unit-5

lesson

1) A 220 V, 12kW, DC shunt motor has a maximum efficieny of 90% and a speed of 800 r.p.m. when delivering 80% of its rated output. the resistance of its shunt field is 80. Determine the efficiency, speed when the motor draws a current of 70 A from mains.

Sol:

Full load motor output $= 12\,KW \Rightarrow 12\times10^6$

$= 12000\,W$

$N_1 = 800rpm$; $R_{sh} = 80$; $V = 220$; $I = 70A$; $\eta = 90\% \Rightarrow \frac{90}{100} = 0.9$

80% of full load output:

$\frac{80}{100} \Rightarrow 0.8$

full load output $= 0.8 \times 12000$

$O/P = 9600W$

$$\text{Input} = \frac{O/P}{\%\eta}$$

$$= \frac{9600}{0.9}$$

Motor I/P $= 10666.67\,W$

Total losses at 80% full load $= IP/ - O/P$

$= 10666.67 - 9600$

$= 1066.66\,W$

As efficiency is maximum at 80% full load.

constant losses = variable losses $= \frac{O/P}{V}$

$$= \frac{10666.67}{220}$$

$$I = 48.48A$$

$$I_{sh} = \frac{V}{R_{sh}}$$

$$= \frac{220}{80}$$

$$= 2.75A$$

$I = I_a + I_{sh}$ I_a.

$$I_a = I - I_{sh} = 48.48 - 2.75$$

$$I_a = 45.73A$$

Armature copper loss $= I_a^2 R_a \Rightarrow (45.73)^2 R_a$

$$R_a = \frac{533.33}{(45.73)^2}$$

$$R_a = 0.25\Omega$$

Motor I/P current $I = 70A$

$$I_a = I - I_{sh}$$

$$= 70 - 2.75$$

$$= 67.25A$$

Armature cu loss $= I_a^2 R_a$

$$= (67.25)^2 (0.25)$$

$$= 1130.64W$$

Total loss = Armature cu loss + constant losses

$$= 1130.64W + 533.33$$

$$= 1663.97W$$

Motor I/P = VI

$= (220)(70)$

$= 15400\,W$

motor O/P = motor i/p - losses.

$= 15400 - 1663.97$

$= 13736.03\,W$

$$\%\eta = \frac{\text{motor O/P}}{\text{motor I/P}} \times 100$$

$$= \frac{13736.03}{15400} \times 100$$

$= 89.195\%$

e.m.f at 80% ; $N_1 = 800$

$E_{b1} = V - I_a R_a$

$= (200) - (45.73)(0.25)$

$= 208.56$ volts

$E_{b2} = V - I_a R_a$

$= (220) - (67.25)(0.25)$

$= 203.18$ volts

In case of D.C shunt motor, $E_b \propto N$

$$\frac{E_{b2}}{E_{b1}} = \frac{N_2}{N_1} \; ; \text{ ie } \frac{203.18}{208.56} = \frac{N_2}{800}$$

$$N_2 = \frac{203.18}{208.56} \times 800$$

$= 779.36$ r.p.m.

2) A 6 pole, 500 Volts, wave connected shunt motor has 1200 armature conductors and usefully flux/pole of 20 mWb. Armature and field resistance are 0.5 ohms and 250 ohms. what will be the speed and torque developed by the motor when it draws 20 amp. from supply? Neglect armature reaction. If magnetic and mechanical losses are 900 watts from i) useful torque ii) Efficiency at this load.

Sol:

$P = 6$, $V = 500$ volts, $A = P$; $Z = 1200$

$\phi = 20$ mWb, $R_a = 0.5\,\Omega$, $R_{sh} = 250\,\Omega$, $I_L = 20$ A

$\phi = 20 \times 10^{-3}$ m

$$I_{sh} = \frac{V}{R_{sh}}$$

$$= \frac{500}{250}$$

$$I_{sh} = 2\,A$$

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

$$= 20 - 2$$

$$I_a = 18\,A$$

$$V = E_b + I_a R_a$$

$$500 = E_b + 18 \times 0.5$$

$$E_b = 500 - 18 \times 0.5$$

$$= 500 - 9$$

$$E_b = 491\,V$$

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

$$491 = \frac{20 \times 10^{-3} \times 6 \times N \times 1200}{60 \times 2}$$

$$N = 409.167 \text{ r.p.m}$$

$$P_m = E_b I_a$$

$$= 491 \times 18$$

$$= 8838 W.$$

$$T_g = \frac{P_m}{\omega} = \frac{P_m}{\left(\frac{2\pi N}{60}\right)}$$

$$= \frac{8838}{\left[\frac{2\pi \times 409.167}{60}\right]}$$

$$= 206.26 \text{ Nm}$$

T_g can be calculated by using expression $0.159 \phi Z I_a$

$$\phi I_a = \frac{PZ}{A}$$

$$P_{out} = P_m - \text{Mechanical losses}$$

$$= 8838 - 900$$

$$= 7938 W.$$

$$\text{Useful torque} = T_{sh} = \frac{P_{out}}{\omega} = \frac{7938}{\left(\frac{2\pi N}{60}\right)} \Rightarrow \frac{7938}{\left(\frac{2 \times \pi \times 409.167}{60}\right)}$$

