Poly - Phase Ckt

$\phi \rightarrow$ phase

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(13 - 15) marks

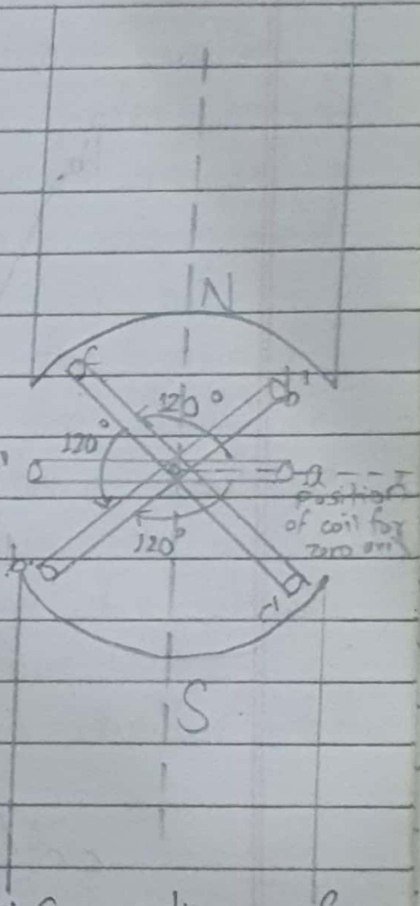
Generation of a three-phase ($3-\phi$) supply :

When the three identical coils are placed with their axis at 120° apart from each other & rotated in uniform magnetic field, a sinusoidal voltage is generated across each coil. This is a basic of $3-\phi$ alternator shown in fig (a) aside.

~~Here, besid these are two~~,

Here, ~~these~~ the fig. aside shows ~~are~~ $3-\phi$, two pole alternator. It has 3 sets of coil aa', bb' & cc' symmetrically mounted on rotor such that there axis are at 120° from each other.

When rotor are rotated in anti-clock wise dir^n at a const. angular velocity omega radian per sec, sinusoidal voltage generate across each coil.



fig(a). Generation of $3-\phi$ supply

All three coil rotate at the same velocity ($\omega = 2\pi f$) i & generated voltage have the same freq. since the coil are identical. The generated voltage have same magnitude but ~~their~~ phase difference of 120° bet^n these voltage.

$$V_{aa'} = V_m \sin\omega t$$

$$V_{bb'} = V_m \sin(\omega t - 120°)$$

$$V_{cc'} = V_m \sin(\omega t - 240°)$$

$$= V_m \sin(\omega t + 120°)$$

In polar form,

$$V_{aa'} = V\angle 0^\circ$$
$$V_{bb'} = V\angle -120^\circ$$
$$V_{cc'} = V\angle -240^\circ \text{ or } V\angle +120^\circ$$

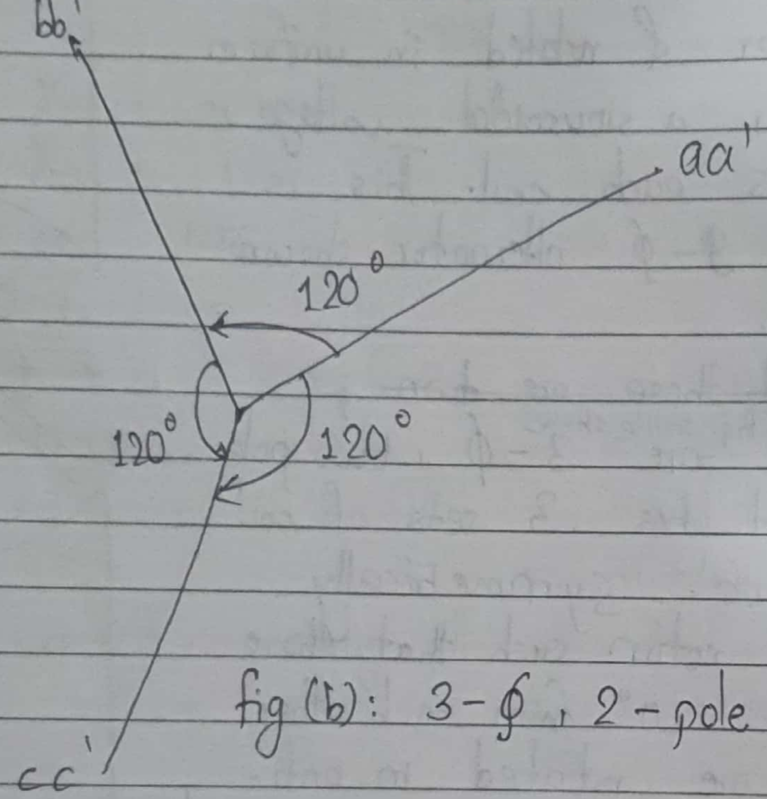


fig (b): 3-ϕ, 2-pole altenator

The voltage waveform is as shown in fig(c). below.

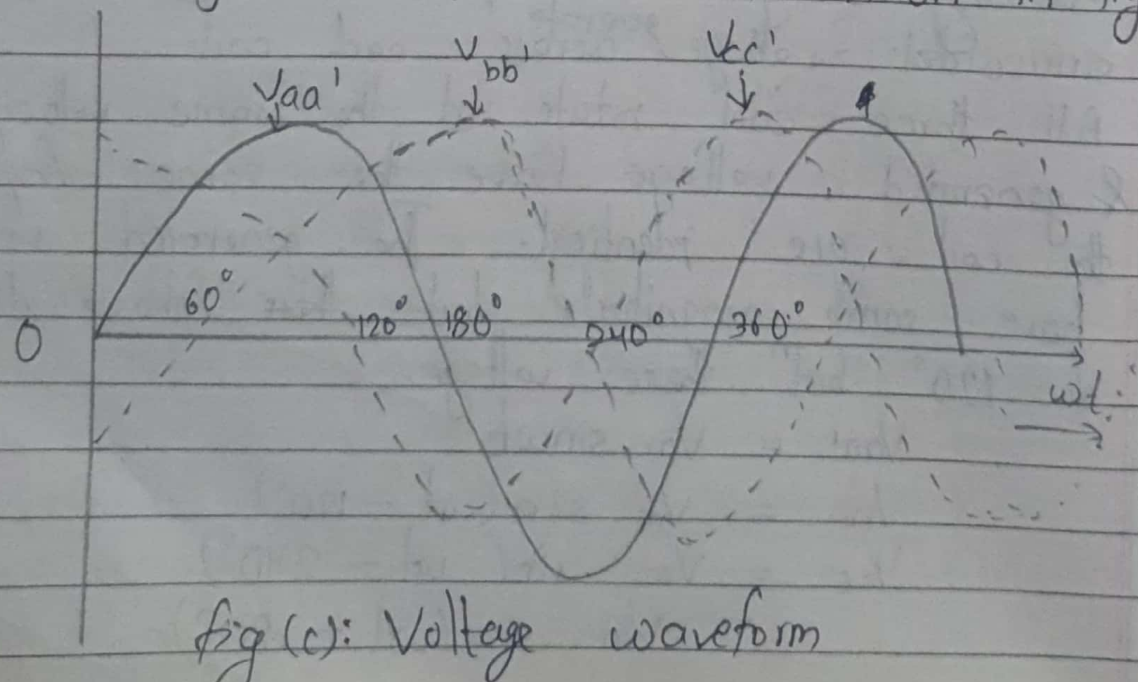


fig (c): Voltage waveform

It is seen that $V_{aa'}$ leads $V_{bb'}$ by $120°$ & $V_{bb'}$ leads $V_{cc'}$ by $120°$. Also, the three voltage reach their position maximum value in the order $V_{aa'}$, $V_{bb'}$ & $V_{cc'}$. The order in which the phase voltage reach their maximum value is called the phase sequence for arrangement shown in fig (c) above. If the coil are rotating in anticlockwise dir^n, the phase sequence is ~~a, b, c~~ abc. If the ~~coil~~ rotor is rotating in clockwise dir^n, the voltage reach their position max^m value in order $V_{cc'}$, $V_{bb'}$ & $V_{aa'}$. In this case, the phase sequence is cba or acb. Thus, the phase sequence determine the dir^n of rotation.

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Advantage of 3-ϕ over 1-ϕ

- It is observed that the poly-phase especially 3-ϕ system has many advantage over 1-ϕ system, both from utility point of view as well as from the consumer points of view. Some advantages are as follows:

1) The power of 1-ϕ ckt is pulsating when p.f. of ckt is ~~utility~~ unity but, 3-ϕ power supply by each phase is pulsating torque. Total power is balanced 3-ϕ ckt is constant at every instant of time. Because 3-ϕ have more absolutely uniform torque.

* 3ϕ motor have uniform torque, whereas 1-ϕ motor ~~of~~ passes pulsating torque (except commutating motor).

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* 3-ϕ motor are more compact; whereas 1-ϕ motor requires more space for conveying the same power.
* Power in polyphase never falls to zero; whereas it may fall to zero in 1-ϕ system.

2) A poly-phase Transmission line requires less conductor than 1-ϕ.

3) Poly-phase are self-starting but single-phase are not self-starting.

4) For given frame-size, 3-ϕ motor or 3-ϕ generator produced more output than 1-ϕ motor (generator).

5) ~~Effective~~ Efficiency of 3-ϕ generator is higher than 1-ϕ generator.

In general, we can conclude that operating characteristics of 3-ϕ apparatus are superior than the 1-ϕ apparatus. Control equipment are smaller, cheaper, lighter in wt. & more efficiency, therefore 3-ϕ ckt is of great important.

most imp

Difference between 1-ϕ over 3-ϕ system.

For, 1-ϕ system:

i) It requires more copper for transmitting the power.
ii) Power may fall to zero '0' value.
iii) Single phase ~~having~~ have fluctuating torque.
iv) 1-ϕ motor posses ~~more~~ no starting torque so that it needs additional starting device.
v) 1-ϕ motor requires more space.
vi) 1-ϕ generator can not start in parallel.
vii) Transmission system or distribution system of 1-ϕ power is costly.

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viii) Less efficient.
ix) less efficiency.
Output of 1-ϕ generator is low.
x) 1 - ϕ are less costly.

For, 3-ϕ system:

i) It requires less copper for transmitting the power.
ii) Power never falls to zero '0'.
iii) It has uniform torque.
iv) 3-ϕ motor can ~~be~~ self - start.
v) 3-ϕ motor are more compact.
vi) 3-ϕ can be started in parallel.
vii) Transmission system or distribution of 3-ϕ power is cheaper.
viii) More efficient.
ix) Efficiency is very high (for generator).
x) output of poly-phase m/c (machine) is very high.
xi) Polyphase are costly (little).
→ Polyphase generator is large in size, more economical in operation.

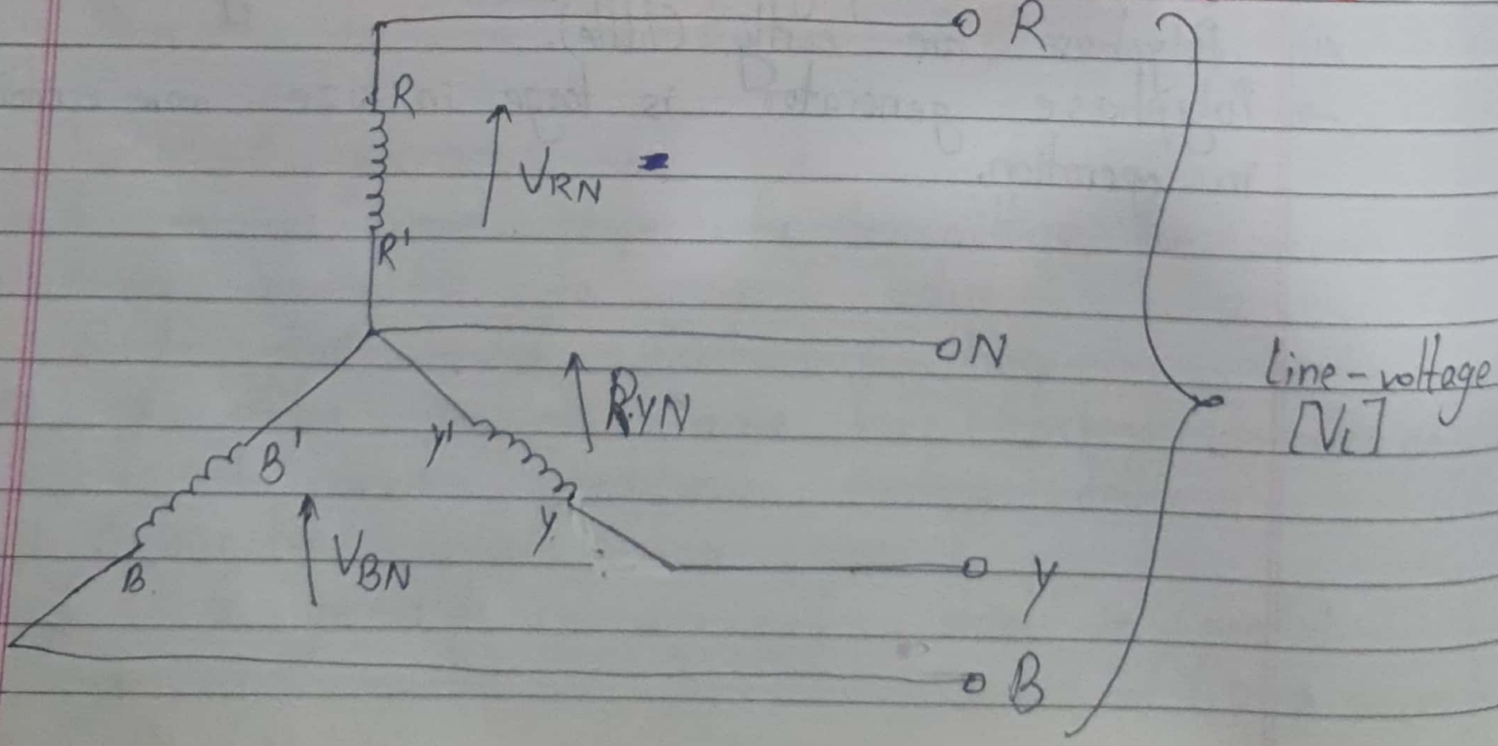
Phase Sequence:

The order in which the phase voltage reach as obtained their maximum value is called the phase sequence. Here, the sequence of the voltage in 3-ϕ are in the order $V_{RR'}$ - $V_{YY'}$ - $V_{BB'}$ & they undergo change one after other is above maintained order, this is called the phase sequence. It can be observed that this sequence depend on the rotation of field. If field system is rotated in anti-clockwise direction, then the sequence of the voltage in 3-ϕ is in order $V_{RR'}$-$V_{BB'}$-$V_{YY'}$. Briefly, we say that the sequence is RBY.

Now, the eq^n can be written as

$$V_{RR'} = V_m \sin\omega t$$
$$V_{YY'} = V_m \sin(\omega t - 120^\circ)$$
$$V_{BB'} = V_m \sin(\omega t - 240^\circ) \text{ or } V_m \sin(\omega t + 120^\circ)$$

Star Connections [Y connection / wye connection]



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balanced load – having equal magnitude & phase angle.

Star connection formula:

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

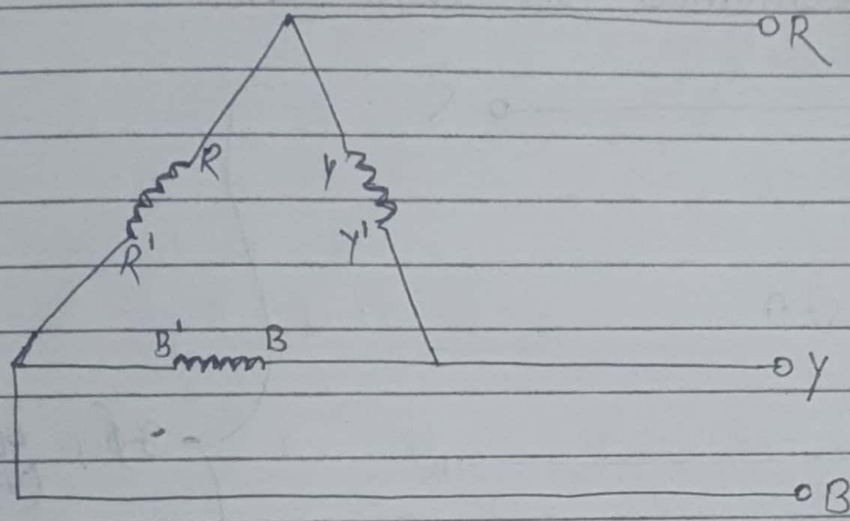
Power consumed $= \sqrt{3}\, V_L \cdot I_L \cos\phi$

$V_L \rightarrow$ line voltage
$I_L \rightarrow$ line current

Delta connection formula:

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

Delta Connections (Mesh connection / Δ - connection):



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

Voltage, current, power for star-delta connection relation (self-study)

$$\boxed{\cos\phi = \frac{R_{ph}}{Z_{ph}}}$$

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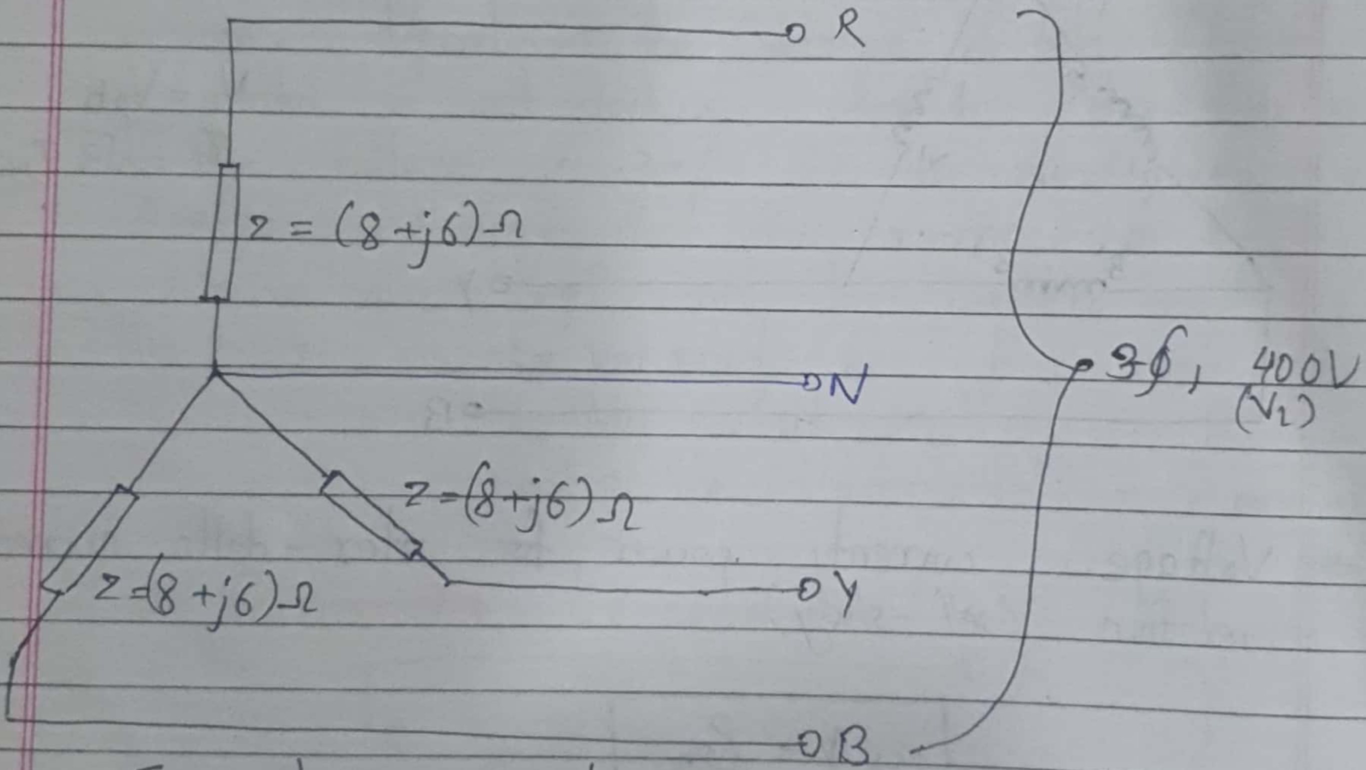
Q.1) Three equal impedances each having the resistance of 8Ω & inductive resistance of 6Ω are connected in series.
(a) star (b) delta across 3-ϕ, 400V system. Find
(i) phase current
(ii) line current
(iii) power consumed in each case.

solution:



For star connection:

$Z_{ph} = \sqrt{8^2+6^2} = 10\Omega$

$\therefore Z_{ph} = 10\Omega$

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

$I_L = I_{ph}$

Now,

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

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

$\Rightarrow V_{ph} = 231V$

$$I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{231}{10} = 23.1 \text{ amp}$$

Also, $I_L = I_{ph} = 23.1$ amp

$$\boxed{\text{power consumed} = \sqrt{3}\ V_L \cdot I_L \cos\phi}$$

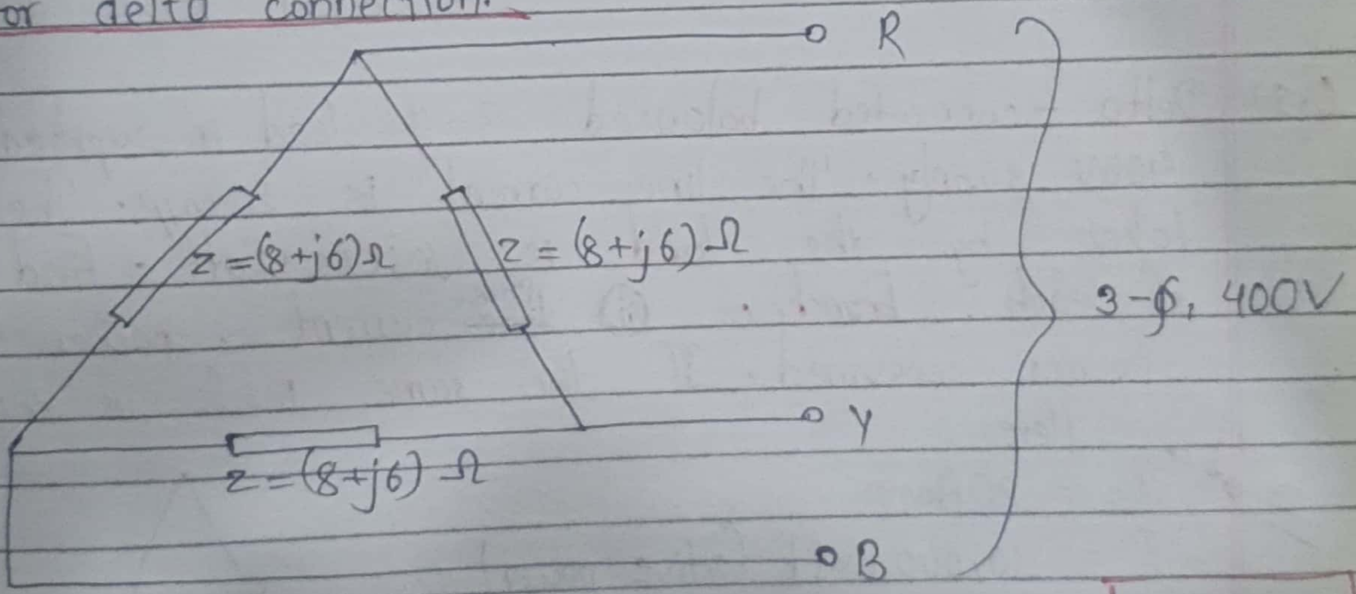
$$= \sqrt{3} \times 400 \times 23.1 \times \cancel{\cos}\left(\frac{R_{ph}}{Z_{ph}}\right)$$

$$= \sqrt{3} \times 400 \times 23.1 \times \frac{8}{10}$$

$$= 12{,}803.32 \text{ watt}$$

$$= 12.8 \text{ kW}$$

For delta connection:



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

Here, $V_L = 400V$

$Z_{ph} = \sqrt{8^2 + 6^2} = 10\ \Omega$

Now,

$V_L = V_{ph} = 400V$

$\therefore V_{ph} = 400\ V$

Again,

$$I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{400}{10} = 40 \text{ amp}$$

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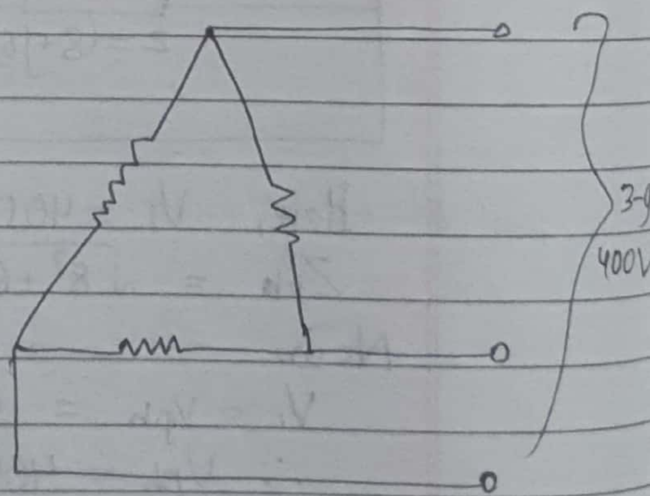
So, $I_L = \sqrt{3}\ I_{ph}$
$= \sqrt{3} \times 40$
$= 69.28$ amp

Again,
$$\cos\phi = \frac{R_{ph}}{Z_{ph}} = \frac{8}{10} = 0.8$$

Now,
power consumed $= \sqrt{3}\ V_L \cdot I_L \cos\phi$
$= \sqrt{3} \times 400 \times 69.28 \times 0.8$
$= 38{,}398.87$ watt
$= 38.39$ KW

Q.2) Delta-connected balanced 3-ϕ load is supplied from 3-ϕ, 400V supply. The line current is 20 amp. The power taken by the load is 10,000 Watt. Find (i) impedance of each branch, (ii) ~~line~~ Phase current, power factor & power consumed. If the same load is connected to star

Here,
Delta
$I_L = 20$ Amp
$P = 10{,}000$ watt (active power)



For delta connection:
$V_L = V_{ph}$
$I_L = \sqrt{3}\ I_{ph}$

Now,
$V_L = 400V$
$\Rightarrow V_{ph} = 400V$

Also, $I_L = \sqrt{3}\ I_{ph}$
$\Rightarrow 20 = \sqrt{3}\ I_{ph}$
$\Rightarrow I_{ph} = 11.52$ amp

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(i) $Z_{ph} = \frac{V_{ph}}{I_{ph}} = \frac{400}{11.52}$

$\therefore Z_{ph} = 34.6\,\Omega$

Now,

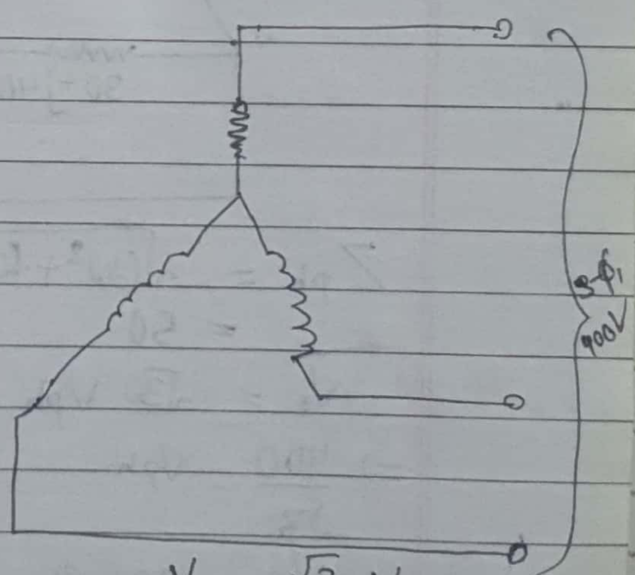
(Power) $P = \sqrt{3}\, V_L \cdot I_L \cos\phi$

or $10000 = \sqrt{3} \times 400 \times 20 \times \cos\phi$

$\Rightarrow \cos\phi = 0.72$

(ii) $\therefore$ power factor $= \cos\phi = 0.72$

For star connection:



$V_L = 400V$

So,

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

$\Rightarrow 400 = \sqrt{3}\, V_{ph}$

$\Rightarrow V_{ph} = 230.94\,V$

Now,

$I_L = 20$ amp

$\Rightarrow I_{ph} = 20$ amp $[\because I_L = I_{ph}]$

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

$I_L = I_{ph}$

Again,

(i), $Z_{ph} = \frac{V_{ph}}{I_{ph}} = \frac{230.94}{20}$

$= 11.55\,\Omega$

(ii) power factor:

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

or $10000 = \sqrt{3} \times 400 \times 20 \times \cos\phi$

$\Rightarrow \cos\phi = 0.72$

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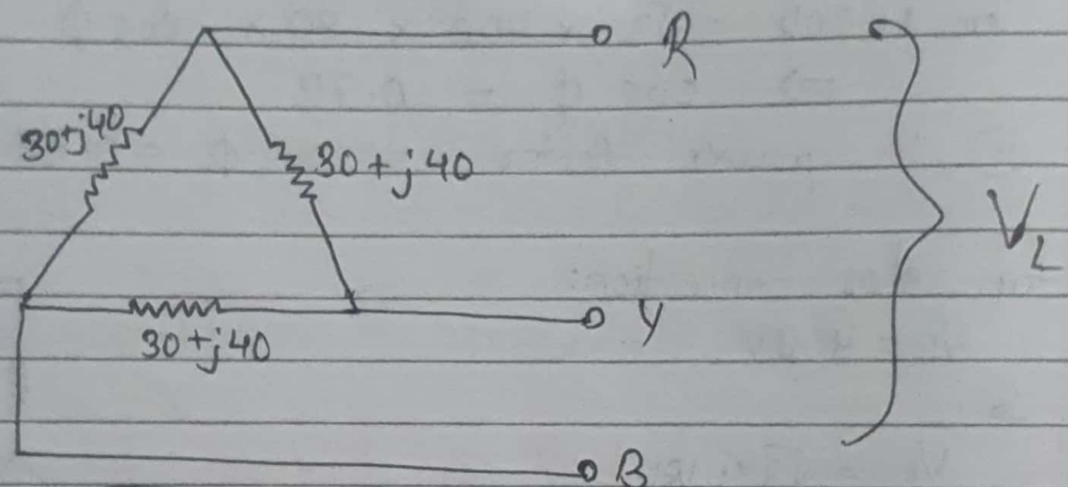
Q. 3) The three equal impedance $(30+j40)\,\Omega$ are connected in star and balanced 3-ϕ, 400V supply is connected across this load. Find the (i) current flowing through load, (ii) power consumed by each phase (iii) p.f. of load.



$Z_{ph} = \sqrt{(30)^2+(40)^2}$
$= 50$

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

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

$\Rightarrow V_{ph} = 230.94$

Now,

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

$= \frac{230.94}{50}$

$= 4.61$ amp

$I_{ph} = I_L = 4.61$ amp

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

$= \sqrt{3} \times 400 \times 4.61 \times \frac{R_{ph}}{Z_{ph}}$

$= \sqrt{3} \times 400 \times 4.61 \times \frac{30}{50}$

$= 1916.34$ watt

pf of load $= \cos\phi$

$= 0.6$

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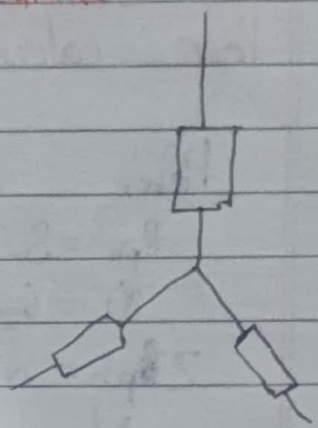
4) The ~~three~~ 3-ϕ balance load connected in star drawn a total power of 20kW at 0.8, if lag. When connected to 3-ϕ, 400V, 50Hz supply, ~~(i)~~ calculate
(i) resistance of coil
(ii) inductance of coil



Here,

$P = 20kW = 20000W$

$V_L = 400V$

$\cos\phi = 0.8$

Now,

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

or $20000 = \sqrt{3} \cdot 400 \cdot I_L \cdot 0.8$

$\Rightarrow I_L = 36.08$ amp

$I_{ph} = I_L = 36.08$ amp

Now,

$$Z_{ph} = \frac{V_{ph}}{I_{ph}} = \frac{V/\sqrt{3}}{I_{ph}} = \frac{230.94}{36.08} = 6.4\ \Omega$$

Again,

$$\cos\phi = \frac{R_{ph}}{Z_{ph}}$$

$\Rightarrow R_{ph} = Z_{ph} \times 0.8$
$= 6.4 \times 0.8 = 5.12$

Also,

$$X_L = \sqrt{Z_{ph}^2 - R_{ph}^2} = 3.84\Omega$$

So,

$X_L = 2\pi f L$

$$\Rightarrow L = \frac{3.84}{2\pi f} = 0.012H = 12.2\ mH$$

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5) Three equal impedances having the resistance 8Ω & inductive reactance 6Ω are connected in delta & connected to 230V, $3-\phi$ - coine, $3-\phi$ delta connected source then calculate (i) phase & line current of load (ii) p.f, (iii) power consumed.

Here,

$R_{ph} = 8\Omega$

$X_L = 6\Omega$

$Z_{ph} = \sqrt{8^2+6^2} = 10\Omega$

$V_L = 230V$

Now,

$V_{ph} = 230V$

So, $I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{230}{10} = 23A$

Also, $I_L = \sqrt{3}\, I_{ph} = 23 \times \sqrt{3} = 39.83A$

So, $pf\ (\cos\phi) = \frac{R_{ph}}{Z_{ph}} = \frac{8}{10} = 0.8$

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

$= \sqrt{3} \times 230 \times 39.83 \times 0.8$

$= \cancel{12696 \text{ watt}}$ 12693.71 watt

$= 12.69$ KW

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active power = $\sqrt{3}\ V_L I_L \cos\phi$ (watt)
reactive " = $\sqrt{3}\ V_L I_L \sin\phi$ (VAR)
apparent = = $\sqrt{3}\ V_L I_L$ (VA)

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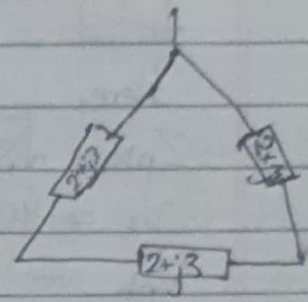
6) The balanced delta connected load of $(2+j3)\ \Omega$ per phase is connected to balance 3-ϕ, 440V supply. The phase current is 10 amp. Find the (i) active power (ii) reactive power (iii) apparent power.



Here,

$Z_{ph} = \sqrt{2^2+3^2} = 3.60\ \Omega$

$V_L = 440V$

$V_{ph} = 440V$

Now,

$I_{ph} = 10$ amp

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

$= 17.32$ A

Again,

(i) Active power $= \sqrt{3}\ V_L I_L \cos\phi$

$= \sqrt{3} \times 440 \times 17.32 \times \frac{2}{3.6}$

$= 7333.12$ watt

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

$= \sqrt{3} \times 440 \times 17.32 \times \sqrt{1-\cos^2(0.55)}$

$= 126.70$ VAR

(iii) Apparent power $= \sqrt{3}\ V_L I_L$

$= \sqrt{3} \times 440 \times 17.32$

$= 13199.61$ VA

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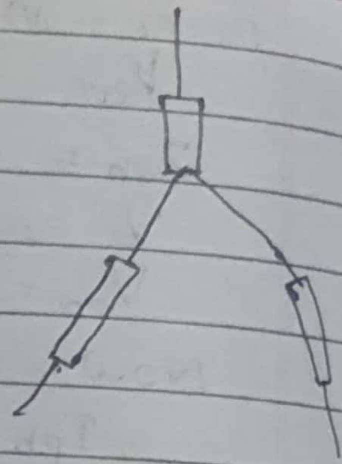
Q. The balanced star-connected load of $(8+j6)$ per phase is connected to the balance 3-ϕ, 400V supply. Find the line current, power factor, power & total volts-amp.

Here,



$Z_{ph} = \sqrt{8^2+6^2} = 10\,\Omega$

$V_L = 400V$

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

So,

$I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{230.94}{10} = 23.09\ A$

Now,

$I_L = I_{ph} = 23.09A$

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

$$\begin{aligned}
\text{Power} &= \sqrt{3}\ V_L\ I_L \cos\phi \\
&= \sqrt{3} \times 400 \times 23.09 \times 0.8 \\
&= 12797.77 \text{ watt} \\
&= 12.79 \text{ kW}
\end{aligned}$$

Also,

$$\begin{aligned}
\text{Volt-amp} &= \sqrt{3}\ V_L\ I_L \\
&= \sqrt{3} \times 400 \times 23.09 \\
&= 15997.22 \text{ VA}
\end{aligned}$$

Measurements of $3-\phi$ power:

1) One - wattmeter method
most imp 2) Two - wattmeter method

1) One - wattmeter method:

The measurement of power in in $1-\phi$ of $3-\phi$ balance ckt where the star point (neutral point) is available. The current coil is connected in $1-\phi$. & the voltage ~~of~~ or pressure coil connected betn the star point; the reading on the wattmeter gives the power per phase.

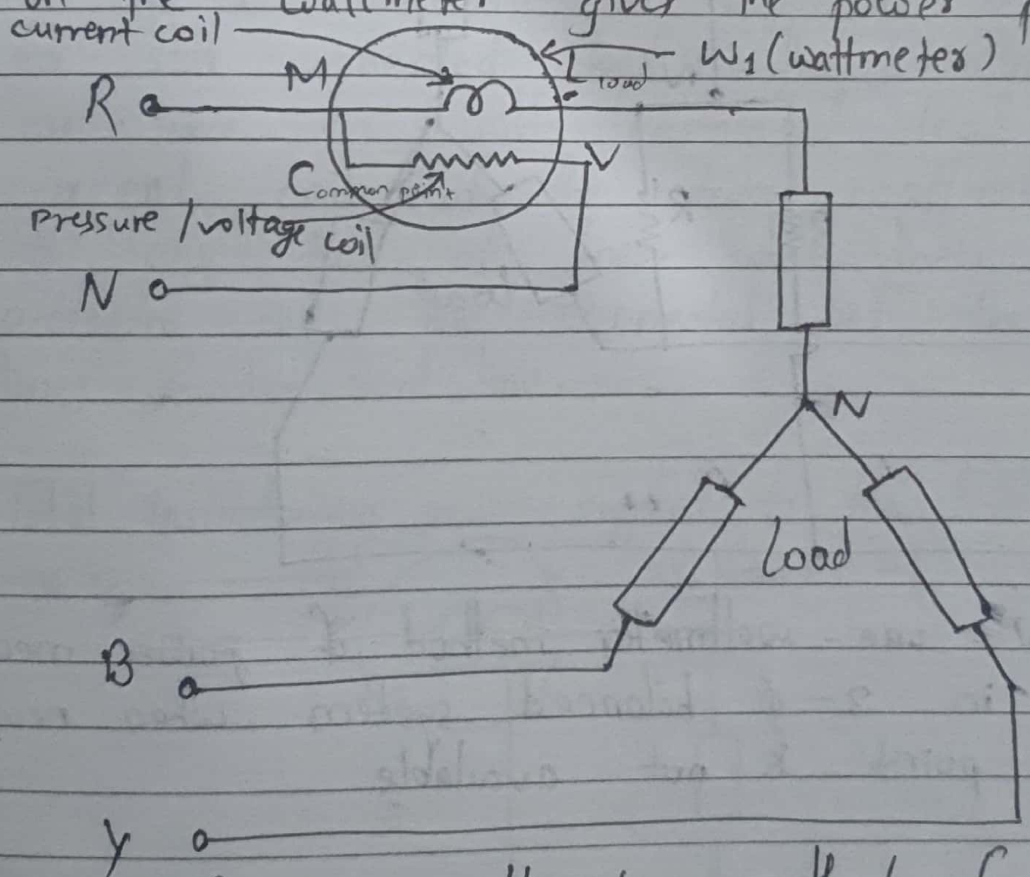


fig (a):- one watt meter method of power - measurement

The 3-ϕ power gives three times the wattmeter reading. If the neutral point is not available & artificial neutral point N' is created by connecting two resistors R, R' shown in fig (b) below. The total power is given by 3 times wattmeter reading.

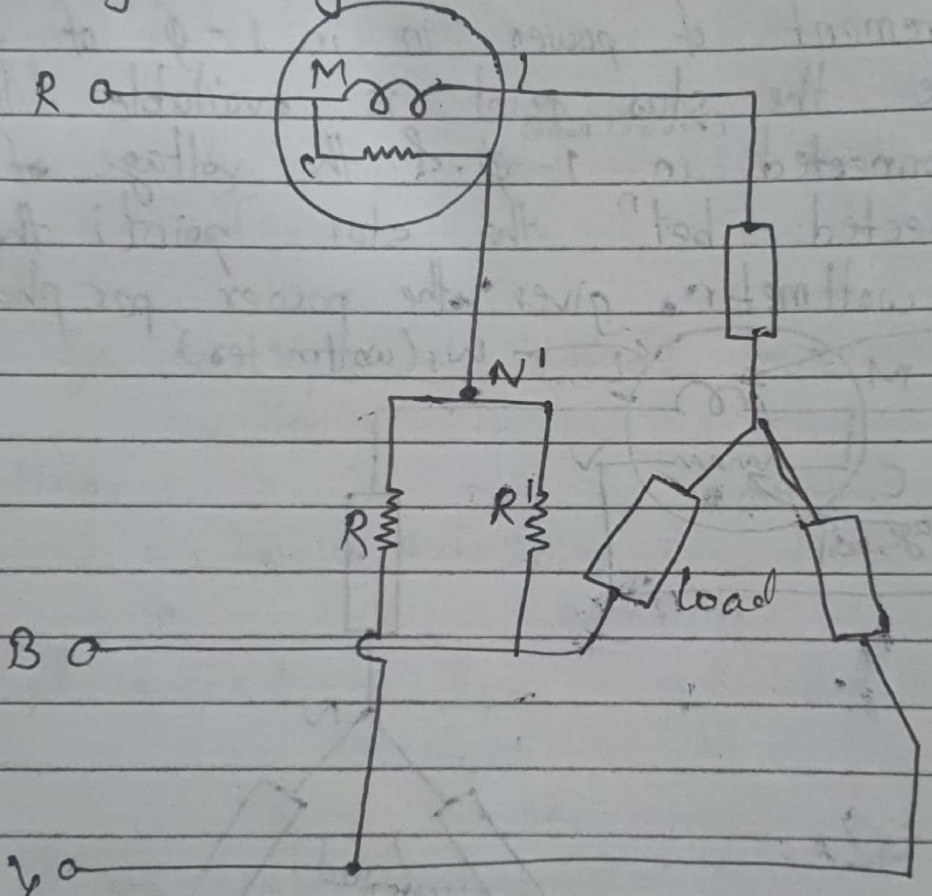


Fig (b) : one - wattmeter method of power measured in 3-ϕ balanced system, when neutral point is not available

* ~~Volt - amp reactive of two~~

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2) Two - wattmeter methods:

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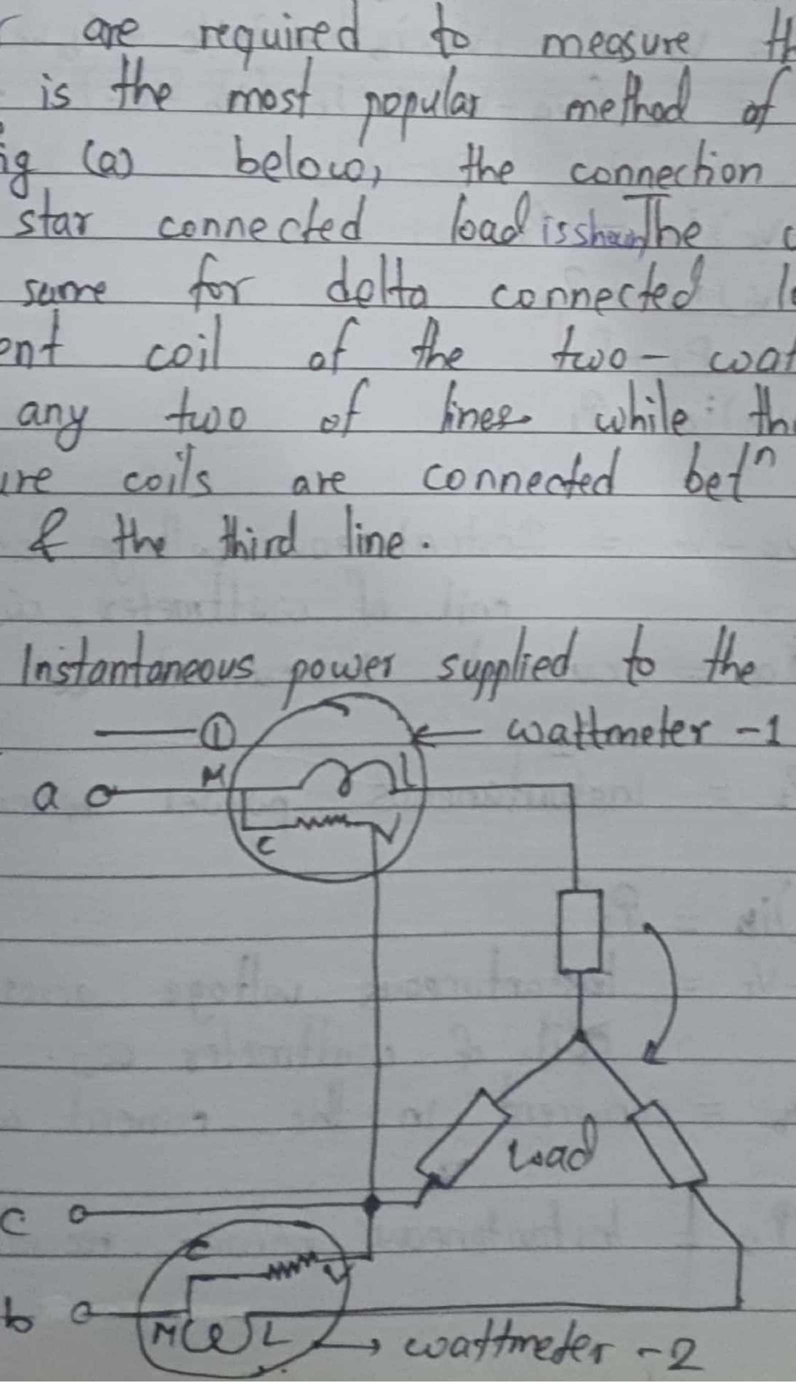
* volt - amp ~~reatance~~ reactive of two - wattmeter method [self study]

one time asked in exam

For three phase, 3 - wire system; whether balanced or unbalanced; star or delta connected, only two-watt-meter are required to measure the 3-ϕ power.
This is the most popular method of measuring the power.
In fig (a) below, the connection of 2-wattmeter for star connected load is shown. The wattmeter connection are same for delta connected load also. The current coil of the two - wattmeter are connected to any two of lines while their voltage coils or pressure coils are connected bet^n the corresponding lines & the third line.

