Tampere University of Technology **DEE-33116 Power Electronics Converters** 14.12.2017
Electrical Engineering
Jenni Rekola Programmable calculator allowed 5 questions/ á 6 p
Answers in English or in Finnish allowed

1. Rectifier

The grid line-to-line voltage (U_{ll}), DC voltage (U_a) and DC current (I_a) are shown in Fig. 1

a) What is the used rectifier topology according to the DC voltage waveform shown in Fig. 1?
b) Draw the used rectifier topology
c) Sketch the waveform of the grid current 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?

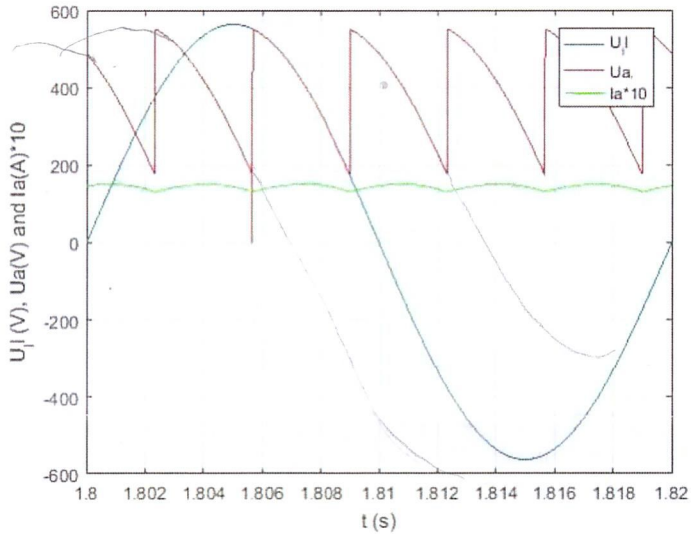
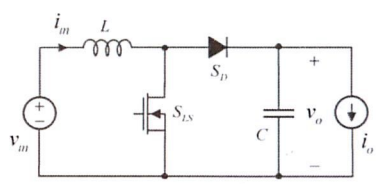


Fig. 1. Grid line-to-line voltage (U_{ll}), DC voltage (U_a) and DC current (I_a)

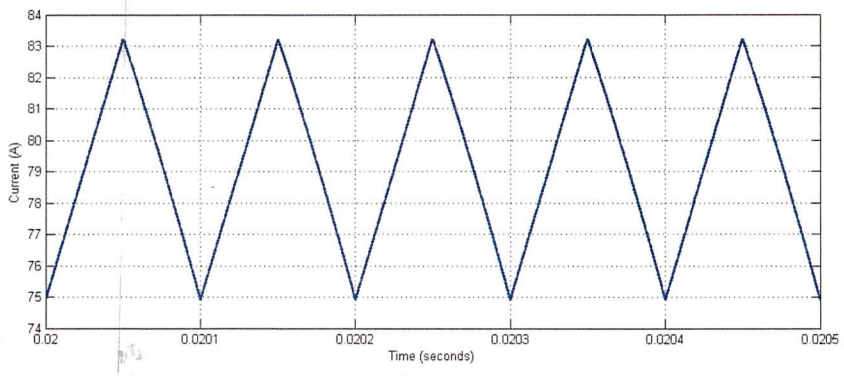
2. Ideal boost converter

Ideal boost converter is shown in Fig. 2a and the input current waveform is shown in Fig. 2b. Input voltage is 100V. Assume that the capacitor voltage ripple is negligible.

a) What is the average input current?
b) What is the average output voltage?
c) What is the inductance L value?
d) What is the average capacitor current?
e) What is the average diode current?
f) Sketch the diode current waveform



a)



b)

Fig 2. a) Ideal boost converter and b) input current

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

a) Which of these have the lowest switching frequency?
b) Which of these have the lowest current capability?
c) Which of these are used in HVDC applications?
d) Which of these are used in mobile phone chargers?
e) Which of these includes a parasitic diode in its structure?
f) Which of these is presented in Fig. 3?

