

NATIONAL UNIVERSITY OF SINGAPORE

EXAMINATION FOR
(Semester I : 2012/2013)

EE2022 – ELECTRICAL ENERGY SYSTEMS

November / December 2012 - Time Allowed: 2 Hours

INSTRUCTIONS TO CANDIDATES

1. This paper contains **SEVEN (7)** 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. Programmable calculators are **NOT** allowed.
5. The total marks for the examination paper is 100.

SECTION A : Answer ALL questions in this section**Q.1 (10 marks)**

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.

- (i) The performance of PV modules deteriorates with increase in the ambient temperature.
- (ii) The typical power conversion efficiency of an average solar PV cell is around 30%.
- (iii) A horizontal axis wind turbine is preferred over vertical axis wind turbine as it is easier to maintain.
- (iv) Wind turbines need at least 5.5 m/s of wind speeds for the use of turbines to be cost effective.
- (v) The main benefit of using hydrogen in a fuel cell is that its production is non-polluting.
- (vi) One of the problems with using wind as a power source is that the wind generator/turbine has to be installed close to the load centers.
- (vii) Substantial investments in geothermal electricity production were made worldwide in the past two decades because total cost of producing electricity from these sources is much lower than that produced using fuel oil.
- (viii) Wind power was the most rapidly growing form of alternative electricity generation in the last decade.
- (ix) Vegetable oils produce biodiesel fuels that are directly usable in petroleum diesel engines.
- (x) Some people believe biofuels are a better source of energy than other alternative fuels, such as solar power, because the technology required for the widespread implementation of biofuels is already available.

Q.2 (20 marks)

Three loads are connected in parallel across a 220 V, 50 Hz, single phase supply as shown in Fig. Q.2. Load $L_1 = 5 + j 5 \Omega$, $L_2 = 6 - j 4 \Omega$, and $L_3 = 2 + j 10 \Omega$.

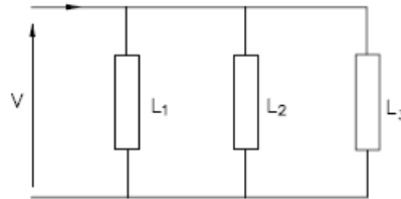


Fig. Q.2

- (i) Determine the total apparent power, real power and reactive power delivered by the source. (8 marks)
- (ii) What is the power factor of the circuit? (3 marks)
- (iii) Draw the phasor diagram showing all currents and voltages. Take source voltage as the reference. (3 marks)
- (iv) What is the value of power factor correction device to make the power factor unity? (6 marks)

Q.3 (20 marks)

Consider a balanced three-phase system shown in Fig. Q.3. If the line-to-line voltage at the load#2 between phase a and b i.e. $V_{2, \text{line-to-line}} = 381 \angle 60^\circ \text{ V}$, assuming positive sequence system, answer the followings.

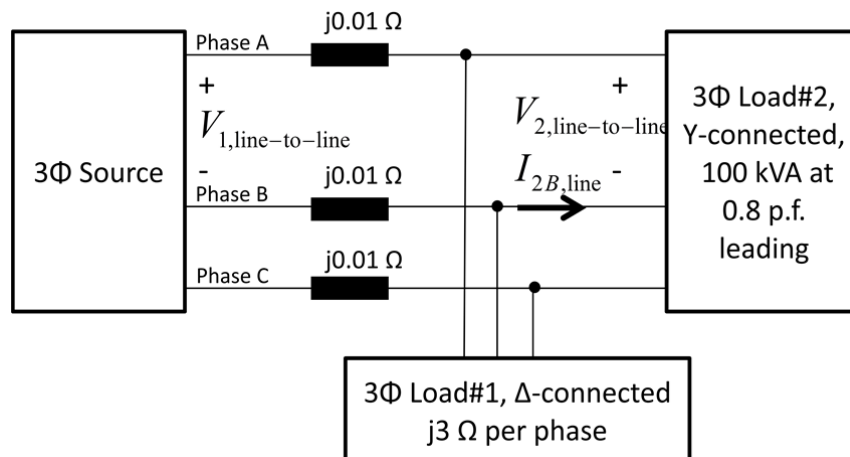


Fig. Q.3

<Question 3 continues on Page 4>

- (i) Draw per phase equivalent circuit of the given three-phase system.
(4 marks)
- (ii) Find the magnitude and phase of the line current drawn by three-phase load #2 at phase B, $I_{2B,line}$.
(8 marks)
- (iii) Find the magnitude and phase of the line-to-line voltage at the source between phase A and B i.e. $V_{1,line-to-line}$.
(8 marks)

Q.4 (10 marks)

Answer the followings. Keep your answers clear and succinct. Limit the answer to each sub-question to 25 words.

