NATIONAL UNIVERSITY OF SINGAPORE
Department of Electrical Engineering

EE2022 ELECTRICAL ENERY SYSTEMS
(Tutorial #7 Generator Modeling)

Tutors will discuss problem 7 to 9.

Problems 1 to 6 are meant for you to practice on your own. Solving these problems will help you to check your understanding of the basic concepts. You are advised to work on all problems before the tutorial class.

1. At what speed must a six-pole three-phase synchronous generator run to generate 50-Hz voltage?

   (Answer: 1000 rpm)

2. An eight-pole three-phase synchronous generator is operated at 900 rpm. What is the frequency of the output voltage?

   (Answer: 60 Hz)

3. A 60kVA three-phase wye-connected 440V, 60 Hz synchronous generator has a resistance of 0.15Ω and a synchronous reactance of 3.5Ω per phase. At rated load and unity power factor, find the internal excitation voltage magnitude and the power angle.

   (Answer: 382.89 V, 46.03°)

4. A 1MVA 11kV three-phase wye-connected synchronous generator supplies a three-phase load of 600kW, 0.8 leading power factor. The synchronous reactance is 24Ω per phase and the armature resistance is negligible. Find the power angle.

   (Answer: 7.44°)

5. Calculate the excitation voltage for a three-phase wye-connected 2500 kVA, 6.6 kV synchronous generator operating at full load and 0.9 p.f. lagging. The per phase synchronous reactance is 4Ω and the per phase armature resistance is negligible. What will be the internal excitation voltage when the generator is operating at full load with 0.9 p.f. leading? Explain whether the machine is overexcited or underexcited in each case.

   (Answer: $4265.11\angle 10.64°$ V overexcited, $3518.42\angle 12.93°$ V underexcited)

6. A 75kVA, 2.2kV, 60 Hz three-phase wye-connected synchronous generator has a resistance of 0.2 Ω, a synchronous reactance of 6Ω per phase and is operated at full load. Draw a phasor diagram of the excitation voltage, load current, and terminal voltage when the load is (i) 0.85 lagging power factor, (ii) unity power factor, and (iii) 0.85 leading power factor. Use the terminal voltage as the reference with the angle of zero degree.

(Answer: (i) Load current = $19.68\angle -31.8^0$ A, Excitation voltage = $1339.36\angle 4.2^0$ V,

(ii) Load current = $19.68\angle 0^0$ A, Excitation voltage = $1279.57\angle 5.3^0$ V,

(iii) Load current = $19.68\angle 31.8^0$ A, Excitation voltage = $1215.61\angle 4.8^0$ V)

7. A 1MVA 11kV three-phase wye-connected synchronous generator has a synchronous reactance of 5 Ω and a negligible armature resistance. At a certain field current the generator delivers rated load at 0.9 lagging power factor at 11kV. For the same excitation, what is the armature current and power factor when the input torque is reduced such that the real power output is half of the previous case?

(Answer: $33.34\angle -44.88^0$ A, 0.71 lagging)

8. An 11kV three-phase wye-connected generator has a synchronous reactance of 6 Ω per phase and a negligible armature resistance. For a given field current, the open-circuit line-to-line excitation voltage is 12kV. Calculate the maximum power developed by the generator. Determine the armature current and power factor at the maximum power condition.

(Answer: 22 MW, $1566.43\ \angle 42.51^0$ A, 0.74 leading)

9. Two three-phase generators (G1 and G2) supply a three-phase load through separate three-phase lines as shown in Fig. 1 below.

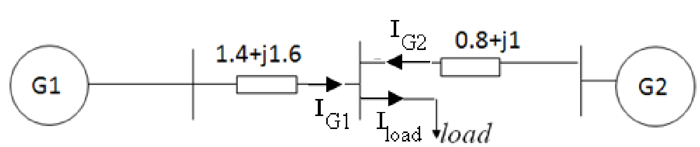

Fig. 1 Single-line diagram of a three-phase circuit

Each generator has a synchronous reactance of 3 Ω per phase and a negligible armature resistance. The three-phase Y-connected load absorbs 30 kW at 0.8 power factor lagging. The line impedance is 1.4+j1.6 Ω per phase between generator G1 and the load, and 0.8+j1 Ω per phase between generator G2 and the load. If generator G1 supplies 15 kW at 0.8 power factor lagging, with terminal voltage of 460 V line-to-line, assume balanced operation, determine internal excitation voltage magnitude (per phase) and power angle of both generators. Use terminal voltage of generator 1 as a reference angle.

(Answer: For G1, 313.07 V, 10.39^0, For G2, 335.73 V, 12.74^0)