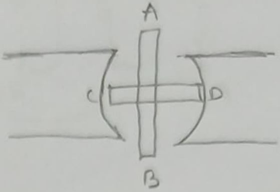
25/03/23

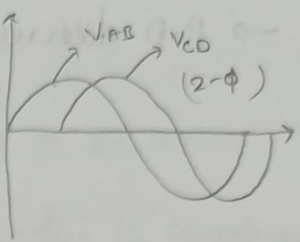
Three Phase Induction Motor

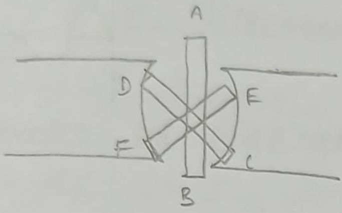
* constructions:-
  - stator
  - Rotor

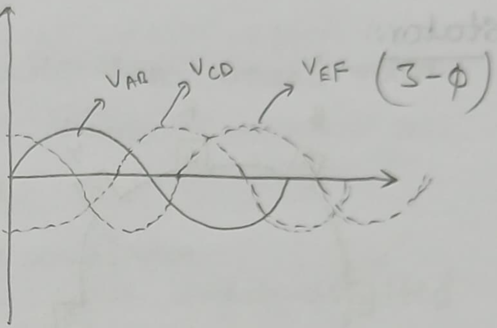


→ DC machine has commutator

→ AC machine does not have commutator.







→ To generate three phase voltage we have to ~~use~~ connect three winding which are 120° apart each.

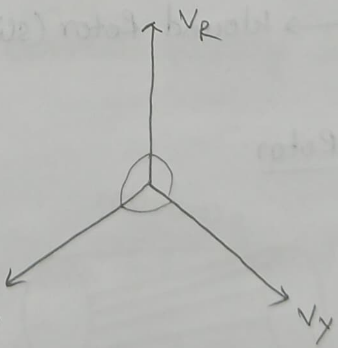
→ R, Y & B → Red & Yellow & Blue wiring.

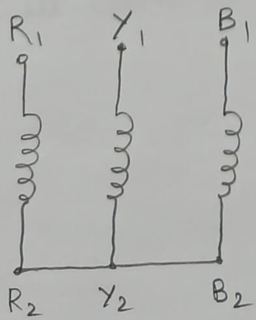
$V_R = V_m \sin\omega t$

$V_y = V_m \sin(\omega t - 120°)$

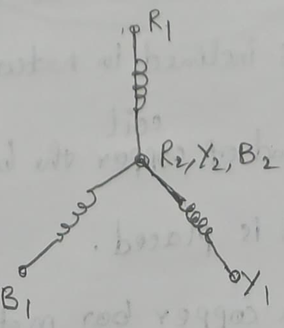
$V_B = V_m \sin(\omega t - 240°)$

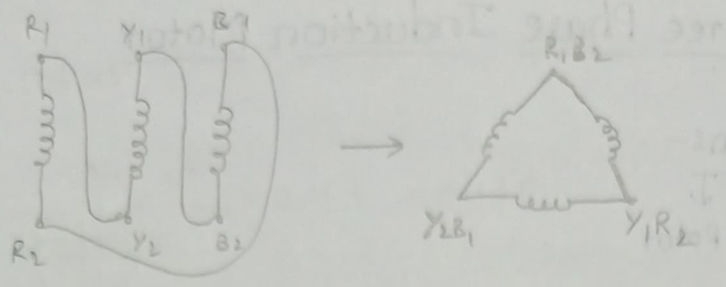
$= V_m \sin(\omega t + 120°)$

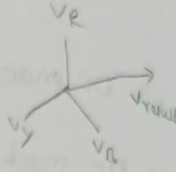




→

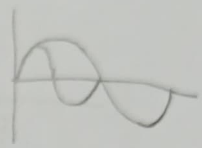




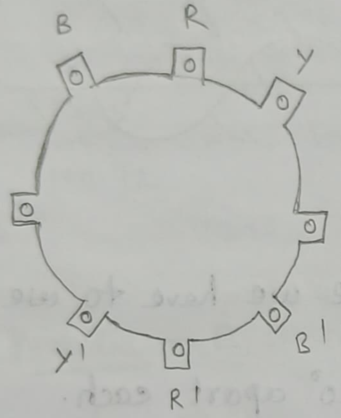


→ P.D difference exits due to phase difference.

due to frequency difference.



Stator:

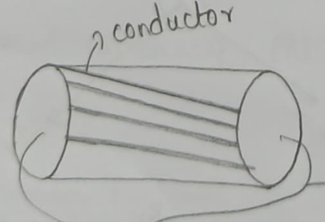


→ The slotting is cut in inner pheriphery

Rotor:- → case Rotor (squirrel cage)

→ Wound Rotor (slip ring)

Cage Rotor:



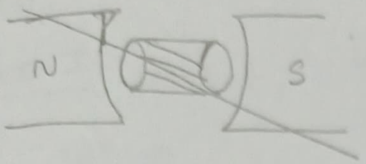
① dumble shape

→ End connector

→ It is inclined in nature.

→ Instead of ~~copper~~ coil the bar material is placed.

→ All the copper bar material short circuited by end connectors.



→ Magnetic locking.

→ It helps to avoid magnetic locking.

