Necessity of TRANSFORMER :-

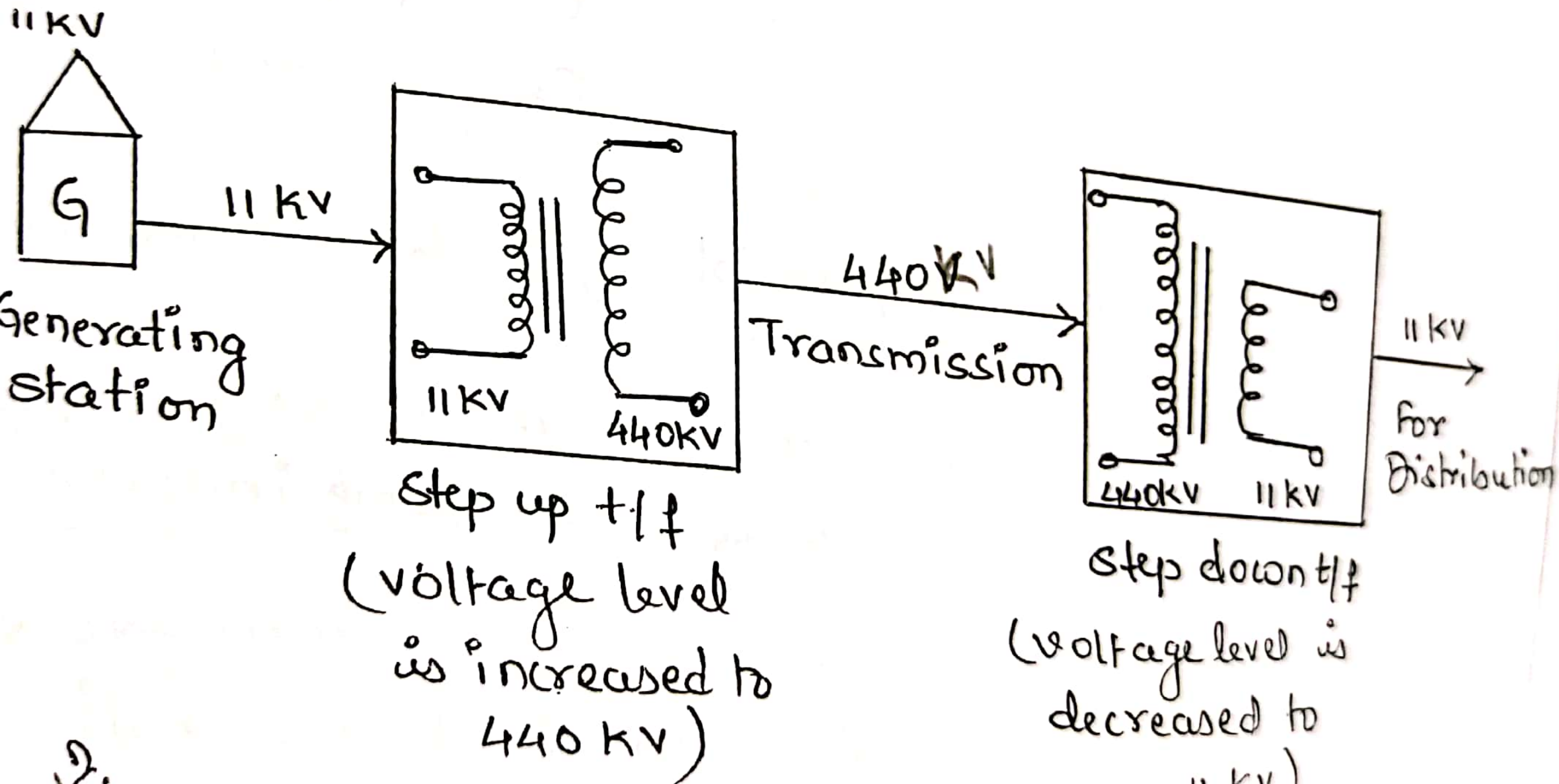
What is transformer ? What are its functions ? Mention its Application in AC transmission ? (5 marks)

Defn:

Transformer is a static device which transfers electrical power from one AC circuit to another with constant frequency.

Function

It is used to increase & decrease the voltage or current.

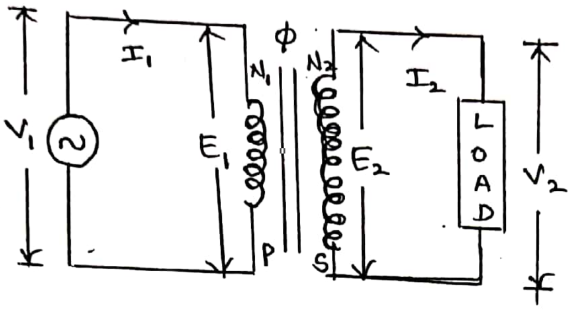


Appl:

Used in Transmission and Distribution system to increase & to decrease the voltage level.

VI) Principle of operation of transformer :-

Q)6) **working principle** → Explain the principle of operation of transformer (5 marks)



where.

N_1 - Primary turns

N_2 - Secondary turns

V_1 - Supply voltage

V_2 - load voltage

I_1 - Primary current

I_2 - Load current.

E_1 - Primary induced emf

E_2 - Secondary induced emf

Working Principle

The working principle of the transformer is mutual inductance.

It states that, when two coils are inductively coupled and current in one coil is changed then emf induces in the second coil.

Explaination

*) ~~Primary winding is~~

*) The supply voltage V_1 is given to the primary hence a current I_1 flows through it.

*) Due to this current an alternating flux ϕ produced & links with secondary through the core.

*) According to faraday's laws an emf induced in the secondary which is mutually induced emf and ϕ as well as emf induces in the primary which is self induced emf (E_1)

*) Due to mutually induced emf E_2 current I_2 flows through the load.

*) The voltage V_2 is known as the load voltage.

VII Basic Parts of transformers :-

Q>7> What are the main parts of transformer? What is the function and main material of construction of these Parts. (6marks)

Main parts of transformer :- There are two parts.

i> Magnetic core → a> limbs, b> Yoke.

ii> Winding

construction and Function :-

i> Magnetic core or core :-

*> It is made up of high grade silicon steel laminations.

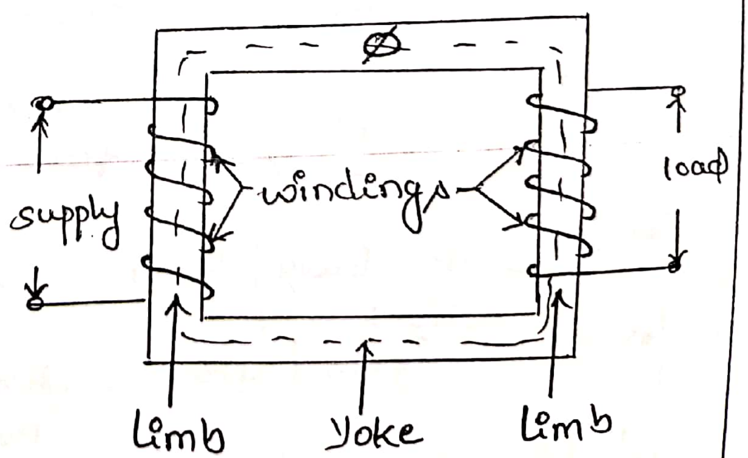
*> The high grade silicon steel is used to minimise the hysteresis loss.

*> The laminations are used to minimize eddy current loss.

*> The laminations are insulated from each other and overlapped to avoid air gap at the joints.

*> The main function of the core is to carry the flux which is done by the yoke and to carry the winding which is done by limbs.

ii> Windings :-



*> The windings are madeup of conducting material like Copper.

*> The windings are wound on the limbs are insulated from each other.

*> The function of the winding is to carry the current.

VIII **EMF equation of a transformer :-**

Q8) Derive the emf equation of a transformer (6 marks)

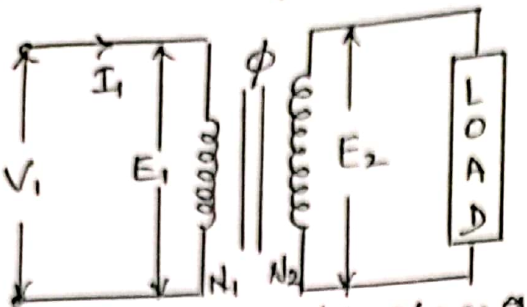


fig ① circuit diagram of t/f

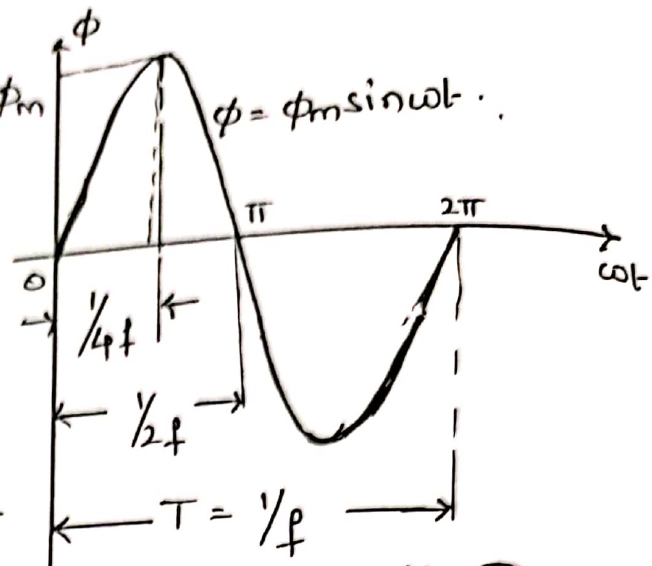


fig ② waveform

Let ϕ – flux in wb

ϕ_m – Max^m value of flux

N_1 – No of primary turns

N_2 – " " secondary "

E_1 – Primary induced emf &

E_2 – secondary induced emf.

From faraday's laws.

*) Avg emf/turn $= \dfrac{\text{change in flux}}{\text{time required to change the flux}} = \dfrac{d\phi}{dt}$ — ①

from fig ②

*) $d\phi = \phi_2 - \phi_1 = \phi_m - 0 = \phi_m$ — ② {∵ flux changes from 0 to ϕ_m}

*) $dt = \dfrac{1}{4f}$ — ③ {ie; time required to change the flux is $1/4f$}

*) ∴ ① ⇒ $E_{avg}/\text{turn} = \dfrac{\phi_m}{1/4f} = 4f\phi_m$ — ④

*) WKT form factor $= \dfrac{\text{Rms value}}{\text{Avg value}} = 1.11$

∴ RMS value of emf/turn $= E_{avg}/\text{turn} \times 1.11 = 4f\phi_m \times 1.11$

∴ $E/\text{turn} = 4.44 f \phi_m$ — ⑤

from fig ① N_1 & N_2 are the Primary & secondary numbers of turns.

