Problem Set 4 Power Converters

1. A 110 V, 5 hp DC motor is controlled by a single-phase AC/DC full converter. The motor voltage constant is 0.055 V/rpm. The AC supply is 120 V, 60 Hz. Assume the DC motor and converter are ideal and a very large inductance is connected in series with the motor. For a speed of 1000 rpm and rated motor current, find

   a. The firing angle of the converter.

   b. The rms value of the supply current

   c. The rms value of thyristor current.

2. A three-phase full converter is used to control the speed of a DC motor. The motor consists of voltage constant of 0.1 V/rpm and armature resistance of 0.2 Ω. The supply line-to-line voltage is 110 V. For firing angle of 50°, the motor speed is 900 rpm.

   a. Assume the motor current is ripple-free, find the average value of the motor current.

   b. Find the thyristor current.

   c. Find the supply line current.

3. A single-phase AC/DC full converter is used to control a DC motor with resistance of 0.25 Ω, motor constant of 0.1 V/rpm and very large inductance. The AC supply is 120 V, 60 Hz. At firing angle of 60°, the motor current is continuous with average value of 20 A and ripple of 20 %. Find

   a. The speed of the motor.

   b. The power loss in armature resistance.

   c. The power developed by the motor.

4. A one-quadrant step-down converter with switching frequency of 250 Hz is used to control the speed of a DC motor with resistance of 0.15 Ω and motor constant of 0.05 V/rpm. The supply DC voltage is 120 V. At a speed of 1200 rpm, the motor draws current of 125 A. Assume the motor current is ripple-free.

   a. Find the duty ratio of the converter and its on-time.

   b. Draw waveform of output voltage, output current and supply current.

   c. Find the developed torque by the armature.

   d. Find the power taken by the motor.

   e. Find the power drawn from the supply.

Answer

1.

(a)

$$V_O = 0.055 \times 1000 = 55V$$

$$I_O = \frac{5 \times 746}{110} = 33.9A$$

$$V_O = \frac{2\sqrt{2} \cdot V}{\pi} \cos\alpha = 108.02 \cos\alpha = 55V$$

$$\alpha = 60^o$$

(b)

$$I = I_O = 33.9A$$

(c)

$$I_{Th} = \frac{33.9}{\sqrt{2}} = 23.97A$$

2.

(a)

$$V_O = \frac{3\sqrt{2} \times 110}{\pi} \cos 50^o = 95.4729V$$

$$E_a = 0.1 \times 900 = 90\,V$$

$$I_O = \frac{95.4729 - 90}{0.2} = \frac{5.4729}{0.2} = 27.3643A$$

(b)

$$I_{Th} = \frac{27.3643}{\sqrt{3}} = 15.8A$$

(c)

$$I_{Lim} = \sqrt{\frac{2}{3}} \times 27.3643 = 22.3429A$$

3.

(a)

$$V_O = \frac{2 \times \sqrt{2} \times 120}{\pi} \cos 60^o = 54V$$

$$E_a = 54 - 0.25 \times 20 = 49V$$

$$n = \frac{49}{0.1} = 490rpm$$

(b)

$$I_O = 20A \; ; \; I_O(rms) = \sqrt{20^2 + (0.2 \times 20)^2} = 20.4A$$

where $(0.2 \times 20)^2$ is ripple content

$$P_R = 20.4^2 \times 0.25 = 105W$$

(c)

$$P_a = E_a I_O = 49 \times 20 = 980W$$

4.

(a)

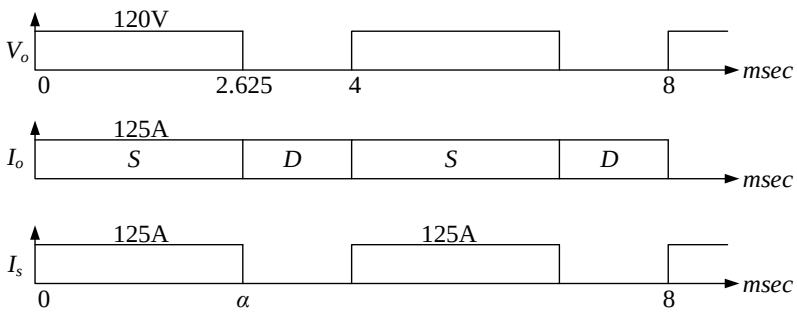
$$V_O = E_a + I_a R_a = 0.05 \times 1200 + 125 \times 0.15 = 78.75V$$

$$T = \frac{10^3}{250} m\sec = 4m\sec$$

$$\alpha = \frac{78.75}{120} = 0.6563$$

$$t_{on} = \alpha T = 0.6563 \times 4 = 2.625m\sec$$

(b)



(c)

$$E_a T_O = 60 \times 125 = 7500W$$

$$T = \frac{7500}{1200/60 \times 2\pi} = 59.683N \cdot m$$

(d)

$$P_O = V_O I_O = 78.75 \times 125 = 9844W$$

(e)

$$P_S = 120 \times 82.03 = 9844W$$