② ~~Wound Rotor~~ :-

→ The rotor construction is same as like as DC motor rotor & the difference is three phase winding is considered

③ Maintance ~~of~~ of cage rotor is better then wound rotor.

→ Cage rotor brush is not there.

→ ultimatey, the 3ϕ winding of wound rotor is short circuited by slip ring.

→ the cage rotor is short circuited by end connection

→ The starting torque of I.M depend on rotor resistance

→ When engine reach the rated ~~current~~ speed quickly due to starting torque.

→ ~~Since the~~ In case of wound rotor we can get starting torque but not in case of cage motor induction motor?

→

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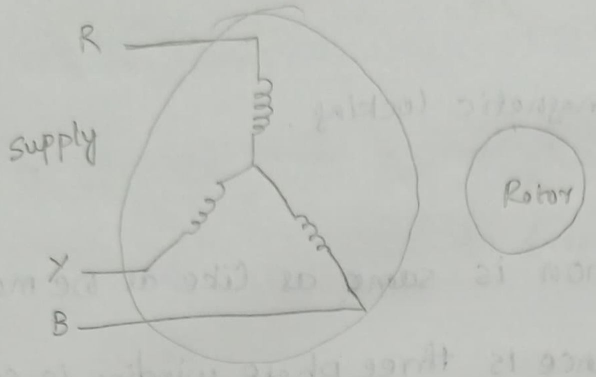
symbol:



Q. What happen when 3ϕ supply applied to starter of 3ϕ induction motor?

$V_R = V_m \sin \omega t$

$V_Y = V_m \sin(\omega t - 120°)$

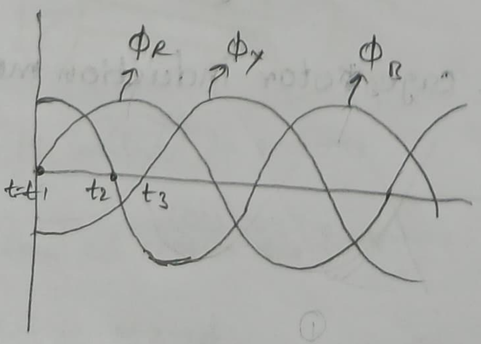
$V_B = V_m \sin(\omega t - 240°)$

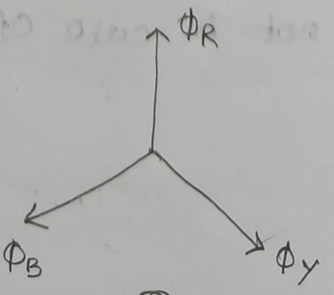
→ Due to flow of I, the stator core is magnetized & the three magnetic field are developed.

$\phi_R = \phi_m \sin \omega t$

$\phi_Y = \phi_m \sin(\omega t - 120°)$

$\phi_B = \phi_m \sin(\omega t - 240°)$





②

Now,

case I:- At $t = t_1$

$$\phi_{res} = \sqrt{\frac{3}{4}\phi_m^2 + \frac{3}{4}\phi_m^2 + 2\cdot\frac{3}{2}\phi_m^2\cos 60}$$

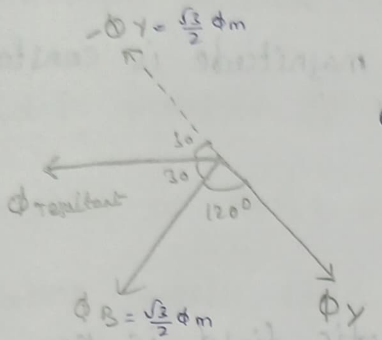
$$\frac{6}{4}\phi_m^2 - \frac{3}{4}\phi_m^2$$

$$\frac{3}{4}\phi_m^2$$

$$\frac{\sqrt{3}}{2}\phi_m$$

$\omega t = 0$

$\phi_R = 0,\ \phi_Y = -\frac{\sqrt{3}}{2}\phi_m,\ \phi_B = \frac{\sqrt{3}}{2}\phi_m$



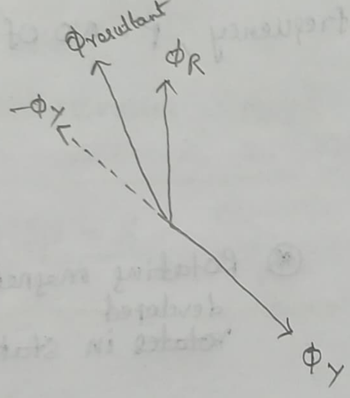
$\phi_{resultant} = 2 \times \frac{\sqrt{3}}{2} \times \cos 30$

$= 1.5\phi_m$

Case-II: At $t = t_2$

$\omega t = 60°$

$\phi_R = \frac{\sqrt{3}}{2}\phi_m,\ \phi_Y = -\frac{\sqrt{3}}{2}\phi_m,\ \phi_B = 0$

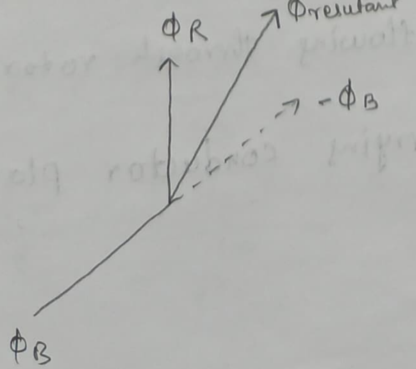


$\phi_{resultant} = 1.5\phi_m$

Case-III:- At $t = t_3$

$\omega t = 120°$

$\phi_R = \frac{\sqrt{3}}{2}\phi_m,\ \phi_Y = 0,\ \phi_B = -\frac{\sqrt{3}}{2}\phi_m$



$\phi_{resultant} = 1.5\phi_m$

① Resultant for all is constant.

