Induction Motor Drives.

- AN IM is a ~~complet~~ commonly used ac electric motor.
- Electrical motor is an electromechanical device.
- Motor converts electrical energy into mechanical energy.

Construction of IM.

3 – ϕ induction Motor
- Stator – ଯେଉଁ ଅଂଶ ବୁଲେନି
- Rotor. – ଯେଉଁ ବୁଲେ

- Stator carries a 3 – ϕ winding (stator winding)
- Rotor carries short-circuited winding (Rotor winding)
- IM is considered to be a Rotating which
  - Primary (Stator) is stationary
  - Secondary (Rotor) is rotating.

Stator.

- It consists of a steel frame which encloses a hollow

Its also reduce hysteresis and eddy current losses.

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• 3 Phase stator winding is wound for a define number of poles as per requirement of speed

Number of poles $(N_P) \propto 1/$ speed of IM (N_S).

• when 3 phase supply is given to the stator winding a rotating magnetic field (RMF) of constant magnitude is produced.

(3 phase apply হলে RMf তৈরি হয়)

ROTOR

• Rotating part of the Motor.

• Rotor winding may be two types.

i) Squirrel cage type → one copper bar is placed each slot.

All these bars are joined at each end by metal rings. Called end rings.

• This forms a permanently short circuited winding.

ii) wound type

Consists of Laminated cylindrical core.

• joined to 3 insulated slip rings.

• wound rotor runs like Squirrel cage at normal speed.

Advantage of IM.

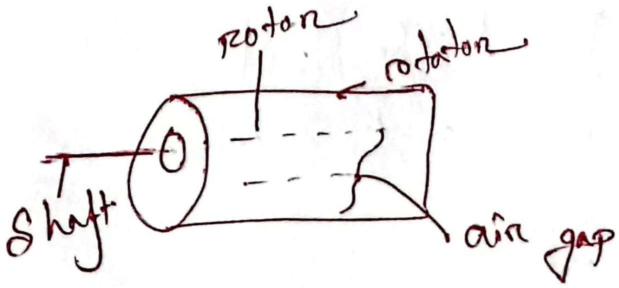
- It has simple construction.
- It is relatively cheap.
- It requires little maintenance
- It has good power factor and efficiency.

Disadvantage of IM.

- It is essentially a constant speed motor and its speed can't changed easily.
- It doesn't have a self starting torque.
- During light load, the power factor of the motor drops to a very low value.

1ϕ induction motor - যেখানে কম power লাগে।
like washing machine
fan

3ϕ induction motor - industry তে use করা হয়।



Math Compan Book 7.1 (381 page in pdf name Pc EEE 62

• A 208-Y, 10-hp, four-pole, 60 Hz Y connected induction motor has a full load slip of 8 percent.

a. what is the synchronous speed of this motor.

Ans

The speed at which the rotating magnetic filed a stator (system) revolves is called synchronous speed (NS).

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

f — frequency / rated frequency.

P — number of poles.

here

$f = 60 HZ$

$P = 4$ pole

$$= \frac{120 \times 60}{4}$$

$$= 1800 \; R/min \; (\text{rotation})$$

b) what is the rotor speed of this motor at the rated load?

Ans [rotor speed = Nm]

synchronous speed

$$N_m = (1 - S) \times N_S$$

% age of slip $\Rightarrow S = \frac{n_s - N_m}{N_S} \times 100$.

$(n_s - N)$ is called Slip speed.

$N = 0$ - 2(m) $S = 1$ on 100%.

here

a full load slip 5 percent

$$S = \frac{5}{100} = 0.05$$

Now

rotor speed $= N_m \Rightarrow (1 - S)\ N_{Sync}$.

$$= (1 - 0.05) \times 1800\ (r/min)$$

$$= \underline{1710}\ r/min$$

c) what is the rotor frequency of this motor at the rated load?

