Problem -2

Given Data

Motor Rating

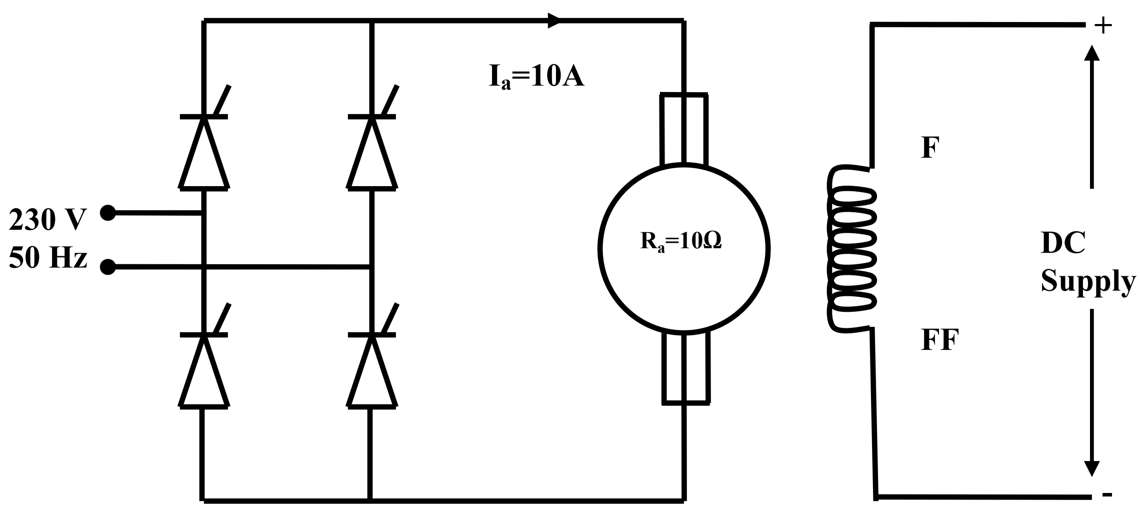
V=200 Volts

N = 1500 rpm

I_a = 10 A

R_a= 10 Ω

Source Voltage V_s=230 volts



Under operating Conditions of separately excited DC motor

$$V_a = E_b + I_a R_a$$
$$V_a = K_b \varphi \omega_m + I_a R_a$$
$$\text{Let } K_b \varphi = K_m$$

$$\therefore V_a = K_m \omega_m + I_a R_a$$
$$220 = K_m \left[\frac{2\pi \, x \, 1500}{60}\right] + (10x10)$$
$$K_m = K_b \varphi = 0.7639 \text{ Volts Seconds/Radians}$$

i. For a torque of 5 Nm, motor armature current is

$$T = K_m I_a$$
$$I_a = \frac{T}{K_m} = \frac{5}{0.7639} = 6.545 A$$

The equation giving the operation of converter motor is

$$V_a = E_b + I_a R_a = \frac{2V_m}{\pi}\cos\alpha$$

$$\frac{2V_m}{\pi}\cos\alpha = K_m\omega_m + I_a R_a$$

$$\frac{2x\sqrt{2}\ x\ 230}{\pi}\cos\alpha = K_m\omega_m + I_a R_a$$

$$\frac{2x\sqrt{2}\ x\ 230}{\pi}\cos 30^o = 0.7639\ x\ \omega_m + 6.545\ x\ 10$$

$$179.33 = 0.7639\ x\ \omega_{\mathrm{m}} + 65.45$$

$$\omega_m = 149.07 rad/\sec$$

$$\text{Motor Speed in RPM} = \text{N} = \frac{149.07\ x\ 60}{2\pi}$$

N= 1423.58 rpm

ii. For $\alpha = 45^0$

$$\frac{2V_m}{\pi}\cos\alpha = K_m\omega_m + I_a R_a$$

$$\frac{2\ \text{x}\ \sqrt{2}\ \text{x}\ 230}{\pi}\cos\alpha = 0.7639\ \text{x}\ \frac{2\pi\ \text{x}\ 1000}{60} + (I_a\ \text{x}\ 10)$$

$$146.4 = 79.99 + 10I_a$$

I_a=6.641 Amps

Motor developed torque

$$\text{T} = \text{K}_\text{m}\text{I}_\text{a} = 0.7639\ \text{x}\ 6.641$$

T= 5.07 Nm

Problem 3

The input current to the motor at rated conditions

$$= \frac{10x10^3}{0.87} = 11.494x10^3 W$$

The supply current to the motor is

$$= \frac{11.494x10^3}{240} = 47.89A$$

Neglecting the field copper loss the armature current = 47.89A

The back EMF at the rated conditions is

$$= 240 - 47.89x0.4 = 220.843 Volts$$

At $\alpha = 0$, the converter voltage is

$$V_a = \frac{2V_m}{\pi}\cos\alpha = \frac{2x\sqrt{2}x250}{\pi}\cos 0^0 = 225 Volts$$

As the load torque is constant the armature current is same. Therefore the back EMF is

$$= 225 - 47.89x0.4 = 200.844 Volts$$

We know that $E_b = K\omega$

$$\omega = \frac{1000x2\pi}{60} = 104.719 rad/\sec$$

$$\therefore K = \frac{E_b}{\omega} = \frac{220.844}{104.719} = 2.11 Volts.\sec/rad$$

At $\alpha = 0^0$

$$\text{Speed} = \frac{E_b}{K} = \frac{200.844}{2.108} = 95.235 rad/\sec$$

$$\text{N} = \frac{95.235x60}{2\pi} = 909.43 RPM$$

Displacement factor DF = $Cos\varphi = \cos 0^0 = 1$

Power Factor PF = $\frac{2x\sqrt{2}}{\pi}\cos\alpha = \frac{2x\sqrt{2}}{\pi}\cos 0^0 = 0.9$

