CMR INSTITUTE OF TECHNOLOGY
Department of Electrical & Electronics Engineering
Solution for Internal Assesment Test 3 – March-2022
Subject:BASIC ELECTRICAL ENGINEERING (21ELE13/23)

1 A 50 KVA, 1Φ transformer has primary and secondary turns of 300 and 20 respectively. The primary winding is connected to a 2200 V, 50 Hz supply. Calculate the followings :

i) Secondary voltage.
ii) Primary & Secondary currents on full load.
iii) Maximum value of flux.

Ans. : 50 kVA, $N_1 = 300$, $N_2 = 20$, $E_1 = 2200$ V, f = 50 Hz.

i) $$\frac{E_1}{E_2} = \frac{N_1}{N_2} \quad \text{i.e.} \quad \frac{2200}{E_2} = \frac{300}{20}$$

$$\therefore \quad E_2 = \mathbf{146.667\ V}$$

ii) $$I_1(FL) = \frac{VA}{V_1} = \frac{50\times10^3}{2200} = \mathbf{22.727\ A} \qquad \ldots E_1 = V_1$$

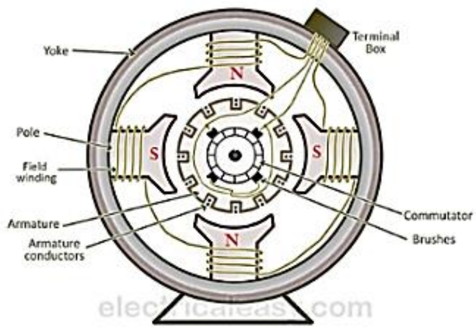
$$I_2(FL) = \frac{VA}{V_2} = \frac{50\times10^3}{146.667} = \mathbf{340.908\ A} \qquad \ldots E_2 = V_2$$

iii) $$E_1 = 4.44\, f\phi_m\, N_1 \quad \text{i.e.}\ 2200 = 4.44\times 50\times \phi_m \times 300$$

$$\therefore \quad \phi_m = \mathbf{33.033\ mWb}$$

2 With a neat sketch, explain the constructional details of a DC generator. Derive the EMF equation of DC generator.

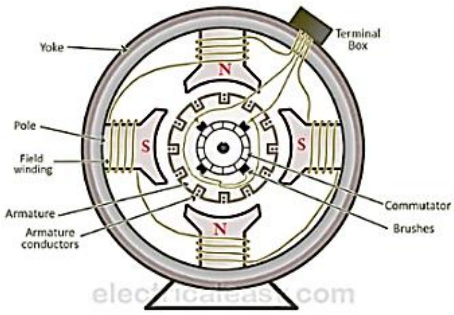
1. Yoke



Yoke:

- The outer frame of a dc machine is called as yoke
- It is made up of cast iron or steel.
- It provides mechanical strength to the whole assembly.
- It also carries the magnetic flux.

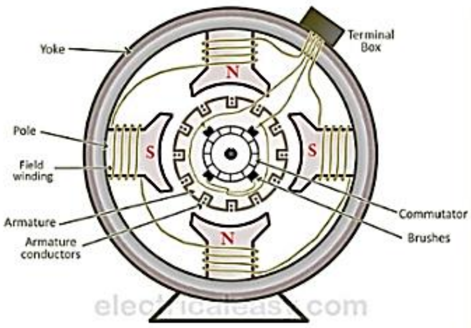
2. Pole



2. Pole:

- Poles are joined to the yoke with the help of bolts. They carry field winding.
- The poles are made of thin laminated sheets, to avoid heating and eddy current loss.
- Pole shoes serve two purposes; (i) they support field coils and (ii) Uni formly spread out the magnetic field in air gap.