- (i) Name two main advantages of balanced three-phase circuit when compared to single-phase circuit.
(2 marks)
- (ii) What are the two main differences between synchronous and asynchronous generators?
(2 marks)
- (iii) List three main factors that characterize the generators' loading capability.
(2 marks)
- (iv) What are the four basic parameters of a transmission conductor and what effect do these parameters represent?
(2 marks)
- (v) List the four main differences between ideal and practical transformer models.
(2 marks)

SECTION B : Answer ANY 2 out of the 3 questions in this section

Q.5 (20 marks)

Consider the following single line diagram of the balanced three-phase system shown in Fig. Q.5. Details of all equipment are listed below.

Synchronous generator G1: 10 MVA, 13.2 kV, synchronous reactance 0.15 p.u.

Transformer T1(Y-Y): 15 MVA, 13.2/161 kV, leakage reactance 0.10 p.u.

Transformer T2(Y-Y): 10 MVA, 161/13.2 kV, leakage reactance 0.10 p.u.

Transformer T3(Y-Y): 10 MVA, 161/6.6 kV, leakage reactance 0.08 p.u.

Transmission Line 1: $10 + j100 \Omega$

Transmission Line 2: $5 + j50 \Omega$

Load#1: $j5 \Omega$ per phase

Load#2: Y-connected load of 8 MW, 0.95 pf leading

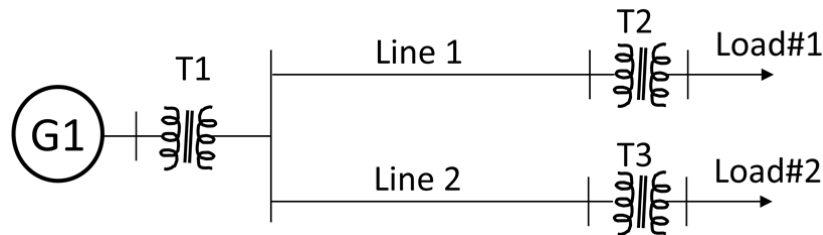


Fig. Q.5

If the line-to-line voltage at Load#2 is measured to be 6.2kV, using 15 MVA as the base complex power and 6.6kV at Load#2 as the base voltage, find the followings.

- (i) How many zones does the system have? What are the values of base voltage, base current, and base impedance in each zone?

(8 marks)

- (ii) Draw per unit circuit representation of the three-phase power system shown in Fig. Q.5. Give per unit value of synchronous reactance, transformer leakage reactances, transmission line impedances, and load impedances.

(12 marks)

Q.6 (20 marks)

- (a) A horizontal axis 500 kW wind turbine with a 40 m rotor diameter is installed at a height of 70 m in a wind farm where the average wind speed is 8 m/s at 70 m. Assume $\rho=1.225 \text{ kg/m}^3$ and turbine efficiency of 85%. Assuming the value of friction coefficient to be 0.2, find the followings.
- The amount of electricity that this wind turbine can produce annually.
(6 marks)
 - The average wind speed at 100 m height. Assume the air density remains unchanged.
(3 marks)
 - The number of households that a wind turbine with hub height 100 m can supply annually; assume that the consumption of a normal household is 4000 kWh/year.
(3 marks)
- (b) What are microgrids? Why are they considered significant to the electrical systems? Limit your answer to about 50 words.
(4 marks)
- (c) What smart grid features are being implemented in Singapore's electricity system? Limit your answer to about 50 words.
(4 marks)

Q.7 (20 marks)

- (a) A PV water pumping system has to be installed at a remote site. It will require a PV array with 8 identical PV modules, each of which can produce 12V, 6 A at 1-Sun.
- Draw the current-voltage curve for this array if the modules are connected in two parallel strings, each with 4 modules in series.
(6 marks)
 - What would be the total power produced by the array at half sun?
(2 marks)
- (b) A commercial building load consumes 180 kW on an average during working hours from 9 am – 9 pm from Mondays to Fridays, and 75 kW during off-peak hours from 9 pm – 9 am. The average consumption is 800 kWh/day on weekends. The maximum demand for the building is 300 kW. For a 30-day month with 22 weekdays, calculate the electricity bill for this customer and average cost of electricity using the rate schedule shown below.

Demand charge	\$3.50 per month per kW of billing demand
Energy charge	\$0.15/kWh for the first 30,000 kWh/month
	\$0.11/kWh for the next 30,000 kWh/month
	\$0.08/kWh for the remaining energy

(12 marks)

END OF EXAM PAPER