② Resultant vector is rotating.

③ A rotating magnetic field is develop when 3ϕ supply apply across terminal. And magnitude is constant (i.e.) $1.5\phi_m$.

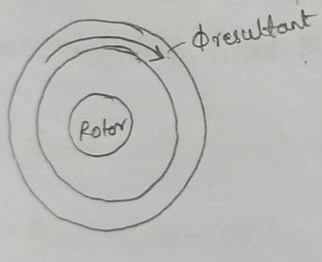
**

→ The speed of rotating magnetic field is known as synchronous speed.

* synchronous speed:-

$$N_s = \frac{120f}{P} \quad (f = \text{frequency},\ P = \text{No. of pole}).$$

Operating Principle:-



* Rotating magnetic field is developed ~~rotates~~ in stator core.

→ Across rotor conductor, induced emf is developed & so due this emf a current will flow througth rotor conductor.

→ since a current is flowing through rotor conductor so it is current carrying conductor placed in magnetic field.

* When rotor is rest, magnetic field is under motion, therefore relative speed exists. betw rotating magnetic field & rotor the flux will cut by rotor conductor and the current will flow through the rotor conductor.

Q. What is direction of rotor:-?

Direction of rotor is same as like as dirn of rotating magnetic field.

* $\boxed{N_r < N_s}$

If $\boxed{N_r = N_s}$ → rotor does not rotate as relative speed is zero

* The machine whose speed is always less than N_s, it is asynchronous speed.

$$\boxed{\text{slip} = S = \frac{N_s - N_r}{N_s}}$$

* Frequency of rotor current or Induced emf:

$$N_s = \frac{120f}{P} \Rightarrow f = \frac{PN_s}{120}$$

Let Rotor frequency $= f_r$

$$\therefore f_r = \frac{P(N_s - N_r)}{120}$$

$$\therefore \frac{f_r}{f} = \frac{\frac{P(N_s - N_r)}{120}}{\frac{P(N_s)}{120}} = \frac{N_s - N_r}{N_s} \Rightarrow \boxed{f_r = f \times S}$$

$\therefore$ Rotor frequency = slip × supplied frequency.

If $S = 1 \Rightarrow$ motor at rest, $\boxed{f_r = f}$

$S < 1 \Rightarrow f_r$ changes.

→ stator of 3-Φ induction motor can be treated as primary of trf

→ Rotor " " " secondary.

→ Induction motor also treated as rotating transformer.

28/03/23:-

Rotor current & Power factor:-

Let R_2 = Rotor resistance

X_{20} = Rotor reactance at stand still condition

X_2S = Rotor reactance at slip, s.

E_{20} = Rotor induced emf at stand still

$f_r = Sf$

$\boxed{S=1}$ at stand still condition

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

$X_2 = 2\pi f_r L$

$= 2\pi S \times f \times L$

At $S = 1$,

$X_{20} = 2\pi f L$ & $\boxed{X_{2S} = S X_{20}}$

$X_{2S} = 2\pi S f L$

$\therefore$ Rotor current at standstill condition, $I_{20} = \dfrac{E_{20}}{R_2 + jX_{20}}$

$$= \frac{E_{20}}{\sqrt{R_2^2 + X_{20}^2}} = \frac{E_{20}}{Z_{20}}$$

And induced emf, $\boxed{E = 4.44 f \phi_m N}$

$\therefore \boxed{E_{2s} = S E_{20}}$

* At any value of slip,

$\boxed{f_r = sf}$

$\boxed{X_{2s} = S X_{20}}$

$\boxed{E_{2s} = S E_{20}}$

* Rotor p.f at stand still condition $= \boxed{\frac{R_2}{Z_{20}} = \cos\phi_{20}}$

$\therefore$ Rotor current at any value slip, $S \Rightarrow I_{2s} = \frac{E_{2s}}{R_2 + jX_{2s}}$

$$= \frac{S E_{20}}{R_2 + jSX_{20}} = \frac{S E_{20}}{\sqrt{R_2^2 + (SX_{20})^2}}$$

$$\boxed{I_{2s} = \frac{S E_{20}}{Z_{2s}}}$$

Torque of the motor:-

1. Depends on Rotor current
2. Rotor induced emf $(E_{2s} \propto \phi)$
3. Rotor power factor

Now, Starting Torque :-

$$\boxed{T_{st} \propto \phi I_{20} \cos\phi_{20}}$$

$$\therefore T_{st} = K \phi I_{20} \cos\phi_{20}$$

$$= k\phi \frac{E_{20}}{\sqrt{R_2^2+X_{20}^2}} \times \frac{R_2}{\sqrt{R_2^2+X_{20}^2}}$$

$$= k E_{20} \frac{E_{20} \cdot R_2}{R_2^2+X_{20}^2} = k \frac{E_{20}^2 R_2}{R_2^2+X_{20}^2}$$

