ELECTRICAL MACHINE II MATLAB ASSIGNMENT

Problem 1: This problem 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:

This is a two-pole, 60 Hz, three-phase machine.

The rating of this machineis1,000MVA with a terminal voltage of26kV, RMS,phase-phase. This means that phase voltage is about 15,011 V, RMS.

The machine is capable of reaching full MVA at a power factor of 0.85, overexcited.

Under test at rated speed and with the stator winding open, field current required to produce rated terminal voltage is AFNL = 2501 A.

Also under test with the stator winding terminals shorted together, field current required to produce rated terminal current in the winding is AFSI = 5003 A.

You may neglect armature winding resistance.

1. What is the armature current rating of the machine, per phase?
2. Generate and plot a vee curve diagram for the turbogenerator. This is a plot of armature current magnitude |Ia| vs. field current If for real values of the output power of 0, 200, 400, 600, 800 and 1000 MW.

Problem 2: This problem concerns a salient pole synchronous generator with the following parameters:

VA Rating 150 MVA

Voltage Rating 13.8 kV (line-line, RMS)

7967 V (line-neutral, RMS)

D-Axis Synchronous Reactance 2.5 Ω

Q-Axis Synchronous Inductance 1.5 Ω

Stator Winding Phase Resistance .009 Ω

Field Winding Resistance 1.0 Ω

Magnetic Core Loss at Rated Voltage 1.0 MW

Field Current for Rated Voltage, Open Circuited (Ifnl) 600 A

Number of pole pairs (p) 7

Stator Connection Wye

1. To start, note that this machine will have a stability limit for operation at low field excitation(corresponding to high absorbed reactive power). For a round rotor machine, this limit is reached at a torque angle of 90◦, but this machine has saliency so you must determine the value of angle for which stability is reached. Compute and plot the angle and corresponding value of field current at the stability threshold for this machine, against real power. Hint: The stability limit is reached when the derivative of torque with respect to angle is zero. Sincetorqueisproportional to real power, you can use the derivative of power with angle. Forthispartof the problem, ignore resistances and core loss.
2. Find the value of reactive power at the under excited stability limit and plot Q(P).

3. Find required field current for operation at rated power at unity power factor, and plot a torque/angle curve for operation at the rated terminal voltage and that field current.
4. Now, considering the loss elements: armature resistance loss, core loss and field winding loss calculate and plot machine efficiency over the range of 50MW $<P<$ 150MW at unity power factor.

Problem 3: Here is a description of a 350 kW induction motor:
Voltage V 600 Line-line, RMS
Frequency F 60 Hz
Number of Pole Pairs p 4
Stator Leakage Reactance X1 38 mΩ
Stator Resistance R1 17 mΩ
Rotor Leakage Reactance X2 114 mΩ
Rotor Resistance R2 10 mΩ
Magnetizing Reactance Xm 3.5 Ω
For this motor, assume core loss at rated frequency and voltage is 10 kW, and that this core loss is proportional to flux density to the power of 2.2 and to frequency to the power of 1.8. That is:

$$P_c = P_{c0} \left(\frac{f}{f_0}\right)^{1.8} \left(\frac{B}{B_0}\right)^{2.2}$$

Assume also that friction and windage loss is proportional to the cube of rotor speed and is 8 kW at rated speed.
Finally, assume that 'stray' loss is 2.5% of output power(8750Wattsatratedpower) and is directly proportional to output power.