$\boxed{\text{The rotor frequency of this motor } f_r}$

$$f_r = S f_e$$

rotor frequency

slip of the motor এর slip টাকে গুণ দিলে পাওয়া যায়

rated frequency

$$\text{or} \quad f_r = \frac{n_{sync} - n_m}{n_{sync}} f_e .$$

here

$$f_r = S f_e = (0.05) \times (60\,Hz)$$

$$= 3\,Hz.$$

rated frequency $= 60\,Hz$

rotor frequency একটা সূত্র আছে

$$f_r = \frac{P}{120}\left(N_{sync} - N_m\right).$$

d) What is the shaft torque of this motor at the rated load?

Shaft load torque:

$$\tau_{load} = \frac{P_{out}}{\omega_m}$$

$$= \frac{10 \text{ hp} \times 746 \text{ W/hp}}{n_m \times (2\pi \text{ rad/r})(1 \text{ min}/60)}$$

$$= \frac{7460}{179.07}$$

$$= 41.7 \text{ N.M.}$$

Example 7.2 395 page (Chapman)

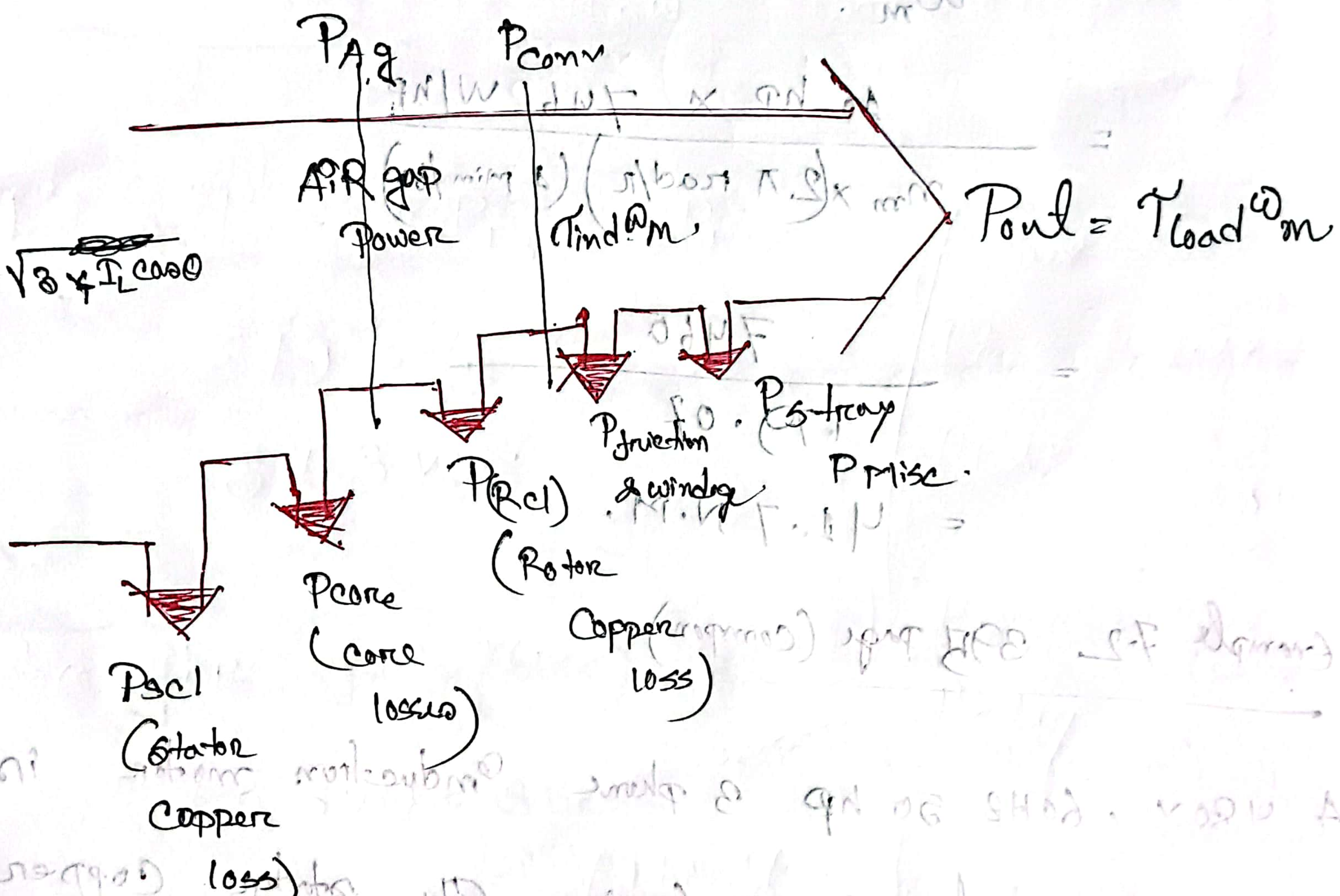
A 480V, 60Hz 50 hp 3 phase induction motor is drawing 60A at 0.85 PF lagging. The stator copper losses are 2 kW, and rotor copper losses are 700W. The friction and windage losses are 600W, the core losses are 1800W and stray losses are negligible.

