NATIONAL UNIVERSITY OF SINGAPORE

EXAMINATION FOR

(Semester I: 2011/12)

EE2022 – ELECTRICAL ENERGY SYSTEMS

Nov/Dec 2011 - Time Allowed: 2 Hours

INSTRUCTIONS TO CANDIDATES:

1. This paper contains **SIX (6) questions** and comprises of **SEVEN (7)** 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

a. Consider a three-phase system shown in Fig. Q1.1. If the power is supplied from a positive sequence, balanced three-phase voltage source, determine the voltage $v_1(t)$ and the current $i_2(t)$. Assume a positive sequence system.

(10 marks)

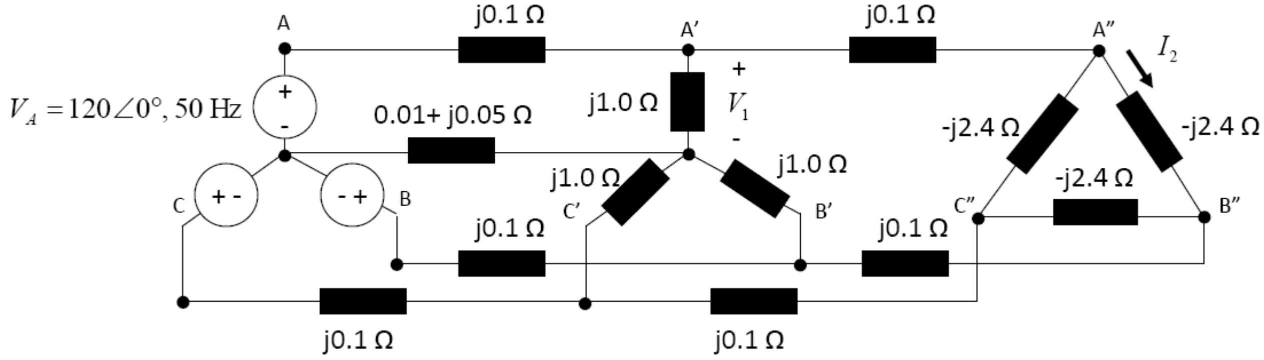

Fig. Q1.1

b. A three-phase 50 Hz voltage source feeds a three-phase balanced load shown in Fig. Q1.2. The three-phase balanced load is wye-connected and absorbs a total of 100 kVA at 0.8 p.f. lagging. If the line-to-line voltage at the terminal of the load is 230 V(rms), find the magnitude of the line-to-line voltage at the source.

(10 marks)

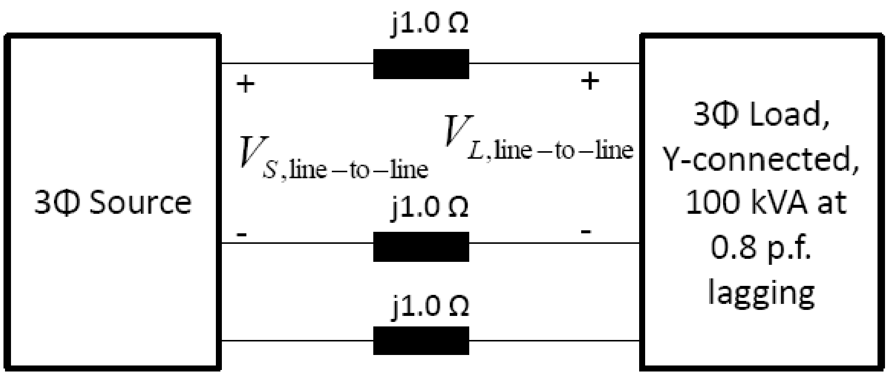

Fig. Q1.2

Q2

a. A 24 MVA, 17.32 kV, 60 Hz three-phase synchronous generator has a synchronous reactance of 5 Ω per phase and negligible armature resistance.

   i. At a certain excitation, the generator delivers a rated load at 0.8 lagging power factor to the grid at a line-to-line voltage of 17.32 kV. Find the excitation voltage per phase.

   ii. If the excitation voltage is changed to 13.4 kV per phase and the terminal voltage is maintained at 10 kV per phase, what is the maximum three-phase real power that the generator can develop before pulling out of synchronism?

   iii. Find the armature current for the condition of part (ii) above.

