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Internal Assessment Test 1 – Sept. 2016

Sub:	**D.C. MACHINES AND SYNCHRONOUS MACHINES**	**Code:**	10EE54
Date: 07/ 09/2016 Duration: **90** mins Max Marks: 50	**Sem:** 5	**Branch:**	EEE

Note: Answer any FIVE questions. Sketch figures as necessary. Each Question is for 10 marks. (5x10=50 M)

1. (a) Derive EMF & Torque equations as applicable to dc machines **(5M)**
(b) The armature of a 4-pole lap-wound dc machine has core length = 0.3 m, diameter = 0.4 m, total conductors = 500, speed = 1200 r.p.m. and current = 20 Amps. For an average flux density of 0.5 T, find the electromagnetic (or gross mechanical) power developed and the internal torque. **(5M)**

2. (a) Explain one type of dc motor starter. **(5M)**
(b) A 440 V, 4 pole, Lap connected Shunt Motor has a no-load input current of 15 Amps and a Shunt Field current of 10 Amps. At full load it takes a current of 150 Amps. If armature resistance =0.1 ohm, flux per pole on no-load= 0.05 Weber, number of armature conductors= 750 and contact drop per brush=1 V, calculate (i) No-load speed (ii) Full load speed. Armature Reaction weakens the field by 1.5% on full load. **(5M)**

3. (a) What are the different types of losses in dc machines? Derive the condition for maximum efficiency. **(5M)**
(b) A 220 V dc shunt motor draws a current of 2 Amps on no-load. The armature resistance is 0.2 Ω and the field current is 1 A. Find the output and the efficiency when the input current is 12 A. **(5M)**

4. (a) Mention the different methods and tests for testing dc motors. Mention their merits and demerits. **(5M)**
(b) While conducting Swinburne's test on a 500 V shunt motor, it is noted that it takes a current of 5A on no-load. The resistances of the armature and field circuits are 0.22 ohms and 250 ohms respectively. Estimate the efficiency when the motor current is 100 A. What is the percentage change of speed between no-load and full-load? **(5M)**

5. (a) Explain Field's test on two similar dc series motors to find the constant losses and efficiency of the machines.**(5M)**

(b)Two shunt motors loaded for the Hopkinson's test take 15 A at 200 V supply. The motor current is 100 A and the shunt currents are 3 A & 2.5 A. If the resistance of each armature is 0.05 ohm, calculate the efficiency of each machine for the given operating conditions. **(5M)**

6. A series generator of total resistance of 0.5 ohms is running at 1000 rpm and delivering 5kW at a terminal voltage of 100V. If the speed is raised to 1500 rpm, and the load adjusted to 8 kW, find the new current and the terminal voltage. [Note: EMF is proportional to (Speed x Flux) and the Flux is proportional to Current] **(10M)**

