AMERICAN UNIVERSITY OF BEIRUT

S. KARAKI FACULTY OF ENGINEERING AND ARCHITECTURE

JUNE 6, 2005

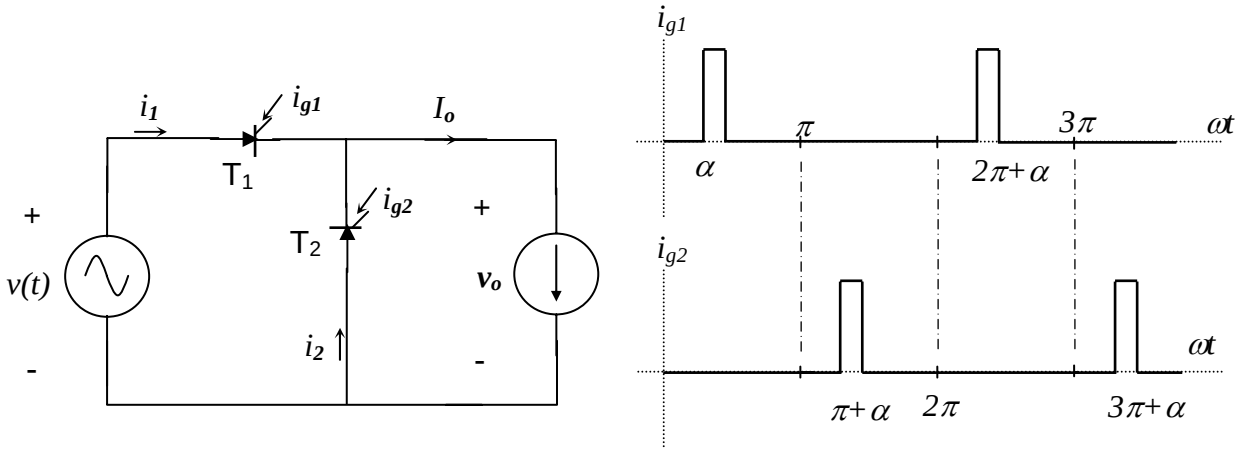
POWER ELECTRONICS (EECE 473)

FINAL EXAMINATION **CLASS OF EE 2006**

CLOSED BOOK (3 HOURS)
PROGRAMMABLE CALCULATORS ARE NOT ALLOWED
THIS QUESTION SHEET MUST BE RETURNED WITH THE ANSWER BOOKLET.

NAME: _____ **ID#: _____**

1. The phase controlled converter shown below along with its gating characteristics supplies a highly inductive load with an average current of I_o. It has a supply voltage $v(t)=V_m sin(\omega t)$ and a firing delay angle of α.



   a) Explain the operation of this circuit and determine its characteristics as the firing delay angle α is varied from 0 to π. Draw the operation quadrants of this converter on a *i-v* plot.
   b) Draw the waveforms on Plot Sheet 1, of v, v_0, i_1, and i_2 for $\alpha = 30°$ and $\alpha = 120°$.
   c) Determine an expression for the rms of the input current i_1 and the average of the output voltage v_0.
   d) Determine an expression for the input power factor of this converter.

2. The speed of a separately excited dc motor is to be controlled by armature voltage control in the range 24 to 72 V. The motor operates with a constant torque and hence constant current at 15A with negligible ripple. A switching mode regulator is to be designed to supply the motor from an available battery of 48V and built using a power BJT that can operate in the range 1 to 25 kHz.

   a) What switching mode regulator would you select? Explain your choice and the operation of the selected regulator and plot appropriate waveforms.

b) What is the regulator's duty cycle range of operation?

c) Determine suitable values for L and C to maintain continous current conduction plus a safe margin and the output voltage peak to peak ripple is less than 0.1V.

d) What is the peak transistor current with L and C as calculated above? What is the effect of the switching frequency and the specified voltage and current variations in Part c above on the peak transistor current.

e) If it is required to perform dynamic breaking on the motor, what minimum additional devices would need to be added to the conventional converter? Draw a diagram of the connections and describe the switching modes involved.

3. It is required to design a single phase inverter that will connect the output of a set of photo-voltaic (PV) arrays to the utility grid at a voltage of 220V line-to-neutral and 50 Hz frequency. A simple design is being considered for the inverter consisting of a half-bridge with the switches controlled using a PWM bipolar voltage scheme. The number of PV panels available are 13, each having a peak voltage of 18V and a power capability of 120W. Due to changes in the solar insolation the voltage of a PV panel may drop. It is required to keep the inverter operating down to a PV pannel voltage of 12V. At this reduced voltage the power capability of a pannel is 30W. To help match the inverter output voltage to that of the utility a step-up transformer may be used. The utility may be modeled by its thevenin equivalent consisting of a voltage source of 220V in series with an inductance of 1.4 mH.

   a) Draw a single-line circuit diagram showing how the switch configuration of the half bridge inverter would connect to the PV arrays one side and to the utility on the other. Explain the operation of the inverter and draw its voltage output, on Plot-Sheet 2, using a frequency modulation factor m_f= 7 for illustrative purposes.

   b) Three transformers are available with turns ratio of 1:2, 1:3, and 1:4 of leakage inductance of 10 mH referred to the high voltage side and of negligible series resistance. Which transformer should be selected and what would be the corresponding range of (m_a) the amplitude modulation index?

   c) The frequency modulation index of the system is m_f= 21. Using the harmonics table of a bipolar PWM voltage scheme given in the formula sheet, determine the rms of the 5 most dominant harmonic voltages. What do you notice about the harmonic content shown in the table in terms of its order and magnitude? Explain.

   d) Draw the equivalent circuits, referred to the inverter side, at the ripple and fundamental frequencies showing the inverter output connected to the grid. Label the equivalent circuits with correct impedance and source voltage values. For m_a= 1 and m_f= 7, on Plot-Sheet 2, draw the output voltage, its fundamental component, the ripple voltage and corresponding ripple current. Estimate approximately the maximum magnitude of the current ripple.

   e) Draw the phasor diagram at the fundamental component showing the inverter output voltage, the utility voltage, the voltage drop across the leakage and utility Thevenin inductances. What should be the fundamental component of the voltage (V_{o1}) for the current to be in phase with the utility voltage. In this case what is the power supplied by the PV cells if the inverter efficiency is 85%?