Some Numerical Examples:

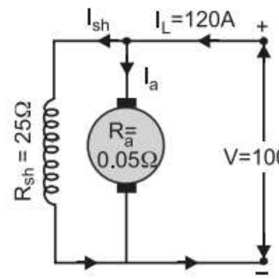
Example-1: The armature and shunt field resistance of a four-pole, lap wound DC shunt motor is 0.05 ohm and 25 ohms respectively. If its armature contains 500 conductors, find the speed of the motor when it takes 120 A current from a DC main of 100 V supply. Flux per pole is 2 × 10–2 Wb.

Solution:

$$I_{sh} = \frac{V}{R_{sh}} = \frac{100}{25} = 4\text{A};$$

$$I_a = I_L - I_{sh} = 120 - 4 = 116 \text{ A}$$

$$E_b = V - I_a R_a = 100 - 116 \times 0.05 = 94.2 \text{ V.}$$



Now, $$E_b = \frac{P\phi ZN}{60A}$$

or $$94.2 = \frac{6 \times 2 \times 10^{-2} \times 500 \times N}{60 \times 6}$$

or $$N = \mathbf{565.2\ rpm}\ (Ans.)$$

Example-2: The electromagnetic torque developed in a DC machine is 80 Nm for an armature current of 30 A. What will be the torque for a current of 15 A? Assume constant flux. What is the induced emf at a speed of 900 rpm and an armature current of 15 A?

Solution:

Torque developed, $T_1 = 80$ Nm

Armature current, $I_{a1} = 30$ A

Armature current, $I_{a2} = 15$ A

Let the torque developed is T_2 Nm when the armature current is 15 A.

Now $$T \propto \phi I_a$$

When flux ϕ is constant, $T \propto I_a$

$\therefore$ $$\frac{T_2}{T_1} = \frac{I_{a2}}{I_{a1}}$$

or $$T_2 = \frac{I_{a2}}{I} \times T1 = \frac{15}{30} \times 80 = \mathbf{40\ Nm}\ (Ans.)$$

Power developed in the armature = $E_2 I_{a_2} = \omega_2 T_2$

where $$\omega_2 = \frac{2\pi N_2}{60} = \frac{2\pi \times 900}{60} = 30\pi$$

$\therefore$ $$\text{Induced emf} = E_2 = \frac{\omega_2 T_2}{I_{a_2}} = \frac{30\pi \times 40}{15} = \mathbf{251{\cdot}33\ V}\ (Ans.)$$

Example-3: The armature resistance of a 220 V DC generator is 0.4 ohm. It is delivering a load of 4 kW at rated terminal voltage. Now the machine is operated as a motor and draws the same armature current at the same terminal voltage. In this operation, if the flux per pole is increased by 10% what will be the ratio of speed from generator to motor.

Solution:

As a generator; $I_{a1} = I_L = \dfrac{4 \times 1000}{220} = 18.182$ A

$$E_g = V + I_{a1}R_a = 220 + 18.182 \times 0.4 = 227.27 \text{ V}$$

As a motor; $I_a = I_{a2} = 18.182$ A

$$E_b = V - I_{a2}R_a = 220 - 18.182 \times 0.4 = 212.73 \text{ V}$$

$$\phi_2 = 1.1\ \phi_1 \text{ (given)}$$

Now $N_1 \propto \dfrac{E_g}{\phi_1}$ and $N_2 \propto \dfrac{E_b}{\phi_2}$

$$\therefore \quad \frac{N_1}{N_2} = \frac{E_g}{\phi_1} \times \frac{\phi_2}{E_b} = \frac{227.27}{\phi_1} \times \frac{1.1\phi_1}{212.73} = \mathbf{1.175}\ (Ans.)$$

Example-4: A DC shunt motor runs at 1000 rpm on 220 V supply. Its armature and field resistances are 0.5 ohm and 110 ohm respectively and the total current taken from the supply is 26 A. It is desired to reduce the speed to 750 rpm keeping the armature and field currents same. What resistance should be inserted in the armature circuit?

