Lecture Note Electrical Drives

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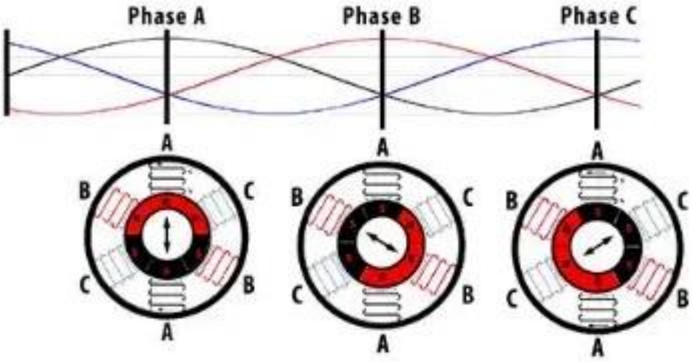
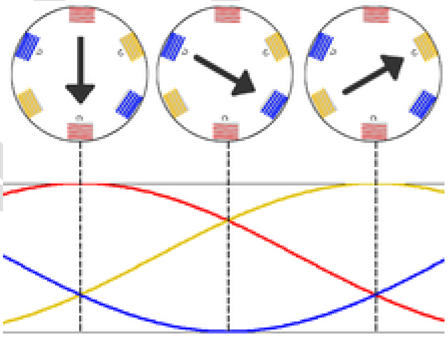
Q: Basic principle of induction Motor

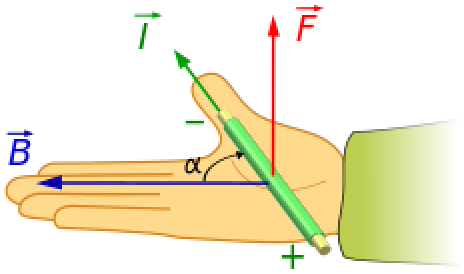
- The stator of the motor consists of overlapping winding that are displaced by 120^o with respect to time and space.



- As a results of this rotating magnetic field is created in the stator that rotates with a speed of $N_s = \frac{120 \times f}{p}$. This speed is called synchronous speed.



- According to Faraday's law an emf induced in any circuit is due to the rate of change of magnetic flux linkage through the circuit. As the rotor winding in an induction motor are either closed through an external resistance or directly shorted by end ring, and cut the stator rotating magnetic field, an emf is induced in the rotor copper bar and due to this emf a current flows through the rotor conductor.
- When a wire carrying an electric current (Rotor conductor) is placed in a magnetic field (Rotating magnetic field by the stator), each of the moving charges, which comprise the current, experiences the Lorentz force.



$$F = Il \times B$$

- Here the relative speed between the rotating flux and static rotor conductor is the cause of current generation; hence as per Lenz's law, the rotor will rotate in the same direction to reduce the cause, i.e., the relative velocity.

Q. Equivalent Circuit and Important Equation

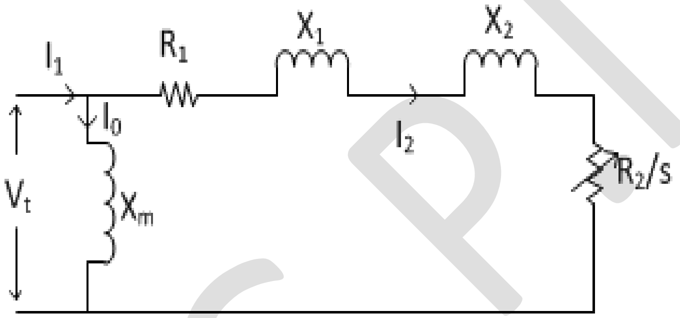


Fig. Per phase equivalent circuit (All quantities refer to stator side)

Synchronous speed:

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

Slip

$$S = \frac{N_s - N}{N_s}$$

Air gap Power

$$P_g = 3I_2^2 \frac{R_2}{s}$$

Copper Loss

$$P_{cu} = 3I_2^2 R_2 = S \cdot P_g$$

Mechanical Power

$$P_m = (1-S)P_g$$

$$T - T_l = J\frac{d\omega}{dt}$$

Torque developed by the motor

$$T = \frac{P_m}{\omega_m} = \frac{(1-S)P_g}{(1-S)\omega_s}$$

$$T = \frac{3}{\omega_s} I_2^2 \frac{R_2}{S}$$

Now, Rotor Current

$$I_2 = \frac{V_1}{\sqrt{(R_1 + \frac{R_2}{s})^2 + (X_1 + X_2)^2}}$$

From the rotor current Torque can be obtained as

$$T = \frac{3}{\omega_s} \frac{V_1^2 \cdot \frac{R_2}{S}}{\sqrt{(R_1 + \frac{R_2}{s})^2 + (X_1 + X_2)^2}}$$