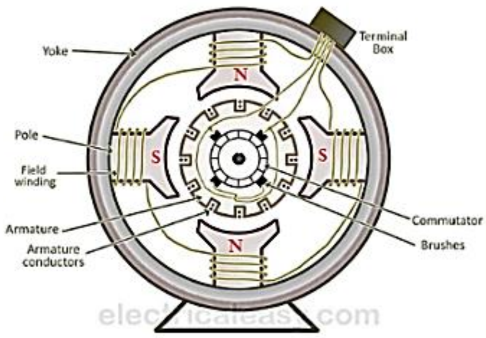
3. Field winding



Field winding

- Field winding is made up of copper.
- They are mounted on the p ole core and carry the dc c urrent.

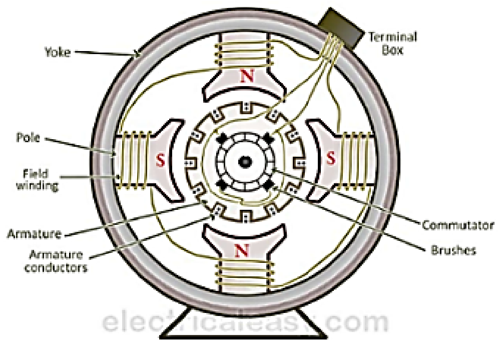
4. Armature & Armature winding



Armature

- Armature is the rotating part
- It is a cylindrical or drum shaped structure with slots on its outer periphery
- The purpose of armature is to rotate the conductors in the uniform magnetic field.

5. Commutator and brushes



Commutator and brushes

- The commutator is a mechanical rectifier which converts the AC voltage of armature into DC volta ge.
- Brushes are usually made from carbon or graphite. The function of brush is to collect the o/p voltage from the commutator and supply it to the external load circuit.

Derive the emf equation of DC generator

$$Induced\ EMF = \frac{Change\ in\ flux}{change\ in\ time}$$

P = Number of pole

ϕ = Flux per pole

Z = Number of armature conductor

N = Speed of armature in r.p.m.

A = Number of parallel path in armature

Consider one revolution of conductor. In one revolution, conductor will cut total flux produced by all the poles i.e. $\phi \times$ P.

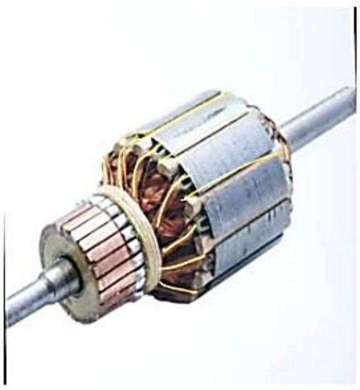
Speed of armature is N r.p.m.

N revolution = 1 min

N revolution = 60 Sec

1 revolution = ?

$$Time\ taken\ for\ one\ revolution = \frac{60}{N}\ Sec$$



Equation of induced emf in dc generator

$$E = \frac{Change\ in\ flux}{change\ in\ time} = \frac{P\phi}{\frac{60}{N}}$$

Induced emf in one conductor

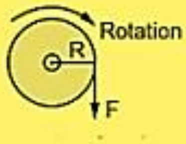
$$= E = \frac{P\phi N}{60}$$

So, EMF induced in all the conductors of each parallel path is:

$$E = \frac{P\phi NZ}{60\,A}$$

3(a) Derive the torque equation of DC Motor.

- Consider a wheel of radius R metres acted upon by a circumferential force F newtons as shown in the Fig.



- The wheel is rotating at a speed of N r.p.m.
- Then angular speed of the wheel is,

$$\omega = \frac{2\pi N}{60} \quad \text{rad/sec}$$

- So work done in one revolution is,

$$W = F \times \text{Distance travelled in one revolution}$$

$$= F \times 2\pi R \text{ joules}$$

$$\text{And } P = \text{Power developed} = \frac{\text{Work done}}{\text{Time}}$$

$$= \frac{F \times 2\pi R}{\text{Time for 1 rev}} = \frac{F \times 2\pi R}{\left(\frac{60}{N}\right)} = (F \times R) \times \left(\frac{2\pi N}{60}\right)$$

$$\therefore \quad P = T \times \omega \quad \text{watts}$$

where T = Torque in N·m and ω = Angular speed in rad/sec.