$$= 185.26 \text{ Nm}.$$

$$P_{in} = V I_L \Rightarrow 500 \times 20 = 10000 W$$

$$\% \eta = \frac{P_{out}}{P_{in}} \times 100 \Rightarrow \frac{7938}{10000} \times 100$$

$$\eta = 79.38\%$$

3) The no load test of a 44.76 KW, 220 V d.c shunt motor gave the following results: Input current = 13.25 A, field current = 2.55 A, Resistance of armature at 75°C = 0.032 Ω, Brush drop = 2 V. Estimate the full load current and efficiency.

Sol:

$I = 13.25A$; $I_{sh} = 2.55A$, $V = 220$; Brush drop = 2V

Full load Pout = 44.76 KW ⇒ 44.76×10^6 ⇒ 44760 W ; $R_a = 0.032$

No load pin = V × I

= 220 × 13.25

= 2915 W

$I = I_{sh} + I_a$

$I_a = I_{sh} - I$

= 13.25 − 2.55

= 10.7 A

No load armature copper loss $= I_a^2 R_a$

$= (107)^2 \times 0.032$

= 3.664 W

Loss due to brush drop = 2 × 10.7

= 21.4 W

constant losses = No load I/P − No load armature cu loss − Loss due to brush drop

= 2915 − 3.664 − 21.4

= 2889.936 W.

$I = I_a + I_{sh}$

$= (I_a + 2.55)A$

Full load motor i/p = $V \times I$

$i/p = 200(I_a + 2.55)W$

motor I/P = Motor O/P + Total losses + constant loss + brush loss + armature Cu loss

$200(I_a + 2.55) = 44760 + 2889.936 + 2I_a + I_a^2 R_a$

$0.032 I_a^2 + 2I_a - 220 I + 44760 + 2889.936 - (220)(2.55) = 0$

$0.032 I_a^2 - 218 I_a + 47088.936 = 0$

$I_a = 223.325 A$

Full load motor I/P current $= 223.325 + 2.55$

$= 225.875 A.$

Full load motor i/p $= V \times I$

$= (220 \times 225.875)$

$= 49692.5 W$

Full load motor efficiency $= \frac{O/P}{I/P} \times 100$

$= \frac{44760}{49692.5} \times 100$

$\eta = 90.074\%.$

4) A 50 kW, 440 V, shunt generator having an armature circuit resistance including the interpole winding of 0.15 Ω at normal working temperature was run as a shunt motor on no load at its rated voltage and speed. The total current drawn by the motor was 5 A, including shunt field current of 1.5 A. Calculate the efficiency of the shunt generator at i) Full load ii) 3/5th load and iii) Half load.

Sol:

$I = 5A$; $V = 440$; $I_{sh} = 1.5A$; $R_a = 0.15$

$P = 50 kW \Rightarrow 50 \times 10^3$

No load i/p $= V \times I$

$= 400 \times 5$

$= 2200 W$

$I_a = I - I_{sh}$

$I_{sh} = 1.5A$; $I = 5A$

$I_a = 5 - 1.5$

$= 3.5 A$

Armature copper loss $= I_a^2 R_a$

$= (3.5)^2 \times (0.15)$

$= 1.8375 W$

constant losses = No load i/p - Armature cu loss

$= 2200 - 1.8375$

$= 2198.16\ W$

$P = V \times I$

$I = P/V = \dfrac{50 \times 10^3}{440}$

$= 113.63\ A$

ii) Full load:-

$I = I_a + I_{sh}$

$I_a = I - I_{sh}$

$= 113.63 - 1.5$

$= 112.13\ A$

Armature cu loss $= I_a^2 R_a$

$= (112.13)^2 (0.15)$

$= 1886\ W.$

Total losses = Armature cu loss + constant loss.

