NATIONAL UNIVERSITY OF SINGAPORE

EXAMINATION FOR

(Semester II : 2013/2014)

EE2022 – ELECTRICAL ENERGY SYSTEMS

May 2014 - Time Allowed: 2 Hours

INSTRUCTIONS TO CANDIDATES

1. This paper contains **FIVE (5)** questions and comprises **SIX (6)** 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) A factory draws 400 kW of power at a lagging power factor of 0.73 from a single phase 400V power supply. It is desired to improve the power factor to 0.9 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) 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. Photosynthesis converts sun's energy into usable chemical energy.
ii. Most of the wind energy turbines in large wind farms are vertical axis type.
iii. As the ambient temperature increases, the voltage across a solar PV cell decreases.
iv. The main limitation of algae as a possible source of biodiesel is the large amount of space required for its cultivation.
v. Horizontal axis wind turbines do not need orientation mechanism.
vi. Of all the fossil fuel sources, natural gas is the least polluting when used for electricity generation.
vii. A grid-connected solar PV system requires battery storage to supply power when the sun is not shining.
viii. In a wind energy conversion machines, the amount of power generated is proportional to the square of the swept area of the rotor.
ix. Solar energy is impractical for the large-scale, commercial generation of electricity.
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.

(c) You have a cabin in the Malaysian wilderness far away from civilization and want to install a small hydro generator to provide electricity. A stream runs down a hill behind your cabin where you can construct a simple run-of-river hydro installation. You calculate that the effective head of the installation is 25 feet and that water would flow through the system at a rate of 50 cubic feet per minute. The simple inexpensive hydro turbo-generator (turbine and electric generator) that you intend to buy has a working efficiency of 70%. Answer the following (show your work). (*Note: 1 meter = 3.28 feet*).

i. How much power can you generate with this system?
ii. How many 100 watt light bulbs can you power with this hydro setup?

(10 marks)

Q.2 (a) Transformers are important part of all AC power systems.

i. **Why are transformers used** in power systems?

(2 marks)

ii. **What are the assumptions** made in an ideal transformer?

(2 marks)

iii. **Draw an equivalent circuit** of a practical transformer. Explain how the various attributes of practical transformer are represented in the equivalent circuit.

(4 marks)

(b) The A, B, C and D parameters of transmission matrix for a 3-phase 11 kV, 50 Hz line are given as:

A=D= 1+j0.005
B= 0.5+j10 Ω
C= $-2.5X10^{-6}$+j0.001 S

The transmission line supplies a balanced 3-phase load: 2MVA, 0.8 lagging power factor, at 10kV.

i. Find the **sending end voltage and current** for this load.

(6 marks)

ii. Find the **transmission efficiency and voltage regulation** for this load.

(6 marks)

(c) A 3-phase delta-connected 2200 kVA, 11 kV synchronous generator is supplying the full load at 0.8 leading power factor. The per-phase synchronous reactance is 5Ω and armature resistance is 0.5Ω.

i. Calculate the **excitation voltage** of the generator under this condition.

(5 marks)

ii. Draw the **per-phase phasor diagram** for the generator, with the terminal voltage as reference. Clearly show the load current, armature voltage drop and excitation voltage.

(3 marks)

iii. Explain whether the machine is **overexcited or underexcited** under this operating condition.

(2 marks)

SECTION B : Answer any two questions

Q.3 (a) The peak demand for a commercial establishment in the summer months of July and August is 130 kW and 147 kW respectively. The peak in every other month is less than 100 kW. An energy saving program implemented in the summer months reduces the peak demand by 12 kW in each of these months. The electricity tariff comprises of an energy charge of 12 ¢/kWh, and a demand charge is $15/kW-mo with an 80% ratchet on the demand charges. Calculate:

i. The **annual electricity bill** before the energy saving program is implemented.
ii. The annual **savings** that will result from implementing the program.

