

HW4 - Synchronous Machines

This homework can be solved by hand (pencil and paper). You should submit your solution to the “homework box” in front of the Machinery Lab. Late submissions will not be accepted!

Q.1. (50 pts) A 400 V, 40 kVA, 50 Hz, 6-pole, Y connected cylindrical rotor synchronous machine operates as a generator. The synchronous reactance is: $X_s = 1 \Omega/\text{phase}$ and the armature resistance is negligibly small. The field current of this generator is adjusted such that the open circuit terminal voltage is measured as 400 V line-to-line.

- a. What is the synchronous speed of this generator in rpm?
- b. What is the terminal voltage if the generator is loaded with:
 - i. rated current at unity power factor?
 - ii. rated current at 0.8 power factor lagging?
 - iii. rated current at 0.8 power factor leading?
- c. How much shaft torque must be applied by the prime mover at the condition in part (b-i), if the friction and windage loss is assumed to be 1 kW at this operating condition?
- d. Draw the phasor diagram corresponding to the operating condition in part (b-ii).
- e. Calculate the load angle (δ) at the operating condition in part (b-ii).

Q.2. (50 pts) A 6 kV, 2.6 MVA, 50 Hz, 8-pole, salient pole synchronous machine has a direct-axis reactance: $X_d = 15 \Omega$.

The machine is operating as a generator connected to a 6 kV infinite bus and delivering rated power at 0.8 power factor lagging. At this operating condition, the load angle (δ) is 21.34° .

Throughout the problem, you may neglect all the losses.

- a. Draw a phasor diagram for this operating condition.
- b. Find the quadrature-axis reactance, X_q .
- c. Find the excitation voltage, E_f for this operating condition.
- d. Find the electromechanical torque, T_{em} for this operating condition.

The machine is operating as a motor at rated voltage and supplying 2 MW to a mechanical load. At the same time, the motor is desired to be used as a reactive power compensator such that, it is supplying 1.5 MVar reactive power to the grid.

- e. What is the value of power factor? Is it leading or lagging?
- f. Draw a phasor diagram for this operating condition.
- g. Find the load angle (δ) at this operating condition.

HINT: $\cos(a + b) = \cos(a)\cos(b) - \sin(a)\sin(b)$