19AIE104 Introduction to Electrical Engineering

TEAM 11 BATCH A

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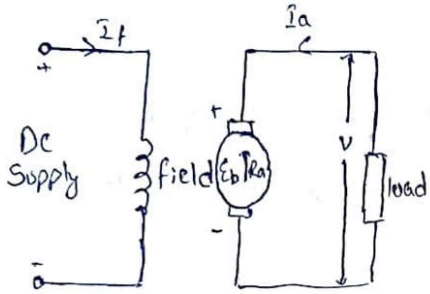
Q1

- **With suitable diagrams, present the governing equations of DC motors: shunt, series and compound, types.**
- **Include specific applications for the same.**
- **Describe the dependency of torque on speed and electric input as well.**

Direct Current Motor (DC) are two types

DC Motors

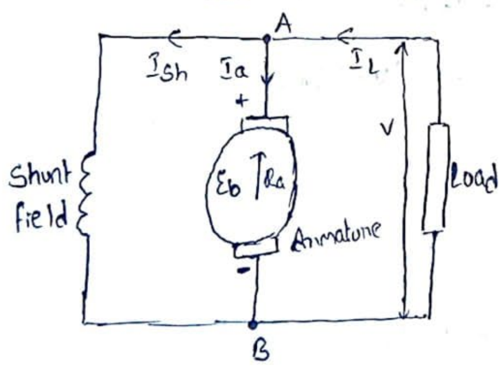
- Separately Excited Motor
- Self Excited DC Motor.
  1. Shunt Wound Motor
  2. Series Wound Motor



E_b = Equivalent Circuit.

R_a = Armature Resistance.

1. ~~Shound~~ Shunt Wound Motor:



Apply KCL at juction "A"

$$I = I_a + I_{sh} \rightarrow (1)$$

Where

I = input line current

I_a = Armature Current

I_{sh} = Shunt field Current

Voltage Equations are:-

Apply (KVL) for the field winding circuit

$$V = I_{sh} \cdot R_{sh} \quad ---- (2)$$

For Armature winding circuit the eq is:-

$$V = E + I_a R_a \quad --- (3)$$

Power Equation:-

Power input = Mechanical power developed + losses in the Armature + loss in field.

$$VI = P_m + I_a^2 R_a + I_{sh}^2 R_{sh} \rightarrow (4)$$

$$VI = P_m + I_a^2 R_a + VI_{sh}$$

$$P_m = VI - VI_{sh} - I_a^2 R_a$$

$$= V(I - I_{sh}) - I_a^2 R_a$$

$$P_m = VI_a - I_a^2 R_a = (V - I_a R_a) I_a$$

$$P_m = E I_a \rightarrow (5)$$

Solving Eq:-

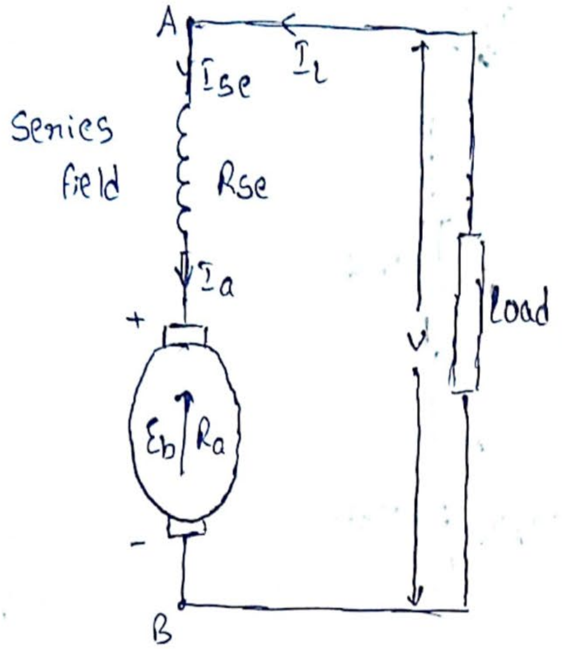
$$Eq(3) \times I_a$$

$$VI_a = E I_a + I_a^2 R_a \longrightarrow (6)$$

$$VI_a = P_m + I_a^2 R_a \longrightarrow (7)$$

Where VI_a is the Electrical power supplied to Armature.