Total Instantaneous power supplied to the load is $P = V_a i_a + V_b i_b + V_c i_c$



In a 3-wire system,

$$i_a + i_b + i_c = 0 \quad \text{--- (ii)}$$

Since, i_c is not flowing in either of wattmeter, we eliminate i_c.

From eq^n (i) & eq^n (ii),

$$i_c = -(i_a + i_b)$$

$$P = V_a \cdot i_a + V_b \cdot i_b - (i_a + i_b) V_c$$

$$P = V_a \cdot i_a + V_b \cdot i_b - i_a V_c - i_b V_c$$

$$P = i_a (V_a - V_c) + i_b (V_b - V_c) \quad \text{--- (iii)}$$

When,

$$(V_a - V_c) i_a = P_1$$

$$(V_b - V_c) i_b = P_2$$

$$\therefore \boxed{P = P_1 + P_2}$$

$$(V_a - V_c) i_a = P_1$$

Where,

$V_a - V_c$ = Instantaneous voltage across the voltage coil of wattmeter W_1

i_a = current in current coil of wattmeter W_1

P_1 = Instantaneous power recorded by W_1

$$(V_b - V_c) i_b = P_2$$

where, $V_b - V_c$ = Instantaneous voltage across voltage coil of wattmeter W_2.

i_b = current in the current coil of W_2

P_2 = Instantaneous power recorded by W_2

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Avg. voltage of P = Avg. value of P_1 + Avg. value of P_2
P = reading of ω_1 + reading of ω_2

$$\boxed{P = P_1 + P_2}$$

Thus, the sum of the two-wattmeter reading gives the total three phase power in 3-wire system (Y or Δ connected) under all conditions of load whether balanced or unbalanced, Y or Δ connected.

$$\boxed{\tan\phi = \sqrt{3} \cdot \frac{\omega_1 - \omega_2}{\omega_1 + \omega_2}}$$ numerical using this formula

→ 3-ϕ induction motor की working phase

→ speed control of dc motor

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Electrical M/C

• Transformer

→ Transformer is the ~~electric~~ static device which consists of two or more stationary electric ckt interlinked by the common magnetic ckt. for the purpose of transforming the electrical energy betⁿ them. The transfer of energy from one ckt to another ckt take place without change in frequency.

Consider the two coil, coil 1 & coil 2 wound on simple magnetic ckt shown in fig (a) below. The coil are insulated from each other & there is no electrical connection betⁿ them. Let T_1 & T_2 be no. of turns in coil 1 & coil 2 resp. When the source of ac voltage V_1 is applied to the coil 1 & coil 2, ac I_1 flow in it. This alternating current produce an alternating flux (Φ_m) in magnetic ckt. The mean path of this flux shown in fig (a) below. By the dotted line, this ϕ_m links turn T_1 of coil 1 & indicates in alternating voltage $\mathcal{E}_1$ by self induction.

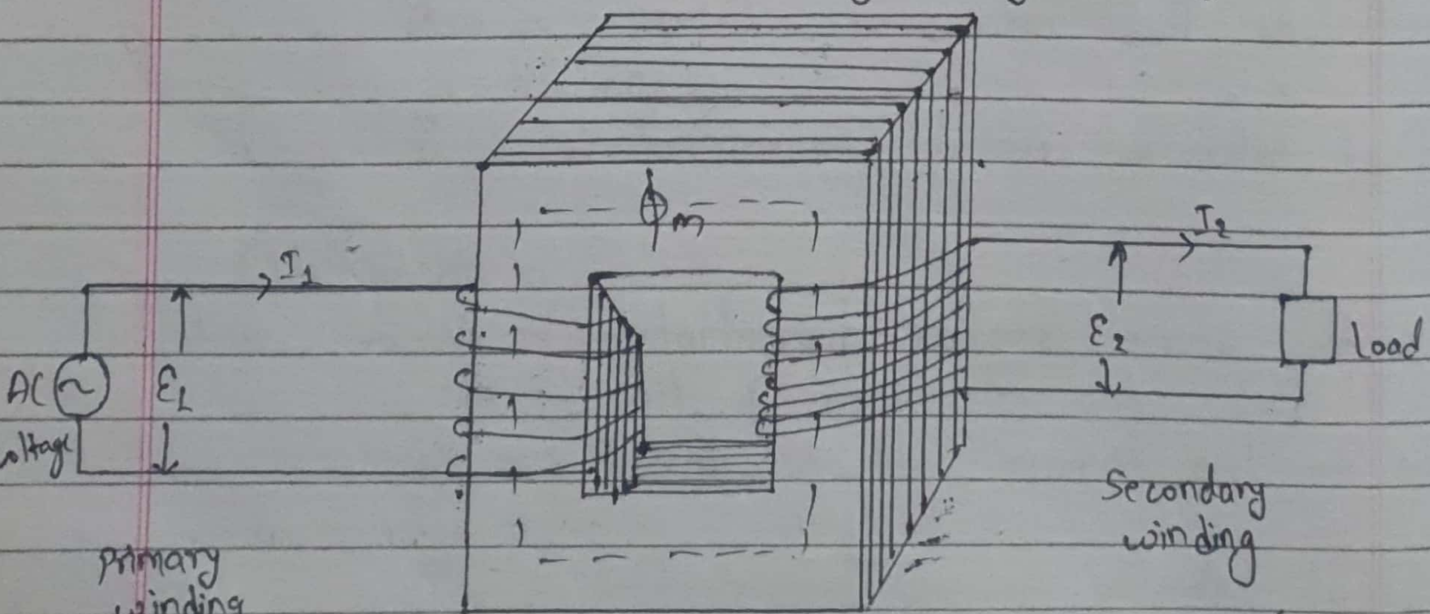

Fig (a) : Simple arrangement of 1-ϕ Transformer

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* Simplifying Assumptions for Ideal Transformer:

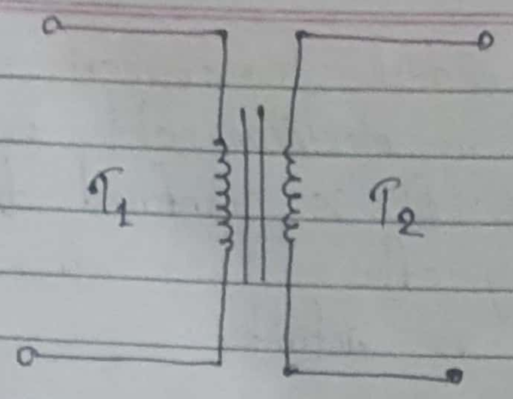
(i) There is no losses either in electrical ckt or magnetic ckt.
(ii) The whole magnetic flux (ϕ) is confined to magnetic ckt so there is no leakage flux.
(iii) The permeability of core is infinite.

All the flux produced by coil-1 also links T_2 turns of coil-2 and induces in them a voltage $\mathcal{E}_2$ by mutual induction. If coil-2 ~~and~~ is connected to the load then alternating current will flow through it and energy will be delivered to the load. Thus electrical energy is transferred from coil-1 to coil-2 by common magnetic ckt. Since, there is no relative motion of coil, the freq. of the induction voltage of coil-2 is exactly the same as the freq. of applied voltage to coil-1.

Coil-1 which receives energy from the source ac supply is called primary coil or primary winding or simply primary.

Coil-2 which is connected to load & delivered energy to the load is called secondary ~~life~~ coil or secondary winding or simply secondary.

The ckt symbol for two-winding transfer is



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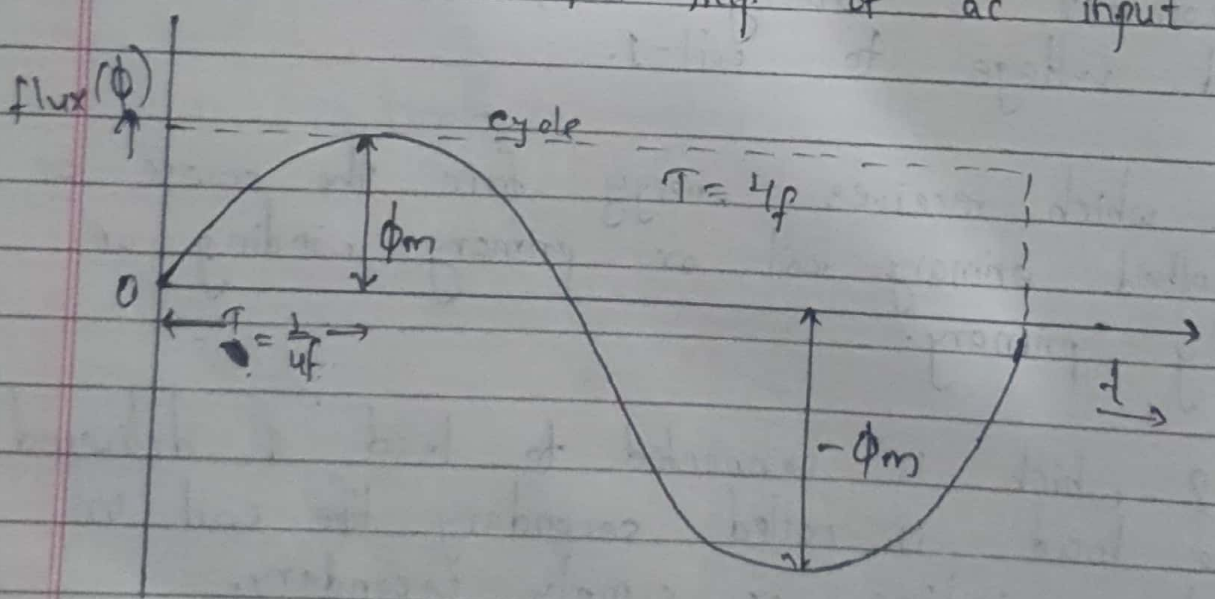
EMF Eq^n of Transformer

N_1 = No. of turns in primary coil
N_2 = No. of turns in secondary coil
ϕ_m = max^m flux in the core (Wb)
$\phi_m = B_m \cdot A$

where, B_m = max^m flux density in the core
A = Area of core
f = freq. of ac input (Hz)



Since, flux increased from zero value to max^m value ϕ_m in one quarter of cycle i.e. $T/4$ or $1/4f$ second. [T being time period of cycle], Avg. rate of change of flux = $\frac{\phi_m}{1/4f}$ = $4f\,\phi_m$

If flux varies sinusoidally, the rms value of induced emf is obtained by multiplying the avg. value with form factor.

rms value = form factor x avg. value

$\therefore$ Form factor = $\frac{\text{rms value}}{\text{avg. value}}$ = 1.11

$\therefore$ RMS value of emf / turn = $1.11 \times 4\,\phi_m f$

Now,
rms value of induced emf in the whole primary winding,

$$E_1 = 4.44 f\,\phi_m \cdot N_1 \quad \text{--- (I)}$$

Similarly,
rms value of induced emf in the whole secondary winding,

$$E_2 = 4.44 f\,\phi_m \cdot N_2 \quad \text{--- (II)}$$

In ideal transformer on No - load:

$V_1 = E_1$ &

$V_2 = E_2$

Transformer on No-load:

A transformer is said to be no load, when the secondary winding side is open ckt & primary winding is connected to sinusoidal alternating voltage V_1. The alternating applied voltage will cause to flow of a.c. in the primary winding which creates the alternating flux. The primary input current I_0 current under no-load condition supply.

(i) Iron loss in core [i.e. Hysteresis loss or eddy current loss].

(ii) Copper loss (in primary) very small amount of loss.

Thus I_0 lags 90° by V_1.

No-load power input, $W_0 = V_1 I_0 \cos\phi_0$

where,

$\cos\phi_0$ = primary pf under no-load condn.

The primary current (I_0) has two components.

$I_w = I_0 \cos\phi_0$ → active or working or iron loss components (wattful amp.)

$I_m = I_0 \sin\phi_0$ → magnetising components (wattless comp)

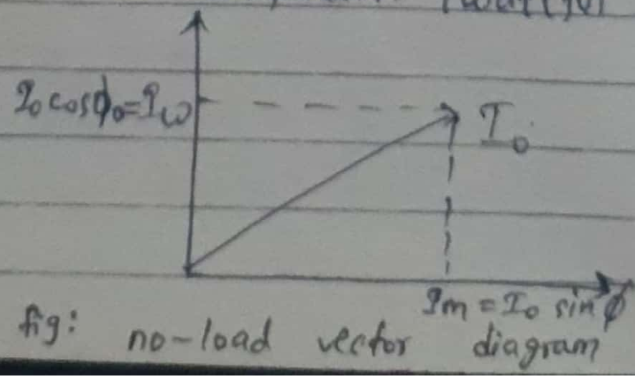


fig: no-load vector diagram

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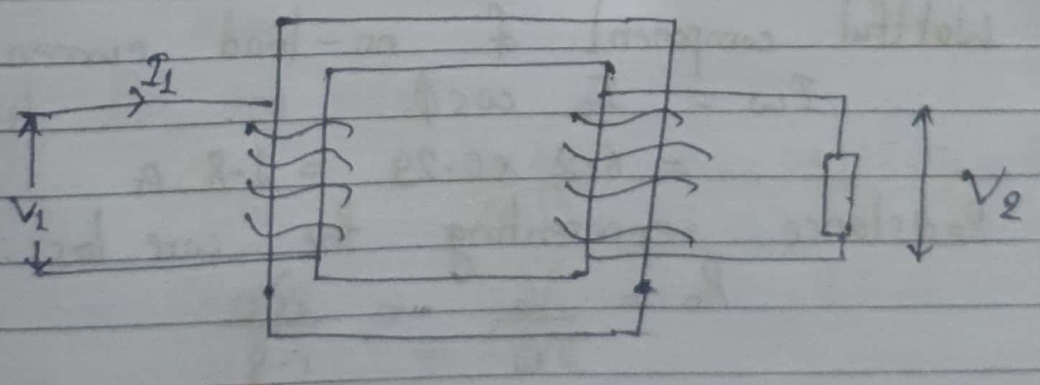
Transformer on load

The transformer is said to be loaded when second ckt of transformer is connected through impedance or load. The magnitude & phase of second current I_2 with respect to second terminal voltage will depend on characteristics of load i.e. the current I_2 will be in phase, lag behind & lead the terminal voltage V_2 resp. when the load is purely resistive, inductive & capacitive. The second current I_2 setup its own amp turn $= N_2 I_2$ creates its own flux ϕ_2 creates by no-load current I_0. The opposing second flux ϕ_2 weaken the primary flux ϕ_0 or back emf E_1 tends to be reduced. Hence, more current flow in primary & additional current be I_2. It is known as the load current of primary current.



Test of Transformer

(a) open ckt or no-load test (o.c. test)
(b) short ckt or impedance test (s.c. test)

$$\eta = \frac{x \times KVA \times 1000 \times pf}{x \times KVA \times 1000 \times pf + x^2 P_c + P_i}$$

$$Cu\ loss = \left(\frac{KVA \times 1000}{Sc\ current \times HV}\right)^2 \times SC\ power$$

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Numericals

Q. 1) Obtain the approx. eq. ckt. of a given 200/2000 V, 1-ϕ 30 KVA transformer having the following test results:
(i) O.C. Test [L.V side]: 200 V, 6.2 A, 360 watt (P_i)
(ii) S.C. Test [H.V side]: 75 V, 18 A, 600 watt (P_c)

solution:

(i) O.C. Test [L.V side]:

Primary voltage (V_0) = 200 V,
No - Load current (I_0) = 6.2 A
No - Load loss (P_0) = 360 watt

$P_0 = V_0 I_0 \cos\phi_0$

$360 = 200 \times 6.2 \cos\phi_0$

$\therefore \cos\phi_0 = \frac{360}{200 \times 6.2} = 0.29$ $\boxed{\sin\phi = \sqrt{1-\cos^2\phi}}$

$\Rightarrow \phi_0 = \cos^{-1}(0.29)$

$\Rightarrow \phi_0 = 73.14$

$\therefore \sin\phi = 0.957$

Wattful component of no-load currents:

$I_w = I_0 \cos\phi_0$

$= 6.2 \times 0.29 = 1.8\ A$

Resistance representing the core loss:

$R_0 = \frac{V_0}{I_w} = \frac{200}{1.8}$

$\therefore R_0 = 111.11\ \Omega$

Magnetizing ~~Magnetivity~~ components of no-load currents:

$I_m = I_0 \sin\phi_0$

$= 6.2 \times 0.95$

$\boxed{I_m = 5.9 A}$

Magnetizing ~~resistance~~ reactance

$$X_0 = \frac{V_0}{I_m} = \frac{200}{5.9} = 33.7\ \Omega$$

$$\therefore X_0 = 33.7\Omega$$

(ii) S.C. Test [H.V. side]: 75V, 18A, 600watt.

S.C. voltage $(V_{SC}) = 75V$

S.C. current $(I_{SC}) = 18A$

losses $(P_{SC}) = 600$ watt

Impedance of Transformer referred to H.V. side:-

$$Z_{02} = \frac{V_{sc}}{I_{sc}} = \frac{75}{18} = 4.167\ \Omega$$

$$P_{sc} = I_{sc}^2 \times R_{02}$$

$$600 = (18)^2 \times R_{02}$$

$$\therefore R_{02} = 1.85\ \Omega$$

Transformation ratio:

$$K = \frac{2000}{200} = 10$$

Transforation ratio: $\frac{V_1}{V_2} = \frac{N_1}{N_2} = \frac{1}{K}$

Reffered to 200 side:

$$Z_{01} = \frac{Z_{02}}{K^2} = \frac{4.167}{(10)^2} = 0.04167\ \Omega = Z_{02} \times \left(\frac{N_1}{N_2}\right)^2$$

$$R_{01} = \frac{R_{02}}{K^2} = \frac{1.85}{(10)^2} = 0.0185\ \Omega$$

$$\therefore X_{01} = \sqrt{(Z_{01})^2 - (R_{01})^2}$$

$$= \sqrt{(0.04167)^2 - (0.0185)^2}$$

$$X_{01} = 0.0373\ \Omega$$

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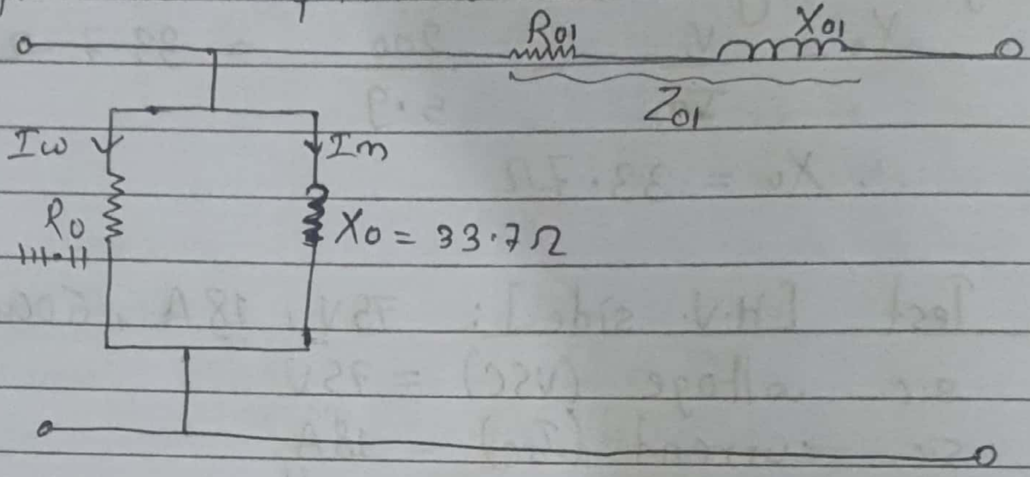
Approximate equivalent circuit:



V. most imp almost sure

3 - ϕ Induction motor:

Working:

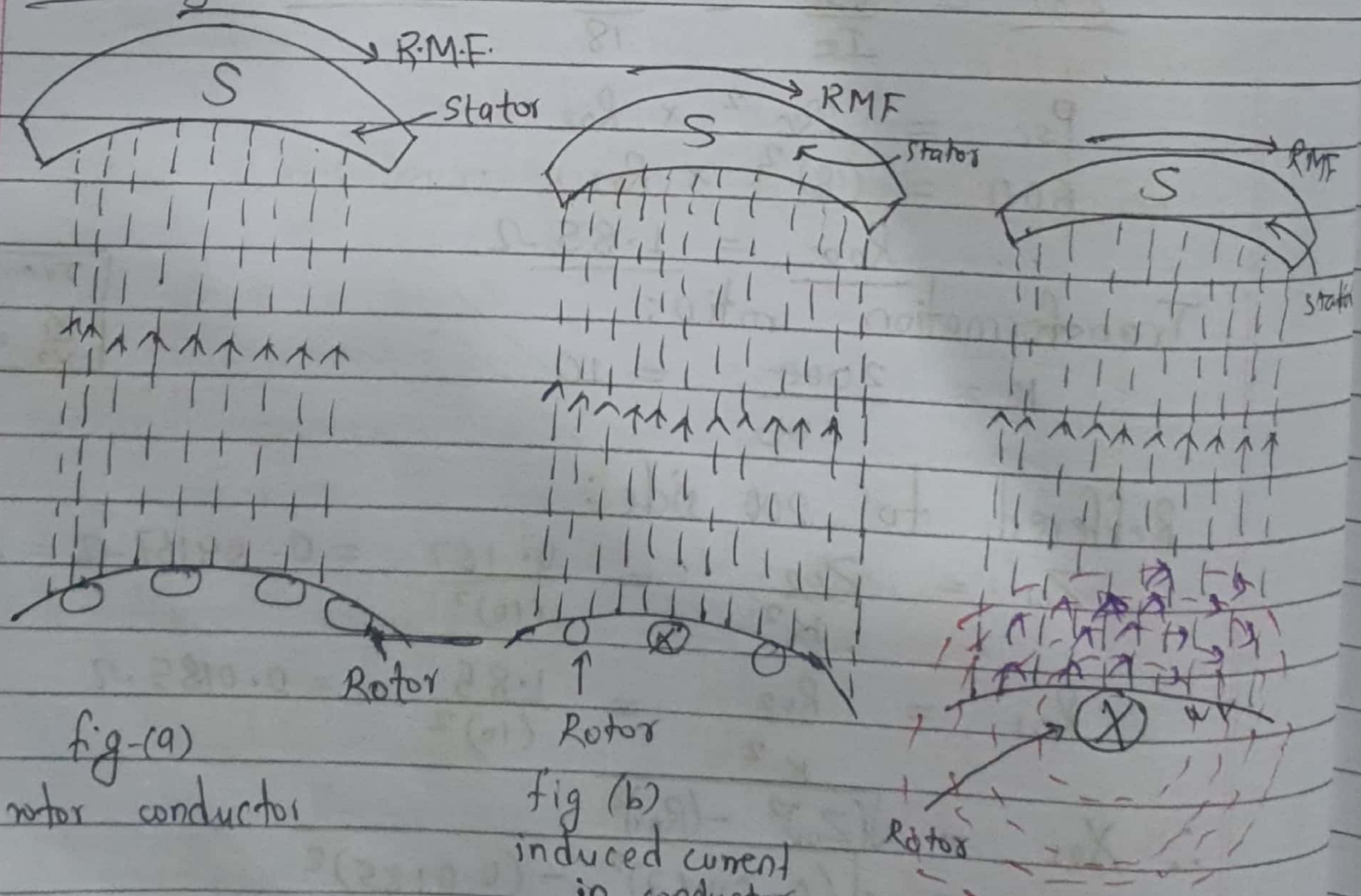


fig-(a) rotor conductor

fig (b) induced current in conductor

fig -(c) flux - due to rotor current

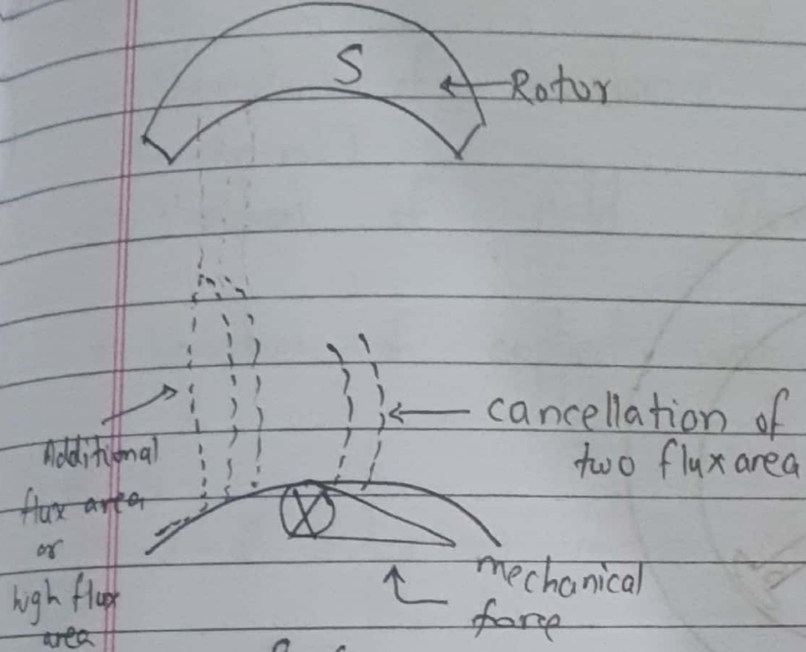
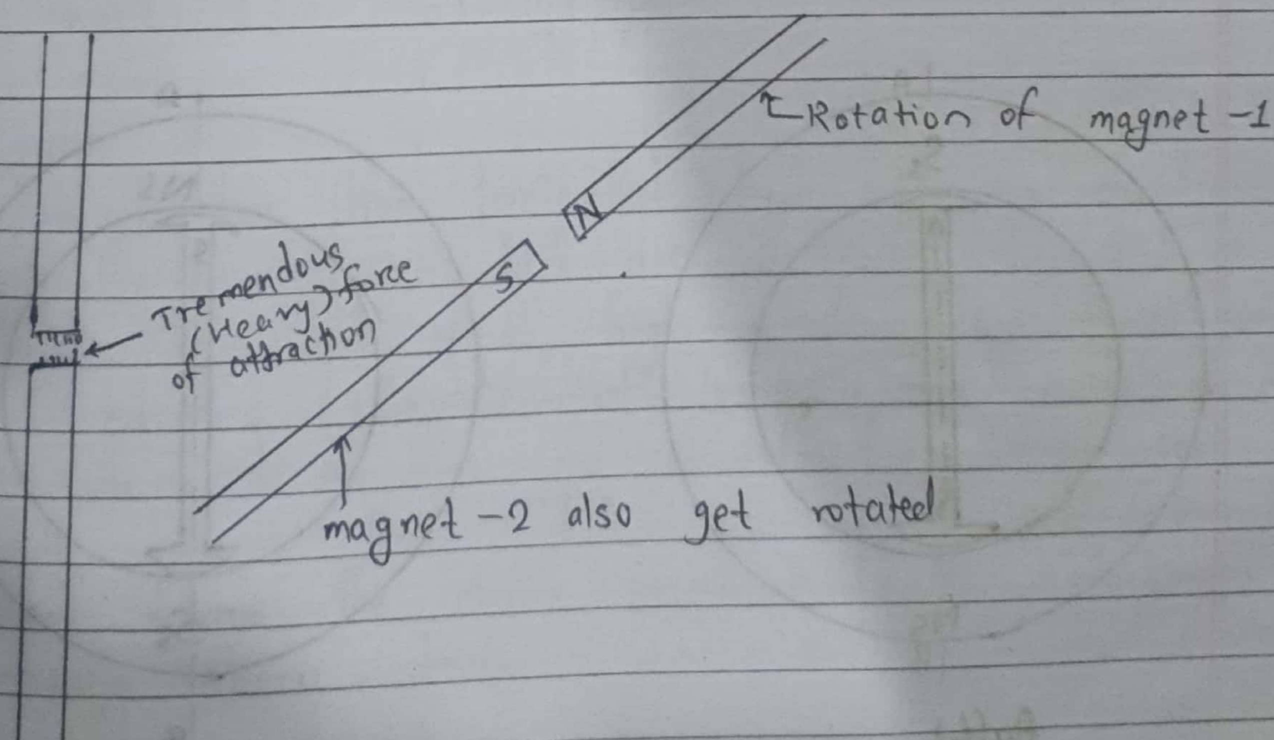


fig (d)

V.V.V Imp Working Principle of Synchronous (syn..) motor:



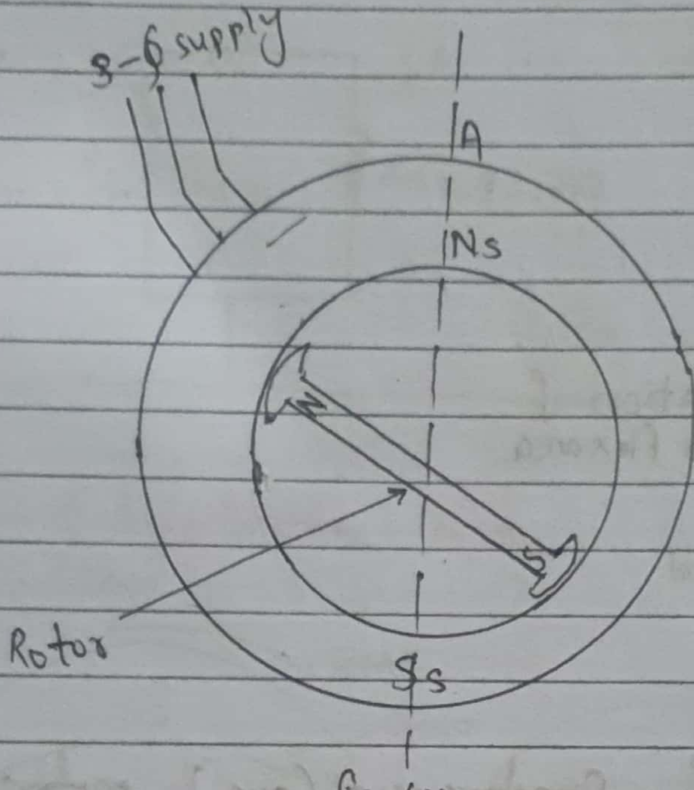


fig (a)

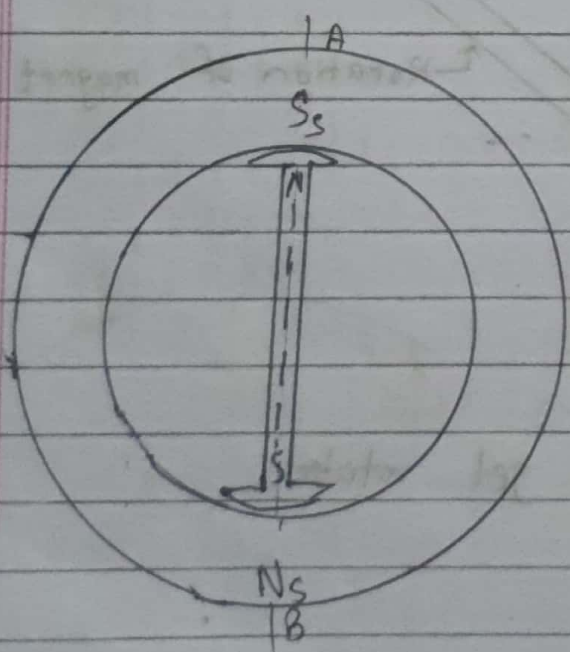


fig (b)

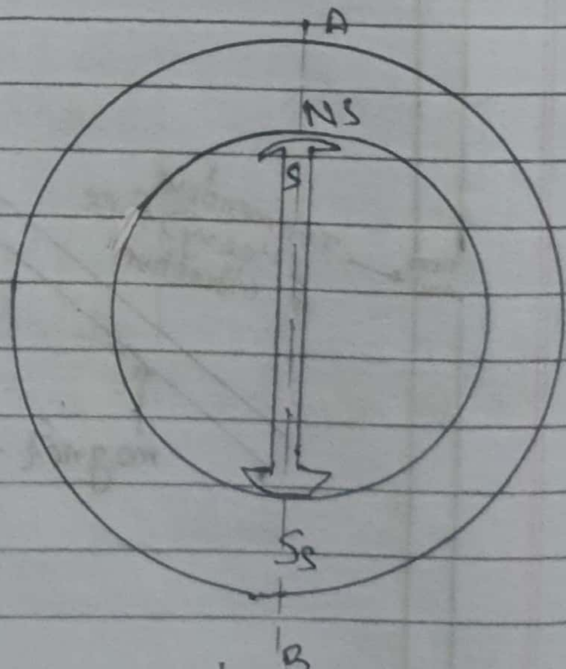


fig (c)

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for internal viva only

Speed ~~Co~~ Control of DC Motor:

1) Variation of resistance in the armature [Armature resistance control].
2) Variation of field flux (ϕ) [field-resistance control]
3) Variation of applied voltage.

Q.

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3-ϕ induction motor Construction:

Basically, induction motor consists of two main parts:-

i) 3-ϕ winding which is called stator. [i.e. stationary part]
ii) Rotor which is connected through mechanical load to shaft [i.e. rotating part]

1) Stator:

The stator has laminated type of construction made up of stamping which are 0.4mm to 0.5mm thick. Stator is built up of high-grade alloy steel laminations to reduced eddy-current losses. The no's of stampings are stamped together to build the stator core. The built up is then fitted in casted or fabricated steel frame. The choice of materials for stampings is generally silicon-steel.
↳ finished plate

The slots on periphery of the stator core consists 3-ϕ winding, connected either ~~stator~~ to core star or

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delta connected 3-ϕ winding ~~is~~ called stator winding. The winding is excited by 3-ϕ supply, produced the rotating magnetic field. The choice of no's of poles depends on the speed of rotating magnetic field required. $N_s \propto \frac{1}{P}$

The radial ducts areas are provided for the cooling purpose.
↳ tube or passage for air

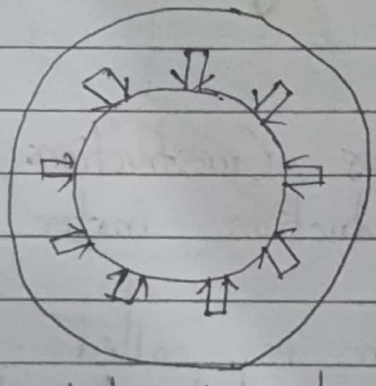


fig: stator lamination

ii) Rotor :

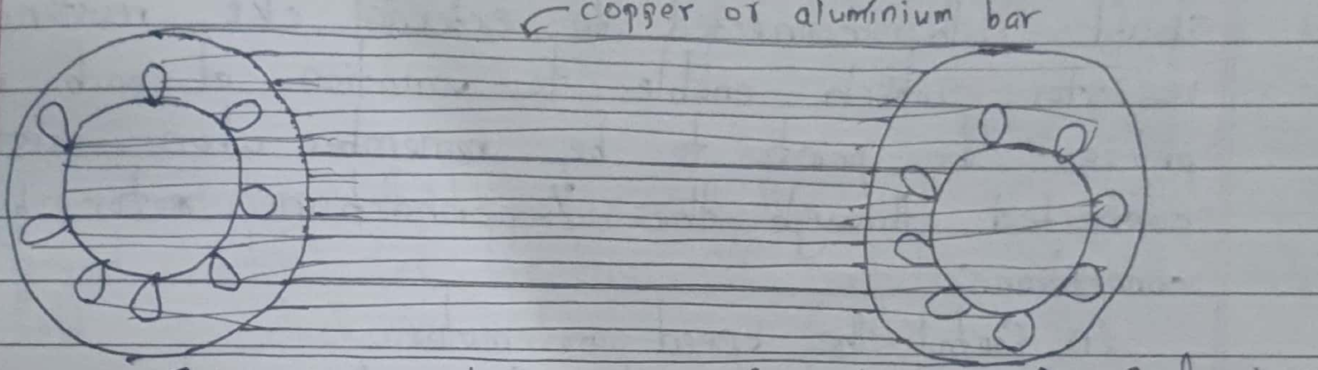
The rotor is placed inside the stator. The rotor core is also laminated in construction and uses as cast iron or same as stator materials. It is cylindrical with slots on its periphery. The Rotor winding or conductor is placed in the rotor slots.

There are two types of rotor construction in induction motors:

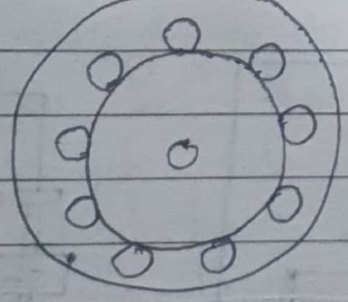
(a) squirrel cage rotor
(b) slip-ring or wound rotor

(a) squirrel cage rotor :-

~~it~~ The rotor core is cylindrical and slotted on its periphery. The rotor consists of uninsulated copper or aluminium bars called rotor conductor. The bars are placed in slots and each end of rotor bars is shortened by same materials. By same materials copper ring called end ring. The entire structure which looks like a cage, forming a closed electrical ckt. so the rotor is called the cage-rotor.



fig(a): Cage-type str of rotor



fig(b): Symbolic representation

The bars are permenantly shorted to each other through end rings, entire rotor resistance is very small. Hence, the rotor is called short ckt rotor.

(b) Slip-ring or wound rotor :-

This type of construction rotor winding is exactly similar to the stator. The rotor carries a 3-ϕ star or delta connected distributed winding, wound for some no. of poles as that of stator. The rotor winding are connected in series.

The slip-ring is mounted on the shaft with brushes are resting on it. The brushes are connected to the star connection, & the slip-ring mounted on the shaft with connected to external ckt resistance. The resistor which enable to variation at each rotor phase. The points to be remember when resistor connected through the Y-connection rotor by given connections:

(i) Control the speed or motor
(ii) Increasing current from the supply.

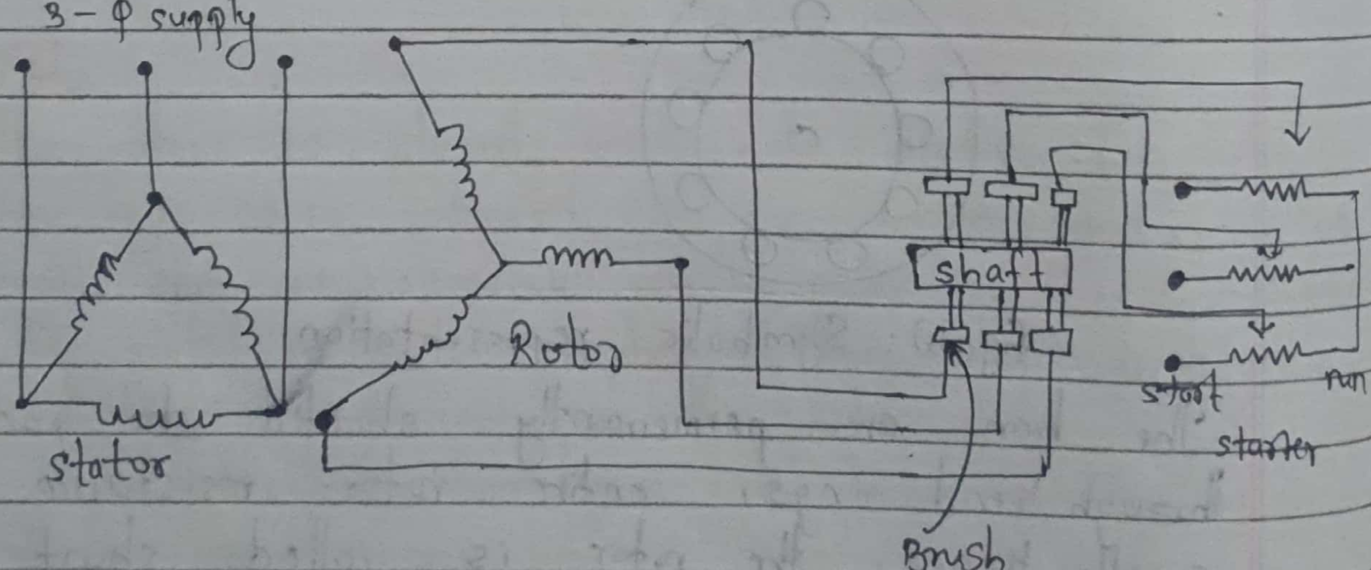


Fig: Slip-ring induction motor

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Working principle of 3-ϕ Induction Motor:

Induction motor works on principle of electromagnetic inductions when 3-ϕ supply is given to the 3-ϕ stator winding. A rotating magnetic field of constant magnitude is produced. The speed of this magnetic field is syn. speed [Ns] in r.p.m.

$$\boxed{N_s = \frac{120f}{P}}$$

where, f = supplied freq.
P = no's of poles for which stator winding is wounded.

This rotating field is produced by the effect of rotating poles around rotor. let direction of rotation of this rotating field is clockwise. ~~shown in fig (a)~~

Now, at this instant, rotor is stationary & stator flux, RMF is rotating so its obvious that there exists a relative motion betn the RMF and rotor conductors. Now the RMF gets cut by rotor conductors as RMF sweeps over rotor conductors. Whenever conductor cuts the flux, emf is induced in it. So emf gets induced in the rotor conductors called rotor induced emf. This is electromagnetic induction. As rotor form closed ckt, induced emf circulat current through rotor called rotor current. let dirn of the current is going into the paper denoted by a cross as shown in fig.(b) above.

Any current carrying conductor produced its own flux. So rotor produces its flux called rotor flux. Assume the dirn of rotor flux ~~So rot~~ & rotor current is clockwise dirn. This dirn is easily determined using shown in fig. (c) above.

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right hand thumb rule. Now, there are two fluxes, one RMF & other rotor flux. Both flux interact with each.

As flux lines acts as stretched rubber band, high flux density ~~axes~~ area exerts a push on rotor towards low flux density area so that rotor conductor force from ~~that~~ left to right. All rotor conductor experience a force, the overall rotor ~~expression~~ experiences a torque & start rotating.

Imp Application of Induction Motor:

i) Use in ~~the~~ different types of fans.
ii) Driving pumps in power stations.
iii) Irrigation project, fertilizer complexes.
iv) Driving compressions in the street mills, paper mills and crushers and coal ~~converg~~ conveyors.

Merits of Induction motor:

i) It is rugged, unbreakable in constructions.
ii) Simple design, low maintainance core.
iii) High overload capacity.
iv) Sufficiently efficiency, so its good.
v) Starting operation is simple.

Demerits:

i) Speed decreases with increases of load.
ii) Low power factor.
iii) Speed cannot be varied without sacrificing some of its efficiency

→ Syn. motor is a 3-ϕ electrical motor that runs only at syn speed. Therefore, a syn. motor runs either at syn. speed or not at all. While running it maintains constant speed.
→ similar to DC motor, rotating part of motor requires DC supply to generate magnetic field.

Construction of Synchronous motor:

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It is similar to d.c. machine where there is no constructional difference betⁿ generator & motor, there is no difference betⁿ construction of syn. motor & the alternator both being the syn. m/c.

The syn. motor construction is basically similar to rotating field type alternator. It consists of two parts:

i) Stator
ii) Rotor

→ similar to Induction Motion, its stationary part (stator) is connected to 3-ϕ supply.

i) Stator:

It consists of 3-ϕ star-delta connected winding. This is excited by 3-ϕ phase a.c. supply.

ii) Rotor:

Rotor field winding ~~the~~ constructions ~~at which~~ can be salient [projected pole] or non-salient [cylindrical] type. Practically, most of the syn. m/c use salient i.e. projected pole type constructions. The field winding is excited by a separate dc supply through slip-ring.