Solution:

Shunt field current, $I_{sh} = \dfrac{V}{R_{sh}} = \dfrac{220}{110} = 2\text{A}$

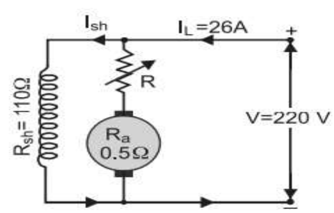
Armature current, $I_a = I_L - I_{sh} = 26 - 2 = 24$ A

When no resistance is connected in series with the armature,

Induced emf, $E_{b1} = V - I_a R_a = 220 - 24 \times 0.5 = 208$ V

Let the resistance connected in series with the armature be R ohm, to reduce the speed to 750 rpm

Then, induced emf, $E_{b2} = V - I_a(R_a + R) = 220 - 24\,(0{\cdot}5 + R) = (208 - 24\,R)$ V ...(*i*)



Now, we know that, $N \propto \dfrac{E_b}{\phi}$

Flux ϕ is constant because shunt field current remains the same.

$\therefore$ $N_1 \propto E_{b1}$ and $N_2 \propto E_{b2}$

Taking their ratio, $\dfrac{E_{b2}}{E_{b1}} = \dfrac{N_2}{N_1}$

or $E_{b2} = \dfrac{N_2}{N_1} \times E_{b1} = \dfrac{750}{1000} \times 208$

$= 156\text{V}$ ...(*ii*)

Equating eq. (*i*) and (*ii*), we get,

$$208 - 24\,R = 156 \quad \text{or} \quad R = \mathbf{2.167\Omega}\ (Ans)$$

Example-5: The field winding resistance and armature resistance of a 240 V DC shunt motor is 120 ohm and 0.1 ohm respectively. It draws 24 A at rated voltage to run at 1000 rpm. Find the value of additional resistance required in the armature circuit to reduce the speed to 800 rpm when (i) the load torque is proportional to speed (ii) the load torque varies as the square of the speed.

Solution:

At normal conditions; $I_{L1} = 24$ A and $N_1 = 1000$ rpm

$$\text{Shunt field current, } I_{sh} = \frac{V}{R_{sh}} = \frac{240}{120} = 2\text{A}$$

$$\text{Armature current, } I_{a1} = I_{L1} - I_{sh} = 24 - 2 = 22 \text{ A}$$

$$\text{Back emf, } E_{b1} = V - I_{a1}R_a = 240 - 22 \times 0.1 = 237.8 \text{ V}$$

(*i*) Let R be the additional resistance required to be connected in armature circuit to reduce the speed to 800 rpm when the load torque is proportional to speed, i.e., $T_1 \propto N_1$ and $T_2 \propto N_2$

$$\therefore \quad T_2 = T_1 \times \frac{N_2}{N_1} = T_1 \times \frac{800}{1000} = 0.8\, T_1$$

or $\quad I_{a2}\, \phi_2 = 0.8\, I_{a1}\phi_1$ (since $T \propto \phi I_a$)

or $\quad I_{a2} = 0.8 \times 22 = 17.6$ (since $\phi_2 = \phi_1$ = constant)

$$E_{b2} = V - I_{a2}\,(R_a + R) = 240 - 17.6\,(0.1 + R) = 238.24 - 17.6\,R$$

Since $\quad \dfrac{E_{b2}}{E_{b1}} = \dfrac{N_2}{N_1}$,

or $\quad \dfrac{238.24 - 17.6\,R}{237.8} = \dfrac{800}{1000}$

or $\quad 238.24 - 17.6R = 190.24$ or $\boldsymbol{R = 2.73\ \Omega}$ (*Ans.*)

(*ii*) Let R_1 be the additional resistance required in the armature circuit to reduce the speed to 800 rpm when the load torque varies as the square of the speed

$$T_3 = T_1 \times \left(\frac{N_2}{N_1}\right)^2 = T_1 \times \left(\frac{800}{1000}\right)^2 = 0.64\, T_1$$

or $\quad I_{a3}\, \phi_3 = 0.64\, I_{a1}\, \phi_1 \quad$ (since $T \propto \phi I_a$)

or $\quad I_{a3} = 0.64 \times 22 = 14.08$ A $\quad$ (since $\phi_3 = \phi_1$ = constant)

$$E_{b3} = V - I_a\,(R_1 + R_a) = 240 - 14.08\,(R_1 + 0.1) = 238.592 - 14.08\,R_1$$

Also, $\quad \dfrac{E_{b3}}{E_{b1}} = \dfrac{N_3}{N_1}$ or $\dfrac{238.592 - 14.08\,R_1}{237.8} = \dfrac{800}{1000}$

$238.592 - 14.08\,R_1 = 190.24$ or $R_1 = \mathbf{3.434}\ \Omega$ (*Ans.*)

Example-6: The field and armature resistance of a 500 V DC series motor is 0.2 ohm and 0.3 ohm respectively. The motor runs at 500 rpm when drawing a current of 49 A. If the load torque varies as the square of the speed, determine the value of the external resistance to be added in series with the armature for the motor to run at 450 rpm Assume linear magnetization.

