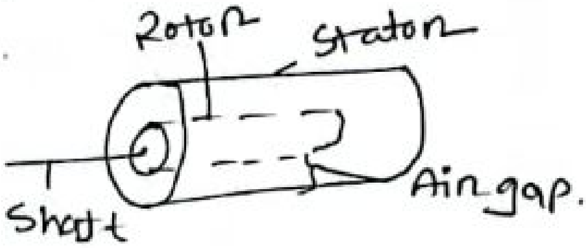
Induction motor

Induction motor is a AC motor. আগে IM এর field কে excite করতে i/p থেকে AC signal supply দেওয়া লাগে, আর ফলে o/p এ আমরা ঘূর্ণনশক্তি পাওয়া যায়,

1) 1 φ induction motor → যেখানে কম পাওয়ার লাগে like washing m/c, fan.
2) 3 φ " "
↳ Industry তে use করা হয়,

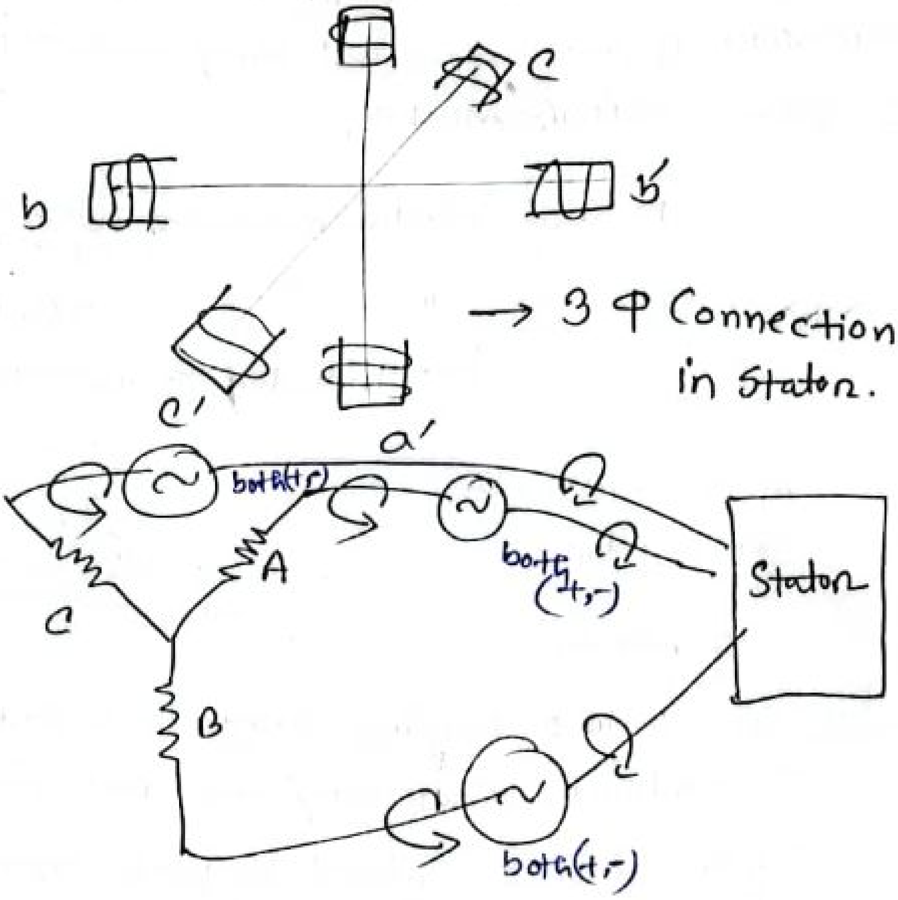
IM এর দুই Part →
1) Stator
2) Rotor.



