UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 3 Examination in Engineering: December 2023

Module Number: EE3304 **Module Name: Power Systems I**

[Three Hours]

[Answer all questions, each question carries 12 marks]

Q1 a) i) Give four reasons for the vast popularity and expansion of electricity as a form of energy.

ii) Briefly explain the relationship between electricity consumption and the prosperity of a nation.

iii) The daily demand profile of three consumers for a day is given in Table Q1. The rated power input values of the three consumers are 1600 kW, 1500 kW and 1400 kW respectively. Plot the load curve of the system and calculate the following for the given day.

I. Connected Load
II. Demand Factor
III. Load Factor
IV. Daily requirement of oil if the entire load is catered by diesel. Calorific value of oil used is 9000 kcal/kg and the average heat rate is 2630 kcal / kWh
V. Comment on the overall cost of the system using the load factor value, if the load is catered by multiply energy sources.

[6 Marks]

b) The single-line diagram of a three-phase power system is shown in Figure Q1. The generators, transformers and transmission line details are given below. The three-phase load absorbs 40 MVA, 11 kV at 0.8 power factor (lagging). Using 50 MVA and 13.8 kV as base values at Generator 1, draw the per unit circuit diagram.

Generator 1 – 40 MVA, 13.8 kV, X'' = 0.25 pu
Generator 2 - 30 MVA, 18 kV, X''= 0.2 pu
Generator 3 – 25 MVA, 20 kV, X'' = 0.125 pu
Transformer 1 – 45 MVA, 220/13.8 kV, X'' = 0.16 pu
Transformer 2 – single phase units each rated 10MVA, 127 Y/18 Y kV, X'' = 0.2 pu
Transformer 3 – 35 MVA, 230/22 kV, X'' = 0.22 pu
Transformer 4 – 40 MVA, 250/11 kV, X''=0.25 pu
Line 1 – j180 Ω
Line 2 - j200 Ω
Line 3 – j50 Ω

[6 Marks]

Q2 a) i) State the main sectors of energy consumption in Sri Lanka.

ii) Who are "Independent Power Producers (IPPs)"? Name 3 IPPs in Sri Lanka.

iii) What is energy intensity index?

iv) Country X has an energy intensity index of 0.5. Comment on this value explaining its' relationship to economy

[6 Marks]

b) i) State four advantages of having a retail economic model for the electricity sector.

ii) Briefly explain why reforms are important in electricity sector.

iii) Explain two reforms implemented in the electricity sector in Sri Lanka with examples.

[6 Marks]

Q3 a) i) Draw a simple schematic diagram of a combined cycle power plant which drives two separate generators by the two systems and name its' main components.

ii) What is the use of a starting motor in a gas power plant.

iii) State two reasons for the popularity of steam turbines when compared with gas turbines.

iv) Briefly explain three strategies used to enhance the overall system efficiency of a coal fired power station.

[8 Marks]

b) i) State four environmental impacts related to hydro power generation.

ii) What is the main environmental impact associated with nuclear power generation.

iii) State two advantages and two disadvantages of a mini hydro power plant over a conventional hydro power plant.

[4 Marks]

Q4 a) i) What is demand side management?

ii) State four advantages that can be gained through demand side management for the operational and management authorities of a power system?

iii) Briefly explain the difference between direct and indirect load control with examples.

iv) Briefly explain the relationship between the power factor of a system and its' efficiency.

[6 Marks]

b) i) What are the three categories of Energy Service Companies.

ii) Explain the reasons for connecting a capacitor bank in parallel rather than in series.

iii) The output power of a 3-phase, 50 Hz, 600 V motor is 200 kW. The efficiency and the power factor of the motor is 90% and 0.7 lagging. In order to increase the power factor to 0.95 lagging, a capacitor bank is connected in delta across the motor's terminals. Each of the capacitance unit per phase is built of 6 similar 100 V capacitors. Determine the capacitance of each capacitor.