Effect of supply voltage:

$$\therefore T_{st} = k \frac{E_{20}^2 R_2}{R_2^2+X_{20}^2}$$

$$\therefore \boxed{T_{st} \propto E_{20}^2}$$

But $E_{20} \propto \phi$ and $\phi \propto V$ (supply voltage)

$$\therefore \boxed{T_{st} \propto V^2}$$

condition of maximum Torque:-

we know that, $T_{st} = k \frac{E_{20}^2 R_2}{R_2^2+X_{20}^2}$

$$\frac{dT_{st}}{dR_2} = k E_{20}^2 \left[\frac{(R_2^2+X_{20}^2) - R_2(2R_2)}{(R_2^2+X_{20}^2)^2} \right]$$

$$\Rightarrow k \frac{E_{20}^2 \left[-R_2^2+X_{20}^2\right]}{(R_2^2+X_2^2)^2} = 0$$

$$\Rightarrow \boxed{X_{20} = R_2}$$

$$\therefore \boxed{T_{st(max)} = k \frac{E_{20}^2 \cancel{R_2}}{2R_2^{\cancel{2}}} = k \frac{E_{20}^2}{2R_2}}$$

Torque of motor at running condition:-

$T \propto \phi I_{2S} \cos\phi_{2S}$

** ϕ is E_{20} as we doesn't change the supply voltage. If we take E_{2S} then voltage changes.

$\therefore T = K\phi \dfrac{E_{2S}}{\sqrt{R_2^2+(SX_{20})^2}} \cdot \dfrac{R_2}{R_2^2+(SX_{20})^2}$

$= KE_{20} \dfrac{SE_{20} \cdot R_2}{R_2^2+(SX_{20})^2} = K \dfrac{SE_{20}^2 R_2}{R_2^2+(SX_{20})^2}$

As, $\boxed{T = K \dfrac{SE_{20}^2 R_2}{R_2^2+(SX_{20})^2}}$ & $\boxed{T \propto V^2}$

Q: Derive torque equation?
we have to derive at running condition.

$\therefore T = K \dfrac{E_{20}^2 R_2}{R_2^2+X_{20}^2}$ $(\because S=1)$

$\dfrac{dT}{dR_2} \Rightarrow KSE_0^2 \left[\dfrac{R_2^2+(SX_{20})^2 - R_2(2R_2)}{R_2^2+(SX_{20})^2}\right] = 0$

$\Rightarrow S^2X_{20}^2 - R_2^2 = 0$

$\Rightarrow \boxed{R_2 = SX_{20}} \rightarrow (1)$

$\therefore T_{max} = \dfrac{KSE_{20}^2 \cdot SX_{20}}{2S^2X_{20}^2}$

[If we substitute R_2 in place of X_{20}, slip is present]

$\boxed{T_{max} = K \dfrac{E_{20}^2}{2X_{20}}}$

$\therefore$ (T_{max} does not depend on rotor resistance)

$\therefore$ At T_{max}, slip will be maximum, $\boxed{S_m = \dfrac{R_2}{X_{20}}}$ [From (1)]

By increasing R_2 value, the slip value also inc at maximum torque.

but max torque does not increase.

Q:- (What is effect of rotor resistant in induction motor)

Note:-

(At any value of slip the T_{max} is doesn't change).

Torque Vs slip characteristics:-

$$T = \frac{K S E_{20}^2 R_2}{R_2^2 + (S X_{20})^2}$$

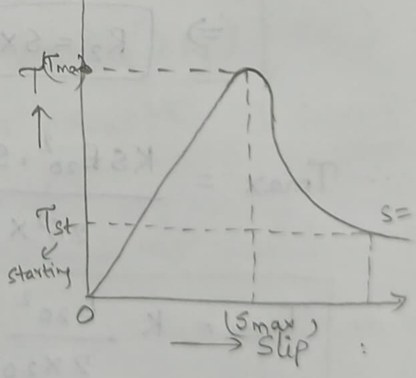
Case I:- ~~At very low value of~~

When the slip of motor, $S = 0$

$\therefore T = 0$

Case-II: When N_r is very near to N_s

$\therefore$ slip s is very less value.



$\therefore$ term $(SX_{20})^2$ is very very less.

$$\therefore T = \frac{K S E_{20}^2 R_2}{R_2^2} \Rightarrow \boxed{T \propto S}$$

Case-III: When slip of motor increases, the torque of motor also increases upto max torque.

At max torque, slip also max i.e. $S_m = \frac{R_2}{X_{20}}$

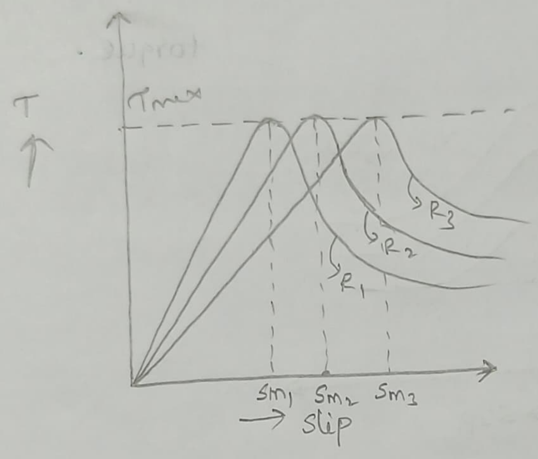
Case - IV :- When slip of motor is high, i.e, full load conditions