$\therefore$ Primary induced emf $E_1 = 4.44 f \phi_m N_1$ volts — ⑥

& secondary induced emf $E_2 = 4.44 f \phi_m N_2$ volts — ⑦

ie;
$$\boxed{\begin{aligned} E_1 &= 4.44 f \phi_m N_1 \\ E_2 &= 4.44 f \phi_m N_2 \end{aligned}}$$

Ratios of transformer :-

i) Voltage transformation ratio :-

WKT :- $E_1 = 4.44 f \phi_m N_1$ & $E_2 = 4.44 f \phi_m N_2$.

by taking the ratios of these eqns. we get,

$$\boxed{\frac{E_2}{E_1} = \frac{N_2}{N_1} = K}$$

where K - voltage transformation ratio

Defn: The ratio of secondary induced emf to the primary induced emf.

ii) Current transformation ratio :-

For an ideal transformer losses = 0

$\therefore$ Input power = Output power

ie; $V_1 I_1 = V_2 I_2$

$$\therefore \boxed{\frac{V_2}{V_1} = \frac{I_1}{I_2} = K}$$

Q) Explain the various transformation ratios of a transformer (4 marks)

9) Losses in a transformer :-

Q9) Explain the various losses in a transformer and how to minimize them? On what factor they depend? Give the equations for these losses (6 marks)

Ans In a transformer two types of losses are present.

i) Core loss & Iron loss → a) Hysteresis loss, → b) Eddy current loss.

ii) Copper loss.

i) Core loss & Iron loss :- The losses takes place in the core of the transformer.

~~a) Hysteresis loss~~

a) Hysteresis loss :- Due to alternating flux the core undergoes magnetisation and demagnetisation due to which Hysteresis loss takes place in the form of heat dissipation.

*) The hysteresis loss can be minimized by using high grade silicon steel as a core material.

*) The eqn. for hysteresis loss is

Hysteresis loss $\propto B_m^{1.67} f \cdot V = K_h B_m^{1.67} f V$ watts.

*) It depends on max^m flux density, frequency and volume of the core.

b) Eddy current loss :- The induced emf in the core sets up eddy current in the core causes eddy current loss.

*) Eddy current loss can be minimized by constructing the core in the form of thin laminations.

*) The eqn for eddy current loss is

eddy current loss $\propto B_m^2 f^2 t^2 = K_e B_m^2 f^2 t^2$ watts.

*) It depends on max^m flux density, frequency and thickness of the core.

ii) Copper losses :- The copper losses are the power loss in ~~pri~~ the windings due to resistance.

*) The copper losses are minimized by using the windings with low resistance ie; good conductors.

*) The eqn for copper loss is

Copper loss $= I^2 R$ watts.

*) It depends on the current and the resistance of the conductor.

Q) Why the Iron loss is known as constant loss & Copper loss is known as variable loss? Explain (6 marks)

Ans :- i) Iron loss :- Iron losses are takes place in the core of the transformer.

a) Hysteresis loss :- Due to alternating flux the core undergoes magnetisation & demagnetisation cycle due to which hysteresis loss takes place in the form heat.

*) The eqn for hysteresis loss is

Hysteresis loss $= K_h B_m^{1.67} f V$ watts.

*) Hysteresis loss depends on Maximum flux density, frequency & volume of the core which are constant.

b) Eddy current loss :- Due to the flow of eddy currents through the core loss takes place.

*) The eqn for eddy current loss is

Eddy current loss $= K_e B_m^2 f^2 t^2$ watts.

*) Eddy current loss depends on Maxm flux density, frequency and thickness of the core which are also constant.

*) from these two equations it is clear that the core loss won't change with current and load. It is constant loss.
Hence Iron loss is know as constant loss.

ii) Copper loss :- It is the power loss in the windings of the transformer due to the resistance.

*) The eqn for copper loss is

$$\text{Copper loss} = I^2 R \text{ watts.}$$

*) From this equation it is clear that copper loss is dependent on current and the load.

*) If load varies, the current also varies and hence the copper loss also.

*) Hence the copper loss is know as variable loss.

X Variation in losses with respect to load :-

WKT :- Total losses in t/f = Iron loss + Copper loss

$$P_T = P_i + P_{cu}$$

$$P_T = P_i + I_2^2 R_2 \quad \text{—— (1)}$$

when $I_2 \rightarrow$ secondary of load current
$R_2 \rightarrow$ secondary resistance.

let $n \rightarrow$ fraction of the load = Actual load / Full load.

As WKT Copper loss depends on current I_2 and the load. Therefore when load varies current I_2 varies & hence Copper loss also varies. Hence $P_{cu} = n^2 I_2^2 R_2$.

Ex :- At full load $n = 1$

$\therefore$ (1) $\Rightarrow P_T = P_i + (n)^2 I_2^2 R_2 = P_i + 1 \times I_2^2 R_2 = P_i + P_{cu}$

At Half load $n = 1/2 = 0.5$

$\therefore$ (1) $\Rightarrow P_T = P_i + (n^2) I_2^2 R_2 = P_i + (0.5)^2 I_2^2 R_2 = P_i + 0.25 P_{cu}$

XI) **Efficiency of a transformer :-**

Q10) Define efficiency of a transformer. How to obtain efficiency at different loads (6marks)

Ans :- **Def^n:**

The efficiency of a transformer is a ratio of output power to input power.

ie; efficiency $(\eta) = \frac{P_{out}}{P_{in}} = \frac{P_{out}}{P_{out} + losses}$ — ①

Total losses (P_T) = Iron loss + Copper loss $= P_i + P_{cu}$.

$\therefore$ ① $\Rightarrow$ $\eta = \frac{P_{out}}{P_{out} + P_i + P_{cu}}$ — ②

WKT :- $P_{out} = V_2 I_2 \cos\phi_2 = VA\cos\phi = KVA\cos\phi$

& $P_{cu} = I_2^2 R_2$

$\therefore$ ② $\Rightarrow$ $\eta = \frac{KVA\cos\phi \times 1000}{KVA\cos\phi \times 1000 + P_i + P_{cu}}$ — ③

Let n – fraction of load. = Actual load / Full load.

when load changes load current also changes.

$\therefore$ (new) $P_{out} = n\, KVA\cos\phi = n\, V_2 I_2 \cos\phi_2$

& (new) $P_{cu} = n^2 P_{cu} = n^2 I_2^2 R_2$

$\therefore$ ③ $\Rightarrow$ $\boxed{\%\eta = \frac{n\,KVA\cos\phi \times 1000}{n\,KVA\cos\phi \times 1000 + P_i + n^2 P_{cu}} \times 100}$

Ex :- For full load $n = 1$ $\therefore$ $P_{out} = KVA\cos\phi$ & $P_{cu} = I_2^2 R_2$

For half load $n = \frac{1}{2} = 0.5$ $\therefore$ $P_{out} = n\, KVA\cos\phi = (0.5)\, KVA\cos\phi$

& $P_{cu} = n^2 P_{cu} = (0.5)^2 P_{cu}$.

XII) Condition for Max^m efficiency :-

Q12) Derive the condition for the Maximum efficiency of a transformer and at what load max^m eff takes place? (5 marks)

Ans The efficiency is the function of load and load current I_2 assuming $\cos\phi_2$ & V_2 constant.

So, for max^m efficiency

$$\frac{d\eta}{dI_2} = 0 \quad \text{\& wkt} \quad \eta = \frac{V_2 I_2 \cos\phi_2}{V_2 I_2 \cos\phi_2 + P_i + I_2^2 R_2}$$

at $n = 1$ (Full load)

$$\therefore \frac{d}{dI_2}\left[\frac{V_2 I_2 \cos\phi_2}{V_2 I_2 \cos\phi_2 + P_i + I_2^2 R_2}\right] = 0$$

$$\therefore [V_2 I_2 \cos\phi_2 + P_i + I_2^2 R_2][V_2 \cos\phi_2] - [V_2 I_2 \cos\phi_2][V_2 \cos\phi_2 + 2 I_2 R_2] = 0$$

cancelling $(V_2 \cos\phi_2)$ from both terms we get

$$[V_2 I_2 \cos\phi_2 + P_i + I_2^2 R_2] - I_2 [V_2 \cos\phi_2 + 2 I_2 R_2] = 0$$

$$[\cancel{V_2 I_2 \cos\phi_2} + P_i + I_2^2 R_2 - \cancel{V_2 I_2 \cos\phi_2} - 2 I_2^2 R_2] = 0$$

$$P_i + I_2^2 R_2 - 2 I_2^2 R_2 = 0$$

$$\therefore I_2^2 R_2 = P_i$$

& $\boxed{P_{cu} = P_i}$ condition for Max^m efficiency.

$$\therefore \% \eta_{max} = \frac{KVA \cos\phi \times 1000}{KVA \cos\phi \times 1000 + 2P_i} \times 100$$

\#> At full load Maximum efficiency occures.

Numericals of Transformer

1) Find the efficiency of 150KVA single phase transformer at i) full load upf ii) 50% of full load at 0.8 p.f. If the copper loss at full load is 1600 watts and iron loss is 1400 watts. Dec 2016/Jan 2017 (5 marks)

sol^n: Given :- rating = 150KVA, $P_{cu(F.L)} = 1600$ watts & $P_i = 1400$ watts

find :- i) $\%\eta_{F.L} = ?$ at $\cos\phi = 1$ ii) $\%\eta_{50\%} = ?$ at $\cos\phi = 0.8$

WKT :-
$$\%\eta = \frac{n\,\text{KVA}\cos\phi \times 1000}{n\,\text{KVA}\cos\phi \times 1000 + P_i + n^2 P_{cu}} \times 100$$

i) $n = 1$, $\cos\phi = 1$

$$\%\eta_{F.L} = \frac{1 \times 150 \times 1 \times 1000}{1 \times 150 \times 1 \times 1000 + 1400 + (1)^2 1600} \times 100$$

$$= \frac{15 \times 10^6}{150{,}000 + 3000} = \frac{15\,000\,000}{153\,000}$$

$$\boxed{\%\eta_{F.L} = 98.03\%}$$

ii) $n = 50/100 = 0.5$, $\cos\phi = 0.8$

$$\%\eta_{50\%} = \frac{0.5 \times 150 \times 0.8 \times 1000}{0.5 \times 150 \times 0.8 \times 1000 + 1400 + (0.5)^2 1600} \times 100$$

$$= \frac{60{,}00{,}000}{60{,}000 + 1800} = \frac{60{,}00{,}000}{61{,}800}$$

$$\boxed{\%\eta_{50\%} = 97.08\%}$$

2) A transformer is rated at 100KVA. At full load its copper loss is 1200 W and its iron loss is 960 W. Calculate i) the efficiency at full load, UPF

ii) the efficiency at half load, 0.8 p.f.

iii) the load kVA at which Maximum efficiency will occur.

iv) Maximum efficiency at 0.85 p.f.

