1.3.

The total inertia at motor shaft J_t (1.13) is

$$J_t = J_m + J_L a^2 = 0.02 + 2 \cdot 1/100 = 0.04\ \text{Kgm}^2$$

The motor torque requirement (1.11) is

$$T_e = J_t \dot{\Omega} + T_L = 0.04 \cdot 1884 + 200 = 275.36\ \text{Nm} \quad \text{for } 0 \le t \le 0.2\ \text{s}$$

$$T_e = T_L = 200\ \text{Nm} \quad \text{for } 0.2 \le t \le 0.8\ \text{s}$$

$$T_e = -J_t \dot{\Omega} + T_L = -0.04 \cdot 1884 + 200 = 124.64\ \text{Nm} \quad \text{for } 0.8 \le t \le 1\ \text{s}$$

1.4.

The motor base torque T_{eb} is

$$T_{eb} = \frac{P_b}{(\omega_b / p)} = \frac{100 \cdot 10^3}{367/2} \approx 545\ \text{Nm}$$

For same power at $\omega_{max} = 3\omega_b$, T_e is

$$T_e = T_{eb}\frac{\omega_b}{\omega_{max}} = \frac{T_{eb}}{3} = \frac{545}{3} = 148.33\ \text{Nm}$$

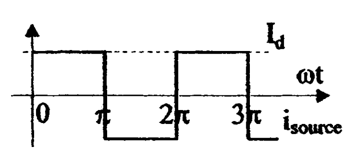
With zero losses the generator torque at $(-P_b)$ is simply

$$T_e = -T_{eb} = -545\text{Nm at } \omega_b \text{ (base speed)}$$

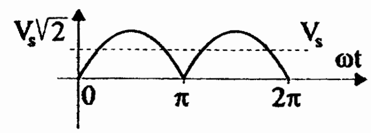
CHAPTER 3

3.1.

a. As seen on Figure 3.12, also, for constant d.c. current I_d the source current will change stepwise from $-I_d$ to I_d at $\omega t = 0$ and from $+I_d$ to $-I_d$ at $\omega t = \pi$.



b. The d.c. voltage will look as in the figure below



The average output voltage $V_{acav} = \frac{2}{\pi}\sqrt{2}V_s = \frac{2}{\pi}\sqrt{2}\cdot 120 = 107.77\ \text{V}$.

c. The source current fundamental (rms) I_{S1} is

$$I_{S1} = \frac{4I_d}{\pi\sqrt{2}} = 50\frac{4}{\pi\sqrt{2}} = 45.17\ \text{A}$$

The displacement power factor DPF is (3.6)

$$DPF = \cos\varphi_1 = 1$$

as the source current fundamental and voltage are in phase.

The power factor PF (3.10) is

$$PF = \frac{I_{S1}}{I_S}DPF = \frac{I_{S1}}{I_S}$$

I_S, (3.11), is

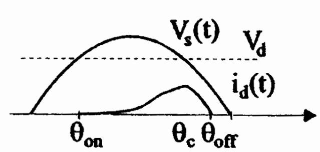
$$I_S = \sqrt{I_{S1}^2 + \sum_{v=2}^{v} I_{Sv}^2} = I_{S1}\sqrt{1 + \frac{1}{3^2} + \frac{1}{5^2} + \frac{1}{7^2} + \cdots} \approx 1.0918$$

$$I_{Sv} = \frac{4I_d}{v\pi\sqrt{2}} = \frac{I_{S1}}{v}$$

Finally
$$PF = \frac{I_{S1}}{I_{S1}\cdot 1.0918} = 0.916$$

3.2.

The current waveform follows from figure below (Figure 3.9).



The turn on angle θ_{on} is obtained when $V_d = V_S(t)$: $120 = 120\sqrt{2}\sin\theta_{on}$

Thus $\theta_{on} = 45^0$, $\theta_c = 135^0$ (at θ_c the current is maximum).

The turn off angle θ_{off} is obtained by making zero the average voltage on the source inductance (3.17).

$$\int_{\theta_{on}}^{\theta_{off}}\left(V_s\sqrt{2}\sin\omega t - V_d\right)d(\omega t) = 0$$

or

$$V_s\sqrt{2}\left(\cos\theta_{on} - \cos\theta_{off}\right) - V_d\left(\theta_{off} - \theta_{on}\right) = 0$$

$$\sqrt{2}\left(1/\sqrt{2} - \cos\theta_{off}\right) = \theta_{off} - \theta_{on}$$

Approximately $\theta_{off} \approx 171^0$ and thus (3.20)

$$i_d = 0 \text{ for } 0 < \theta < 45^0 \text{ and } 171^0 < \theta < 180^0$$

and

$$i_d = \frac{V_s\sqrt{2}\left(\cos\theta_{on} - \cos\omega t\right) - V_d\left(\omega t - \theta_{on}\right)}{\omega L_s}$$

$$= \frac{120\left[\sqrt{2}\left(0.707 - \cos\omega t\right) - \left(\omega t - \pi/4\right)\right]}{367\cdot 5\cdot 10^{-3}} \text{ for } 45^0 < \theta < 171^0$$

3.3.

The maximum overlapping angle $u_{max} = 30^0$ is (from 3.28)

$$\cos u_{max} = 1 - \frac{2\omega L_s}{V_s\sqrt{2}} I_{d\,max}$$

$$I_{d\,max} = \frac{(1-0.867)120\sqrt{2}}{2\cdot 367\cdot 1\cdot 10^{-3}} = 30.66 \text{ A}$$

The ideal d.c. voltage V_{dc}, (3.29), is

$$V_{d0} = \frac{2\sqrt{2}}{\pi}V_s = \frac{2\sqrt{2}}{\pi}120 = 108 \text{ V}$$

While the actual one, V_d, (3.30), is

$$V_d = V_{d0} - \frac{2\omega L_s}{\pi} I_d = 108 - \frac{2\cdot 367\cdot 1\cdot 10^{-3}}{\pi}\cdot 30.66 = 100.833 \text{ V}$$

CHAPTER 4

4.1.

a. As the armature resistance $R_a = 0.14\Omega$ from (4.18) the voltage at standstill V_a for rated current is

$$V_a = R_a I_n = 0.14\cdot 29.18 = 4.088 \text{ V}$$