a. The air-gap power P_{AG} what?

এই ধরনের type math করতে $\boxed{\text{power flow diagram}}$ জানতে হবে

~~Per phase equivalent circuit of IM জানতে হবে~~

$P_{in} = \sqrt{3} \times I_L \cos\theta$



ঐ math এ P_{AG} বের করতে হলে $P_{in} - P_{SCL} - P_{core}$ করতে হবে,

$$P_{in} = \sqrt{3}\, V_T I_L \cos\theta$$

$$= \sqrt{3} \times 480 \times 60 \times 0.85$$

$$= 42.4\ \text{kW}$$

here

$V_T = 480V$

$I_L = 60A$

0.85 PF Lagging

So $\cos\theta = 0.85$

So $P_{Ag} = P_{in} - P_{scl} - P_{core}$

$= \cancel{\sqrt{3} \cdot 480 \times 60} \times 0.85$

$= \cancel{42.4\,kW}$ $42.4 - 2 - 1.8$

$= 38.6\ kW$.

$P_{scl} = 2\,kW$

$P_{core} = 1800\,W$

$= \frac{1800}{1000}$

$= 1.8\,kW$

b) find the power converted P_{conv}.

P_{conv} বের করতে হলে P_{conv} থেকে P_{scl} P_{core}

P_{rcl} বিয়োগ a থেকে $P_{ag} = 38.6$ পাবো So

$P_{conv} = P_{Ag} - P_{rcl}$

$= 38.6 - 0.7$

$= 37.9\,kW$

here

$P_{Ag} = 38.6\,kW$

$P_{rcl} = 700\,W$

$= \frac{700}{1000}$

$= 0.7\,kW$

c. what is input power P_{out} ?

Pout বের করতে হলে ক্ষতগুলো থেকে বিয়োগ করতে হবে

Here P_{conv} মান $37.9\ kW$ (আগে পাই)

So P_{conv} থেকে $P_{F\&W}$, P_{misc} বিয়োগ করলে হবে।

$$P_{out} = P_{conv} - P_{F\&W} - P_{misc}$$

$$= 37.9 - 0.6 - 0$$

$$= 37.3\ kW$$

here

$P_{conv} = 37.9\ kW$

$P_{F\&W} = 600\ W = 0.6\ kW$

$P_{misc} = 0\ kW$

and $P_{stray} = 0$ (negligible ধরা হয়েছে)

এখন hp দিতে হলে

$37.3\ kW$

$= 37300\ W$. [$1\ hp = 746\ W$]

So in hp, $P_{out} = \frac{37300\ W}{746\ W}$

$= 50\ hp$.

d) find the induction motor efficiency?

