NATIONAL UNIVERSITY OF SINGAPORE

EXAMINATION FOR

(Semester I : 2013/2014)

EE2022 – ELECTRICAL ENERGY SYSTEMS

Nov/Dec 2013 - Time Allowed: 2 Hours

INSTRUCTIONS TO CANDIDATES

1. This paper contains **FIVE (5)** questions and comprises **FOUR (4)** printed pages.

2. Answer **ALL** questions in **Section A** and **ANY TWO (2)** questions in **Section B**.

3. This is a **CLOSED BOOK** examination.

4. The total marks for the examination paper is 100.

SECTION A : Answer ALL questions in this section

Q.1 (a) An industrial workshop draws 500 kW at a lagging power factor of 0.707 from a single phase 400V power supply. It is desired to improve the power factor to 0.95 lagging by connecting a power factor correcting capacitor.

     i. Determine the **current drawn from the supply** before and after the addition of the capacitor.

     ii. What is the **reactive power supplied** by the power factor correcting capacitor?

     iii. Calculate the **capacitance** of the capacitor.

(10 marks)

(b) The average wind speed measured by an anemometer at a height of 10 m on a level field with tall grass is 6 m/s. Assuming standard conditions and 1 atm pressure, calculate the average power that a turbine mounted at a height of 80 m would produce. The friction coefficient is 0.15.

If a 1300-kW wind turbine with a rotor diameter of 60 m is mounted at 80 m in this location, estimate the **annual energy delivered** if the overall turbine efficiency is 30%.

(10 marks)

(c) Answer the following TRUE/FALSE questions. The correct answer (TRUE or FALSE) to each question should be written neatly on a separate line in your answer book. Each correct answer carries 1 mark.

(10 marks)

     i. Fuel cells are excellent renewable energy sources, as they are efficient and ideally suited for distributed energy generation.

     ii. Off-grid solar power plants are typically used for supplying electricity in rural and remote areas.

     iii. Biomass can be converted into solid, liquid and gaseous fuels

     iv. Vertical axis wind turbines do not need orientation mechanism

     v. On wind farms, wind turbines occupy only about 5% of the land, leaving the rest for other uses

     vi. The amount of solar energy being collected depends on the quality of solar panels and collectors

     vii. A wind turbine generates about four times more power when wind speed is 8 m/s compared to when it is 4 m/s

     viii. Of all the fossil fuel sources, natural gas is the least polluting when used for electricity generation.

     ix. Spacing wind turbines too close to each other reduces the output of the machine

     x. A "Flash" type geothermal plant uses a heat exchanger to transfer heat to a secondary fluid with much lower boiling point than water, which vaporizes and then drives the turbines.

Q.2 (a) A balanced three-phase load is supplied by a balanced three-phase 440 V source. It is delta-connected and draws 200 kW at 0.9 power factor leading. Assuming positive sequence system, and with the line-to-neutral source voltage of phase A being with reference angle of zero degree, find the **line current supplied by the source in phase B, I_B.**

(6 marks)

(b) The reactance of a single-phase transformer designated X is given as 0.08 per unit based on its name plate rating of 440/230V, 100 kVA. What is the **reactance value in ohm**? What is the **new p.u. value** of reactance, with base voltage of 430V and base power of 200kVA?

(10 marks)

(c) A 10kVA three-phase Wye-connected 440V, 50 Hz synchronous generator has armature resistance of 0.2Ω and a synchronous reactance of 2Ω per phase. At rated load and 0.8 lagging power factor, find the **internal excitation voltage magnitude and the power angle**.

Draw a phasor diagram showing the terminal voltage, load current, voltage drop in the armature winding and excitation voltage.

(14 marks)

SECTION B : Answer any two questions

Q.3 (a) A factory has a peak load of 200 kW at a lagging power factor of 0.8. The tariff is $50/kVA of maximum demand per month plus $0.1 per kWh of energy consumed. What would be the **annual electricity bill** if the factory works for 2000 hours in a year at peak load, 2500 hours at 75% load and 1700 hours at 40% load?

(6 marks)

(b) A photovoltaic cell with an area of 100-cm^2 and reverse saturation current $I_0 = 10^{-10}$ A/cm2 produces a short-circuit current of 45 mA/cm2 at 25°C in full sun.

i. What would be the open circuit voltage at full sun?
ii. What is the change in open circuit voltage when the sunlight drops to 40% from full sun?

(10 marks)

(c) Discuss the main advantages of **pumped hydro** systems.
Limit your answer to 50 words.

(4 marks)

Q.4 (a) A short transmission line has a per phase resistance of 1Ohm and inductance of 50mH. Find the **voltage regulation and efficiency** of the transmission line when supplying a balanced 3 phase load: 1.1MVA, unity power factor, at 11kV, 50Hz.

(10 marks)

(b) A 50 kVA, 2400/240 V, single phase transformer was tested and the following test data were obtained. Determine the **transformer model parameters**. Draw the transformer equivalent circuit showing the parameter values.

	Voltage (V)	Current (A)	Power (W)
Short-circuit test	55	20.8	600
Open-circuit test	240	5.0	450

(10 marks)

Q.5 The one-line diagram of a three-phase power system is shown in Figure Q5. Select a common base of 100 MVA and 22kV on the generator side. The manufacturer's data for each device is given as:

- G: 90 MVA   22kV   X = 18%
- T1: 50 MVA   22/220kV   X = 10%
- T2: 40 MVA   220/11kV   X = 6%

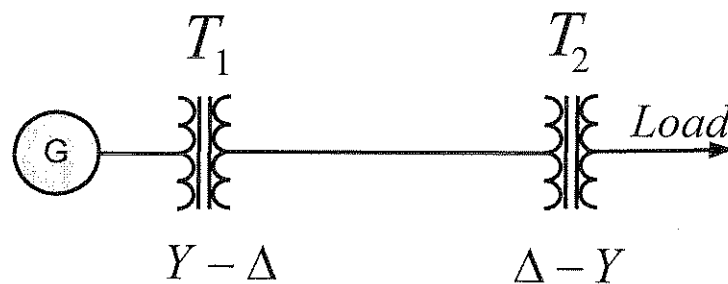$$T_1 \qquad\qquad T_2$$

$$Y - \Delta \qquad\qquad \Delta - Y$$

Figure : Q5

Three-phase Y-connected load absorbs 48 MVA 0.6 pf lagging at 10.45kV. The short transmission line has per phase series reactance of 48.4 Ω.

Draw a per phase and p.u. impedance diagram showing all impedances including the load impedance.

Find the **excitation voltage of the generator**.

(20 marks)

END OF PAPER