \sin(\omega t + 120°)$$

∴ Sum of all 3-voltage at a instant is zero

$$V_R + V_y + V_B = 0.$$

It can be proved mathematically also

$$V_R + V_y + V_B = 0$$

$$= V_m[\sin\omega t + \sin(\omega t - 120°) + \sin(\omega t + 120°)]$$

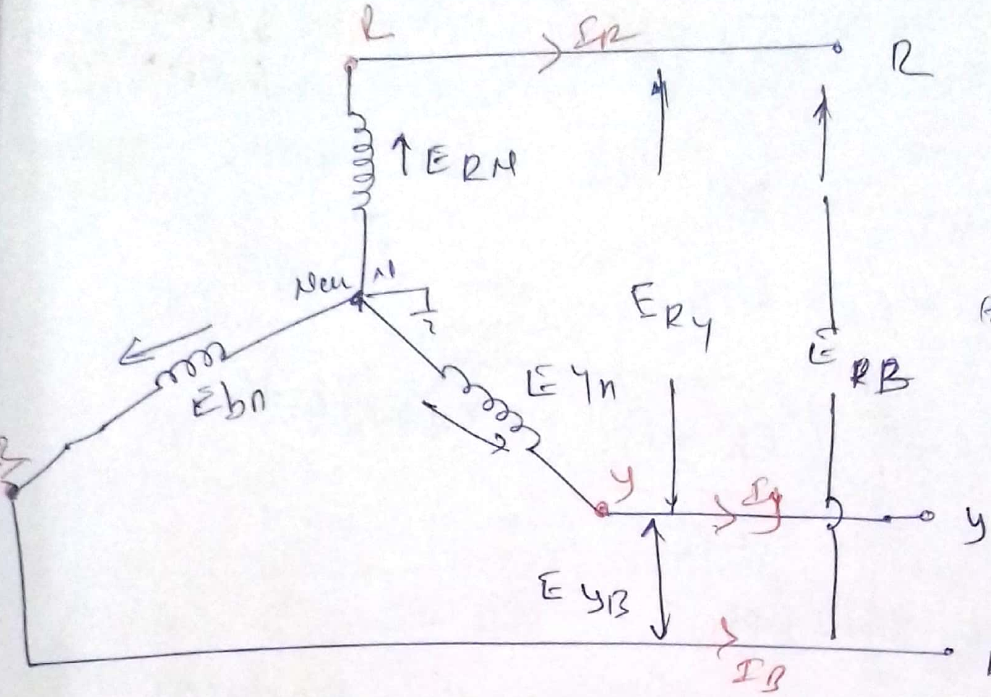
$$= V_m[\sin\omega t + \sin\omega t \cdot \cos 120 - \cancel{\cos\omega t \cdot \sin 120°} + \sin\omega t \cdot \cos 120° + \cancel{\cos\omega t \cdot \sin 120}]$$

$$= V_m[\sin\omega t + 2\sin\omega t \cdot \cos 120]$$

$$= V_m[\sin\omega t + 2\sin\omega t(-1/2)]$$

$$= 0$$

Relation B/w line & phase values for Star Connection



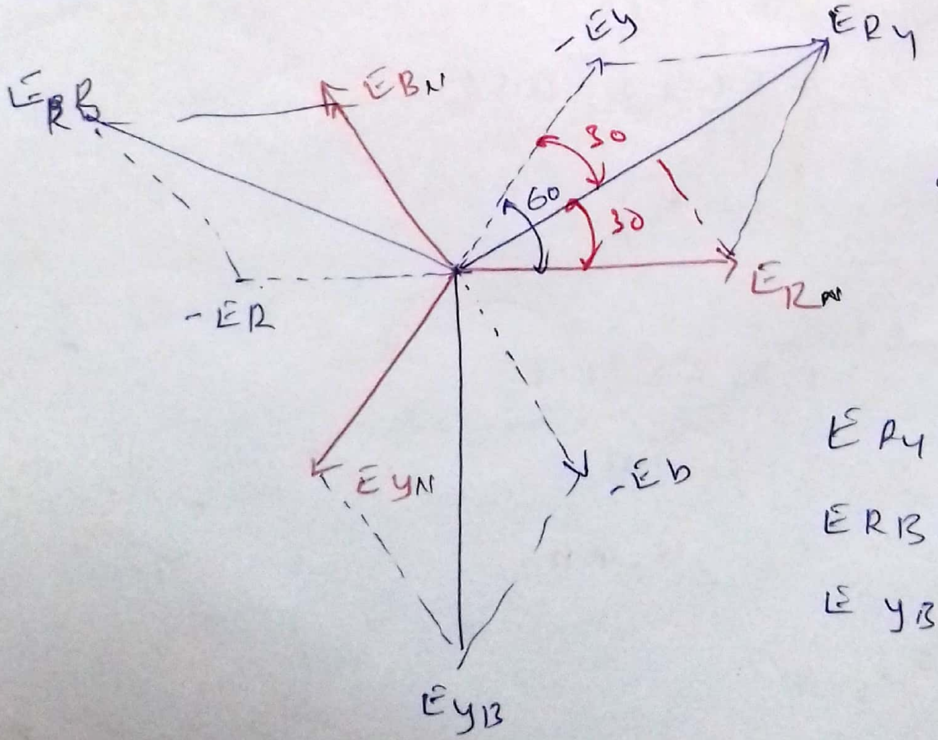
(*) * Starting and finishing ~~connection is~~ end of the 3 coils are connected to point N as known as neutral pt

(*) E_{RN} ; E_{Yn} & E_{bn} are the phase voltage & each one of them equal to E_{ph}

(*) E_{RY} ; E_{YB}, E_{RB} are line voltage & each one of them are E_L

(*) Line voltage :- potential difference b/w any 2-line's of supply is called line voltage & current passing through any line is called line current

(*) Phase voltage :- potential difference b/w line & neutral



vector sum of E_R & $-E_Y$ give E_{Ry}

angle B/w E_R & $-E_Y = 60°$

$E_{Ry} = E_R - E_Y$

$E_{RB} = E_R - E_B$

$E_{YB} = E_Y - E_b$

$E_{RY} = \bar{E}_R - \bar{E}_Y$ (vector difference)

