Synchronous Generators

Name_____ ECE 3600 Homework SG2 e

1. A 60 Hz, 4-pole, Y-connected, 3-phase synchronous generator supplies 60 kW of power to a 3.6-kV bus. The synchronous reactance is 40 Ω/phase. The generator emf is 2.2 kV. Find the following.
   a) The power angle, δ.

   b) The total reactive power generated.

   c) Find a new magnitude of the generator emf so that $Q := 18 \cdot kVAR$

ECE 3600 homework SG2 p2

2. A 3-phase synchronous generator operates onto a grid bus of voltage $12\ \text{kV}$ (line value). The synchronous reactance is $5\ \Omega$/phase. The magnitude of the generator emf equals the magnitude of the bus voltage. The machine delivers $18\ \text{MW}$ to the grid. Find:
   a) The power angle, δ.

   b) The complex phase current, (Assume the bus voltage phase angle is 0^o).

   c) The magnitude and direction of reactive power.

3. A $60\ \text{Hz}$, 2-pole, 3-phase synchronous generator supplies power to a $12.5\ \text{kV}$ bus. The synchronous reactance is $4\ \Omega$/phase. The generator emf is $7\ \text{kV}\ \underline{/20^o}$ (the angle is referenced to the terminal voltage). Find the following.
   a) The total power generated.

   b) The total reactive power generated.

c) The shaft torque from the prime mover, neglecting friction.

d) Increase the magnitude of the generator emf so that $Q := 0 \cdot VAR$ The prime mover torque does not change.

Note: If the prime mover torque doesn't change, neither does P. δ can change.

e) The new power angle, δ.

f) Increase the magnitude of the generator emf so that $Q := 9 \cdot MVAR$

g) The new power angle, δ.

4. A 3-phase, synchronous generator is not electrically connected to anything. The prime mover is spinning the generator at $3600\ \text{rpm}$. The input torque is $30\ \text{Nm}$. When the field current is $10\ \text{A}$, DC, the terminal voltage is $1100\ \text{V}$.

   The field current is raised to $20\ \text{A}$, and the terminal voltage goes up to $2200\ \text{V}$.
   The generator is now Y-connected to a $3.6\ \text{kV}$, $60\ \text{Hz}$, bus. The line current is measured at $4\ \text{A}$.
   The input torque is still $30\ \text{Nm}$, just enough to overcome rotational losses.

   a) What is the power angle and/or how much power is being generated?

   b) Find the synchronous reactance. X_s = ?

   c) Find the total reactive power generated.

   d) The prime mover torque is increased to $\tau_{in} := 530 \cdot \text{N} \cdot \text{m}$ Find the generated electrical power P = ?

   The prime mover torque is held at this value for the rest of the problem.

   e) Find the power angle. δ = ?

f) Find the total reactive power generated.

g) The generator operator is told to produce $30\ \text{kVAR}$, no change in real power. Find the required E_A.

h) What does the operator change to get this new E_A, and to what new value.
Hint: reread the initial problem statement.

i) Did the power angle change with the the previous change?
If yes, say whether it increased or decreased. No calculation is required.

Answers

1. a) $10.08 \cdot \text{deg}$ b) 13.66kVAR c) $2227 \cdot \text{V}$ 2. a) $38.68 \cdot \text{deg}$ b) $918 \cdot \text{A} \angle 19.34 \cdot \text{deg}$ c) $-6.32 \cdot \text{MVAR}$
3. a) $12.96 \cdot \text{MW}$ b) $-3.459 \cdot \text{MVAR}$ c) $3.437 \cdot 10^4 \cdot \text{N} \cdot \text{m}$ d) $7.604 \cdot \text{kV}$ e) $18.35 \cdot \text{deg}$ f) $9.197 \cdot \text{kV}$ g) $15.1 \cdot \text{deg}$
4. a) 0^{o} $0 \cdot \text{W}$ b) $30.38 \cdot \Omega$ c) $24.94 \cdot \text{kVAR}$ d) $188.5 \cdot \text{kW}$ e) $24.68 \cdot \text{deg}$ f) $-16.29 \cdot \text{kVAR}$ g) $2407 \cdot \text{V}$
h) The operator changes the field current to: $21.9 \cdot \text{A}$ i) decreased