7. Explain the construction and operation of Brushless dc motors and mention their applications. **(10M)**

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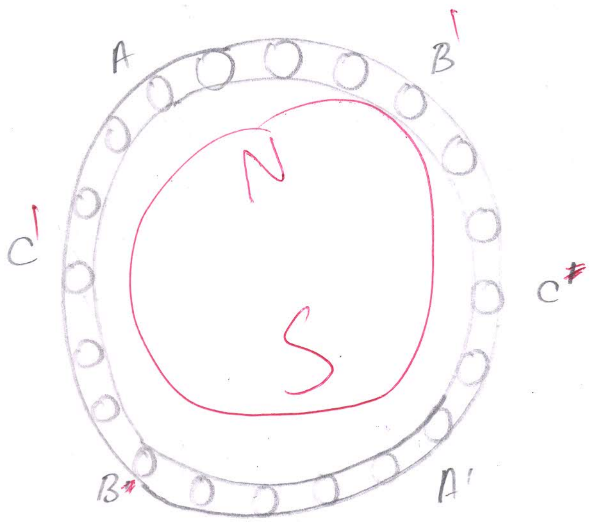
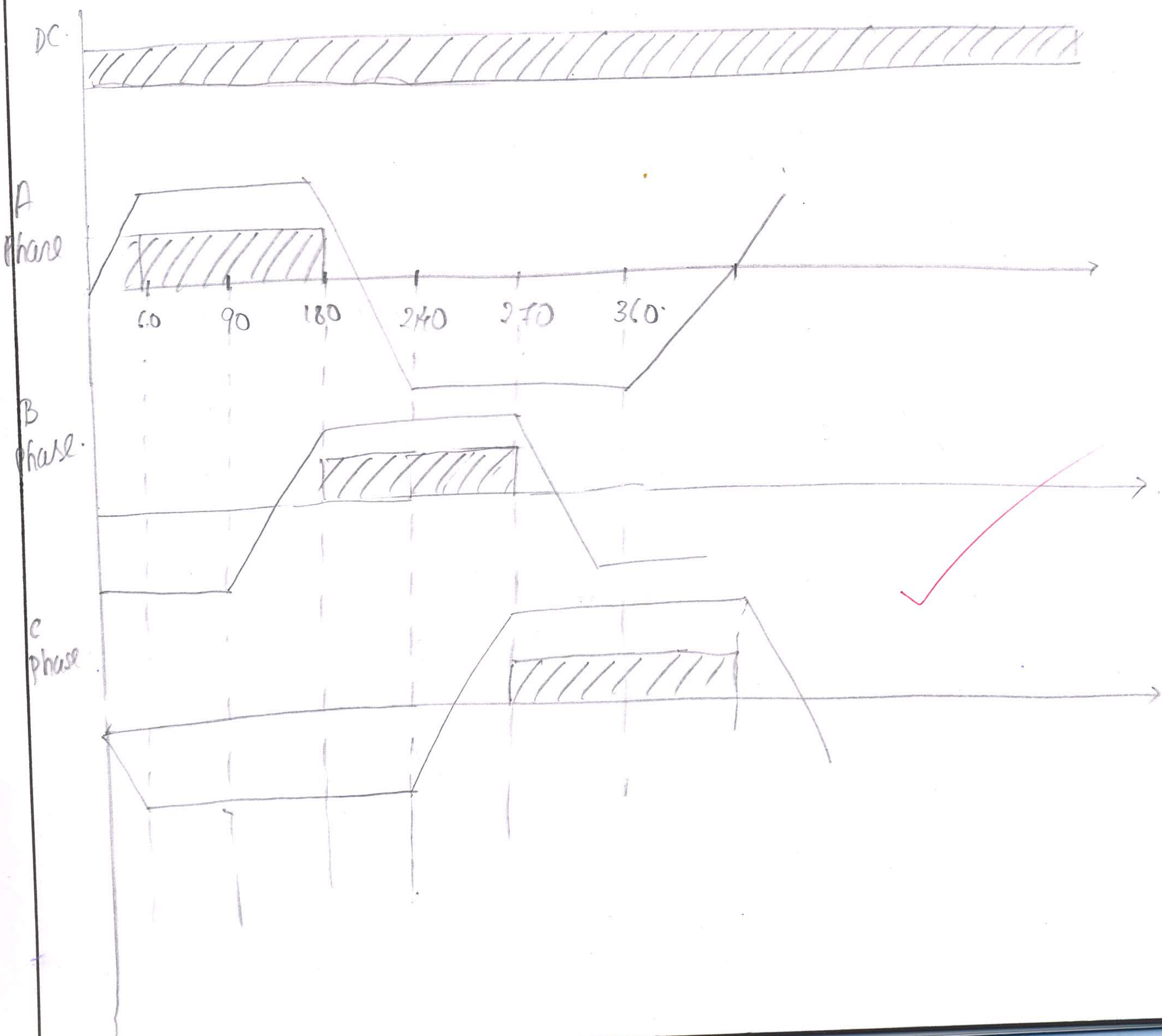




- Initially current is given to the A phase. due to torque it rotates. By then B comes to the position and current is given to B phase it further rotates. By this cumulative process the motor starts rotating

- The permanent magnets are mounted on the rotor it can be projected or inset or may be burried.

- Ferrite is used as the permanent magnets.

- Rare earth magnets can also be used as permanent magnets and the motor becomes less weight and less bulky.

- But Rare earth magnets are expensive.

- The inverter fed trapezoidal shaped input is given to self mode starting motor. These motors are brushless motors.

Advantages:

- No maintenance.
- Low friction and inertia
- There are less losses
- Efficiency is 70 %.

Applications:

- Used in tape recorder players
- Artificial heart pumps.

6)