$= 1886 + 2198.16$

$= 4084.16\ W$

$= 4.084\ kW$

O/P of generator = 50 kW

I/P to generator = O/P + losses

$= 50 + 4.084$

$= 54.084\ kW.$

(iii) 3/4th load:

$3/4 P = V \cdot I$;

$37.5 = V \cdot I$

$$I = \frac{37.5 \times 10^3}{440}$$

$I = 85.22 A$

$Ia = I - Ish$

$= 85.22 - 1.5$

$= 83.72 A$

Armature cu loss $= Ia^2 Ra$

$= (8372)^2 (0.15)$

$= 1051.35 W$

Total loss $= 1051.35 + 2198.16$

$= 3250 W \Rightarrow 3.25 kW$

output of generator $= 3/4 \times 50 \Rightarrow 37.5 kW$

I/P to generator $= 37.5 + 3.25 = 40.75 kW$

$$\% \eta g = \frac{O/P}{I/P} \times 100$$

$$= \frac{37.5}{40.75} \times 100$$

$= 92.02\%$

iii) half load:-

$1/2\,P = V \cdot I$

$I = \frac{1/2\,P}{V}$

$= \frac{1/2 \times 50 \times 10^3}{440}$

$= 56.81\,A$

$I_a = I - I_{sh}$

$= 56.81 - 1.5$

$= 55.31\,A$

Armature cu loss $= I_a^2 R_a$

$= (55.31)^2 (0.15)$

$= 458.87\,W$

Total losses $= 458.87 + 2198.16$

$= 2.657\,kW$

O/P of generator = O/P + losses

$= 25 + 2.657$

$= 27.657$

$\%\,\eta_g = \frac{O/P}{I/P} \times 100$

$= \frac{25}{27.657} \times 100$

$= 90.39\,\%$

5) A 500 V, DC shunt motor takes a total current of 5 A when running unloaded. The resistance of armature circuit is 0.25 Ω and the field resistance is 125 Ω. calculate the efficiency and output when the motor is loaded and drains a current of 100 A.

Sol:

$V = 500$ volts, $I_0 = 5A$, $R_a = 0.25\Omega$, $R_{sh} = 125\Omega$, $I = 100A$

No load input $= V \times I_0$

$= 500 \times 5$

$= 2500\,W$

$I_{sh} = \dfrac{V}{R_{sh}}$

$= \dfrac{500}{125} \Rightarrow 4A.$

$I_{a0} = I_0 - I_{sh}$

$= 5 - 4 \Rightarrow 1A$

constant losses = No load i/p - armature cu loss.

$= 2500 - 0.25$

$= 2499.75\,W$

$I_a = I - I_{sh}$

$= 100 - 4$

$= 96\,A$

Armature cu loss $= I_a^2 R_a$

$= (96)^2(0.25)$

$= 2304 W.$

Total losses = Armature cu loss + constant losses

$= 2304 + 2499.75$

$= 4803.75 W$

$= 4.80 KW$

Input $= V \times I$

$= (500)(100)$

$= 50 KW$

output = input - losses

$= 50 - 4.80$

$= 45.2 KW$

% Efficiency $= \frac{O/P}{I/P} \times 100$

$= \frac{45.2}{50} \times 100$

$= 90.4$

% Efficiency = 90.4 %

6) A 220 V, D.C Shunt motor takes 4A at no-load when running at 700 r.p.m. the field resistance is 100 ohm. the resistance of armature at standstill gives a drop of 6 volts across armature terminals when 10A pass through it. Calculate i) speed on load ii) Torque in N-m iii) Efficiency : the normal i/p of the motor is 8 kW.

Sol:

$V = 220\ V$, $I_0 = 4A$, $N_0 = 700$ rpm, $R_{sh} = 100\ \Omega$, $P_{in} = 8KW \Rightarrow 8 \times 10^3$

Armature drop $= 6V$. the current of $10A$.