Solution:

Here, $N_1 = 500$ rpm; $I_{a1} = 40$A; $V = 600$ V; $N_2 = 450$ rpm

$$T \propto N^2;\ R_a = 0.3\ \Omega;\ R_{se} = 0.2\ \Omega;\ \phi \propto I_a$$

$$E_{b1} = V - I_{a1}\,(R_a + R_{se}) = 600 - 40\,(0.3 + 0.2) = 580 \text{ V}$$

$$T \propto \phi I_a \text{ or } T \propto I_a^2$$

and $\quad T \propto N^2$

$\therefore \quad I_a^2 = N^2$

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

or $\quad I_{a2} = \dfrac{N_2}{N_1} \times I_{a1} = \dfrac{450}{500} \times 40 = 36$ A

Let R be the resistance added in series with the armature

$$E_{b2} = V - I_{a2}\,(R_a + R_{sc} + R) = 600 - 36\,(0.3^0 + 0.2 + R) = 582 - 36R$$

Now $\quad \dfrac{N_2}{N_1} = \dfrac{E_{b2}}{\phi_2} \times \dfrac{\phi_1}{E_{b1}}$ or $\dfrac{N_2}{N_1} = \dfrac{E_{b2}}{I_{a2}} \times \dfrac{I_{a1}}{E_{b1}}$

or $\quad \dfrac{450}{500} = \dfrac{(582 - 36R)}{36} \times \dfrac{40}{580}$

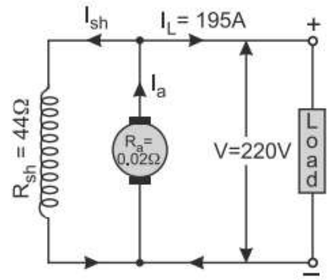
or $\quad 582 - 36R = \dfrac{450 \times 36 \times 580}{500 \times 40}$

or $\quad 582 - 36R = 469.8$ or $R = \mathbf{3.117}\ \Omega$ (*Ans.*)

Example-7: A shunt generator supplies 195 A at 220 V. Armature resistance is 0.02-ohm, shunt field resistance is 44 ohms. If the iron and friction losses amount to 1600 watts, find (i) emf generated; (ii) copper losses; (iii) b.h.p. of the engine driving the generator. (iv) commercial, mechanical and electrical efficiency.

Solution:

The conventional circuit is shown in Fig. 5.54.



Shunt field current, $I_{sh} = \dfrac{V}{R_{sh}} = \dfrac{220}{44} = 5A$

Armature current, $I_a = I_L + I_{sh} = 195 + 5 = 200$ A

(*i*) Generated or induced emf, $E = V + I_a R_a$

$= 220 + 200 \times 0{\cdot}02$

$= \mathbf{224\ V}$ (*Ans.*)

Armature copper loss $= i_a^2 R_a = (200)^2 \times 0 \cdot 02 = 800$ W

Shunt field copper loss $= I_{sh}^2 R_{Sh} = (5)^2 \times 44 = 1100W$

(*ii*) Total copper losses = 800 + 1100 = **1900 W** (*Ans.*)

Output power $= V I_L = 220 \times 195 = 42900$ W

Input power = 42900 + 1600 + 1900 = 46400 W

(*iii*) B.H.P. of the engine driving the generator $= \dfrac{46400}{735 \cdot 5} = \mathbf{63{\cdot}08\ H.P.}$ (*Ans.*)

(*iv*) Commercial efficiency, $\eta = \dfrac{\text{final output of machine}}{\text{input to machine}}$

$= \dfrac{42900}{46400} \times 100 = \mathbf{92.45\%}$ (*Ans.*)

Mechanical efficiency, $\eta_m = \dfrac{\text{Power developed in armature}}{\text{Power input}}$

$= \dfrac{E_g I_a}{46400} \times 100 = \dfrac{224 \times 200}{46400} \times 100 = \mathbf{96.55\%}$ (*Ans.*)