(12 marks)

b. The ABCD parameters of a three-phase 345 kV transmission line are given as follows.

   A = D = 0.98182 + j0.0012447
   B = 4.035 + j58.947
   C = j0.00061137

   i. The line delivers 400 MVA at 0.8 lagging power factor at 345 kV. Determine the sending end voltage and current, and voltage regulation.

   ii. Is this a short or long transmission line? Why is it so?

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.

(8 marks)

Q3

a. Paula is a utility engineer with an electrical engineering background. Her company just bought a new 10 kVA, 240/120V, 60 Hz single-phase transformer. Paula is assigned to conduct the open circuit and short circuit test to find the equipment's equivalent circuit diagram for a system integration study. The following are the test results.

Short circuit test:	Voltage measurement reads 20 V
	Power measurement reads 150 W
Open circuit test:	Current measurement reads 5 A
	Power measurement reads 100 W

Draw an equivalent circuit of this single-phase transformer. Indicate the values of the series impedance and shunt admittance of this transformer.

(10 marks)

b. The single-line diagram of the three-phase system is shown in Fig. Q3. The system comprises two generators, three transmission lines, three transformers, and two loads. The details of all equipment are listed below.

Synchronous generator G1: 50 MVA, 13.8 kV, synchronous reactance 0.15 p.u.
Synchronous generator G2: 20 MVA, 14.4 kV, synchronous reactance 0.15 p.u.
Transformer T1: 60 MVA, 13.2/161kV, leakage reactance 0.10 p.u.
Transformer T2: 25 MVA, 13.2/161 kV, leakage reactance 0.10 p.u.
Transformer T3: 25 MVA, 13.2/161 kV, leakage reactance 0.10 p.u.
Transmission Line TL1: 20 + j80 Ω
Transmission Line TL2: 10 + j40 Ω
Transmission Line TL3: 10 + j40 Ω
Load L1: 20 + j15 MVA at 12.63 kV

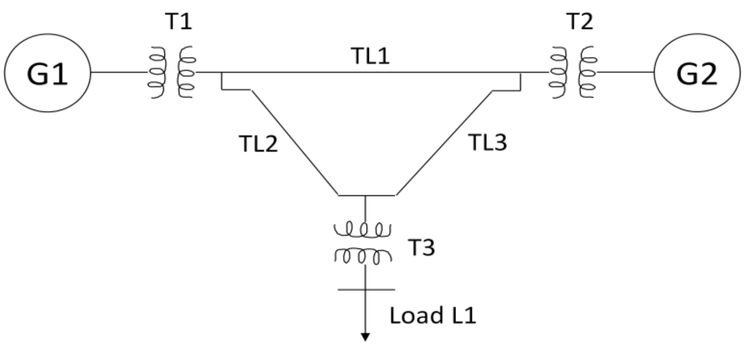

Fig. Q3

Use 60 MVA as the power base value for the system and 161 kV as the line-to-line base voltage at the transmission lines.

Draw a per-unit equivalent circuit to represent this three-phase system. Indicate the base values for each zone and all the <u>per unit</u> values of transmission line impedance of TL1, TL2, and TL3, transformer reactance of T1, T2, and T3, synchronous reactance of G1 and G2, complex power at load, and voltage at the load.

(10 marks)

Q4

a. The equivalent plant loads of an industrial client are illustrated in Fig. Q4.1. Lights, represented by R_1, consume 12kW power. The electric furnace is an inductive load modelled as (2.4 + j3.2)Ω. The motor consumes 80kW power at 0.8 lagging power factor.

i. Determine the total real power (P_t) and total reactive power (Q_t).
ii. Determine the power factor and total impedance of the combined load.
iii. Determine the total current drawn by this industrial plant.