$= E_R + (-E_y)$ vector sum

from the vector dig

$E_R = E_Y = E_{ph}$

$E_{RY} = 2\, E_{ph} \cdot \cos \frac{60}{2}$

$= 2\, E_{ph} \cos 30$

$= 2\, E_{ph} \times \sqrt{3}/2$

$\bar{E}_{RY} = \sqrt{E_R^2 + E_y^2 + 2\bar{E}_R \bar{E}_y \cos 60^\circ}$ (Law's of parallelogram

Let E_R + $\bar{E}_Y$, $\bar{E}_B$ are the phase voltage

$E_R = \bar{E}_Y = \bar{E}_B = E_{Ph}$

line voltage $\bar{E}_{RY} = \sqrt{E_{Ph}^2 + E_{Ph}^2 + 2 E_{Ph} \cdot E_{Ph} \cdot 0.5}$

$= \sqrt{3 E_{Ph}^2}$

$E_L = \sqrt{3}\, E_{Ph}$

(Q) In Star connected system each line conductor is connected to separate phase, hence line & phase current are same

cln flowing through the lines are equal to ph. current flowing through the phases

$I_L = I_{ph}$

Total power $= 3 E_{ph} \cdot I_{ph} \cos\phi$

$= 3 \dfrac{E_L}{\sqrt{3}} \times I_L \cos\phi$

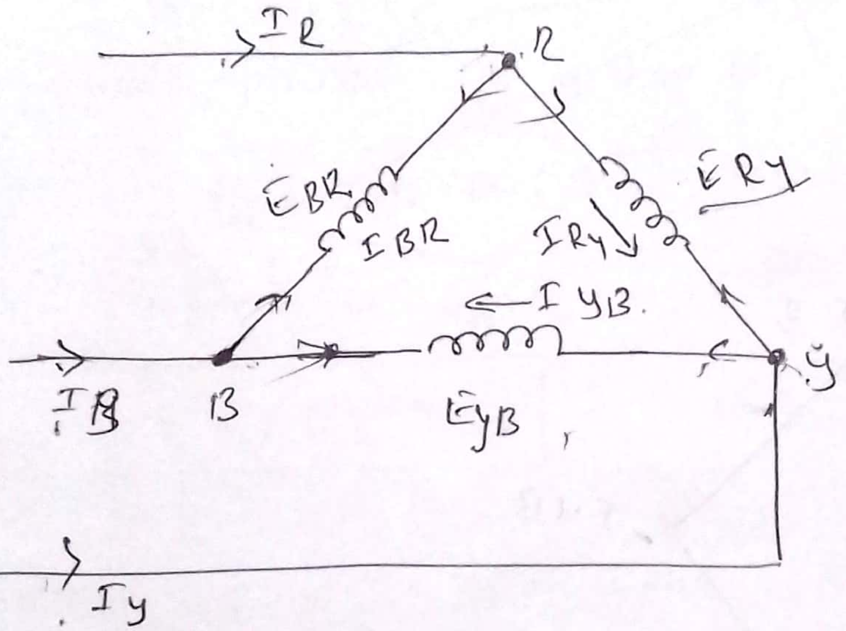
$\boxed{\text{Power} = \sqrt{3}\, E_L I_L \cos\phi}$

Apparent power $= \sqrt{3}\, E_L I_L =$ VA

$= 3\, E_{ph} \cdot I_{ph}.$

Relation B/w line & phase values for Delta connected load :-

Delta Connection is formed when one end of the winding connected to starting end of other & connections are continued to form a closed loop.



~~Line voltage ERY = EYB = EBR = VL~~

~~Phase voltage = Vph = ERY = VBR =~~

Line voltage = $E_{RY} = E_{YB} = E_{BR} = E_L$

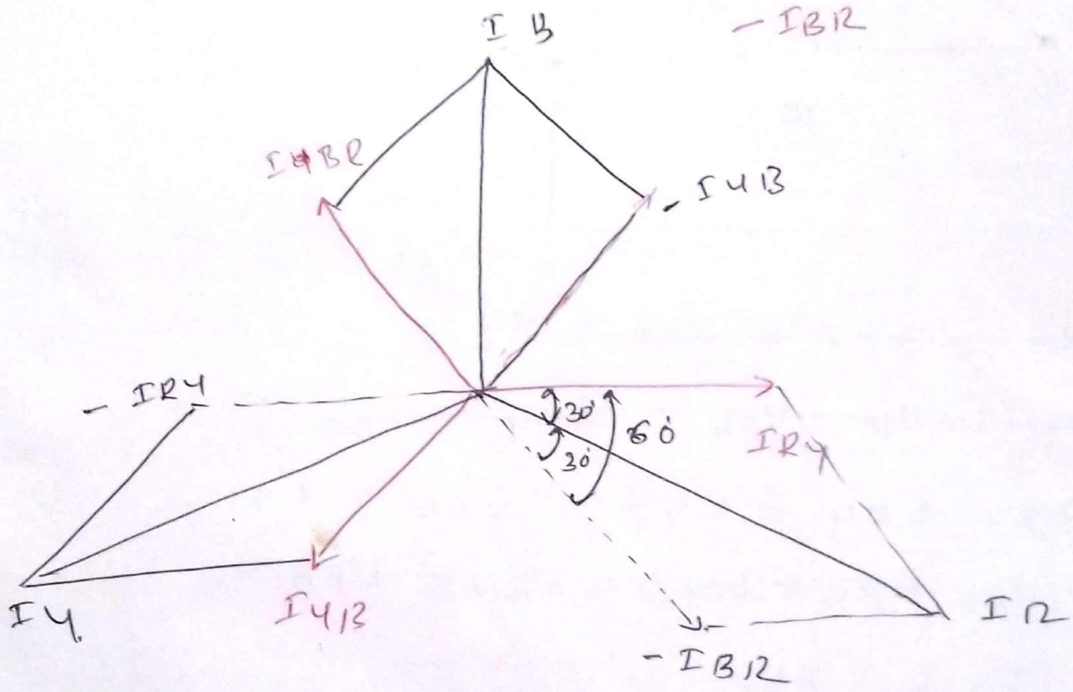
Phase voltage = $E_{RY} = E_{YB} = E_{BR} = E_{ph}$.