Sol: Given :- rating = 100 kVA, $P_{cu} = 1200 W$, $P_i = 960 W$.

Find i) $\% \eta_{F.L} = ?$, $\cos\phi = 1$ ii) $\% \eta_{H.L} = ?$, $\cos\phi = 0.8$

iii) kVA for $\eta_{Max} = ?$ iv) $\% \eta_{Max} = ?$, $\cos\phi = 0.85$

WKT :- $$\% \eta = \frac{n \, KVA \cos\phi \times 1000}{n \, KVA \cos\phi \times 1000 + P_i + n^2 P_{cu}} \times 100$$

i) $n = 1$, $\cos\phi = 1$

$$\% \eta_{F.L} = \frac{1 \times 100 \times 1 \times 1000}{1 \times 100 \times 1 \times 1000 + 960 + (1)^2 1200} \times 100$$

$$= \frac{100,00,000}{100,000 + 2160} = \frac{100,00,000}{102,160}$$

$$\boxed{\% \eta_{FL} = 97.88 \%}$$

ii) $n = \frac{1}{2} = 0.5$, $\cos\phi = 0.8$

$$\% \eta_{H.L} = \frac{0.5 \times 100 \times 0.8 \times 1000}{0.5 \times 100 \times 0.8 \times 1000 + 960 + (0.5)^2 1200} \times 100$$

$$= \frac{40,00,000}{40,000 + 1260} = \frac{40,00,000}{41,260}$$

$$\boxed{\% \eta_{H.L} = 96.94 \%}$$

iii) KVA for $\eta_{Max} = KVA\sqrt{\frac{P_i}{P_{cu}}}$

$$= 100\sqrt{\frac{960}{1200}}$$

$$\boxed{\text{new KVA for } \eta_{Max} = 89.4427\,KVA}$$

iv) WKT :- $\%\eta_{Max} = \frac{\text{new } KVA \times \cos\phi \times 1000}{\text{new } KVA \times \cos\phi \times 1000 + 2P_i} \times 100$

$$\%\eta_{Max} = \frac{89.4427 \times 0.85 \times 1000 \times 100}{89.4427 \times 0.85 \times 1000 + 2 \times 960}$$

$$= \frac{7602629.5}{76026.295 + 1920} = \frac{7602629.5}{77946.295}$$

$$\boxed{\%\eta_{Max} = 97.53\%}$$

3) The Maximum efficiency at full load and UPF of a single phase, 25KVA, 500/1000 V, 50Hz transformer is 98%. Determine the efficiency at i) 75% load 0.9 p.f ii) 50% load 0.8 p.f iii) 25% load 0.6 p.f

DEC2015/JAN2016 (8Marks)
DEC 2017/JAN 2018 (7Marks)

Sol^n Given :- rating = 25KVA, $E_1 = 500V$, $E_2 = 1000V$, $f = 50Hz$

$\%\eta_{Max} = 98\%$, $\cos\phi = 1$

Find :- i) $\%\eta_{75\%} = ?$ $\cos\phi = 0.9$, $n = 0.75$

ii) $\%\eta_{50\%} = ?$ $\cos\phi = 0.8$, $n = 0.5$

iii) $\%\eta_{25\%} = ?$ $\cos\phi = 0.6$, $n = 0.25$

WKT :-
$$\%\eta_{Max} = \frac{KVA \times 1000 \times \cos\phi \times 100}{KVA \times 1000 \times \cos\phi + 2P_i}$$

$$98 = \frac{25 \times 1000 \times 1 \times 100}{25 \times 1000 \times 1 + 2P_i}$$

$$25000 + 2P_i = \frac{25\,00\,000}{98} = 25,510 \cdot 204$$

$$\therefore 2P_i = 25510 \cdot 204 - 25000 = 510 \cdot 204$$

$$P_i = 255 \cdot 102 \text{ watts} = P_{cu}$$

WKT :-
$$\%\eta = \frac{n\,KVA \times 1000 \times \cos\phi \times 100}{n KVA \times 1000 \times \cos\phi + P_i + n^2 P_{cu}}.$$

i) $n = 0.75$, $\cos\phi = 0.9$

$$\therefore \%\eta_{75\%} = \frac{0.75 \times 25000 \times 0.9 \times 100}{0.75 \times 25000 \times 0.9 + 255.102 + (0.75)^2 \times 255.102}$$

$$= \frac{1687500}{16875 + 255 \cdot 102 + 143 \cdot 494} = \frac{1687500}{17273.59}$$

$$\boxed{\%\eta_{75\%} = 97.69\,\%}$$

ii) $n = 0.5$, $\cos\phi = 0.8$

$$\therefore \%\eta_{50\%} = \frac{0.5 \times 25000 \times 0.8 \times 100}{0.5 \times 25000 \times 0.8 + 255.102 + (0.5)^2 \times 255.102}$$

$$= \frac{10\,00\,000}{10\,000 + 255.102 + 63.7755} = \frac{10\,00\,000}{10\,318 \cdot 8775}$$

$$\boxed{\%\eta_{50\%} = 96.9\,\%}$$

iii) $n = 0.25$, $\cos\phi = 0.6$

$$\%\eta_{25\%} = \frac{0.25 \times 25000 \times 0.6 \times 100}{0.25 \times 25000 \times 0.6 + 255.102 + (0.25)^2 \times 255.102}$$

$$= \frac{375000}{3750 + 255.102 + 15.9438} = \frac{375000}{4021.0458}$$

$\boxed{\%\eta_{25\%} = \text{[illegible]}\%}$ $\boxed{\%\eta_{25\%} = 93.25\%}$

4) A 600KVA transformer has an efficiency of 92% at full load unity Power factor and half full load 0.9 Power factor. Determine it's efficiency at 75% of full load, 0.9 Power factor.

Dec 2014 | Jan 2015 (8 marks)

Sol^{n}: Given :- rating = 600KVA

Full load :- $\%\eta = 92\%$, $\cos\phi = 1$ & $n = 1$

Half load :- $\%\eta = 92\%$, $\cos\phi = 0.9$ & $n = 0.5$

Find :- $\%\eta_{75\%} = ?$, $\cos\phi = 0.9$ & $n = 0.75$

WKT :- $$\%\eta = \frac{n\,KVA \times 1000 \times \cos\phi \times 100}{n\,KVA \times 1000 \times \cos\phi + P_i + n^2 P_{cu}}$$

for full load :- $n = 1$, $\cos\phi = 1$, $\%\eta_{F.L} = 92\%$

$$92 = \frac{1 \times 600 \times 1000 \times 1 \times 100}{1 \times 600 \times 1000 \times 1 + P_i + (1)^2 P_{cu}} = \frac{6\,00\,00\,000}{600\,000 + P_i + P_{cu}}$$

$$6\,00\,000 + P_i + P_{cu} = \frac{6\,00\,00\,000}{92} = 652173.913$$

$$\therefore P_i + P_{cu} = 652173.913 - 6\,00\,000$$

$$P_i + P_{cu} = 52173.913 \quad \text{—— (1)}$$

<u>For Half load</u> :- $n = 0.5$, $\cos\phi = 0.9$, $\% \eta_{H.L} = 92\%$

$$92 = \frac{0.5 \times 600 \times 1000 \times 0.9 \times 100}{0.5 \times 600 \times 1000 \times 0.9 + P_i + (0.5)^2 P_{cu}}$$

$$= \frac{270\,00\,000}{270\,000 + P_i + 0.25 P_{cu}}$$

$$270000 + P_i + 0.25 P_{cu} = \frac{270\,00\,000}{92} = 293478.26$$

$$P_i + 0.25 P_{cu} = 293478.26 - 270000$$

$$P_i + 0.25 P_{cu} = 23478.26 \quad \text{——} \quad (2)$$

solving eq^{n} (1) & (2)

$$\cancel{P_i} + P_{cu} = 52173.913$$

$$\cancel{P_i} + 0.25 P_{cu} = 23478.26$$

$$- \quad - \qquad -$$

$$0.75 P_{cu} = 28695.652$$

$$P_{cu} = 38260.869 \text{ watts}$$

$\therefore$ (1) $\Rightarrow$ $P_i = 52173.913 - 38260.869$

$$P_i = 13913.043 \text{ watts}$$

ii) <u>3/4 FL</u> :- $n = 0.75$, $\cos\phi = 0.9$

$$\% \eta_{75\%} = \frac{0.75 \times 600 \times 1000 \times 0.9 \times 100}{0.75 \times 600 \times 1000 \times 0.9 + 13913.043 + (0.75)^2 \times 38260.869}$$

$$= \frac{40\,500\,000}{405\,000 + 13913.043 + 21521.738}$$

$$= \frac{40500000}{440434.78}$$

$$\boxed{\% \eta_{75\%} = 91.95\%}$$

5) Find the number of turns on the primary and secondary side of a 440/230V, 50Hz single phase transformer, if the net-area of cross section of the core is $30 cm^2$ and the flux density is $1 wb/m^2$. June/July 2016 (6 marks)

Sol^n:- Given :- E_1 & $V_1 = 440V$, E_2 & $V_2 = 230V$, $f = 50Hz$.

A & a $= 30 cm^2 = 30 \times 10^{-4} mt^2$, $B = 1 wb/m^2$

Find :- $N_1 = ?$ & $N_2 = ?$

WKT :- $B_m = \frac{\phi_m}{A}$

$\therefore$ $\phi_m = B_m \times A = B \times A = 1 \times 30 \times 10^{-4}$

$\phi_m = 30 \times 10^{-4}$ wb.