$$R_a = \frac{6}{10} = 0.6\ \Omega$$

$$I_{sh} = \frac{V}{R_{sh}} = \frac{220}{100}$$

$$= 2.2A$$

$$I_{a0} = I_0 - I_{sh}$$

$$= 4 - 2.2$$

$$= 1.8A$$

$$E_{b0} = V - I_{a0} R_a$$

$$= 220 - 1.8 \times 0.6$$

$$E_{b0} = 218.92V$$

$P_{in} = V \times I_L$

$I_L = \frac{P_{in}}{V} = \frac{8 \times 10^3}{220}$

$I_L = 36.364A$

$I_{aL} = I_L - I_{sh}$

$= 36.364 - 2.2$

$I_{aL} = 34.1636A$

$E_{bL} = V - I_{aL}R_a$

$= 220 - 34.1636 \times 0.6$

$E_{bL} = 199.5018V$

(i) Speed on load:-

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

$\frac{N_0}{N_L} = \frac{E_{b0}}{E_{bL}}$

$\frac{700}{N_L} = \frac{218.92}{199.5018}$

$N_L = 637.91 \text{ rpm}$

(ii) Torque N-m load:-

$P_m = E_{bL} I_{aL}$

$= 199.5018 \times 34.1636$

$= 6.8157 \text{ kW}$

$$T = \frac{pm}{\omega} \Rightarrow \frac{pm}{(2\pi N/60)}$$

$$= \frac{6.8157 \times 10^3}{\left(\frac{2\pi \times 637.91}{60}\right)}$$

$$= 102.0287 \text{ NM}.$$

(iii)

No load $P_{i/p} = VI_0$

$= 220 \times 4$

$= 880 \text{ W}$

No load power input = copper losses + stay losses

copper losses $= I^2_{sh} R_{sh} = 484 \text{ W}$

No load armature copper losses $= I_{a0}^2 R_a$

$= 9.6 \text{ W}$

stray losses $= 880 - 484 - 9.6$

$= 386.4 \text{ W}$

constant losses $= 386.4 + 484$

$= 470.4 \text{ W}$

on load, Armature copper losse $= I_{aL}^2 R_a = (34.1636)^2 (0.6)$

$= 700.29 \text{ W}$

Total losses on load $= 870.4 + 700.29$

$= 1570.69 \text{ W}$

$$\% \eta_L = \frac{P_{out}}{P_{in}} \times 100$$

$$= \frac{P_{in} - \text{total losses}}{P_{in}} \times 100$$

$$= \frac{8 \times 10^3 - 1570.69}{8 \times 10^3} \times 100$$

$$\% \eta_L = 80.366 \%$$

7) In a brake test conducted on a d.c shunt motor the full load readings are observed as, Tension on tight side = 9.1 kg, Tension on slack side = 0.8 kg. Total current = 10A. supply voltage = 110V, speed = 1320 r.p.m, the radius of the pulley is 7.5 cm. calculated its full load efficiency.

Sol:

$W_1 = 9.1 kg$, $W_2 = 0.8 kg$, $I = 10A$, $V = 110V$, $R = 7.5 cm$

$$T_{sh} = (W_1 - W_2)\, 9.81 \times R$$

$$= (9.1 - 0.8) \times 9.81 \times 0.075$$

$$= 6.1067 \text{ Nm}$$

$$P_{out} = T_{sh} \times \omega$$

$$= T_{sh} \times \frac{2\pi N}{60}$$

$$= \frac{6.1067 \times 2\pi \times 1320}{60}$$

$$= 844.133 W$$

$Pin = VI = 110 \times 10$

$= 1100\,W$

$\% \eta = \frac{Pout}{Pin} \times 100$

$= \frac{844.133}{1100} \times 100$

$\% \eta = 76.74\%$

8) A retardation test is made on a separately excited d.c machine as a motor. the induced voltage falls from 240 V to 225 V in 25 seconds on opening the armature circuit and 6 seconds on suddenly changing the armature connection from supply to a load resistance taking a current 10 A. Find the efficiency of the machine when running as a motor and taking a current of 25 A on a supply of 250 V. the resistance of its armature is 0.4 Ω and that its rading is 250 Ω.

Sol:

Average voltage across the load $= \frac{240 + 225}{2}$

$= 232.5\,V$

$I_{av} = 10\,A,\ R_a = 0.4\,\Omega,\ R_{sh} = 250\,\Omega,\ t_1 = 25\,s,\ t_2 = 6\,s$