$\therefore \quad E_L = E_{ph}$.

Line current = $I_R = I_Y = I_B = I_L$

$I_{ph} = I_{RY} = I_{YB} = I_{BR}$

Scanned by CamScanner



$I_R = I_{RY} - I_{BR}$

$I_Y = I_{YB} - I_{RY}$

$I_B = I_{BR} - I_{YB}$

$I_R = I_{RY} - I_{BR}$ (vector Diff)

$I_R = I_{RY} - (+I_{BR})$ (vector sum)

$I_R = \sqrt{I_{RY}^2 + I_{BR}^2 + 2 I_{RY} \cdot I_{BR} \cdot \cos 60^\circ}$

Scanned by CamScanner

$$I_R = \sqrt{I_{ph}^2 + I_{ph}^2 + I_{ph}^2}$$

$$= \sqrt{3 I_p^2}$$

$$I_R = \sqrt{3}\, I_{ph}$$

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

for star connec

$E_L = \sqrt{3}\, E_{ph}$

$I_L = I_{ph}$

for Delta connection

$E_L = E_{ph}$

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

3-phase power is given by

Total

$$P = 3\, E_{ph} \cdot I_{ph} \cdot \cos\phi \rightarrow \text{Power}$$

$$= 3\, E_L \cdot \frac{I_L}{\sqrt{3}} \cdot \cos\phi$$

per phase

$$P_{phase} = E_{ph}\, I_{ph} \cos\phi.$$

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

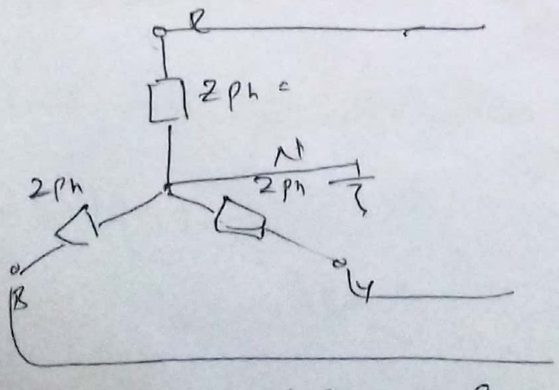
(*) appeerent power $= 3\, E_{ph} \cdot I_{ph}$

$$3 \cdot E_L \times \frac{I_L}{\sqrt{3}}$$

$$= \sqrt{3}\, E_L \cdot I_L$$

(Q) A balanced 3ϕ - star connected load of $(8+j6)$ per phase is connected to a 3-ϕ 230V supply, find line current, power factor, power, reactive power, ~~power~~ & voltamp.

5



$Z = (8+j6) = 10 \angle 36.86^\circ$

$V_{ph} = \frac{V_L}{\sqrt{3}} = 132.79V$

Phase current $(I_p) = \frac{132.79}{10} = 13.27$

$I_L = I_{ph} = 13.27$ A

$\phi = \cos^{-1}(0.8) = 36.86$

$\therefore$ power factor $= R/Z = \frac{8}{10} = 0.8$

8

$P = \sqrt{3}\, I_L V_L \cos\phi = \sqrt{3} \times 132.27 \times 13.27 \times 0.8 = 4231.98$ W.

$Q = \sqrt{3}\, V_L I_L \sin\phi = \sqrt{3} \times 132.27 \times 13.27 \times 0.6 = 3173.98$ VAR

$S = \sqrt{3}\, V_L I_L = \sqrt{3} \times 132.27 \times 13.27 = 5289.97$ A

(2) Calculate the active & reactive power of each phase of star connected 10KV 3ϕ alternator supply of 5MW at 0.8 p.f. If the total current remains same, when load p.f raised to 0.9 calculate new o/p & its active & reactive component per phase

$\Rightarrow$ $P = 5M$ = $\cos\phi = 0.8$ $V_L = 10KV$ star

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

$5\times10^6 = \sqrt{3} \times 10 \times 10^{-3} \times I_L \times 0.8$ $I_L = 360.84\,A = I_{ph}$

$V_{ph} = \frac{V_L}{\sqrt{3}} = 5773.50\,V.$

(i) Active component of each phase $= V_{ph} \cdot I_{ph} \cdot \cos\phi$

$= 1.666\,MW$

(ii) reactive " " " $= V_{ph} \cdot I_{ph} \sin\phi = 1.25\,MVAR$

Now current remains but $\cos\phi_2 = 0.9$

$P_r = \sqrt{3}\, V_L I_L \cos\phi = \sqrt{3} \times 10 \times 10^3 \times 360.84 \times 0.9$

$= 5.625\,MW$

Now Active component of each phase $= V_{ph} \cdot I_{ph} \cdot \cos\phi$

$= 1.875\,MW$

reactive " " $= V_{ph} \cdot I_{ph} \cdot \sin\phi_2$

$= 0.9081\,MVAR$

R

A Balanced Starconnected load is supplied from a balanced 3Φ, 400V, 50Hz system. The current in each phase 30A & lags 30° behind the phase voltage Find 1) total power 2) phase voltage & Draw the phasor diagram