WKT :- $E_1 = 4.44 f \phi_m N_1$

$\therefore$ $N_1 = \frac{E_1}{4.44 f \phi_m} = \frac{440}{4.44 \times 50 \times 30 \times 10^{-4}}$

$\boxed{N_1 = 660.66 \approx 662}$

WKT :- $E_2 = 4.44 f \phi_M N_2$

$\therefore$ $N_2 = \frac{E_2}{4.44 f \phi_M} = \frac{230}{4.44 \times 50 \times 30 \times 10^{-4}}$

$\boxed{N_2 = 345.34 \approx 346}$

---

or WKT :- $\frac{E_2}{E_1} = \frac{N_2}{N_1}$

$\therefore$ $N_2 = \frac{E_2}{E_1} \times N_1 = \frac{230}{440} \times 662$

$N_2 = 346$

6) A single phase 20KVA transformer has 1000 primary turns and 2500 secondary turns. The net cross-sectional area of the core is $100cm^2$. When the primary winding is connected to 550V, 50Hz supply. Calculate

i) The maximum value of the flux density in the core

ii) The voltage induced in the secondary winding and

iii) The primary & secondary full load currents.

Dec2017/Jan2018 (8marks)

Sol:- Given :- rating = 20KVA = 20000VA, $N_1 = 1000$, $N_2 = 2500$

A & a = $100cm^2 = 100 \times 10^{-4} m^2$, E_1 & $V_1 = 550V$

$f = 50Hz$.

Find :- i) $B_m = ?$ ii) $E_2 = ?$ iii) I_1 & $I_2 = ?$

i) WKT $E_1 = 4.44 f \phi_m N_1$ & $B_m = \frac{\phi_m}{A}$

$$\therefore \phi_M = \frac{E_1}{4.44 f N_1} = \frac{550}{4.44 \times 50 \times 1000}$$

$$\boxed{\phi_m = 0.00247 wb} \quad \therefore B_m = \frac{0.00247}{100 \times 10^{-4}} = \boxed{0.247 wb/m^2}$$

ii) WKT :- $E_2 = 4.44 f \phi_m N_2 = 4.44 \times 50 \times 0.00247 \times 2500$

$$\boxed{E_2 = 1375 \text{ Volts.}}$$

iii) WKT :- $I_1 = \frac{KVA \times 1000}{V_1} = \frac{20 \times 1000}{550} = 36.36 A$

$$\boxed{I_1 = 36.36 A}$$

WKT :- $I_2 = \frac{KVA \times 1000}{V_2} = \frac{20 \times 1000}{1375} = 14.54 A$

$$\boxed{I_2 = 14.545 A}$$

7) A 10 KVA, 1ϕ transformer has a primary winding of 300 turns and secondary winding of 750 turns, cross-sectional area of core is 64 cm^2. If primary voltage is 440V at 50 Hz find the maximum flux density in the core, emf induced in secondary of transformer. At 0.8 lag p.f calculate the efficiency of transformer if full load copper loss is 400W and iron-loss is 200W. June/July 2017 (5 marks)

Soln:- Given:- Rating = 10 KVA, $N_1 = 300$, $N_2 = 750$,

A & a = $64 \times 10^{-4} mt^2$, $E_1 \cong V_1 = 440V$, $f = 50Hz$.

Find:- $B_m = ?$, $E_2 = ?$ & % $\eta_{F.L} = ?$ $n = 1$, $\cos\phi = 0.8$

Given:- $\cos\phi = 0.8$, & $P_{cu(F.L)} = 400W$ & $P_i = 200W$.

WKT:- $B_m = \frac{\phi_m}{A}$ — (1)

WKT:- $E_1 = 4.44 f \phi_m N_1$

$$\therefore \phi_m = \frac{E_1}{4.44 f N_1} = \frac{440}{4.44 \times 50 \times 300} = 0.0066 \text{ wb}$$

$$\therefore (1) \Rightarrow B_m = \frac{0.0066}{64 \times 10^{-4}} = 1.032 \text{ wb/mt}^2$$

$$\boxed{B_m = 1.032 \text{ wb/m}^2}$$

WKT:- $\frac{E_2}{E_1} = \frac{N_2}{N_1}$

$$\therefore E_2 = \frac{N_2}{N_1} \times E_1 = \frac{750}{300} \times 440$$

$$\boxed{E_2 = 1100 \text{ volts}}$$

WKT :- $\% \eta = \frac{n KVA \times 1000 \cos\phi}{n KVA \times 1000 \cos\phi + P_i + P_{cu}(n^2)} \times 100$

$= \frac{1 \times 10 \times 1000 \times 0.8 \times 100}{1 \times 10 \times 1000 \times 0.8 + 200 + (1)^2 \times 400}$

$= \frac{8\,000\,00}{8\,000 + 600} = \frac{8\,00\,000}{8\,600}$

$\boxed{\% \eta_{FL} = 93.02\%}$

8) A 50 kVA, 400/200V, single phase transformer has an efficiency of 98 % at full load and 0.8 P.f, while its efficiency is 96.9 % at 25 % of full load and unity power factor. Determine the iron and full load cu-losses.

Dec 2011 (6 marks)

Sol^n: Given :- rating = 50 KVA, $E_1 = 400V$ & $E_2 = 200V$.

full load :- $\% \eta_{F.L} = 98\%$, $\cos\phi = 0.8$, $n = 1$

25% of F.L :- $\% \eta_{25\%} = 96.9\%$, $\cos\phi = 1$, $n = 0.25$

find :- i) $P_i = ?$ ii) $P_{cu} = ?$

WKT :- $\% \eta = \frac{n KVA \cos\phi \times 1000 \times 100}{n KVA \cos\phi \times 1000 + P_i + n^2 P_{cu}}$

full load :- $\% \eta_{FL}$.

$98 = \frac{1 \times 50 \times 1000 \times 0.8 \times 100}{1 \times 50 \times 1000 \times 0.8 + P_i + (1)^2 P_{cu}}$

$98 = \frac{40\,00\,000}{40,000 + P_i + P_{cu}}$.

$$\therefore \quad 40000 + P_i + P_{cu} = \frac{4000000}{98} = 40816.326$$

$$\therefore \quad P_i + P_{cu} = 40816.326 - 40000$$

$$P_i + P_{cu} = 816.326 \quad \text{——— (1)}$$

25% of full load :-

$$96.9 = \frac{0.25 \times 50000 \times 1 \times 100}{0.25 \times 50000 \times 1 + P_i + (0.25)^2 P_{cu}}$$

$$96.9 = \frac{1250000}{12500 + P_i + 0.0625 P_{cu}}$$

$$12500 + P_i + 0.0625 P_{cu} = \frac{1250000}{96.9} = 12899.896$$

$$P_i + 0.0625 P_{cu} = 12899.896 - 12500$$

$$P_i + 0.0625 P_{cu} = 399.896 \quad \text{——— (2)}$$

solve (1) & (2)

$$\cancel{P_i} + P_{cu} = 816.326$$

$$-\ \cancel{P_i} + 0.0625 P_{cu} = 399.896$$

$$0.9375 P_{cu} = 416.43$$

$$\therefore \quad P_{cu} = \frac{416.43}{0.9375}$$

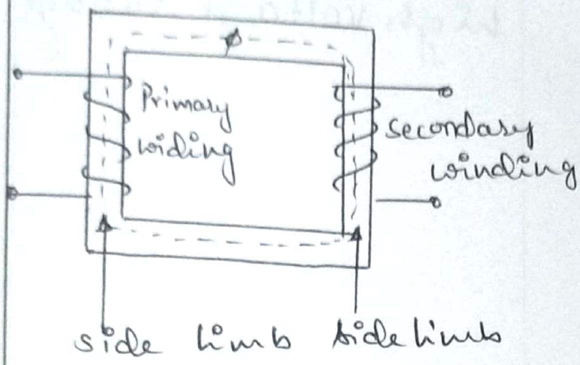
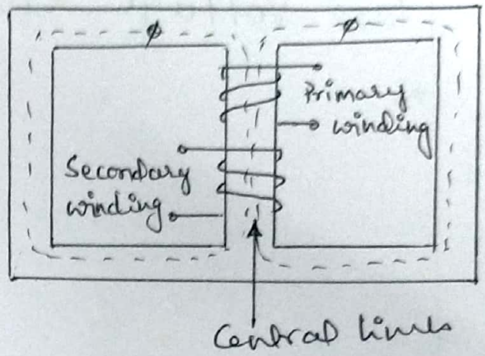
$$\boxed{P_{cu} = 444.192 \text{ watts}}$$

$$\therefore (1) \Rightarrow P_i = 816.326 - P_{cu} = 816.326 - 444.192$$

$$\boxed{P_i = 372.134 \text{ watts}}$$

Types of single phase transformers :-

Based on the construction of s/m there are two types of 1ϕ transformers.

i) Core type	ii) Shell type
	
*) The winding encircles the core	*) The core encircles the winding.
*) Cylindrical coils are used	*) Multilayer disc types coils are used.
*) As windings are distributed the natural cooling is more effective	*) As windings are surrounded by the core, the natural cooling is not possible.
*) The coils can be easily removed from maintenance point of view.	*) for removing the winding for the maintenance, large numbers of laminations of core should be removed first which is difficult.
*) It has single magnetic circuit.	*) It has double magnetic circuit.
*) The core has two side limbs	*) The core has two side limbs & one central limb.

Core type	Shell type
*) The primary and secondary windings are wound on two side limbs.	*) The primary & secondary windings are wound on the same central limb
*) It is preferred for low voltage ratings	*) It is preferred for very high voltage ratings
*	

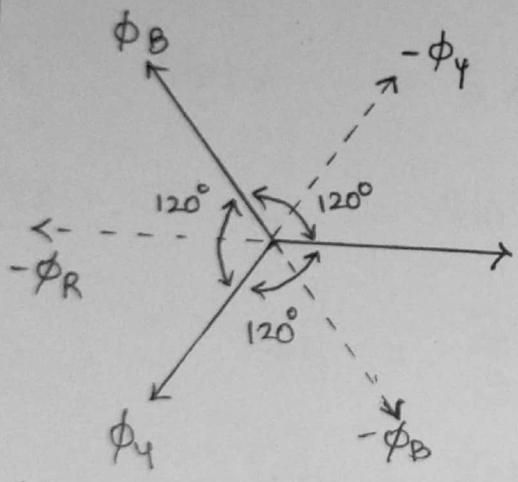
Module V THREE PHASE INDUCTION MOTOR

I> Generation of rotating Magnetic field :-

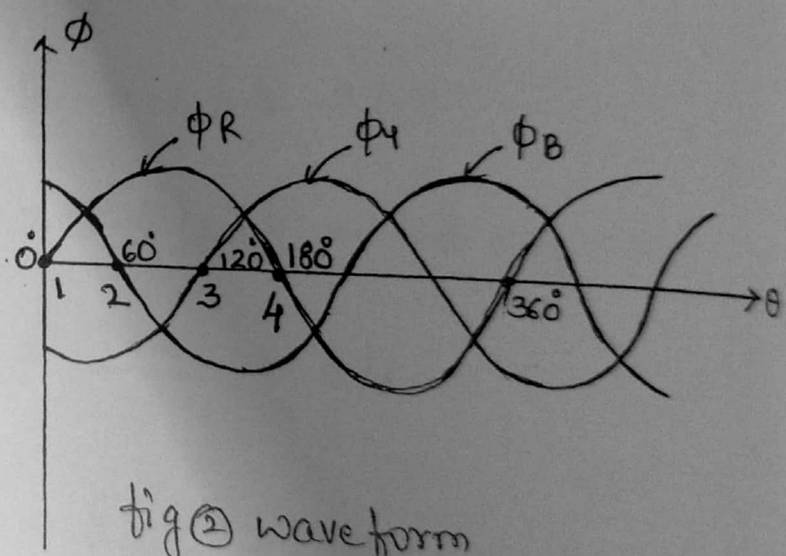
1> With diagrams explain the concept of RMF Hence define RMF
June|July 2018 (8marks)
or
Explain with neat vector diagrams, the concept of rotating magnetic field theory June|July 2017 (6marks)

