ECE4643: Power Electronics

Assignment 4: Solution

Q1:

Q2

A 1ϕ half-bridge inverter is fed with $V_s = 48$ V(dc), to supply a resistive load of $R_L = 2.4\,\Omega$ at 60 Hz. for this inverter determine:

a) The rms value of the fundamental component of the output voltage.

The rms value of the fundamental component of the output voltage V_{O1} for a half-bridge inverter is determined as:

$$V_{O1} = \frac{2V_s}{\sqrt{2}\pi} = \frac{2 \times 48}{\sqrt{2}\pi} = 21.6 \quad V$$

b) The output power,

The output power P_O can be determined as:

$$P_O = \frac{V_{O1}^2}{R_L} = \frac{21.6^2}{2.4} = 194.4 \quad W$$

c) The output current peak and rms values.

The output peak current can be calculated as:

$$(i_O)_{Peak} = \sqrt{2} \times \frac{V_O}{R_L} = \sqrt{2} \times \frac{48/2}{2.4} = 14.14 \quad A$$

The rms value of the output current I_O is determined as:

$$I_O = \frac{V_O}{R_L} = \frac{48/2}{2.4} = 10 \quad A$$

d) The value of THD$_V$.

$$THD_V = \frac{\left(\sum_{n=1,3,..}^{\infty} V_{On}^2\right)^{\frac{1}{2}}}{V_{O1}}$$

where:

$$\left(\sum_{n=1,3,..}^{\infty} V_{On}^2\right)^{\frac{1}{2}} = \left(V_O^2 - V_{O1}^2\right)^{\frac{1}{2}} = \sqrt{24^2 - 21.6^2} = 10.46$$

The value of THD$_V$ can be evaluated s:

$$THD_V = \frac{10.46}{21.6} = 48.43\%$$

Q3:

Repeat **Q2** for a full-bridge inverter.

a) The rms value of the fundamental component of the output voltage.

The rms value of the fundamental component of the output voltage V_{O1} for a full-bridge inverter is determined as:

$$V_{O1} = \frac{4V_s}{\sqrt{2}\pi} = \frac{4 \times 48}{\sqrt{2}\pi} = 43.2 \quad V$$

b) The output power,

The output power P_O can be determined as:

$$P_O = \frac{V_{O1}^2}{R_L} = \frac{43.2^2}{2.4} = 777.6 \quad W$$

c) The output current peak and rms values.

The output peak current can be calculated as:

$$(i_O)_{Peak} = \sqrt{2} \times \frac{V_O}{R_L} = \sqrt{2} \times \frac{48}{2.4} = 28.28 \quad A$$

The rms value of the output current I_O is determined as:

$$I_O = \frac{V_O}{R_L} = \frac{48}{2.4} = 20 \quad A$$

d) The value of THD$_V$.

$$THD_V = \frac{\left(\sum_{n=1,3,..}^{\infty} V_{On}^2\right)^{\frac{1}{2}}}{V_{O1}}$$

where:

$$\left(\sum_{n=1,3,..}^{\infty} V_{On}^2\right)^{\frac{1}{2}} = \left(V_O^2 - V_{O1}^2\right)^{\frac{1}{2}} = \sqrt{48^2 - 43.2^2} = 20.92$$

The value of THD$_V$ can be evaluated s:

$$THD_V = \frac{20.92}{43.2} = 48.43\%$$

Q4

A 1ϕ full-bridge inverter is switched using the bipolar SPWM for $V_s = 300$ V(dc), $m_a = 0.8$, $m_f = 39$, and $f_o = 47$ Hz. For this inverter, determine the rms value of the fundamental component of the output voltage, and the first 5 dominant harmonic components. The rms values of the harmonic components due the bipolar SPWM can be stated as:

$$(V_O)_n = \frac{V_s}{\sqrt{2}} \times (V_{On})_{p.u}$$

where $(V_{On})_{p.u}$ is the associated p.u value of the harmonic components as stated in the table of lecture 23. For $n = 1$ (the fundamental component):

$$(V_O)_1 = \frac{300}{\sqrt{2}} \times 0.8 \times 0.49 = 103.94 \times 0.8 = 83.16$$