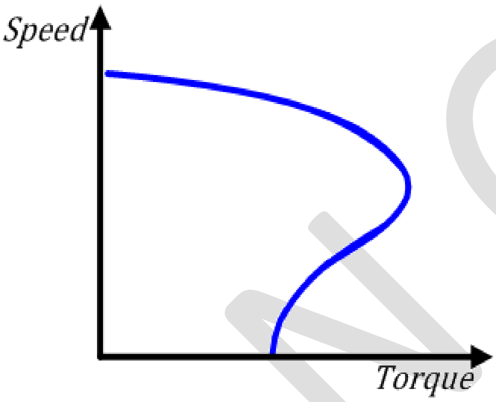
Slip at which maximum torque occurs (Obtained by differentiating torque and equate to zero)

$$S_{\max T} = \frac{\pm R_2}{\sqrt{R_1^2 + (X_1 + X_2)^2}}$$

Maximum torque

$$T_{\max} = \frac{3}{2\omega_s} \frac{V_1^2}{R_1 \pm \sqrt{R_1^2 + (X)^2}}$$

Q. Speed Torque Characteristic equation of Induction motor:



Q. Speed Control Method of Induction motor:

Stator side control:

1) Variable terminal voltage control
2) Variation of supply frequency
3) Introduction of resistor or inductor in the stator circuit

Rotor side control:
4) Addition of balance Resistor in the circuit
5) Injection of voltage in the circuit

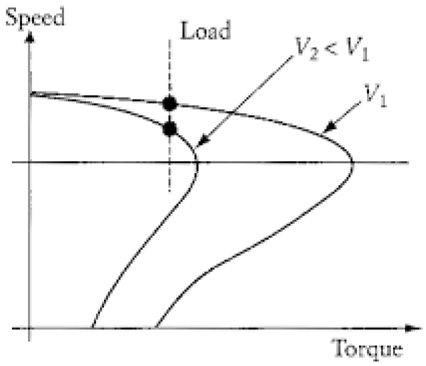
Q. Speed Control Method (Variable terminal voltage control):

The speed of a three-phase induction motor can be varied by varying the supply voltage. As it is known from the below equation that by reducing the supply voltage torque and maximum torque will reduced (torque developed is proportional to the square of the supply voltage).

$$T = \frac{3}{\omega_s} \frac{V_1^2 \cdot \frac{R_2}{S}}{\sqrt{(R_1 + \frac{R_2}{s})^2 + (X_1 + X_2)^2}} \qquad T_{\max} = \frac{3}{2\omega_s} \frac{V_1^2}{R_1 \pm \sqrt{R_1^2 + (X)^2}}$$

But, slip at which maximum torque is occur is independent of supply voltage.

$$S_{\max T} = \frac{\pm R_2}{\sqrt{R_1^2 + (X_1 + X_2)^2}}$$



Dynamics involved when we reduce the supply voltage:

As we decrease the supply voltage as a result of this current will decrease immediately and thus machine torque will reduce $T = \frac{3}{\omega_s} I_2^2 \frac{R_2}{S}$; so speed of the machine will falls ($T_m - T_L = J\frac{d\omega}{dt}$; and thus Slip ‘s’ will increase and again Current ‘I’ start to increase and as a result machine torque increases to meat the load torque.

At Low value of Slip torque and current can be written as:

$$T = \frac{3}{\omega_s} \frac{V_1^2}{R_2} S \qquad I = \frac{SV_1}{R_2}$$

So, $\frac{T}{I} \propto V_1$

Now as we decrease the voltage to negotiate the same load torque machine current has to be increase and thus efficiency is poor. This is major disadvantage of stator voltage control method.

Disadvantages:

1) Efficiency poor. $efficiency\ n = \frac{mech\ power\ input}{ele\ input} = \frac{(1-s)P_g}{P_g} = (1-s)$.

$$;cu\ loss\ increses\ \ P_g = \uparrow SP_g + (1-S)P_g \downarrow$$

2) Speed range is very poor (used for fan type load where $T_L \propto V_1^2$)
3) Allow controls only below base speed.
4) Starting torque and maximum torque production capability decreases as we decrease the supply voltage

Advantage:

1) Cost effective and simplicity