Please answer all 4 questions. The 1st three questions are worth 6 points each and the last is 7 points.

Question 1:

The rectifier in Fig. 1*a* is supplied by a voltage source with waveform as shown in Fig. 1*b*, where $t_H = t_L = 10$ µs, $T = 25$ µs, and $\hat{U}_s = 100$ V. The load consists of a resistance $R = 4\ \Omega$ and a large inductance L connected in series. Assuming ideal diodes and infinitely large L calculate the average output voltage U_o, current I_o, and draw the waveforms of:

a) The supply current i_s, output voltage u_o, and current i_o when $L_s = 0$ H.
b) The supply current i_s, output voltage u_o, and current i_o when $L_s = 25$ µH.

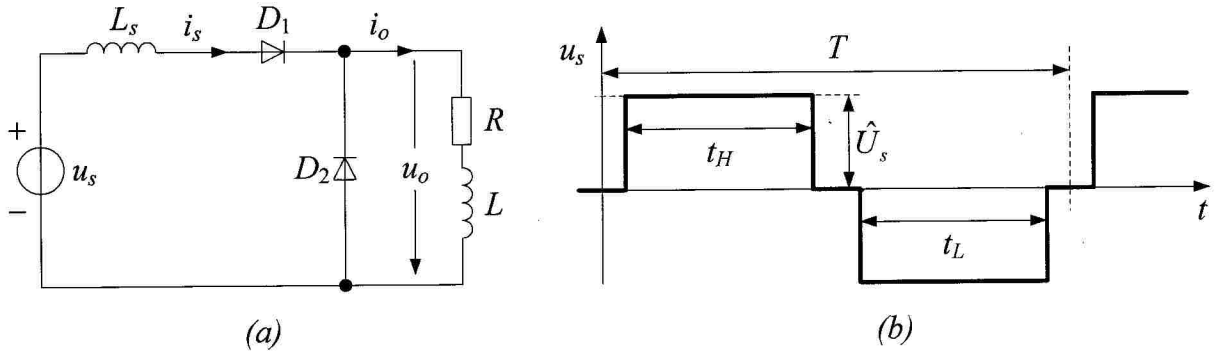

Fig. 1: *a)* Diode rectifier and *b)* voltage source waveform

Question 2:

A three-phase thyristor rectifier is connected to a 50 Hz supply with line-to-line voltage 400 V. Assume that the thyristors are ideal and the load consists of series connected inductance ($L \rightarrow \infty$) and resistance $R = 12\sqrt{2}/\pi$. Draw the input and output voltage and current waveforms when the control angle is 60°. Derive the equations and calculate the average DC voltage, power factor, displacement power factor, crest factor, and total harmonic distortion of the line current. The commutation time can be ignored.

Question 3:

A buck-boost converter operates with duty ratio $D = 60$ % and input voltage $U_{in} = 100$ V. Calculate the input power, if the load resitance is $R = 15\ \Omega$. Draw the waveforms of the input voltage (v_i) and current (i_i), inductor voltage (v_L) and current (i_L), switch current (i_s), diode current (i_d), capacitor current (i_c), and output voltage (v_o) and current (i_o). You can assume that the inductor and capacitor in the circuit are infinitely large and you must justify your waveforms, i.e. provide reason(s) why they are one way or another.

Question 4:

The input voltage of a three-phase PWM inverter (Fig. 2) is 650 V and its frequency modulation ratio is $m_f = 15$. Write the equations for its line and phase voltages. Draw one period of the control voltages for the three phases, if the amplitude modulation ratio $m_a < 1$. Based on your control voltages, draw one

period of v_{CN} and half a period of v_{BN}, v_{AN}, v_{AB}, and v_{An}. Draw your waveforms on the template page with the grid and write your student number on it.

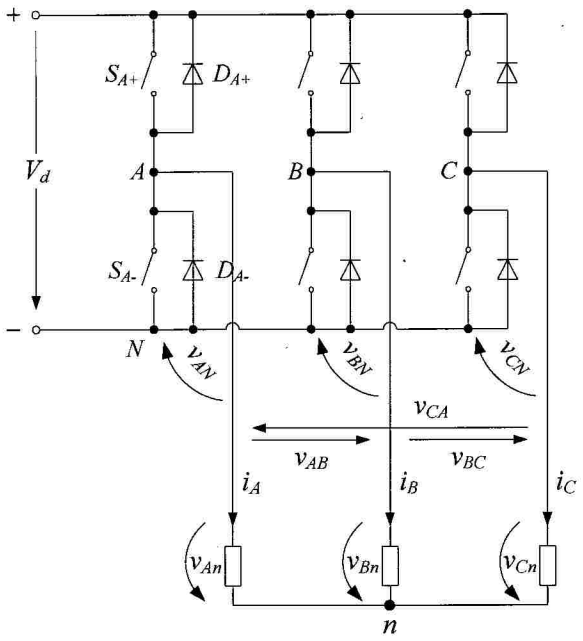

Fig. 2: A three-phase inverter.

Fourier series:

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

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

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