$w' =$ Power absorbed $= (V_{av})(I_{av}) = 232.5 \times 100$

$= 2325\,W$

W = stray losses

$$\frac{W}{W'} = \frac{t_2}{t_1 - t_2}$$

$$\frac{W}{2325} = \frac{6}{25-6}$$

$$W = 734.2105\,W$$

$$I_{in} = 25A \quad , \quad I_{sh} = \frac{V}{R_{sh}}$$

$$= \frac{250}{250} = 1A$$

$$I_a = I_{in} - I_{sh}$$

$$= 25 - 1$$

$$= 24A$$

Armature copper loss $= I_a^2 R_a$

$$= (24)^2 (0.4)$$

$$= 230.4W$$

Field copper loss $I_{sh}^2 R_{sh} = 250W$

Total loss $= 734.2105 + 230.4 + 250$

$$= 1214.6105\,W$$

$P_{in} = VI_{in} = 250 \times 25 = 6250\,W$

$P_{out} = P_{in} - \text{Total loss} = 5035.3895\,W$

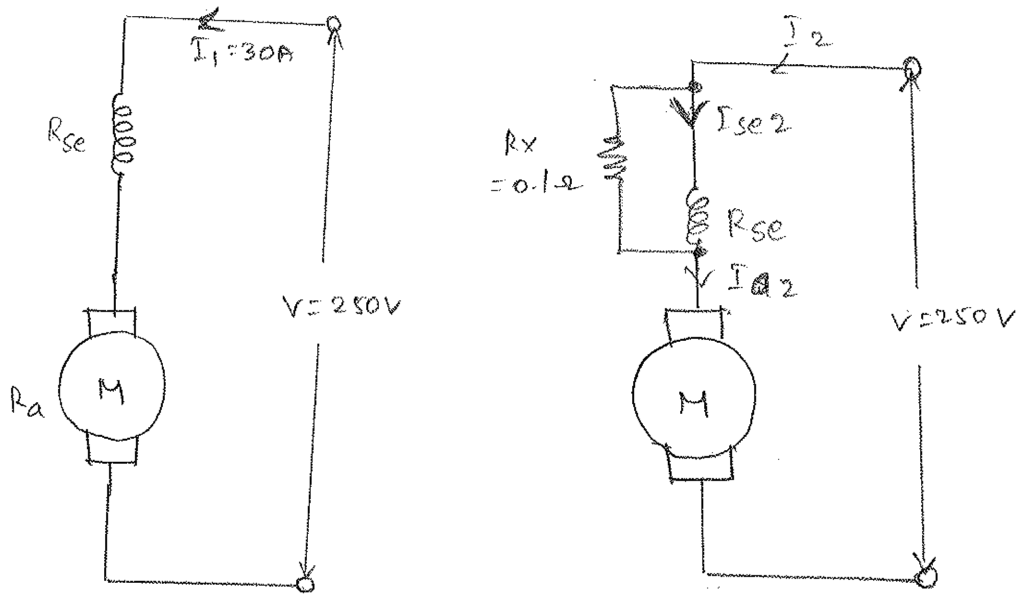
$$\%\,\eta_m = \frac{P_{out}}{P_{in}} \times 100 = \frac{5035.3895}{6250} \times 100$$

$$\%\,\eta_m = 80.566\%.$$

PROBLEMS:

1. A 250 V, dc, series motor takes 30 A when running at 800 r.p.m. calculate the speed at which motor will run if field winding is shunted by a resistance equal to the field winding resistance and the load torque is increased by 50%. Armature resistance is 0.15 Ω and series field resistance is 0.1 Ω, assume the flux produced is proportional to the field current.

Sol



$V = 250V$, $R_a = 0.15\Omega$, $R_{se} = 0.1\Omega$

$N_1 = 800 rpm$ $\quad I_1 = I_{a1} = I_{se1} = 30A$

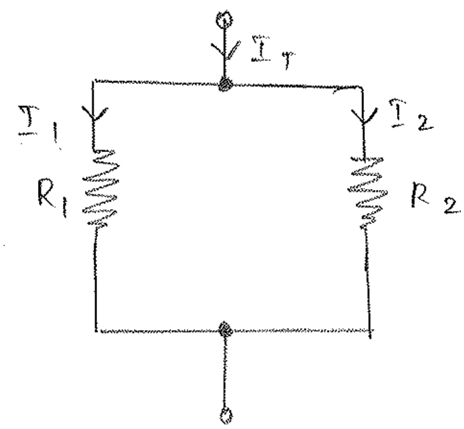
$\phi \propto I_{se}$

$T \propto \phi I_a \propto I_{se} I_a$

$$\frac{T_1}{T_2} = \frac{I_{se1}}{I_{se2}} \times \frac{I_{a1}}{I_{a2}}$$

$T_2 = T_1 + 0.5T_1 = 1.5T_1$ —— ①

According to current distribution in parallel circuit shown in the figure the current I_T gets divided as,



$$I_1 = I_T \times \frac{R_2}{R_1+R_2}$$

$$I_2 = I_T \times \frac{R_1}{R_1+R_2}$$

$$I_2 = I_{a2}$$

$$I_{se2} = I_{a2} \times \frac{R_x}{R_x+R_{se}} = I_{a2} \times \frac{0.1}{0.1+0.1}$$

