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Solutions Manual

Power Electronics: Converters, Applications and Design

SECOND EDITION

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Problem 3-5

(a) This is illustrated for only the waveform in Prob 3-3(a).

(i) $F_1 = \frac{1}{\sqrt{2}} \frac{4}{\pi} A = 0.9 A$

$F_{rms} = A$

$\therefore \frac{F_1}{F_{rms}} = \frac{1}{\sqrt{2}} \frac{4}{\pi} = 0.9$

(ii) $F_{dis} = \sqrt{F_{rms}^2 - F_1^2} = 0.436 A$ Using Eq 3-35

$\therefore \frac{F_{dis}}{F_{rms}} = 0.436$

(b) This is illustrated only for the waveform in Prob 3-3(f).

$F_0 = \frac{20}{\pi}$ [From Prob 3-3 f solution]

$F_{rms} = 7.071$ [From Prob 3-4 Solution]

$\therefore \frac{F_0}{F_{rms}} = 0.9$

The same procedure can be used for the rest of the waveforms.

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Problem 5-4

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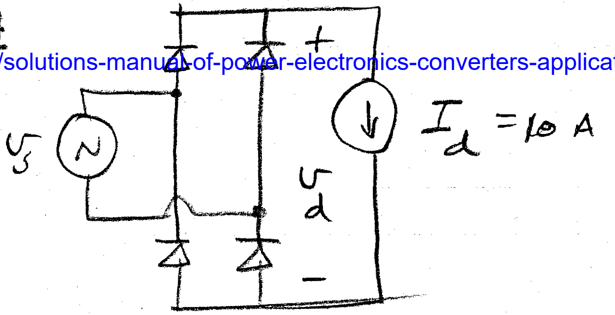

(a) v_s: Sinusoidal, $V_s = 120V$ $\therefore V_d = 0.9 V_s = 108\ V$

$$P_d = V_d I_d = 1080\ W.$$

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$$A_u = 200\, u = 2\omega L_s I_d$$

$$\therefore \quad u = \frac{2\omega L_s I_d}{200} \text{ rad} = 0.0377 \text{ rad} = 2.16 \text{ deg}$$

