Please answer all 5 questions.

Question 1:

Consider a buck-boost converter supplied by a 100 V DC voltage source. Draw the converter circuit (1 p.) and the following waveforms (3 p.): input current (i_{in}), inductor current (i_L), switch current (i_s), diode current (i_d), capacitor current (i_c), and output current (i_o). Calculate the output power, if the load resistance is $R = 15\ \Omega$ and the converter operates with duty ratio $D = 60\ \%$ (1 p.).

You can assume that the capacitor in the circuit is infinitely large. Note that in order to justify some of the current waveforms in this question, you may have to provide some voltage waveform(s) as well.

Question 2:

Draw the circuit of a three-phase voltage source inverter. Write the equations for its line and phase voltages and draw the switching functions and the waveforms of the line and phase voltages, when the inverter operates in square-wave mode (3 p.). Assume balanced load and sinusoidal output current, which lags the fundamental of the phase voltage by 60°. Draw the conducting devices for one period of the output voltage (2 p.).

Question 3:

Why is the efficiency of power converters below 100 %? Where do the losses come from in a linear and *switch-mode power converter* (SMPC)? Which type of losses is dominant in a SMPC? What measures could be taken to increase the efficiency of SMPCs and what restricts those measures?

Question 4:

Consider a three-phase thyristor converter. Assume that the load is a DC current source. Draw the circuit of the converter and the waveforms of the phase voltages, as well as the DC and AC side currents. Derive expressions for the *power factor* (PF) and *displacement power factor* (DPF) (3 p.). What causes the commutation delay and how it affects the input and output current waveforms (1 p.)? Give an approximate expression for the DPF if the commutation interval is known (1 p.). You can assume that the current changes linearly during the commutation.

Question 5:

Consider a single-phase (full-wave) diode rectifier supplied by an ideal AC voltage source. Assume that there is an ideal infinitely large filtering capacitor at the output of the rectifier and the load is an ideal resistor $R = 10\ \Omega$ (Figure 1). Draw the circuit of the rectifier and the waveforms of u_o, i_o, i_{in}, i_R, and i_c (3 p.). Calculate U_o, I_R, I_o and I_c, if the input voltage is $U_{in} = 230$ V and $L = 1$ mH (2 p.).

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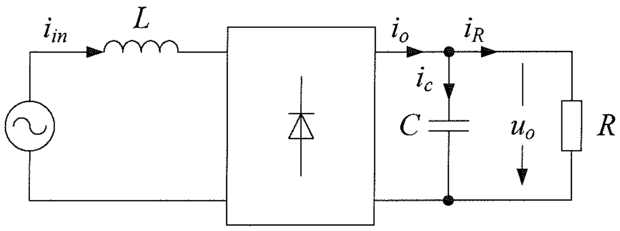

Figure 1: Single-phase diode rectifier with output capacitor and resistor as a load.

Fourier series:

$$f(t) = F_0 + \sum_{h=1}^{\infty} f_h(t) = \frac{1}{2}a_0 + \sum_{h=1}^{\infty}\left[a_h \cos(h\omega t) + b_h \sin(h\omega t)\right]$$

$$F_0 = \frac{1}{2}a_0 = \frac{1}{2\pi}\int_0^{2\pi} f(t)\,d(\omega t) = \frac{1}{T}\int_0^{T} f(t)\,dt$$

$$a_h = \frac{1}{\pi}\int_0^{2\pi} f(t)\cos(h\omega t)\,d(\omega t) \quad b_h = \frac{1}{\pi}\int_0^{2\pi} f(t)\sin(h\omega t)\,d(\omega t) \quad h = 1,2,\ldots,\infty$$