We know

here

$P_{out} = 37.3\,KW$

$P_{in} = 42.4\,KW$

$$\text{Efficiency } \eta = \frac{P_{out}}{P_{in}} \times 100\,\%$$

$$= \frac{37.3}{42.4} \times 100\,\%$$

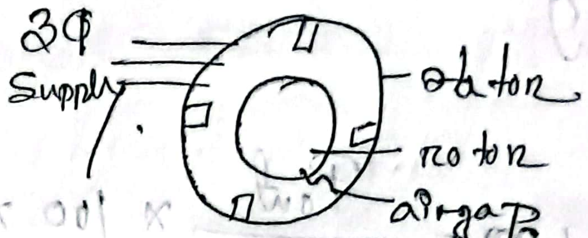
$$= 87.8\,\%$$

$$\simeq 88\,\%$$

Ans

Working Principle of Im.

The working principle of 3ϕ Im is based on the production of rotating megnatic field. It contains two parts - Stator and Rotor.



The stator part create megnatic field and Rotor is the rotating part.

- Stator winding are often connected to the Ac power supply.

- when Ac supply is given to stator winding. it produces rotating megnatic field (RMf).

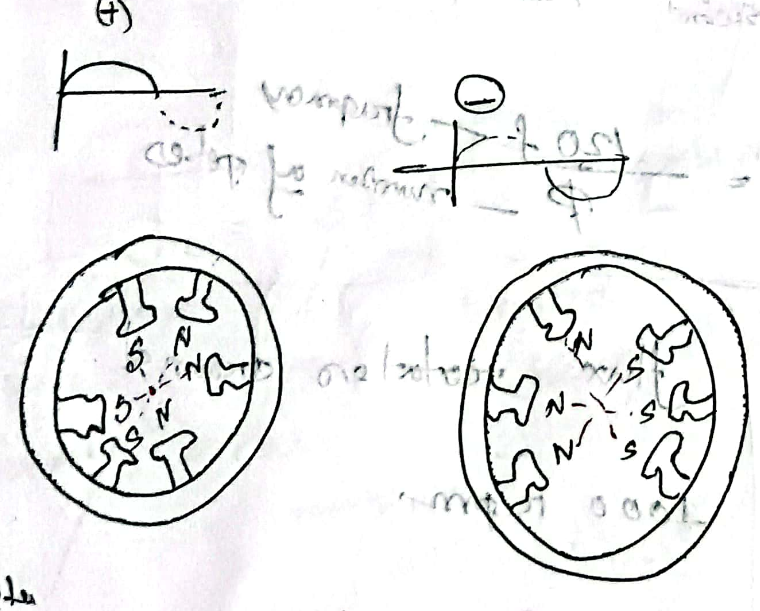
- The flux lines of megnatic field will cut the rotor, and Induce an emf acording faraday's law

• Induced emf will induce a current that generate another magnetic field which is rotor magnetic filed.

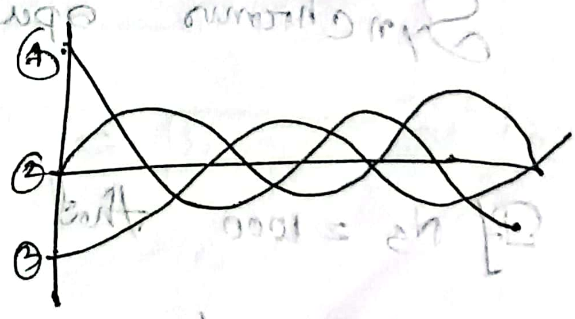
• The magnetic field of stator and the magnetic field of rotor will interact and give rise to a torque which will turn the motor.

• 3φ IM is self starting motor

* (N-S) ম্যাগনেট পূর্ণ Rotation করতে ২টি AC cycle দরকার হয়। ১টি + cycle North pole, ১টি - cycle South তৈরি হয়ে থাকে।



3 phase input.



+ cycle

after 120: (N) pole and (S) Pole are determined in (+) (N-S) are turn into (S-N) so that its induced rotating magnetic friend and How does the IM 3φ works.