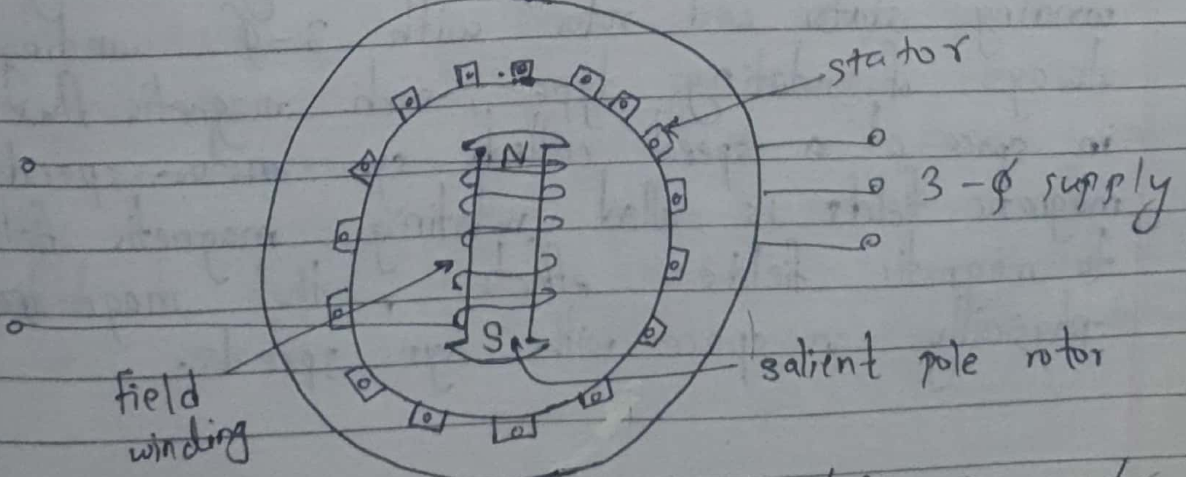

Fig: Schematic representation of three-phase syn. motor

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most imp # Working Principle of Syn. motor:-

Syn. motor works on the principle of the magnetic locking. When other two unlike poles are brought near each other, if the magnets are strong, there exists a tremendous (heavy) force of attraction betⁿ those two poles in such condition the two magnets are said to be magnetically locked.

If one of the two magnets is rotated, the other also rotates in the same directions, with same speed due to force of attractions i.e. due to magnetic locking conditions.
So that, magnetic locking condition, thee must exists unlike poles & magnetic ~~force~~ axes of two must be brought very close to each other. Let us see application of this principle in case ~~of~~ syn. motor.

Consider the 3-ϕ synchronous motor, whose stator is wound for ~~2 plates~~ 2-poles, the magnetic fields are produced in the syn. motor by exciting both the winding stator and rotor with 3-ϕ winding is always of rotating type, such magnetic flux rotated in space at a speed called syn. ~~motor~~ speed. This magnetic fields is called rotating magnetic fields. Due to magnetic fields effect, the magnetic rotates physically in space with syn. speeds.

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~~Due to magnetic fields effects, the magnet~~

The syn. speed of a stator rotating in magnetic field depends upon the supply freq. and no's of poles which stator winding is ~~upward~~ wound.

$$\boxed{N_s = \frac{120f}{P}}$$

For simplicity of understanding:-

Consider a two-pole stator, which makes in N_s & S_s & rotating at syn. speed say clockwise directions with rotor positions.

Two similar poles N [at rotor] & N_s [stator] as well as S & S_s will repel each other with results that rotor tends to rotates in the only clockwise directions, but half of period later, stator peaks, having rotated around interchange their position. i.e. N_s is at points & S_s at point A. Under this, N_s attracts S & S_s attracts N. Hence rotor tends to rotate clockwise [which is just the reverse of the first direction] so that syn. motor restores at only one speed i.e. syn. speed. We find that due to continuous and rapid rotation of stator poles, the rotor is subjected to a torque which rapidly reversing i.e. quick succession. The rotor is subjected to torque which tends to move it first in one direction and then in opposite directions.

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Now, consider the condition. The stator and rotor poles are attracting but is rotating clockwise with such a speed that it turn through one-pole pitch by the time the stator pole interchanging their position. Here again the stator & rotor poles attract each other. ~~at~~ It means that if the rotor poles also shift their position along with the stator poles. They will ~~be~~ continuously experience a unidirectional torque i.e. clockwise torque.

Uses of syn. motor:-

1) Syn. motor used for const. speed power application in size above 20 H.P. & more often in size larger than 100 H.P.

11) Typical application are fan, blowers, d.c. generator, rolling mills, flour-mills, line-shaft, air & gas-compressor rubber mills, mixers crushers, etc.

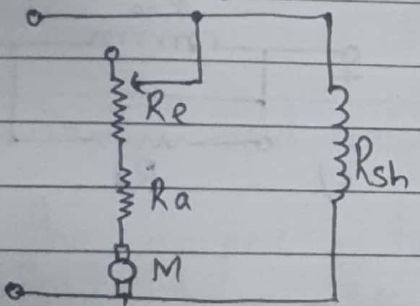
111) Useful for power-factor control & pulp [soft] grinders & refiners, use in paper making industry.

Speed Control of a D.C. motor:-

most imp (1) Variation of resistance in the armature [armature resistance control].
(2) Variation of field flux (ϕ) [field - resistance control].
(3) Variation of applied voltage.

1) Armature Resistance Control:

In this method, variable series [Re] is put in the armature ckt. The voltage applied to the armature is varied.



fig(a): speed control of dc. shunt motor by armature control

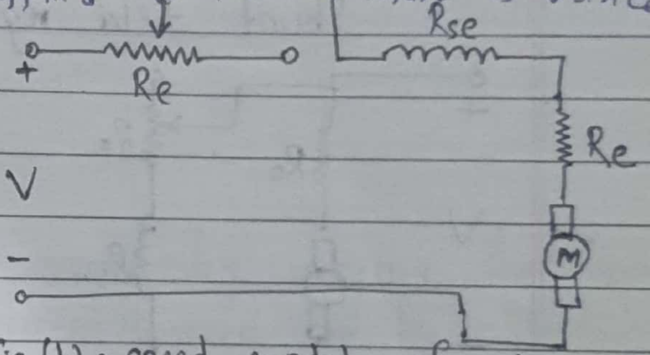


fig (b) : speed control of d.c. series motor by armature control

The simplest way to achieve this is to connect an external resistor in the armature ckt. By this method, only speed below the rated value can be obtained. As the value of external resistor is increased the speed decreases.

This method have following drawbacks:
(1) large amount of power is wasted in the external resistance Re.
(ii) Control is limited to give speeds.
(iii) The value of Re, the speed reductions is not constant but varies with motor load.
This method is useful for small motor.

Speed / current char^n:

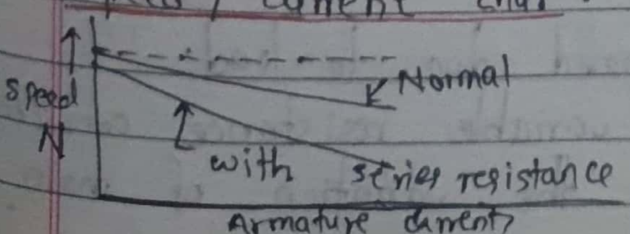


fig (a) : shunt motor

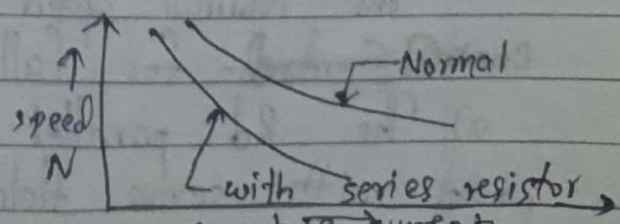


fig (b) : Series motor

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2) Variation of field ϕ [field resistant control]: Imp

Flux is produced by the field current control of speed by this method is obtained by control the field current.

In Shunt Motor:-

Connecting variable resistance [Re] in the series with shunt field winding. Re is called shunt field regulator

Shunt field regulator:-

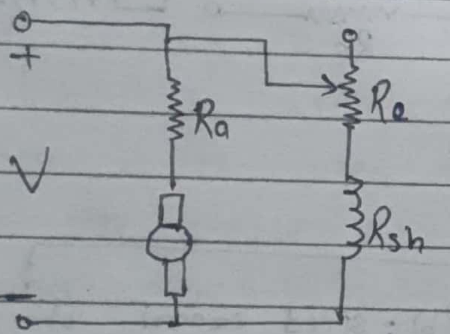


fig (a): speed control of d.c. shunt motor with ϕ field

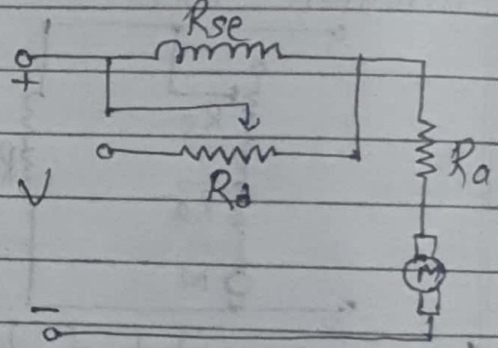


fig (b): Diverter is parallel with the series field of d.c. motor

Shunt field current, $I_{sh} = \frac{V}{R_{sht} \cdot R_e}$

The connection of Re in the field reduces the field current & hence the flux ϕ is also reduced. The reduction in flux will result in an increase in the speed. The motor runs as speed ~~for~~ higher than the Normal speed.

Control ~~Control~~ for fall the speed due to load:

a) The Rd parallel ~~variable~~ variable resistance connected parallel with series field winding the variation of main current in the series motor through the diverter [R_d]. Thus, the diverter reduces the currents flowing through the field winding. This reduces the flux or increased the speed.

b) The second method used a tapped field control.

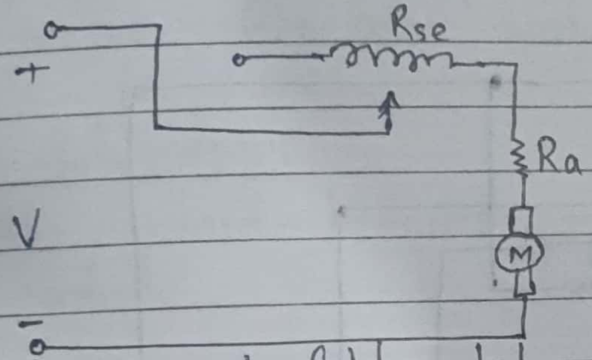
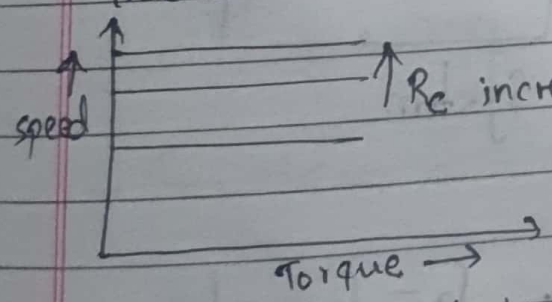
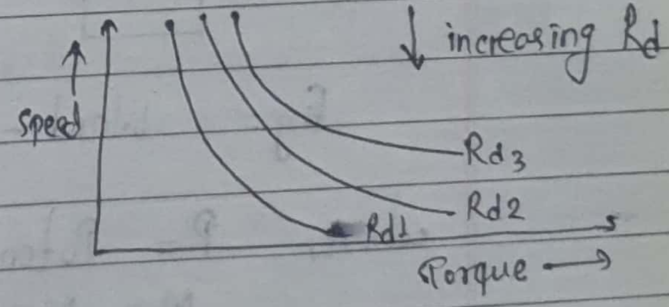


fig: Tapped field control

Here the ampere - turns are varied by varying the number of field turns. This arrangement is used ~~to~~ in electric traction.



fig(a) : speed - torque [shunt motor]



Advantages:

a) This method is easy.
b) Shunt field current (I_{sh}) is very small so power loss is small.
c) flux weakens so that speed is increasing.

3) Variation of applied Voltage:

For separately excited motors, speed control is obtained by varying the applied voltage to the armature in ward-leonard system. In this method [M] is main motor whose speed is to be controlled.

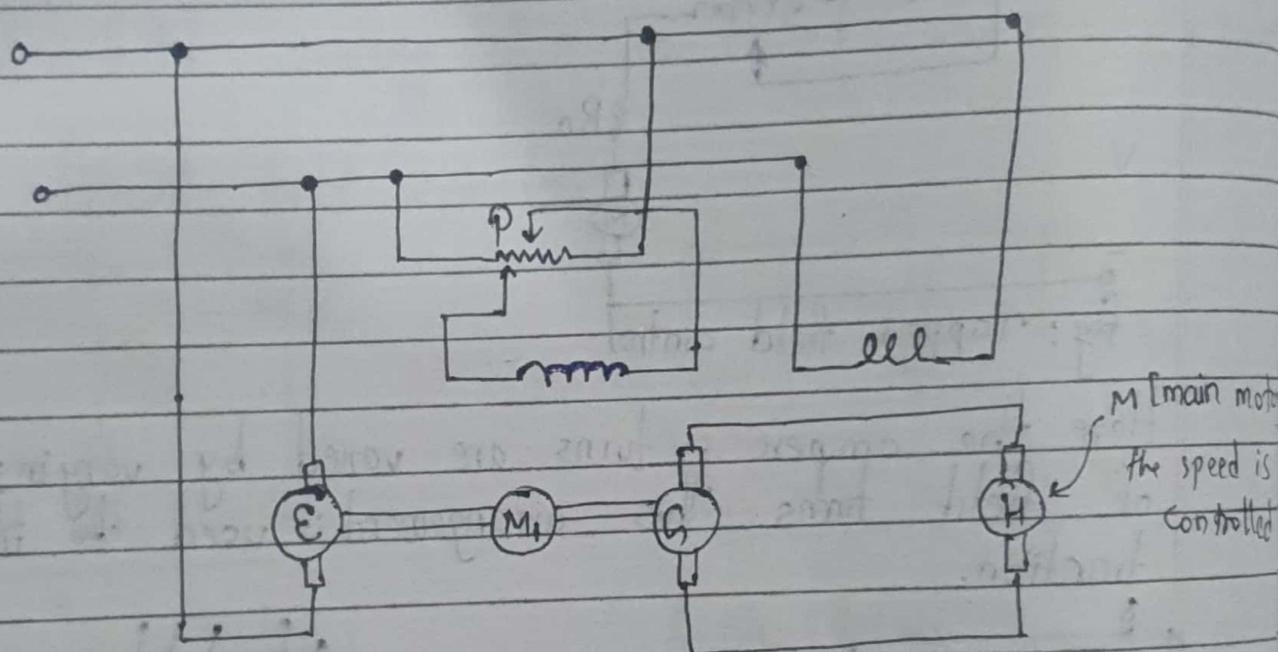


fig: Ward - leonard System

where, P = Potentiometer
M = Main motor , G = Generator
M_1 = Auxiliary motor ~~drives~~

Auxiliary motor drives the d.c. generator G. The field of G (generator) is separated ~~excited~~ from an excited E & the driving motor M_1 & the generator [G]. ~~Me~~ The purpose of small generator [E] or excited to supply voltage of generator to main motor field.

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The output of G can be varied wide range by means of potentiometer. The variable voltage when applied direct to the main motor [M]. Wide range of speed to it. Generator field current can also be reversely by the potentiometer. Thus motor can be rotated in reverse dir^n. Motor - Generator always run in same directions.

Advantage:

Ward-Leonard system offer smooth system speed control.

Drawbacks:

1) Sum of extra m/c makes the system costly.
ii) Overall efficiency is low, specially at light.
iii) Large speed range as in motor driving rolling mills, colliery winder, etc.

~~D.C. Motor Problem:~~

Numericals

Q. A 4KVA, 400/200V, 50Hz, single phase transformer has following test data:
O.C. Test [LV side] : 200V, 1A, 64 watt
S.C. Test [H.V. side] : 15V, 10A, 80 watt
(a) Determine ckt refered to L.V. sides.
(b) secondary load voltage on full-load at 0.8 p.f. lagging.

solution:

O.C. Test [L.V. side]:

Voltage $[V_0] = 200V$

No-load current $[I_0] = 1A$

No-load loss $[P_0] = 64$ watt

Now,

$P_0 = V_0 I_0 . \cos\phi_0$

$64 = 200 \times 1 \times \cos\phi_0$

$\Rightarrow \cos\phi_0 = 0.32$

$\Rightarrow \sin\phi_0 = 0.9474$

Wattfull component of no-load current:

$I_W = I_0 \cos\phi_0$

$\therefore I_W = 1 \times 0.32 = 0.32 A$

Magnetizing component of no-load current:

$I_m = I_0 \sin\phi_0 = 1 \times 0.9474$

$\therefore I_m = 0.9474 A$

Resistance representing the core loss:

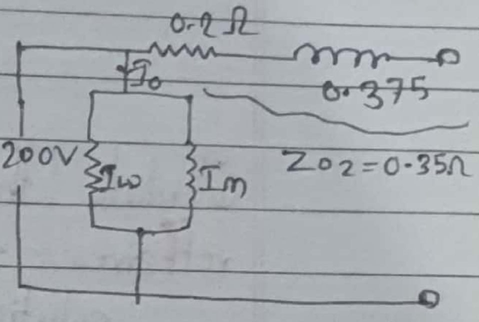
$$R_0 = \frac{V_0}{I_W} = \frac{200}{0.32} = 625\,\Omega$$

Magnetising reactance:

$$X_0 = \frac{V_0}{I_m} = \frac{200}{0.0474} = 211.1\,\Omega$$

$$X_0 = 211.1\,\Omega$$

Approximate eq ~~ckt~~:



S.C. Test [H.V. sides]:

s.c. ckt voltage $[V_{sc}] = 15\ V$

" " current $[I_{sc}] = 10\ A$

losses $[P_{sc}] = 80$ watt

Impedance of the ckt referred to H.V. side:

$$Z_{01} = \frac{V_{sc}}{I_{sc}} = \frac{15}{10} = 1.5\,\Omega$$

$$\boxed{Z_{01} = 1.5\,\Omega}$$

Also,

$$P_{sc} = I_{sc}^2 \times R_{01}$$

or $80 = 10^2 \times R_{01}$

$\Rightarrow \boxed{R_{01} = 0.8\,\Omega}$

Referred to L.V. side:

$$K = \frac{200}{400} = \frac{1}{2}$$

$$Z_{02} = K^2 \times Z_{01}$$

$$= (1/2)^2 \times 1.5$$

$$\therefore \boxed{Z_{02} = \cancel{0.2}\ 0.375\,\Omega}$$

$$R_{02} = K^2 . R_{01}$$

$$= (1/2)^2 \times 0.8$$

$$\boxed{R_{02} = 0.2\,\Omega}$$

$$X_{02} = \sqrt{Z_{02}^2 - R_{02}^2}$$

$$= \sqrt{(0.375)^2 - (0.2)^2}$$

$$\boxed{X_{02} = 0.3172\,\Omega}$$

$V_2 = 193 - j\,2.675$

Secondary load voltage = ?

$$I_2 = \frac{4 \times 10^3}{200} = 20\,A$$

$$\therefore \boxed{I_2 = 20A}$$

$\cos\phi_2 = 0.8$; $\sin\phi_2 = 0.6$

$\therefore I_2 = 20[0.8 - j0.6]$

$I_2 = 16 - j.12$

$Z_{02} = R_{02} + j\,X_{02}$

$= 0.2 + j0.3172$

Secondary load voltage

$V_2 = 193 - j\,2.0675 = 200 - I_2 . Z_{02}$

$= 200 - (16 - j.12)(0.375$

Transformer Problems

Q. A 200 kVA, 1-ϕ Transformer with a voltage ratio 6350/660 V has the following winding resistance & reactances. $R_1 = 1.56\,\Omega$

$R_2 = 0.016\,\Omega$

$X_1 = 4.67\,\Omega$

$X_2 = 0.048\,\Omega$

Calculate the resistance & reactance of the transformer reffered to the high voltage winding.

solution:

$$R_{01} = R_1 + R_2\left[\frac{N_1}{N_2}\right]^2$$

$$X_{01} = X_1 + X_2\left[\frac{N_1}{N_2}\right]$$

formula used

$$R_{01} = 1.56 + 0.016\left[\frac{6350}{660}\right]^2 = 3.04\,\Omega$$

$$X_{01} = X_1 + X_2\left[\frac{N_1}{N_2}\right]^2 = 4.67 + 0.048\left[\frac{6350}{660}\right]^2$$

$$= 9.12\,\Omega$$

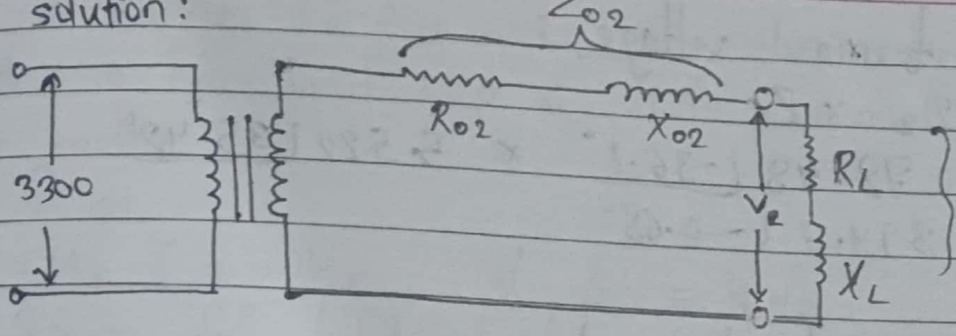
Q. 1-ϕ 3300/400 V transformers has the following winding resistance & reactance.

$R_1 = 0.7\,\Omega$ $\quad$ $R_2 = 0.011\,\Omega$

$X_1 = 3.6\,\Omega$ $\quad$ $X_2 = 0.045\,\Omega$

The secondary is connected to coil having a resistance of $4.5\,\Omega$ & inductive reactance $3.2\,\Omega$, calculate the secondary terminal voltage & the power consumed by the coil.

solution:



$Z_L = 4.5 + j\,3.2\ \Omega$

$$R_{02} = R_2 + R_1\left[\frac{N_2}{N_1}\right]^2 = 0.011 + 0.7\left[\frac{400}{3300}\right]^2$$

$$\therefore\ R_{02} = 0.0213\ \Omega$$

$$X_{02} = X_2 + X_1\left[\frac{N_2}{N_1}\right]^2 = 0.045 + 3.6\left[\frac{400}{3300}\right]^2$$

$$\therefore\ X_{02} = 0.0979\ \Omega$$

$$Z_{02} = R_{02} + X_{02} = 0.213 + j\,0.0979\ \Omega$$

$$Z_L = 4.5 + j\,3.2 = 5.522\angle 35.45^\circ$$

Total impedance in the secondary:

$$Z = Z_{02} + Z_L$$

$$= 0.0213 + j\,0.0979 + 4.5 + j\,3.2$$

$$= 4.5213 + j\,3.2979$$

$$= 5.696\angle 36.1^\circ$$

$$I_2 = \frac{400\angle 0^\circ}{Z}$$

$$I_2 = \frac{400\angle 0^\circ}{5.696\angle 36.1^\circ}$$

$$I_2 = 71.48\angle -36.1^\circ$$

Secondary terminal voltage :

$V_2 = I_2 \times Z_L$

$\doteq 72.48 \angle -36.1^\circ \times 5.522 \angle 35.42^\circ$

$= 394.7 \angle -0.68^\circ$

Power consumed by coil:

$P_L = I_2^2 \cdot R_L = (71.48)^2 \times 4.5$

$= 22992.26$ watt.