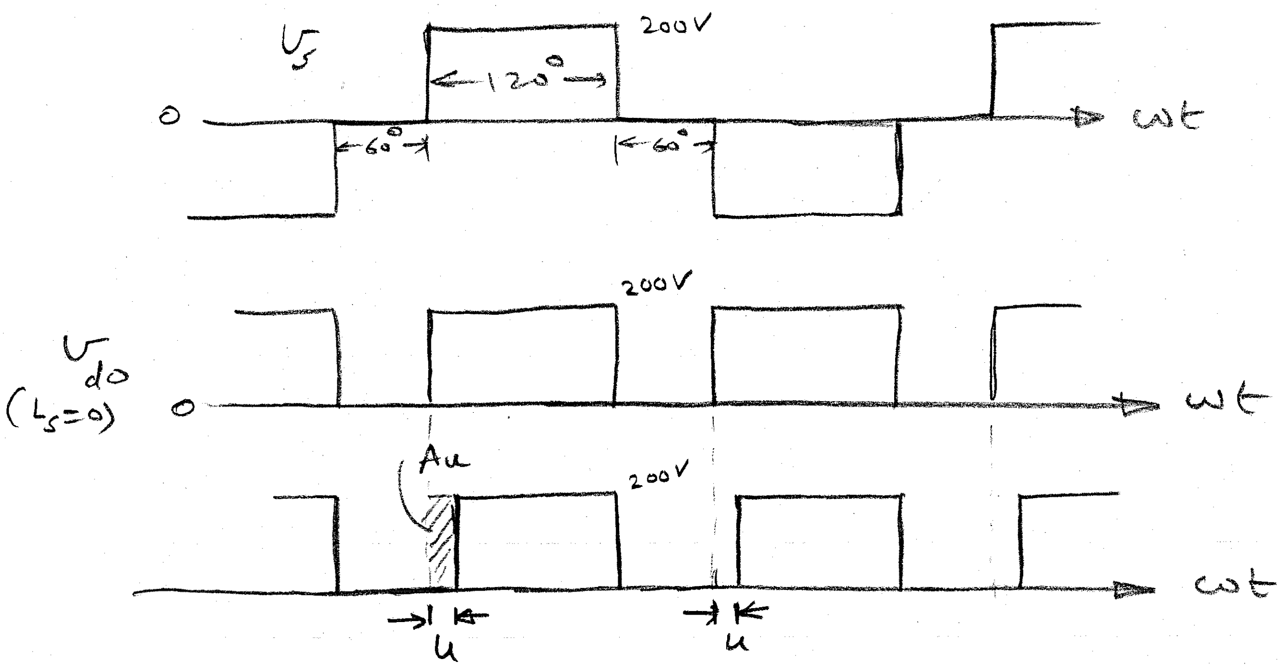
$$V_{do} = 200\text{V}$$

$$V_d = V_{do} - \frac{A_u}{\pi} = 200 - \frac{2\omega L_s I_d}{\pi} = 197.6$$

$$P_d = V_d I_d = 1976\text{W}$$

$$\text{drop } \Delta V_d\% = \frac{V_{do} - V_d}{V_{do}} \times 100 = 1.2\%$$

(b)



$$V_{do} = 200 \times \frac{120}{180} = 133.33\text{V}$$

$$A_u = 200\, u = 2\omega L_s I_d$$

$$u = \frac{2\omega L_s I_d}{200} \text{ rad} = 0.0377 \text{ rad} = 2.16 \text{ deg}$$

$$V_d = V_{do} - \frac{A_u}{\pi} = 133.33 - \frac{2\omega L_s I_d}{\pi} = 130.93\text{V}$$

$$P_d = V_d I_d = 1309.3\text{W} \qquad \text{drop } \Delta V_d\% = 1.8\%$$

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$$-\frac{\pi}{6} < \theta < \frac{\pi}{6}$$

Calculate I_d:

$$I_d = \int_{-\pi/6}^{\pi/6} i_d(\theta)d\theta \Big/ \frac{\pi}{3}$$

$$= \frac{3}{\pi}\frac{V_{LL}}{\omega L_d}\int_{-\pi/6}^{\pi/6}(\sqrt{2}\ \sin\theta - 1.35\theta + 0.0129)d\theta$$

$$= \frac{3V_{LL}}{\pi\omega L_d}\left[-\sqrt{2}\ \cos\theta - \frac{1.35}{2}\ \theta^2 + 0.0129\theta\right]_{-\pi/6}^{\pi/6}$$

$$= \frac{3V_{LL}}{\pi\omega L_d}\ (0.0129(\pi/6 - (-\pi/6))) = \frac{3V_{LL}}{\pi\omega L_d}\ (0.0129\ \frac{\pi}{3})$$

