

1. A simplified ideal single-phase thyristor rectifier circuit is shown in Fig. 1.

Assume that the supply voltage  $v_s$  is sinusoidal (RMS value 230V at 50 Hz) and  $\alpha=30^\circ$ . Suppose the components to be ideal (power losses are not taken into account).  $I_d=10A$ .

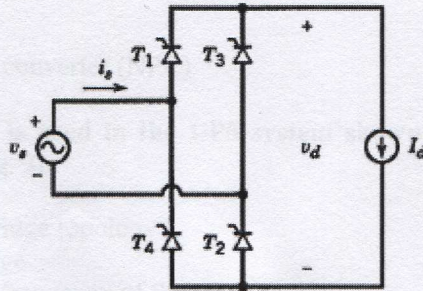
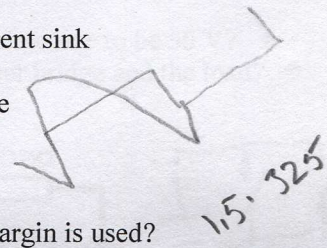


Fig. 1. Single-phase thyristor rectifier loaded by a current sink

- Sketch the waveform of the output voltage  $v_d$  as a function of time
- Calculate the average output voltage value
- Sketch the waveform of the input current as a function of time
- Calculate the rms-value of the input current
- What should be the voltage rating of the thyristors if 1.5 safety margin is used?
- What is the power factor of the rectifier? Hint: in the ideal converter  $P_{in} = P_{out}$



2. Ideal boost converter is shown in Fig. 2.

Output voltage is 48V and input voltage is 12V. The power is 200W and the inductance value is 1mH. Assume that the capacitor voltage ripple is negligible.

- What is the average inductor current?
- Sketch the inductor current waveform
- What is the average capacitor current?
- What is the average transistor current?
- What should be the switching frequency that the peak-to-peak ripple in the inductor current would be 20 %?
- The switching frequency is 10 kHz. How large the inductor should be to achieve 10 % peak-to-peak ripple in the inductor current?

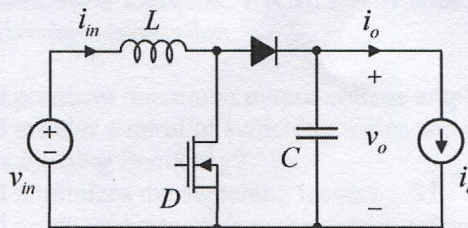


Fig 2. Ideal boost converter

3. Explain shortly the meaning of the following terms

- a) dead time
- b) diode reverse recovery
- c) reactive power
- d) overmodulation
- e) voltage notching
- f) neutral-point clamped converter (NPC)

4. The single-phase inverter is used in the UPS-system shown in Fig. 3a and the output voltage waveform is shown in Fig. 3b.

- a) What is the inverter bridge topology?
- b) Draw the inverter bridge
- c) What is the switching frequency of the transistors?
- d) What is the minimum battery voltage to produce 230Vrms to the load with the bridge topology of a)? The energy efficiency of the inverter is 96 %.
- e) How large the output voltage would be if the battery voltage decrease to be 50 V?
- f) Why inductor and capacitor are connected between the inverter bridge and the load?

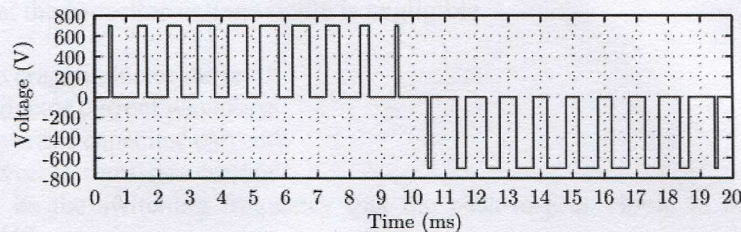
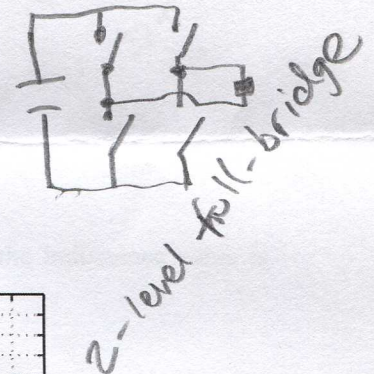
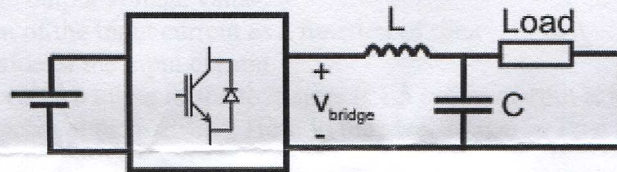


Fig. 3. a) UPS and b) inverter bridge voltage  $V_{bridge}$

5. Compare the following modulation methods: PWM, PWM with 3<sup>rd</sup> harmonic injection, space vector modulation and six-step modulation

- a) Which method produces maximum output voltage amplitude? *six-step*
- b) Which method enables control of switching losses and common mode voltage without changing the switching frequency? *space*
- c) Which method minimizes the switching losses? *space*
- d) Which method produces harmonics to the output voltage at the highest frequencies? *six-step*
- e) Which method is possible to use with single-phase inverters? *PWM/mat*
- f) Which method is possible to use with three-level neutral-point-clamped (NPC) inverters? *kaikkia*

Multiple modulation methods might be a correct answer to one question. In this case, mention all of them.