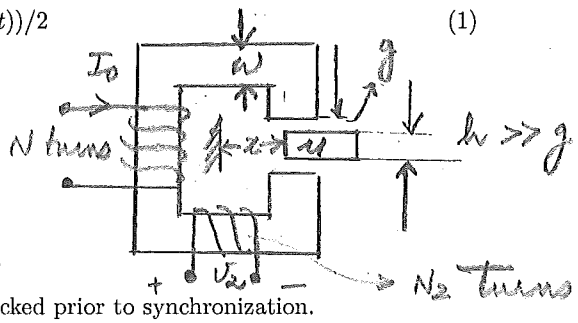
ECE 331: Energy Conversion: Sample Questions: Magnetic Circuits, Transformers, Induction machines, Synchronous generators

1. The magnetic circuit has a movable plunger (position x) supported such that it can slide in and out of the core while maintaining a constant air gap of length g on each side of the core. Assume that the plunger and the core have infinite permeability. The motion of the plunger is constrained by $0 \leq x \leq b$. There are two windings on this circuit. The first has N_1 turns and carries a constant (dc) current of I_0. The second, which has N_2 turns is open circuited. Neglect fringing.

- 1. (6 pts) Determine an expression for the mutual inductance between windings 1 and 2 as a function of the plunger position x.
- 2. (4 pts) Determine an expression for the voltage induced ($v_2(t)$) if the plunger is driven by an external source such that its motion is given by

$$x(t) = b(1 + sin(\omega t))/2 \quad (1)$$



2. A synchronous generator needs to be synchronized to the grid.

- a. (2 points) State the conditions that must be verified/checked prior to synchronization.
- b. (4 points) Draw a phasor diagram that depicts the generator when it is delivering power to the grid under lagging power-factor conditions. Use solid lines. Now suppose the excitation (or field) of the generator is boosted by 50 % with respect to case (b). Draw the phasor diagram corresponding to this condition using dotted lines; superimposed on the phasor diagram from case (b).
- (3 points) c. Based on (b), explain what a "V" curve is and how it is constructed for a synchronous machine.
- (3 points) d. Derive and explain how the capability curves are constructed for synchronous machines.

3. A single phase 50 kVA, 2400/240 V transformer is connected to a load through a feeder. The transformer has an equivalent impedance of 1.42 + j 1.82 ohms (referred to the HV side) and the feeder impedance is 0.3 + j 1.6 (also referred to the HV side). The voltage at the sending end of the feeder is 2400 V. Compute the secondary voltage if the load draws rated current from the transformer and the load power factor is 0.6 (lag).

4. A 4 pole 60 Hz 24 kV 650 MVA synchronous generator with a synchronous reactance of 1.82 pu (i.e. $X_s = j1.82$) is connected to an external power system which can be represented by a 24 kV infinite bus in series with a reactive impedance of j0.21 Ω. The generator is equipped with a voltage regulator that adjusts the field such that the terminal voltage is maintained at 24 kV independent of generator loading. The generator delivers 375 MW to the system.

- Compute the armature current and the generator's terminal power factor.
- Compute the generator's excitation voltage (E).

5. A 208 V, 7.5 HP, 60 Hz, 4 pole, Y connected induction motor (inrush code "H") has a rated current of 24 A. The motor is to be started using series resistors connected in each line. Calculate the inductance required to limit the starting current to twice the rated current. You may assume that the locked rotor impedance has a phase angle of 70 degrees.