Electrical efficiency, $\eta_e = \dfrac{\text{Electrical Power output}}{\text{Power generated in armature}}$

$= \dfrac{VI_L}{E_g I_a} \times 100 = \dfrac{220 \times 195}{224 \times 200} \times 100 = \mathbf{95.76\%}$ (*Ans.*)

Alternatively, commercial efficiency,

$\eta = \eta_m \times \eta_e$

$= \dfrac{96.55}{100} \times \dfrac{95.76}{100} \times 100 = 92.45\%$ (*True as above*)

1. A 230 V dc shunt motor has an armature resistance of 0.4 Ω and field resistance of 115 Ω. This motor drives a constant torque load and takes an armature current of 20 A at 800 rpm. If the motor speed is to be raised from 800 to 1000 rpm, find the resistance that must be inserted in the shunt field circuit. Assume magnetization curve to be a straight line.

Solution. At 800 rpm, $T_{e1} \propto \phi_1 I_{a1}$

At 1000 rpm, $T_{e2} \propto \phi_2 I_{a2}$

$$\therefore \quad \frac{T_{e1}}{T_{e2}} = 1 = \frac{\phi_1 \times 20}{\phi_2 I_{a2}}$$

$$\therefore \quad I_{a2} = 20 \frac{\phi_1}{\phi_2} = 20\,k$$

where $k = \dfrac{\phi_1}{\phi_2}$

At 800 rpm, $E_{a1} = 230 - 20 \times 0.4 = 222$ V.

At 1000 rpm, $E_{a2} = 230 - 20\,k \times 0.4 = 230 - 8\,k$

Now $\dfrac{E_{a1}}{E_{a2}} = \dfrac{N_1 \phi_1}{N_2 \phi_2}$

$$\therefore \quad \frac{222}{230 - 8k} = \frac{800 \times \phi_1}{1000 \times \phi_2} = 0.8\,k$$

or $222 = 230 \times 0.8\,k - 6.4\,k^2$

or $k^2 - 28.75\,k + 34.69 = 0$

$$\therefore \quad k = \frac{28.75 \pm \sqrt{826.5625 - 138.76}}{2} = 27.49 \text{ or } 1.26$$

Higher value of 27.49 is not feasible.

$$\therefore \quad k = \frac{\phi_1}{\phi_2} = 1.26$$

Since magnetization curve is linear,

$$\frac{\phi_1}{\phi_2} = \frac{I_{f1}}{I_{f2}} = 1.26$$

But $I_{f1} = \dfrac{230}{115} = 2$ A

$$\therefore \quad I_{f2} = \frac{2}{1.26} = 1.587 \text{ A}$$

New shunt-field circuit resistance

$$= \frac{V_t}{I_{f2}} = \frac{230}{1.587} = 144.93\ \Omega$$

External resistance that must be inserted in shunt-field circuit

$$= 144.93 - 115 = 29.93\ \Omega.$$

2. A dc series motor running a friction load at 1000 rpm, takes 40 A from 240 V supply mains. Its field resistance is 0.2 Ω and that of armature is 0.25 Ω. If a diverter of 0.3 Ω is put in parallel with series field winding, find the motor speed. Assume that the field flux to be proportional to the field current.

Solution. Note that the torque required by a friction load (*e.g.*, a reciprocating pump) at different speeds remains constant.

Now electromagnetic torque $T_e \propto \phi I_a$.

Since ϕ has been assumed proportional to I_a,

$$T_e \propto I_a^2.$$

$$\therefore \quad T_{e1} \propto (40)^2.$$

With a diverter in parallel with the field winding, the field current is reduced. Therefore, if new armature current is I_{a2}, then only a part of it passes through the series field. Thus the new field current is given by

$$I_{a2} \frac{R_{div}}{R_{div} + r_s} = I_{a2} \frac{0.3}{0.3 + 0.2} = 0.6\,I_{a2}.$$

New value of field flux $\phi_2 \propto (0.6 I_{a2})$

Thus
$$\begin{aligned} T_{e2} &\propto (\phi_2)\, I_{a2} \\ &\propto (0.6\, I_{a2})\, I_{a2} \\ &\propto 0.6\, I_{a2}^2 \end{aligned}$$

$$\therefore \quad \frac{T_{e2}}{T_{e1}} = 1 = \frac{0.6\, I_{a2}^2}{(40)^2}$$

or $I_{a2} = \sqrt{\dfrac{1600}{0.6}} = 51.6$ A.

