or, $$\frac{R_{12}\times R_{23}+R_{23}\times R_{31}+R_{31}\times R_{12}}{R_{12}+R_{23}+R_{31}}=R_1+R_2+R_3 \qquad (4)$$

Now, subtracting equation (1) from equation (4), $$R_3=\frac{R_{23}\times R_{31}}{R_{12}+R_{23}+R_{31}} \qquad (5)$$

subtracting equation (2) from equation (4), $$R_1=\frac{R_{12}\times R_{31}}{R_{12}+R_{23}+R_{31}} \qquad (6)$$

subtracting equation (3) from equation (4), $$R_2=\frac{R_{23}\times R_{12}}{R_{12}+R_{23}+R_{31}} \qquad (7)$$

Now, multiplying equations (5x6, 6x7 and 7x5) and adding all, we get:

$$R_3R_1+R_1R_2+R_2R_3=\frac{R_{12}\times R_{23}\times R_{31}^2+R_{12}^2\times R_{23}\times R_{31}+R_{12}\times R_{23}^2\times R_{31}}{(R_{12}+R_{23}+R_{31})^2}$$

or, $$R_3R_1+R_1R_2+R_2R_3=\frac{R_{12}\times R_{23}\times R_{31}(R_{12}+R_{23}\times R_{31})}{(R_{12}+R_{23}+R_{31})^2}$$

or, $$R_3R_1+R_1R_2+R_2R_3=\frac{R_{12}\times R_{23}\times R_{31}}{(R_{12}+R_{23}+R_{31})} \qquad (8)$$

Now divide equations (8/5, 8/6 and 8/7), we get:

$$R_{12}=\frac{R_3R_1+R_1R_2+R_2R_3}{R_3} \qquad (9)$$

$$R_{23}=\frac{R_3R_1+R_1R_2+R_2R_3}{R_1} \qquad (10)$$

$$R_{31}=\frac{R_3R_1+R_1R_2+R_2R_3}{R_2} \qquad (11)$$

1.23 A delta connection contains three equal resistances R. Find the resistances of the equivalent star connection.
Solution:

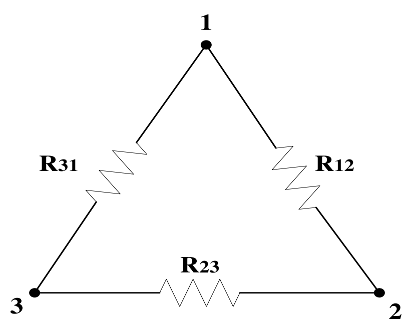


Fig.1.23(a): Delta Connection

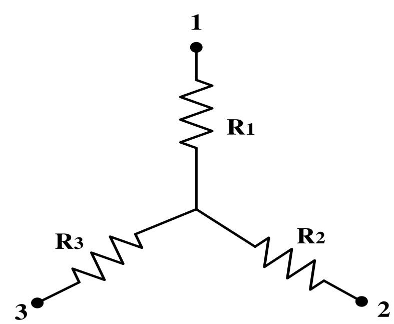


Fig.1.23(b): Star Connection

Given that: $R_{12}=R_{23}=R_{31}=R$

From fig.1.23(a) and fig.1.23(b)

$$R_1=\frac{R_{12}\times R_{31}}{R_{12}+R_{23}+R_{31}}=\frac{R\times R}{R+R+R}=\frac{R}{3}=R_2=R_3$$

Unit-II

Q. Define Form Factor and Peak Factor.
Answer: Form Factor of a waveform is defined as the ratio of its RMS value to the average value, i.e.

$$F.F.=\frac{RMS\ Value}{Average Value}=\frac{I_{rms}}{I_{av}}=\frac{V_{rms}}{V_{av}}$$

Power factor, $Cos\theta = \frac{V_R}{V} = \frac{170}{177.20} = 0.9593$

Q. Discuss Apparent, active & reactive powers, Power factor, Causes and problems of low power factor, Concept of power factor improvement

Answer:

$A= VI$ =Apparent Power, unit: VA

$P= VICos\theta$ = Real Power, unit: Watt

Q= VI $Sin\theta$ = Reactive Power: VAR

Power Factor: Power Factor is the ratio of true power to apparent power.

$$PowerFactor = \frac{TruePower}{ApparantPower} = \frac{VICos\theta}{VI} = Cos\theta$$

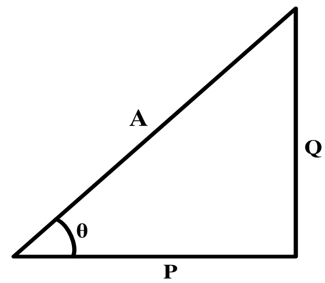


Fig: Power Triangle

Causes of Low Power Factor

(i) Transformer
(ii) Induction motors
(iii) Induction Generators
(iv) High Intensity discharge (HID) Lighting

Problem of Low Power Factor: All the problems of low power factor arise due t more current needed to supply a given power.