2) Series Wound Motor:



I_{se} : Series field Current

By Applying (KCL) at "A"

$$I = I_{se} = I_a$$

By Applying (KVL) for voltage Eq.

$$V = E + I(R_a + R_{se}) \rightarrow (1)$$

Power Eq:

$$Eq(1) \times I$$

$$VI = EI + I^2(R_a + R_{se}) \rightarrow (2)$$

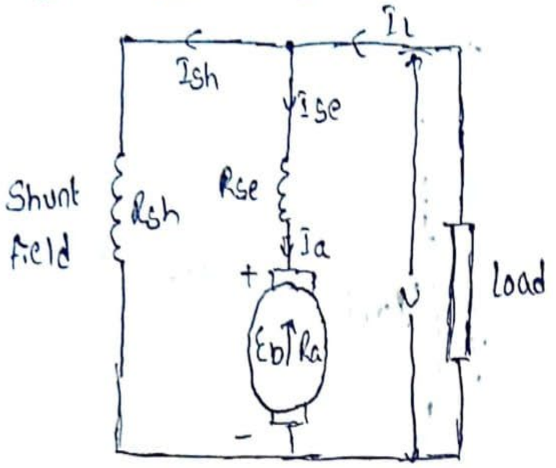
Power input = Mechanical power developed + losses in the Armature + losses in the field.

$$VI = P_m + I^2R_a + I^2R_a \rightarrow (3)$$

=> Comparing Eq (2) & (3)

$$\boxed{P_m = EI}$$

Compound Wound Motor:



Compound Motor

↓ Cumulative Compound

↓

In this flux produced by both windings is in the same direction i.e;

$$\boxed{\psi_n = \psi_{sh} + \psi_{se}}$$

↓ Differential Compound

↓

In this flux produced by the series field windings is opposite to the flux produced by shunt field winding i.e;

$$\boxed{\psi_n = \psi_{sh} - \psi_{se}}$$

∴ The positive and negative sign indicates that the direction of flux produced in the field windings.

Torque Equation of a DC Motor:-

When the current carrying current is placed in the magnetic field, a force is exerted on it when exerts turning moment (or) torque $F \times r$.

$$V = E_b + I_a R_a \rightarrow (1)$$

$\Rightarrow$ Eq (1) $\times I_a$

$$V I_a = E_b I_a + I_a^2 R_a \rightarrow (2)$$

$V I_a$ = Electrical power input to armature

$I_a^2 R_a$ = Copper loss in armature

W.K.T

The mechanical power developed by the armature is P_m.

$$P_m = E_b I_a \rightarrow (3)$$

$$P_m = \omega T = 2\pi n T \rightarrow (4)$$

n = revolution per sec

T = Newton - meter.

$$2\pi n T = E_b I_a \quad (or) \quad T = \frac{E_b I_a}{2\pi n}$$

But,

$$E_b = \frac{\phi Z N P}{60 A}$$

N = revolution per minute

$$n = \frac{N}{60}$$

So, Torque eq

$$T = \frac{\psi Z n P}{2\pi A} \cdot I_a$$

For particular DC motor, P = no. of poles

no. of conductors per ||el

paths are const (Z/A)

$$T = k \psi I_a$$

Where

$$k = \frac{ZP}{2\pi A} \text{ (or)}$$

$$\boxed{T \propto \psi I_a} \rightarrow 5$$

Q2

- **A 250 V DC shunt motor has armature resistance of 0.25 ohm on load it takes an armature current of 50A and runs at 750rpm. If the flux of the motor is reduced by 10% without changing the load torque, find the new speed of the motor.**

Q2 $E_1 = 250\ v$ (or E)

$R_a = 0.25\Omega$

$N_1 = 750$ (speed that is given)

I_a (current already given) $= 50A$

Net flux is changed by 10%. by reducing initial flux

let initial flux be ϕ_1

New flux is $\phi_2 = \phi_1 - \frac{10}{100}\phi_1$

$$\phi_2 = \frac{90}{100}\phi_1$$

Torque is given constant

$N_2 = ?$

we are already familiar with following formulaes

$V = \frac{\phi Z N}{60} * \frac{P}{A}$ — (1)   E, Eg : EMF generated in armature

