Massachusetts Institute of Technology

Department of Electrical Engineering and Computer Science

6.061 and 6.690 Introduction to Power Systems

Problem Set 3 — Issued February 14, 2011

Due February 23, 2011

Problem 1: Problem 9 from Chapter 2 of the text.

1. Please note that, in part d), the voltage asked for is across the resistor. Plot this vs. capacitance for $.5C_c < C < 2C_c$, where C_c is the capacitance you calculated in part b).
2. Part e): For the conditions of part d), calculate and sketch (or plot) real and reactive power from the source.

Problem 2: Problem 11 from Chapter 2 of the text.

Problem 3: Figure 3 shows, in schematic form a *boost* converter. We will make some approximations to try to understand how this thing works. For this circuit, $L = 10mH$, $C = 50\mu F$ and $R = 40\Omega$. Source voltage is $V_s = 10$ volts.

The switch is operated in the same fashion as the switch in the 'buck' converter you analyzed in Problem Set 2. This one has a basic switching frequency of 10 kHz. So each cycle the switch is on for $t_{on} = TD$ and off for $t_{off} = T(1 - D)$.

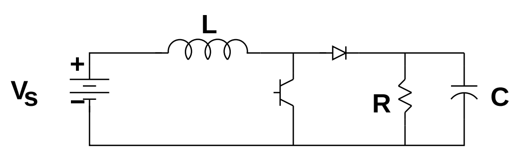

Figure 1: Boost Converter

1. Assuming that the component values are such that current in the inductor is continuous (that is, never goes to zero), what is the output voltage as a function of the duty cycle D? What is the *average* current in the inductor?
2. Now, assuming for the moment that the capacitor voltage is just about constant, what is the ripple in the inductor? Do a labeled sketch of that current, showing the average, maximum and minimum values and the ripple amplitude.
3. Assuming that inductor current is nearly constant, estimate ripple *voltage* across the capacitor (which is also output voltage).
4. How realistic were your assumptions?
5. For 6.690: Use MATLAB to simulate a startup transient.Start with zero current in the inductor and zero voltage across the capacitor. Use a duty cycle of 50 %. Run the simulation until you approach steady state.

Problem 4: This is a transmission line problem. The situation is shown in Figure 2. The 8 kV (RMS) source is feeding a 100Ω load through a transmission line which may be represented as a simple inductance. Two capacitors that can provide reactive power are connected at either end of the line.

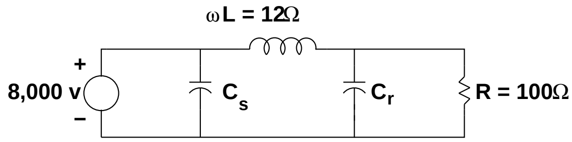

Figure 2: Compensated Load

1. Assuming both capacitances to be zero, draw a phasor diagram showing sending and receiving end voltages and voltage across the transmission line. What is power dissipated in the resistance?
2. Size the receiving end capacitance C_r so that receiving end voltage is equal in magnitude to sending end voltage.
3. For 6.690: Calculate and plot, over the range of $1\mu F < C_r < 3\mu F$, receiving end voltage. You will probably want to use MATLAB to do the grunge work here.
4. For 6.690: Calculate and plot sending end real and reactive power, assuming that $C_s = C_r$ for the same conditions as the previous part.

Problem 5: Current Source Inverter:

Figure 3 shows, in highly simplified form, a situation similar to the inverters that are use for some renewable generation sources (wind, solar, ...). The current source on the left represents an inverter that is injecting current into the power system. The system itself is represented by the reactive impedance (representing a transmission line) and the voltage source on the right. For the moment we will assume a single phase system, although that is not the way most systems are built.

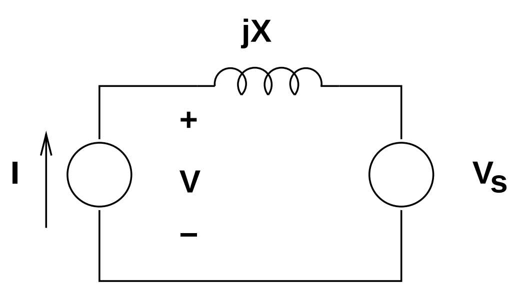

Figure 3: Inverter Connected to Power System

Assume the transmission line reactance $X = \omega L = 4\Omega$. The voltage source on the right is $V_s = 10kV$ (RMS). The current source on the left injects 250 A (RMS) into the system with a power factor angle **with respect to its measured terminal voltage**.

1. Calculate the terminal voltage V, assuming the power factor of the current injection is: a) unity, b) 0.9, current lagging voltage, and c) 0.9, current leading voltage.
2. (For 6.690) Calculate and plot the terminal voltage for the same three cases for current between $0 < I < 250A$
3. (Also for 6.690) Do the same calculation, for the same set of power factor angles, but this time assume the *Real* power varies between zero and 2.5 MW.

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6.061 / 6.690 Introduction to Electric Power Systems
Spring 2011

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