Now
$$\begin{aligned} E_{a1} &= V_t - I_{a1}\,(r_a + r_s) \\ &= 240 - 40\,(0.25 + 0.2) = 222 \text{ V}. \end{aligned}$$

When diverter is put in parallel with r_s, then

$$E_{a2} = V_t - I_{a2}\left[r_a + \frac{r_s \cdot R_{div}}{r_s + R_{div}}\right]$$

$$= 240 - 51.6\left[0.25 + \frac{(0.2)\,(0.3)}{0.5}\right] = 220.9\text{ V}$$

But $$\frac{E_{a2}}{E_{a1}} = \frac{n_2\Phi_2}{n_1\Phi_1}$$

$\therefore$ $$\frac{220.9}{222} = \frac{n_2\,(0.6 \times 51.6)}{(1000)\,(40)}$$

$\therefore$ $$n_2 = 1285\text{ r.p.m.}$$

3. A 200V shunt motor takes 10A when running on no-load. At higher loads the brush drop is 2V and at light load it is negligible. The stray load loss at a line current of 100 V is 50% of the no-load loss. Calculate the efficiency at a line current of 100A if armature and field resistance are 0.2 ohm and 100 ohm respectively.

Solution:

Here, $V = 200$ V; $I_{L0} = 10$ A; $V_{bf} = 2$V; $V_{b0} = 0$ V

Stray load loss = 50% of no-load loss; $R_a = 0.2\ \Omega$; $R_{sh} = 100\ \Omega$

$$\text{Input at no-load} = V \times I_{L0} = 200 \times 10 = 2000\text{ W}$$

$$I_{sh} = \frac{V}{R_{sh}} = \frac{200}{100} = 2\text{A}$$

$$\text{Shunt field Cu loss} = I_{sh}^2 R_{sh} = (2)^2 \times 100 = 400\text{ W}$$

$$\text{Stray loss} = \frac{50}{100} \times 2000 = 1000\text{ W}$$

At load, armature current, $$I_a = I_L - I_{sh} = 100 - 2 = 98\text{ A}$$

$$\text{Armature copper loss} = I_a^2\ R_a = (98)^2 \times 0.2 = 1920.8\text{ W}$$

$$\text{Loss at brushes} = V_{bf} \times I_a = 2 \times 98 = 196\text{ W}$$

Total losses = Stray loss + Armature Cu loss + Shunt field Cu los + Brush contact

$$= 1000 + 1920.8 + 400 + 196 = 3516.8\text{ W}$$

$$\text{Input to motor} = V \times I_L = 200 \times 100 = 20000\text{ W}$$

$$\text{Motor efficiency, } \eta = \frac{\text{output}}{\text{input}} = \frac{\text{Input} - \text{Losses}}{\text{Input}} \times 100$$

$$= \frac{20000 - 3516.8}{20000} \times 100 = \mathbf{82.416\%}\ (Ans.)$$

4. A 250 V, 15 kW, shunt motor has a maximum efficiency of 80% and a speed of 700 rpm, when delivering 80% of its rated output. The resistance of the shunt field is 100 Ω. Determine the efficiency and speed when the motor draws a current of 78 A from the mains.

Solution. Rated output = 15 kW

$$\text{Efficiency } \eta = \frac{\text{Output}}{\text{Output + Losses}}$$

or $$\text{Total losses} = \left(\frac{1}{\eta} - 1\right)\text{Output}$$

$$= \left(\frac{1}{0.88} - 1\right) \times 0.8 \times 15{,}000 = 1636\text{ W.}$$

At maximum efficiency,

Constant losses = (Rotational losses + Shunt field losses)

= Variable armature circuit losses $I_a^2\, r_a$

$$= \frac{1636}{2} = 818\text{ W.}$$

$\therefore$ Input to motor at maximum efficiency

$$= 0.8 \times 15000 + 1636 = 13636\text{ W.}$$

Input line current $\quad I_{L1} = \dfrac{13{,}636}{250} = 54.6 \text{ A}$

$\therefore$ Armature current $\quad I_{a1} = 54.6 - \dfrac{250}{100} = 52.1 \text{ A}$