$R = 0.5\,\Omega$

$N_2 = 1000\,rpm$

$P = 5\,kW$

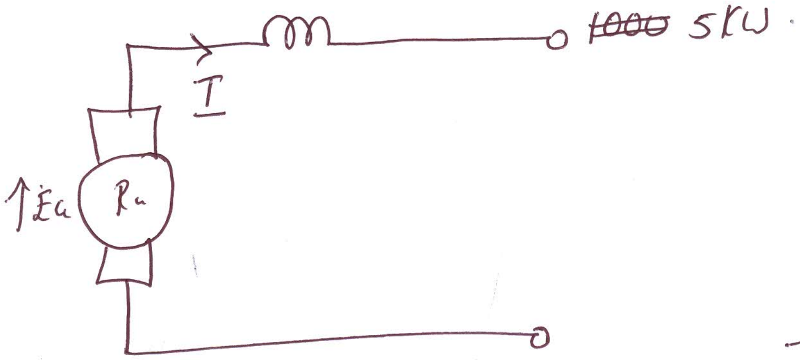
$V = 100\,V$

$N_1 = 1500\,rpm$

$P = 8\,kW$

$I_1 = ?$

$V_1 = ?$



$I = \frac{P}{V}$

$= \frac{5\,kW}{100}$

$= 50\,A$

$E = V + I\,R_a$

$= 100 + (50 \times 0.5)$

$E = 125$

$$\frac{E}{E_1} = \frac{IN}{I_1 N_1}$$

$$\frac{125}{E_1} = \frac{50 \times 1000}{I_1 \times 1500} \rightarrow (1)$$

$$E_1 = V_1 + I_1 R.$$

$$E_1 = \frac{8K}{I_1} + I_1(0.5) \longrightarrow (2)$$

$$V_1 = \frac{8K}{I_1} \longrightarrow (3).$$

foom (1).

$$\frac{125}{E_1} = \frac{100}{3 I_1}$$

$$E_1 = \frac{125 \times 3}{100} I_1$$

$$E_1 = \frac{15}{4} I_1$$

substitute in (2).

$$\frac{15}{4} I_1 = \frac{8K}{I_1} + 0.5 I_1$$

$$\frac{15}{4} I_1 = \frac{8K + 0.5 I_1^2}{I_1}$$

$$\frac{15}{4} I_1^2 = 8K + 0.5 I_1^2$$

$$\frac{13}{4} I_1^2 = 8K.$$

$$I_1^2 = \frac{8K \times 4}{13}$$

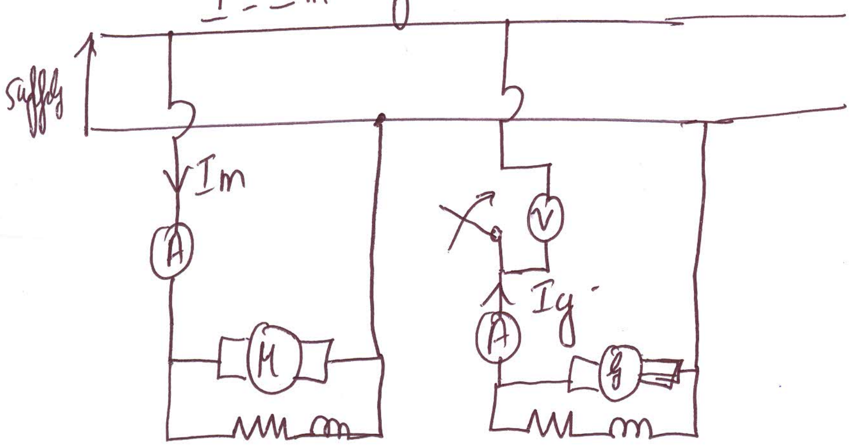
$$I_1 = 49.61A$$

$$\therefore \; E_1 = \frac{8K}{49.61} + (49.61 \times 0.5) = 186.06V$$

$$V_1 = \frac{8K}{I_1} = 161.25V$$

$I = I_m - I_g$.

5b)



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$V = 200V$

$I = 15A$

$I_m = 100A$

$I_{sh} = 3A$ for motor

$I_{sh} = 2.5A$ for generator

$R_a = 0.05\Omega$

$\eta = ?$

Total i/p $= V \times I = 200 \times 15$

$= 3000W$

Cu loss of motor $= I_m^2 R_a$.