Ans:- Def^n:-

RMF is defined as the field & flux having constant amplitude but its axis is continuously rotating in a plain with constant speed.



fig① Phase sequence



fig② waveform

$$\therefore \phi_R = \phi_m \sin \omega t = \phi_m \sin\theta \quad \text{—— ①}$$

$$\phi_Y = \phi_m \sin(\omega t - 120°) = \phi_m \sin(\theta - 120°) \quad \text{—— ②}$$

$$\phi_B = \phi_m \sin(\omega t - 240°) = \phi_m \sin(\theta - 240°) \quad \text{—— ③}$$

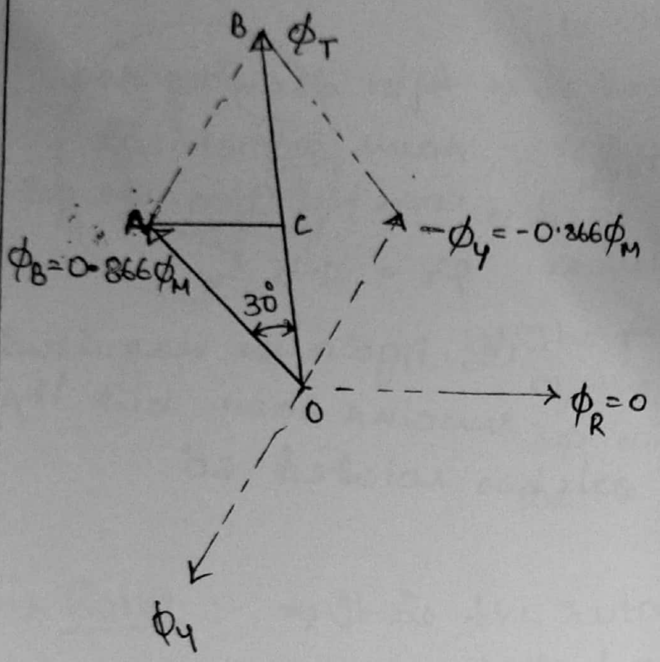
$$\therefore \bar{\phi}_T = \bar{\phi}_R + \bar{\phi}_Y + \bar{\phi}_B \quad \text{—— ④}$$

Case 1 :- $\theta = 0°$

① ⇒ $\phi_R = \phi_m \sin 0° = 0$

② ⇒ $\phi_Y = \phi_m \sin(-120) = -0.866\,\phi_M$

③ ⇒ $\phi_B = \phi_m \sin(-240) = +0.866\,\phi_m$



Draw a ⊥lar bisector AC on OB such that

$OC = CB = \phi_T/2$

$OB = \phi_T$

$OA = \phi_B = 0.866\,\phi_M$

In Δle AOC

$\angle AOC = 30°$

$\therefore \cos 30 = \frac{OC}{OA} = \frac{\phi_T/2}{0.866\,\phi_M}$

$\frac{\sqrt{3}}{2} = \frac{\phi_T}{2 \times 0.866\,\phi_M}$

$\therefore \boxed{\phi_T = 1.5\,\phi_M}$

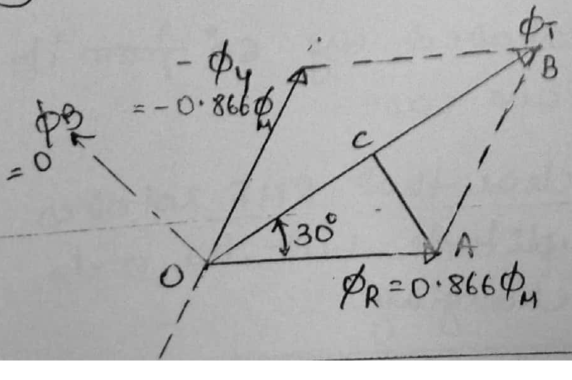
So, the total flux is $1.5\,\phi_M$ and its axis is vertically upwards at $\theta = 0°$

Case 2 :- $\theta = 60°$

① ⇒ $\phi_R = \phi_m \sin(60°) = 0.866\,\phi_M$

② ⇒ $\phi_Y = \phi_m \sin(-60°) = -0.866\,\phi_M$

③ ⇒ $\phi_B = \phi_m \sin(-180°) = 0$



By drawing the same geometrical construction we get $\phi_T = 1.5\,\phi_M$

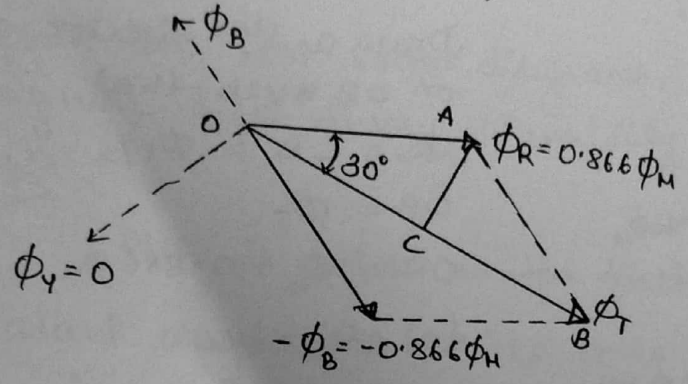
ie; the magnitude remains same but its axis has rotated 60° from its previous position.

case iii) $\theta = 120°$

① ⇒ $\phi_R = \phi_m \sin(120°) = 0.866\phi_M$

② ⇒ $\phi_Y = \phi_m \sin(0°) = 0$

③ ⇒ $\phi_B = \phi_m \sin(-120°) = -0.866\phi_M$



After drawing the same geometrical construction we get $\phi_T = 1.5\phi_M$

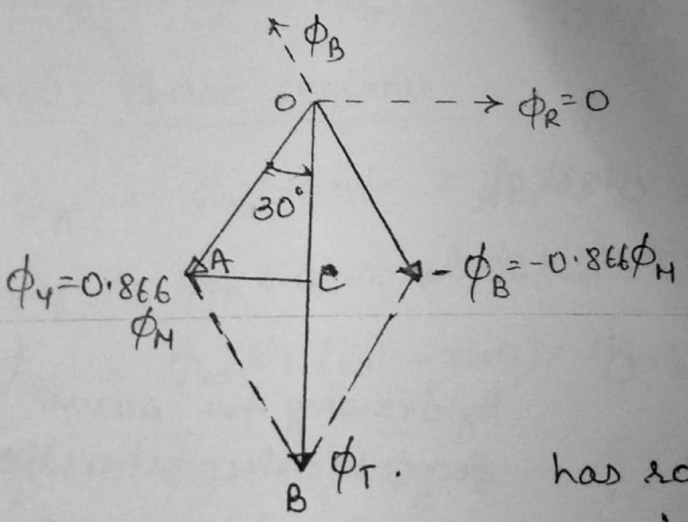
ie; Again the magnitude remains same but its axis has rotated 60°

case iv) $\theta = 180°$

① ⇒ $\phi_R = \phi_M \sin(180°) = 0$

② ⇒ $\phi_Y = \phi_m \sin(60°) = 0.866\phi_M$

③ ⇒ $\phi_B = \phi_m \sin(-60°) = -0.866\phi_M$



After doing the same geometrical construction we get $\phi_T = 1.5\phi_M$ but its axis ~~is~~ ~~rot~~ has rotated by 60° from its previous case.

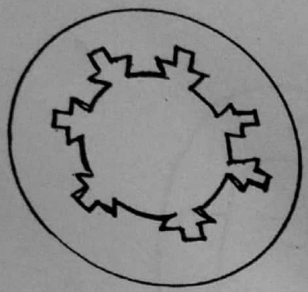
From these four cases it is clear that RMF rotates in plain with constant amplitude but the axis is continuously rotating & changing.

II

Construction of 3ϕ Induction Motor :-

There are two main parts in a 3ϕ IM
i) Stator ii) Rotor.

i) Stator :-



*) It is the stationary part of the motor to which supply is given.

*) It has laminated construction to reduce eddy current loss.

*) It is madeup of silicon steel to reduce hysteresis loss. so are insulated from each other.

*) The slots are present on the periphery of the stator core which carries 3ϕ winding connected in star or Delta called stator winding.

ii) Rotor :-

*) It is the rotating part of the motor connected to the load through shaft.

*) It is placed inside the stator.

*) It is made up of cast iron and laminated construction to reduces eddy current loss.

*) The rotor windings are placed inside the rotor slots.

*) There are two types of rotor

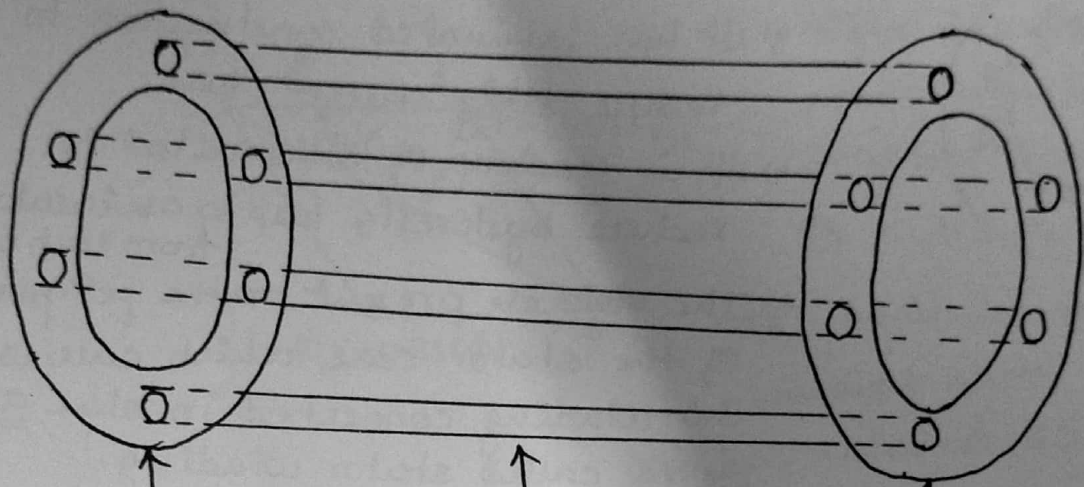
a) squirrel cage rotor

b) Phase wound or slip ring rotor.