Speed of Rotating magnetic field — magnetic field of stator

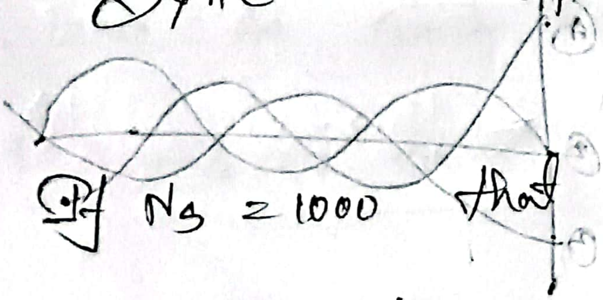
Synchronous speed (N_s): The speed at which the rotating magnetic field in stator revolves/rotating.

In 2 pole stator winding → 1 revolution in one cycle current

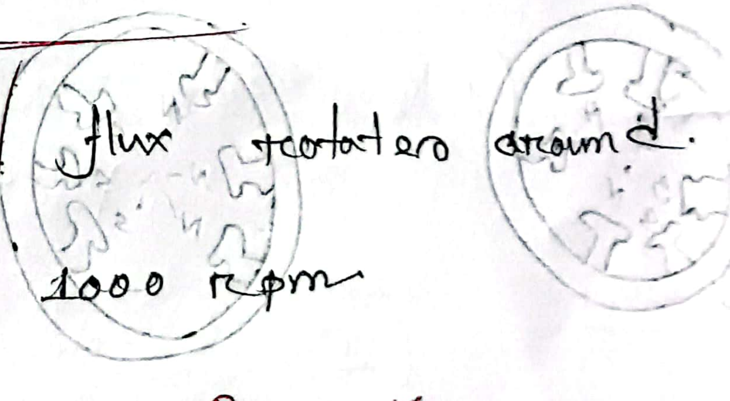
" 4 " " " → 1 revolution 2 cycles of current.

Thus P poles → 1 revolution per second P/2 cycles current.

Synchronous speed $N_s = \frac{120 f}{P}$ — frequency, number of poles



If $N_s = 1000$ that means flux rotates around the stator at a speed of 1000 rpm



$$f = \frac{P}{2} \times \frac{N_s}{60}$$

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

Slip

difference between the (N_s) of the rotating stator field.
and the actual rotor speed (N) is called slip

if $N = 0$ then $S = 1$, 100%.

$$\text{Percentage (\%) of slip } S = \frac{N_s - N}{N_s} \times 100$$

($N_s - N$) called slip speed.

Change of slip No Load to full load is 0.1 % to 3 %.

Rotor Current Frequency.

$$\boxed{f_r = S f_e}$$

rotor frequency.

