UNIVERSITY OF AGDER

FACULTY OF ENGINEERING AND SCIENCE

EXAMINATION

Course code:	**ENE505**
Course name:	**Power Electronics for Renewable Energy**
Date:	13 Dec 2016
Duration:	4 hours
Total number of pages	4
Permitted tools:	Approved type of scientific calculator, physical and mathematical tables. No textbooks, mobiles, tablets.
Notes:	Make suitable assumptions if necessary.

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1. A buck-boost DC-DC converter is used for maximum power point tracking of solar photovoltaic system (Fig. 1).

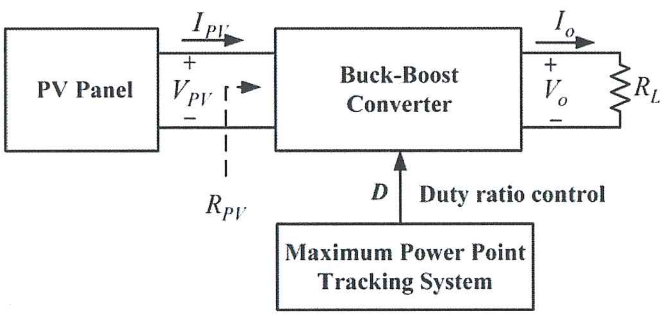

Fig.1

DC-DC converter diagram is given in Fig. 2. Please note that $V_{PV} = V_d$

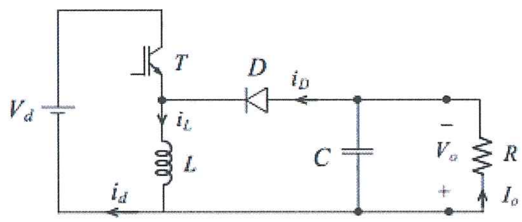

Fig.2

The DC-DC converter is operating under steady state. The switching frequency is 400 kHz. This buck-boost converter is to be designed under the following conditions: V_d = 12 V, D = 0.6, P_o = 36 W, L = 25 μH. Assume ideal components.

(i) Calculate and draw the waveforms for the variables.

(ii) In this converter, the output load is changing. Calculate the critical value of the output load (i.e. P_o) below which the converter will enter the discontinuous conduction mode of operation.

(iii) Calculate the critical value of the inductance (L) below which this converter will enter the discontinuous conduction mode of operation at $P_o = 5$ W.

(25 marks)

2.

2.1 For designing feedback controller, the power stage of the DC-DC converter must be linearized around the steady state DC operating point, assuming a small signal disturbance. A typical linearization of the switching power-pole is given in Fig. 3. Each average quantity in Fig. 3 can be expressed as the sum of its steady state dc value (represented by upper case letter) and a small-signal perturbation (represented by a '~' on top). Neglect the products of the small perturbation terms.

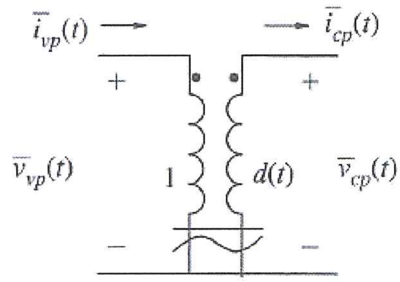

Fig. 3

$$d(t) = D + \tilde{d}(t)$$

$$\bar{v}_{vp}(t) = V_{vp} + \tilde{v}_{vp}(t)$$

$$\bar{v}_{cp}(t) = V_{cp} + \tilde{v}_{cp}(t)$$

$$\bar{\imath}_{vp}(t) = I_{vp} + \tilde{\imath}_{vp}(t)$$

$$\bar{\imath}_{cp}(t) = I_{cp} + \tilde{\imath}_{cp}(t)$$

Draw the linear representation of power-pole for small signals around a steady state operating point given by D, V_{vp}, I_{cp}.

(15 marks)

2.2 Draw linearized single switch converter for a buck converter in CCM.

(10 marks)

3.

3.1 A single phase diode bridge rectifier is used for storing the electrical energy in the form of electrolytic hydrogen through electrolyzer. This rectifier has lower power quality. It is operating under the following conditions: Supply current (I_s) 10 A (rms), fundamental frequency input current (I_{s1}) 8 A (rms), and it is operating at displacement power factor (DPF) of 0.85.

Calculate (a) distortion component of the input current ($I_{distortion}$) and (b) total harmonic distortion (THD) and (c) overall power factor of the load. Give comments on the results.

(15 marks)

3.2 Draw a block diagram for power factor correction (PFC) circuit along with its control circuit. And briefly explain its operation.

(10 marks)

4.

4.1 A single phase AC-DC power factor correction (PFC) boost converter is given in Fig.4.

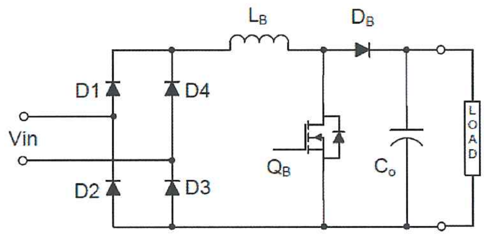

Fig. 4. PFC boost converter

It is operating in continuous conduction mode. For improving the input supply power factor to unity, duty ratio needs to be varied. In this circuit V_{in} is 120 V rms at 60 Hz. The output voltage V_d is 250 V and the output power is 300 W. Calculate and draw the following waveforms, synchronized to V_{in}, inductor current $i_L(t)$, duty ratio $d(t)$, and the load current as well as capacitor current.

(17 marks)

4.2 DC-DC converters are widely used in renewable energy systems and their operations are controlled through pulse-width modulator (PWM). Describe linearization of PWM of DC-DC converters using control voltage $v_c(t)$ generated through error amplifier and compared with a ramp signal with peak value $\hat{V}_r$ at constant switching frequency f_s. Find linearized transfer function associated with the PWM.

(8 marks)

Appendix: Formulas

Voltage drop across an inductor: $v_L = L\frac{di_L}{dt}$

Current through a capacitor: $i_C = C\frac{dv_C}{dt}$

<u>Buck-Boost Converter</u>

$$V_o = \frac{D}{1-D}V_{in}$$

$$\Delta i_L = \frac{1}{L}V_{in}(DT_s) = \frac{1}{L}V_0(1-D)T_s$$

$$I_{in} = \frac{D}{1-D}I_o$$

$$I_{L,critical} = \frac{V_{in}}{2Lf_s}D\ (average\ value)$$

<u>Displacement Power Factor (DPF)</u>

$$DPF = cos\emptyset_1$$

$$PF = \frac{1}{\sqrt{1+\left(\frac{\%THD}{100}\right)^2}}DPF$$

$$PF = \frac{I_{s1}}{I_s}DPF$$

$$I_s^2 = I_{s1}^2 + I_{disto}^2$$

$$\%THD = \frac{I_{distortion}}{Is1}x100$$

Distortion Factor (DF) $DF_n = \frac{V_{on}}{V_{01}n^2}, for\ n > 1$

Single Phase PFC output current

$$i_d(t) = \frac{1}{2}\frac{\widehat{V_{in}}}{V_d}\widehat{I_L} - \frac{1}{2}\frac{\widehat{V_{in}}}{V_d}\widehat{I_L}cos2\omega t.$$