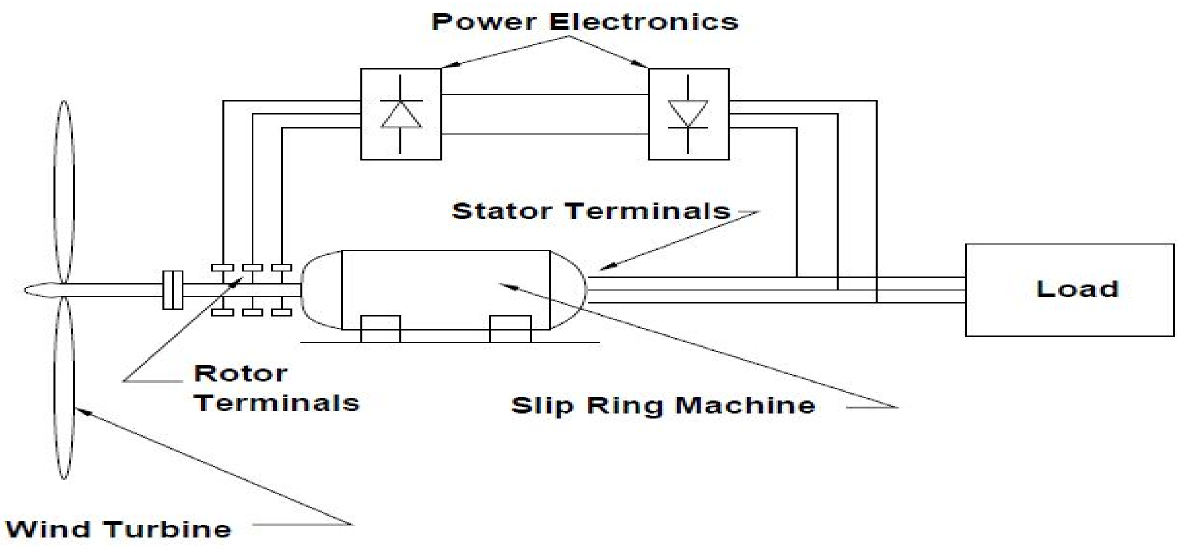
1. Ignoring all of those added loss elements(Core, Friction, Windage and stray, generate and plot a torque-speed curve for this motor, at the rated terminal voltage and frequency.
2. Now, accounting for the added loss elements, estimate and plot motor efficiency and terminal power factor, while the motor is operated at the rated terminal voltage and frequency for mechanicalloadsbetween100kW and400kW. (Yes, we are overloading the machine.)

Problem 4: The very same motor you analyzed in problem 3 is to be used in an adjustable speed drive application. For lower speeds, the motor is to be driven by a balanced voltage that is proportional to frequency('constant voltsperHz'). For drive frequency greater than 60Hz, the terminal voltage is fixed at 600 V, RMS, line-line.

1. Plot torque-speed curves for this motor and drive combination, for frequencies of 20, 40, 60, 80, 100 and 120 Hz. Be sure to use the right terminal voltages.
2. Calculate and plot efficiency and power factor for the motor operating at a power output of175kW over a range of speeds from about 450 to1,800RPM. Note that you

may find it convenient to fix electrical frequency and across-plot, so your plot may not extend exactly between these two speeds.

Problem 5: This is about a three-phase wound-rotor Doubly Fed induction generator that might be used as a wind turbine generator. The stator and rotor windings are identical, except for the numbers of turns. It has characteristics as shown here:
Number of Poles 2p 6
Armature Phase Self Inductance La 3.5 mH
Armature Phase-to-Phase Mutual Inductance Lab -1.75 mH
Rotor Phase Self Inductance LA 31.5 mH
Rotor Phase-to-Phase Mutual Inductance LAB -15.75 mH
Rotor to Stator (Peak) Mutual Inductance LaA 10.37 mH
Effective Transformer Turns Ratio Nr/Ns 3
Nominal Rotational Speed 1200 RPM
Terminal Voltage (RMS, Line-Line) Va 690 v
Rated Power 2,400 kVA
Frequency 60 Hz
The rotor windings are connected to a set of slip rings and so can be driven by an inverter as shown in Figure.



The inverter is part of a bidirectional AC/DC/AC converter with the other end connected directly to the power system. Assume that the 'line side' converter interacts with the machine stator(and power bus) terminals at unity power factor(that is, the reactive power either drawn or supplied by the right-hand end of the converter is zero).
Assume that the load is drawing P=2,000 kW, Q=500 kVAR. Ignoring losses in the system, find and plot the following quantities over a speed range of between 70% and 130% of synchronous:

1. Real and Reactive Power out of the stator winding
2. Real and Reactive Power into the slip rings(and rotor winding)
3. Power delivered by the wind turbine