Fall 2015
Problem 9
Power Systems & Power Electronics Solution

Problem 9(a)

In a Flyback converter operating in steady state, $V_{in} = 48V$, duty-ratio $D = 0.385$, $N_1 / N_2 = 6$, the magnetizing inductance $L_{m1} = 150\mu H$, and the switching-frequency $f_s = 200\,kHz$. Neglect the leakage inductances and assume this converter to be lossless. Assume the output voltage to be ripple-free.

(a) This converter is operating at the output power P_o at which the flux in the core is at the border of incomplete-demagnetization and the complete-demagnetization modes (similar to the border of continuous and the discontinuous current-conduction modes in non-isolated dc-dc converters).

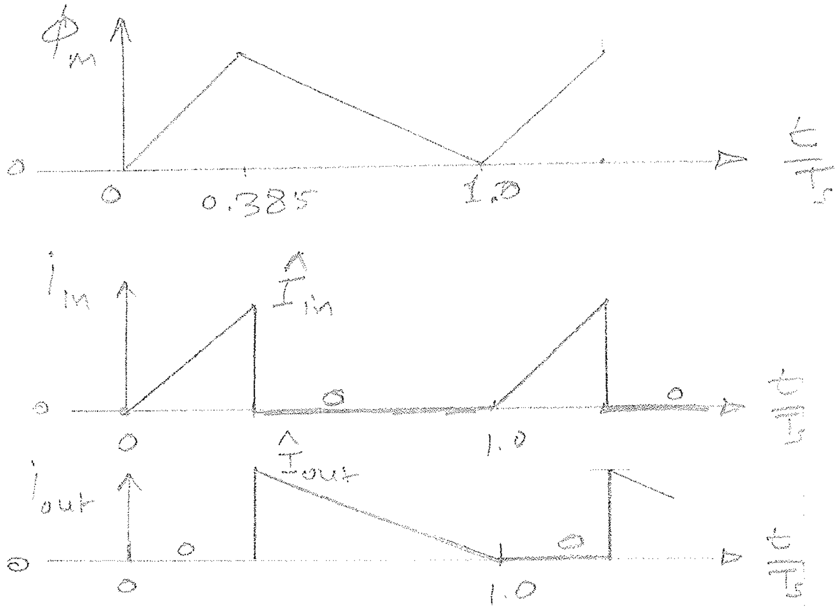
1. Calculate the output voltage V_0.
2. Calculate and draw the waveforms of the input current, and the current supplied to the output stage consisting of the parallel combination of the output capacitor and the load-resistance.
3. Calculate the output power P_0.

(b) If this converter is operating at double the power calculated in part (a), calculate the following:

1. The output voltage V_0.
2. Calculate and draw the waveforms of the input current, and the current supplied to the output stage consisting of the parallel combination of the output capacitor and the load-resistance.

Solution

(a)



$V_o = \frac{N_2}{N_1} \frac{D}{1-D} V_{in}$

$= 5V$

$I_{in}(0) = 0 \qquad \hat{I}_{in} = \frac{48 \times 0.385 \times 5\mu}{150\mu} = 0.616\,A$

$\hat{I}_{out} = 6 \times 0.616\,A \simeq 3.696\,A$

$I_{in}(avg) = \frac{1}{2}\hat{I}_{in}(0.385) = 0.1186\,A$

$P_o = 48 \times 0.1186 = 5.69\,W$

(b) $P_o = 2 \times 5.69 = 11.38W$

$V_o = 5V$

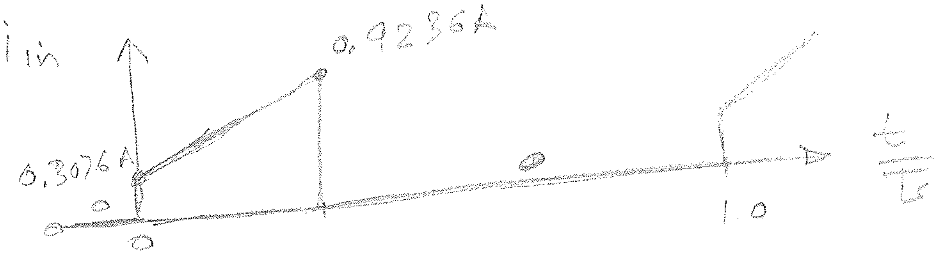
$$I_{in}(avg) = \frac{11.38}{48} = 0.237A$$

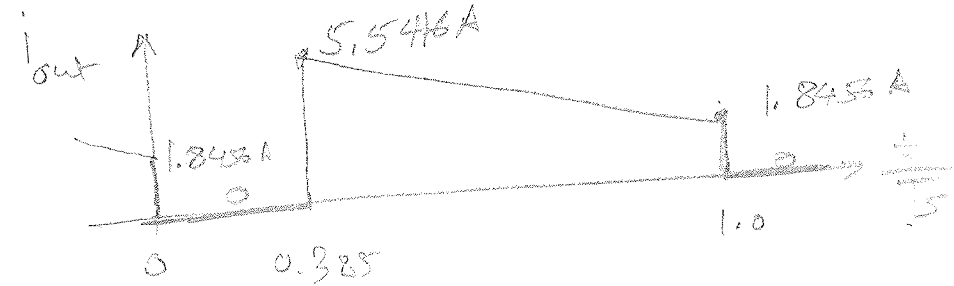
$$\hat{I}_{in} - I_{in}(0) = \frac{48 \times 0.385 \times 5\mu}{150\mu} = 0.616A$$

$\therefore \quad I_{in}(0) = 0.3076A, \quad \hat{I}_{in} = 0.9236$

$\hat{I}_{out} = 6\,\hat{I}_{in} = 5.5416A$

$I_{out}(0) = 6 \times I_{in}(0) = 1.8456A$





Problem 9 (b) Suppose an industrial plant is served from a three-phase 208 V (RMS line-line) transformer. The real power demand of the plant is 80 kW at a power factor of 0.5 (lag).

(i) Find the apparent power and RMS line current magnitude.

$$\begin{aligned} P_{3\phi} &= 80\,\text{kW} \\ &= \sqrt{3}V_{LL}I_L\cos\theta \\ &= S_{3\phi}\cos\theta \\ \Rightarrow S_{3\phi} &= \frac{80\,\text{kW}}{0.5} = 160\,\text{kVA} \\ I_L &= \frac{80}{\sqrt{3}(208)(0.5)} = 444\,\text{A} \end{aligned}$$

(ii) Suppose the power factor is corrected to 0.9 (lag) with capacitor banks. Find the new apparent power and RMS line current magnitude.

$$\begin{aligned} S_{3\phi} &= \frac{80\,\text{kW}}{0.9} \\ &= 88.9\,\text{kVA} \\ I_L &= \frac{80}{\sqrt{3}(208)(0.9)} = 247\,\text{A} \end{aligned}$$

(iii) Suppose the line losses before power factor correction were 4 kW. What are the line losses after power factor correction?

$$\begin{aligned} \frac{P_{loss,before}}{P_{loss,after}} &= \frac{I^2_{L,before}}{I^2_{L,after}} \\ \Rightarrow P_{loss,after} &= 4\,\text{kW} \times \frac{247^2}{444^2} \\ &= 1.24\,\text{kW} \end{aligned}$$