TSTE19
Power Electronics

Examination (TEN1)

Time:	Monday 25 March 2013 at 8.00 - 12.00
Place:	U3
Responsible teacher:	Kent Palmkvist, ISY, 28 13 47, 0705 23 31 59 (kentp@isy.liu.se) Will visit exam location at 9 and 11.
Number of tasks:	5
Number of pages:	4 (including this one)
Allowed aids:	Calculator
Notes:	A pass on the exam requires approximately 30 points. Remember to indicate the steps taken when solving problems. Answers may be given in Swedish and/or English.
Exam presentation:	Monday 8 April 2013 12.30-13.30 (Kent Palmkvist's office)

1. a) What will be the output waveform shape of a PWM based DC-AC inverter if the controlling sinusoidal waveform is driving the inverter with maximum overmodulation? (2)

b) Is the speed of the induction motor dependent on the amplitude or frequency of the input voltage? (2)

c) Does a power bipolar transistor have a larger or smaller current amplication factor B compared to a small signal bipolar transistor? (2)

d) Can the switch mode DC-AC inverter feed energy back into the voltage source? (2)

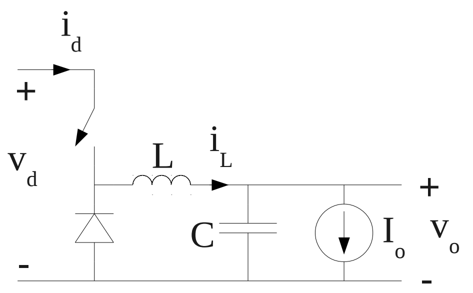
e) What does the acronym IGBT mean? (2)

2. The buck converter shown below is generating an output voltage V_o = 3 V. The inductor L = 18 μH, switching frequency f_s = 50 kHz, C is large, switching ratio D = 0.1, and the input voltage V_d = 12 V.

a) What is the output current I_O? (6)

b) What is the average input current I_d? (4)

c) At what switching ratio D will the converter switch from discontinuous mode to continuous mode? (4)

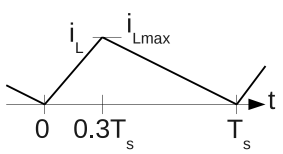


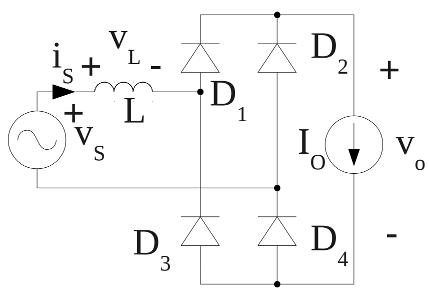
3. Assume the inductor current i_L shown below is the inductor current of the buck converter above (at a different D, V_O and I_O setting compared to task 2). Assume the maximum ripple voltage is defined as 0.1 V, T_s = 20 us, and that i_{Lmax} = 6 A.

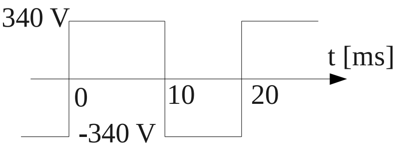
a) Draw the output voltage ripple on V_O. (4)

b) What minimum size of C to keep the ripple within limits? (6)

c) What will be the additional ripple voltage contributed by capacitors ESR if it is 0.1 Ω? (4)





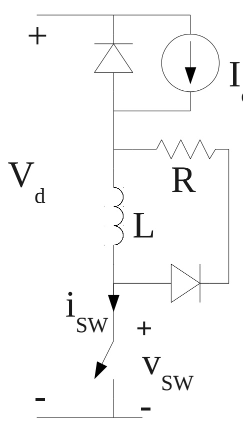


4. The full-bridge rectifier shown above to the left have the source voltage v_S shown above to the right. The inductor L = 34 mH and the output current I_O = 10 A.

a) Draw the current i_S and voltages v_L and v_O waveforms. Indicate also when each diode is conducting or not conducting. (6)

b) Calculate the average output voltage V_O. (6)

c) What is the source displacement power factor (DPF)? (4)