$= 100^2 \times 0.05$

$= 500W$

$I_g = I_m - I$

$= 100 - 15$

$= 85A$

Cu loss of generator $= I_g^2 R_a$

$= 85^2 \times 0.05$

$= 361.25W$

Motor field losses $= VI$

$= 200 \times 3$ 2.5

$= 600W$

3

Generator field losses $= VI = 200 \times 2.5 = 500W$

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Total loss = 1961.25 W

Mechanical losses = i/p − Total losses

= 3000 − 1961.25

= 1038.75 W

Mechanical losses / machine = $\frac{1038.75}{2}$ = 519.37 W

$\eta\%_{\text{for motor}} = \frac{i/p - \text{losses}}{i/p}$

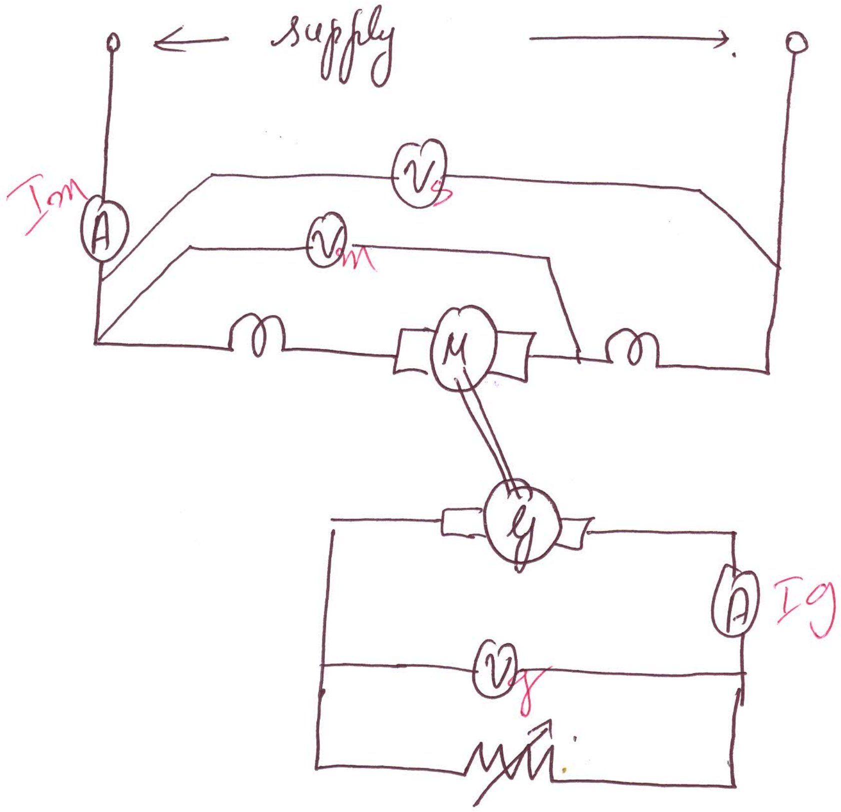
$= \frac{(200 \times 100) - (500 + 600 + 519.37)}{200 \times 100}$

= 91.9%

$\eta\%_{\text{for generator}} = \frac{o/p}{o/p + \text{losses}} = \frac{(200 \times 85)}{(200 \times 85) + (361.25 + 500 + 519.37)}$

= 92.48%

5a. <u>Field's test:</u>



- This test is done for two similar dc series motor to find the constant losses & efficiency of the machine.

- The series motor cannot be tested using other normal test because carrying out test on no load is very dangerous

- Series motors having high starting Torque with small currents.

- In this test two series motors are taken. One is treated as motor & another one has generator, both are mechanically coupled.
- The windings of both the machines are in series and therefore iron losses are same for both the machines.
- When the supply is given both to motor it starts rotating. Due to excitation of field because of the current in motor circuit, generator also starts rotating. Both the machines runs at same speed.
- The current of the generator is given to the variable load.

Total Cu loss $= I_m^2 [R_a + 2R_{se}] + I_g^2 R_a$. (4)

Constant loss = Total loss − Cu loss
for 2 m/cs: $= V_s I_m$ — (4)

Formulae for η_m & η_g?

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3a) Different types of losses in DC machines:

A. Constant losses:

1) Magnetic losses

i) Hypteresis losses

$$W = \eta B_m^{1.2} f V$$

ii) Eddy current losses

$$W = K B_m^2 f^2 t^2 V.$$

2) Mechanical losses:

i) friction losses

ii) Windage losses.

B. Variable losses:

1) Copper loss

i) Rotor copper loss

ii) Stator copper loss

iii) Brush ~~gear~~ loss.
Contact

2) Core loss.

Condition for Max efficiency.

η for η_{max} $\frac{d\eta}{dI} = 0$.

$$\eta = \frac{VI}{VI + W_{const} + I^2R}$$

$$\frac{d\eta}{dI} = \frac{(VI + W_{const} + I^2R)V - (V + 2IR)VI}{(VI + W_{const} + I^2R)^2}$$

$$\frac{d\eta}{dI} = 0$$

$$\therefore (VI + W_{const} + I^2R)V = (V + 2IR)VI$$

$$VI + W_{const} + I^2R = VI + 2I^2R$$

$$\boxed{W_{const} = I^2R}$$

This is the condition for maximum efficiency.

35) $V = 220V$

$I_a = 2A$ (I_L)

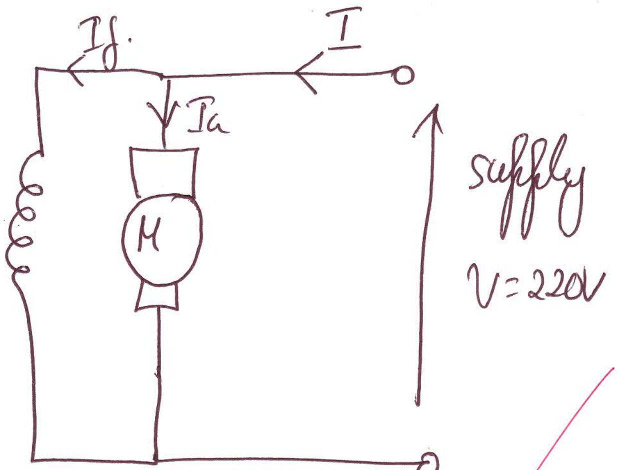
$R_a = 0.2$

$I_f = 1A$

O/P = ?