(8 marks)

(b) The average wind speed measured by an anemometer at a height of 10 m on a level field with tall grass is 4.5 m/s. Assuming standard conditions and 1 atm pressure, calculate the average power that a turbine mounted at a height of 65 m would produce. The friction coefficient is 0.18.

If a 600-kW wind turbine with a rotor diameter of 40 m is mounted at 65 m in this location, estimate the **annual energy delivered** if the overall turbine efficiency is 32%.

(6 marks)

(c) A solar PV array comprises of two parallel strings of four identical modules connected in series. At a certain insolation, each module produces 13.2 V, 7 A.

i. Draw the **current-voltage curve** for the solar PV array.
ii. What would be the **total voltage, current and power** produced by the array if the insolation is reduced to 60% compared to that in (i)?

(6 marks)

Q.4 (a) A balanced 3-phase source of 440 V/50Hz is supplying power to two loads as shown Figure Q4.(a).

Load 1 is delta-connected and draws 200 kW at 0.8 power factor lagging.
Load 2 is wye-connected and draws 100 kW at 0.5 power factor leading.
The cable impedance is given as $j0.5\,\Omega$.

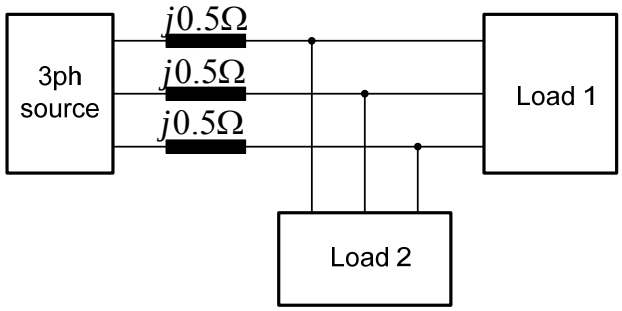

Figure : Q4.(a)

Find the **complex power supplied by the source**.

(15 marks)

(b)

i. What are the **advantages** of using **per unit system** in power system analysis?

(2 marks)

ii. The reactance of a 3-phase generator is given as 0.25 per unit based on the generator's name plate rating of 13 kV, 130 MVA. What is the **per phase reactance** value in ohm? If the new base for calculations is 11 kV, 500 MVA, find **per unit reactance** on the new base.

(3 marks)

Q.5 (a) The one-line diagram of a three-phase power system is shown in Figure Q5(a). Select a common base of 100 MVA and 11kV on the generator side. The manufacturer's data for each device is given as:

- G: 100 MVA 11kV X = 10%
- T1: 100 MVA 11/200kV X = 8%
- T2: 50 MVA 200/11kV X = 6%
- T3: 20 MVA 200/11kV X = 5%
- TL1: $1+j10\,\Omega$
- TL2: $2+j20\,\Omega$
- TL3: $0.5+j5\,\Omega$
- Load 1: 3-phase, 40MW, at 10.5kV, power factor of 0.8 lagging
- Load 2: 3-phase, 15MVA, at 10.8kV, power factor of 0.7 leading

Q.5 continued on page 6.

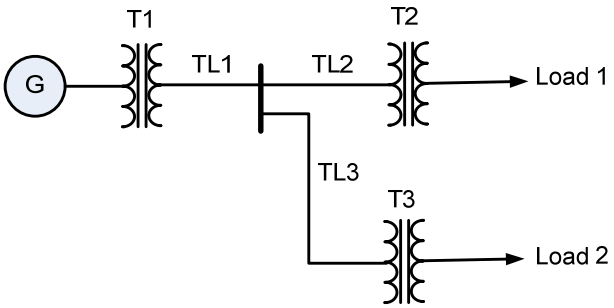

Figure : Q5 (a)

Draw the **per unit impedance diagram for the power system in Figure Q5(a)**.

(15 marks)

(b)

i. What are the **advantages** of using in 3-phase power system over single phase?

(2 marks)

ii. Explain the use of **reactive compensation** in power systems.

(3 marks)

END OF PAPER