Power in armature = Armature torque × ω

i.e. $$E_b I_a = T_a \times \frac{2\pi N}{60}$$

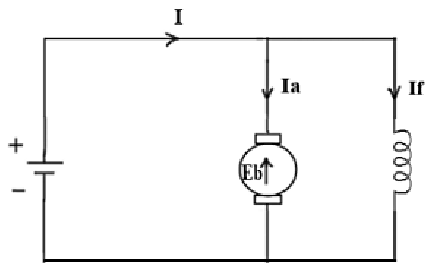
- But E_b in a motor is given by, $E_b = \frac{\phi P N Z}{60\, A}$

$$\therefore \quad \frac{\phi P N Z}{60\, A} \times I_a = T_a \times \frac{2\pi N}{60}$$

$$\boxed{\therefore \quad T_a = \frac{1}{2\pi}\phi I_a \times \frac{PZ}{A} = 0.159\, \phi I_a \cdot \frac{PZ}{A} \text{ Nm}}$$

- This is the **torque equation** of a d.c. motor.

3(b) Explain the significance of back EMF in DC Motor.



- When the armature of a motor is rotating, the armature conductors are also cutting the magnetic flux lines and hence according to the Faraday's law of electromagnetic induction, an emf induces in the armature conductors.
- The direction of this induced emf is such that it opposes the armature current (Ia).

Back EMF:

$$E = \frac{P\phi NZ}{60\, A}$$

- Hence the voltage equation of a d.c. motor can be written as,

$V = E_b + I_a R_a$ + Brush drop and negelcting brush drop,

$$I_a = \frac{V - E_b}{R_a} \quad \text{i.e.} \quad E_b = V - I_a R_a$$

Significance of back emf

Back EMF:

$$E = \frac{P\phi NZ}{60\,A}$$

- the voltage equation of a d.c. motor can be written as,

$V = E_b + I_a R_a$ + Brush drop and negelcting brush drop,

$I_a = \frac{V - E_b}{R_a}$ i.e. $E_b = V - I_a R_a$

- When load is suddenly put onto the motor, motor tries to slow down. So speed of the motor reduces due to which back e.m.f. also decreases. So the net voltage across the armature $(V - E_b)$ increases and motor draws more armature current.
- Due to increased current, force experienced by the conductors increases and hence the torque on the armature increases. This satisfies increased load demand.
- When load on the motor is decreased, the speed of the motor tries to increase. Hence back e.m.f. increases. This causes $(V - E_b)$ to reduce which eventually reduces the current drawn by the armature. This produces the less torque required by the new load.
- Thus back e.m.f. regulates the flow of armature current and it aut omatically alters the armature current to meet the load requirement. This is the practical significance of the back e.m.f.

4(a) Define slip & slip speed. Mention the significance of slip.

The difference between synchronous speed (N_s) and the actual speed (N) of the induction motor is called slip speed.

Slip speed = $(N_s - N)$ r.p.m.

*The **slip** is defined as the ratio of slip speed and synchronous speed (Ns)*

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

$$\%s = \frac{N_s - N}{N_s} \times 100$$

Value of Slip (s)	Significance
s=0	The slip is 0 when N=Ns but this condition is not possible in induction motor as it cannot rotate at synchronous speed
s=1	Slip = 1, means that rotor is stationary
s = Negative	The slip is negative means N>Ns. this is possible only when the rotor is turned in the rotating magnetic field direction using the prime mover
s > 1	Slip more than 1 implies that, rotor is rotating in a direction opposite to the direction of rotation of magnetic flux.