(i) Reduce equipment operation by deceasing voltage
(ii) Decrease energy efficiency
(iii) Increase line losses
(iv) Forced for costly upgrades

Power Factor Improvement

(i) by Capacitors banks
(ii) by running synchronous motors

Unit-III

3.1 For star and delta connected system in 3-phase circuit prove that $V_L = \sqrt{3}V_{ph}$ and $I_L = \sqrt{3} I_{ph}$

Answer

Let, phase voltage of three phase valance system is V_{ph} and line voltage V_L.

From figure, $Cos 30^0 = \frac{V_L/2}{V_{ph}}$,

or, $V_{ph} \times \frac{\sqrt{3}}{2} = V_L/2$

or, $V_L = \sqrt{3} V_{ph}$

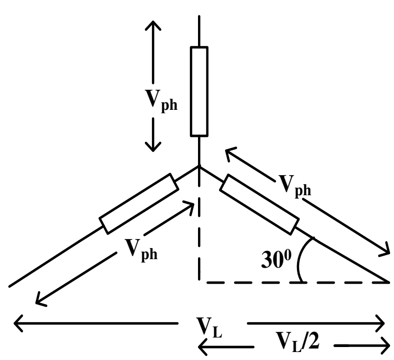


Fig.3.1(a)

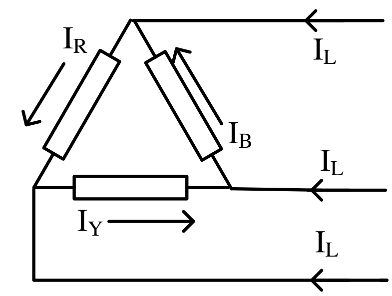


Fig.3.1(b)

A transformer in which part of the winding is common to both of the primary and secondary circuits is known as an auto-transformer. The primary and secondary are connected electrically as well as coupled magnetically.

As in ordinary transformer, the transformation ratio is equal to turn-ratio.

i.e. $\frac{V_2}{V_1} = \frac{E_{BC}}{E_{AC}} = \frac{N_2}{N_1} = \frac{I_1}{I_2} = K$

Power delivered to load, P = $V_2 I_2$

Power transformed = $V_2 I_2 (1-K)$

Power conducted directly = KV_2I_2

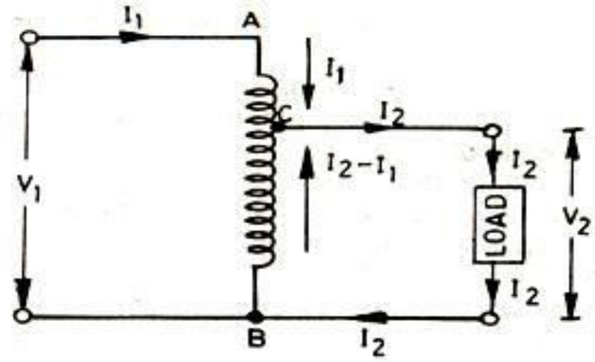


Figure: Auto- Transformer

Merits:

- **a.** It provides continuously varying voltage.
- **b.** Saving in copper requirements. Weight of copper required on an auto-transformer is (1-K) times of that required in an ordinary two-winding transformer.
- **c.** Ohmic losses and core losses is less.
- **d.** Higher Efficiency.
- **e.** Superior voltage regulation.

Demerits:

- **a.** There is no primary to secondary isolation.
- **b.** Current rating is limited to the size of the conductor used for the entire winding.

4.19 Discuss the applications of auto-transformer.

Answer

- **a.** Auto-transformer is used for interconnection of power system, having voltage ratio not differing far from unity.
- **b.** Auto-transformer is used for obtaining variable output votages i.e. variac, dimmerstate, autostate etc.
- **c.** A special form of autotransformer called a *zig zag* is used to provide grounding (earthing) on three-phase systems
- **d.** In audio applications, tapped autotransformers are used to adapt speakers to constant-voltage audio distribution systems, and for impedance matching.