⟹

$V_L = 400\,V$

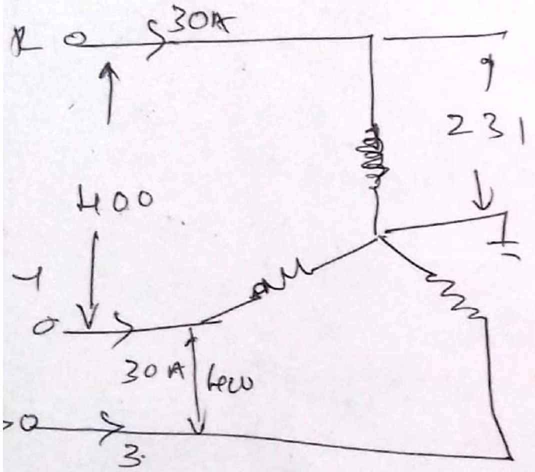
③

$V_{ph} = \frac{V_L}{\sqrt{3}} = \frac{400}{\sqrt{3}} = 231\,V$

$E_{RY} = E_R + (-E_Y)$

$I_{ph} = 30\,A = I_L$

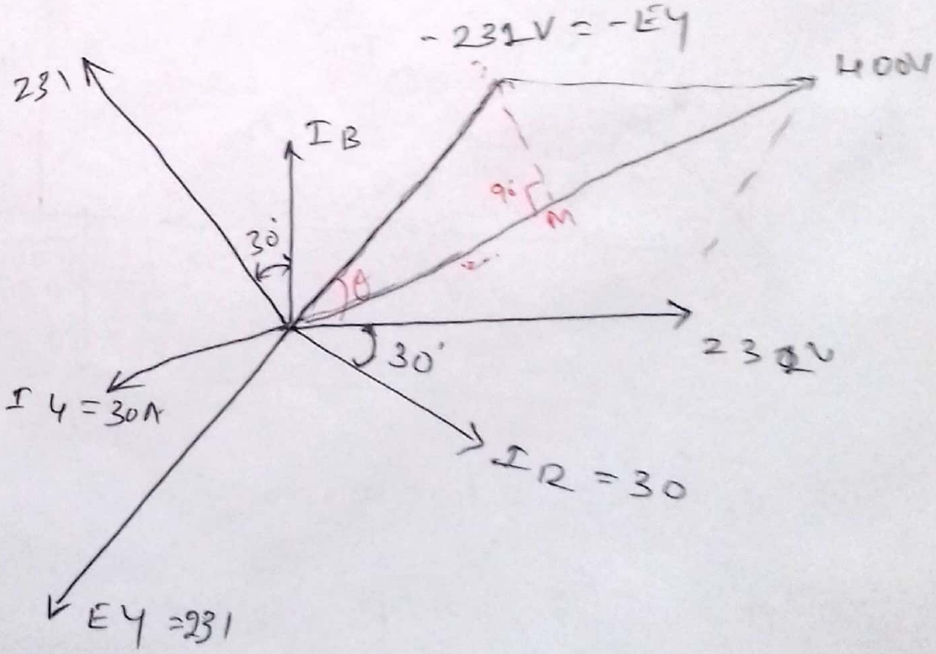
Power factor $= \cos\phi = \cos 30° = 0.866$



Total power $= 3 E_{ph} \cdot I_{ph} \cos\phi$

$= 3 \times 231 \cdot 30 \times 0.866$

$= 18\,kW$



$\cos 30 = \frac{OM}{231}$

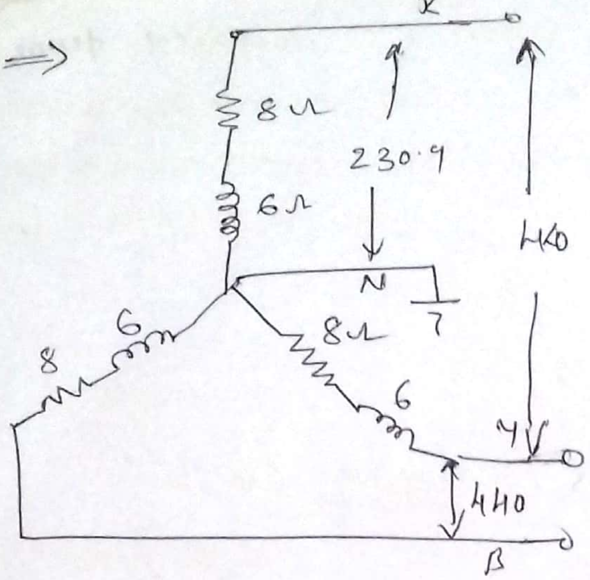
$OM = \cos(30) \cdot 231$

$= 400$

②

④ 3-equal impedence, each having a Resistance of 8Ω & inductive reactance of 6Ω are connected in 1) Star 2) Delta, a/c 3Φ 400V system Find Phase current 2) line current 3) total power consumed

3) ⇒



$V_L = 400V$

$V_{ph} = \frac{V_L}{\sqrt{3}} = \frac{400}{\sqrt{3}} = 230.9V$

$Z_{ph} = \sqrt{R^2 + X_L^2}$

$= \sqrt{8^2 + 6^2}$

$= 10$

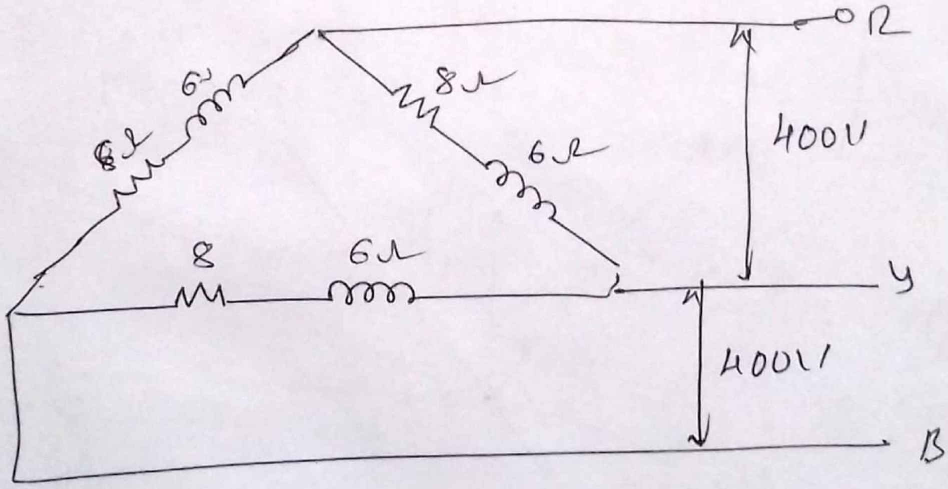
$I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{230.9}{10} = 23.09A$

$I_{ph} = I_L = 23.09A$

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

$\cos\phi = \frac{R}{Z_{ph}} = \frac{8}{10} = 0.8$

$P = \sqrt{3} \times 400 \times 23.09 \times 0.8 = 12.79\,kW$



$V_L = V_{ph} = 400V$

9

$I_{ph} = \frac{400}{10} = 40A$

$I_L = \sqrt{3} \times 40 = 69.28A$

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

$= \sqrt{3} \times 69.28 \times 400 \times 0.8 = 38.39\,kW$

) 3ϕ Delta connected load consumes a power of 60kW taking a lagging current of 200A at a line voltage of 400V 50Hz. Find the parameters of each phase. what would be the power consumed if the load where connected in star.