$\therefore$ the term $R_2^2 <<< (sX_{20})^2$ — $\uparrow$ high sX_{20} — s is $\uparrow$ so we neglect R_2 denominator

$$\therefore T = \frac{KSE_{20}^2 R_2}{s^2 X_{20}^2}$$

$$\Rightarrow \boxed{T \propto \frac{1}{s}}$$

⊗ Effect of rotor resistance in T Vs slip characteristics :-



$$\because S_m = \frac{R_2}{X_{20}}$$

And from the graph $S_{m3} > S_{m2} > S_{m1}$

$$\therefore \boxed{R_3 > R_2 > R_1}$$

→ If we $\uparrow$ rotor resistance, the starting torque will increase accordingly. But there is no change in T_{max} Because T_{max} does not depend on rotor resistance.

Effect of supply voltage in τ vs slip characteristics:

$$\tau = \frac{K S E_{20}^2 R_2}{R_2^2 + (S X_{20})^2}$$

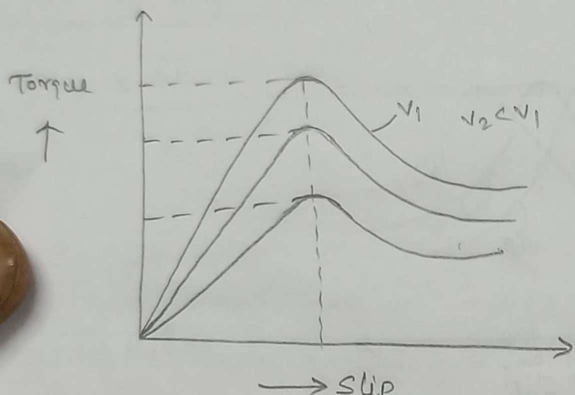
rotor induced emf at starting

For a particular case, $\boxed{T \propto E_{20}^2}$

But E_{20} depend on supply voltage as induction principle

$\therefore \boxed{T \propto V^2}$

If we change V according all changes (i.e.) starting torque.



Relation between T_{fl} & T_{max}:-

we know that,

$$\tau = \frac{K S E_{20}^2 R_2}{R_2^2 + (S X_{20})^2}$$

$$\therefore T_{fl} = \frac{K S_{fl} E_{20}^2 R_2}{R_2^2 + (S_{fl} X_{20})^2}$$

And $T_{max} = K \dfrac{E_{20}^2}{2 X_{20}}$

Now, $$\frac{T_{max}}{T_{fl}} = \frac{\dfrac{K E_{20}^2}{2 X_{20}}}{\dfrac{K S_{fl} E_{20}^2 R_2}{R_2^2 + (S_{fl} X_{20})^2}} = \frac{R_2^2 + (S_{fl} X_{20})^2}{2 S R_2 X_{20}}$$

$$= \frac{\left(\frac{R_2}{X_{20}}\right)^2 + (S_{fl})^2}{2S_{fl}\left(\frac{R_2}{X_{20}}\right)} = \frac{S_m^2 + S_{fl}^2}{2S_mS_{fl}}$$

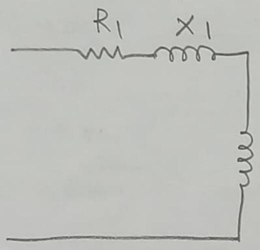
(*) $\frac{T_m}{T_{st}}$

(2) Equivalent circuit of three phase induction motor:

Stator model: Since the stater of induction motor is similar to primery of transformer. so,

R_1 is stater winding Resistance

X_1 is stater Leakage reactance.



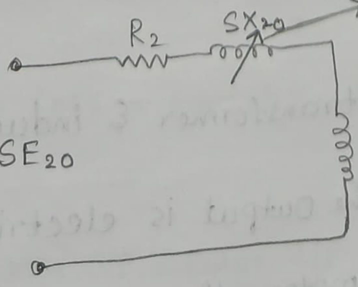
Rotor model:

$$\therefore I_{2S} = \frac{E_{2S}}{R_2 + X_{2S}}$$

$$= \frac{SE_{20}}{R_2 + SX_{20}}$$

∴ the Circuit is

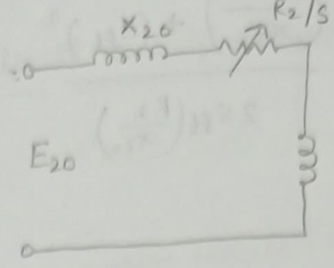
(symbol indicates variable)