(1) & (2) sub in torque equation $= 0.5 I_{a2}$

$$\frac{T_1}{1.5T_1} = \frac{30}{0.5I_{a2}} \times \frac{30}{I_{a2}} \qquad \therefore (I_{a2})^2 = 2700$$

$$I_{a2} = 51.9615 \text{ A}$$

$$I_{se2} = 0.5\, I_{a2} = 25.9807 \text{ A}$$

$$E_{b1} = V - I_{a1}R_a - I_{se1}R_{se} = 250 - 30 \times 0.15 - 30 \times 0.1$$

$$= 242.5 \text{ V}$$

$$E_{b2} = V - I_{a2}R_a - I_{se2}R_{se}$$

$= 250 - 51.9615 \times 0.15 - 25.9807 \times 0.1 = 239.607\ V$

$N \propto \frac{E_b}{\phi}$ (Speed equation)

$$\frac{N_1}{N_2} = \frac{E_{b1}}{E_{b2}} \times \frac{I_{se2}}{I_{se1}},$$

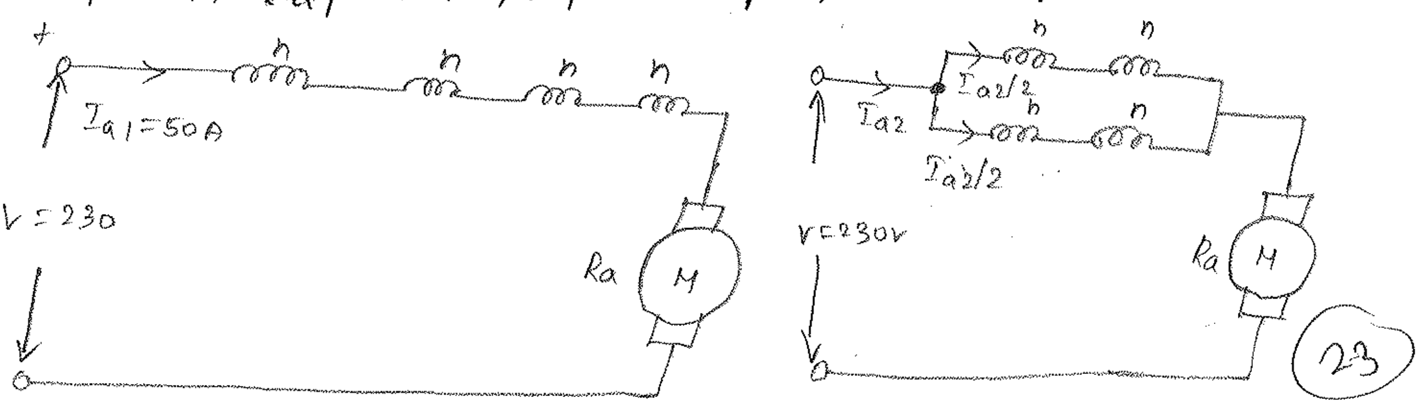
$$\frac{800}{N_2} = \frac{242.5}{239.607} \times \frac{25.9807}{30}$$

$N_2 = 912.744$ rpm.

2). A 4 pole series wound fan motor draws an armature current of 50 Amps, when running at 2000 rpm on a 230 V DC supply with four field coils connected in assumming flux/pole to be proportional to the exciting current and the load torque proportional to the square of the speed, the four field coils are than reconnected in two parallel groups of two coils in series. find the new speed and armature current.

Sol

$P = 4$, $I_{a1} = 50A$, $N_1 = 2000$ rpm, $V = 230V$



The field coils is divided into 4 groups each of say 'n' turns. In first case, the coils are in series as shown in fig

So flux ϕ_1 produced in this case is proportional to total ampere turns produced by field coils.

$$\phi_1 \propto I_{a1} \times (4n) \propto 50 \times 4n \propto 200n \quad -(1).$$

now the coils are reconnected in two parallel groups of two coils in series, this is shown in the fig. as coil group resistance are equal the current I_{a2} will split into two equal parts as $I_{a2}/2$ now ϕ_2 will be proportional to the total ampere turns.

$$\phi_2 \propto \left[\frac{I_{a2}}{2} \times 2n + \frac{I_{a2}}{2} \times 2n\right] \propto 2n I_{a2} \quad -(2)$$

$\div$ (1) & (2)

$$\frac{\phi_1}{\phi_2} = \frac{200}{2nI_{a2}} = \frac{100}{I_{a2}}$$

$$T \propto \phi I_a$$

$$\frac{T_1}{T_2} = \frac{\phi_1}{\phi_2} \times \frac{I_{a1}}{I_{a2}}$$

$$T \propto N^2$$

$$\frac{T_1}{T_2} = \left(\frac{N_1}{N_2}\right)^2$$

$$\left(\frac{N_1}{N_2}\right)^2 = \frac{\phi_1}{\phi_2} \times \frac{I_{a1}}{I_{a2}}$$

$$N \propto \frac{E_b}{\phi}, \quad \frac{N_1}{N_2} = \frac{E_{b1}}{E_{b2}} \times \frac{\phi_2}{\phi_1}$$