Q. A 4-pole, 3-ϕ induction motor is supplied from 50Hz supply, determine its syn. speed on full load, its speed is observed to be 1410 rmp. Calculate its full load slip.

solution:

Given data are :

$P = 4, \quad f = 50\,Hz, \quad N = 1410$ rmp

$N_s = \frac{120f}{P} = \frac{120 \times 50}{4} = 1500$ rmp.

full load absolute slip is given by

$S = \frac{N_s - N}{N_s} \cancel{\times 100}$

$= \frac{1500 - 1410}{1500} \cancel{\times 100} = 0.06$

$\therefore S = 0.06$

$\% S = 0.06 \times 100 = 6\%$

$\boxed{\% S = 6\%}$

Q. A 4-pole, 3-ϕ, 50Hz star connected induction motor has a full load slip of 4%. Calculate full-load speed of the motor.

Given,

$P = 4$, $f = 50Hz$, $\% S_{f1} = 4\%$

S_{f1} = full load absolute slip $= 0.04$

$$N_s = \frac{120f}{P} = \frac{120 \times 50}{4} = 1500 \text{ rpm}$$

Now,

$$S_{f1} = \frac{N_s - N_{f1}}{N_s}$$ where N_{f1} = full-load speed of motor

or $$0.04 = \frac{1500 - N_{f1}}{1500}$$

$\Rightarrow N_{f1} = 1440$ rpm

This is full-load speed of the motor.

D.C. Motor Problems

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Q. A 220 d.c. shunt motor draws a current at 40A at full-load & runs with speed of 1400 rpm. Calculate the value of resistance required to be inserted in the armature ckt so that speed drops to 1200 rpm at const. load. Given that $R_a = 0.02\Omega$ & $R_f = 100\,\Omega$

solution:- Given,

$I_{a1} = 40A$, $N_1 = 1400$ rpm, $V = 220V$

$N_2 = 1200$ rpm, $R_a = 0.02\,\Omega$, $R_f = 100\,\Omega$

Now,

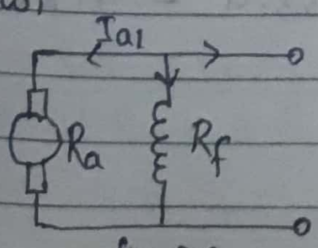


fig (a)

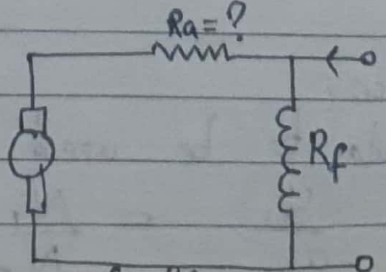


fig (b)

Note:

$\boxed{I_{a1} = I_{a2}}$

becz shunt resistor is not changed

$E_{b1} = V - I_{a1} \cdot R_a = 220 - 40 \times 0.02 = 219.2$

$E_{b2} = V - I_{a2} [R_a + R_x]$ where, R_x = unknown resistance

$= 220 - 40 [0.02 + R_x]$

$= 220 - 40 \times 0.02 - 40 R_x$

$= 219.2 - 40 R_x$

$\frac{N_1}{N_2} = \frac{E_{b1}}{E_{b2}}$ [formula used].

$\frac{1400}{1200} = \frac{219.2}{219.2 - 40 R_x}$ $\Rightarrow$ $R_x = 0.75 \Omega$

Q. A 240V shunt motor runs at 1450 rpm at full-load with armature current 11A. The total resistance of armature and brush is 0.6 ohm, if the speed to be reduced to 1000 rpm with the same armature current, calculate the value of resistance to be connected in series with the armature.

solution:

Given,

$V = 240 V$ | $R_a = 0.6 \Omega$

$N_1 = 1450$ rpm | $N_2 = 1000$ rpm.

$I_{a1} = 11$ A | $I_{a2} = 11$ A [same as earlier]

$R_x = ?$

$E_{b1} = V - I_{a1} \cdot R_a = 240 - 11 [0.6] = 233.4$

$E_{b2} = V - I_{a2} [R_a + R_x] = 240 - 11 [0.6 + R_x]$

$= 233.4 - 11 R_x$

Now,

formula to be used is

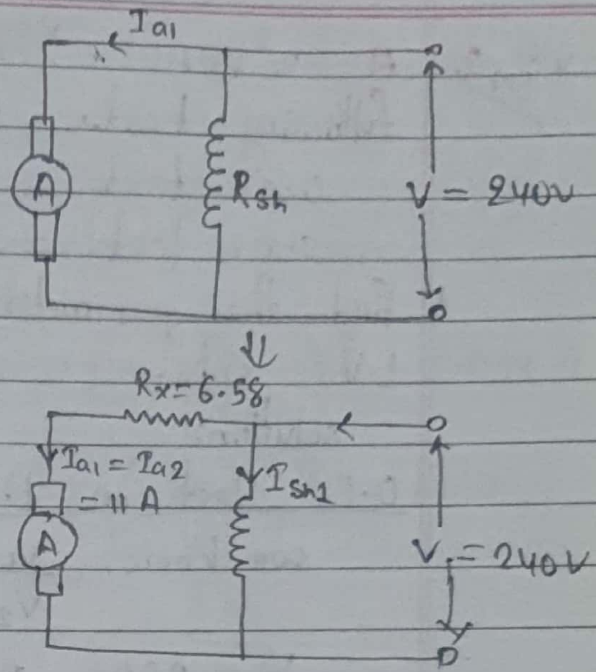
$$\frac{E_{b1}}{E_{b2}} = \frac{N_1}{N_2}$$

or $\dfrac{233.4}{233.4 - 11R_x} = \dfrac{1450}{1000}$

or $233400 = 1450\,[233.4 - 11R_x]$

or $160.96 - 233.4 = -11R_x$

$\Rightarrow \boxed{R_x = 6.58\,\Omega}$



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Q. A 220V dc shunt motor runs with 1000 rpm & an armature current of 40A. The resistance of armature is 0.5Ω, calculate the value of resistance to be centred in series so that the speed drops to 600 rpm.

Given data,

$V = 220V$, $N_1 = 1000$ rpm, $I_{a1} = 40A = I_{a2}$

$R_a = 0.5\,\Omega$, $N_2 = 600$ rpm, R_x = unknown resistance

Now,

$E_{b1} = V - I_{a1}R_a = 220 - 40 \times 0.5 = 200V$

$E_{b2} = V - I_{a2}[R_a + R_x] = 220 - 40[0.5 + R_x]$

$= 200 - 40R_x$

So,

$\dfrac{E_{b1}}{E_{b2}} = \dfrac{N_1}{N_2}$

$\Rightarrow \dfrac{200}{200 - 40R_x} = \dfrac{1000}{600}$

fig. as above

$\Rightarrow \boxed{R_x = 2\,\Omega}$

Transformer

VV Imp Q. A 20 kVA, 200/100 A, 1-ϕ transformer gives the following test result.

o.c. test = 200V, 100A, 120 watt [H.V. side]

s.c. test = 25V, 35A, 320 watt [L.V side]

Find the parameters of equivalent ckt as refered to L.V. side.

solution:

O.C. Test on L.V. side :

we know, $\frac{V_1}{V_2} = \frac{N_1}{N_2} = \frac{200}{400}$ [Transformation ratio]

$V_1 = 200$, $I_0 = 100A$, $w = 120$ watt

$\therefore \cos\phi = \frac{W}{V_1 \cdot I_0} = 0.006$

$\sin\phi = \sqrt{1-\cos^2\phi_0} = \sqrt{1-(0.006)^2} = 0.9999$

$I_m = I_0 \sin\phi_0 = 99.99$ A

$I_w = I_0 \cos\phi_0 = 0.6$ A

$X_{01} = \frac{V_1}{I_m} = \frac{200}{99.99} = 2.0\ \Omega$

$R_{01} = \frac{V_1}{I_w} = \frac{200}{0.6} = 333.3\ \Omega$

S.C. Test on H.V. side :

$V_{sc} = 25V$, $I_{sc} = 35A$, $W_{sc} = 220$ watt

$R_{eq} = \frac{W_{sc}}{(I_{sc})^2} = \frac{220}{(35)^2} = 0.179\ \Omega$

$Z_{eq} = \frac{V_{sc}}{I_{sc}} = \frac{25}{35} = 0.71\ \Omega$

$X_{eq} = \sqrt{Z_{eq}^2 - R_{eq}^2} = \sqrt{(0.71)^2 - (0.179)^2}$

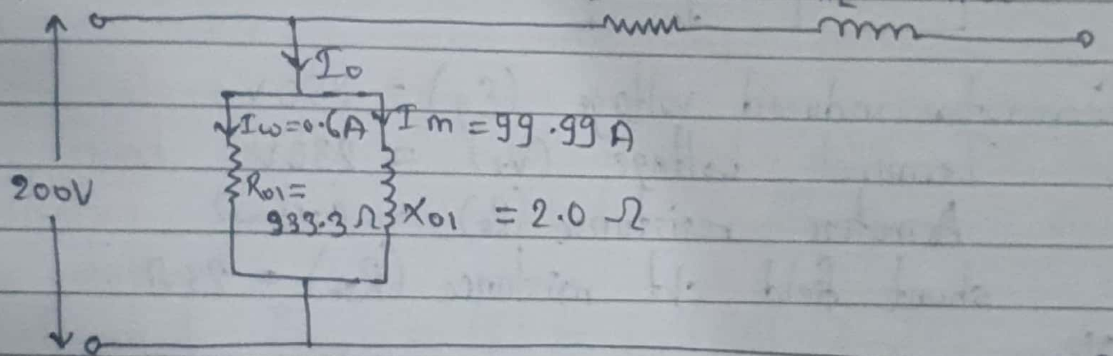
$\therefore X_{eq} = 0.68\ \Omega$

So, required parameter of eq. ckt, resistance & reactance refered to L.V. side:

$R_L = R_{eq}\left(\frac{N_1}{N_2}\right)^2 = 0.179 \times \left(\frac{200}{400}\right)^2 = 0.044\ \Omega$

$X_L = X_{eq}\left(\frac{N_1}{N_2}\right)^2 = 0.68 \times \left(\frac{200}{400}\right)^2 = 0.17\ \Omega$

Eq. ckt:



Q. A 4-pole d.c. shunt generator with lap-connected armature supplied a load of 100A at 200V. The armature resistance is $0.1\ \Omega$ & the shunt field resistance is $80\ \Omega$. Find the total armature current & emf generated:

solution:

Terminal voltage $(V_t) = 200V$

Load current $(I_L) = 100\ A$

armature resistance $(R_a) = 0.1\ \Omega$

Shunt field resistance $(R_{sh}) = 80\ \Omega$

Shunt field current $(I_{sh}) = \frac{V_t}{R_{sh}} = \frac{200}{80} = 2.5\ A$

Armature current $(I_a) = I_L + I_{sh}$

$= 100 + 2.5 = 102.5$ amp

Generated emf (E_g)

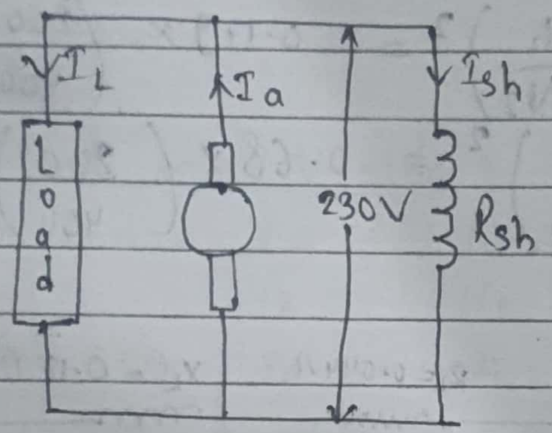
$= V + I_a R_a$

$= 200 + 102.5 \times 0.1$

$= 210.25\ V$

Q. A shunt generator has induced voltage of 250V, when the m/c is loaded. The terminal voltage drops down to 230V. Determine the load current if the armature resistance is 0.05 Ω & the field ckt resistance is 23 Ω.

solution:



$I_a = I_{sh} + I_L$

Generator induced voltage $(E_g) = 250V$

Terminal voltage $(V_t) = 230V$

Armature resistance $(R_a) = 0.05\,\Omega$

shunt field ckt resistance $(R_{sh}) = 23\,\Omega$

Now,

Armature current $(I_a) = \dfrac{E_g - V_t}{0.05} = 400$ amp

shunt field current $(I_{sh}) = \dfrac{V_t}{R_{sh}} = \dfrac{230}{23} = 10$ A

Armature current $(I_a) = I_L + I_{sh}$

$\therefore I_a - I_{sh} = I_L$

$\therefore I_L = 400 - 10 = 390$ amp

Transformer formula:

1) Equivalent resistance refered to primary $R_{eq} = R_1 + \left(\frac{N_1}{N_2}\right)^2 \cdot R_2$

2) Equivalent ~~resistance~~ reactance refered to primary $X_{eq} = X_1 + \left(\frac{N_1}{N_2}\right)^2 \cdot X_2$

3) Equivalent resistance referred to secondary $R_{eq}' = R_2 + \left(\frac{N_2}{N_1}\right)^2 \cdot R_1$

4) Equivalent ~~resistance~~ reactance referred to secondary $X_{eq}' = X_2 + \left(\frac{N_2}{N_1}\right)^2 \cdot X_1$

Overall Chapter Numericals

R-L, R-C & R-L-C series ckt Additional Problems

1) A resistance & inductance are connected in series across the voltage $v = 283 \sin 314t$. An expression of current is found to be $i = 4 \sin(314t - 45°)$. Find the value of resistance, ~~reactance~~ inductance & power factor.

solution:

Supplied frequency $(f) = \frac{\text{coeff. of time}(t)}{2\pi} = \frac{314}{2\pi} = 50\ Hz$

R.M.S. value of applied voltage $(V) = \frac{V_{rms}}{\sqrt{2}} = \frac{283}{\sqrt{2}} = 200.11V$

RMS value of current $(I) = \frac{I_{rms}}{\sqrt{2}} = \frac{4}{\sqrt{2}} = 2.82A$

Phase angle $(\phi) = 45°$ lagging

Impedance of the ckt:

$Z = \frac{V}{I} = \frac{200.11}{\sqrt{2}} = 70.75\ \Omega$

Resistance of the ckt:

$X_L = Z \cos\phi = 70.75 \cos 45° = 50\ \Omega$

Reactance of the ckt :

$X_L = Z \sin\phi = 70.75 \cos 45° = 50\ \Omega$

$X_L = 2\pi f L$

$50 = 2\pi \times 50 \times L$

$\therefore L = 0.159 H$

Power factor :

$pf = \cos\phi = \cos[45°] = 0.707$ lagging

2) If the load draws a current of 10A at 0.8 pf lagging when connected to 100V supply, calculate the value of real reactive & apparent power. Also find the resistance of load.

solution:

Supply voltage $(V) = 100V$

Current $(I) = 10A$

$pf = \cos\phi = 0.8$ (lagging)

Phase angle $(\phi) = \cos^{-1}(0.8) = 36.87$ (lagging)

Real power $(P) = VI\cos\phi$

$= 100 \times 10 \times 0.8 = 800$ watt

Reactive power $(Q) = VI\sin\phi$

$= 100 \times 10 \times \sin(36.87°)$

$= 600$ VAR (lagging)

Apparent power $(S) = \sqrt{P^2 + Q^2}$

$= \sqrt{800^2 + 600^2} = 1000$ VA

Load impedance $(Z) = \frac{V}{I} = \frac{100}{10} = 10\ \Omega$

Resistance of load $(R) = Z\cos\phi = 10 \times 0.8 = 8\ \Omega$

3) A voltage $v(t) = 170 \sin(377t + 10^\circ)$ is applied to a ckt it causes a steady state current to ~~find~~ flow which is described by $i(t) = 14.14 \sin(377t - 20^\circ)$. Determine the variation of instantaneous power. Also find the avg. power delivered to ckt & power factor.

solution:

$v(t) = 170 \sin(377t + 10^\circ)$

$i(t) = 14.14 \sin(377t - 20^\circ)$

$V_{max} = 170V$

$I_{max} = 14.14A$

Phase Angle $(\phi) = 10^\circ - (-20^\circ)$

$= 30^\circ$ (lagging)

Variation of instantaneous power $= \frac{1}{2} V_{max} \cdot I_{max} \cdot \cos(2\omega t - \phi)$

$= \frac{1}{2} \times 170 \times 14.14 \times \times \cos(2 \times 377t - 30^\circ)$

$= 1.202 \cdot \cos[754t - 30^\circ]$

Average power delivered,

$P = V_{rms} \times I_{rms} \times \cos\phi$

$= \frac{170}{\sqrt{2}} \times \frac{14.14}{\sqrt{2}} \times \cos 3^\circ$

$= 1.041$ watt

4) A voltage $v(t) = 150 \sin(2\pi f)t$, 50Hz is applied to series ckt considering of 10Ω resistance, 0.0318H inductance. Determine :
(a) the current $i(t)$ expression
(b) phase angle bet^n voltage & current
(c) pf . (d) active power consumed
(e) max^m value pulsating energy.

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solution:

$v(t) = 150 \sin(2\pi f)t$

$= 150 \sin(2\pi \times 50)t$

$= 150 \sin(100\pi)t$

Resistance (R) $= 10\,\Omega$

Inductance (L) $= 0.0318\ H$

Inductive reactance $(X_L) = 2\pi f \cdot L = 2\pi \times 50 \times 0.0318 = 10\,\Omega$

Phase angle $(\phi) = \tan^{-1}\left(\frac{X_L}{R}\right) = \tan^{-1}\left(\frac{10}{10}\right) = 45^\circ$ or $\frac{\pi}{4}$ (lagging)

Ckt impedance $(Z) = \sqrt{R^2 + X_L^2} = \sqrt{10^2 + 10^2} = 14.142$

Max^m value of currents $(I_{max}) = \frac{V_{max}}{Z} = \frac{150}{14.142} = 10.6A$

(a) The current i(t) expression $i(t) = I_{max} \cdot \sin[100\pi t - \phi]$

$= 10.6 \times \sin[100\pi \cdot t - \pi/4]$

(b) Phase angle bet^n voltage & current

$\phi = \frac{\pi}{4} = 45^\circ$ (lagging)

(c) pf $= \cos\phi = \cos 45^\circ = 0.707$ lagging

(d) Active power consumed $= VI\cos\phi$

$= \frac{V_{max}}{\sqrt{2}} \times \frac{I_{max}}{\sqrt{2}} \times 0.707$

$= \frac{150}{\sqrt{2}} \times \frac{10.6}{\sqrt{2}} \times 0.707$

$= 562$ watt

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(e) Max^m value pulsating energy

$$= \frac{1}{2} V_{max} \cdot I_{max} = \frac{1}{2} \times 150 \times 10 \cdot 6$$

$$= 79.5 \text{ VA}$$

5) A 50Hz sinusoidal voltage = 311 sinωt is applied to RL-series ckt. If the magnitude of resistance is 5Ω & that of inductance is 0.02 H:

(a) calculate the effective value of steady current & relative phase angle.

(b) obtain the expression for instantaneous value.

solution:

Peak value of applied voltage:

$$V_{max} = 311V$$

Rms value of applied voltage

$$V_{rms} = \frac{V_{max}}{\sqrt{2}} = \frac{311}{\sqrt{2}} = 219.91 V$$

Resistance of ckt:

$$R = 5\Omega$$

Inductive reactance of ckt:

$$X_L = 2\pi f \cdot L = 2\pi \times 50 \times 0.02 = 6.28\Omega$$

Impedance of the ckt:

$$Z = \sqrt{R^2 + X_L^2} = \sqrt{5^2 + 6.28^2} = 8.03\Omega$$

(a) Effective value of steady current:

$$I_{rms} = \frac{V_{rms}}{Z} = \frac{219.91}{8.03} = 27.387 \text{ A}$$

$$\text{Phase angle } (\phi) = \tan^{-1}\left(\frac{X}{R}\right) = \tan^{-1}\left(\frac{6.28}{5}\right) = 51.474$$

(lagging)

Since, in R-L ckt current lags behind the applied voltage

(b) $i = I_{max} \cdot \sin(\omega t - \phi)$

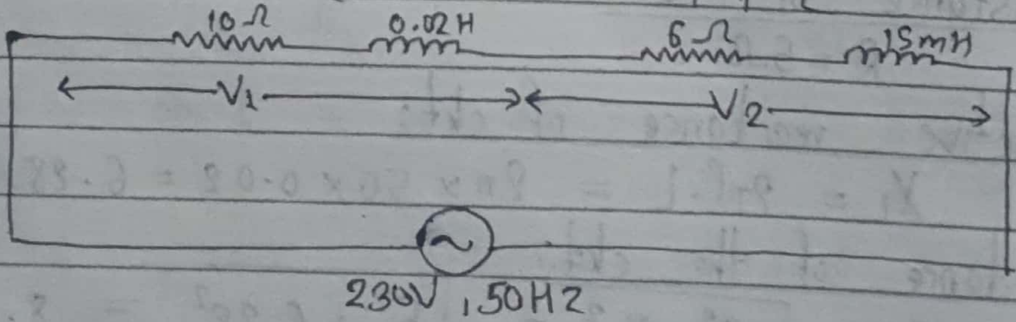
$= 27.387 \times \sqrt{2} \sin(\omega t - 51.474^\circ)$

$= 38.73 \sin(\omega t - 51.474^\circ)$

6) A coil of resistance 10Ω & inductance $0.02H$ is connected in series with another coil of resistance 6Ω & inductance $15mH$ across a 230V, 50Hz supply, calculate
(a) Impedance of the ckt
(b) voltage drop across each coil
(c) total power consumed by the ckt.

solution:

$R = 10\Omega$	$R = 6\Omega$
$L = 0.02H$	$L = 15\ mH = 15\times10^{-3}H$
$X_L = 2\pi f.L$	$X_L = 2\pi f.L$
$= 2\pi\times50\times0.02$	$= 2\pi\times50\times15\times10^{-3}$
$= 6.28\ \Omega$	$= 4.71\ \Omega$



$Z_1 = (10 + j\,6.28)\Omega = 11.81\angle 32.14^\circ$

$Z_2 = (6 + j\,4.71)\Omega = 7.629\angle 38.14^\circ$

(a) Impedance of whole ckt:

$Z = Z_1 + Z_2 = (10 + j\,6.28) + (6 + j\,4.71)\ \Omega$

$= (16 + j\,10.99)\ \Omega$

$= 19.414\angle 34.5^\circ\ \Omega$

Current through the ckt:

$$I = \frac{V}{Z} = \frac{230 \angle 0^\circ}{19.41 \angle 34.5^\circ} = 11.847 \angle -34.5^\circ$$

(b) Voltage drop across coil-1:

$$V_1 = I Z_1 = 11.847 \angle -34.5^\circ \times 11.81 \angle 32.14^\circ$$
$$= 139.9 \angle -2.36^\circ$$

Voltage drop across coil-2:

$$V_2 = I Z_2 = 11.847 \angle -34.5^\circ \times 7.629 \angle 38.14^\circ$$
$$= 90.38 \angle -2.36^\circ \text{ V}$$

(c) total power consumed by the ckt:

$$P = VI \cos\phi = 230 \times 11.847 \times \cos 34.5^\circ$$
$$= 2246 \text{ watt} = 2.246 \text{ kW}$$

or,

Total power consumed by the ckt:

$$P = I^2 [R_1 + R_2]$$
$$= 11.847^2 [10 + 6] = 2246 \text{ watt}$$
$$= 2.246 \text{ kW}$$

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7) Two coil A & B are connected in series across 240V, 50Hz supply. The resistance of A & B is 5Ω & the Inductance of B is 0.015H. If input of supply is 3kW or 2kVAR. Find the inductance of A & resistance of B. Calculate the voltage across each coil.