⇒ $P = 60kW \quad I_L = 200A \quad V_L = 400V$

$P = \sqrt{3} V_L I_L \cos\phi = 60\times10^3 = \sqrt{3}\times 400\times 200 \cos\phi$

$\cos\phi = 0.433$ i.e. $\phi = \cos^{-1}(0.433) = 64.34$

(I_{ph} lags V_{ph})

for delta $V_L = V_{ph} = 400V \quad I_{ph} = \frac{I_L}{\sqrt{3}} = 115.47$.

$Z_{ph} = \frac{V_{ph}}{I_{ph}} = \frac{400}{115.57} = 3.4641\Omega$

$Z_{ph} = 3.4641\angle 64.34\ \Omega = 1.5 + j3.1225$

$R_{ph} = 1.5\Omega \quad X_{Lph} = 3.1225$

$X_{Lph} = 2\pi f L_{ph} = \quad L_{ph} = \frac{3.1225}{2\pi\times 50} = 9.939mH.$

star connected

$V_{ph} = \frac{V_L}{\sqrt{3}} = \frac{400}{\sqrt{3}} = 230.94V$

$I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{230.94}{3.464} = 66.67 = I_L$

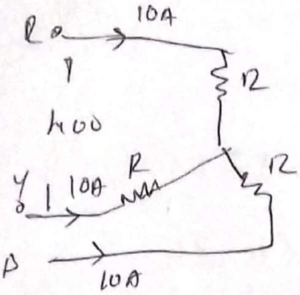
$\cos\phi = 0.433$

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

$= \sqrt{3}\times 400\times 66.67\cdot 0.433 = 20kW$

6

(3) 3 - Similar resistors are connected in star all a 400 3-ϕ supply. The line current is 10A. calculate (1) value of each resistor (2) line voltage required to get the same line current if the resistors are connected in delta



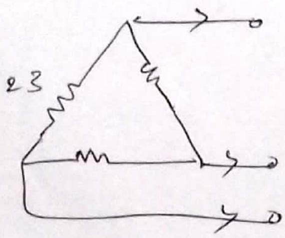
$I_L = I_{ph} = 10A$

$V_L = 400$

$V_{ph} = \frac{400}{\sqrt{3}} = 230.91$

$R = \frac{230.91}{10} = 23.09\Omega$

Delta :->



$I_L = 10 A$

$I_{ph} = \frac{10}{\sqrt{3}} = 5.77$

$R = 23.09$

$V_{ph} = I_{ph} \cdot R$

$= 5.77 \times 23.09$

$= 133.3 V.$

$\boxed{V_L = V_{ph} = 133.3V}$

(*) While solving 3 ϕ problem

(1) given supply voltages are line voltage

(2) Determine phase voltage depending on whether load is Y or Delta

(3) Determine phase ch

$I_{ph} = \frac{V_{ph}}{Z_{ph}}$

4) Determine line current depending whether load is Δ or Star

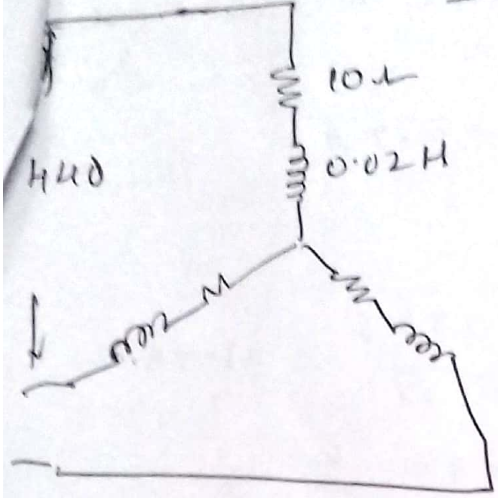
5) ϕ is angle b/w V_{ph} & I_{ph} value can be obtained from given Z_{ph}

6) Total power consumed $= \sqrt{3} V_L I_L \cos\phi$

$3 V_{ph} \cdot I_{ph} \cdot \cos\phi$.

13

3 - coils ~~are~~ each having resistance of 10Ω & inductance of 0.02H are connected in star ac 440V, 50Hz, 3φ supply. Calculate the line current & total power consumed



$\Rightarrow$ $X_L = 2\pi f L = 2\pi \times 50 \times 0.02$

$= 6.28\,\Omega$

$R = 10\,\Omega$

$Z = \sqrt{R^2 + X_L^2} = \sqrt{10^2 + 6.28^2}$

$= 11.81\,\Omega$

$V_L = 440$

$V_{ph} = \frac{440}{\sqrt{3}} = 254.03V$

$I_{ph} = \frac{V_{ph}}{Z} = \frac{254.03}{11.81} = 25.51A = I_L$

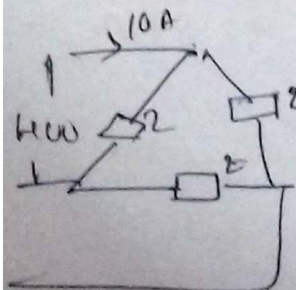
(7)

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

$= \sqrt{3} \times 440 \times 21.51 \times R/Z$

$\boxed{P = 13.88\,KW}$

(*) a 3φ load of 3 equal impedances connected in Δ - ac a balanced 400V supply takes 10A at a power factor of 0.7 lagging calculate ① phase current 2) Total power ③ The total reactive KVA if winding are connected in star, what will be the new values of phase ch & total power