But as resistance are not given, the drops across windings can be neglected as practically the drop are very small hence $E_{b1} = E_{b2}$

$$\frac{N_1}{N_2} = \frac{\phi_2}{\phi_1}$$

$$\left(\frac{\phi_2}{\phi_1}\right)^2 = \frac{\phi_1}{\phi_2} \times \frac{I_{a1}}{I_{a2}}$$

$$\left(\frac{\phi_2}{\phi_1}\right)^3 = \frac{I_{a1}}{I_{a2}}$$

$$\left(\frac{I_{a2}}{100}\right)^3 = \frac{50}{I_{a2}}$$

$$(I_{a2})^4 = 50 \times (100)^3$$

$$I_{a2} = 84.089\ A$$

$$\left(\frac{N_1}{N_2}\right)^2 = \frac{\phi_1}{\phi_2} \times \frac{I_{a1}}{I_{a2}}$$

$$\left(\frac{N_1}{N_2}\right)^2 = \frac{N_2}{N_1} \times \frac{I_{a1}}{I_{a2}}$$

$$\left(\frac{N_1}{N_2}\right)^3 = \frac{I_{a1}}{I_{a2}}$$

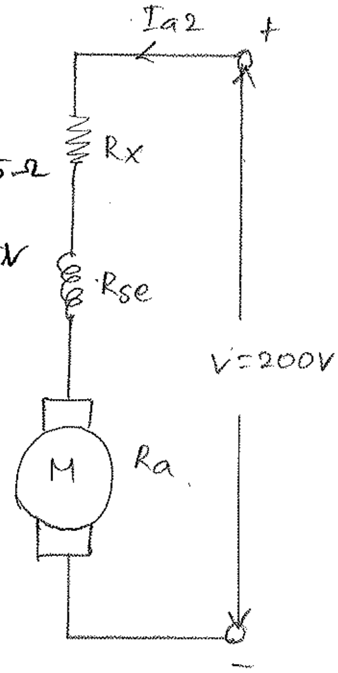
$$\left(\frac{2000}{N_2}\right)^3 = \frac{50}{84.089}$$

$$N_2 = 2378.408\ rpm.$$

3). A 200 V dc, series motor drives a load at a certain speed and takes a current of 30A, the resistance between its terminals is 1.5 Ω, find the extra resistance to be added in series with the motor circuit to reduced the speed to 60% of its original value assume that the torque produced is proportional to the cube of the speed.

<u>Sol</u>

$V = 200\,V, \quad I_{a1} = 30\,A$



Resistance across terminals $= R_a + R_{se} = 1.5\,\Omega$

$$E_{b1} = V - I_{a1}(R_a + R_{se}) = 200 - 30 \times 1.5 = 55V$$

$$N_2 = 0.6 N_1$$

$$\frac{N_1}{N_2} = \frac{1}{0.6}$$

$$T \propto \phi I_a \propto I_a^2$$

$$\frac{T_1}{T_2} = \left(\frac{I_{a1}}{I_{a2}}\right)^2 \quad \text{—①}$$

$$T \propto N^3$$

$$\frac{T_1}{T_2} = \left(\frac{N_1}{N_2}\right)^3 = \left(\frac{1}{0.6}\right)^3 \quad \text{—②}$$

(1) & (2) equating

$$\left(\frac{1}{0.6}\right)^3 = \left(\frac{30}{I_{a2}}\right)^2$$

$$I_{a2} = 13.9427\,A$$

$$E_{b2} = V - I_{a2}(R_a + R_{se} + R_x) = 200 - 13.9427\,(1.5 + R_x)$$

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

$$\frac{N_1}{N_2} = \frac{E_{b1}}{E_{b2}} \times \frac{I_{a2}}{I_{a1}}$$

$$\frac{1}{0.6} = \frac{155}{E_{b_2}} \times \frac{13.9427}{30}$$

$$E_{b_2} = 43.22\,V$$

equating (3) & (4)

$$43.22 = 200 - 13.9427(1.5 + R_x)$$

$$R_x = 9.745\,\Omega.$$

4). A series motor having resistance of 1Ω between its terminals drives a fan, the torque of which is proportional to the square of the speed. At 230 V, its speed is 300 rpm, and takes 15 A. The speed of the fan is to be raised to 375 rpm, by supply voltage control, estimate the supply voltage required.

sol.

