Tutorial –II

Chopper Fed DC drives

Problem -1

Given Data:

V_s=120 volts, R_a=0.5 ohms, L_a=20mH, K=0.05 V/RPM. I_a=20A

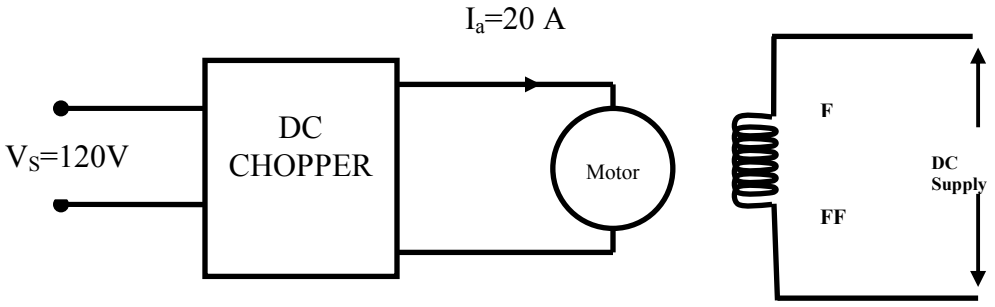
Constant Load, Separately excited DC motor

Find

- ✓ The range of Speed Control
- ✓ The range of duty cycle

Assume Continuous current mode

Solution



(i) Range of Duty cycle

Average output voltage of the motor

$$V_a = E_b + I_a R_a$$

$$\alpha V_s = E_b + I_a R_a \quad \begin{bmatrix} \because V_a = \alpha V_s \\ E_b = KN \end{bmatrix}$$

$$\alpha V_s = KN + I_a R_a$$

As motor drives a constant load, T is constant and I_a is 20A and minimum possible speed is **ZERO**

$$\alpha x 120 = (0.05)x0 + (20x0.05)$$

$$120\alpha = 10$$

$$\alpha = \frac{10}{120} = 0.08$$

Maximum possible speed corresponds to $\alpha = 1$, i.e. when 120 volts is directly applied to the motor. Therefore the range of duty cycle is

$$0.08 \le \alpha \le 1$$

(ii) The range of Speed

$\alpha V_s = KN + I_a R_a$

Minimum speed N=0

Maximum speed at $\alpha = 1$

$$1x120 = 0.05xN + (20x0.5)$$
$$120 = 0.05N + 10$$
$$N = \frac{120 - 10}{0.05} = 2200rpm$$

The range of speed control is $0 \le N \le 2200RPM$

Problem-6

Given Data:

V_s=220 volts, R_a=0.2 ohms, L_a=20mH, K=0.08 V/RPM. I_a=25A

Constant Load, Separately excited DC motor

Find

- ✓ The range of Speed Control
- ✓ The range of duty cycle

Assume Continuous current mode

Solution

(i) Range of Duty cycle

Average output voltage of the motor

$$V_a = E_b + I_a R_a$$
$$\alpha V_s = E_b + I_a R_a \quad \begin{bmatrix} \because V_a = \alpha V_s \\ E_b = KN \end{bmatrix}$$
$$\alpha V_s = KN + I_a R_a$$

As motor drives a constant load, T is constant and I_a is 25A and minimum possible speed is **ZERO**

$$\alpha x220 = (0.08)x0 + (25x0.2)$$
$$220\alpha = 10$$
$$\alpha = \frac{10}{220} = 0.04$$

Maximum possible speed corresponds to $\alpha = 1$, i.e. when 120 volts is directly applied to the motor. Therefore the range of duty cycle is

$$0.04 \le \alpha \le 1$$

(ii) The range of Speed

$\alpha V_s = KN + I_a R_a$

Minimum speed N=0

Maximum speed at $\alpha = 1$

$$1x220 = 0.08xN + (25x0.2)$$
$$220 = 0.08N + 5$$
$$N = \frac{220 - 5}{0.08} = 2687.5rpm$$

The range of speed control is $0 \le N \le 2687.5RPM$

Problem -2

Given Data

V_s=230 volts, N=960 rpm, I_a=200 amps, R_a=0.02 ohms separately excited DC motor, chopper drive for both motoring and braking operation, Assume continuous conduction

Find

(i) $\alpha = ?$ at rated Torque and Speed =350rpm.