এখানে, Stator এ Rotating magnetic field তৈরি হয় Continuous North pole/ South Pole তৈরি মাধ্যমে, এর ফলে Rotor এ induced magnetic field তৈরী হয় যেটি দিয়ে Rotor কে ঘুরানো হয়,

এখানে, Stator আর Rotor এর মাঝখানে Air gap থাকে. ফলে Stator এর সৃষ্ট ঘূর্ণন magnetic field create হয়. তাইটা পুরোটা Rotor এর সাথে আসে না, ফলে Stator আর Rotor এর মাঝখানে Speed এর পার্থক্য হয়,

How Rotating magnetic field Produced in Stator/ Induction motor →



A rotating magnetic field is produced in a three phase induction motor by the 3 phase AC currents that flows through the stator windings. The current is each phase is 120 out of the phase with others, create a magnetic field that rotates around the stator at a constant speed. Each alternating phase current produces its own flux which is sinusoidal. So, all three fluxes are sinusoidal and are seperated from eachother by 120°.

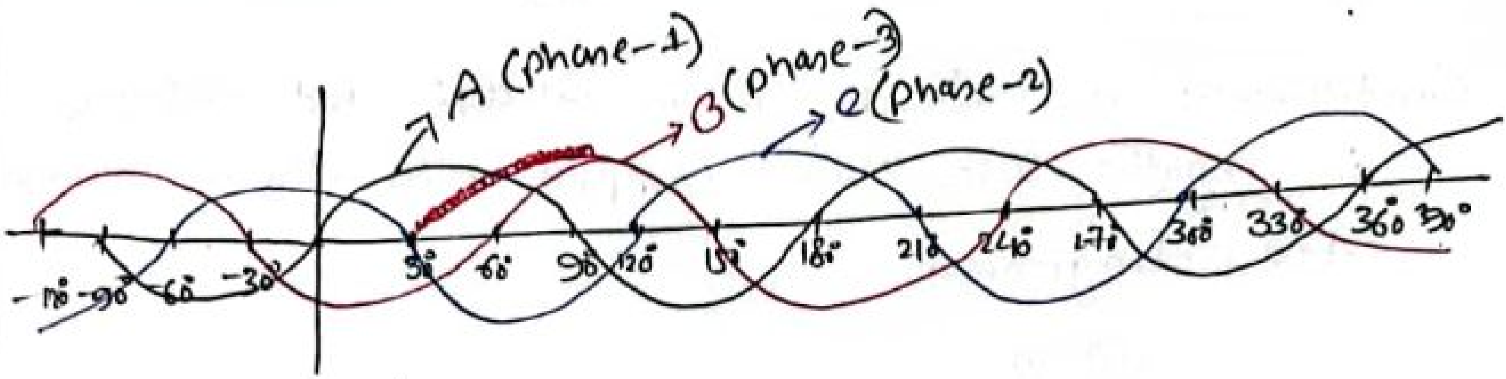


fig → wave form of the phase
(1)
[এখানে তিনটি different supply source 120° Angle এ Stator এ supply দেওয়া হয়]

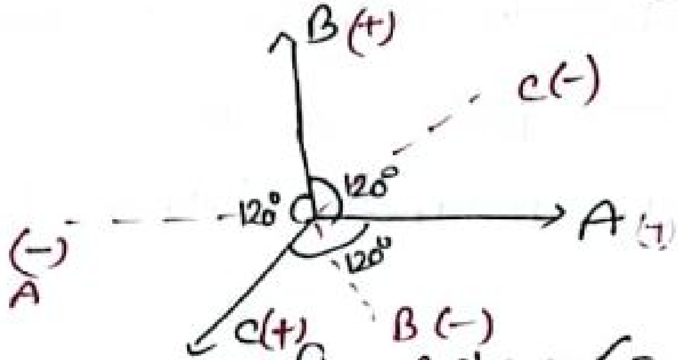
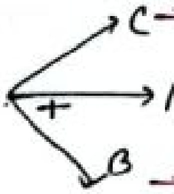


fig: 3 phase (Each phase is 120° out of phase with others)
(2)

Condition-1:

In fig-1, A is upward means (direction of phase A is in (+) side) but B & C is in negative side

Now compare with fig-2 → Re-arrange the diagram.

