Tampere University of Technology **DEE-33116 Power Electronics Converters** 22.3.2017
Electrical Engineering
Jenni Rekola Programmable calculator allowed 5 questions/ á 6 p
Answers in English or in Finnish allowed

1. The grid phase-voltage and grid current are shown in Fig. 1

a) What is the rectifier topology used in the system according to the grid current waveform shown in Fig. 1?
b) Draw the rectifier topology used in the system according to the grid current waveform shown in Fig. 1
c) Sketch the waveform of the output DC voltage as a function of time
d) Calculate the average output voltage value
e) What should be the maximum peak repetitive reverse voltage rating of the power semiconductor switching components used in the rectifier if 1.5 safety margin is used?
f) What is the lowest frequency of the produced grid current harmonic component?

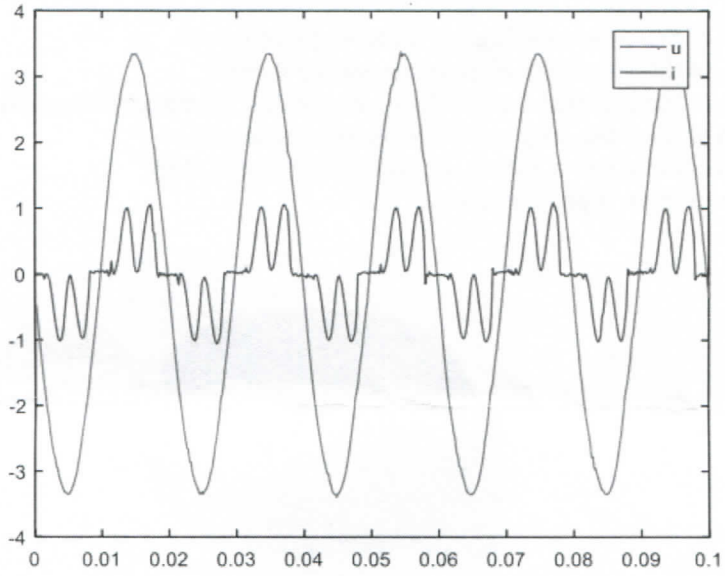


Fig. 1. Measured grid phase voltage (amplitude *100) and grid current (amplitude*10)

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

Input voltage is 12V and output voltage is 48V. The power is 500W. Assume that the capacitor voltage ripple is negligible.

a) What is the average capacitor current?
b) What is the average diode current?
c) Sketch the diode current waveform
d) What is the average transistor current?
e) What is the average input current?
f) The switching frequency is 10 kHz. How large inductor is needed to achieve 20 % peak-to-peak ripple in the inductor current?

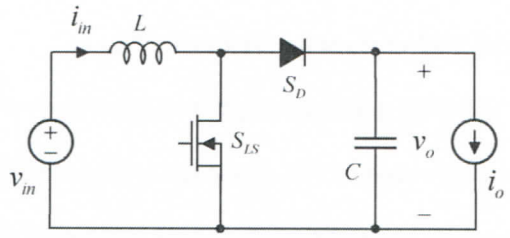


Fig 2. Ideal boost converter

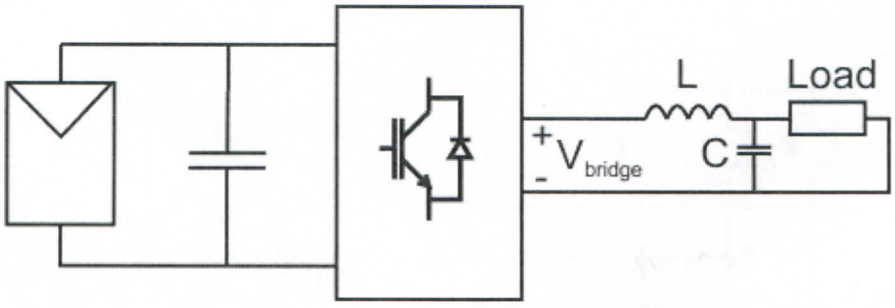
3. **Compare the characteristics of thyristor (SCR), MOSFET and IGBT**

a) Which of these have the highest switching frequency?
b) Which of these have the highest current capability?
c) Which of these are used in conventional welding machines (hitsauskone in Finnish)?
d) Which of these are used in mobile phone chargers?
e) Which of these needs antiparallel connected diode? Why?
f) Which of these is presented in Fig. 3.?

