Department of
ENERGY TECHNOLOGY
Aalborg University

E.T.

Written re-examination in

High Voltage Engineering and Design of Switch Mode Converters

Monday 27th of February 2012

09.00 – 13.00 (4 hours)

Please provide sufficient text description and reference to textbook and equations so your method of solution is clear and easy to follow. Statements and results will only give credit if explained thoroughly.

Both the HV part and the SMC part individually have to be passed in order to pass the course. This means that at least 50 % of both the HV exercise and the SMC exercise have to be correctly answered.

The HV exercise and the SMC exercise have the same weight.

Exercise 1 (High Voltage)

A company tests their dielectric materials by placing them in a test capacitor setup. Suppose you can assume that such capacitor is an ideal plate capacitor possessing a uniform field. In this exercise the dielectric material is inserted in the test capacitor in all questions a-e.

a) The test capacitor (including the dielectric material) has a capacitance C = 43,8 pF, a diameter D = 10 cm and a gap length d = 1 cm. Calculate the relative permittivity of the dielectric material assuming the capacitor is lossless.

b) The test capacitor is energized with DC High Voltage. The voltage is measured by means of a sphere gap. This sphere gap breaks down for a gap length (sphere diameter 12,5 cm) of 20 mm. The ground return current is measured with a precise ammeter to I = 12 pA (neglect all stray fields and creeping currents). Calculate the DC specific conductivity σ_0 of the dielectric material.

c) Now the test capacitor is tested with the Schering Bridge. The bridge is balanced for 50 Hz with R_4 = 1000/π Ω and C_4 = 300 nF. Calculate the dielectric loss angle? Sketch the loss angle by means of a phasor diagram.

d) Calculate the effective relative complex permittivity $\tilde{\varepsilon}_r = \varepsilon'_r + j\varepsilon''_r$ for the dielectric material. Explain the importance of the real and imaginary part of the complex permittivity and calculate the ratio of the conductive losses to the polarization losses.

e) Calculate the specific losses [mW/cm^3] of the dielectric material exposed to a 50 Hz alternating electric field stress with a peak value E = 11,34 kV/mm

Exercise 2 (High Voltage)

Danish Transmission system operator Energinet.dk is replacing major parts of the transmission network with PEX cables. All new installations are made with PEX cables. Such an example is the Anholt offshore wind farm connection at 220 kV (245 kV maximum). Such cables are frequently on-site HV tested after installation. According to IEC 60840 the test voltage should (for this voltage level) be 1,3 * maximum voltage between phase conductor and screen. The Anholt cable has a length of 55 km and a capacitance per phase C = 0,25 μF/km.

a) What will be the reactive power necessary to test one phase of the cable in its full length? Comment on the practical application of such level of reactive power for testing.

b) In order to test such large cables series resonant circuits are used. Test frequency can be in the range of 30 – 200 Hz for PEX cables. Draw a simple single line diagram of such test setup and calculate the inductance of the reactor for both 30 Hz and 200 Hz.

c) Assume a quality factor Q = 200 for the reactor and neglect losses in the cable. Calculate necessary supply voltage and current to supply the resonant test circuit for the two frequencies in b)

d) Select a test frequency (30 Hz or 200 Hz). Justify your answer!

Exercise 3 (Design of Switch Mode Converters)