I_a : current in armature

$E - I_a r_a = V$ R_a : Resistance in armature

V : Terminal voltage

$\phi_A i_a = \phi_b i_b$ (when torque is constant)

$$V_1 = E_1 - I_a r_a$$
$$= 250 - (50 * \frac{25}{100})$$
$$= 237.5V$$

as load torque is constant (already given in Q)

$$T_1 = T_2$$
$$\phi_1 I_1 = \phi_2 I_2$$
$$(100)(50) = 90(I_{a2})$$
$$55.5A = (I_{a2})$$

$$V_2 = 250 - (55.5 * \frac{25}{100})$$
$$= 236.12V$$

we already know that

$$\frac{N_2}{N_1} = \frac{V_2}{V_1} * \frac{\phi_1}{\phi_2} \text{ (from 1)}$$

$$\frac{N_2}{750 = N_1} = \frac{236.12}{237.5} * \frac{\frac{100}{100}\phi_1}{\frac{90}{100}\phi_1}$$

$$N_2 = 828\ rpm$$

Q3

When a generator is being driven at 1,200 rpm, the generated emf is 125 volts. Determine the generated emf if the field flux is decreased by 10 percent with the speed remaining unchanged.

Q 3) a) Speed of Generator : 1200 Rpm

EMF $E_1 = 125$ Volts

field flux reduced by 10 %

$\Rightarrow \phi' = 0.9\phi$

$$E_1 = \frac{\phi Z N P}{60 A}$$

$$125 = \frac{\phi Z N P}{60 A}$$

Here, Z = No. of conductors , P = no. of poles,

A = no. of ||el paths

Now,

$$E \propto \phi . N$$

$$\Rightarrow E_b = 0.9 \times \frac{\phi Z N P}{60 A}$$

$$\Rightarrow E_b = 0.9 \times 125$$

$$\Rightarrow E_b = 112.5 \text{ V}$$

(b) if the speed is reduced to 1,100 rpm, the field flux remains unchanged.

b) When speed reduced to 1100 rpm

so our initial speed = 1200 rpm (N_0)

Our New speed = 1100 rpm (N_1)

$$\Rightarrow E \propto \phi . N$$

$$\frac{E_0}{E_1} = \frac{\phi_2}{\phi_1} \times \frac{N_1}{N_0}$$

$$\Rightarrow E_0 = E_1 \times \frac{1100}{1200} \times 1 \quad [\phi_2 = \phi_1]$$

$$\Rightarrow E_0 = \underline{\underline{114.58V}}$$

Q4

- **A DC motor (200 kW, 220 V) is used to drive a blower for maintaining steady wind in a mini wind tunnel. The torque required to drive the blower at 15 rotations/second is 200 N-m, which the motor produces while working at 90% of the rated capacity. The power loss incurred in the blower is 5 kW. Calculate the efficiency of the whole system and break it down to individual components. What will the current consumption by the motor?**

Q4)

Given:- $P_{in} = 200\ kW = 200 \times 10^3 W$

$V = 220V$

While working at 90% efficiency the motor can produce a torque of 200 N-m.

$N = 15\ rps \Rightarrow 900\ rpm$

Power loss $= 5\ kW = 5 \times 10^3\ W$

Formula:- $\boxed{\eta\ (\text{efficiency}) = \frac{P_{Output}}{P_{Input}}}$

and $\boxed{\text{Power input} = \text{Power out} + \text{loss}}$

Solution:-

(i) While working at 90% efficiency,

$\frac{90}{100} = \frac{P_{output}}{200 \times 10^3} \Rightarrow \boxed{P_{output} = 180 \times 10^3\ W}$

So, the blower has 5kW power loss.

total $P_{output} = 180 \times 10^3 - 5 \times 10^3\ W$

$\Rightarrow \boxed{P_{out} = 175 \times 10^3}$

efficiency $(\eta) = \frac{175 \times 10^3}{175 \times 10^3 + 5 \times 10^3} = 97.2\%$

$$\tau \text{ (torque)} = \frac{1}{\omega}(V - I_aR_a) \times I_a$$

$R_a = 0$ ($\because$ considering the motor as ideal motor)

So,
$$\tau = \frac{1}{\omega}(V - 0) \cdot I_a$$

$$200 = \frac{1}{30 \times \pi}(220) I_a$$

$$I_a = \frac{6000\pi}{220}$$

$$\therefore I_a = 85.714 \text{ A}$$