Again,

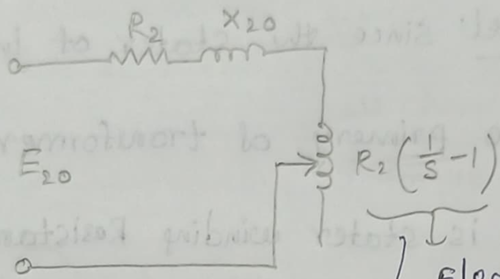
$$I_{2S} = \frac{SE_{20}}{R_2 + SX_{20}}$$

$$= \frac{E_{20}}{\frac{R_2}{S} + X_{20}}$$



Now, $\frac{R_2}{S} = R_2 + R_2\left(\frac{1}{S} - 1\right)$

the ckt is



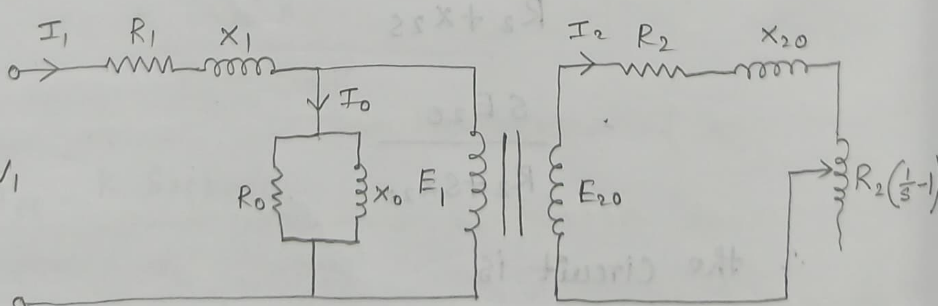
Electrical load

output is mechanical powe

At no-load condition:

$$I_0 = \underset{X_0}{I_\mu} + \underset{R_0}{I_w}$$

Whole equivalent ckt of induction motor is :-



Diff of eq. ckt b/w transformer & induction motor ?

→ In case of trf, the output is electrical but in case of induction motor, the output is mechanical.

component of
(1) The I_0 current is different.

(2) The no-load current of induction motor is high.

→ In trf there is no air gap.

→ Due to air gap in motor more current is required. for secondary.

06/04/23.

Relation of rotor input, Rotor output and Rotor copper loss:-

Let T = developed torque

N_s = synchronous speed

N_r = Rotor speed,

$$\text{Rotor Input} = \frac{2\pi N_s T}{60}$$

$$\text{Rotor output} = \frac{2\pi N_r T}{60}$$

then, Rotor I/P − Rotor O/P = Rotor copper Loss

$$\therefore \text{Rotor copper loss} = \text{Rotor I/P} - \text{Rotor O/P}$$

$$= \frac{2\pi N_s T}{60} - \frac{2\pi N_r T}{60}$$

$$= \frac{2\pi T}{60}(N_s - N_r)$$

$$\text{Now, } \frac{\text{Rotor copper loss}}{\text{Rotor I/P}} = \frac{\frac{2\pi T}{60}(N_s - N_r)}{\frac{2\pi N_s T}{60}} = \frac{N_s - N_r}{N_s} = S$$

$$\Rightarrow \text{Rotor copper loss} = S \times \text{Rotor I/P}$$

Again,

$$\text{Gross Rotor O/P} = \text{Rotor I/P} - \text{Rotor cu Loss}$$

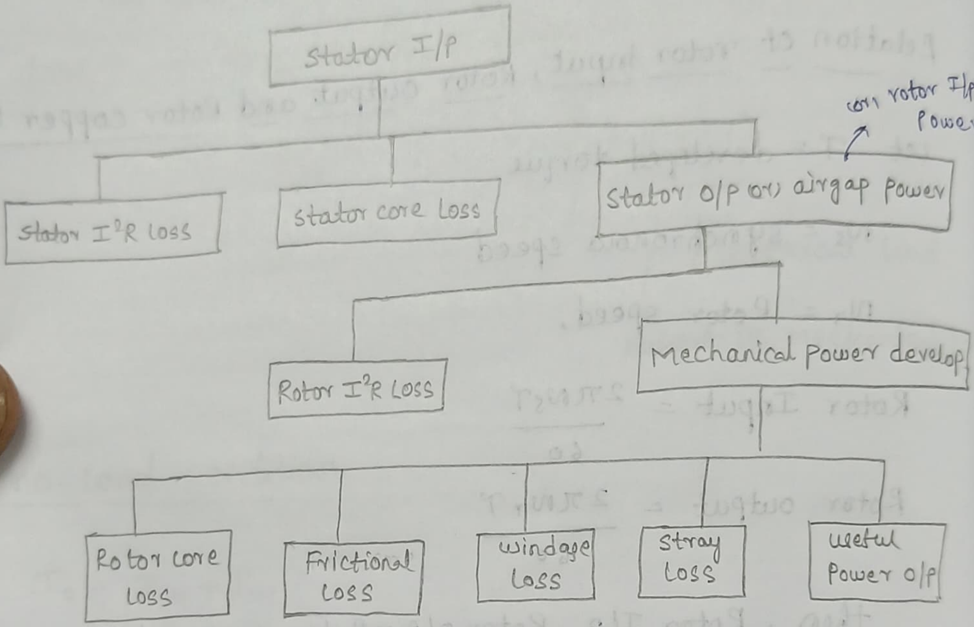
$$= \text{Rotor I/P} - S \times \text{Rotor I/P}$$

$$= (1-S)\ \text{Rotor I/P}$$

Again, $\frac{\text{Rotor o/p}}{\text{Rotor I/p}} = 1-s$

or $\boxed{\frac{\text{Rotor cu loss}}{\text{Rotor o/p}} = \frac{s}{1-s}}$ (for Numerical problem)