$I_{ph} = \frac{I_L}{\sqrt{3}} = \frac{10}{\sqrt{3}} = 5.774A$

$Z = \frac{V_{ph}}{I_{ph}} = \frac{400}{5.774} = 69.27\,\Omega$

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

$= \sqrt{3} \times 400 \times 10 \times 0.7$

$= 4.849\,KW$

$\phi = \cos^{-1}(0.7) = 45.57$

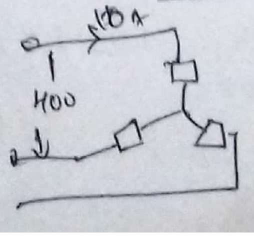
reactive $KVA = \sqrt{3}\, V_L I_L \sin\phi$

$= \sqrt{3} \times 400 \times 10 \times \sin(45.57)$

$= 4.947\,VAR$

(14)

when star



$Z = 69.27\,\Omega$

$I_{ph} = \frac{V_{ph}}{Z} = \frac{400/\sqrt{3}}{69.27}$

$I_{ph} = 3.334 = I_L$

$P = \sqrt{3} \times 400 \times 3.334 \times 0.7 = 1.619\,KW$

Scanned by CamScanner

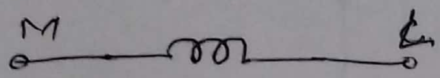
wattmeter

It is device used to measure the power when connected in 1Φ or 3Φ system, in watts

① ~~current~~ wattmeter has 2-coils

① current coil ② Potential coil or voltage coil.

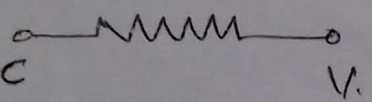
① current coil



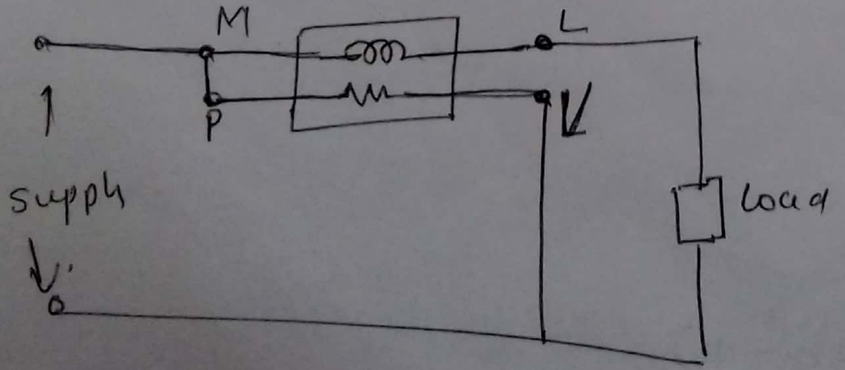
This senses the current & always connected in series with the load.

& It is similar to Ammeter. The resistance of this coil is as small as possible & hence its cross-section Area is large & it has less Number of turns

