NATIONAL UNIVERSITY OF SINGAPORE

EXAMINATION FOR

(Semester II: 2011/12)

EE2022 – ELECTRICAL ENERGY SYSTEMS

April/May 2012 - Time Allowed: 2 Hours

INSTRUCTIONS TO CANDIDATES:

1. This paper contains **SIX (6) questions** and comprises of **FIVE(5)** pages.
2. Answer any **FIVE (5)** out of the SIX (6) questions.
3. This is a **closed** book examination.
4. All questions carry equal marks.
5. Programmable calculators are **NOT** allowed.

Q1(20 marks)

a. A three-phase 50 Hz voltage source feeds two balanced three-phase loads connected in parallel. The single-line diagram of the three-phase system is shown in Fig. Q1. Load#1 is inductive load of j3 Ω per phase in delta connection and Load#2 is wye-connected and absorbs a total of 100 kVA at 0.8 p.f. leading. If the line-to-line voltage at the terminal of Load#2 is $230\angle 0°$ V(rms), assume positive sequence circuit find both magnitude and phase of line-to-line voltage at the source, $V_{S,line\text{-}to\text{-}line}$.

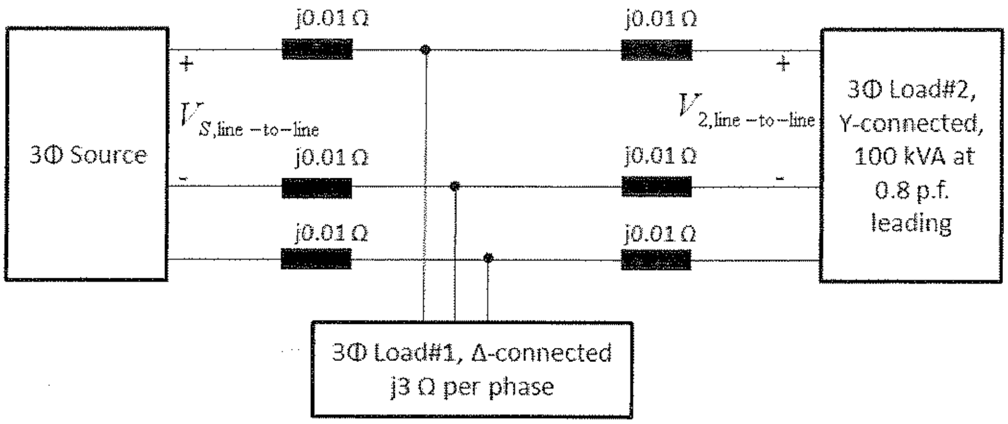

Fig. Q1

(16 marks)

b. Name four advantages of three-phase balanced circuit.

(4 marks)

Q2 (20 marks)

a. A 12 kVA 120 V 60 Hz single-phase synchronous generator has a synchronous reactance of 0.1 Ω and armature resistance of 0.001 Ω.

   i. At a certain excitation, the generator delivers rated load at 0.85 power factor lagging to the grid at the voltage of $120\angle 0°$ V. Find the excitation voltage.

   ii. If the excitation voltage is set to $100\angle 10°$ V and the terminal voltage at $110\angle 0°$ V, find the armature current.

(6 marks)

b. What is the main advantage of asynchronous generators?

(2 marks)

c. Name two main differences between synchronous and asynchronous generators.

(2 marks)

<Question Q2 continues on next Page>

d. Edward is an electrical engineer working in the local utility company. He is tasked to perform voltage drop analysis of a 230 kV, 70 km three-phase transmission line, which supply a three-phase balanced load of 50 MW, 0.9 power factor lagging at 220 kV. The analysis requires an equivalent model of this transmission line. The following table gives the ABCD parameters of the line using medium and long transmission line model.

Model	A=D	B	C
Medium line model	1.0010 + j0.0041	8.7500 + j35.0000	0.0002
Long line model	0.9959 + j0.0010	8.7262 + j34.9554	j0.0002

Note that $\begin{bmatrix} V_S \\ I_S \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix}$ where V_S, I_S are sending end voltage and current, and V_R, I_R are receiving end voltage and current.

i. What are the sending end voltages calculated from the two models?

ii. For the analysis to be valid and acceptable, the voltage magnitude should be accurate to the level of ±100 V, which of the two models should he use in the voltage drop analysis? Why?

(8 marks)

e. What are the purposes of compensation techniques for medium and long transmission lines?