$\eta = ?$

$I_1 = 12A$



$I = I_f + I_a$

$\eta = \frac{i/P - losses}{i/P}$

Find constant loss from no load test

$R_f = \frac{220}{1} = 220\Omega$

$E = V + I_a R_a + ~~220~~ I_f R_f$

$E = 220 + [2 \times 0.2] + [1 \times 220]$

$E = 440.4V$

$\eta = \frac{(220 \times 12) - I_a^2 R_a - I_f^2 R_f - \text{other const loss}}{(220 \times 12)}$

$= \frac{(220 \times 12) - (2^2 \times 0.2) - (1^2 \times 220)}{220 \times 12}$

$= 91.63\%$

1(c) EMF - Torque equations.

The induced emf By Faraday's law is given by

$$e = \frac{d\phi}{dt}$$

For one revolution, the conductors cuts flux according no of poles. And the time required for one revolution is $\frac{60}{N}$

$$\therefore e = \frac{\phi \times P \times N}{60}$$

This equation is for just one conductors. There A parallel path and the conductors are in series.

$$\therefore e = \frac{\phi PN}{60} \times \frac{Z}{A}$$

This is the equation for emf.

For lap winding A = no of poles

For wave winding A = 2 always.

Torque $\propto \phi I$

$$T = \frac{K \phi^2 PN}{60} \times \frac{Z}{A}.$$

4a) Different methods and tests for testing DC Motor:

1) Hopkinson's test for two similar shunt motors
2) Retardation test for shunt motors
3) Field's test for two similar series motors.
4) ~~Sch~~ Swinburne's test

Merits:

1) From tests efficiency can be found out
2) The losses per machine is calculated

Demerits:

1) ~~Tests~~ For different motors different tests has to be done
2) Coupling of machines is difficult
3) Due to mechanical coupling, due to friction tests results may be inaccurate.

Extra question an[illegible] not Conside[illegible]

1. The armature of a 4-pole lap-wound dc machine has core length = 0.3m, diameter = 0.4m, total conductors = 500, speed = 1200 r.p.m. and current = 20A. For an average flux density of 0.5T. Find the electromagnetic (or gross mechanical) power developed and the internal torque.

Solution:

Given: $l = 0.3m$; $P = 4$

$d = 0.4m \Rightarrow r = 0.2m$.

$N = 1200 r.p.m$

$B_{av} = 0.5T$

$Z = 500$

$I = 20A$

$$n = \frac{1200}{60} = 20 r.p.s.$$

$$B_{av} = \frac{P \cdot \phi}{2\pi r l} \Rightarrow \phi = \frac{2\pi r l B_{av}}{P}$$

$$= \frac{2\pi \times 0.2 \times 0.3 \times 0.5}{4} = \underline{0.04712 Wb}$$

E.m.f generated:

$$E_a = \frac{\phi Z n P}{A} = \frac{0.04712 \times 500 \times 20 \times 4}{4}$$

$$= \underline{471.2V}$$

Gross mechanical power developed $= E_a I_a = 471.2 \times 20 = \underline{9424W}$

Internal Torque $= T_e = \frac{E_a I_a}{\omega_m} = \frac{471.2 \times 20}{2\pi \times 20}$

$= 74.993$ Nm

$= \underline{75 \text{ Nm}}$

2. A 440V, 4 pole, Lap connected Shunt Motor has no load input current of 15A and a shunt Field current of 10A. At full load it takes a current of 150A. If armature resistance = 0.1Ω, flux per pole on no-load = 0.05 Weber, number of armature conductors = 750 and contact drop per brush = 1V, calculate (i) No-load speed. (ii) Full load speed. Armature Reaction weakens the field by 1.5% on full load.

__Solution:__

$I_0 = 15A$, $I_f = 10A$; $I_{a0} = 15 - 10 = \underline{5A}$

Resistance drop : $I_{a0} R_a = 5 \times 0.1 = \underline{0.5V}$

Brush drop $= 2 \times 1 = \underline{2V}$

$E_{b0} = V - I_{a0} R_a - BD = 440 - 0.5 - 2$

$\underline{E_{b0} = 437.5V}$

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

$$E_{b0} = \phi_0 \frac{Z N_0}{60} \times \frac{P}{A}$$

$$437.5 = 0.05 \times 750 \times \frac{N_0}{60} \times \frac{4}{4}$$

$$N_0 = 700 \text{ r.p.m}$$

$I_L = 150A$

$_{FL}I_F = 10$

$F.L.\ I_a = 150 - 10 = 140A$

$$E_{b(FL)} = V - I_{aFL} R_a - B.D$$

$$= 440 - (140 \times 0.1) - (2 \times 1)$$

$$= 424V$$

$$\phi_{FL} = (1 - 1.5\%)$$

$$\frac{E_{b(FL)}}{E_{b0}} = \frac{N_{FL}}{N_0} \frac{\phi_{FL}}{\phi_0}$$

$$N_{FL} = \frac{\phi_0}{\phi_{FL}} N_0 \frac{E_{b(FL)}}{E_{b0}}$$

$$= \frac{1}{(1-1.5\%)} \times 700 \times \frac{424}{437.5}$$

$$= 688.73 \text{ r.p.m}$$

$$\% \text{ Regulation} = \frac{N_0 - N_{FL}}{N_{FL}} = \frac{700 - 688.73}{688.73} = 1.63\%$$

