ELEC-E8412 Power Electronics

Exercise # 6_Solutions 26.11.20

Problem 1:

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) an expression for load current,
b) rms load current, and
c) average source current.

Solution:

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

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

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

Part (a)

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

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

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

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

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

Part (b)

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

$$= 7.0143\ A$$

Part (c)

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

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

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

Problem 2:

A square-wave inverter has a dc input of 150 V and supplies a series *RL* load with *R*=20Ω and L=40 mH. The output frequency is 60 Hz.

a) Determine an expression for steady state load current.
b) Sketch the load current and indicate the time intervals when each switch component (Q1, D1; . . . Q4, D4) is conducting.
c) Determine the peak current in each switch component.
d) What is the maximum voltage across each switch?

Assume ideal components.

Solution:

$$T = \frac{1}{f} = \frac{1}{60} = 0.0167\ s$$

$$\tau = \frac{L}{R} = \frac{0.040}{20} = 0.002$$

$$\frac{T}{2\tau} = \frac{0.0167}{2 * 0.002} = 4.175$$

Part (a):

$$I_{max} = -I_{min} = \frac{V_{in}}{R}\left(\frac{1 - e^{-T/2\tau}}{1 + e^{-T/2\tau}}\right) = \frac{150}{20}\left(\frac{1 - e^{-4.175}}{1 + e^{-4.175}}\right) = 7.27\ A$$

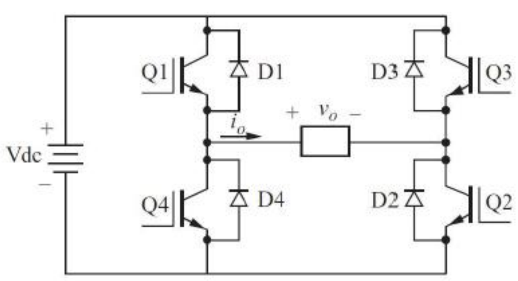
$$i_o(t) = \frac{V_{in}}{R} + \left(I_{min} - \frac{V_{in}}{R}\right)e^{-t/\tau} = 7.5 + (-7.27 - 7.5)e^{-t/0.002}$$

$$= 7.5 - 14.77e^{-t/0.002} \qquad 0 \le t \le \frac{1}{120}$$

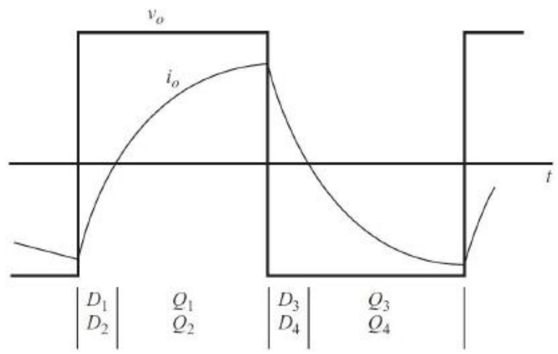
$$i_o(t) = \frac{-V_{in}}{R} + \left(I_{max} + \frac{V_{in}}{R}\right)e^{-(t-\frac{T}{2})/\tau} = -7.5 + (7.27 + 7.5)e^{-(t-0.0084)/0.002}$$

$$= -7.5 + 14.77e^{-(t-0.0084)/0.002} \qquad \frac{1}{120} \le t \le \frac{1}{60}$$

Part (b):



(a)



(b)

Part (c): the peak current in each switch component is equal to the peak output current,

$$I_{max} = \frac{V_{in}}{R}\left(\frac{1 - e^{-T/2\tau}}{1 + e^{-T/2\tau}}\right) = \frac{150}{20}\left(\frac{1 - e^{-4.175}}{1 + e^{-4.175}}\right) = 7.27\ A$$

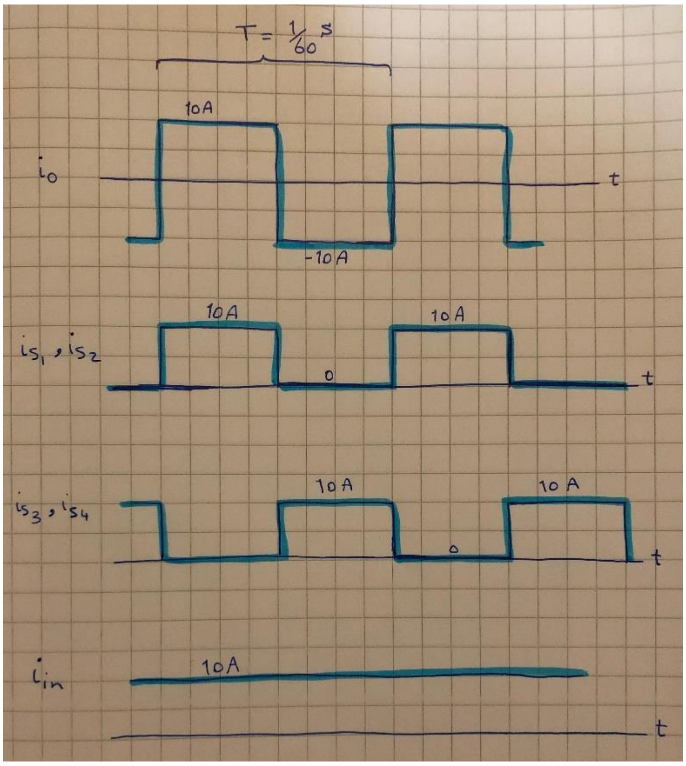
Part (d):

The maximum voltage across each switch is $V_{in} = 150\ V$

Problem 3:

A square-wave inverter has Vdc=125 V, an output frequency of 60 Hz, and a resistive load of 12.5 Ω. Sketch the currents in the load, each switch, and the source, and determine the average and rms values of each.

Solution:



$\langle i_o \rangle = 0$

$\langle i_{s1} \rangle = \langle i_{s2} \rangle = \langle i_{s3} \rangle = \langle i_{s4} \rangle = 5\ A$

$\langle i_{in} \rangle = 10\ A$

$I_{o,rms} = 10\ A$

$I_{s,rms} = \sqrt{50} = 7.07\ A$

$I_{in,rms}$=10 A