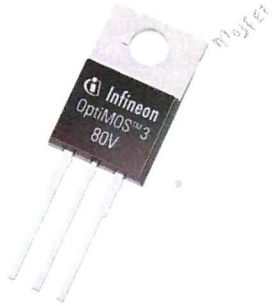
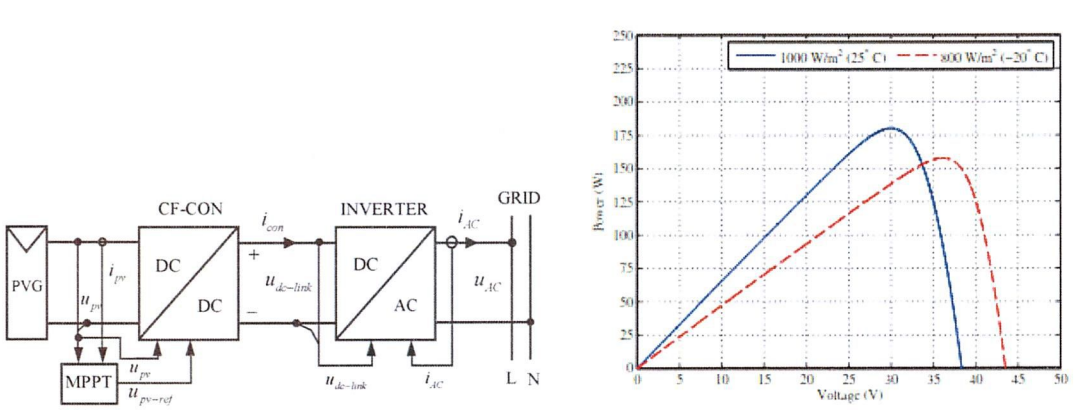


Fig 3. Transistor

4. Single-phase inverter

The single-phase DC/DC converter and inverter is used in the solar power system shown in Fig. 4a. The power-voltage characteristics of a PV module is shown in Fig. 4b.

a) What is the minimum DC voltage $u_{dc\text{-}link}$ if the system is grid connected (230 V_{rms}, 50Hz) and if two-level full-bridge inverter is used?
b) Would it be better idea to use bipolar or unipolar PWM method? Why?
c) Why DC/DC converter is added between solar power panel and inverter?
d) What kind of DC/DC converter is required? Draw the converter.
e) What is the duty cycle of the DC/DC converter in the maximum power point in winter? Minimum DC voltage is produced.
f) What is MPPT shown in Fig. 4a?



a) b)

Fig. 4. a) Solar power system and b) produced power

5. Space-vector modulation

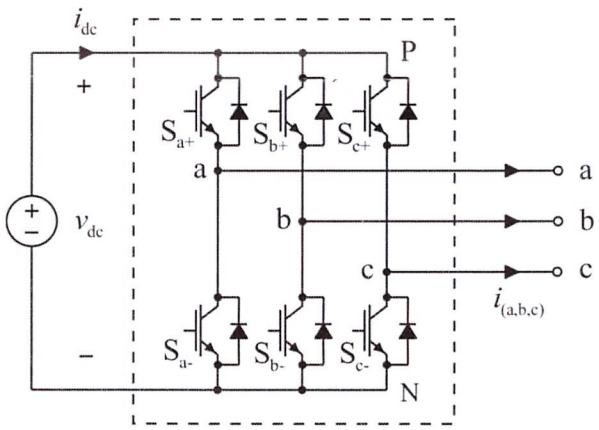
Three-phase inverter is shown in Fig. 5a and the corresponding space vector sectors (i.e., hexagon) in Fig. 5b. Assume that dc-link voltage equals 560 V.

a) What is the length of the active vectors?
b) How many active switching states and zero switching states can be produced by the converter presented in Fig. 5?
c) Present the switching sequence of the inverter bridge when a conventional space-vector pulse-width modulation (SV-PWM) algorithm is used and the reference voltage equals $v^{ref} = 200\ \mathrm{V} \cdot e^{j\frac{7\pi}{4}}$. (2 p)

d) What is the maximum output voltage with the analyzed inverter in the linear modulation region when SV-PWM modulation method is used?
e) What are the advantages of SV-PWM compared to conventional PWM method?

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

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



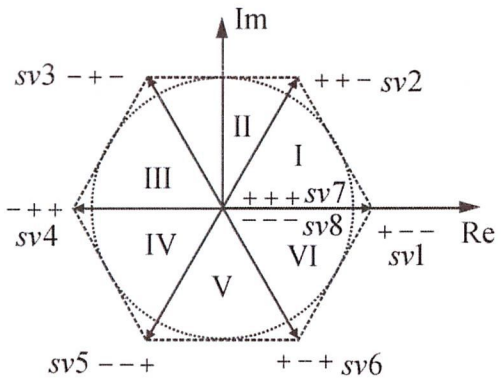


Fig. 5. a) Three-phase inverter b) vector diagram