3. A 220V dc shunt motor draws a current of 2A on no-load. The armature resistance is 0.2 Ω and the field current is 1A. Find the output and the efficiency when the input current is 12A.

Solution:

$V = 220V$

$R_a = 0.2\,\Omega$

$I_f = 1A$

At no load $I_{L0} = 2A$

$I_{a0} = I_{L0} - I_f = 2 - 1 = 1A$

Constant losses $\approx VI_{a0} + VI_f = V[I_{a0} + I_f] = 440W$

At a load drawing an input current of 12A,

$I_L = 12A$,

$I_a = I_L - I_f = 12 - 1 = 11A$

Input power $= V_L I_L$

$= 220 \times 12 = 2640W$

Armature copper loss $= I_a^2 R_a$

$= 11^2 \times 0.2 = 24.2W$

Output power = Input − Losses

$= 2640 - (440 + 24.2)$

$= 2175.8W$

$$\eta = \frac{\text{output power}}{\text{input power}} \times 100$$

$$= \frac{2175.8}{2640} \times 100 = \underline{82.42\%}$$

4. While conducting Swinburne's test on a 500V shunt motor, it is noted that it takes a current of 5A on no-load. The resistances of the armature and field circuits are 0.22Ω and 250Ω respectively. Estimate the efficiency when the motor current is 100A. What is the percentage change of speed between no-load and full-load?

Solution:

$V = 500$

$I_0 = 5A$

$R_a = 0.22\Omega$

$R_f = 250\Omega$.

$I_L = 100A$; $\eta = ?$

ON NO-LOAD:

$$I_{sh} = \frac{500}{250} = 2A$$

$$I_{a0} = 5 - 2 = \underline{3A}$$

$$\text{Armature Cu loss} = I_{a0}^2 R_a$$

$$= 3^2 \times 0.22 = \underline{1.98W}$$

Field Cu loss = $2^2(250) = 1000W$

$E_{bo} = V - I_{ao}R_a = 500 - 3(0.22) = 499.3V$

Constant losses = Input to armature − Armature Cu loss

$= VI_{ao} - I_a^2 R_a$

$= (V - I_{ao}R_a) I_{ao}$

$= E_{bo} I_{ao}$

$= 499.3 \times 3 = 1498W$

ON LOAD:

$I_L = 100$

$I_{sh} = 2A$

$\therefore I_a = 100 - 2 = 98A$

Armature Cu loss $= 98^2 \times 0.22 = 2113W$

Total losses = Field Cu loss + Constant loss + Armature Cu loss

$= 1000 + 1498 + 2113$

$= 4611W$

Input $= 500 \times 100 = 50{,}000W$

Output $= 50{,}000 - 4611 = 45{,}389W$

$$\eta = \frac{o/p}{i/p} \times 100 = \frac{45389}{50000} \times 100 = 90.78\%$$

$E_{bL} = V - I_a R_a$

$E_{bL} = 500 - 98 \times 0.22 = \underline{478.4V}$

If speed on no-load is N_0:

Speed on load $= N = \dfrac{E_{bL}}{E_{b0}} \times N_0$

$$N = \frac{478.4}{499.3} \times N_0$$

$$N = 0.958 N_0$$

% drop of speed $= \dfrac{N_0 - 0.958 N_0}{N_0} \times 100$

$= \underline{4.2\%}$

5. Two shunt motors loaded for the Hopkinson's test take 15A at 200V supply. The motor current is 100A. and the shunt currents are 3A & 2.5A. If the resistance of each armature is 0.05Ω. Calculate the efficiency of each machine for the given operating conditions.