But $\quad I_{a1}^2 r_a = (52.1)^2 \times r_a = 818 \text{ W}$

$\therefore$ Armature circuit resistance,

$$r_a = \frac{818}{(52.1)^2} = 0.301\ \Omega.$$

Now motor input current,

$$I_{L2} = 78 \text{ A}$$

$\therefore \quad I_{a2} = 78 - 2.5 = 75.5 \text{ A}.$

Now $\quad I_{a2}^2 r_a$ loss $= (75.5)^2 \times 0.301 = 1718 \text{ W}$

Total power input $\quad = 78 \times 250 = 19{,}500 \text{ W}$

Total losses $\quad = 1718 + 818 = 2536 \text{ W}$

$\therefore$ Motor efficiency for a line current of 78 A is

$$= \left(1 - \frac{2536}{19{,}500}\right) \times 100 = 87\%.$$

Now counter e.m.f. $\quad E_{a1} = V_t - I_{a1} r_a = 250 - 52.1 \times 0.301 = 234.32 \text{ V}$

$$E_{a2} = 250 - 75.5 \times 0.301 = 227.28 \text{ V}$$

But $\quad \dfrac{E_{a1}}{E_{a2}} = \dfrac{234.32}{227.28} = \dfrac{n_1 \phi_1}{n_2 \phi_2} = \dfrac{700 \times \phi_1}{n_2 \times \phi_2}$

For constant field current $\phi_1 = \phi_2$

$\therefore \quad n_2 = \dfrac{700 \times 227.28}{234.32} = 678 \text{ r.p.m.}$

5. In a brake test on a DC shunt motor, the load on the tight side of the brake band was 32 kg and the other side 2 kg. The motor was running at 1200 rpm, its input being 65 A at 400 V DC. The pulley diameter is 1 m. Determine the torque, output of the motor and efficiency of the motor.

Solution:

Effective force, $F = 32 - 2 = 30$ kg

Pulley radius, $r = \dfrac{1.0}{2} = 0.5$ m

Torque exerted, $T = F \times r = 30 \times 0.5 = 15$ kg-m or $15 \times 9.81 =$ **147.15 Nm** (*Ans.*)

Motor output $= T \times \dfrac{2\pi N}{60} = \dfrac{147.15 \times 2\pi \times 1200}{60} =$ **18499 W** (*Ans.*)

Input power to motor $= V \times I = 400 \times 65 = 26000$

Motor efficiency, $\eta = \dfrac{\text{Output}}{\text{Input}} \times 100 = 71.15\%$ (*Ans.*)

6. A 50 kW, 250 V long shunt compound motor takes a current of 9A while running on no-load at rated voltage and speed. The shunt field current is 5A. The resistances of the windings when hot are: Armature 0.1 Ω, series field 0.07 Ω and interpole 0.03 Ω. The brush drop is 2V. Determine motor output and the efficiency when the motor intake is 155 A.

Solution:

At No-load; $I_{L0} = 9\text{A}$; $I_{sh} = 5\text{A}$

Input at no-load $= I_{L0} \times V = 9 \times 250 = 2250$ W

Armature current, $I_{a0} = I_{L0} - I_{sh} = 9 - 5 = 4\text{A}$

Considering the machine as long-shunt;

Variable losses = Copper losses in armature circuit and at brushes

$= I_{a0}^2\ (R_a + R_{se} + R_i) + I_{a0} \times$ brush drop

$= 4^2\ (0.1 + 0.07 + 0.03) + 4 \times 2 = 11.2$ W

Constant losses, P_C = Input at no-load – variable losses

$= 2250 - 11.2 = 2238.8$ W

At full-load; Line current, $I_{Lf} = 155$ A

$$\text{Power input} = I_{L1} \times V = 155 \times 250 = 38750 \text{ W}$$

$$\text{Armature current, } I_{af} = I_{Lf} - I_{sh} = 155 - 5 = 150 \text{ A}$$

$$\text{Variable losses} = I_{af}^2 (R_a + R_{se} + R_1) + I_{af} \times \text{brush drop}$$

$$= 150^2 (0.1 + 0.07 + 0.03) + 150 \times 2 = 4800 \text{ W}$$

$$\text{Total losses} = P_C + \text{variable losses} = 2238.8 + 4800 = 7038.8 \text{ W}$$

$$\text{Motor output, } P_{out} = P_{in} - \text{total losses}$$

$$= 38750 - 7038.8 = 31711.2 \text{ W or } \mathbf{31.7\ kW}\ (Ans.)$$

$$\text{Motor efficiency, } \eta = \frac{P_{out}}{P_{in}} \times 100 = \frac{31711.2}{38750} \times 100 = \mathbf{81.84\%}\ (Ans.)$$

