CHAPTER 10

Additional Problems

Solved Problems

10.1 A single-phase to single-phase cycloconverter is supplying and inductive load comprising of a resistance of 5Ω and an inductance of 40 mH from a 230 V, 50 Hz single-phase supply. It is required to provide an output frequency which is 1/3 of the input frequency. If the converters are operated as semiconverter such that $O \leq \alpha \leq \pi$ and firing delay angle $\alpha_p = 120°$. Neglecting the harmonic content of load voltage, determine:

(a) rms value of output voltage.

(b) rms current of each thyristor and

(c) input power factor.

Sol. Given: $E = 230 \text{ V}, f_1 = 50 \text{ Hz}, \alpha_p = \dfrac{2\pi}{3}$

$$f_0 = 50/2 = 16.2/3 \text{ Hz}, R = 5\Omega, L = 40 \text{ mH}.$$

$$\omega_0 = 2\pi \times 50/3 = 104.72 \text{ rad/s}.$$

$$X_L = \omega_o L = 104.72 \times 40 \times 10^{-3} = 4.188\ \Omega$$

$$Z_L = \sqrt{5^2 + (4.188)^2} = 6.52\ \Omega.$$

$$\theta = \tan^{-1}(\omega_o L/R) \cong 40°.$$

(a) For $O \leq \alpha \leq \pi$, *rms* value of output voltage,

$$E_o = E \cdot \left[\frac{1}{\pi}\left(\pi - \alpha_p + \frac{\sin 2\alpha_p}{2}\right)\right]^{1/2}$$

$$= 230 \cdot \left[\frac{1}{\pi}\left\{\left(\pi - \frac{2\pi}{3}\right) + \frac{\sin 240}{2}\right\}\right]^{1/2}$$

$$= 101.6 \text{ V}$$

(b) RMS value of load current, $I_o = \dfrac{E_o}{Z_L}$

$$= \frac{101.6}{4.188} = 24.26 \text{ A}.$$

The *rms* current through each converter group is

$$I_P = I_N = \frac{I_o}{\sqrt{2}} = 17.1542 \text{ A.}$$

and the *rms* current through each thyristor

$$I_{Trms} = \frac{I_p}{\sqrt{2}} = \frac{17.1542}{\sqrt{2}} = 12.13 \text{ A.}$$

(c) *rms* input current, $I_i = I_o = 24.26$ A.

The volt-amp rating $= E \,.\, I_i = 230 \times 24.26 = 5580$ VA

The output power, $P_o = E_o \,.\, I_o.\cos\theta = 101.6 \times 24.26 \times \cos 40°$

$= 1888.1$ watts.

$$\therefore \quad \text{Power factor} = \frac{P_o}{E \cdot I_i} = \frac{1888}{5580}$$

$= 0.3384$ (lagging)

$$\text{Now,} \quad \text{P.F.} = \frac{m_f}{\sqrt{2}} \,.\, \cos\phi$$

$$m_f = \cos(180 - \alpha_p) = \cos 60° = 0.5$$

$$\cos\phi = \cos 40 = 0.766.$$

$$\text{Hence,} \quad P_f = \frac{0.5}{\sqrt{2}} \,.\, \cos 40 = 0.27$$

which shows that the harmonic content is the output voltage reduces the power-factor.

10.2 A six-pulse cycloconverter is supplying a load current of 50 A from a 440 V, 50 Hz supply having a reactance of 0.5 Ω/phase. Determine the input-load voltage for firing delay angles of 0° and 45°.

Sol. (1) When firing delay angle, $\alpha = 0$,

we have the relation from chapter 6,

$$I_{dc} = \frac{\sqrt{2}.\text{E}}{w \cdot L_s.} \,.\, \sin\frac{\pi}{p} \,.\, [\cos\alpha - \cos(\alpha + \mu)]$$

Now, $\alpha = 0$, and $\pi = 6$

$$\therefore \quad (w \,.\, L_s) \,.\, I_{dc} = \sqrt{2} \times E \,.\, \sin\frac{\pi}{6}\ [1 - \cos\mu)$$

$$0.5 \times 50 = \sqrt{2}.\ 440 \times \frac{1}{2}\ 1. - \cos\mu)$$

or, $25 = 311.127\,(1 - \cos\mu)$

or $\cos\mu = 0.917 = \cos(23.12°)$

$\therefore \quad \mu = 23.12°$

Now, average value of load voltage

$$\text{E}_{\text{omax}} = \sqrt{2} \cdot E\,\frac{p}{\pi}.\sin\frac{\pi}{p} \cdot \left[\frac{\cos(\alpha+\mu) + \cos\alpha}{2}\right] \qquad \text{(ii)}$$

$\therefore \quad E_{omax} = \sqrt{2} \times 440 \times \frac{6}{\pi} \cdot \frac{6}{\pi} \frac{1}{2} \left(\frac{1 + \cos 23.12°}{2} \right)$

$= 570.35$ V.

rms value of load voltage, $E_o = \frac{570.35}{\sqrt{2}}$

$= 403.3$ V.

(ii) When firing delay angle $\alpha = 45°$.

from eqn., (ii),

$$0.5 \times 50 = \sqrt{2} \times 440 \times \frac{1}{2} [\cos 45° - \cos (45° + \mu)]$$

$$0.08 = 0.707 - \cos (45° + \mu)$$

or $\quad \cos (45° + \mu) = 0.707 - 0.08 = 0.627$

or $\quad \cos (45° + \mu) = \cos (51.6°)$

$\therefore \quad \mu = 6.163°$.

Average d.c. voltage is given by

$$E_{oav} = 1.35 \times 440 \times \left[\frac{\cos 45° + \cos (51.16)}{2} \right] = 396.27 \text{ V.}$$

$\therefore$ ***rms*** value of load voltage E_o

$$= \frac{396.27}{\sqrt{2}} = 280.2 \text{ V.}$$