Solution:

$I = 15A$

$I_m = 100$

$R_a = 0.05\Omega$

$I_g = I_m - I$

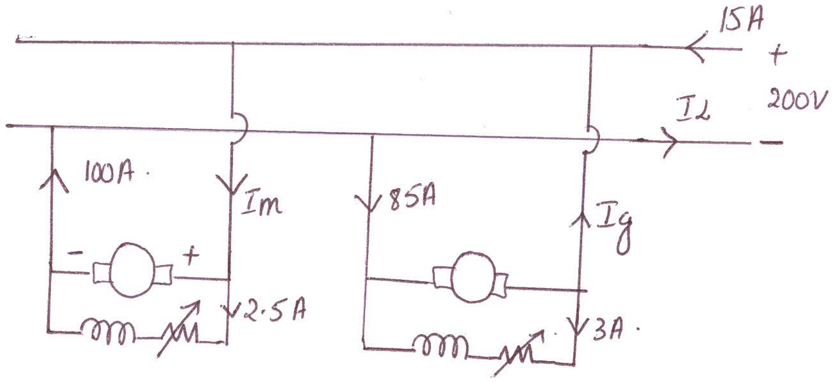
$= 100 - 15$

$= \underline{85A}$

I/p power taken = Total losses $= VI$

$= 200 \times 15$

$= \underline{3000W}$



Take motor current = 2.5A

$I_{am} = 100 - 2.5 = 97.5A$

Motor Cu losses $= I^2R = 97.5^2 \times 0.05 = 475.31W$

Generator current = 3A

$I_{ag} = 85 + 3 = 88A$

Generator Cu loss $= I^2R = 88^2 \times 0.05$

$= 387.2W$

Motor field losses $= V \times I_{fm} = 200 \times 2.5 = 500W$

Generator field losses $= V \times I_{fg} = 200 \times 3 = 600W$

Total losses $= 475.31 + 387.2 + 500 + 600$

$= 1962.51W$

∴ Mechanical & Magnetic losses $= 3000 - 1962.51 = 1037.49W$

∴ Losses per Machine $= \frac{1037.49}{2} = 518.745W \simeq 520W$

Efficiency of motor $= \frac{i/p - losses}{i/p}$

$$= \frac{(100 \times 200) - (475.31 + 500 + 520)}{100 \times 200}$$

$$= \underline{\underline{92.5\%}}$$

$$\text{efficiency of generator} = \frac{O/P}{O/P + \text{losses}}$$

$$= \frac{200 \times 85}{(200 \times 85) + (387 + 600 + 520)}$$

$$= \underline{\underline{91.85\% \simeq 92\%}}$$

6. A series generator of total resistance of 0.5 Ω is running at 1000 rpm and delivering 5KW at a terminal voltage of 100V. If the speed is raised to 1500 r.p.m, and the load adjusted to 8KW. find the new current and the terminal voltage. [Note: EMF is proportional to (Speed x Flux) and the Flux is proportional to Current]

Solution:

a) N = 1000 r.p.m

Output = 5000 W

V = 100V

$$I = \frac{5000}{100} = 50A$$

$$\text{EMF generated} = V + IR_a = 100 + 50(0.5) = \underline{\underline{125V}}$$