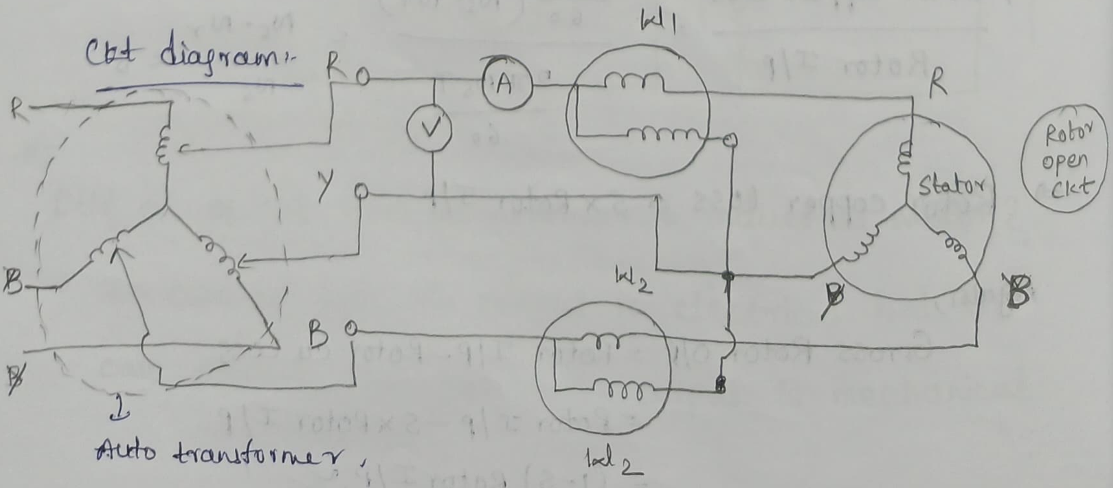
Power flow diagram:



Tests on Induction motor

No-load — Blocked Rotor

Ckt diagram:



→ By 1-ϕ we have connect three watt meter

→ If we connect 2 watt meter for any two phases it is enough to measure power. (i.e (R, Y), (R, B), (B, Y))

$$P = W_1 \pm W_2$$

No Load test

→ When induction motor at no load ; draw, no load curren I_0.

→ Hence Draw very less amount of current.

→ By conducting No-Load test, we calculate core ~~copper~~ loss for induction motor.

→ One wattmeter deflects negative, so, ~~W~~

$$\boxed{P_0 = W_1 \sim W_2}$$

$$\& \quad P_0 = W_1 \sim W_2 = \underbrace{3}_{\text{3 for 3phase}} V_{ph} I_{ph} \cos\phi_0$$

$$I_0 = I_\mu + I_w$$

$$\sqrt{3}\, \underbrace{V_L}_{\text{Line voltage}} I_L \cos\phi_0$$

** theroy of

→ (No Load test is similar to O.C.t of trf)

Blocked Rotor test:-

→ We block rotor by means of mechanical.

→ Since rotor is not allow for rotating, as ~~it~~ stator conhect to three phase supply, then rotor draw more current from supply.

→ It is similar to S.C.t of trf.

Stator of Three phase I/M:-

For case Rotor I/P

- D.O.L
  - Direct online
  - ↓
  - By using this,
  - ① over load protection
  - ② under voltage protection.
- Auto trf
  - ↓
  - (we have to inc voltage from 0 to rated value)
- ~~Stator Rotor~~ star-delta
  - $\boxed{75\%}$ of rated voltage then star converts to delta.

For wound Rotor I/P:-

(By ↑ Rotor ↑ starting torque ↑ (wound rotor)

For case rotor, Rotor 'R' permanently short circuited.)

Doubt ?

Method of speed control:-

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

By changing,

① supply voltage

② supply frequency

③ By changing poles

④ By variable resistance

⑤ By Injecting voltage to the rotor.

Cogging: Magnetic locking.

By design if no. of slot of stator and rotor are same then there is tendency of magnetic locking.

Crawling:- Harmonic effect.

If the supply voltage is impure, the effect of 5^{th} and 7^{th} harmonic of the speed of I/m automatically reduced.

i.e., $\frac{N_s}{5}$ (or) $\frac{N_s}{7}$. So the moter treated as over load condition & may cause burnt.

Problems:

A 3-ϕ 4 pole, 400V, 50Hz

(1) determine synchronous speed,

(2) actual speed of motor when running at 4% slip,

(3) Frequency of induced emf in rotor.

Sol: ① $N_s = \frac{120f}{P}$

$= \frac{120 \times 50}{4} = 1500$

② $N_r = (1-s) N_s$ $\left[s = \frac{N_s - N_r}{N_s} \right]$

$= (1-0.04) \times 1500$

$f_r = s \times f = 0.04 \times 50 = 2$

power to an induction motor supplied by 12 pole, 3ϕ 500 rpm alternator, the full load speed of motor is 1440 rpm. Find % slip & No. of pole of motor.

sol. supply frequency,

$$f = \frac{PN_s}{120} = 50\,(Hz) \qquad \boxed{N_r < N_s}$$

For 1500 N_s

nearest to 1440 — No. of pole is 4

8) 8 hp, 3ϕ 4 pole I.M connected to 400V, 50Hz, the motor is operating at full load with 5% of slip. Calculate

(i) the slip of revolving field relative to stator structure. N_s

(ii) the frequent of rotor $\boxed{f_r = sf}$

(iii) the speed of rotor mmf relative to rotor structure

(iv) the speed of rotor mmf relative to stator u,

(v) the " relative ii stator field distribution.