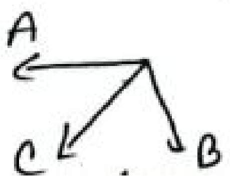


C → (change due to C in negative side

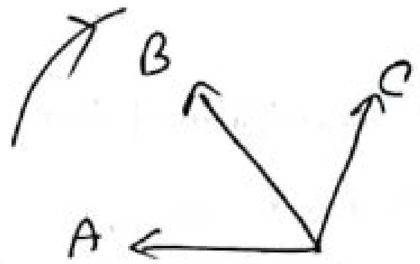
A (No change because in both figure A is in positive side.

B → change due to B in negative side

Condition-2: In fig-1, C is in (+) side, but A & B in in negative side → Now compare with fig-2 and re arrange the diagram →



Condition-3:- In fig-1 B is in (+) side but A & C is in negative side. Now compare with fig-2. Rearrange the diagram→



Here, the rotation is continuous. So, the above figures of shifting the position of the phase describe how rotating magnetic field is produced.

Working Principle of 3 φ IM motor:

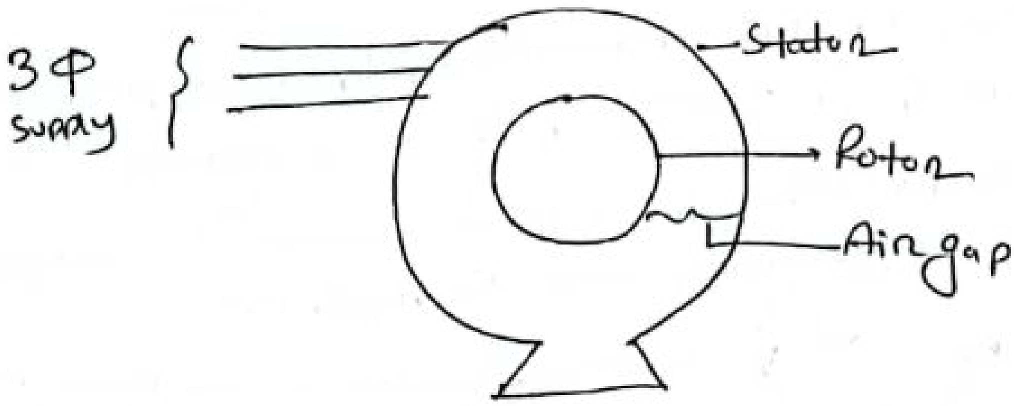


fig: 3 φ IM motor.

The working principle of 3 φ IM is based on the production of rotating magnetic field. It consists two part Rotor & Stator.

[নিজেদের মতো করে লিখবা]