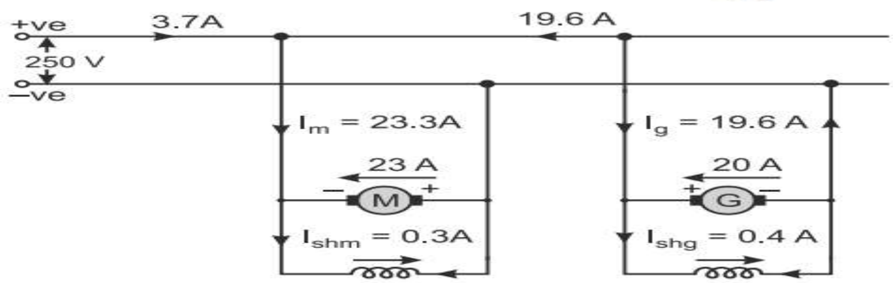
7. The results of Hopkinson's test on two similar DC machines are as follows: Line voltage 250 V, Motor armature current 23A, Generator armature current 20A, Generator field current 0.4 A. Motor armature current 0.3 A. Armature resistance of each machine 0.5 Ω. Calculate the efficiency of each machine.

Solution:

$$\text{Supply voltage, } V = 250 \text{ V}$$

$$\text{Generator armature current, } I_{og} = 20 \text{ A}$$

$$\text{Generator shunt field current, } I_{shg} = 0.4 \text{ A}$$



Circuit diagram

$$\text{Generator output current, } I_g = I_{ag} - I_{shg} = 20 - 0.4 = 19.6 \text{ A}$$

$$\text{Motor armature current, } I_{am} = 23 \text{ A}$$

$$\text{Motor shunt field current, } I_{shg} = 0.3 \text{ A}$$

$$\text{Motor input current, } I_m = 23.3 \text{ A}$$

$$\text{Input line current, } I_L = \text{Motor input current} - \text{generator output current}$$

$$= 23.3 - 19.6 = 3.7 \text{ A}$$

$$\text{Input power to set} = VI_L = 250 \times 3.7 = 925 \text{ W}$$

$$\text{Motor armature copper loss} = (I_{am})^2 R_{am} = (23)^2 \times 0.5 = 264.5 \text{ W}$$

$$\text{Generator armature copper loss} = (I_{ag})^2 R_{ag} = (20)^2 \times 0.5 = 200 \text{ W}$$

$$\text{Motor shunt field copper loss} = VI_{shm} = 250 \times 0.3 = 75 \text{ W}$$

$$\text{Generator shunt field copper loss} = VI_{shg} = 250 \times 0.4 = 100 \text{ W}$$

$$\text{Total copper loss} = 264.5 + 200 + 75 + 100 = 639.5 \text{ W}$$

$$\text{Total stray power loss, } P_S = \text{Input to machines} - \text{total copper loss}$$

$$= 925 - 639.5 = 285.5 \text{ W}$$

$$\text{Stray power loss per machine} = \frac{P_S}{2} = \frac{285.5}{2} = 142.75 \text{ W}$$

$$\text{Input to motor} = VI_m = 250 \times 23.3 = 5825 \text{ W}$$

$$\text{Total losses in motor} = \text{Armature loss} + \text{field loss} + \text{stray power loss}$$

$$= 264.5 + 75 + 142.75 = 482.25 \text{ W}$$

$$\text{Motor efficiency, } \eta_m = \frac{\text{Input} - \text{Total losses}}{\text{Input}} \times 100 = \frac{5825 - 482.25}{5825} \times 100$$

$$= 91.72\%\ (Ans.)$$

$$\text{Generator output} = VI_g = 250 \times 19.6 = 4900 \text{ W}$$

$$\text{Total losses in generator} = \text{Armature loss} + \text{field loss} + \text{stray power loss}$$

$$= 200 + 100 + 142.75 = 442.75 \text{ W}$$

$$\text{Generator efficiency, } \eta_g = \frac{\text{Output}}{\text{Output} + \text{Total losses}} \times 100$$

$$= \frac{4900}{4900 + 442.75} \times 100 = 91.72\%\ (Ans.)$$