4(b) A 4 pole, 3300 V, 50 Hz induction motor runs at rated frequency and voltage. The frequency of the rotor current is 2.5 Hz. Calculate the (i) Slip, (ii) Synchronous speed (*Ns*) and (ii) Speed of rotor (*N*).

Ans. : $P = 4$, $f_r = 2.5$ Hz, $f = 50$ Hz

$$f_r = sf \quad \text{i.e.} \quad 2.5 = s \times 50$$

$$\therefore \quad s = \mathbf{0.05} \quad \text{i.e.} \quad \mathbf{5\ \%} \qquad \text{... Slip}$$

$$N_s = \frac{120f}{P} = \frac{120\times 50}{4} = 1500 \text{ rpm}$$

$$\therefore \quad N = N_s(1-s) = 1500\times(1-0.05) = \mathbf{1425\ rpm}$$

5(a) Compare between Squirrel cage and wound type rotor.

— comparision of both types of induction motor

Squirrel cage induction motor	Wound - type induction motor
i) Economical and simpler in construction	(i) Costly.
(ii) More rugged, so requires less maintenance.	(ii) Need more maintenance
(iii) No control over starting torque	(iii) Starting torque can be controlled using external resistance connection.
(iv) Speed cannot be controlled using resistance.	(iv) Easy control of speed using external resistance.

5(b) A 3-phase, 6 pole star connected alternator is rotating at a speed of 1000 rpm. The stator has 90 slots and 8 conductors/slot. The flux per pole is 0.05 Wb. Calculate the voltage generated by the machine. [Assume Pitch factor=1 & Distribution Factor=0.96].

Ans. : $P = 6$, Slots $= 90$, 8 conductors /slot,

$N_s = 1000$ r.p.m., $\phi = 0.05$ Wb, $K_d = 0.96$, $K_c = 1$

$$N_s = \frac{120\,f}{p} \quad \text{i.e.} \quad f = \frac{1000\times 6}{120} = 50 \text{ Hz}$$

$$Z = \text{Slots} \times \text{Conductors / slot}$$

$$= 90 \times 8 = 720$$

$$Z_{ph} = \frac{Z}{3} = 240$$

$$T_{ph} = \frac{Z_{ph}}{2} = 120 \qquad \text{...2 conductors} \rightarrow \text{1 turn}$$

$$\therefore \quad E_{ph} = 4.44\,K_c\,K_d\,\phi F\,T_{ph} = 1278.72 \text{ V}$$

$$\therefore \quad E_{line} = \sqrt{3}\,E_{ph} = \mathbf{2214.808\ V}$$

6(a)	Explain Salient pole and non-salient Pole Rotor.

(a) Salient Pole or Projected Pole Rotor:

- All the poles are projected out from the surface of the rotor.
- The poles are built up of thick steel laminations.
- The field windings are provided on the pole shoe.
- This type has large diameter and small axial length.
- These are used in low speed alternators due to less mechanical strength.

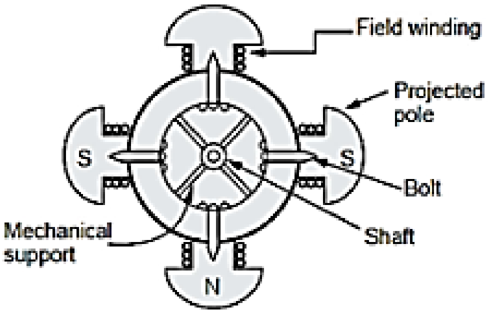
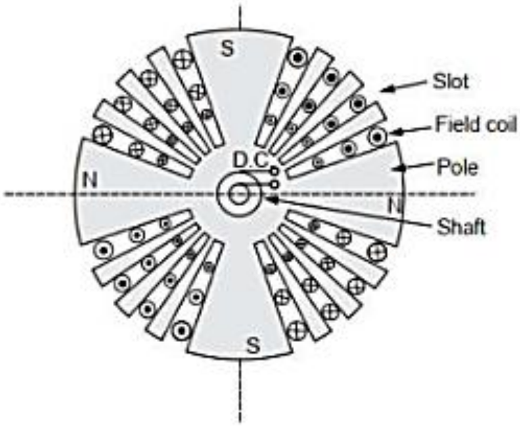