Speed of Rotating magnetic field

2 Pole

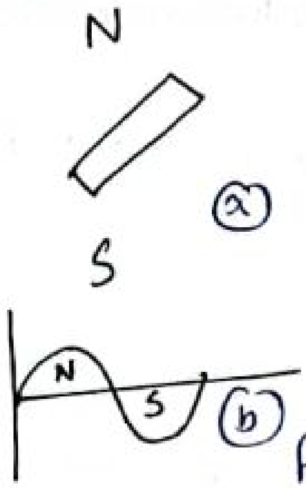


fig-1

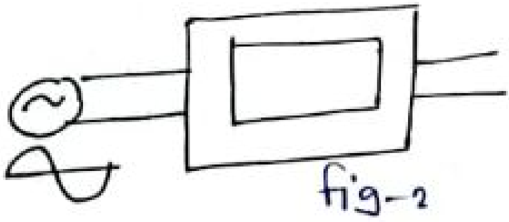


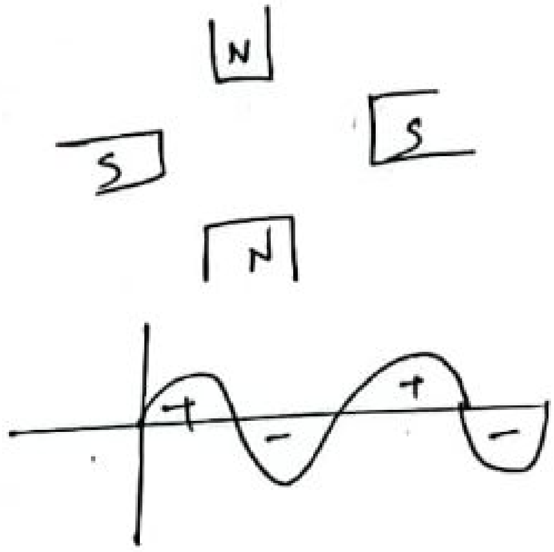
fig-2

In transformer,
when AC is supply; Positive half ($\frac{1}{2}$) cycle produced North pole in the transformer windings, negative half cycle produced South pole in the transformer windings.
means, to produce North pole & South pole a complete AC cycle (supply) is required.

Similar → In fig (1)
(N-S) মধ্যেকে ঘুরে ঘুরে Rotation দেখার জন্য একটি পূর্ণ AC Cycle দরকার।
কারণ

(+) Cycle North pole create করে
(-) " South " " ".

4 Pole



Same → (N-S) মধ্যেকে ঘুরে পূর্ণ Rotation দেখার জন্য দুইটি AC cycle দরকার।
কারণ প্রথম (+) cycle North pole create করে
" (-) " South " "
" (+) " North " "
" (-) " South " "
তবেই ঘূর্ণন সম্পন্ন হবে।

Now, we can write →
In 2 pole stator winding, the field makes one revolution in one cycle of current.

In 4 pole stator winding, the field makes one revolution in two cycles of current.

∴ for P poles, the rotating field makes one revolution in $P/2$ cycles of current.

∴ cycle of current $= P/2 \times$ revolution of field.

or " " " per seconds $= P/2 \times$ " " " per second

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

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

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

$N_s \rightarrow$ synchronous speed of stator

$P \rightarrow$ No. of poles

$f \rightarrow$ frequency of stator.

% age slip $\Rightarrow$ $S = \dfrac{N_s - N}{N_s} \times 100$

N.B → The rotor can never reach the speed of stator flux.

∴ Rotor speed (N) < the stator field speed (N_s)

∴ the relative speed between the rotating flux and the rotor is $N_s - N$. Due to speed change in rotor, so frequency also change.