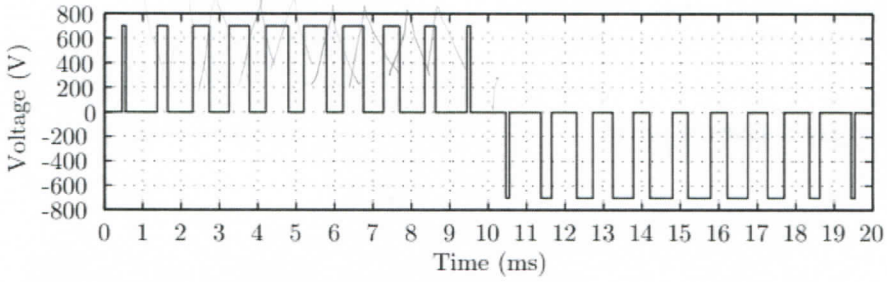
Fig 3. Transistor

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

a) What is the inverter bridge topology used in the solar power system according to the output voltage waveform? Draw the inverter bridge.
b) What is the switching frequency of the transistors?
c) How large DC voltage is produced by the solar power plant?
d) What is the maximum output voltage rms value if conventional sinusoidal PWM modulation method is used in linear modulation region?
e) What should be the PWM modulation index if the load is designed to be grid connected (230 Vrms) and the DC voltage is the same as in Fig. 4b?
f) What is the lowest frequency of the produced output current harmonic component?



a)



b)

Fig. 4. a) Solar power system and b) inverter bridge voltage v_{bridge}

5. Space-vector modulation

Three-phase inverter is shown in Fig. 5a. Suppose that the DC voltage is 560V.

a) What is the length of the active vectors (Fig. 5b)? (1p)

b) The instantaneous reference voltage of the inverter is $v^{ref} = 150\ \mathrm{V} \cdot e^{j\frac{3\pi}{5}}$. Present the switching sequence required to produce the reference voltage (vectors shown in Fig. 5b). The conventional space-vector pulse-width modulation SV-PWM method is used. (2p)

c) What is the maximum output voltage with the analyzed inverter in the linear modulation region when SV-PWM modulation method is used? (1p)

d) What are the advantages of SV-PWM modulation method compared to conventional sinusoidal PWM modulation method? (2p)

The complex space vector of three-phase variable is defined as

$$\underline{x} = \frac{2}{3}\left(x_a + \underline{a}x_b + \underline{a}^2 x_c\right), \qquad \text{where} \qquad \underline{a} = e^{j\frac{2\pi}{3}}. \tag{1}$$

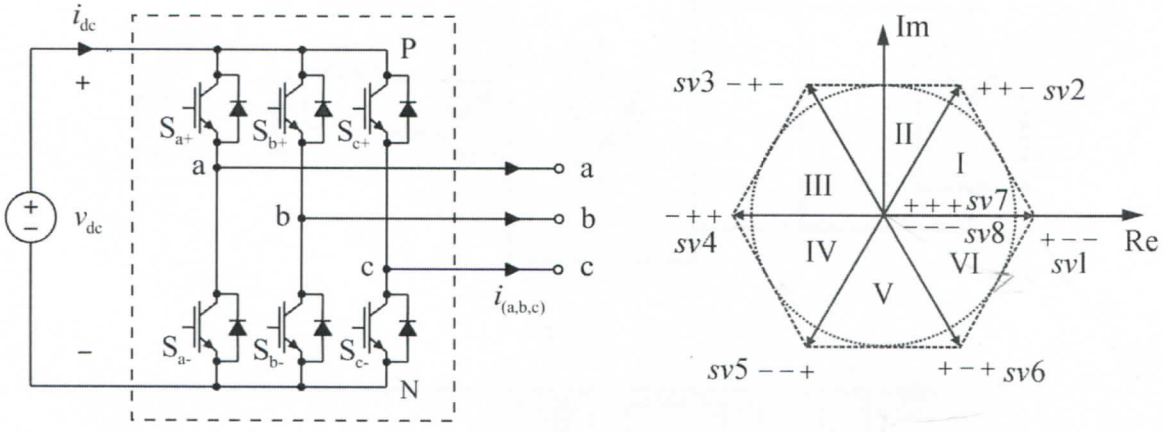


Fig. 5. a) Three-phase inverter b) vector diagram