Fig. . Salient pole type rotor

(b) Non-Salient Pole or Smooth cylindrical Rotor:

- The rotor consists of smooth solid cylinders having slots to accommodate field windings.
- The unslotted portions of the cylinder itself act as poles.
- Due to smooth surface of the cylinder, it maintains uniform air gap between stator and rotor.
- This type has small diameter and large axial length.
- These are used in high speed alternators due to higher mechanical strength.



6(b) Derive the EMF equation of synchronous generator

Z_P : No. of conductor connected in series per phase

$Z_P = 2\,T_P$ $\quad$ T_P : turns per phase

P : No. of poles $\quad$ K_d : Distribution factor

f : frequency $\quad$ K_f : Form factor

ϕ : Flux per pole $\quad$ N_S : Speed in rpm

K_P : Pitch factor

One conductor cuts flux $= P\phi$ webber in 1 revolution

Time taken for 1 revolution $= 60/N_S$ sec.

$$\text{Average emf} = \frac{\text{Flux cut}}{\text{Time taken}} = \frac{P\phi}{60/N_S} = \frac{P\phi N_S}{60} \text{ volt}$$

But, Synchronous speed $N_S = \frac{120 f}{P}$

$$\therefore \text{Average emf per conductor} = \frac{P\phi}{60} \times \frac{120 f}{P} = 2\phi f$$

$$\therefore \text{Average emf per phase} = 2\phi f \times 2T_P = 4\phi f T_P$$

$$\text{RMS value} = \text{Average value} \times \text{Form factor} = 4\phi f T_P \times 1.11 = 4.44\,\phi f T_P \text{ volt}$$

Now, K_P and K_d are the pitch factor & Distribution factor respectively

$\therefore$ Net emf per phase

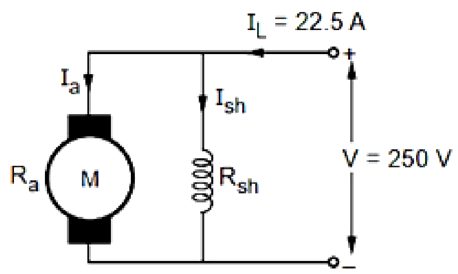
$$\boxed{E_P = K_P K_d\, 4.44\,\phi f T_P}$$

7 A 4 pole DC shunt motor takes 22.5 A from a 250 V supply. Ra=0.5 Ohm, Rsh=125 Ohm. The armature is wave wound with 300 conductors. If the flux per pole is 0.02 Wb. Calculate:

(i) Speed

(ii) Torque developed

(iii) Power developed



Ans. : $I_{sh} = \frac{V}{R_{sh}} = \frac{250}{125} = 2$ A

$I_a = I_L - I_{sh} = 20.5$ A

Wave wound A = 2, Z = 300, P = 4

$E_b = V - I_a R_a = 250 - 20.5 \times 0.5$

$= 239.75$ V, $\phi = 0.02$ Wb

$$\text{(i)}\quad E_b = \frac{\phi PNZ}{60\,A}$$

$$\therefore\quad N = \frac{239.75 \times 60 \times 2}{0.02 \times 4 \times 300} = \mathbf{1198.75\ r.p.m.}$$

$$\text{(ii)}\quad T = 0.159\,\phi I_a \left[\frac{PZ}{A}\right]$$

$$= 0.159 \times 0.02 \times 20.5 \times \left[\frac{4 \times 300}{2}\right] = \mathbf{39.114\ Nm}$$

(iii) Power developed $= T \times \omega = T \times \dfrac{2\pi N}{60} = \mathbf{4912.066\ W}$

The power developed is also given by $E_b I_a$.