UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 3 Examination in Engineering: July 2022

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

[Three Hours]

[Answer **all questions**, each question carries **12 marks**]

Q1. a) i) State the main stages of a power grid.

ii) Briefly explain the role of power transformers in a power grid.

iii) Discuss the difference between spinning reserve and non-spinning reserve of a power system.

iv) The four-hour average daily load profile of a power system is shown in Figure Q1(a). This system has an installed capacity of 250 MW and a connected load of 230 MW. Calculate the reserve capacity, the demand factor, the load factor and the plant capacity factor of the system for the given day.

[6.0 Marks]

b) Single line diagram of a single-phase power system is shown in Figure Q1(b). T_1, T_2 and T_3 are single-phase transformers.

i) Draw the per-unit circuit diagram for 20 MVA and 11 kV base values at the generator G.

ii) Calculate the transmission power loss in watts if the voltage of busbar *A* is 11.5 kV.

[6.0 Marks]

Q2 a) i) State four factors that determine the energy portfolio of a country.

ii) Briefly explain the differences between Independent Power Producers (IPPs) and micro power producers in Sri Lanka.

iii) Describe the demand-supply model for the energy sector composition.

iv) Briefly discuss four strategies recently used by Ceylon Electricity Board (CEB) in generation sector to reduce the generation cost and environmental impact.

[6.0 Marks]

b) i) What is the objective of energy reforms?

ii) State four characteristics of the monopoly model in electricity sector.

iii) Briefly discuss the role of Public Utilities Commission of Sri Lanka (PUCSL) in the energy sector of Sri Lanka.

iv) Why income elasticity of energy demand in a developed country is relatively high compared to that of a developing country?

v) Some energy-economy related data for two countries X and Y are given in Table Q2. Taking 2010 as the base year, comment on the energy utilization of X and Y in terms of energy intensity values and energy intensity index values.

[6.0 Marks]

Q3. a) i) State three advantages of gas power plants compared to diesel power plants.

ii) Briefly discuss three environmental impacts related to hydro-electric power plants with possible mitigation options.

iii) A hydro-electric power plant with a 130 km^2 catchment area has an average annual rain fall of 1400 mm where 70% of this rainfall is available for power generation. The power house is situated 80 m below the river. The turbine and generator efficiencies are 92% and 90% respectively. If the plant is to be operated 4000 hours annually, calculate the average power output of the plant and comment on the type of water turbine suitable for this power station.

[6.0 Marks]

b) i) State three commonly used starting systems in diesel power plants.

ii) Draw a schematic diagram of a diesel power plant.

iii) Briefly explain the difference between economizer and superheater in a steam power plant.

iv) Nuclear reaction event of uranium releases approximately 3.2×10^{-11} J of energy. 1 kg of uranium can have 25.4×10^{23} events. Calculate the mass of uranium required to produce an average thermal power output of 500 MW throughout a year.

[6.0 Marks]

Q4 a) i) State three objectives of demand side management (DSM).

ii) Name four changes that can be achieved in the load curve of a power system through DSM.

iii) Briefly explain two types of automatic lighting control systems.

iv) A 30 hp centrifugal pump with a nominal efficiency of 90% operates 1,000 hours annually at its rated speed. A throttling valve is used to regulate the flow to 70% on average. Calculate the electricity saving per year if the throttling valve is replaced with an adjustable speed drive (ASD) with an efficiency of 95%. State the assumptions you make.

[6.0 Marks]

b) i) State three differences between the walk-though energy audit and the detailed energy audit.

ii) Name the three types of Energy Service Companies (ESCOs) registered with Sri Lankan Sustainable Energy Authority (SLSEA) and briefly explain the services provided by each type.

iii) A 3-phase motor connected to a 400 V, 50 Hz supply draws a line current of 25.7 A at a power factor of 0.67 lagging. A bank of capacitors is connected in star configuration across the supply terminals where each of the branch is built with six 1.5 mF capacitors connected in series. The total power loss in the capacitor bank is 600 W. Calculate the new power factor of the system.

[6.0 Marks]

Q5 a) i) State the five attributes of a power system protection scheme.

ii) Explain the difference between a measurement current transformer and a protective current transformer.

iii) Briefly explain the operation of auto re-closer.

iv) A Very Inverse (VI) type over current relay is connected through a 200/5 current transformer. Operating time of the relay t is given by the equation shown below where $T.S.M$ is the time setting multiplier and $P.S.M$. is the plug setting multiplier. The current setting of the relay is set to 50%. Calculate the time setting multiplier of the relay if it operates in 1.2 s for a 1000 A overcurrent fault.

$$t = T.S.M \times \frac{13.5}{P.S.M - 1}$$

[6.0 Marks]

b) i) State three objectives of power system earthing.

ii) Briefly explain when and why TN earthing systems are allowed in Sri Lanka.

iii) Explain three methods that can be used to minimize the corrosion of earth electrodes.

iv) An earth electrode contains seven earth rods in a linear arrangement. Each rod has a length of 1.5 m and outer radius of 15 mm. The total earthing resistance of linearly arranged earth rods R_n is given by the equation shown below where notations have their usual meanings. Assuming that each rod is fully driven into the soil with a resistivity of 60 Ωm, determine the required rod spacing to achieve an earth resistance of 6 Ω.

