ELEC-E8412 **Power Electronics**

Exercise No 07 23.11.2023

Problem 1:

A buck-boost converter circuit has the following parameters:

V_{in} =24 V, D =0.65, R =7.5 Ω, L=50 μH, C =200 μF, f_{sw} =100 kHz.

Determine

a) V_{out}

$$V_o = \frac{V_{in} * D}{1 - D} = \frac{24}{1 - 0.65} = 44.571V$$

b) Average, maximum, and minimum inductor currents.

$$I_{avg} = \left(\frac{V_{in} * D}{(1 - D)^2 * R}\right) = \left(\frac{24 * 0.65}{(1 - 0.65)^2 * 7.5}\right) = 16.98A$$

$$\Delta I_L = \left(\frac{V_{in} * DT}{L}\right) = \frac{24 * 0.65}{50 * 10^{-6} * 10^5} = 3.12A$$

$$I_{min} = I_{avg} - \frac{\Delta I_L}{2} = 16.98 - \frac{3.12}{2} = 15.42A$$

$$I_{max} = I_{avg} + \frac{\Delta I_L}{2} = 16.98 + \frac{3.12}{2} = 18.54A$$

Problem 2:

A buck-boost converter circuit has the following parameters:

V_{in} =12 V, D =0.6, R =10 Ω, L=10 µH, C =20 µF, f_{sw} =200 kHz.

Determine

a) V_{out}

$$V_o = \frac{V_{in} * D}{1 - D} = \frac{12 * 0,6}{1 - 0.6} = 18V$$

b) Average, maximum, and minimum inductor currents.

$$I_{avg} = \left(\frac{V_{in} * D}{(1 - D)^2 * R}\right) = \left(\frac{12 * 0.6}{(1 - 0.6)^2 * 10}\right) = 4.5A$$

$$\Delta I_L = \left(\frac{V_{in} * DT}{L}\right) = \frac{12 * 0.6}{10 * 10^{-6} * 2 * 10^5} = 3.6A$$

$$I_{min} = I_{avg} - \frac{\Delta I_L}{2} = 4.5 - \frac{3.6}{2} = 2.7A$$

$$I_{max} = I_{avg} + \frac{\Delta I_L}{2} = 4.5 + \frac{3.6}{2} = 6.3A$$

c) Average value of input current

$$I_{in(avg)} = ?$$

$$V_{in} * I_{in(avg)} = \frac{V_o^2}{R} = \left(\frac{(V_{in} * D)^2}{(1 - D)^2 * R}\right)$$

$$I_{in(avg)} = \frac{V_o^2}{R} = \left(\frac{(V_{in} * D)^2}{(1 - D)^2 * R * V_{in}}\right) = \frac{0.6^2 * 12}{(1 - 0.6)^2 * 10 * 12} = 2.7A$$

Problem 3:

A square-wave inverter has a dc source of 125 V, an output frequency of 50 Hz, and an RL series load with R=12 Ω and L=35 mH. Determine

a) expression for load current
b) rms load current
c) average source current

$$i_o(t) = \begin{cases} \frac{V_{in}}{R} + (I_{min} - \frac{V_{in}}{R})e^{-t/\tau} & 0 < t < \frac{T}{2} \\ \frac{-V_{in}}{R} + (I_{max} + \frac{V_{in}}{R})e^{-(t-\frac{T}{2})/\tau} & \frac{T}{2} < t < T \end{cases}$$

$$I_{max} = -I_{min} = \frac{V_{in}}{R}\left(\frac{1-e^{-T/2\tau}}{1+e^{-T/2\tau}}\right)$$

$$T = \frac{1}{f} = \frac{1}{50} = 0.02\ s$$

$$\tau = \frac{L}{R} = \frac{0.035}{12} = 0.00292$$

$$\frac{T}{2\tau} = \frac{0.02}{2 * 0.00292} = 3.425$$

a) expression for load current

$$I_{max} = -I_{min} = \frac{V_{in}}{R}\left(\frac{1 - e^{-T/2\tau}}{1 + e^{-T/2\tau}}\right) = \frac{125}{12}\left(\frac{1 - e^{-3.425}}{1 + e^{-3.425}}\right) = 9.76\ A$$

$$i_o(t) = \frac{V_{in}}{R} + \left(I_{min} - \frac{V_{in}}{R}\right)e^{-t/\tau} = \frac{125}{12} + \left(-9.76 - \frac{125}{12}\right)e^{-t/0.00292}$$

$$= 10.417 - 20.177e^{-t/0.00292} \qquad 0 \le t \le \frac{1}{100}$$

$$i_o(t) = \frac{-V_{in}}{R} + \left(I_{max} + \frac{V_{in}}{R}\right)e^{-(t-\frac{T}{2})/\tau} = \frac{-125}{12} + \left(9.76 + \frac{125}{12}\right)e^{-(t-0.01)/0.00292}$$

$$= -10.417 + 20.177e^{-(t-0.01)/0.00292} \qquad \frac{1}{100} \le t \le \frac{1}{50}$$

b) rms load current

$$I_{rms} = \sqrt{\frac{1}{T}\int_0^T i^2(t)\,d(t)} = \sqrt{\frac{2}{T}\int_0^{T/2} \left[\frac{V_{dc}}{R} + \left(I_{min} - \frac{V_{dc}}{R}\right)e^{-t/\tau}\right]^2 dt}$$

$$I_{rms} = \sqrt{\frac{2}{T}\int_0^{T/2} \left(\frac{V_{in}}{R} + \left(I_{min} - \frac{V_{in}}{R}\right)e^{-t/\tau}\right)^2} = \sqrt{100\int_0^{0.01} (10.417 - 20.177e^{-t/0.00292})^2}$$

$$= 7.0143\ A$$

c) average source current

$$I_{in} = \frac{p_{in}}{V_{in}}$$

$$p_{in} = p_{out} = RI_{rms}^2 = 12 * (7.0143)^2 = 590.4\ W$$

$$I_{in} = \frac{p_{in}}{V_{in}} = \frac{590.4}{125} = 4.72\ A$$