Unit V

Electrical Machines:

Concept of electro mechanical energy conversion

DC machines: Types, EMF equation of generator and torque equation of motor, Characteristics and applications of DC motors (simple numerical problems)

Three Phase Induction Motor: Types, Principle of operation, Slip-torque characteristics, Applications (Numerical problems related to slip only)

Single Phase Induction motor: Principle of operation and introduction to methods of starting, applications.

Three Phase Synchronous Machines: Principle of operation of alternator and synchronous motor and their applications.

5.1 Discuss the principle of operation of three phase induction motor.

Answer:

(i) When three phase stator winding are fed from three phase supply, a magnetic flux of constant magnitude $\left(N_s = \frac{120f}{P}\right)$ but rotating at synchronous speed is set up. The flux passes through air gap, sweeps past the rotor surface and cuts the rotor conductors which as yet are stationary.

(ii) Due to relative speed between rotating flux and stationary conductor an e.m.f. is induced on the rotor conductor.

(iii) Since the rotor conductors form a close circuit, rotor current is produced whose direction is given by Lenz law (which opposes the cause to producing it).

(iv) Now we have current carrying rotor conductors which are placed in the rotating magnetic field produced by the stator. So a mechanical force is exerted on the rotor and rotor starts rotating. The direction of rotation is given by Fleming left hand rule.

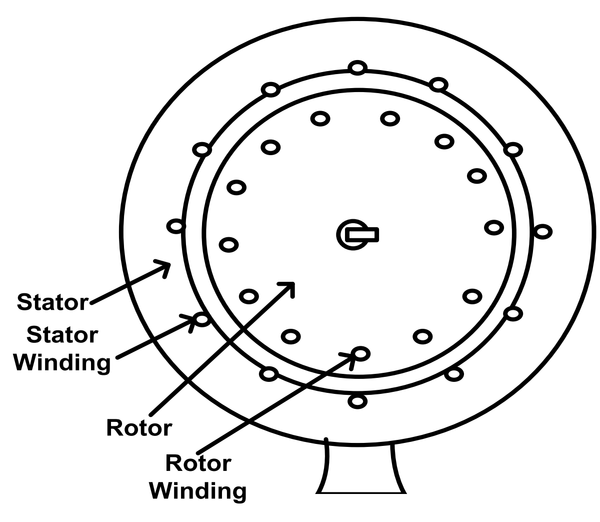


Fig.5.1: Three Phase Induction Motor

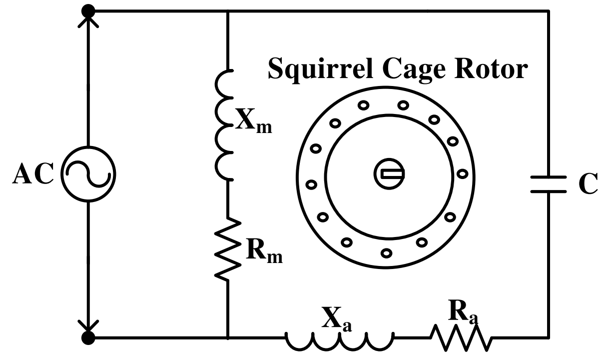
Permanent Capacitor Induction Motor:

It is also called single – value capacitor run motor, has a single cage rotor and its stator has two windings, a main winding and a starting winding (auxiliary winding). The main winding and starting winding are displaced 90^0. The motor used one capacitor C and connected in series with auxiliary winding and is always paper type .

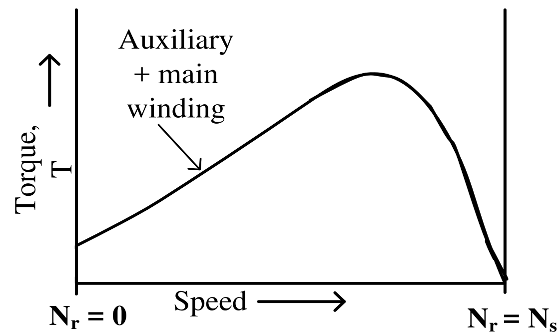
Applications:

These motors are used where quiet operation is essential, as in offices, class room, theater etc. For example Ceiling Fan.

The value of capacitor should be in the range of 2 to 3 μF.