② Voltage coil

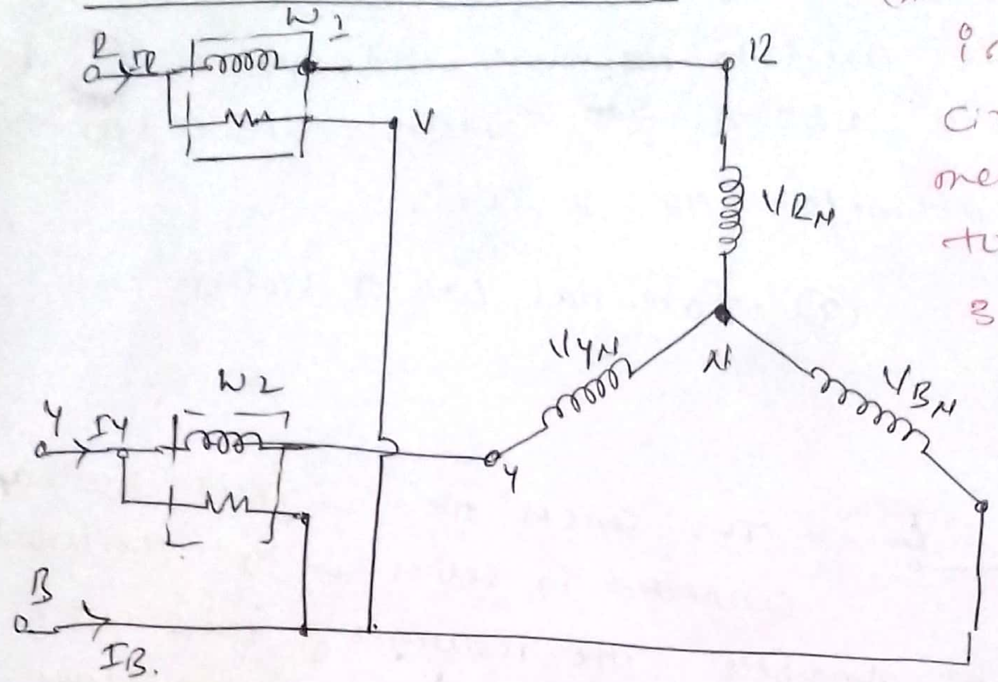


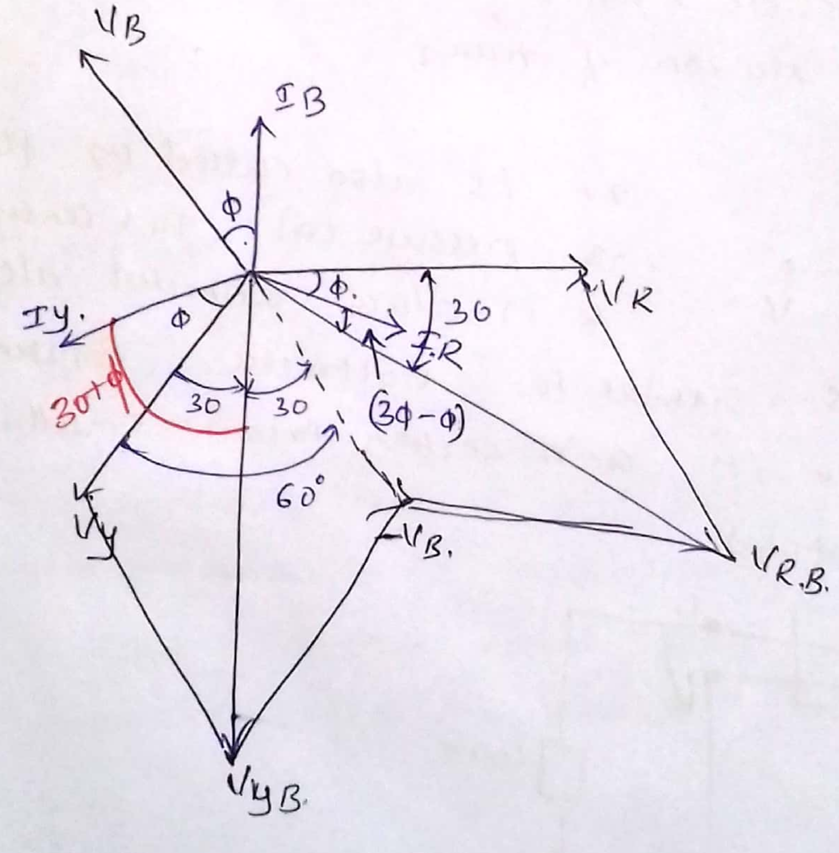
It is also called as potential coils or pressure coil. This senses the voltage & is always connected a/c the supply terminals. similar to voltmeter. Resistance of this coil is large & its cross section Area is small. hence large no's of turns.



2- wattmeter method :-

(x) Show that in a balanced 3ϕ circuit two wattmeters are sufficient to measure the total 3ϕ power & power factor of the ckt





$$W_1 = I_R \cdot V_{RB} \cdot \cos(30 - \phi)$$

$$W_2 = I_Y \cdot V_{YB} \cdot \cos(30 + \phi)$$

$$I_R = I_Y = I_B = I_L$$

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

$$W_1 + W_2 = I_R \cdot V_{RB} \cos(30 - \phi) + I_Y V_{YB} \cos(30 + \phi)$$

$$= I_L V_L [\cos(30 - \phi) + \cos(30 + \phi)]$$ 10

$$= I_L V_L [\cos 30 \cdot \cos\phi + \cancel{\sin 30 \cdot \sin\phi} + \cos 30 \cdot \cos\phi - \cancel{\sin 30 \cdot \sin\phi}]$$

$$= I_L V_L [2 \cos 30 \cdot \cos\phi]$$

$$= I_L V_L \left[\cancel{2} \times \frac{\sqrt{3}}{\cancel{2}} \times \cos\phi\right]$$

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

$$\boxed{W_1 + W_2 = \sqrt{3} V_L I_L \cos\phi} \longrightarrow (1)$$

Expression for P.f :-

$$W_1 - W_2 = V_L I_L [\cos(30 - \phi) - \cos(30 + \phi)]$$

$$= V_L I_L [\cancel{\cos 30 \cdot \cos\phi} + \sin 30 \cdot \sin\phi - \cancel{\cos 30 \cdot \cos\phi} + \sin 30 \cdot \sin\phi]$$

$$= V_L I_L [2 \sin 30 \cdot \sin\phi]$$

$$= V_L I_L \left[\cancel{2} \times \frac{1}{\cancel{2}} \sin\phi\right.$$

$$W_1 - W_2 = V_L I_L \sin\phi \longrightarrow (2)$$

divide (2) ÷ (1) we get

$$\frac{W_1 - W_2}{W_1 + W_2} = \frac{\cancel{V_L} \cancel{I_L} \sin\phi}{\sqrt{3} \cancel{V_L} \cancel{I_L} \cos\phi} = \frac{1}{\sqrt{3}} \tan\phi.$$

$$\tan\phi = \frac{\sqrt{3}(W_1 - W_2)}{W_1 + W_2} \quad \text{OR} \quad \phi = \tan^{-1}\left[\frac{\sqrt{3}(W_1 - W_2)}{W_1 + W_2}\right]$$

$$P.f = \cos\phi$$

$$P.f = \cos\left[\tan^{-1}\left\{\frac{\sqrt{3}(W_1 - W_2)}{W_1 + W_2}\right\}\right]$$

Scanned by CamScanner

(1) The power flowing in a 3ϕ, 3 wire balanced (X) load system is measured by 2-wattmeter method. The reading in wattmeter A is 750 watts & wattmeter B is 1500 watts. What is power factor of the system & load current per phase

$W_1 = 750W$ $W_2 = 1500$

$$\cos\phi = \cos\left\{\tan^{-1}\left[\frac{\sqrt{3}(W_1 - W_2)}{(W_1 + W)}\right]\right\}$$

$$= \cos\left\{\tan^{-1}\left[\frac{\sqrt{3}(750 - 1500)}{750 + 1500}\right]\right\} \Rightarrow \cos\{\tan^{-1}(-0.$$

$= \cos(-29.11)$

$= 0.873$ (leading)

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

$W_1 + W_2 = \sqrt{3} V_L I_L \cos\phi$

$(750 + 1500) = \sqrt{3} V_L I_L \cdot 0.873$

$\boxed{V_L I_L = 1500 VA}$ → if V_L is known, I_L can be obtained, hence load current per phase can be obtained

(X) A balanced 3ϕ, star connected load draws power from 440 supply. The 2-wattmeters connected indicate $W_1 = 5kW$ & $W_2 = 1.2kW$ calculate power, Pf, current in ckt

⟹ $V_L = 440V$ $W_1 = 5kW$, $W_2 = 1.2kW$

$P = W_1 + W_2 = 5 + 1.2 = 6.2kW$,

$$\cos\phi = \cos\left\{\tan^{-1}\left(\frac{\sqrt{3}(W_1 - W_2)}{W_1 + W_2}\right)\right\} = \cos\left\{\tan^{-1}\left[\frac{\sqrt{3}(5 - 1.2)}{6.2}\right]\right\}$$

$= \cos\{\tan^{-1}(1.0615\}$

$= 0.6857$ (lagging)

$P = \sqrt{3} V_L I_L \cos\phi = 6.2kW = \sqrt{3} \times 440 \times I_L \times 0.6856$ $(I_L = 11.86A)$