The motor works for 150 hrs per month. The tariff has a maximum demand charge of Rs.50 per kVA and an energy charge of Rs.10 per kWh. Calculate the monthly electricity bill after the installation of the capacitor bank.

[6 Marks]

Q5 a) i) What are the two types of fault classification according to dependence on continuity of power flow.

ii) Explain the operation of a typical protection scheme in power systems with a suitable diagram.

iii) What is meant by "Sensitivity" and "Speed" of a Power system protection equipment?

iv) Briefly explain the difference between the operating point of a measurement current transformer and a protective current transformer with a suitable diagram.

[8 Marks]

b) i) State two benefits of having an earthing system in an installation.

ii) Sketch the earth fault loop of a TT earthing system.

iii) An earthing system uses 8 earth rods in a linear arrangement. Each rod has an outer radius of 12 mm and a length of 2 m. The rods are to be separated by a distance of 6 m. It is required to obtain an earth resistance below 20 Ω in the installation. Assuming that each rod is fully driven into the soil with a resistivity of 50 Ωm, determine whether the required earth resistance limitation could be achieved by this arrangement.

The total earthing resistance of linearly arranged earth rods R_n is given by the equation given below where notations have their usual meaning.

$$R_n = \frac{1}{n}\frac{\rho}{2\pi L}\left[\ln\left(\frac{8L}{d}\right) - 1 + \frac{\lambda L}{S}\right]$$

[4 Marks]

Table Q1. Daily Demand Profile of Three Consumers

Time	12am - 6am	6am - 12pm	12pm - 5pm	5pm - 9pm	9pm - 12am
Consumer 1	90 kW	350 kW	1600 kW	800 kW	No load
Consumer 2	No load	250 kW	700 kW	1200 kW	700 kW
Consumer 3	100 kW	800 kW	1100 kW	900 kW	150 kW

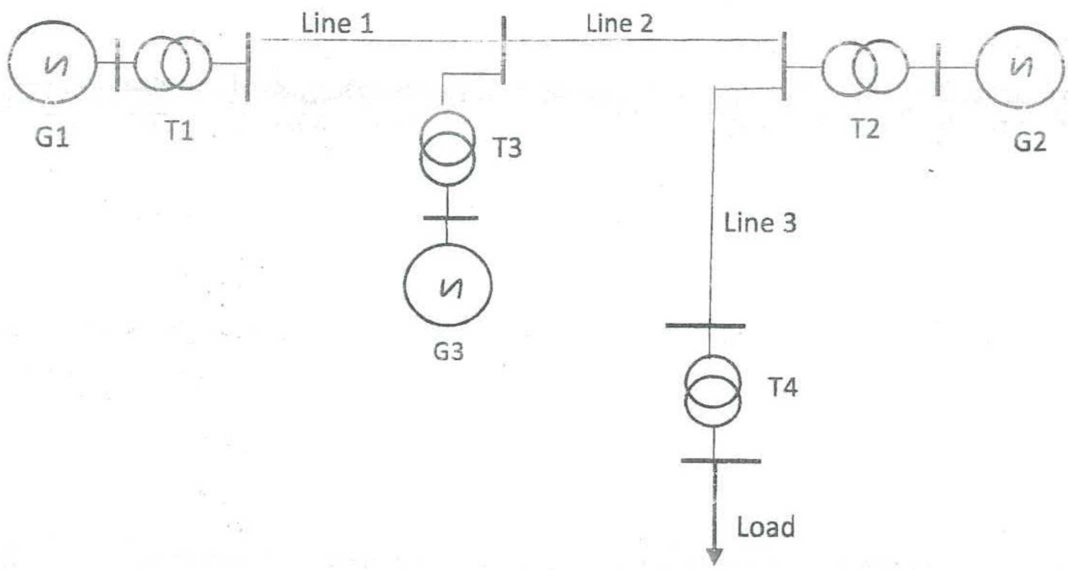

Figure Q1.