Massachusetts Institute of Technology
Department of Electrical Engineering and Computer Science
6.061/6.690 Introduction to Power Systems

Problem Set 7 — Issued March 27, 2011 — Due April 6, 2011

Problem 1: Figure 1 shows a load flow situation. There are two generators, one generating at unity power factor, the other under voltage control. The generator on bus 1 is producing two per-unit real power and zero reactive power. The generator on bus 3 is providing one per-unit real power and is controlled to unity voltage. There are loads of two per-unit on bus 2 and one per-unit on bus 5. Bus 4 is the 'swing bus', with voltage magnitude of one and angle of zero.

For this problem, calculate the bus voltages and line currents. In your answer, generate a list of bus voltage magnitudes and angles and a list of line currents. Also, estimate the reactive power supplied by the generator at Bus 3 and the real and reactive power supplied by the swing bus. To assist in this you will find a nearly complete, simple load flow program on the web site. You will need to fill in the bus incidence matrix.

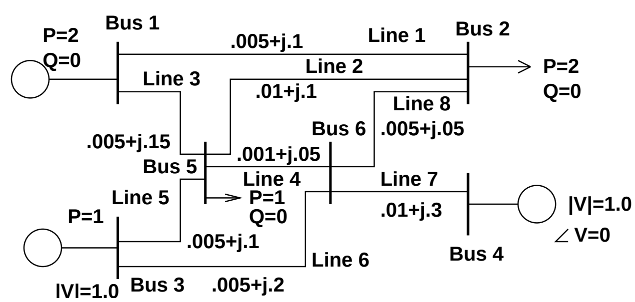

Figure 1: Load Flow Problem

You will note that the voltages at the various buses are actually not very good. It would be good if we could get the voltage magnitudes to be within ±5% of one per-unit. You should be able to accomplish this by injecting some reactive power into the system at selected points. Figure out where and how much reactive power to inject and show, with a run of the program, that this does correct the voltage profile to within the required tolerance.

Problem 2: Figure 2 shows two views of a linear actuator. It consists of a core that is basically "U" shaped. The moving element is a flat bar that is restrained by a mechanism not shown to be in one direction (noted by the position x, which is how far that bar extends into the gap area. There is a current NI in a coil that is wrapped around the core. In terms of the directions shown in the sketch, estimate and sketch, as a function of x, the force of magnetic origin pulling the bar into the gap. Assume that the bar length $L = 2D$,

Problem 3: Figure 3 is a cartoon picture of a core to be used for an inductor. The core consists

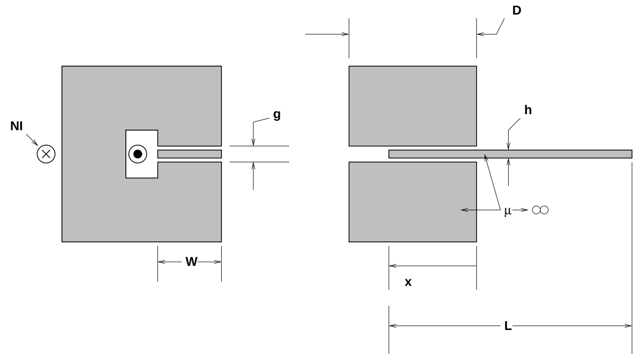

Figure 2: Linear Actuator

of two "U" shaped elements that are identical, separated by a fixed gap. The core elements are highly permeable and the gap has the magnetic properties of air. The dimensions are:

Depth	D	4 cm
Core Width	W	2 cm
Window Width	W_w	2 cm
Window Height	H	2 cm
Gap	g	$1/2mm$

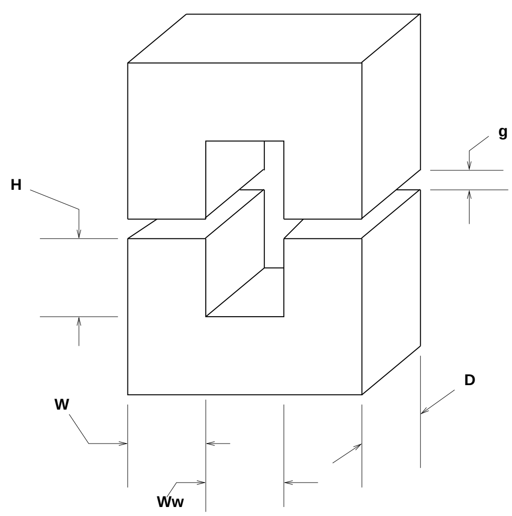

Figure 3: Transformer Core

1. Assuming a winding with $N = 100$ turns is wound on the core. What is the inductance of that coil?
2. How much current can this coil carry before saturating the core? (Assume that saturation flux density is about 1.8 T).
3. (For 6.690) Now we let the gap dimension and number of turns vary as required. We want to design an inductor with an inductance of 10 mH and the maximum current capability (corresponding to saturation of the core).

Problem 4: Figure 4 shows a rather fanciful and cartoonish picture of a magnetically levitated vehicle similar to the "Trans-Rapid" train developed in Germany. The purpose of this problem is to look into two aspects of the magnetic levitation support.The car is supported by two levitation rails, each of width w and length L (not shown in the illustration, but L approximates the length of the car). The stationary rail is fastened to the underside of a structural system that holds everything up. The car carries a magnetic circuit which consists of a series of poles with coils wrapped around them. Assume the number of poles is even so there is an equal number of north and south poles.The rails are of width w and you can assume that the stationary and moving structures are of the same width. Assume that the rails and poles are of highly permeable material ($\mu \rightarrow \infty$).

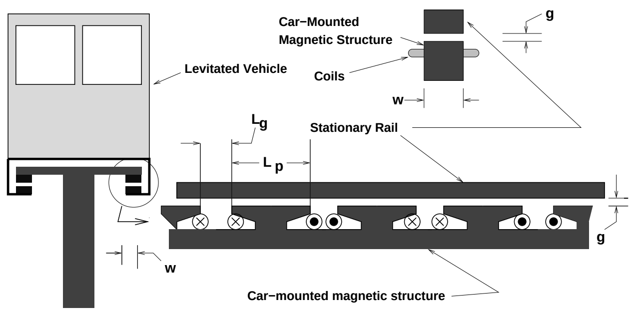

Figure 4: Maglev Rail Car

1. Assume the car weighs about 40 metric tons (40,000 kg) and that the active length of each of the two rails is $L = 12m$ and the active width is $w = 10cm$. If the car is to be suspended with a gap of about one centimeter ($g = .01m$), what is the required current (NI) in each pole? Note, NI is total ampere-turns per pole, and you don't need to worry about how that is divided into turns. Assume the pole gap L_g is small compared with the pole length L_p.
2. Assume the current in the lifting coils is set to the value you calculated in the previous part. Estimate and sketch the lift force as a function of gap over the range $0.5cm < g < 1.5cm$.
3. Note that this suspension force is *unstable* (why?) so that an active control system will be required.
4. There will also be a *lateral* force if the car becomes misaligned to the side. What is this force? Estimate its magnitude and sketch it as a function of lateral displacement. Is the cars lateral position stable or unstable?