Input = 225 x 47.89 = 10775.25 W

Output varies linearly with speed

$$\therefore output \text{ at 909.4 rpm} = 10\text{kw}_{\text{(rated)}} x \frac{909.4}{1000} = 9.094 KW$$

$$\therefore \eta = \frac{O/P}{i/p} = \frac{9.094}{10.7752} = 84.4\%$$

At $\alpha = 60$, the converter voltage is

$$V_a = \frac{2V_m}{\pi}\cos\alpha = \frac{2x\sqrt{2}x250}{\pi}\cos 60^0 = 112.5 Volts$$

As the load torque is constant the armature current is same. Therefore the back EMF is

$$= 112.5 - 47.89x0.4 = 93.344Volts$$

We know that $E_b = K\omega$

$$\omega = \frac{1000x2\pi}{60} = 104.719 rad/\sec$$

$$\therefore K = \frac{E_b}{\omega} = \frac{220.844}{104.719} = 2.11Volts.\sec/rad$$

At $\alpha = 60^0$

$$\text{Speed} = \frac{E_b}{K} = \frac{93.344}{2.108} = 44.28 rad/\sec$$

$$\text{N}=\frac{44.28x60}{2\pi} = 422.8RPM$$

Displacement factor DF = $Cos\varphi = \cos 60^0 = 0.5$

Power Factor PF = $\frac{2x\sqrt{2}}{\pi}\cos\alpha = \frac{2x\sqrt{2}}{\pi}\cos 60^0 = 0.45$

Input = 112.5 x 47.89 = 5.387 KW

Output varies linearly with speed

$$\therefore output \text{ at } 909.4 \text{ rpm} = 10\text{kw}_{\text{(rated)}} x \frac{422.8}{1000} = 4.227KW$$

$$\therefore \eta = \frac{O/P}{i/p} = \frac{4.227}{5.387} = 78.46\%$$

Problem 4

At rated Conditions

$$E_{b1} = V - I_a R_a = 200 - 150x0.06 = 191Volts$$

$$N_1 = 875rpm$$

$$\omega_1 = \frac{875x2\pi}{60} = 91.629 rad/\sec$$

We know that

$$E_{b1} = K\omega_1$$
$$\therefore K = \frac{191}{91.629} = 2.08 volts.\sec/rad$$

I. E_{b2} at 750 rpm

$$\omega_2 = \frac{750x2\pi}{60} = 78.54 rad/\sec$$
$$\therefore E_{b2} = 2.08x78.54 = 163.37 volts$$
$$\therefore V_a = E_{b2} + I_a R_a = 163.37 + (150x0.06) = 172.7 Volts$$

We know that

$$V_a = \frac{2V_m}{\pi}\cos\alpha$$
$$172.7 = \frac{2x\sqrt{2}x220}{\pi}\cos\alpha$$
$$\alpha = 29.3^0$$

II. At $\alpha = 160^0$ N =? at rated torque

$$V_a = \frac{2V_m}{\pi}\cos\alpha = \frac{2x\sqrt{2}x220}{\pi}\cos 160^0 = -186.12 Volts$$

We know that $V_a = E_b + I_a R_a$

$$-186.12 = E_b + (150x0.06)$$
$$E_b = -195.12 Volts$$
$$\therefore \omega = \frac{-195.12}{2.08} = -93.81$$
$$N = \frac{-93.81x60}{2\pi} = -895.79 rpm$$

Problem 5

For 3 phase controlled rectifier the average output voltage is given by

$$V_a = \frac{3V_m}{\pi}\cos\alpha$$

Given that V_a =220 Volts

$$\therefore 220 = \frac{3V_m}{\pi}\cos 0^o$$
$$\Rightarrow V_m = 230.4 Volts$$

<u>At 1500 rpm</u>

$$E_{b1} = V_a - I_a R_a = 220 - (10x0.5) = 215 volts$$

We know that

$$\therefore E_{b1} = K\omega_1$$

$$\omega_1 = \frac{1500x2\pi}{60} = 157.08$$

$$K = \frac{215}{157.08} = 1.37 volt.\sec/ rad$$

<u>At 1200 rpm</u>

$$\therefore E_{b2} = K\omega_2$$

$$\omega_2 = \frac{1200x2\pi}{60} = 125.66 rad / \sec$$

$$K = 1.37 volt.\sec/ rad$$

$$E_{b2} = 1.37x125.66 = 172.2 Volts$$

Average output voltage is

$$V_a = E_{b2} + I_a R_a = 172.2 + (10x0.5) = 177 Volts$$

$$\because V_a = \frac{3V_m}{\pi} Cos\alpha$$

$$\Rightarrow Cos\alpha = \frac{V_a \pi}{3V_m} = \frac{177x\pi}{3x230.4} = 0.8$$

$$\Rightarrow \alpha = 36.4^0$$

At -800 rpm, α **= ? T = 2 x** $\mathbf{I_{rated}}$

$$\omega = \frac{-800x2\pi}{60} = -83.77 rad / \sec$$

$$\therefore E_b = 1.37x - 83.77 = 114.77 volts$$

$$Current = 2xRated = 20A$$

$$\therefore V_a = E_b + I_a R_a = -114.77 + (20x0.5) = -104.77 Volts$$

$$V_a = \frac{3V_m}{\pi} Cos\alpha$$

$$-104.77 = \frac{3x230.4}{\pi} x \cos\alpha$$

$$Cos\alpha = \frac{-104.67x\pi}{3x230.4} = -0.475$$

$$\Rightarrow \alpha = 118.4^0$$