EE 331 Homework Set 5 (Due at 11AM on October 30th, 2019)

Problem 1 (15 points) (5 points each question)

A three phase eight pole 60 Hz wye connected synchronous generator is rated at 2.50 MVA, 4.16/2.4 kV. The generator has a stator resistance of R_s = 0.15 Ω and a synchronous reactance of X_s = 4.0 Ω.

a. Find the rated stator current of the generator

b. The generator is operating at rated terminal voltage with rated current. The current is lagging the line to neutral voltage by 25°. Find the internal voltage E_f of the generator.

c. Find the converted power and the developed torque T_e.

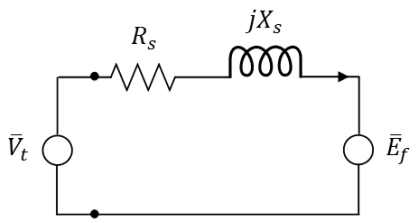
Problem 2 (15 points) (5 points each question)

A three phase 60 Hz synchronous motor has eight poles. The motor rated voltage is 480V/277V wye. The motor rated stator current is 300 A. The per-phase diagram of the motor is shown below with R_s = 1 Ω, X_s = 0.2 Ω. The motor is operating with a terminal voltage magnitude of V_t = 282 V with a frequency of 60 Hz. The current magnitude I_s = 200 A. I_s is in phase with V_t.

a. Calculate the magnitude and angle of the internal voltage E_f .

b. The internal voltage magnitude $E_f = 0.075\omega_e I_f$, where ω_e is the electrical frequency in radians per second, and I_f is the field current. Find the field current for this operating point.

c. The converted power for the motor is the real power entering the internal voltage source E_f. Find the converted power for this motor. Find the developed torque of the motor.



Equivalent circuit.

Problem 3 (20 points) (5 points each question)

The motor of problem 2 is operating with a developed torque of Te = 500 N m and a field current of If = 20 A. The electrical frequency is 60 Hz.

a. Determine the internal voltage E_f .

b. Calculate the converted power P_e.

c. Assume that the stator current is in phase with the internal voltage. Determine the stator current magnitude I_s and calculate the motor terminal phasor voltage V_t .

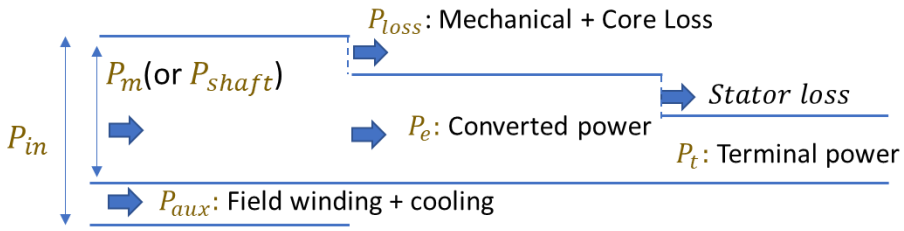
e. Calculate the terminal real power P_t and reactive power Q_t.

Problem 4 (20 points) (5 points each question)

A 32-pole 60 Hz synchronous turbine generator has 150 MW shaft power. It has a stator copper loss of 0.5 MW, friction and windage loss of 5 MW, electromagnetic losses of 1.5 MW and field winding and cooling losses of 2.1 MW. The generator is operating with electrical frequency of 60 Hz.

a. Determine the rotor speed of the generator in (revolutions per minute) RPM and in rad/s. Determine corresponding mechanical torque T_m.

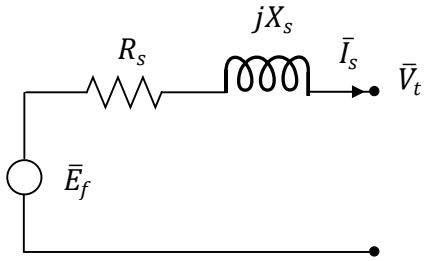
b. Calculate the magnitude of the stator current I_s if R_s = 0.2 Ω.
c. Using the power flow diagram as shown below, determine the converted power P_e of the machine, and the developed torque T_e.
d. Determine the terminal power and overall efficiency of the generator at this operating point.



Power flow diagram.

Problem 5 (20 points) (5 points each question)
A three phase, four pole 60 Hz synchronous generator is rated at 800 kVA, 440 V/254 V wye. The generator synchronous reactance X_s = 0.8 Ω and the stator resistance is R_s = 0.004 Ω. The generator internal voltage magnitude is $E_f = 0.035\omega_e I_f$. The field resistance is R_f = 8 Ω. The generator is operating at 60 Hz.
a. The generator is initially supplying power to a wye connected load with impedance of Z_{wye} = 1.2 + j0.3 Ω. The terminal voltage is V_t = 270V. Determine the stator current from the per phase diagram.
b. Determine the internal phasor voltage $\bar{E}_f$.
c. Find the field current and the field voltage that will provide this value of E_f.
d. A new load is added in parallel to the original load. The impedance of this load is Z_{wye2} = 1.8 + j0.5 Ω. The value of $\bar{E}_f$ remains the same. What is the new phasor terminal voltage $\bar{V}_t$?

Problem 6 (10 points) (5 points each question)
The per phase diagram of a synchronous generator connected to an in finite bus is shown below. The generator has a stator resistance of R_s = 0.05 Ω and a synchronous reactance of X_s = 4.0 Ω. The generator is a wye connected 66 MVA, 60 Hz 32-pole machine driven by a hydraulic turbine. The generator is operating with a terminal voltage of 13.2 kV L-L (7.62 kV L-N). The generator is operating with rated output volt–amps at an 0.85 lagging power factor. The system frequency is 60.0 Hz.
a. Find the phasor values of internal voltage $\bar{E}_f$ and phase current $\bar{I}_s$.
b. Find the generator shaft speed and developed torque.



Equivalent circuit.