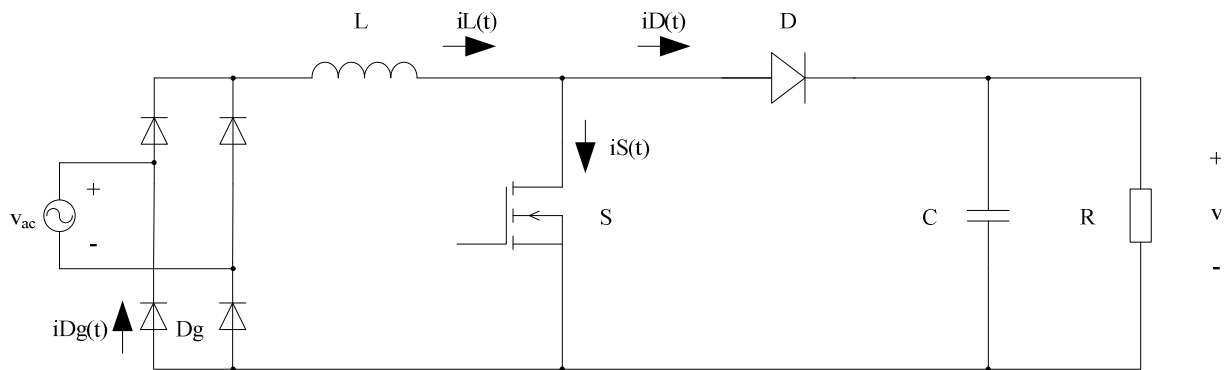Current Programmed Control of Buck-Boost converter
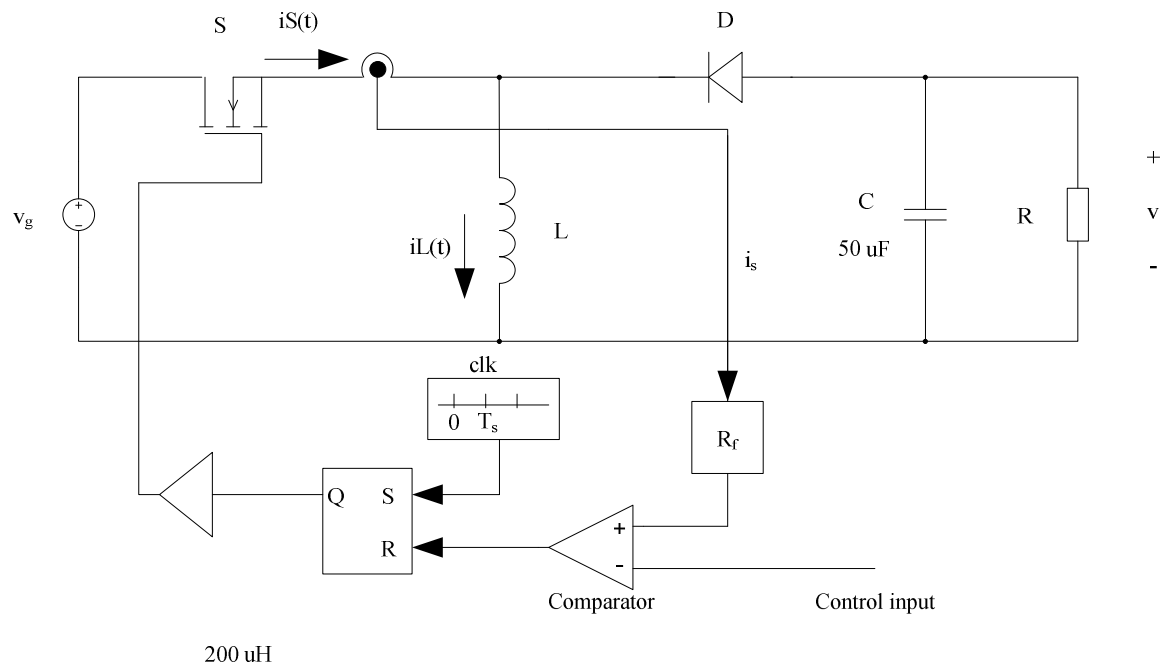
T_s = 10 μs   R= 20 Ω V_g = 20 V   V = -100 V R_f = 1 Ω L= 200μH

Assume ideal components (=> no power loss in power conversion)

a) Calculate the steady state average current value of the switch S.

b) Calculate the slopes m1 and m2.

Exercise 4 (Design of Switch Mode Converters)

Design a boost converter,

Specification:

Output voltage	390 V
Output power	500 W
Rms input voltage	230 V
Efficiency	1.0
Fundamental frequency	50 Hz
Switching frequency	100 kHz

In question a, b, c and e assume the converter operate in CCM and switching frequency ripple current in L is very small – so small you may ignore it.

a) For one fundamental period sketch the current of iDg(t) and v_{ac}(t) label the axis

b) For one switching period sketch the current of iS(t) assume the average current is 1 A and the duty-cycle of S is 25 %. Label the axis

c) Calculate the RMS value of the inductor current iL(t).

d) For what values of L is the converter operating in CCM?

e) Sketch the waveform of the current in capacitor C. Label the axis.