As for the bipolar SPWM, the harmonic patches will be centered at multiples of $mf \times f_m$. The first harmonic patch will be centered at $(m_f \pm 2)\, f_m$. In this inverter case, $m_f = 39$, and $m_a = 0.8$. Remember that n is the harmonic order.

for $n = m_f - 2 = 37$:

$$(V_O)_{37} = \frac{300}{\sqrt{2}} \times 0.135 = 212.13 \times 0.135 = 28.64$$

for $n = m_f + 2 = 41$:

$$(V_O)_{41} = \frac{300}{\sqrt{2}} \times 0.135 = 212.13 \times 0.135 = 28.64$$

There will be another harmonic patch centered at $(m_f \pm 4)\, f_m$, and using the table, these harmonic components will have a p.u value of 0.005 (negligible). The second patch of harmonics will be centered at $(2m_f \pm 1)\, f_m$.

for $n = 2m_f - 1 = 77$:

$$(V_O)_{77} = \frac{300}{\sqrt{2}} \times 0.192 = 212.13 \times 0.192 = 40.73$$

for $n = 2m_f + 1 = 79$:

$$(V_O)_{79} = \frac{300}{\sqrt{2}} \times 0.192 = 212.13 \times 0.192 = 40.73$$

There will another harmonic patch centered at $(m_f \pm 5)\, f_m$, and using the table, these harmonic components will have a p.u value of 0.008 (negligible).

Q5

Repeat **Q4** for the unipolar SPWM. The rms values of the harmonic components due the unipolar SPWM can be stated as:

$$(V_O)_n = \frac{V_s}{\sqrt{2}} \times (V_{On})_{p.u}$$

where $(V_{On})_{p.u}$ is the associated p.u value of the harmonic components as stated in the table of lecture 23. As for the unipolar SPWM, the harmonic patches will be centered at multiples of $2mf \times f_m$. The first harmonic patch will be centered at $(2m_f \pm 1)\, f_m$. In this inverter case, $m_f = 39$, and $m_a = 0.8$. Remember that n is the harmonic order.

for $n = 1$ (the fundamental component):

$$(V_O)_1 = \frac{300}{\sqrt{2}} \times 0.8 \times 0.49 = 103.94 \times 0.8 = 83.16$$

for $n = 2m_f - 1 = 77$:

$$(V_O)_{75} = \frac{300}{\sqrt{2}} \times 0.192 = 212.13 \times 0.192 = 40.73$$

for $n = 2m_f + 1 = 79$:

$$(V_O)_{77} = \frac{300}{\sqrt{2}} \times 0.192 = 212.13 \times 0.192 = 40.73$$

There will be another harmonic patch centered at $(2m_f \pm 5)\, f_m$ with a p.u value of 0.008 (negligible). The second patch of harmonics will be centered at $(4m_f \pm 1)\, f_m$.

for $n = 4m_f - 1 = 155$:

$$(V_O)_{155} = \frac{300}{\sqrt{2}} \times 0.064 = 212.13 \times 0.064 = 13.58$$

for $n = 4m_f + 1 = 157$:

$$(V_O)_{157} = \frac{300}{\sqrt{2}} \times 0.064 = 212.13 \times 0.064 = 13.58$$

There will be harmonic patches centered at $(4m_f \pm 5)\, f_m$ with:

for $n = 4m_f - 5 = 151$:

$$(V_O)_{151} = \frac{300}{\sqrt{2}} \times 0.051 = 212.13 \times 0.051 = 10.82$$

for $n = 4m_f + 5 = 161$:

$$(V_O)_{161} = \frac{300}{\sqrt{2}} \times 0.051 = 212.13 \times 0.051 = 10.82$$

A third patch of harmonics is centered by $(4m_f \pm 7)\, f_m$ with a p.u value of 0.01 (negligible).

Notes for Q4 and Q5:

- For the bipolar SPWM, the dominant harmonics are located at $n = 37,\ n = 41,\ n = 77,$ and $n = 79$.
- For the unipolar SPWM, the dominant harmonics are located at $n = 77,\ n = 79,\ n = 151,\ n = 155,\ n = 157$, and $n = 161$.
- Harmonic components, due to the unipolar and bipolar SPWM, may share magnitude values, however, they are located in different frequency bands.