2) With neat diagrams, explain the construction of types of rotor of 3ϕ Induction motor. June/July 2017 (6 marks)

Ans: Types of Rotor of 3ϕ IM :-

i) Squirrel cage Rotor :-



*) The rotor core is cylindrical & slotted on its periphery.

*) It consists of uninsulated copper or Aluminium bars called as rotor conductors which are placed in slots.

*) The rotor conductors are permanently short circuited to the two copper End rings. Hence the rotor resistance is very small and external resistance canot be added.

*) The entire structure looks like a cage forming a closed electrical circuit.

Advantages :- *) Rugged and simple construction with less cost

*) No sliprings and brushes are required hence maintainance is less.

*) Rotor copper losses are less hence more efficiency.

*) Comparatively better cooling condition.

*) The rotor automatically adjusts itself for the same number of poles as that of stator.

*) Very common and almost 95% of Induction motor use this type (squirrel cage type) of rotor.

~~*) App~~

Disadvantages :- *) low starting torque

*) Higher starting current (5 to 6 times the rated current)

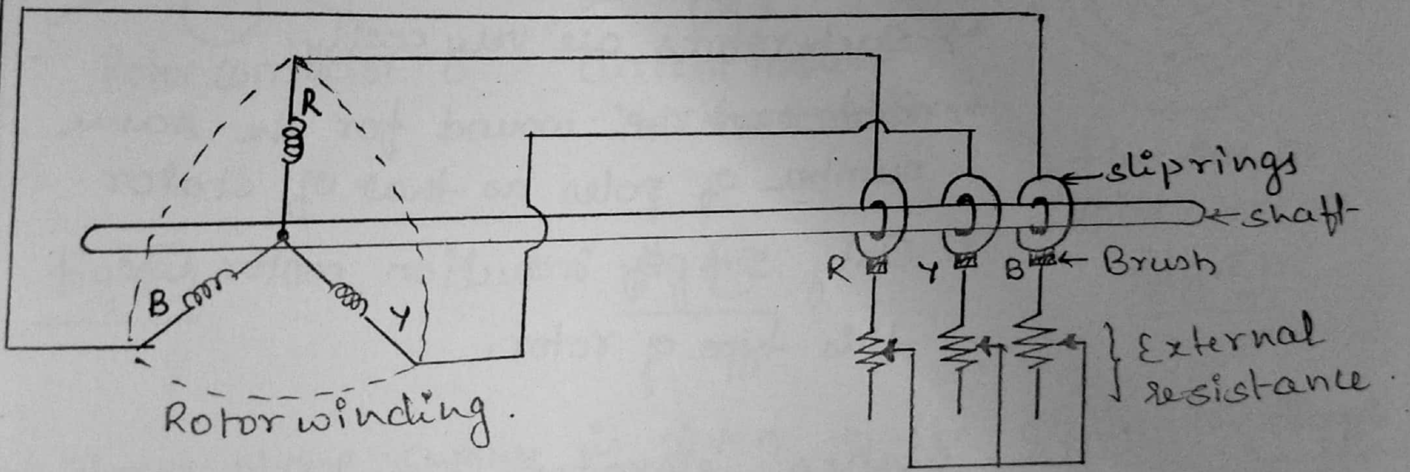
*) No speed control.

*) Needs a starter.

*) Cannot be used for the high starting torque loads.

Appl^n s :- fans, blowers, water pumps, grinders, printing machines etc.

ii) Slipring or Phase wound Rotor :-



*) Rotor construction is laminated and slotted.

*) Slots contain the rotor winding.

*) The 3ϕ windings are permanently connected to the sliprings which are mounted on the same shaft

*) The external resistance can be added with the help of Brushes and sliprings.

Advantages :- *> External resistance can be added.

*> Much higher starting torque

*> Comparatively lesser starting current (2 to 3 times the rated current)

*> Speed can be controlled by varying external resistance.

*> Can be started directly on lines.

Disadvantages :- *> Construction is complicated and delicate.

*> Due to brushes frequent maintenance is required.

*> Due to external resistance losses are more hence efficiency is less.

*> Such rotors are very costly.

*> Rotor must be wound for the same number of poles as that of stator

*> Only 5% of Induction motor use this type of rotor.

Appl^{n}s :- Lifts, cranes, elavators, compressors etc

III Working of 3ϕ Induction Motor :

3> With neat diagram explain the working principle of 3ϕ Induction Motor. Dec 2016/Jan 2017 (5 marks)

Ans: working Principle :- ~~whenever~~ The 3ϕ Induction motor works on the principle of Electromagnetic Induction.

Explaination :-

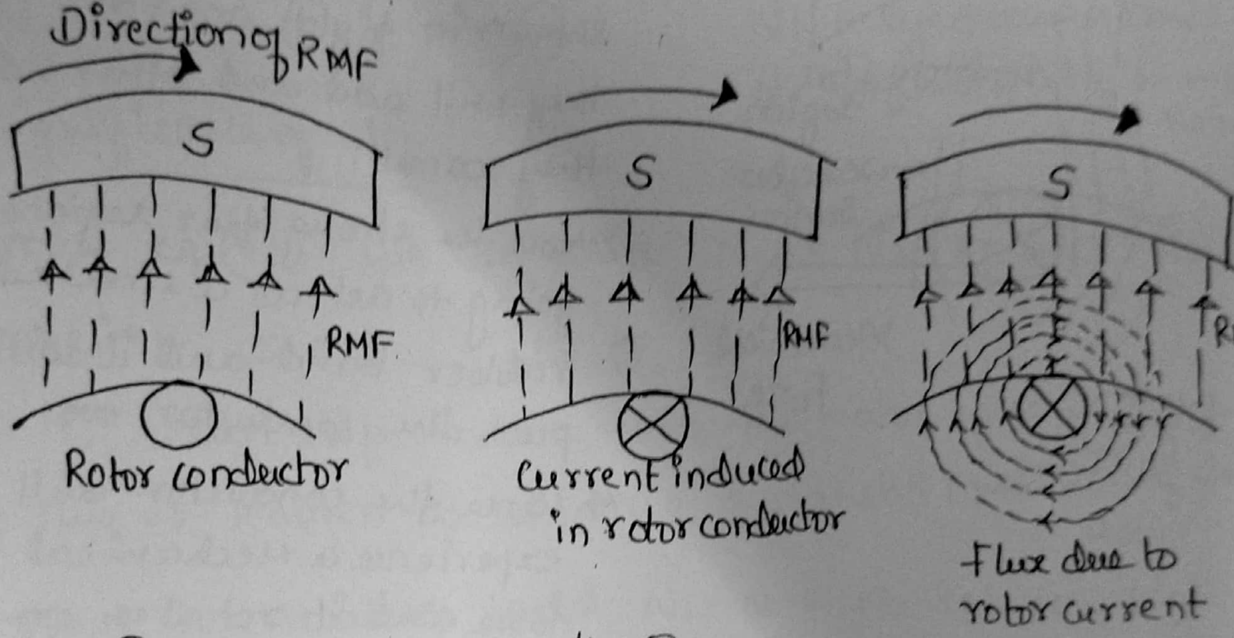


fig ⓐ   fig ⓑ   fig ⓒ

*> Three phase supply is given to the stator winding hence rotating magnetic field is ~~p~~ (RMF) produced.

*> At synchronous speed RMF rotates betⁿ stator and rotor which gives the effect of rotating poles.

*> Let the direction of RMF is clockwise as shown in fig ⓐ.

*> At starting rotor is stationary and RMF is rotating hence an emf gets induced in the rotor conductor due to which current starts to flow as shown in fig ⓑ [let the direction of current is into the paper]

*> hence rotor conductor produces its flux called rotor flux as shown in fig ⓒ.

*> According to right hand thumb rule the direction of the flux is clockwise.

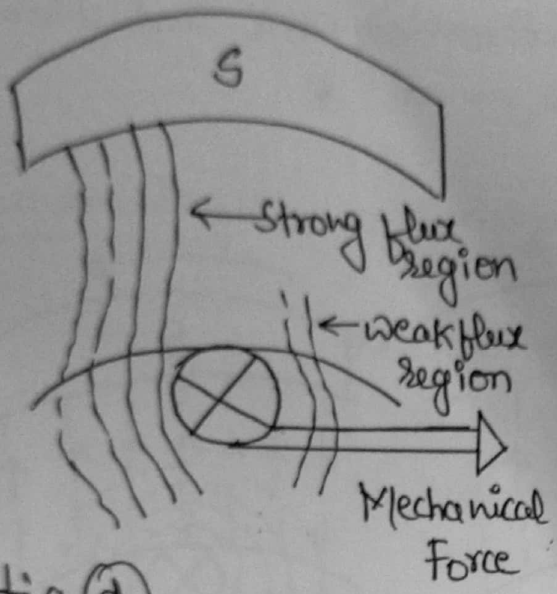


fig ⓓ.

*> Now there are two fluxes RMF and rotor flux so they interact each other and as shown in fig ⓓ one side they will add and other side they cancel.

*> Now the strong flux region is going to act as a streched rubber band and it will push the conductor.

*> Hence the conductor will experience a Mechanical force and it rotates on its axis called TORQUE.

*> Like this all the rotor conductor will experiences a torque and starts to rotate.

IV Slip and it's significance :-

4) What is slip ? Explain the significance of slip in three phas Induction Motor (6 marks)

Ans Defn

Slip is the ratio of slip speed to the synchronous speed of the motor.

ie; $S = \frac{N_s - N}{N_s}$ —① where $N_s - N$ - slip speed.

N_s - Synchronous speed

N - Actual speed of the rotor or Motor.

Significance of slip :-

from eq ① we can write $N = N_s(1-S)$ —②

case i) :- $S = 1$, $N = 0$.

*) ie; when slip is one then the motor speed is zero.

*) this is known as starting & standstill condition of the Motor

*) Then the relative speed $N_s - N = N_s$ ie; very high.