19

Scanned by CamScanner

(*) 3- similar impedances are connected in Δ. a/c a 3ϕ supply. The 2 wattmeters are connected to measure the i/p power indicate 12kW & 7kW calculate
① Power i/p & 2) power factor of the load

⟹ $W_1 = 12kW$ & $W_2 = 7kW$

$P_{in} = W_1 + W_2 = 12 + 7 = 19kW$

$\cos\phi = \cos\left\{\tan^{-1}\left(\frac{\sqrt{3}(W_1 - W_2)}{W_1 + W_2}\right)\right\} = 0.9099$

(*) power is measured in 3ϕ Balanced load using 2-wattmeters. The line voltge is 400V. & The load & its P.f is so adjusted that the line current is alway 10A. Find the reading of the wattmeter when p.f is i) unity 2) 0.866 iii) 0.5 & 4) 0

⟹ $V_L = 400V$, $I_L = 10A$ $V_L I_L = 4000$

The wattmeter redly are

$W_1 = V_L I_L \cos(30 - \phi)$ & $W_2 = V_L I_L \cos(30 + \phi)$

① $\cos\phi = 1$ ⟹ $\phi = 0^\circ$

$W_1 = 4000 \times \cos(30) = 3461.1 W$

$W_2 = 4000 \times \cos(30) = 3461.1 W$

② $\cos\phi = 0.866$ $\phi = 30^\circ$

$W_1 = 4000 \cos(30 - 30)$, $W_2 = 4000 \cos(30 + 30)$

$= 4000$ $= 2000W.$

③ $\cos\phi = 0.5$, $\phi = 60$

$W_1 = 4000 \cos(30 - 60) = 3464.1$

$W_2 = 4000 \cos(30 + 60) = 0$

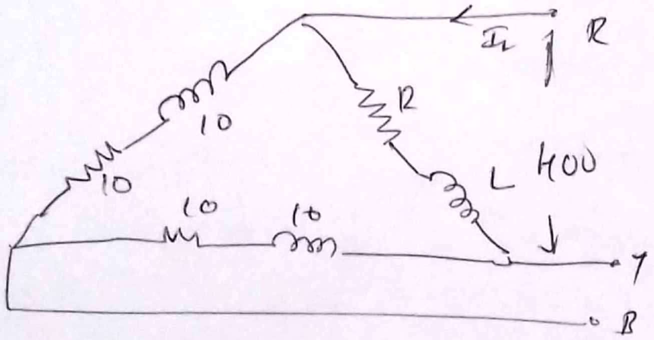
4) $\cos\phi = 0$ $\phi = 90^\circ$

$W_1 = 4000 \cos(30 - 90) = 2000W$

$W_2 = 4000 \cos(30 + 90) = -2000W.$

(*) Three identical coils each having $R = 10\Omega$ & inductive reactance of 10Ω are connected in delta a/c 400V, 3φ supply. Find the current & reading on the two wattmeters connected to measure power

$\Longrightarrow$



$V_L = V_{ph} = 400V$

$Z_{ph} = \sqrt{10^2+10^2} = 14.14\Omega$

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

$I_{ph} = \dfrac{V_{ph}}{Z_{ph}} = \dfrac{400}{14.14} = 28.29A \Rightarrow I_L = \sqrt{3} \times 28.29$

$= 49A$

$\cos\phi = \dfrac{R}{Z} = 10/14.14 = 0.707$

$P = \sqrt{3}\, V_L I_L \cos\phi \Rightarrow \sqrt{3} \times 400 \times 49 \times 0.707 = 24001W$

$W_1 + W_2 = 24001\,W \rightarrow (1)$

$P_f = \cos\left\{\tan^{-1}\left(\sqrt{3}\dfrac{(W_1 - W_2)}{24001}\right)\right\} \Rightarrow$

$\cos^{-1}(0.707) = 45°$

$0.707 = \cos\left\{\tan^{-1}\left(\sqrt{3}\dfrac{(W_1 - W_2)}{24001}\right)\right\}$

$\tan^{-1}\sqrt{3}\dfrac{(W_1 - W_2)}{W_1 + W_2}$

$W_1 - W_2 = 13856.98W \rightarrow (2)$

$W_1 = 18928.99W$ $\quad W_2 = 5072.01$ watt

(81)

(*) each of the 2-wattmeters connected to measure the i/p to a 3ϕ ckt reads 20kW. What does each instrument reads when p.f is 0.866 lagging with the total 3ϕ power remaining unchanged in the altered condition?

$\Rightarrow$ $W_1 + W_2 = 20+20 = 40 \, kW \rightarrow (1)$

$0.866 = \cos\left(\tan^{-1}\left(\frac{\sqrt{3}(W_1 - W_2)}{40k}\right)\right)$

$W_1 - W_2 = 13.355 \, kW \rightarrow (2)$

$W_1 = 26.6676 \, kW$ $\quad W_2 = 13.33 \, k\Omega$

(*) A 415V 3ϕ motor has o/p of 80H.P & operates at a power factor of 0.866 with an η% 90%. calculate

(1) The current in each phase of motor if the motor is connected in Δ

(2) The reading of the two wattmeters connected in the line the measure the i/p power

$\Rightarrow$ motor o/p power $= 80 \times 735.35 = 58828$ watt

$\eta = \frac{o/p}{i/p}$ $\quad$ motor i/p $= \frac{58.82 \, kW}{0.9} = 65.364 \, kW$

$W_1 + W_2 = 65.364 \, kW \rightarrow (1)$

$\cos\phi = 0.866 = 30°$ $\quad \boxed{\phi = 30°}$

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

$65.364 \times 10^3 = \sqrt{3} \times 415 \times I_L \times 0.866$ $\quad I_L = 105A$ $\quad I_{ph} = \frac{I_L}{\sqrt{3}} = 60.62 A$

$\tan\phi = \frac{\sqrt{3}(W_1 - W_2)}{W_1 + W_2}$ $\quad (W_1 - W_2) = 21788 \, W \rightarrow (2)$

$\tan(30) = \frac{\sqrt{3}(W_1 - W_2)}{65364}$

$0.577 \times 65364 = \sqrt{3}(W_1 - W_2)$

$W_1 = 43.57 \, kW$
$W_2 = 21.788$

23