5. The snubber circuit above is designed to reduce the di/dt over the switch at turn-on. The switch have a t_{ri} of 4 µs. The input voltage V_d is 200 V, and the output current I_0 is 10 A. The turn-on snubber shall be designed so that the switch voltage at turn on is 5% of the V_d voltage, and that the switch current I_{SW} is equal to I_0 after t_{ri}. The switching frequency is 1 kHz. Assume the snubber time constant is much larger than the transistor turn-off time.

a) Draw the waveform of the switch current i_{SW} and voltage v_{SW} when turning on the switch turns on and when the switch turns off. (4)

b) Calculate the value of L. (6)

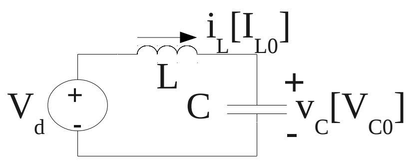
c) Assume the turn-off switch voltage v_{SW} is not allowed to be larger than twice the value of V_d. What is the largest allowed value of R? (6)

Formula collection TSTE19 Power Electronics

Fourier series coefficients using symmetri, Table 3.1

Even	$f(-t)=f(t)$	$b_h=0$	$a_h=\frac{2}{\pi}\int_0^{\pi} f(t)\cos(h\omega t)\,d(\omega t)$
Odd	$f(-t)=-f(t)$	$a_h=0$	$b_h=\frac{2}{\pi}\int_0^{\pi} f(t)\sin(h\omega t)\,d(\omega t)$
Half-wave	$f(t)=-f(t+\frac{1}{2}T)$	$a_h=b_h=0$ for even h	
		$a_h=\frac{2}{\pi}\int_0^{\pi} f(t)\cos(h\omega t)\,d(\omega t)$ for odd h	
		$b_h=\frac{2}{\pi}\int_0^{\pi} f(t)\sin(h\omega t)\,d(\omega t)$ for odd h	
Even quarter-wave	Even and half-wave	$b_h=0$ for all h	
		$a_h=\frac{4}{\pi}\int_0^{\frac{\pi}{2}} f(t)\cos(h\omega t)\,d(\omega t)$	for odd h
		$a_h=0$	for even h
Odd quarter-wave	Odd and half-wave	$a_h=0$ for all h	
		$b_h=\frac{4}{\pi}\int_0^{\frac{\pi}{2}} f(t)\sin(h\omega t)\,d(\omega t)$	for odd h
		$b_h=0$	for even h

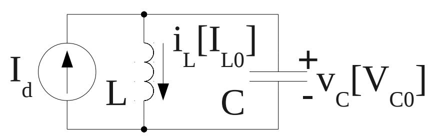
Undamped series resonant circuit, equations 9-3, 9-4



$$i_L(t)=I_{L0}\cos\omega_0(t-t_0)+\frac{V_d-V_{c0}}{Z_0}\sin\omega_0(t-t_0) \qquad (9\text{-}3)$$

$$v_c(t)=V_d-(V_d-V_{c0})\cos\omega(t-t_0)+Z_0 I_{L0}\sin\omega_0(t-t_0) \qquad (9\text{-}4)$$

Undamped parallel resonant circuit, equations 9-20, 9-21



$$i_L(t)=I_d+(I_{L0}-I_d)\cos\omega_0(t-t_0)+\frac{V_{c0}}{Z_0}\sin\omega_0(t-t_0) \qquad (9\text{-}20)$$

$$v_c(t)=Z_0(I_d-I_{L0})\sin\omega(t-t_0)+V_{c0}\cos\omega_0(t-t_0) \qquad (9\text{-}21)$$

Integration rules

$$\int_a^b f(x)dx=\int_A^B f(g(t))g'(t)dt \quad \text{if } a=g(A),\ b=g(B),\ \text{and } g \text{ is monotone in } [A,B]$$

$$\int_a^b \sin(x)\,dx=\left[-\cos(x)\right]_a^b$$

$$\int_a^b \cos(x)\,dx=\left[\sin(x)\right]_a^b$$