*) Hence the induced emf $e \propto N_s - N$ is very high

ie; $e \cong V$ (supply voltage)

*) Due to this very high current starts to flow in the rotor conductors which damages the rotor & Motor.

case ii) :- $S = 0$, $N = N_s$

*) ie; when slip is zero then the rotor speed becomes equal to synchronous speed.

*) Then the relative speed $N_s - N = 0$ ie; zero.

*) Then the induced emf $e \propto N_s - N = 0$ ie; zero

*) Hence there is no current in the rotor conductors

*) Hence the torque is also zero hence rotor

*) Therefore the wont rotate.

Q5) "A 3ϕ Induction motor can never run at N_s" Justify.

June/July 2016 (4 marks)

Ans:- WKT:- $N = N_s(1-s)$

if $N = N_s$ then $s = 0$

*) ie; when the slip is zero then the Motor catches the speed of RMF (N_s).

*) Then the relative speed $N_s - N = 0$ ie; zero.

*) Therefore the induced emf in the rotor $e \propto N_s - N = 0$ is zero.

*) If induced emf is zero then the current in the rotor is also zero.

*) Hence the torque ~~wount~~ wont produce and the rotor ~~of motor~~ wont rotate it will stop.

*) $\therefore$ always the speed of the motor (N) is ~~always~~ less than Synchronous speed N_s.

*) Hence it is justified that A 3ϕ Induction motor can never run at N_s.

CS CamScanner

Q67 Define the slip of an Induction Motor and derive the relation bet^n the supply frequency and rotor current frequency.

June/July 2016 (5 marks)

Ans:- Def^n

It is the ratio of slip speed to the synchronous speed of the motor.

ie; $S = \frac{N_s - N}{N_s}$ where $(N_s - N) \to$ slip speed

$N_s \to$ Synchronous speed

$N \to$ Actual speed of the motor.

WKT:- the speed of the RMF is

$$N_s = \frac{120 f}{P} \quad \text{--- (1)}$$

where f - Supply frequency in Hz.

At starting:- $N = 0$ & $S = 1$

ie; rotor is standstill hence it has maximum relative motion with RMF. ie; $N_s - N = N_s$

$\therefore$ the induced emf is very high ie; $e \propto N_s - N = N_s$

& nearly equal to supply voltage $\therefore e \cong V$.

Hence the frequency of this induced emf is same as the supply frequency.

At running:-

As motor starts to rotate with speed N the relative motion decreases hence the induced emf and the frequency also decreases.

If f_r - frequency of the rotor induced emf.

then

$$(N_s - N) = \frac{120 f_r}{P} \quad \text{--- (2)}$$

Dividing eq^n (2) by (1)

$$\frac{N_s - N}{N_s} = \frac{120 f_r / P}{120 f / P}$$

$$= \frac{120 f_r}{P} \times \frac{P}{120 f}$$

$$S = \frac{f_r}{f}$$

$$\therefore \boxed{f_r = S \cdot f}$$

Q 14
V **Necessity of starter:-**

Q 7) Explain the necessity of starters in 3-phase induction - Motor

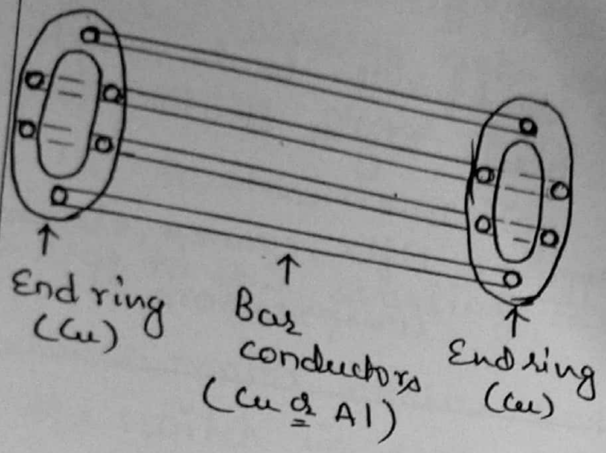
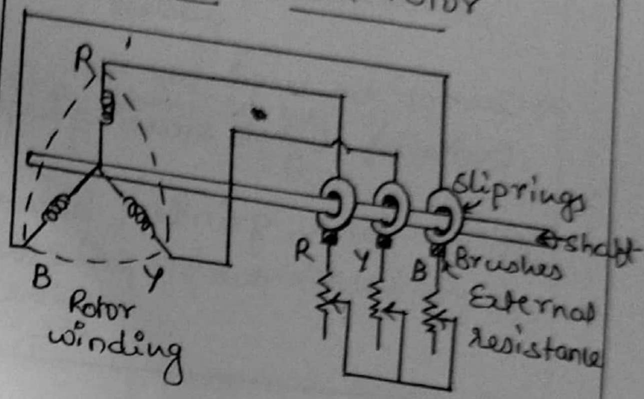
Dec 2015 | Jan 2016 (4 marks)

this topic is not there

Ans:- At starting $N=0$ & $S=1$ ie; the rotor is standstill the relative speed is very high ie; $N_s - N = N_s$ the induced emf of rotor is also very high which is nearly equal to supply voltage ie; $e \propto N_s - N \simeq V$
This large emf circulates very high current in the rotor hence stator draws very high current from the supply (5 to 8 times rated current). Due to such high current at starting the motor winding may get damage. To avoid such effects it is necessary to limit the starting current drawn by the motor. Hence starter is necessary for Induction motor. starter limits the starting current and also provides protection against over loading and low voltage conditions.

Q8) List the differences between squirrel cage and phase wound rotor of Induction Motor
Dec2015/Jan2016 (4 marks)

Ans

Squirrel cage rotor	Phase wound rotor
	
*> Construction is very simple and strong.	*> Construction is complicated and delicate.
*> Cost is very less	*> Cost is more.
*> The rotor automatically adjusts itself for the same number of poles as that of stator.	*> Rotor must be wound for the same number of poles as that of stator.
*> No sliprings and brushes hence maintenance is less	*> Due to slipring and brushes regular maintenance is required..
*> Maintenance cost is very less.	*> Maintenance cost is more.
*> Due to permanently shorted ~~end ring~~ bar conductors to the end rings external resistance can not be added Hence losses are less and efficiency is more.	*> External resistance can be added to the rotor by using slipring and brush assembly Hence losses are more and efficiency is less
*> Very common and 95% of Induction motor uses this type of rotor.	*> Only 5% of Induction motors are of this type.

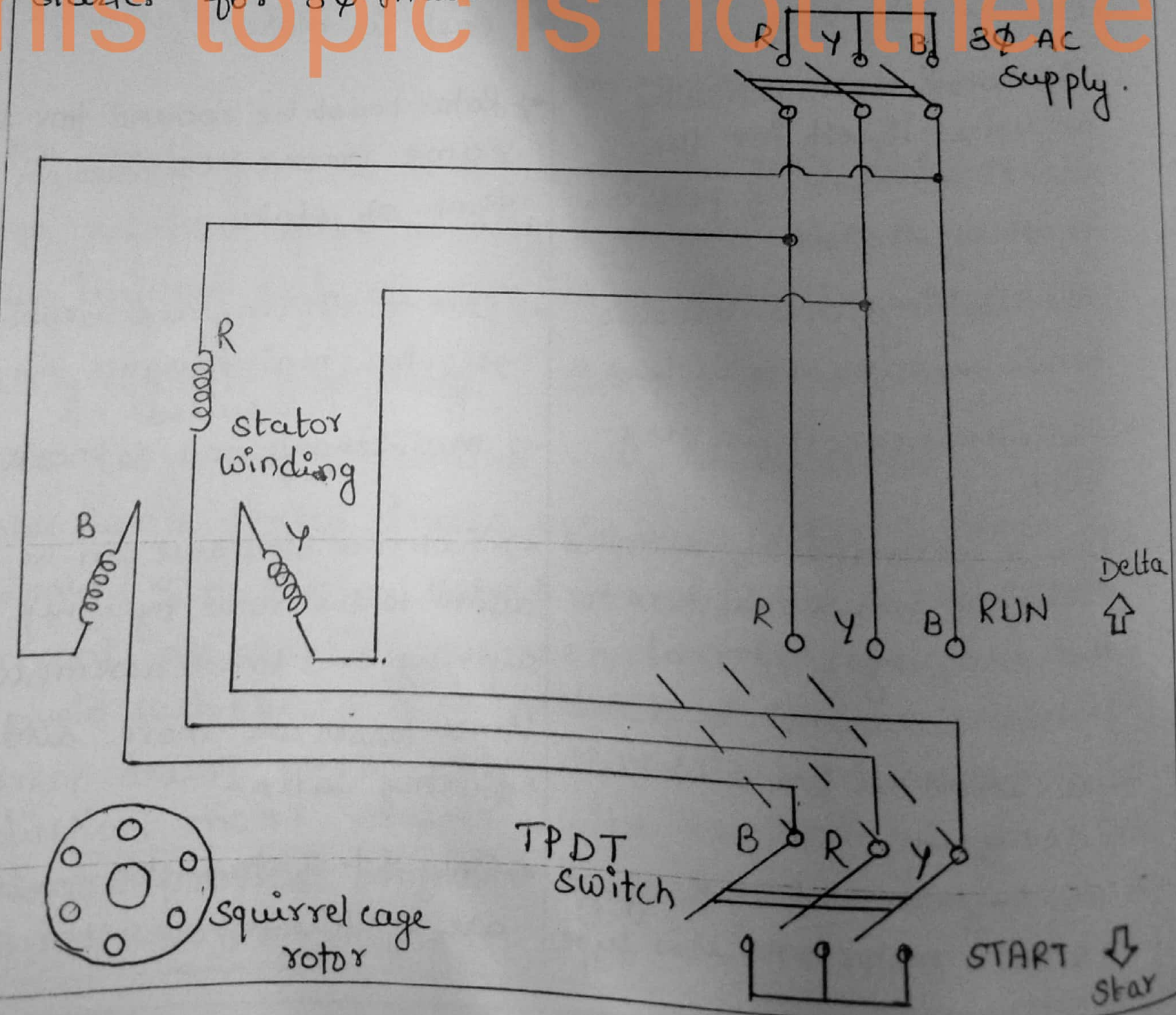
*> starting torque is very less	*> Very high starting torque.
*> Starting current is high	*> Comparatively less starting current
*> Needs a starter	*> Can be started directly on lines
*> Speed cannot be controlled ∵ external resistance can't be added.	*> Speed can be controlled by varying the external resistances
*> Cannot be used for the loads of higher starting torque	*> Used for the loads which needs higher starting torque.
Applⁿs :- fans, grinder, blowers, water pump, printing machine etc.	Applⁿs :- Lifts, cranes, elevators, compressors etc.