Capacitor Run Motor



Torque - Speed Characteristic

Capacitor Start & Capacitor Run Motor

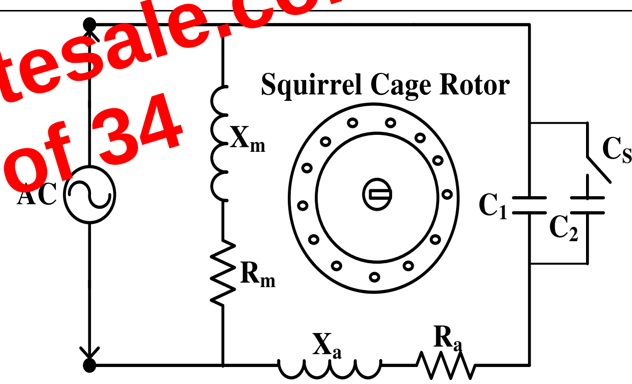
It has a single cage rotor and its stator has two windings, a main winding and a starting winding (auxiliary winding). The main winding and starting winding are displaced 90^0. The motor used two capacitors C_1 & C_2. The two capacitors are connected in parallel at starting.

The capacitor C_1 is called starting capacitor. In order to obtain high starting torque capacitive reactance should be low, short time rated and electrolyte type.

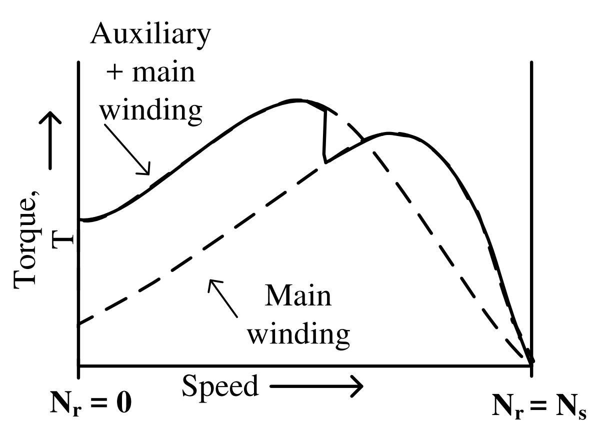
The capacitor C_2 is permanently connected in the circuit. It is called run capacitor.

The Capacitor Start & Capacitor Run Motor is quiet and smooth running. They have a higher efficiency than motors that run on the main winding alone.

Applications: This type of motor is used in hospitals, studios etc, where silence is important.



Capacitor Start and Run Motor



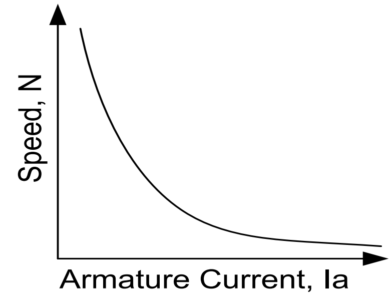
Torque - Speed Characteristic

The speed N of a dc motor is given by;

$$N \propto \frac{E_b}{\phi}$$

The flux $\phi \propto I_a$ and back e.m.f. E_b in a series dc motor is almost constant under normal conditions. Therefore, speed of a series motor as given in the figure,

$$N \propto \frac{1}{I_a}$$



(iii) Speed and Torque characteristic (N - T):

The speed N of a dc motor is given by;

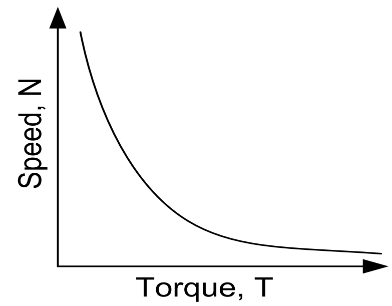
$$N \propto \frac{E_b}{\phi} \quad \text{and}$$

$$T \propto \phi \times I_a$$

From above two equations,

$$N \propto \frac{E_b I_a}{T}$$

Since, under normal conditions, speed of series Motor is constant. Therefore, speed of a series motor as given in the figure.



5.18 What are the applications of dc series motor and dc shunt motor?

Answer:

Direct current motors are very commonly used as variable – speed drives and in applications where severe torque variations occur. The main applications of the three types of dc motors are given below.

Series motors

These motors are used where high starting torque is required and speed can vary, for example, traction, cranes etc

Shunt motors

These motors are used where constant speed is required and starting condition are not severe, for example, lathes, centrifugal pump, fans, blower, conveyor, lift etc.

Compound motors

These motors are used where constant high starting torque and fairy constant speed is required, for example, presses, shears, conveyor, elevators, rolling mills etc.