Slip of the motor

rated frequency

$$\boxed{f_r = \frac{n_s - N_m}{N_s} f_e}$$

OR

$$f_r = \frac{P}{120}(n_s - n_m)$$

$$\frac{1}{N_s}(N_s - n_m) \cdot f_e$$

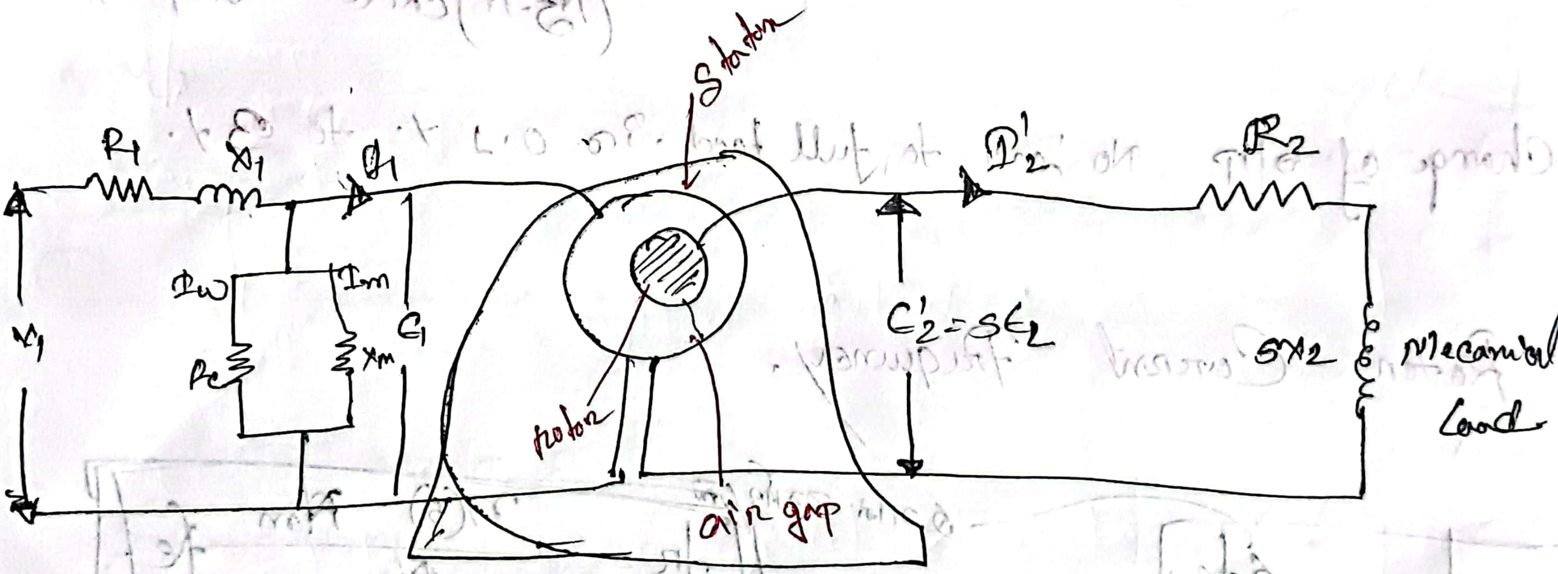
$$N_s = \frac{120 f}{P}$$

$$= \frac{P}{120 f} \times (N_s - n_m) \times \cancel{f}$$

Equivalent Circuit & Vector Diagram of 3φ IM.

at any slip

IN (IM) Input $\xrightarrow{to}$ Stator, rotor are electrical
output → rotor (from the) is mecanical.