$$I_d = 0.0129\ \frac{V_{LL}}{\omega L_d}$$

Therefore,

$$L_{d,min} \simeq \frac{0.013}{\omega I_d}\ V_{LL}$$

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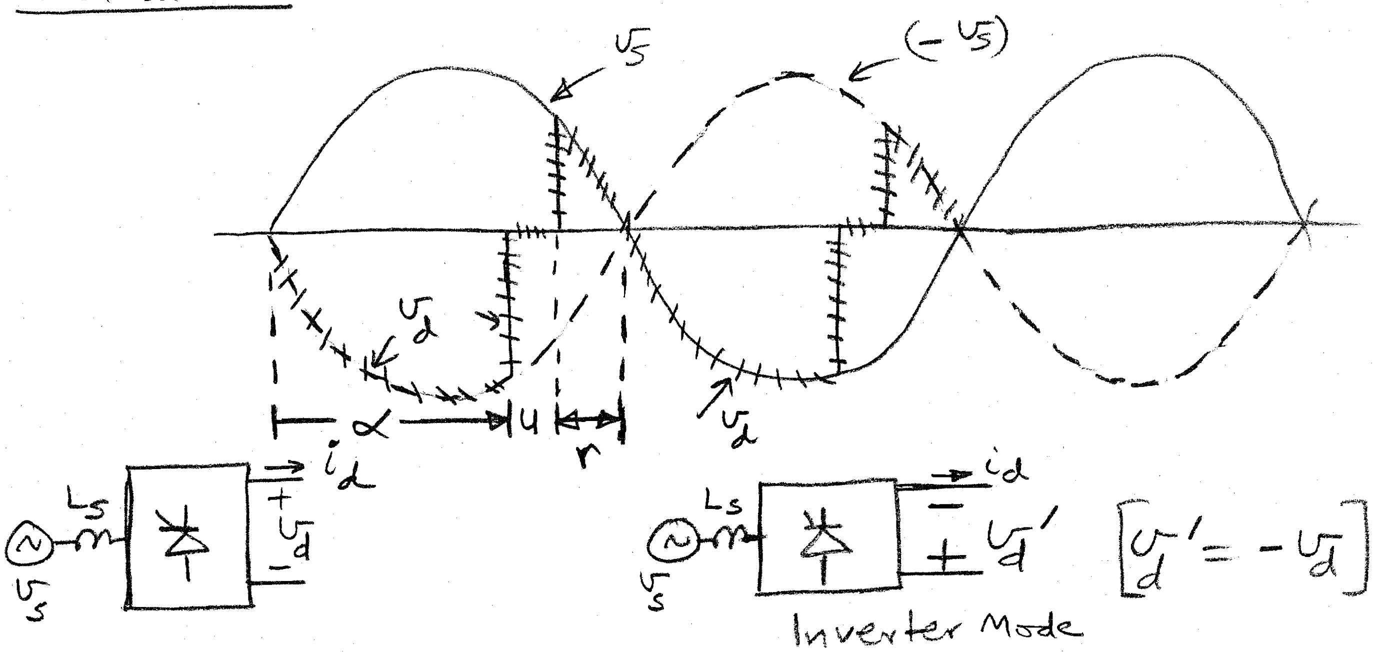
Problem 6-8



To represent the inverter mode of operation, often the output dc voltage polarity is defined as shown in the diagram ~~to~~ the right by v_d' where $v_d' = -v_d$.

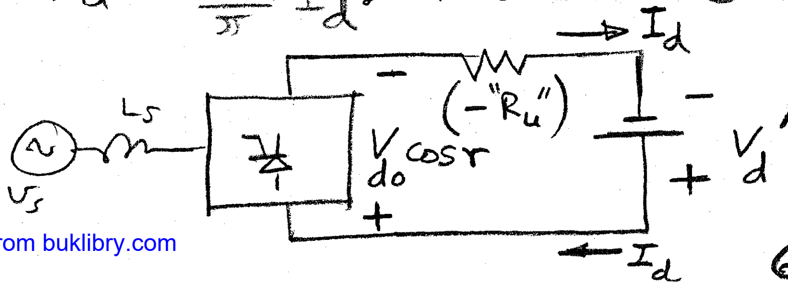
If $L_s = 0$ (and hence $u = 0$) but r is the same as in the waveforms above, then we can calculate

$$V_d'(\text{with } L_s = 0) = 0.9 V_s \cos r$$

Because of a finite L_s and a finite u,

$$V_d' = \overbrace{0.9 V_s}^{V_{do}} \cos r - \frac{2\omega L_s}{\pi} I_d = V_{do} \cos r - \text{"}R_u\text{"} I_d$$

where "R_u" $= \frac{2\omega L_s}{\pi} I_d$. This can be represented as below:



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(b)
$$I_{base} = \frac{V_d/2}{Z_o} = \frac{77.5}{30.89} = 2.51A$$

From problem 9-1

$$I_{L,peak} = [1+(V_o)_N] \cdot I_{base} = (1 + 0.9) \cdot 2.51 = 4.77A$$

$$V_{c,peak} = 2V_{base} = 2 \cdot \frac{155}{2} = 155V$$

$$\therefore \; S = (\frac{1}{2} \cdot 22.12 \cdot 10^{-6} \cdot 4.77^2) + (\frac{1}{2} \cdot 23.18 \cdot 10^{-9} \cdot 155^2)$$

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$$= 10^{-6} \cdot (251.6 + 278.4) = 530.0 \; \mu J$$

Problem 18-1

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transformer: 240V, 25 kVA

$$\therefore \quad \text{rated current} = \frac{25 \times 10^3}{240} = 104.17$$

$$\text{base impedance} = \frac{\text{rated voltage}}{\text{rated current}} = \frac{240}{104.17} = 2.3\ \Omega$$

and leakage impedance = 0.04 x base impedance = 0.092 Ω

(a)

Therefore, the short-circuit current is

$$I_{sc} = \frac{240}{0.092} = 2604.2\text{ A}$$

and per-phase short-circuit capacity

$$SCC = \frac{240 \times 2604.2}{10^3} = 625\text{ kVA}$$

(b) Load power is 5 kW at 240V and at a unity displacement power factor. Therefore, the fundamental current at full load is

$$I_1 = \frac{5 \times 10^3}{240} = 20.83\text{ A}$$

$$\frac{I_{sc}}{I_1} = \frac{2604.2}{20.83} = 125$$

$$THD = \sqrt{\sum_{h \neq 1} \left(\frac{I_h}{I_1}\right)^2} = 34.6\% \quad \text{(from Table P18-1)}$$

Comparing THD and the harmonics of Table P18-1 with the limits in Table

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18-2 for I_{sc}/I_1 in a range of 100 to 1000, we see that the limits for the third harmonic and the THD are violated.

25-5. IGBT current - $I_{on,IGBT}$; $V_{on}(IGBT) = V_j + I_{on,IGBT}\, R_{on,IGBT}$

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Assume $V_j \approx 0.8$ V ; Exact value not critical to an approximate estimate of $I_{on,IGBT}$.

$$I_{on,IGBT} \approx \frac{3 - 0.8}{R_{on,IGBT}} \; ; \; R_{on,IGBT} \approx \frac{W_d}{q\,(\mu_n + \mu_p)\,n_b\,A}$$

$$W_d = (10^{-5})(750) = 75\ \mu m \; ; \; R_{on,IGBT} = \frac{7.5\times10^{-3}}{(1.6\times10^{-19})(900)(10^{16})(2)} = 2.6\times10^{-3}\ \Omega$$

$$I_{on,IGBT} \approx \frac{2.2}{2.6\times10^{-3}} \approx 850 \text{ amps}$$

MOSFET current - $I_{on,MOS}$; $V_{on}(MOS) = I_{on,MOS}\, R_{on,MOS}$

$$I_{on,MOS} = \frac{V_{on}(MOS)}{R_{on,MOS}} \; ; \; R_{on,MOS} = \frac{W_d}{q\,\mu_n\,N_d\,A} \; ; \; W_d = 75\ \mu m$$

$$N_d = \frac{1.3\times10^{17}}{750} = 1.7\times10^{14}\ cm^{-3}$$

$$R_{on,MOS} = \frac{7.5\times10^{-3}}{(1.6\times10^{-19})(1.5\times10^{3})(1.7\times10^{14})(2)} = 0.09 \text{ ohms}$$

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$$I_{on,MOS} = \frac{3}{0.09} = 33 \text{ amps}$$