$R_a + R_{se} = 1\Omega$, $V_1 = 230\,V$, $N_1 = 300$ rpm, $I_1 = I_{a1} = 15A$

$N_2 = 375$ rpm

$$T \propto \phi I_a \propto I_a^2$$

$$\frac{T_1}{T_2} = \left(\frac{I_{a1}}{I_{a2}}\right)^2 \longleftarrow (1)$$

$$T \propto N^2$$

$$\frac{T_1}{T_2} = \left(\frac{N_1}{N_2}\right)^2 \longleftarrow (2)$$

equating (1) & (2)

$$\left(\frac{N_1}{N_2}\right)^2 = \left(\frac{I_{a1}}{I_{a2}}\right)^2$$

$$\left(\frac{300}{375}\right)^2 = \left(\frac{15}{I_{a2}}\right)^2$$

$I_{a2} = 18.75\,A$

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

$\frac{N_1}{N_2} = \frac{E_{b1}}{E_{b2}} \times \frac{I_{a2}}{I_{a1}}$

$E_{b1} = V_1 - I_{a1}(R_a + R_{se})$

$= 230 - 15 \times 1 = 215\,V$

$E_{b2} = V_2 - I_{a2}(R_2 + R_{se})$

$= V_2 - 18.75$

$\frac{300}{375} = \frac{215}{(V_2 - 18.75)} \times \frac{18.75}{15}$

$V_2 - 18.75 = \frac{215 \times 18.75 \times 375}{300 \times 15}$

$V_2 - 18.75 = 335.9375$

$V_2 = 354.6875\,V.$

this is the new supply voltage required to raise the speed from 300 rpm to 375 rpm.

5) A series motor of resistance 1 Ω b/w terminals runs at 800 rpm. at 200 V with a current of 15 A, find the speed at which it will run when connected in series with a 5 Ω resistance and taking the same current at the same supply voltage.

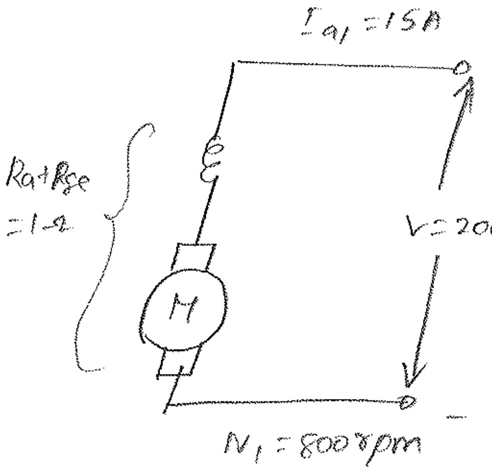
$E_{b1} = V - I_{a1}(R_a + R_{se})$

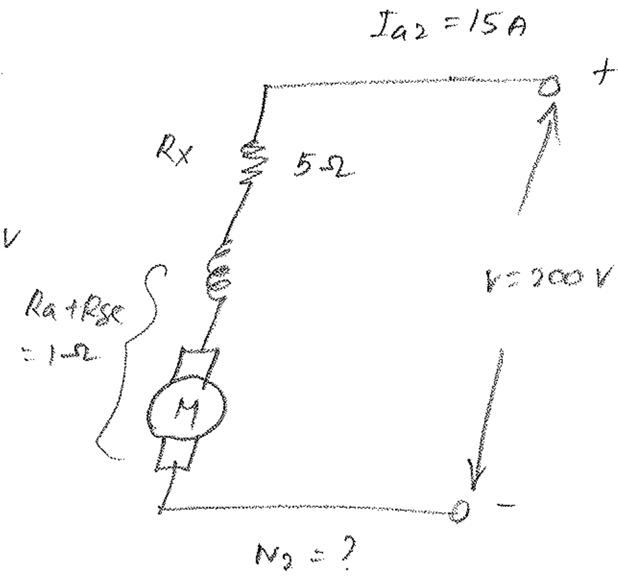
$= 200 - 15 \times 1 = 185\ V$

$E_{b2} = V - I_{a2}(R_a + R_{se} + R_x)$

$= 20 - 15 \times 6$

$= 110\ V$





$N \propto \frac{E_b}{\phi} \propto E_b \qquad \because I_{a1} = I_{a2} = 15A$

$\frac{N_1}{N_2} = \frac{E_{b1}}{E_{b2}}$

$\frac{800}{N_2} = \frac{185}{110}$

$N_2 = 475.6756\ rpm.$