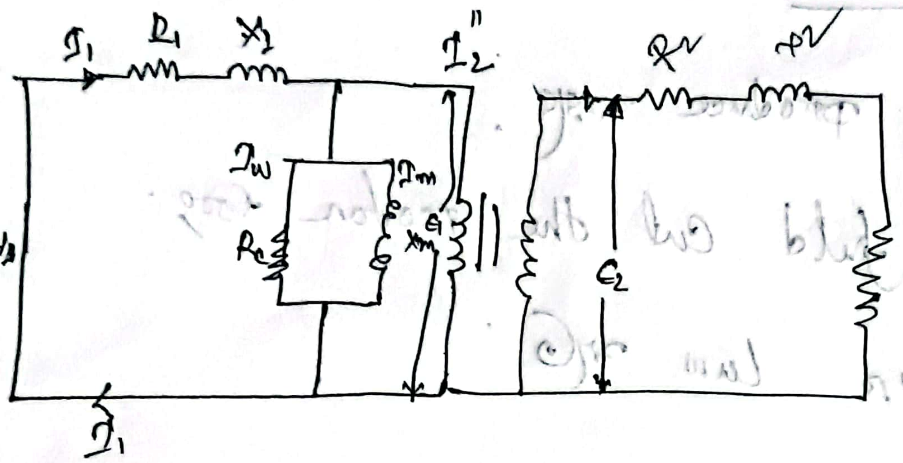


Stator Circuit → $V_1 = -E_1 + I_1(R_1 + jX_1)$
└ self induced emf

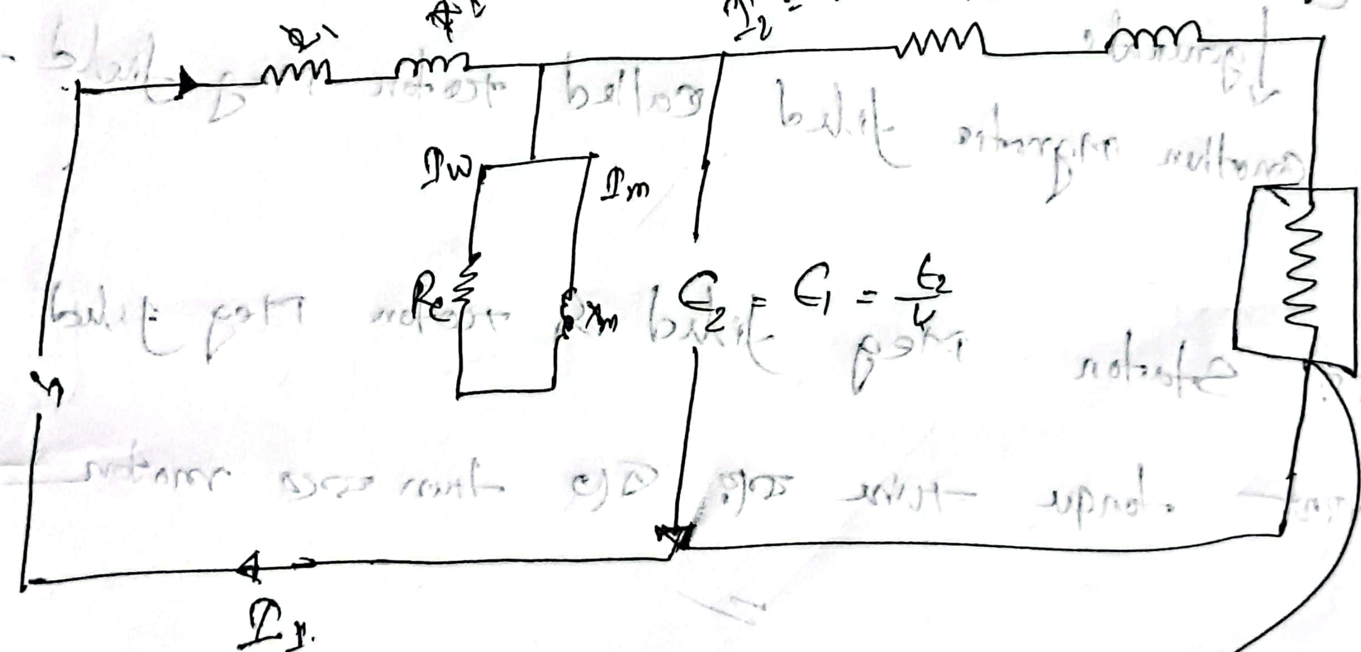
Rotor Circuit → $E_2' = I_2'(R_2 + X_2)$

I_m = air gap

Transformer Equivalent circuit of IM.



$R_L = R_2\left(\frac{1}{S} - 1\right)$



$I_2'' = KI_2'$ $R_2' = \frac{R_2}{K^2}$ $X_2' = \frac{X_2}{K^2}$

$E_2 = E_1 = \frac{E_2}{K}$

$R_L' = \frac{R_2}{K^2}\left(\frac{1}{S} - 1\right)$

Converted to Mecnalcal power

Stortcut of IM working principle:

①. Stator Ac power supply তে connected থাকে.

↓ দিলে

② দিলে RMF produce করবে.

③ flux lines magnetic field cut the rotor তার

emf induce হবে faraday র law হতে

↓ induce হবে

Current

↓ generate

another magnetic field called rotor mag field.

তারা Stator mag field & rotor mag field

সংঘাতে torque তৈরি করে যা turn করে motor