Problem 6-11

$$V_d = V_{do} \cos\alpha - \frac{3\omega L_s}{\pi} I_d \qquad \text{Eq 6-55}$$

$$\cos(\alpha+u) = \cos\alpha - \frac{2\omega L_s}{\sqrt{2}V_{LL}} I_d \qquad \text{Eq 6-62}$$

$$V_{do} = \frac{3\sqrt{2}}{\pi} V_{LL} \qquad \text{Eq 6-36}$$

Replacing $(\omega L_s I_d)$ in Eq 6-55 by Eq 6-62,

$$\therefore V_d = V_{do}\cos\alpha - \underbrace{\frac{3}{\pi}\frac{\sqrt{2}}{2} V_{LL}}_{(V_{do}/2)} \left[\cos\alpha - \cos(\alpha+u)\right]$$

$$\therefore V_d = \frac{V_{do}}{2}\left[\cos\alpha + \cos(\alpha+u)\right]$$

$$\therefore \text{dc power } P_d = V_d I_d = \frac{V_{do} I_d}{2}\left[\cos\alpha + \cos(\alpha+u)\right]$$

On the ac side; ac power is

$$P_{ac} = \sqrt{3}\, V_{LL} I_{s1} \cos\phi_1$$

Approximation: $$I_{s1} \simeq \underbrace{\frac{\sqrt{6}}{\pi}}_{0.78} I_d \qquad \text{Eq 6-44}$$

The above equation is approximate because the above equation is correct only if $L_s = 0$ (and hence $u = 0$).

$$\therefore \quad P_{ac} \simeq \sqrt{3}\, V_{LL} \frac{\sqrt{6}}{\pi} I_d \cos\phi_1$$

Equating $\quad P_{ac} = P_{dc}$

$$\sqrt{3}\, V_{LL} \frac{\sqrt{6}}{\pi} I_d \cos\phi_1 \simeq \underbrace{\frac{3\sqrt{2}}{\pi} V_{LL}}_{V_{do}} \frac{I_d}{2} \left[\cos\alpha + \cos(\alpha + u)\right]$$

$$\therefore \quad DPF = \cos\phi_1 \simeq \frac{1}{2}\left[\cos\alpha + \cos(\alpha + u)\right]$$