Massachusetts Institute of Technology
Department of Electrical Engineering and Computer Science
6.685 Electric Machines

Problem Set 3

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This problem set concerns a synchronous generator. Here is what we know about the machine. It is 'round rotor', meaning the stator winding inductances are not a function of rotor position and:

- Terminal voltage rating is 8.0 kV, RMS per phase. That is about 11.3 kV peak. Since this is a three-phase machine connected in 'Wye', that means the terminal voltage is about 13.8 kV, line-line, RMS.
- The current rating of the machine is 20 kA, RMS per phase, so that the *rating* of the machine is 480 MVA.
- This is a 60 Hz machine, so $\omega = 377$ Radians/second.
- Under test at rated speed and with the stator winding open, field current required to produce rated terminal voltage is AFNL = 1000 A.
- Also under test with the stator winding terminals shorted together, field current required to produce rated terminal current in the winding is AFSI = 2000 A.

In working this set you may neglect armature winding resistance.

1. What is the field-to-phase mutual inductance of this machine?
2. What is the synchronous inductance of the machine?
3. Draw a phasor diagram of operation of this machine for operation at rated terminal voltage and current at unity power factor. How much field current is required for such operation?
4. Synchronous machines have a stability limit when operating under-excited. For 'round rotor' machines this stability limit is reached when torque angle $\delta = 90°$. What is the real power capability of this machine when it is operating at power factors of 0.4, and 0.6, underexcited?
5. Compounding curves describe field current required as a function of real power for fixed values of power factor. Using your favorite mathematical assistant, find and plot compounding curves for this machine for power factors of 0.4, 0.6, 0.8, both under- and over- excited, and for unity power factor. Be sure to observe the stability limit you just figured for the underexcited curves and the overall current limit for the stator winding.