(vi) Are this condition right for the net unidirectional torque

(i) ~~$N_r = \frac{120f}{}$~~ $N_s = \frac{120f}{P} = \frac{120 \times 50}{4} = 1500$

(iii) $N_r = \frac{120 f_r}{P} = \frac{120 \times 2.5}{4} = 75$

Speed of rotor mmf

$N_r = (1-s)N_s = 1425$?

This is not formula.

0.05×50

$\frac{5}{100} \times 50$

$\frac{95}{100} \times 1500$

975
95
1425

(iv) $N_r = (1-s)N_s = \cancel{1425}$ 1425 rpm

(v) = rotor mmf + N_r = 75 + 1425 = 1500 rpm

(v) 1500 − 1500 = 0

(vi) valid, this condition is satisfied for the net unidirectional torque.

(Q) The resistance and stand still reaction per ϕ of 3ϕ, 4 pole, 50 Hz I/m is 0.2 Ω & 2 Ω. The rotor is connected in a star & emf induced b/w the slip ring at start is 80 V. If at full load the motor is running at a speed of 1440 rpm calculate the

(1) slip,

(2) Rotor induced emf per phase

(3) The rotor current and power factor under running condition

(4) Rotor current and power factor at stand still when slip ring is shortcircuited.

$$N_s = \frac{120f}{P} = \frac{\overset{30}{\cancel{120}} \times 50}{4} = 1500$$

Sol:- $s = \frac{N_s - N_r}{N_s} =$

$$s = \frac{1500 - 1440}{1500} = \frac{60}{1500} = 0.04$$

(4) $I_2 = 22.98$ Amp

$\cos\phi_2 = 0.0995$.

(2) $V_{ph} = \frac{V_L}{\sqrt{3}} = 46.19$ V

(3) $$I_{2s} = \frac{sE_{20}}{\sqrt{R_2^2 + (sX_{20})^2}}$$

$= 8.58$ A

(5) $\cos\phi_2 = 0.928$

(5) 10 H.P, 4 Pole, 25 Hz, 3-ϕ wound rotor induction motor is taking 9100 Watt from the line, core loss 290 W, stator copper loss 568 W, rotor copper loss is 445 and frictional windage is 100 W

9100 − coper loss − core loss
↑
air gap

(a) Determine power transfer across air gap,

rotor input − rotor copper loss

(b) mechanical power develop by the rotor

(c) Mechanical power output

stator Input power = core loss + copper loss

(d) Efficiency of the motor

= 858

(e) slip of the motor.

* rotor copper Loss = S × rotor input

(c) rotor output = mechanical power develop − rotational loss.

(d) $\frac{\text{output}}{\text{input}}$

(6) The impedance of 3ϕ, 16 pole I.M is $(0.02 + j0.15)\,\Omega$

It develops full load torque at 360 rpm, then what will be the

(1) the ratio max to full Load torque.

(2) The speed at max torque

(3) The rotor resistance to be added to get max starting torque.

$$N_s = \frac{120 \times 50}{16} = 375$$

$$S = \frac{N_s - N_r}{N_s} = \frac{375 - 360}{375} = 0.04$$

(1) $$\frac{R_2^2+(S_{fl}X_{20})^2}{2SR_2X_{20}}$$

$$= \frac{(0.02)^2+(0.04\times0.15)^2}{2\times0.04\times0.02\times0.15} = 1.816$$

(2) At Tmax slip is $S_m = \frac{R_2}{X_{20}}$

$$\therefore N_r = \left(1-\frac{R_2}{X_{20}}\right)N_s$$

$$= \left(1-\frac{0.02}{0.15}\right)\times 375$$

$$\boxed{N_r = 325}$$

(3) $0.13\,\Omega$

(7) 4pole, 50Hz I/m has resistance & standstill reactance are $0.03\,\Omega$ & $0.12\,\Omega$. Find the amount of rotor resistance to be inserted to obtain 75% of max torque at starting.

Ans: $$\frac{T_{st}}{T_{max}} = \frac{2a}{a^2+1}$$

$a = 2.215$

$= 0.417 \rightarrow$ slip must be less than 1

$$S = 0.4517 = \frac{R_2}{X_{20}} = 0.242$$

(8) The no load and blocked rotor test performed on 400V 3-ϕ delta connected I/m.

↳ Line voltage & phase voltage are same.

No-load test: 400V, 2.5A, 600W

Blocked rotor test: 200V, 12.5 A, 1500W

Determine energy (or working) component

No load powerfactor, exciting resistance and reactance per phase R_0, X_0 refer to stator side assuming that friction & windage loss are 180W.

→ Also determine equivalent resistance and reactance referred to primary side (stator) as well as current & p.f

Ans:-

No load current per phase = 1.443 =

stator copper loss $= 3 I_0^2 R_1 = 3(1.443)^2 \times 5$

stator iron loss = 600 − friction loss − copper loss

$= 600 - 180 - (2.5)^2 \times 5\Omega$

$= 388.75$

$P_0 = 3 V_{ph} I_{ph} \cos\phi_0$

$600 = 3 \times 400 \times 2.5 \times \cos\phi_0$

$\cos\phi_0 = 0.2$

Blocked rotor:-

$$\boxed{P_{sc} = 3 I_{sc}^{'2} R_{sc}}$$