(2 marks)

Q3 (20 marks)

a. Russell is planning to connect a 220V 50Hz single-phase voltage supply to a 5 Ω speaker. Russell would like to make sure that the maximum power is transferred from the voltage supply to the speaker. If the voltage supply has internal resistance of 5k Ω, what equipment should he use to make this happen? Provide necessary specification of this equipment.

(4 marks)

b. The single-line diagram of a three-phase system is shown in Fig. Q3.2 where all impedances are in per unit on a 100-MVA base.

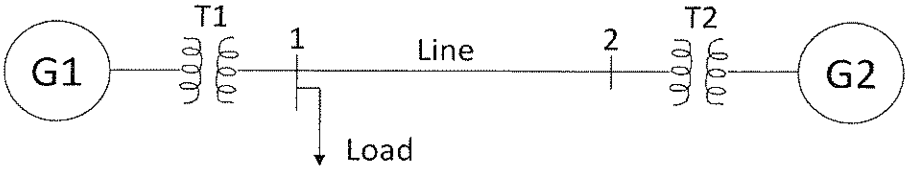

Fig. Q3.2

The three-phase complex power and line-to-line voltage ratings are given below.

< Question Q3 continues on Page 4.>

Synchronous generator G1: 90 MVA, 20 kV, synchronous reactance 0.09 p.u.
Synchronous generator G2: 90 MVA, 18 kV, synchronous reactance 0.09 p.u.
Transformer T1: 80 MVA, 20/200 kV, leakage reactance 0.16 p.u.
Transformer T2: 80 MVA, 200/20 kV, leakage reactance 0.20 p.u.
Transmission Line: 200 kV, j120 Ω
Load: Complex power of 48 MW + j64 MVAR at 180 kV

If the voltage at node 1 is $180\angle 0^\circ$ kV and the voltage at node 2 is $190\angle 10^\circ$ kV, answer the following.

i. Choose 90MVA as the base value for complex power and 20 kV as the voltage base for generator G1. Draw the per unit equivalent circuit. Describe all voltages, load, and impedance in per unit value.
ii. What is the current along the transmission line? What is the current direction? Answer the actual value.
iii. What is the current supplied by the generator G2? Answer the actual value.
iv. Find the excitation voltage in Volt and power angle of the generator G2.

(16 marks)

Q4 (20 marks)

a. Power consumed by a load, when connected to 400V, 50 Hz power supply, is 30 kW with lagging p.f. 0.5.
    i. Find apparent power, reactive power and load current.
    ii. A capacitor C is now connected in parallel with the load to improve the power factor. Determine the value of C to make the overall power factor 0.85 lagging, and the current drawn by the load after adding the capacitor.
    iii. Draw a phasor diagram showing all voltages and currents.

(14 marks)

b. A coil of resistance 20Ω and inductance 0.6H is connected in series with a capacitance of 20μF. If a variable frequency source of 220V is applied to this circuit, determine the frequency at which the current flow in the circuit will be maximum. Under this condition, calculate the voltage across the inductance and capacitance, and power in the circuit.

(6 marks)

Q5 (20 marks)

a. It is desired to produce power from solar panels for a residential establishment to provide electricity at 48 V, 18 A. If each module is rated at 12 V, 6 A, determine the number of modules needed to provide the desired electricity, and suggest two possible ways to connect the modules. Which of these is the preferred arrangement and why? Draw the corresponding voltage-current curve for the array.

(6 marks)

b. An industrial customer operating night and day, 7 days/week, consumes 300,000 kWh/month. The maximum demand is 2000 kW. What would be the monthly electricity bill for this customer using the rate schedule shown below?

Demand charge	\$3.00 per month per kW of billing demand
Energy charge	\$0.04/kWh for the first 100 hours of billing demand
	\$0.02/kWh for the next 50,000 kWh/month
	\$0.012/kWh for the remaining energy

(8 marks)

c. How will the Smart Grid help us integrate renewables into the grid? Limit your answer to 60 words.

(6 marks)

Q6 (20 marks)

a. A horizontal-axis wind turbine with rotor diameter of 22 meters is installed at a height of 40 m in 12 m/s winds, 1 atmosphere of pressure and 15°C. The air density is 1.225 kg/m^3. If the efficiency of the wind turbine is 33%, calculate the following.
   i. The specific power produced in those winds.
   ii. The power produced by this wind turbine if it is mounted on a hill at a height of 240 m where the air density is 1 kg/m^3 and friction coefficient α=0.25. Assume that the efficiency is not affected by air density.

(14 marks)

b. What is the main motivation behind deregulation of electrical marks? Briefly explain the hybrid model for deregulation.

(6 marks)

-END OF PAPER-