∴ the rotor current frequency f' is given

$$f' = \frac{(N_s - N) P}{120}$$

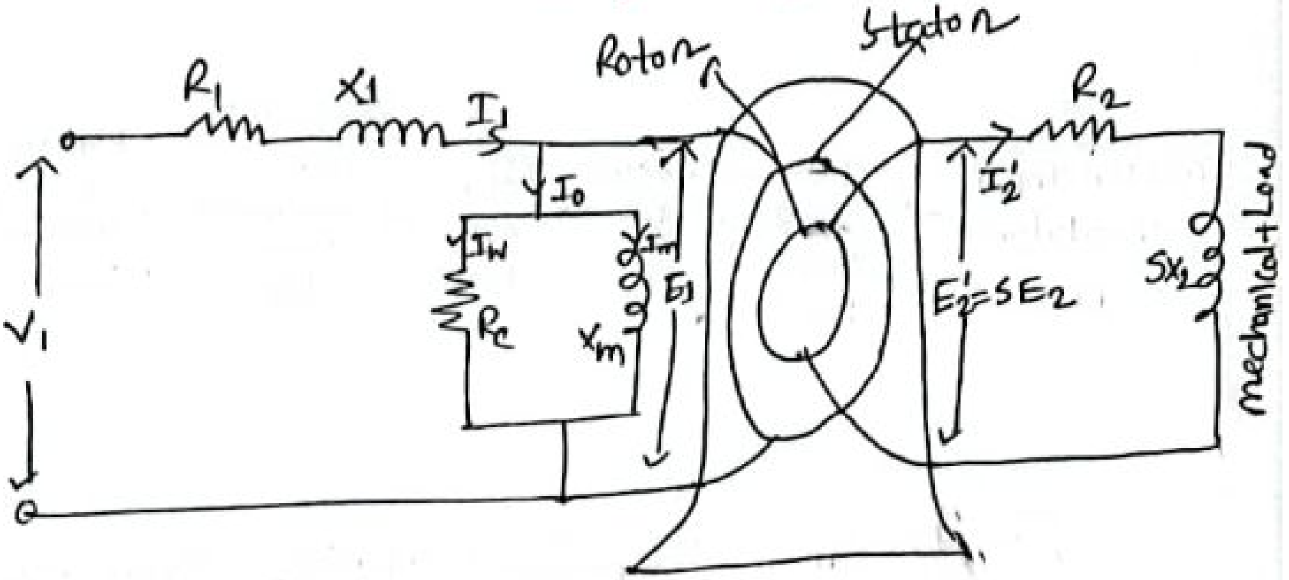
$$= \frac{S N_s P}{120}$$

$$\left\{ S = \frac{N_s - N}{N_s} \quad f = \frac{N_s \times P}{120} \right.$$

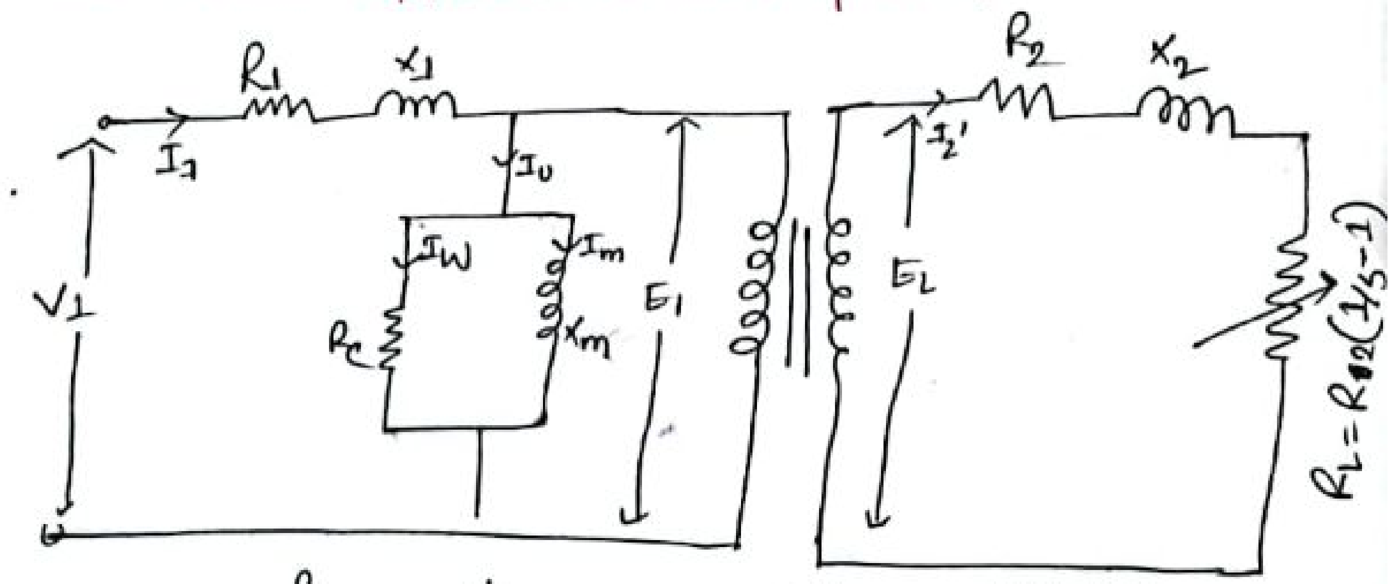
$$\boxed{f' = S f}$$

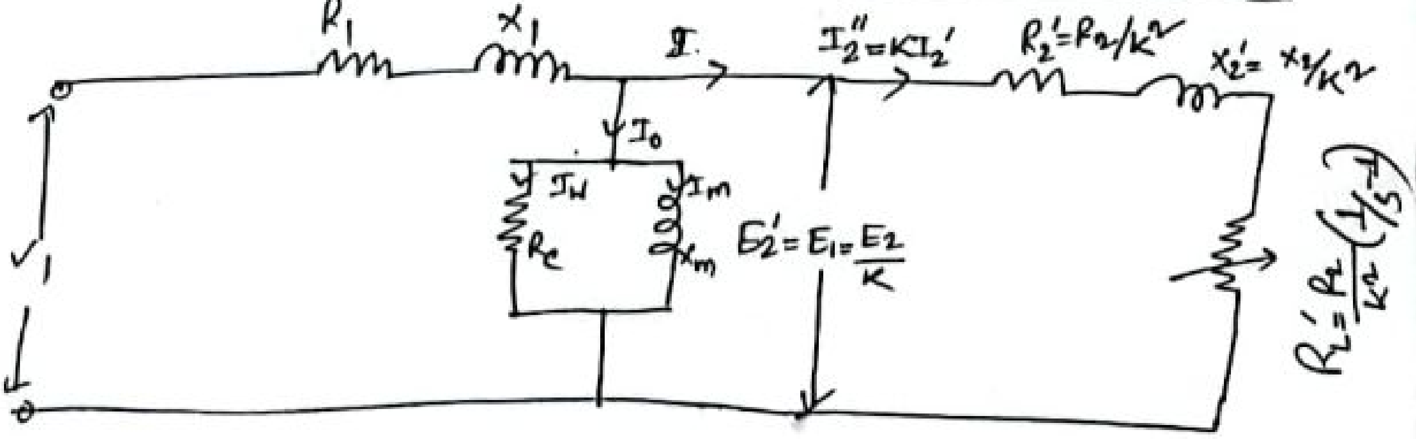
Math (from theraja → 34.3, 34.4, 34.5)

Equivalent ckt & of IM (3 Φ) at any Slip:-



Transformer equivalent ckt of 3 Φ IM:-





Induction motor torque equation

Power Stages in 3φ IM:-

Motor Input in Stator P_1 → Stator Cu & Iron Losses → Rotor i/p P_2 → Rotor Cu Losses → mechanical power developed in Rotor P_m → Windage & friction Losses → Rotor o/p P_{out}

Math (from theraja → 34.14(a), 34.19, 34.27)

Induction motor torque Equation

Torque, $= P/\omega$

$\tau = P/\omega$