VI **Star - Delta Starter**

Q9) With a neat diagram explain the working of a star-Delta starter for 3 ϕ Induction motor June/July 2016 (5 marks)

this topic is not there

Ans :-



Numericals of 3ϕ Induction Motor.

Q 1) 3 ϕ, 50Hz, 6 pole induction motor has a full load percentage slip of 8 %. find synchronous speed and actual speed. June / July 2018 (6 marks).

Sol^n: Given :- $f = 50Hz$, $P = 6$, $\% S_{F.L} = 3\% = 0.03$

Find :- $N_s = ?$, $N = ?$

WKT :- $N_s = \frac{120f}{P} = \frac{120 \times 50}{6} = 1000 rpm$

$$\boxed{N_s = 1000 \, rpm}$$

WKT :- $N = N_s(1-s) = 1000(1-0.03)$

$$\boxed{N = 970 rpm}$$

Q 2) A 3ϕ 4-pole, 400V, 50Hz Induction motor runs with a slip of 4%., find rotor speed and frequency. Dec2016 / Jan2017 (6 marks)

Sol^n: Given :- $P = 4$, $V = 400V$, $f = 50Hz$, $\% s = 4\% = 0.04$

find :- $N = ?$ & $f_r = ?$

WKT :- $N_s = \frac{120f}{P} = \frac{120 \times 50}{4} = 1500 \, rpm$

WKT :- $N = N_s(1-s) = 1500(1-0.04) = 1500 \times 0.96$

$$\boxed{N = 1440 \, rpm}$$

WKT :- $f_r = S \times f = 0.04 \times 50 = 2 \, Hz$

$$\boxed{f_r = 2 Hz}$$

Q3) Define slip speed and slip. What is the slip speed and slip and at what speed rotor runs if the frequency of the emf in the stator of 4-pole, 3ϕ IM is 50Hz and in the rotor is 1.5 Hz. June / July 2017 (5 marks)

Sol^n: ~~Given~~

Slip speed:- It is difference between the speed of the RMF ie; N_s and the actual speed of the rotor ie; N.

Slip speed $= (N_s - N)$

Slip:- It is the ratio of slip speed to the ~~actual~~ synchronous speed of the motor.

ie; slip $s = \dfrac{N_s - N}{N_s}$

& $\% \, s = \dfrac{N_s - N}{N_s} \times 100$

Given:- $P = 4$, $f = 50Hz$ and $f_r = 1.5 Hz$

Find:- $N = ?$, slip speed and $s = ?$

WKT:- $N_s = \dfrac{120f}{P} = \dfrac{120 \times 50}{4} = 1500 rpm$

~~Slip speed = Ns > N > Ns.~~

WKT:- $s = \dfrac{f_r}{f} = \dfrac{1.5}{50} = 0.03$

$$\boxed{\% \, s = 3\%}$$

WKT:- $N = N_s(1 - s) = 1500(1 - 0.03) = 1500 \times 0.97$

$$\boxed{N = 1455 rpm}$$

WKT:- slip speed $= N_s - N = 1500 - 1455 = \boxed{45 rpm}$

Q4) A 3ϕ, 6-pole, 50 Hz induction motor has a slip of 1% at no load and 3% at full load. Determine:
i) Synchronous speed ii) No load speed iii) full-load speed
iv) frequency of rotor current at stand still
v) frequency of rotor current at full-load.

Dec 2015 / Jan 2016 (5 marks)

Soln:- Given:- $P = 6$, $f = 50\,Hz$, $\% S_{NL} = 1\% = 0.01$, $\% S_{FL} = 3\% = 0.03$

find:- i) $N_s = ?$ ii) $N_{NL} = ?$ iii) $N_{FL} = ?$ iv) f_r at standstill $= ?$ v) $f_{F.L} = ?$

WKT:- i) $N_s = \frac{120f}{P} = \frac{120 \times 50}{6} = 1000\,rpm$

$$\boxed{N_s = 1000\,rpm}$$

WKT:- ii) $N_{NL} = N_s(1 - S_{NL}) = 1000(1 - 0.01) = 1000 \times 0.99$

$$\boxed{N_{NL} = 990\,rpm}$$

WKT:- iii) $N_{FL} = N_s(1 - S_{FL}) = 1000(1 - 0.03) = 1000 \times 0.97$

$$\boxed{N_{FL} = 970\,rpm}$$

WKT:- iv) f_r at standstill $= f = 50\,Hz$

$$\boxed{f_r = 50\,Hz}$$

WKT:- v) f_r at F.L $= S_{FL} \times f = 0.03 \times 50 = 1.5\,Hz$

$$\boxed{f_r = 1.5\,Hz}$$

Q5) If a 6-pole induction motor supplied from a 3ϕ 50Hz supply has a rotor frequency 2.3Hz. Calculate:
i) the percentage slip ii) the speed of the motor.
Dec2015|Jan2016 (4 marks)

Sol^n. Given :- $P = 6$, $f = 50Hz$, $f_r = 2.5Hz$

Find :- $\% S = ?$ ii) $N = ?$

WKT :- $N_s = \frac{120f}{P} = \frac{120 \times 50}{6} = 1000\ rpm$

WKT :- $S = \frac{f_r}{f} = \frac{2.5}{50} = 0.05$

$\therefore$ $\boxed{\% S = 5\%}$

WKT :- $N = N_s(1-S) = 1000(1-0.05) = 1000 \times 0.95$

$\boxed{N = 950\ rpm}$

Q6) A 3ϕ induction motor with 4 poles is supplied from the alternator having 6 poles running at a 1000rpm. Calculate synchronous speed of the induction motor, its speed when slip is 0.04 and frequency of the rotor emf when the speed is 600 rpm. June|July 2018 (6 marks)

Sol^n. Given :-

Alternator
$P_A = 6$
$N_s = 1000\ rpm$

$\longrightarrow$

3Φ IM
$P_M = 4$, $S = 0.04$
$N_s = ?$ & $N = ?$
$f_r = ?$ when $N = 600\ rpm$

WKT :- $N_s = \frac{120f}{P_A}$

$f = \frac{P_A \times N_s}{120}$

$f = \frac{6 \times 1000}{120} = 50Hz$

i) $N_s = \frac{120f}{P_M} = \frac{120 \times 50}{4}$

$\boxed{N_s = 1500\ rpm}$

ii) $N = N_s(1-S)$
$= 1500(1-0.04)$

$\boxed{N = 1440\ rpm}$

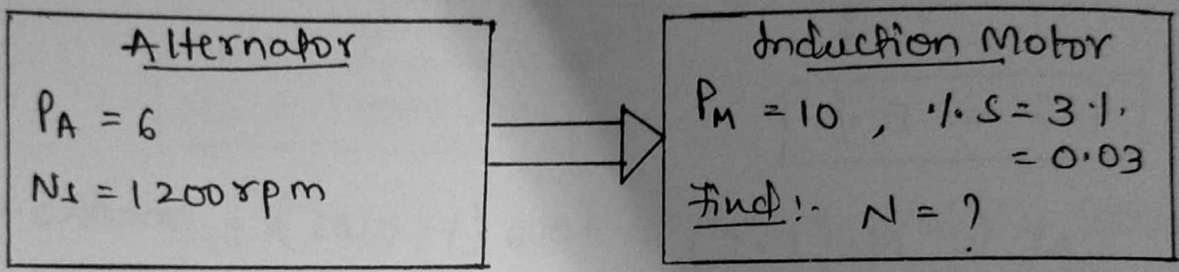
WKT :- $S = \frac{N_s - N}{N_s} = \frac{1500-600}{1500} = \frac{900}{1500} = 0.6$

WKT :- iii) $f_r = S \cdot f = 0.6 \times 50 = 30\,Hz$

$$\boxed{f_r = 30\,Hz}$$

Q7) A 10 pole induction motor supplied by a 6 pole alternator which is driven at 1200 rpm. If the motor runs at slip of 3%. what is its speed?

Sol:-



WKT :- $N_s = \frac{12f}{P_A}$

$\therefore f = \frac{P_A N_s}{120}$

$= \frac{6 \times 1200}{120}$

$f = 60\,Hz$

WKT :- $N_s = \frac{120f}{P_M} = \frac{120 \times 60}{10}$

$N_s = 720\,rpm$

WKT :- $N = N_s(1-S)$

$N = 720(1-0.03)$

$N = 698.4\,rpm$.

Q8) A 6-pole, 3ϕ alternator running at 1200rpm feeds a 4-pole, 3ϕ induction motor having slips of 3% at full load and 2.5% at half load. The rotor induced emf/phase at stand still is 160V. At full load and half load, find each of the following: i) the motor speed ii) frequency of the rotor induced emf & iii) the rotor induced emf/phase.

Dec2017/Jan2018 (7marks)

Find:- i) $N_{F.L}$ & $N_{H.L}$ ii) $fr_{F.L}$ & $fr_{H.L}$ iii) $Er_{F.L}$ & $Er_{H.L}$.

Alternator

$P_A = 6$

$N_s = 1200$ rpm

IM

$P_M = 4$, $\% S_{F.L} = 3\% = 0.03$

$\% S_{H.L} = 2.5 = 0.025$

$E_2 = 160V$

WKT:- $N_s = \frac{120 f}{P_A}$

$\therefore f = \frac{N_s P_A}{120}$

$= \frac{1200 \times 6}{120}$

$f = 60Hz$

WKT:- $N_s = \frac{120 f}{P_M} = \frac{120 \times 60}{4}$

$N_s = 1800$ rpm

i) WKT:- $N_{F.L} = N_s(1 - S_{F.L})$

$= 1800(1 - 0.03)$

$\boxed{N_{F.L} = 1746 \text{ rpm}}$

WKT:- $N_{H.L} = N_s(1 - S_{H.L})$

$= 1800(1 - 0.025)$

$\boxed{N_{H.L} = 1755 \text{ rpm}}$

ii) WKT:- $fr_{(F.L)} = S_{(F.L)} \times f$

$= 0.03 \times 60$

$\boxed{fr_{(F.L)} = 1.8 Hz}$

WKT:- $fr_{(H.L)} = S_{(H.L)} \times f$

$= 0.025 \times 60$

$\boxed{fr_{(H.L)} = 1.5 Hz}$

iii) WKT:- $Er_{(F.L)} = S_{(F.L)} \times E_2$

$= 0.03 \times 160$

$\boxed{Er_{(F.L)} = 4.8V}$

WKT:-

$Er_{(H.L)} = S_{H.L} \times E_2$

$= 0.025 \times 160$

$\boxed{Er_{(H.L)} = 4V}$

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