b) Speed, $N = 1500$ r.p.m

Output $= 8000W$

$$V_1 = \frac{8000}{I_1}$$

$$EMF = E_1 = V_1 + I_1 R_a$$

$$= V + I_1(0.5)$$

$$E_1 = \left[\frac{8000}{I_1} + I_1(0.5)\right]$$

$\because E \propto \phi N \propto IN$

But $$\frac{E}{E_1} = \frac{IN}{I_1 N_1}$$

$$\frac{125}{E_1} = \frac{50 \times 1000}{I_1 \times 1500}$$

$$E_1 = \frac{15}{4} I_1$$

$$I_1 = \frac{4}{15} E_1$$

$$\therefore \frac{15}{4} I_1 = \frac{8000 + I_1^2(0.5)}{I_1}$$

$$I_1^2 \frac{15}{4} - 8000 - I_1^2 0.5 = 0$$

$$I_1^2 (3.25) - 8000 = 0$$

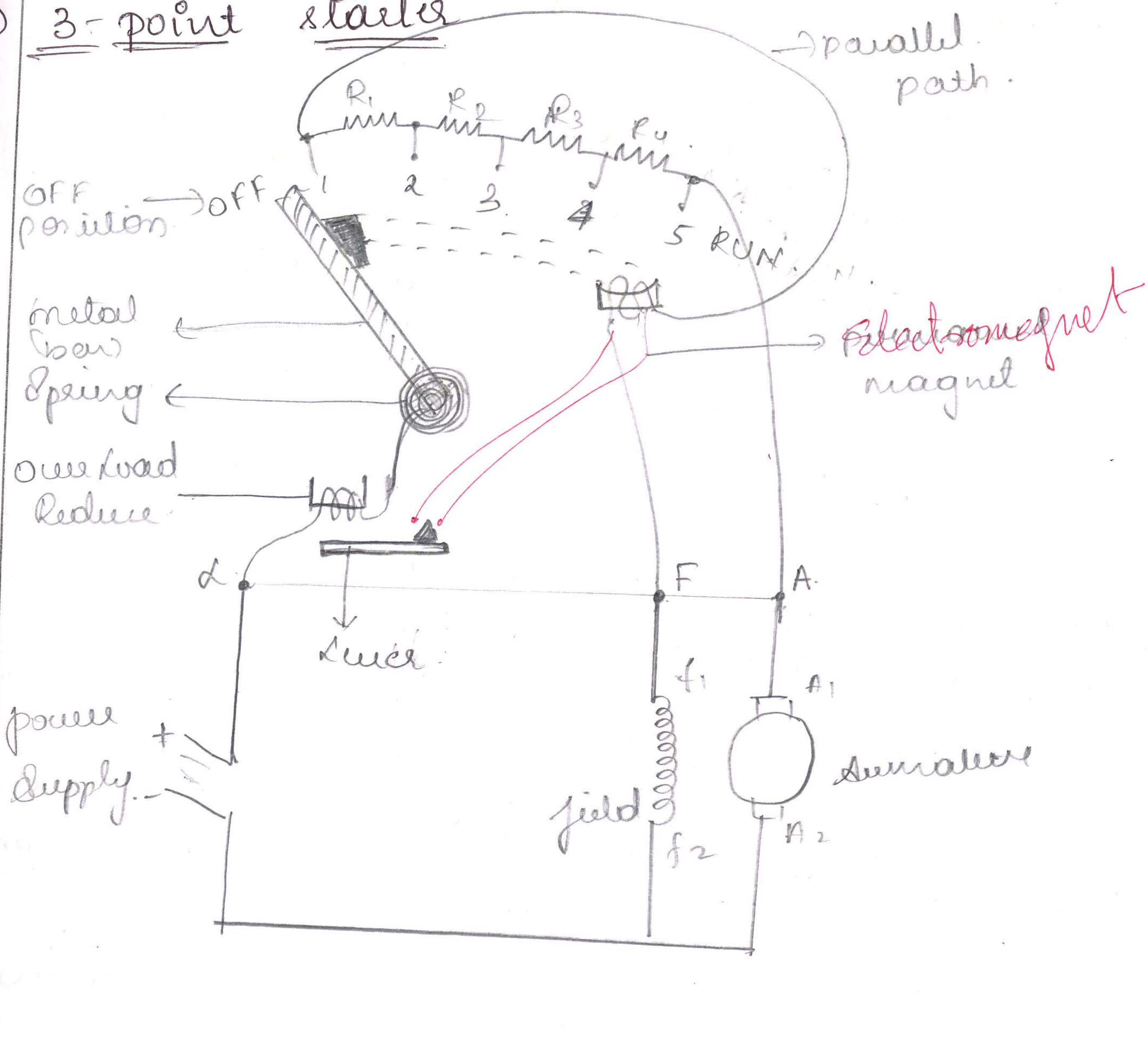
$$\underline{\underline{I_1 = 49.61A}}$$

$$\therefore V_1 = \frac{8000}{I_1} = \frac{8000}{49.61} = \underline{\underline{161.25V}}$$

(2) (a) sol - Dc Motor Starter

Dc motor is a self starter. when armature is subjected with (supply) it get switched (ON) & starts automatically. so we need starter inorder start the Dc motor in a properly & easy way.

(i) 3-point starter



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Three point starter

→ It consist of 3 points mainly (L F A)

L → Line connected to (+ve) power supply.

F → Line connected to field of the motor.

A → Line connected to Armature.

~~Now. the~~

Construction :-

* The line from positive power supply it is connected over load Release point.
* other end is connected to the string where the metal rod is connected.
* ~~Also~~ One parallel path from point (L) is taken & given to the Permanent magnet and other end to (F) point.
* The points are called as ~~stug~~ studs.

(OFF 1 2 3 4 5 RUN)

* Resistance connected in series with the Armature.

Operation:-

* Before ~~when~~ the supply is given the string will ~~held~~ being the (OFF) position and dont allow the metal rod to the move
* when the DC supply is given the metal rod moves from OFF position to (1) stug Hence. Now from the same point it is excites the field which is connected to Parallel path. Hence the magnet ~~paral~~ Through field get excited.
* Now the All the resistance will come in series with Armature.

* As the supply increases the metal rod will go on moving from 1 to 2 and 3 to 5 studs Hence the High Current in the armature goes on decreasing. Hence torque increase, speed increases.
* when it reaches to (RUN) position then the speed will be Normal. and (RUN) at constant speed.
* ~~The electro~~ ~~permanent~~ electro magnet will attract the iron piece which is present near the rod. So that rod remains permanent at run position as long as supply is there. Hence the 3 point starter is used.
* This is how 3 point starter is used.

(b) Soln.

$V = 440V$.

$P = 4$.

$I_0 = 15A$.

$I_{sh} = 10A$.

$I_L = 150A$.

$R_a = 0.1 ohm$.

$\phi_0 = 0.05 wb$.

$Z = 750$.

$V_b = 1V$.

(i) No load speed (N_0).

(ii) Full load speed (N_L).

As armature reaction weaken by $= 0.15\phi_0$.