$\therefore \tau \propto P$ we know, $P = VI\cos\theta$

$= E_r I_r \cos\theta$

or, $\tau \propto E_r I_r \cos\phi_2$

or, $\tau \propto \phi I_r \cos\phi_2$ [$\because E_r \propto \phi$ ফ্লাক্স যত বেশি Emf generation হবে তত বেশি]

or, $\tau = K\phi I_r \cos\phi_2$

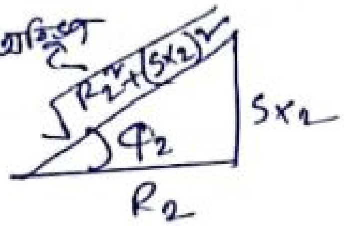
$= K\phi \dfrac{sE_2}{Z_2} \cos\phi_2$ [$I_r = \dfrac{E_r}{Z_r}$ এখানে r মানে rotor, 2 → মানেও Rotor]

$= K\phi \dfrac{sE_2}{\sqrt{R_2^2 + (sX_2)^2}} \cos\phi_2$

বুঝানোর জন্য

$\sqrt{R_2^2 + (sX_2)^2}$

ভূমি লম্ব



$Z_2 = \sqrt{R_2^2 + (sX_2)^2}$

impedance (from equivalent ckt)

R_2 jsX_2

$\therefore Z_r = R_2 + jsX_2$

$Z_2 = R_2 + jsX_2$

from trigonometry

$\cos\phi_2$ (Power factor)

$= \dfrac{R_2}{\sqrt{R_2^2 + (sX_2)^2}}$

$\therefore \tau = K\phi \dfrac{sE_2}{\sqrt{R_2^2+(sX_2)^2}} \dfrac{R_2}{\sqrt{R_2^2+(sX_2)^2}}$