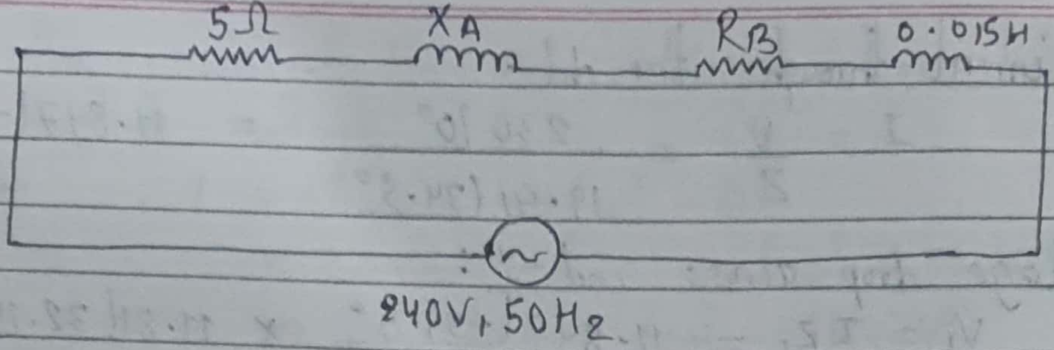
solution:

Input true power $(P) = 3\text{ kW}$

Input reactive power $(Q) = 2\text{ kVAR}$

Input apparent power $(S) = \sqrt{P^2 + Q^2}$

$$= \sqrt{3^2 + 2^2} = 3.606 \text{ kVA}$$



Ckt current:

$$I = \frac{S \times 1000}{V} = \frac{3.606 \times 1000}{240}$$

$$\therefore I = 15.025\ A$$

Total resistance of the ckt:

$$P = I^2 R_T$$
$$R_T = \frac{P}{I^2}$$

$$R_T = R_A + R_B = \frac{P}{I^2} = \frac{3 \times 1000}{(15.025)^2} = 13.29\,\Omega$$

Resistance of coil - B:

$$R_B = R_T - R_A = 13.29 - 5 = 8.29\,\Omega$$

Impedance of the ckt:

$$Z = \frac{V}{I} = \frac{240}{15.025} = 15.97\,\Omega$$

Total inductive reactance of the ckt:

$$X_{LT} = \sqrt{Z^2 - R_T^2}$$
$$= \sqrt{(15.97)^2 - (13.29)^2}$$
$$= 8.86\,\Omega$$

$$Z^2 = R_T^2 + X_{LT}^2$$

Inductive reactance of the coil - A:

$$X_A = X_{LT} - X_B$$
$$= 8.86 - 2\pi f L$$
$$= 8.86 - 314 \times 0.015$$
$$= 4.15\,\Omega$$

$$X_B = X_L = 2\pi f L$$
$$= 314 \times 0.015$$

Inductance of coil - A:

$\cancel{2\pi f}\, X_L = X_A$

$\therefore X_A = X_L = 2\pi f \cdot L$

$\Rightarrow L = \frac{X_A}{2\pi f} = \frac{4.15}{314}$ $[X_A = 4.15]$

$\Rightarrow L = 0.0132\ H$

Voltage across coil - A:

$V_A = I \times Z_A = I\sqrt{R_A^2 + X_A}$ $[Z_A = \sqrt{R_A^2 + X_A}]$

$= 15.025\sqrt{5^2 + 4.15^2}$

$= 97.63\ V$

Voltage across coil - B:

$V_B = I \times Z_B = I \times \sqrt{R_B^2 + X_B^2}$

$= 15.025 \times \sqrt{8.29^2 + 4.71^2} = 143.25V$

8) For a.c. ckt, the voltage & current are given by

$V = (200 \sin 377t)\ V$

$I = 8 \sin(377t - 30^\circ)$ amp

Determine the power factor, true power, apparent power & reactive power of the ckt. Also cross verify by Power Triangle.

solution:

$V = 200 \sin 377t\ v$

$I = 8 \sin(377t - 30^\circ)\ A$

Phase angle $(\phi) = 30^\circ$

RMS value of applied voltage:

$V = \frac{V_{max}}{\sqrt{2}} = \frac{200}{\sqrt{2}} = 141.42\ V$

RMS value of current:

$$I = \frac{I_{max}}{\sqrt{2}} = \frac{8}{\sqrt{2}} = 5.65\,A$$

(a) Power factor = $\cos\phi = \cos 30^\circ = 0.866$ (lagging)

(b) True power (P) = $VI\cos\phi$

$= 141.42 \times 5.65 \times 0.866$

$= 692.82$ watt

(c) Apparent power (S) = $VI = 141.42 \times 5.65$

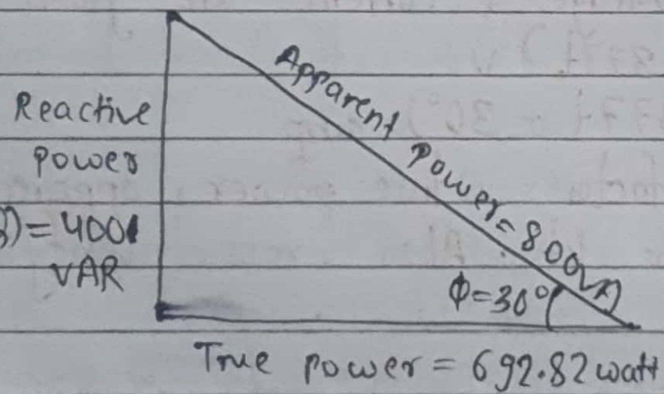
$= 800$ VA

(d) Reactive power (Q) = $VI\sin\phi$

$= 141.42 \times 5.65 \times \sin 30^\circ$

$= 400$ VAR

By Power triangle:



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

$$= \sqrt{(692.82)^2 + (400)^2}$$

$$= 800\ VA$$

~~Phange~~ Phase angle

$$\phi = \tan^{-1}\left(\frac{Q}{P}\right)$$

$$= \tan^{-1}\left(\frac{400}{692.82}\right)$$

$$= 30^\circ$$

9) The voltage applied to the ckt is $v = 100\sin(\omega t + 30^\circ)$ & current flowing in the ckt is $i = 20\sin(\omega t + 60^\circ)$. Determine the impedance, resistance, reactance, power & power factor of the ckt.

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solution:

$V = 100 \sin(\omega t + 30^\circ)$ → Voltage applied to the ckt
$i = 20 \sin(\omega t + 60^\circ)$ → current flowing in the ckt

Current leads the applied voltage by $[60^\circ - 30^\circ]$ i.e. 30°

Ckt impedance $(Z) = \frac{V_{max}}{I_{max}} = \frac{100}{20} = 5\Omega$

ckt Resistance $(R) = Z\cos\phi = 5 \times \cos 30^\circ = 4.33\Omega$
ckt Reactance $(X) = Z\sin\phi = 5 \times \sin 30^\circ = 2.5\Omega$ [capacitive]

Pf $= \cos\phi = \cos 30^\circ = 0.866$ [lagging]

Power ~~factor~~ of ckt $(P) = V_{rms} \cdot I_{rms} \cos\phi$

$= \frac{V_{max}}{\sqrt{2}} \cdot \frac{I_{max}}{\sqrt{2}} \cdot \cos\phi$

$= \frac{100}{\sqrt{2}} \times \frac{20}{\sqrt{2}} \times \cos 30^\circ$

$\therefore \boxed{P = 866 \text{ watt}}$

10) A supply of 400V, 50Hz is applied to a series R.C. ckt. Find the value of C. If the power absorbed by the resistor be 500 watt at 150V. What is the energy stored in capacitor?

solution:

$V = 400V$ Voltage across resistor $(V_R) = 150V$
$P = 500$ watt

Current through R.C. series ckt:

$I = \frac{P}{V_R}$ $[\because P = I \cdot V_R]$

$= \frac{500}{150} = 3.33A$

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$V^2 = V_R^2 + V_C^2$

$V_C = \sqrt{V^2 - V_R^2}$

Voltage drop across capacitor:

$$V_C = \sqrt{400^2 - 150^2}$$

$$\therefore \boxed{V_C = 370 \cdot 8V}$$

Capacitive reactance of the ckt:

$$X_C = \frac{V_C}{I} \qquad \because V_C = I \cdot X_C$$

$$\therefore X_C = \frac{310 \cdot 8}{3 \cdot 33} = 111 \cdot 30 \Omega$$

Capacitance of ckt:

$$C = \frac{1}{2\pi f \cdot X_C} = \frac{1}{314 \times 111 \cdot 30}$$

$$\Rightarrow C = 28 \cdot 6 \mu F$$

$$\left[\because X_C = \frac{1}{\omega C} \Rightarrow C = \frac{1}{\omega \cdot X_C} \right]$$

Energy stored at capacitive:

$$= \frac{1}{2} C \times V_{C max}^2$$

$$= \frac{1}{2} \times 28 \cdot 6 \times 10^{-6} \times (370 \cdot 9 \times \sqrt{2})^2$$

$$= 3 \cdot 934 \text{ J}$$

11) A series ckt has $R = 10 \Omega$, $L = 50$ mH & $C = 100 \mu F$ & supply is 200V, 50 Hz, find

(a) Impedance
(b) Current
(c) Power
(d) pf
(e) voltage drop across each elements.

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solution:

$R = 10\,\Omega$; $L = 50mH = 0.05H$; $C = 100\mu F = 10^{-4}F$

Inductive reactance of ckt:

$$X_L = 2\pi f \cdot L = 2\pi \times 50 \times 0.05$$
$$= 15.7\,\Omega$$

Capacitive reactance of ckt:

$$X_C = \frac{1}{2\pi f \cdot C} = \frac{1}{2\pi \times 50 \times 10^{-4}}$$
$$= 31.83\,\Omega$$

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

$$= \sqrt{(10)^2 + (15.7 - 31.83)^2}$$
$$= 18.979\,\Omega$$

(b) ckt current $(I) = \frac{V}{Z} = \frac{200}{18.979} = 10.538\,A$

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

$$= \tan^{-1}\left(\frac{15.7 - 31.83}{10}\right) = -58.2^\circ$$

(c) Power of ckt:

$$P = VI\cos\phi$$
$$= 200 \times 10.53 \times \cos(-58.2^\circ)$$
$$= 1110.61 \text{ watt}$$

(d) $pf = \cos\phi$

$$= \cos(-58.2^\circ) = 0.529 \text{ leading}$$

(e) Voltage drop across ~~resistance (R)~~ each elements:

$V_R = IR = 10.53 \times 10 = 105.38V$

$V_L = I \cdot X_L = 10 \times 15.7 = 157\,V$

$V_C = I \cdot X_C = 10 \times 31.38 = 313.8V$

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12) A voltage $v(t) = 150 \sin 1000t$ is applied across a series RLC ckt where, $R = 40\,\Omega$, $L = 0.13H$, $C = 10\mu F$.
(a) compute rms value of steady state current
(b) find rms voltage across the inductor.
(c) find rms voltage across capacitor.
(d) draw phasor diagram showing all voltage component
(e) Determine the reactive power supply by source.

solution:

$V_{max} = 150V$

$\omega = 1000\ rad/sec$

RMS value of supply voltage

$$V_{rms} = \frac{V_{max}}{\sqrt{2}} = \frac{150}{\sqrt{2}} = 106V$$

$R = 40\Omega$

$X_L = 2\pi f \cdot L = \omega L = 1000 \times 0.13 = 130\Omega$

$$X_C = \frac{1}{\omega C} = \frac{1}{1000 \times 10 \times 10^{-6}} = 100\,\Omega$$

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

$$= \sqrt{(40)^2 + (130-100)^2}$$

$\therefore Z = 50\,\Omega$

(a) RMS value of steady state current:

$$I_{rms} = \frac{V_{rms}}{Z} = \frac{106}{50} = 2.12A$$

$$\text{Phase angle } \phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right) = \tan^{-1}\left[\frac{130-100}{40}\right]$$

$\phi = 36.87°$ lagging

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(a) Voltage across ~~inductor~~ resistance (R):

$V_R = I_{rms} \times R = 2.12 \times 40 = 84.8V$ in phase with I

(b) Voltage drop across inductor (L):

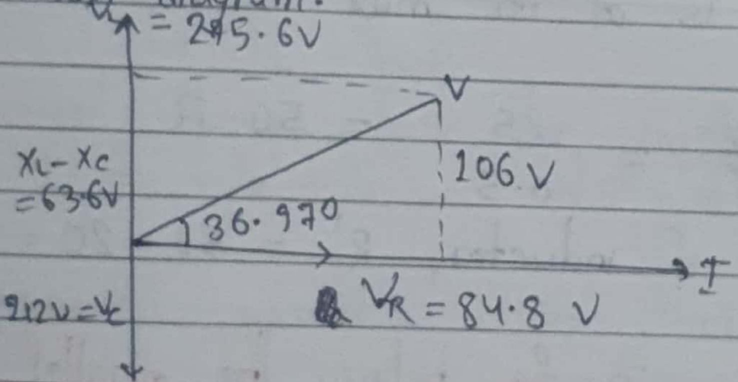
$V_L = I_{rms} \times X_L = 2.12 \times 130 = 275.6V$ leading current I by 90°

(c) Voltage drop across capacitor (C):

$V_C = I_{rms} \times X_C = 2.12 \times 100$

$= 212\ V$ lagging current I by 90°

(d) Phasor diagram:



13) A 20 Ω resistor is connected ~~to~~ in series with an inductor, a capacitor & ammeter across a 25V variable freq supply when the freq. is 400Hz, the current is at its maximum value of 0.5A & potential difference across the capacitor is 150V, calculate (a) the capacitance of capacitor. (b) the resistance & inductance of inductor.

solution:

Voltage drop across capacitor C,

$V_C = 150V$

Current through capacitor,

I = supply current = 0.5 A

(a) Capacitance (C) $= \dfrac{1}{2\pi f \cdot V_c} = \dfrac{1}{2\pi \times 400 \times 150} = 1.326\ \mu F$

Since current is at its max^m value, reactance is zero.

Inductive reactance of ckt = capacitive reactance of ckt

$\Rightarrow X_L = X_c$

or $2\pi f_0 L = \dfrac{1}{2\pi f_0 C}$

$\Rightarrow L = \dfrac{1}{4\pi^2 f^2 \cdot C} = \dfrac{1}{4\pi^2 \times (400)^2 \times \cancel{150}\ 1.32 \times 10^{-6}}$

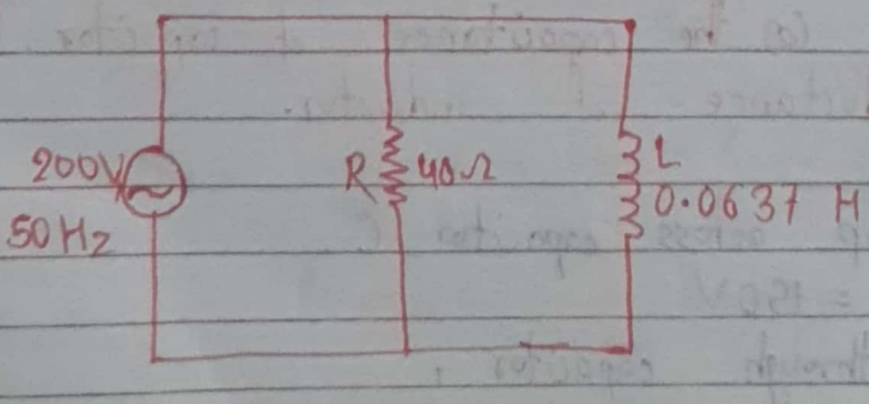
$\cancel{\Rightarrow L = 1.326\ \mu F}$ $\Rightarrow L = 0.1193 H$

~~Since current is at its max^m value, reactance is zero~~

$R = \dfrac{V}{I} = \dfrac{25}{0.5} = 50\ \Omega$

So, resistance of inductor, $R' = 50 - 20 = 30\ \Omega$

14) The ckt shown in fig below, the parallel R-L arrangement connected across 200 volts, 50Hz ac supply. Calculate: (a) current drawn from supply (b) apparent power, (c) real power, (d) reactive power



solution:

Resistance of ~~reactive~~ resistive branch:

$$R = 40\Omega$$

Inductive reactance of inductive branch:

$$X_L = 2\pi f \cdot L = 2\pi \times 50 \times 0.0637 = 20\,\Omega$$

Current drawn by resistive branch:

$$I_R = \frac{V}{R} = \frac{200}{40} \qquad \therefore V = I_R \cdot R$$

$$\therefore I_R = 5A$$

Current drawn by inductive branch:

$$I_L = \frac{V}{X_L} = \frac{200}{20} \qquad \because V = I_L \cdot X_L$$

$$\Rightarrow I_L = 10\,A$$

(a) Current drawn from the supply:

$$I = \sqrt{I_R^2 + I_L^2} = \sqrt{5^2 + 10^2} = 11.18 \text{ amp}$$

(b) Apparent power: $S = V \times I$

$$= 200 \times 11.18 = 2236 \text{ VA}$$

(c) Real power, $P = V \cdot I_R = 200 \times 5$

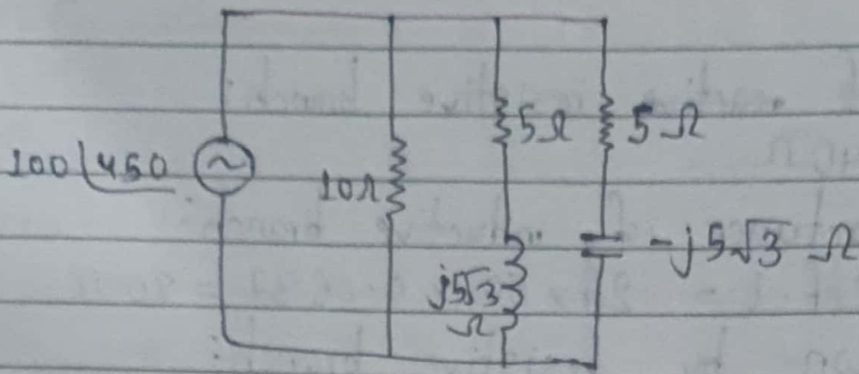
$$= 1000 \text{ watt}$$

(d) Reactive power, $Q = V \cdot I_L$

$$= 200 \times 10$$

$$= 2000 \text{ VAR}$$

15) Consider an electric ckt shown in fig. below, determine
(a) the current & power consumed in each branch.
(b) the supply current & p.f.



solution:

$$I_1 = \frac{V}{R} = \frac{100\angle 45^\circ}{10\angle 0^\circ} = 10\angle 45^\circ \text{ A}$$

Current in inductive branch:

$$I_2 = \frac{V}{Z_2} = \frac{100\angle 45^\circ}{5 + j\,5\sqrt{3}} = \frac{100\angle 45^\circ}{10\angle 60^\circ} = 10\angle -15^\circ$$

Current in capacitive branch:

$$I_3 = \frac{V}{Z_3} = \frac{100\angle 45^\circ}{5 - j\,5\sqrt{3}} = \frac{100\angle 45^\circ}{10\angle -60^\circ} = 10\angle 105^\circ$$

Power consumed in resistive branch:

$$P_1 = I_1^2 R = 10^2 \times 10 = 1000 \text{ W} = 1 \text{ kW}$$

Power consumed in inductive branch:

$$P_2 = I_2^2 R_2 = 10^2 \times 5 = 500 \text{ watt}$$

Power consumed in capacitive branch:

$$P_3 = I_3^2 \cdot R_3 = 10^2 \times 5 = 500 \text{ watt}$$

Supply current:

$$I = I_1 + I_2 + I_3 = 10\angle 45^\circ + 10\angle -15^\circ + 10\angle 105^\circ$$
$$= (7.0 + j\,7.0) + (9.6 - j\,2.5) + (-2.5 + j\,9.6)$$
$$= (14.14 + j\,14.14) \text{ A}$$
$$= 20\angle 45^\circ \text{ A}$$

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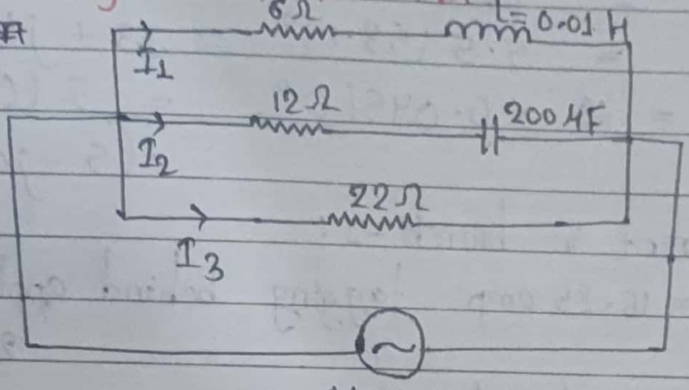
16) For ckt shown in fig below, (a) calculate the current in each branch (b) total current taken, (c) total power consumed by ckt (d) Reactive power consumed / generated (e) p.f of the ckt. (f) phasor diagram of the ckt.

~~solution~~



solution:

$X_L = 2\pi f \cdot L = 2\pi \times 50 \times 0.01 = 3.14$

$Z_1 = R_1 + jX_L = (6 + j\,3.14)\,\Omega$

$Z_2 = R_2 + jX_C = (12 - j\,15.92)\,\Omega$

$Z_3 = (22 + j0)\,\Omega$

$X_C = \dfrac{1}{2\pi f \cdot C} = \dfrac{1}{314 \times 200 \times 10^{-6}} = -j\,15.92$

Admittance of Branch-1:

$Y_1 = \dfrac{1}{Z_1} = \dfrac{1}{6 + j3.14} = \dfrac{6 - j3.14}{(6)^2 + (3.14)^2} = \dfrac{6 - j\,3.14}{45.85}$

Admittance of Branch-2:

$Y_2 = \dfrac{1}{Z_2} = \dfrac{1}{12 - j\,15.92} = \dfrac{12 + j\,15.92}{(12)^2 + (15.92)^2} = 0.03 + j\,0.0415$

$= 0.05\angle 53.13^\circ$

Admittance of branch-3:

$Y_3 = \dfrac{1}{Z_3} = \dfrac{1}{22 + j0} = \dfrac{22 - j0}{(22)^2 + (j0)^2} = \dfrac{22\angle 0^\circ}{484} = 0.045\angle 0^\circ$

$I_1 = VY_1$ current in branch-1

$I_2 = VY_2$ " " branch-2

$I_3 = VY_3$ " " branch-3

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$I_1 = 110\angle 0^\circ \times 0.147\angle -27.64^\circ$
$= 16.25\angle -27.64^\circ$
$= (14.4 - j\,7.54)$ amp
$I_2 = VY_2 = 110\angle 0^\circ \times 0.05\angle 53.13^\circ$
$= 5.5\angle 53.13^\circ = 3.3 + j4.4$ amp
$I_3 = VY_3 = 110 \times 0.045\angle 0^\circ = 5\angle 0^\circ$
$= (5 + j0)$ amp

(a) Thus, current in branch-1:
$I_1 = 16.25$ amp lagging behind applied voltage by 27.64°

Current in branch-2:
$I_2 = 5.5$ amp leading applied voltage by 53.13°

Current in branch-3:
$I_3 = 5$ amp in phase with applied voltage.