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

[6.0 Marks]

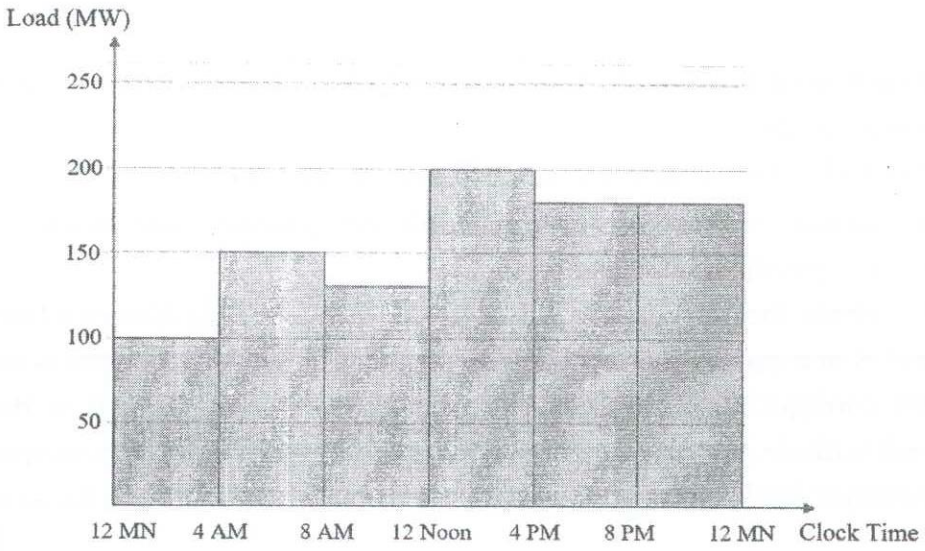

Figure Q1(a): Four-hour average daily load curve

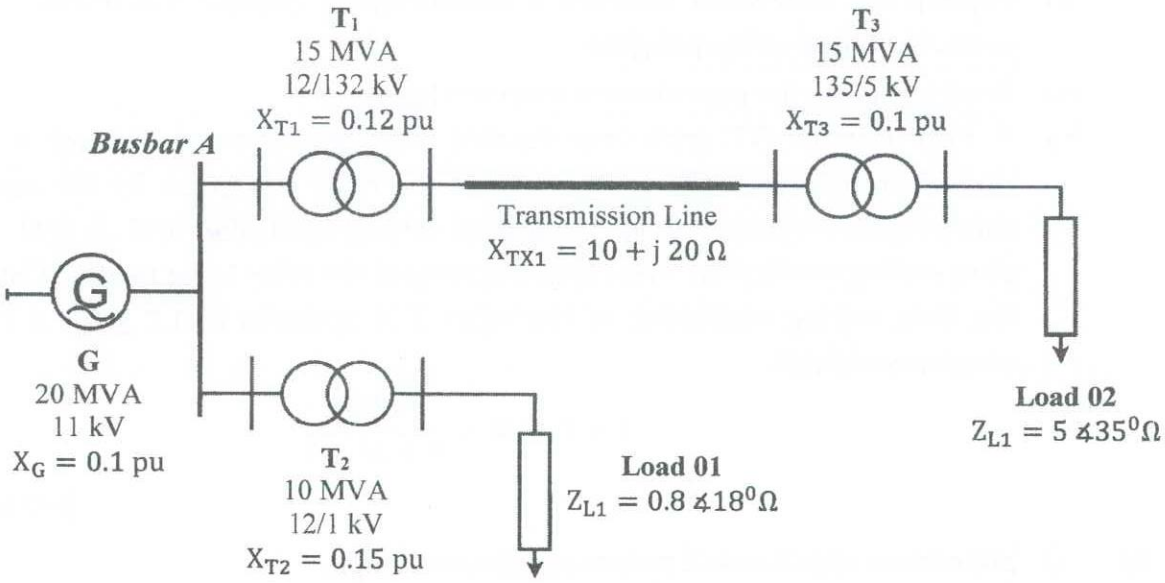

Figure Q1(b): Single line diagram of the single-phase power system

Year	Country X		Country Y	
	Energy Consumption	Gross Domestic Product	Energy Consumption	Gross Domestic Product
2010	1.2×10^7 toe	LKR billion 2500	6.5×10^7 toe	LKR billion 8100
2022	4.3×10^7 toe	LKR billion 6450	9.4×10^7 toe	LKR billion 14450

Table Q2: Energy-economy data for country X and country Y