$= \dfrac{K\phi s E_2 R_2}{R_2^2 + (sX_2)^2}$

$$= \frac{kk' E_2 \, s E_2 R_2}{R_2^2 + (sX_2)^2}$$

Now, Again we use

$\phi \propto E_2$

$\therefore \phi = k' E_2$

$$= \frac{kk' E_2^2 s R_2}{R_2^2 + (sX_2)^2} \quad \text{---} (1)$$

we know, $S = \dfrac{N_s - N}{N_s}$

At initial moment, there is No Rotor speed.

$\therefore$ At this point Rotor in fixed/Stand still

$\therefore N = 0$

$$S = \frac{N_s - 0}{N_s} = 1$$

Put, $S = 1$ in eqn (1)

$$\tau = \frac{k_1 E_2^2 s R_2}{R_2^2 + (sX_2)^2}$$

kk' দুটোই constant

$\therefore kk' = k_1$ নিলাম;

$$\tau_{(Starting)} = \frac{k_1 E_2^2 R_2}{R_2^2 + X_2^2} \quad \text{---} (11)$$

যখন $S = 1$;

সর্বোচ্চ/সর্বাধিকের জন্য প্রথমে Differentiate করে value (0) zero

(11) নং eqn কে S এর সাপেক্ষে → Differentiate

$$\therefore \frac{d\tau}{ds}(max) = \frac{\{R_2^2 + (sX_2)^2\} k_1 E_2^2 R_2 - k_1 s E_2^2 R_2 \cdot 2 s X_2 \cdot X_2}{[R_2^2 + (sX_2)^2]^2}$$

ব্যবহার

$$0 = \frac{\{R_2^2 + (sX_2)^2\} k_1 E_2^2 R_2 - k_1 s E_2^2 R_2 \cdot 2 s X_2 \cdot X_2}{[R_2^2 + (sX_2)^2]^2}$$

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$$\therefore \left\{R_2^2 + (Sx_2)^2\right\} K_1 E_2^2 R_2 = K_1 S E_2^2 R_2 \cdot 2Sx_2 \cdot x_2$$

$$\therefore R_2^2 + (Sx_2)^2 = 2S^2 x_2^2$$

$$R_2^2 = S^2 x_2^2$$

$$S x_2 = R_2$$

$$\boxed{\therefore S = \frac{R_2}{x_2}} \rightarrow$$ for max Condition

$$\therefore S_{max} = \frac{R_2}{x_2}$$

$$\therefore R_2 = S_{max} \cdot x_2$$

Now, $$T_{max} = \frac{K_1 S E_2^2 R_2}{R_2^2 + (Sx_2)^2}$$

Put; $R_2 = Sx_2$

$$= \frac{K_1 S E_2^2 R_2}{(Sx_2)^2 + (Sx_2)^2}$$

$$= \frac{K_1 S E_2^2 R_2}{2(Sx_2)^2}$$

$$= \frac{K_1 E_2^2}{2x_2} \quad \text{— (iii)}$$

(ii) ÷ (iii)

$$\frac{T_{st}}{T_{max}} = \frac{K_1 E_2^2 R_2}{R_2^2 + (x_2)^2} \times \frac{2x_2}{K_1 E_2^2}$$

$$= \frac{2x_2 R_2}{R_2^2 + (x_2)^2}$$

$$= \frac{2x_2 \, S_{max} \cdot x_2}{(S_{max} \cdot x_2)^2 + x_2^2} = \frac{2x_2^2 S_{max}}{S_{max}^2 x_2^2 + x_2^2}$$

$$= \frac{2x_2^2 S_{max}}{x_2^2(S_{max}^2 + 1)} = \frac{2S_{max}}{S_{max}^2 + 1}$$

$$\therefore \frac{\tau_{st}}{\tau_{max}} = \frac{2S_{max}}{S_{max}^2+1}$$

$$\boxed{\frac{\tau_{st}}{\tau_{max}} = \frac{2a}{a^2+1}}$$