ECE 4643: Power Electronics

Exam 1: Solution

Time: Monday 21st, 2019, 10:30-11:25 AM

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Q1 [5 marks]

Q1.1–

Q1.2–

Q2 [4 marks]

A 3ϕ full-wave rectifier supplies an inductive load that has $R_L = 9\ \Omega$ and $L_L = 3$ mH. The input AC voltage is supplied from a feeder at 340 V, 60 Hz. Design an input LC filter that will ensure an input ripple factor of $RF \leq 6\%$, and an output LC filter for a ripple voltage $\Delta v_o \leq 5\%$. [2 marks].

The output DC voltage V_{dc} can be determined for the load as:

$$V_{dc} = \frac{3\sqrt{3}}{\pi} V_m$$

The feeder voltage is an rms line-to-line voltage (default specifications). The required the peak line-to-neutral value V_m:

$$V_m = \sqrt{2}\left(\frac{V_s}{\sqrt{3}}\right) = 277.61 \quad V$$

V_{dc} becomes:

$$V_{dc} = \frac{3\sqrt{3}}{\pi} \times 277.61 = 459.16 \quad V$$

The output DC current I_{dc} is determined as:

$$I_{dc} = \frac{V_{dc}}{R_L} = \frac{459.16}{9} = 51.02 \quad A$$

The input LC Filter

The values of the input filter parameters (L_S and C_S) can be determined based on the the value of the RF as:

$$\frac{X_{Ls}}{X_{Cs}} = \frac{1}{5^2}\left(\frac{I_{an}(n\omega)}{(I_{an}(n\omega))_{Ls}} + 1\right) = \frac{1}{25}(RF + 1) = 0.04 \times (0.06 + 1) = 0.0424$$

Let $C_S = 30\mu$F. This value produces L_S as:

$$2\pi \times 60 L_S = 0.0424 X_{Cs} = \frac{0.0424}{2\pi \times 60 \times 30 \times 10^{-6}} = 3.75 \Longrightarrow L_S = 10 \;\; mH$$

The output C Filter

The value of the output side capacitor C_O can be determined using the ripple voltage conditions as:

$$C_O = \frac{100\,(I_o(n=6))_{peak}}{\sqrt{2} \times (\Delta v_O\%) \times V_{dc} \times 12\pi \times f_s}$$

The peak value of the 6^{th} harmonic voltage is:

$$(v_o(n=6))_{peak} = 0.9549 V_m \times \frac{2}{35} = 0.9549 \times 277.61 \times 0.0571 = 15.12 \;\; V$$

The peak value of $I_o(n=6)$ can be determined as:

$$(I_o(n=6))_{peak} = \frac{(v_o(n=6))_{peak}}{Z_L(6f_s)} = \frac{15.12}{\sqrt{R_L^2 + (2\pi \times 6 f_s L_L)^2}} = 1.34 \;\; A$$

The value of C_O can be determined as:

$$C_O = \frac{100 \times 1.34}{\sqrt{2} \times 5 \times 459.16 \times 2 \times 6 \times \pi \times 60} = 18.27 \;\; \mu F$$

Q3 [6 marks]

A 3ϕ full-wave rectifier supplies a resistive load with $R_L = 10\,\Omega$. The input AC voltage is supplied from a Y-connected feeder at 208 V, 60 Hz. For this rectifier, determine:

a) The output DC voltage [1 marks].

The rms value of the phase voltage is $V_{sP} = \frac{208}{\sqrt{3}} = 120$ V, $(V_m)_{peak} = \sqrt{2} \times V_{sP} = 169.7$ V. The output DC voltage is obtained is:

$$V_{dc} = \frac{3\sqrt{3} V_m}{\pi} = 1.654 \times 169.7 = 280.68\, V$$

b) $(I_O)_{rms}$ and I_{dc} [3 marks].

The rms output voltage is determined as:

$$(V_O)_{rms} = \sqrt{3}\,(V_m)_{Ph} \sqrt{\frac{1}{2} + \frac{3\sqrt{3}}{4\pi}} = \sqrt{3} \times 169.7 \sqrt{0.5 + 0.4135} = 280.93 \;\; V$$

$$(I_O)_{rms} = \frac{(V_O)_{rms}}{R_L} = \frac{280.93}{10} = 28.093 \ A$$

The output DC current I_{dc} is:

$$I_{dc} = \frac{V_{dc}}{R_L} = \frac{280.68}{10} = 28.068 \quad A$$

c) The current in each diode [1 marks].
The average current in each diode I_D is determined as:

$$I_D = \frac{I_{dc}}{3} = \frac{28.068}{3} = 9.36 \quad A$$

d) The input power factor [1 marks].
The input power factor can be determined as:

$$PF = \frac{P_{dc}}{S_{in}} = \frac{V_{dc} I_{dc}}{\sqrt{3} V_s I_s}$$

The input current $(I_s)_{rms}$ can be determined as:

$$(I_s)_{rms} = (I_O)_{rms} \times \sqrt{\frac{2}{3}} = 28.093 \times 0.8165 = 22.94 \quad A$$

$$PF = \frac{P_{out}}{\sqrt{3}\,(V_{sL})_{rms}\,(I_{sL})_{rms}} = \frac{280.68 \times 28.068}{\sqrt{3} \times 208 \times 22.94} = 0.9532 \quad Lag$$