$Y = Y_1 + Y_2 + Y_3$
Total admittance of ckt:
$Y = 0.1308 - j0.668 + 0.03 + j0.04 + 0.045$
$= 0.2063 - j\,0.0285 = 0.208\angle -7.866^\circ$

(b) Total current taken:
$I = VY = 110\angle 0^\circ \times 0.208\angle -7.866^\circ$
$= 22.88\angle -7.866^\circ$
i.e. Total current drawn:
$I = 22.88$ lagging behind the applied voltage by 7.866°.

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(c) Total power consumed by the ckt:

$$P = VI\cos\phi$$
$$= 110 \times 22.88 \times 0.99$$
$$= 2.493 \text{ kW}$$

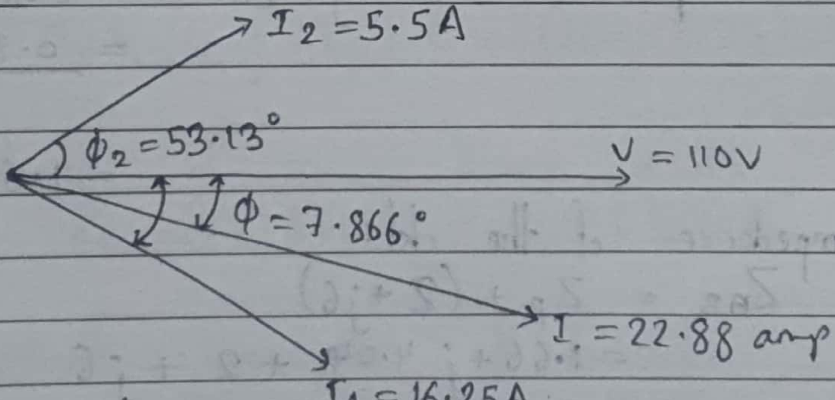
(d) Reactive power (Q):

$$Q = VI\sin\phi$$
$$= 110 \times 22.88 \times \sin(7.866)$$
$$= 344.44$$

(e) Power factor consumed by the ckt:

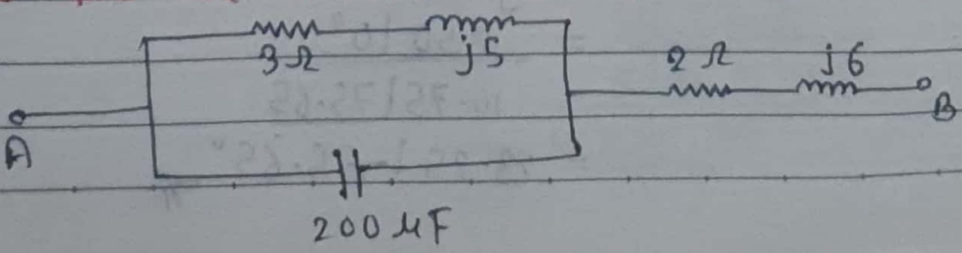
$$pf = \cos\phi = \cos(7.866) = 0.99 \text{ lagging}$$

(f) Phasor diagram: voltage phasor has been taken as reference phasor.



phasor diagram

15) A voltage of 250V at 50Hz is applied to the ckt drawn in fig below find the current drawn from the source.



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solution:

Reactance of 200 μF at 50Hz supply freq.

$$X_c = \frac{1}{2\pi f \cdot C} = \frac{1}{2\pi \times 50 \times 200 \times 10^{-6}} = 15.91\,\Omega$$

Admittance of parallel branches:

$$Y_p = \frac{1}{Z_1} + \frac{1}{Z_2} = \frac{1}{3+j5} + \frac{1}{j15.91} \quad [\because Y = 1/Z]$$

$$= \frac{3-j5}{9+25} + \frac{1}{j15.91}$$

$$= 0.087 - j0.145 - j0.066$$

$$= (0.087 - j\,0.211)\,\Omega$$

Impedance in parallel branch:

$$Z_p = \frac{1}{Y_p} = \frac{1}{0.087 - j0.211} = \frac{0.087 + j\,0.211}{(0.087)^2 + (0.211)^2}$$

$$= \frac{0.228\angle 67.59^\circ}{0.052}$$

$$= 1.66 + j\,4.04$$

Total impedance of the ckt:

$$Z_{AB} = Z_p + (2 + j6)$$

$$= 1.66 + j\,4.04 + 2 + j6$$

$$= 2.66 + j\,10.04$$

Current drawn from the source:

$$I = \frac{V}{Z_{AB}} = \frac{250\angle 0^\circ}{2.66 + j10.04} = \frac{250\angle 0^\circ}{10.73\angle 75.65^\circ}$$

$$= \frac{250\angle 0^\circ}{10.75\angle 75.65}$$

$$= 23.25\angle -75.65^\circ$$ #

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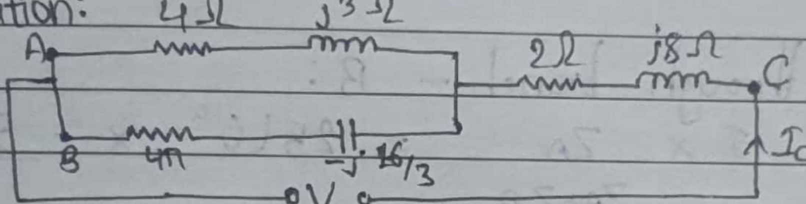
18) In series - parallel ckt, the parallel branches A & B are in series with branch C. The impedance are
$Z_A = (4+j3)\,\Omega$; $Z_B = (4 - j\,16/3)\,\Omega$,
$Z_C = (6+j8)\,\Omega$, if the current $I_C = (25+j0)$ amp,
determine, (a) branch current & voltage,
(b) total voltage,
(c) phasor diagram.

Solution:



Impedance of branch A of parallel ckt:

$$Z_A = (4+j3)\,\Omega = 5\angle 36.86^\circ\ \Omega$$

Impedance of branch B of ∥ ckt:

$$Z_B = \left(4 - j\,\tfrac{16}{3}\right)\Omega = (4 - j\,5.33)\,\Omega = 6.66\angle -53.11^\circ$$

Impedance of series branch of C:

$$Z_C = (2+j8)\,\Omega = 8.24\angle 75.96^\circ$$

Equivalent impedance of ∥ ckt:

$$Z_{AB} = \frac{Z_A \cdot Z_B}{Z_A + Z_B} = \frac{5\angle 36.86^\circ \times 6.66\angle -53.11^\circ}{5\angle 36.86^\circ + 6.66\angle -53.11^\circ}$$

$$= \frac{33.3\angle -16.25^\circ}{(8 - j\,2.33)\,\Omega}$$

$$= \frac{33.3\angle -16.25^\circ}{8.33\angle -16.23^\circ}$$

$$= 4\angle 0^\circ\ \Omega$$

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(a) Current through branch A:

$$I_A = I \times \frac{Z_B}{Z_A + Z_B} = \frac{25\angle 0^\circ \times 6.66\angle -53.11^\circ}{8.33\angle -16.23^\circ}$$

$$= \frac{166.6\angle -53.11^\circ}{8.33\angle -16.23^\circ}$$

$$= 19.98\angle -36.88^\circ$$

$Z_A + Z_B$
$= 8.33\angle -16.2$
$Z_A = 4 + j\,3$
$Z_B = (4 - j\,5.3$
$Z_A + Z_B = (8 - j\,2.3$
$= 8.33\angle -16.23^\circ$

Current through branch - B:

$$I_B = I \times \frac{Z_A}{Z_A + Z_B} = 25\angle 0^\circ \times \frac{5\angle 36.86^\circ}{8.33\angle -16.23^\circ}$$

$$= \frac{125\angle 36.86^\circ}{8.33\angle -16.23^\circ} = 15\angle 53.09^\circ$$

Voltage drop across the parallel branch:

$V_{AB} = I \times Z_{AB}$ $\quad [\because V = IZ]$

$= 25\angle 0^\circ \times 4\angle 0^\circ$

$= 25 \times 4\angle 0^\circ = 100\angle 0^\circ$

Voltage drop across series branch:

$V_C = I \cdot Z_C = 25\angle 0^\circ \times 8.29\angle 75.96^\circ$

$= 206\angle 75.96^\circ$

(b) Impedance of the whole ckt:

$Z = Z_{AB} + Z_C$

$= (4 + j0) + (2 + j8)$

$= 6 + j8\,\Omega$

$\therefore Z = 10\angle 53.13^\circ$

381
50

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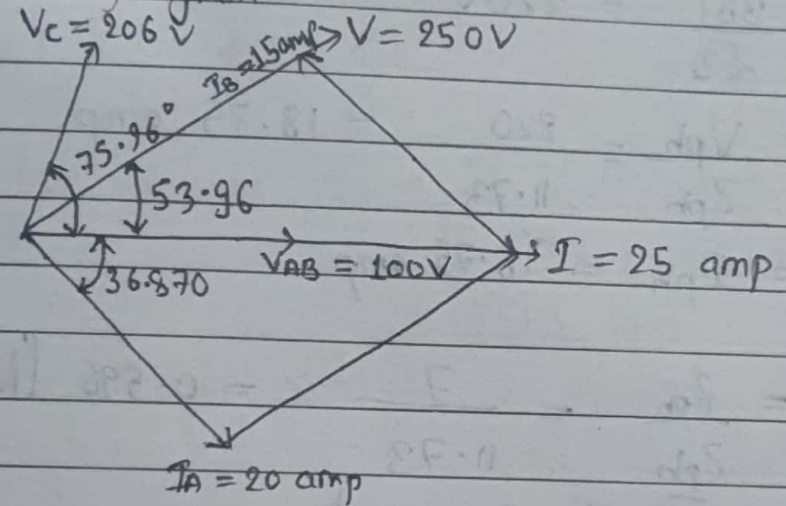
Voltage across the whole ckt:

$V = IZ$

$= 25\angle 0^\circ \times 10\angle 53.13^\circ$

$= 250\angle 53.13^\circ$

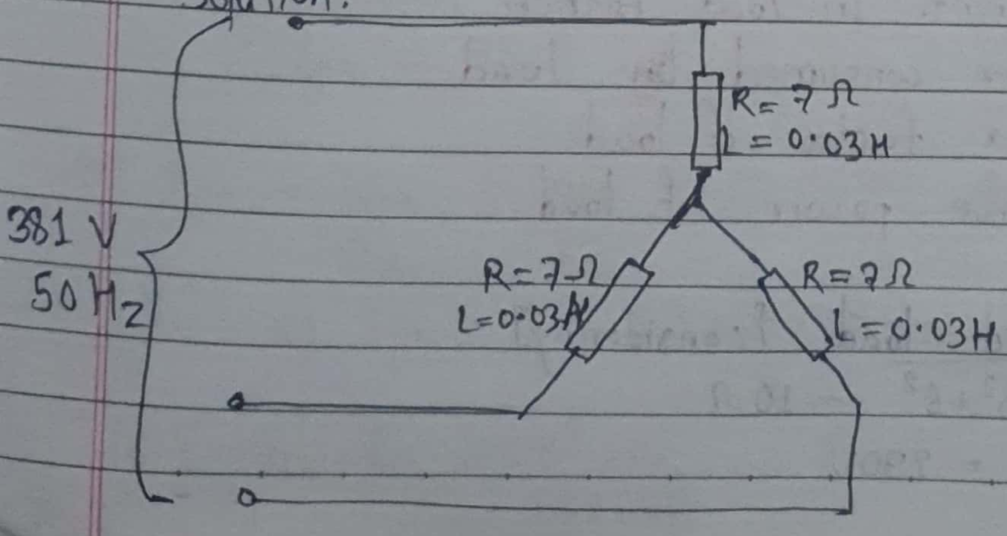
(c) Phasor diagram:



Star - delta Problems

1) Three similar coil each of resistance 7 Ω & inductance 0.03H are connected in Y (wYe) (or star) to a 381 V, 3-φ, 50Hz supply. Calculate: (a) line currents. (b) Total power

Solution:



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$X_L = \omega L = 2\pi f \cdot L = 2\pi \times 50 \times 0.03 = 9.42\ \Omega$

for star
$V_L = \sqrt{3}\, V_{ph}$
$I_L = I_{ph}$

$Z_{ph} = \sqrt{R^2 + X_L^2}$
$= \sqrt{7^2 + (9.42)^2} = 11.73\ \Omega$

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

$\Rightarrow V_{ph} = \frac{381}{\sqrt{3}} = 220V$

Now, $I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{220}{11.73} = 18.75$ amp

$I_L = I_{ph} = 18.75$ amp

Again,

$\cos\phi = \frac{R_{ph}}{Z_{ph}} = \frac{7}{11.73} = 0.596$ [lag]

Power $= \sqrt{3}\, V_L \cdot I_L \cdot \cos\phi$
$= \sqrt{3} \times 381 \times 18.75 \times 0.596$
$= 7374.50$ watt

2) A star-connected alternator supplied a delta connected lo[ad]. The impedance of the load branch is $(8+j6)\ \Omega$/phase. The line voltage is 230V. Determine:

(a) ~~Det~~ currents in load branch
(b) power consumed by load
(c) power factor of load
(d) reactive power of load

solution:

Delta connected load [considering]

$Z_{ph} = \sqrt{8^2 + 6^2} = 10\ \Omega$

$V_L = V_{ph} = 230V$

(a) $I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{230}{10} = 23A$

(b) $I_L = \sqrt{3}\ I_{ph} = \sqrt{3} \times 23 = 39.8\ A$

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

$= \sqrt{3} \times 230 \times 39.8 \times 0.8$

$\therefore P = 12,684$ watt

(c) $\cos\phi = \cancel{Z_{ph}}\ \frac{R_{ph}}{Z_{ph}} = \frac{8}{10} = 0.8$

$\boxed{\begin{array}{l} Z = 8+j6 = 10\angle 36.86° \\ \phi = 36.86° \\ \cos\phi = 0.8 \end{array}}$

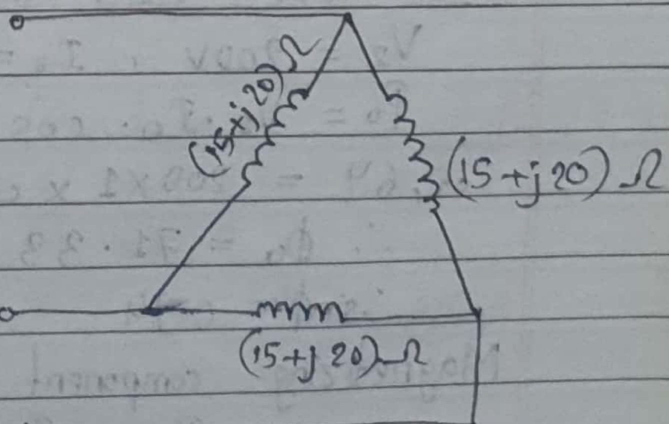
(d) Reactive power $(Q) = \sqrt{3}\ V_L \cdot I_L \cdot \sin\phi$

$= \sqrt{3} \times 230 \times 39.8 \times 0.6$

$= 9513$ watt

3) A 220V, 3-ϕ voltage is applied is applied to balanced delta - connected 3-ϕ, load of phase impedance$(15+j20)\Omega$.
(a) find phasor current in each live.
(b) what is power ~~connected~~ consumed per phase?
(c) what is the phasor sum of the three live current? What does it have this value?

solution:



$V_{ph} = 220V$

$Z_{ph} = \sqrt{(15)^2 + (20)^2}$

$\therefore Z_{ph} = 25\Omega$

(a) $I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{220}{25} = 8.8A$

$I_L = \sqrt{3}\ I_{ph} = \sqrt{3} \times 8.8 = 15.24A$

(b) $P = I_{ph}^2 \cdot R_{ph} = 8.8^2 \times 15$

$= 1162$ watt

Phasor sum would be zero because the three currents are equal in magnitude & have a equal phase difference of 120°.

Transformer Problems

1) A 4 KVA, 400/200 V, 50Hz, 1-ϕ transformer has following test delta are given:

O.C. test [L.V. side]: 200, 1A, 64 watt

S.C. test [H.V. side]: 15 10A, 80 watt

Determine

(a) ckt reffered to L.V side.

(b) secondary load voltage on full-load 0.8 pf lagging

solution:

$$\frac{V_1}{V_2} = \frac{N_1}{N_2} = \frac{400}{200} = \text{transformation ratio}$$

$$\frac{V_1}{V_2} = \frac{N_1}{N_2} = \frac{2}{1} = \text{transformation ratio}$$

O.C. Test [L.V. side]:

$V_2 = 200V$, $I_0 = 1A$, $P_0 = 64$ watt

$P_0 = V_2 \cdot I_0 \cdot \cos\phi_0$

or, $64 = 200 \times 1 \times \cos\phi_0$

$\therefore \phi_0 = 71.33$

$\therefore \sin\phi = 0.94$

Magnetizing component of no-load current:

$$I_m = I_0 \cdot \sin\phi_0$$

$$= 1 \times 0.94$$

$$= 0.94$$

Wattful component of no-load current:

$$I_w = I_o \cdot \cos\phi_o$$
$$= 1 \times 0.32 = 0.32$$

Magnetizing reactance:

$$X_{o2} = \frac{V_2}{I_m} = \frac{200}{0.94} = 212.76\,\Omega$$

Resistance representing the core loss:

$$R_{o2} = \frac{V_2}{I_w} = \frac{200}{0.32} = 625\,\Omega$$

S.C. Test [H.V. side]:

$V_{sc} = 15V$, $I_{sc} = 10A$, $P_{sc} = 80$ watt

$$P_{sc} = I_{sc}^2 \cdot R_{eq}$$
or $80 = (10)^2 \cdot R_{eq}$

$\Rightarrow R_{eq} = 0.8$

$$Z_{eq} = \frac{V_{sc}}{I_{sc}} = \frac{15}{10} = 1.5\,\Omega \qquad [\because V_{sc} = I_{sc} Z_{eq}]$$

$$X_{eq} = \sqrt{Z_{eq}^2 - R_{eq}^2} = \sqrt{1.5^2 - (0.8)^2}$$
$\therefore X_{eq} = 1.26\,\Omega$

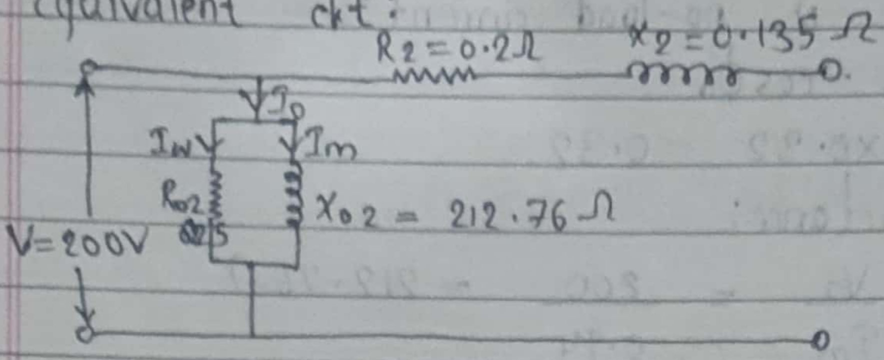
Equivalent ckt, reqd parameter (Resistance & reactance) refered to L.V. side

$$R_2 = R_{eq} \cdot \left(\frac{N_2}{N_1}\right)^2 = 0.8\left(\frac{200}{400}\right)^2 = 0.2\,\Omega$$

$$X_2 = X_{eq} \cdot \left(\frac{N_2}{N_1}\right)^2 = 1.26\left(\frac{200}{400}\right)^2 = 0.315\,\Omega$$

$$Z_2 = R_2 + j X_2$$
$$= (0.2 + j\,0.315)\,\Omega$$
$$= 0.37 \angle 57.58^\circ$$

Equivalent ckt:



(b) Secondary load voltage $(V_2) = ?$

Secondary full-load current $(I_2) = \frac{4\times10^3}{200} = 20$ amp

$\cos\phi = 0.8$ [lag]

$I_2 = 20 \angle -36.86°$

<u>Secondary load voltage:</u>

$V_2 = 200 - I_2 . Z_2$

$= 200 - 20\angle -36.86° \times 0.37 \angle 57.58°$

$= 200 - 74 . \angle 94.44°$

$= 200 - 7.4 \angle 20.72°$

$\therefore V_2 = 192.6V$

Working Principle of Syn. Motor

→ When the 3-ϕ winding of a syn. motor is fed with a 3-ϕ supply, a rotating magnetic field is produced having constant magnitude which revolves around the stator with syn speed $N_s = 120f/p$. It is called syn. speed because it synchronizes to the power frequency.

→ Suppose at any instant N_s happens to face S. N_s tries to pull S in clockwise direction due to mutual attraction. The rotor takes little time to move since it has high inertia. Now,

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the revolving pole Ns is replaced by Ss. Then S is repelled in the anticlockwise dir^n. Here, the high inertia motor first moves in one direction & then in other direction in quick succession. As a result, the rotor stays where it is. That's why syn. motor is not self starting.

→ However rotor can be made self starting with the help of squirrel cage when 3-ϕ supply is fed to stator winding. Then a rotating magnetic field is produced which induces an EMF in the damper winding. Now the syn. motor starts up as an induction motor. When it reaches near its syn. speed, the rotor poles get magnetized & start rotating at syn. speed in same dir^n. Here, the stator & rotor run at same speed. In fact, torque in a syn. motor never develop any other speed other than the syn. speed.

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→ State ohm's law and write its limitations:

It states that,

At constant temp^r, the current through an ideal resistor is directly proportional to the voltage applied across the resistor.

$$I \propto V \Leftrightarrow V \propto I$$

The constant of proportionality is written as R & this is the resistance value of the resistor.

$$V = IR$$

Limitations of ohm's law

1) This law cannot be applied to unilateral networks. A unilateral network has unilateral elements like diode, transistor, etc., which do not have same voltage current relation for both directions of current.

2) Ohm's law is also not applicable for non-linear elements. Non-linear elements are those which do not have current exactly proportional to the applied voltage, that means the resistance value of those elements changes for different values of voltage and current. Examples of non-linear elements are thyristor, electric arc, etc.