(ii) If $\alpha = 0.95$ and current is twice rated calculate speed

Solution

(i) At rated operation

$E_1 = V_a - I_a R_a$

$\Rightarrow 230 - (200x0.02) = 226volts$

E at 350 rpm (ie) $E_2 = ?$

From rated condition

$$E_1 = K\omega_1$$
$$220 = Kx\omega_1$$
$$\omega_1 = \frac{960x2\pi}{60} = 100.53 rad/\sec$$
$$\therefore K = \frac{226}{100.53} = 2.24 Volts.\sec/rad$$

E_2 at 350 rpm is given by

$$\omega_2 = \frac{350x2\pi}{60} = 36.651$$
$$\therefore E_2 = 36.65x2.24 = 82.1 Volts$$

Motor terminal voltage at 350 rpm is

$$V_{350rpm} = 82.1 + (200x0.02) = 86.1 Volts$$
$$\alpha = \frac{V_{350\,\text{rpm}}}{V_{960\,\text{rpm}}} = \frac{86.1}{230} = 0.37$$

(ii) Maximum available

$$V_a = \alpha V_s$$
$$= 0.95\text{x}230 = 218.5 \text{ Volts}$$
$$\therefore E = V_a + I_a R_a = 218.5 + (200x0.02) = 222.5 Volts$$

Speed at 222.5 volts E_b is

$$E_b = K\omega$$
$$\omega = \frac{222.5}{2.24} = 99.330 rad/\sec$$
$$N = \frac{99.330x60}{2\pi} = 948.53 rpm$$

Problem -5

Given Data

V_s=230 volts, N=1100 rpm, I_a=220 amps, R_a=0.02 ohms separately excited DC motor, chopper drive for both motoring and braking operation, Assume continuous conduction

Find

(i) $\alpha = ?$ at rated Torque and Speed =400rpm.

(ii) If $\alpha = 0.9$ and current is twice rated calculate speed

Solution

(i) At rated operation

$$E_1 = V_a - I_a R_a$$
$$\Rightarrow 230 - (220x0.02) = 225.6volts$$
$$E \text{ at } 400 \text{ rpm (ie) } E_2 = ?$$

From rated condition

$$E_1 = K\omega_1$$
$$\omega_1 = \frac{1110x2\pi}{60} = 115.192rad/\sec$$
$$\therefore K = \frac{225.6}{115.192} = 1.95Volts.\sec/rad$$

E_2 at 400 rpm is given by

$$\omega_2 = \frac{400x2\pi}{60} = 41.887rad/\sec$$
$$\therefore E_2 = 41.887x1.95 = 81.68Volts$$

Motor terminal voltage at 400 rpm is

$$V_{400rpm} = 81.68 + (220x0.02) = 86.1Volts$$
$$\alpha = \frac{V_{400\,\text{rpm}}}{V_{1100\,\text{rpm}}} = \frac{86.1}{230} = 0.37$$

(ii) Maximum available

$$V_a = \alpha V_s$$
$$= 0.9\text{x}230 = 207 \text{ Volts}$$
$$\therefore E = V_a + I_a R_a = 207 + (2x220x0.02) = 215.8Volts$$

Speed at 222.5 volts E_b is

$$E_b = K\omega$$
$$\omega = \frac{215.8}{1.95} = 110.667rad/\sec$$
$$N = \frac{110.667x60}{2\pi} = 1056.78rpm$$

Problem-4

Given Data

V_s=600 volts, I_a=300 amps, R_a=0.04 ohms, R_f=0.06 ohms, K= $4x10^{-3}\,Nm/amp^2$ $\delta = 0.6$

DC SERIES motor.

Solution

a. Power input to the motor = P = $V_a I_a$

$$V_a = \delta V_s = 0.6x600 = 360Volts$$
$$\therefore P = 360x300 = 108KW$$

b. For a DC series motor

$$E_a = K_a \phi \omega_m$$
$$= \mathrm{KI_a}\omega_m \left[\because \phi = I_a\right]$$
$$= 4x10^{-3}x300x\omega_m$$
$$\therefore V_a = E + I_a\left(R_a + R_s\right) = KI_a\omega_m + I_a\left(R_a + R_s\right)$$
$$\Rightarrow 0.6x600 = 4x10^{-3}x300x\omega_m + 300\left(0.04 + 0.06\right)$$
$$\omega_m = \frac{360 - 30}{1.2} = 27.5rad/\sec(or)2626rpm$$
$$Motor\ \text{Torque T} = \mathrm{Ka}\phi\mathrm{I_a} = KI_a^{\,2}$$
$$= 4\mathrm{x}10^{-3}x300^2$$
$$= 360\ \mathrm{N\text{-}M}$$