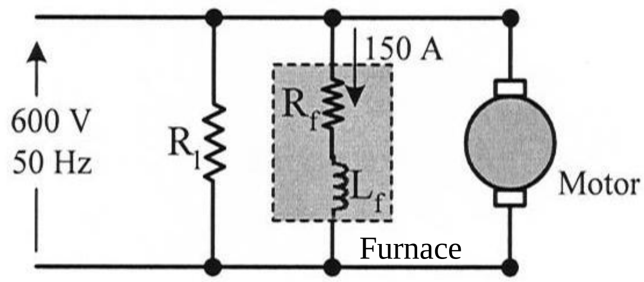

Fig. Q4.1

(12 marks)

b. In the circuit of Fig. Q4.2, $R = 2\Omega$, $L = 3.25$mH and $C = 100\mu$F. The steady state voltage across C is $v_C = 100\sqrt{2}\, cos(2000t - 90^{\circ})$ volts.

i. Determine the voltages across the capacitor and the inductor.
ii. Determine the total instantaneous current $i(t)$ flowing into the circuit.

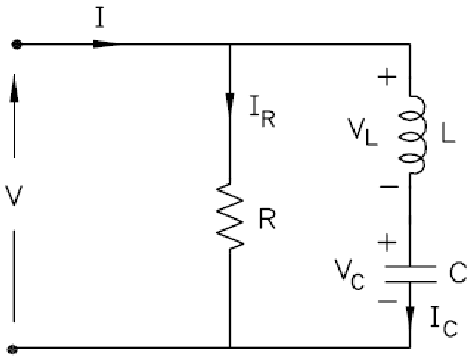

Fig. Q4.2

(8 marks)

Q5

a. A substation operating at its full load of 1000kVA supplies a load at power factor 0.707 lagging.

i. Draw the power triangle showing real, reactive and complex power.

ii. Calculate the rating of a power factor correcting device to raise the substation power factor to 0.87 lagging. Assume that the power factor correcting device is operating at 0 power factor leading.

(10 marks)

b. Four identical PV modules, each with an idealized 1-sun, current-voltage (I-V) curve shown in Fig. Q5 are to be connected together to deliver power to a load.

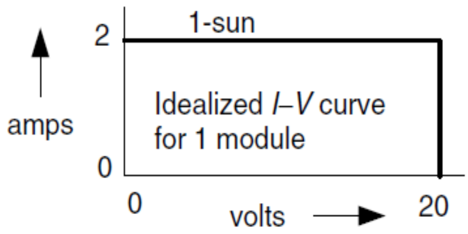

Fig. Q5

i. Using a simple block diagram, show the three possible ways that the modules can be connected.

ii. Plot the I-V curves for these three combinations and determine the energy generated over a period of 4 hours, assuming that the I-V curve remains the same over this period.

(8 marks)

c. What are the four main features of a smart grid?

(2 marks)

Q6

a. An anemometer mounted at a height of 10-m on a level field with tall grass shows an average windspeed of 10 m/s.

i. Estimate the average specific power in the wind at a height of 85m. Assume a friction coefficient $\alpha = 2/9$ and the standard air density $\rho = 1.225$ kg/m^3.

ii. A 750-kW wind turbine with 45-m diameter is mounted in these winds at 85m. Estimate the annual energy delivered if the turbine efficiency is 32%.

(10 marks)

b. An office building is billed based on the rate structure given in the table below. As a money saving strategy, during the 21 days per month that the office is occupied, it was decided to shed 10 kW of load for an hour during the period of high demand in the summer months.

i. How much energy will be saved as a result?

ii. What would be the savings in the electricity bill per month in summer?

Charges	Winter (Oct-March)	Summer (April-Sept)
Energy charges	\$ 0.065/kWh	\$ 0.075/kWh
Demand charges	\$ 8/month-kW	\$ 9.5/month-kW

(6 marks)

c. What are the two main advantages of using energy storage in distributed energy systems? Explain your rationale in not more than 50 words.

(4 marks)

END OF PAPER