UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 3 Examination in Engineering: March 2021

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

[Three Hours]

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

Q1. a) i) Give four reasons as to why electricity has become the most favored form of energy.

ii) Draw a schematic diagram showing the main stages and corresponding voltage levels in national power grid of Sri Lanka.

iii) Consider a power system with three generators and three loads. Rated output power of each generator is 40 MW. Power ratings of loads L_1, L_2 and L_3 are 20 MW, 35 MW and 40 MW respectively. Six-hour average power demand profile of the three loads for a day is given in Table Q1. Draw the load curve for the system and calculate the load factor, diversity factor, reserve capacity, demand factor and the utilization factor of the system for the given day. Neglect the reactive power flow and power losses in the system.

[6.0 Marks]

b) Single line diagram of a three-phase power system is shown in Figure Q1. T_1, T_2, T_3 and T_4 are transformers. TX1, TX2 and TX3 are transmission lines. Take 20 MVA and 5 kV as base values at the generator G_1. Draw the per-unit circuit diagram.

[6.0 Marks]

Q2 a) i) Name three energy resources available in Sri Lanka.

ii) Briefly discuss the reasons which lead to establish the Sri Lanka Sustainable Energy Authority (SLSEA) in 2007.

iii) Name three state-owned thermal power plants in Sri Lanka.

iv) Describe the organizational structure of the energy market in Sri Lanka.

[6.0 Marks]

b) i) What is meant by energy reforms?

ii) Discuss three differences between monopoly model and retail model relating to the electricity sector.

iii) Cross price elasticity of demand values of three products X, Y and Z referred to the price of electricity are given as 0, -1.5 and 1.8 respectively. Comment on the three products and name one appropriate example for each.

iv) Some energy-economy related data for two countries A and B are given in Table Q2. Comment on the energy utilization of A and B in terms of energy intensity values and energy intensity index values. Take 2015 as the base year.

[6.0 Marks]

Q3. a) i) State three dam types used in hydro-electric power stations in Sri Lanka with an example for each type.

ii) Explain the operation of the surge tank in a hydro-electric power station.

iii) A proposed 30 MW hydro-electric power station is to be supplied from a reservoir having a catchment area of 1500 km^2. The average annual rainfall in the catchment area is 160 cm and 65% of the rainfall is available for power generation. The expected load factor at the plant is 55%. Take the efficiencies of the turbine and the generator as 87% and 90% respectively. Calculate the required net water head and comment on the type of water turbine suitable for this power station.

[6.0 Marks]

b) i) What is the purpose of day tank in a diesel power plant?

ii) Explain how superchargers and turbochargers are used to improve the efficiency of a diesel engine.

iii) What is a combined cycle power plant?

iv) A coal power plant has a plant capacity of 250 MW and a thermal efficiency of 25%. The plant has an annual plant capacity factor of 0.65 and a peak demand of 200 MW. Take the calorific value of coal as 27000 kJ/kg. Calculate the annual coal requirement and the load factor of the power plant.

[6.0 Marks]

Q4 a) i) Sate three strategies used to implement indirect load control in demand side management (DSM).

ii) Discuss the challenges associated with increasing generation to meet the increasing electricity demand.

iii) Briefly explain how DSM plans are implemented in industrial, commercial and residential sectors of Sri Lanka.

iv) Briefly explain three energy saving measures associated with lighting systems.

[6.0 Marks]

b) i) Explain different levels of an energy audit process.

ii) Two motors are connected to a 400 V, 60 Hz, 3-phase supply where one motor draws a line current of 10 A at a power factor of 0.65 lagging. The second motor develops an output of 12.5 hp at a power factor of 0.6 lagging and efficiency of 90%. A capacitor bank having three branches of capacitors connected in delta configuration is connected in parallel to the supply terminals. Each capacitor branch consists of five 80 V, 0.5 mF capacitors connected in series and has a power loss of 250 W. Calculate the power factor of the system before connecting the capacitor bank and after connecting the capacitor bank.

[6.0 Marks]

Q5 a) i) Draw the arrangement of a typical protection scheme in power systems and explain its operation.

ii) Briefly explain how directional overcurrent relays are used in protection schemes using an example.

iii) A Standard Inverse (SI) type overcurrent relay is connected through a 200/5 current transformer. The current setting and the time setting multiplier of the relay are 60% and 0.7 respectively. 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. Calculate the fault current if the relay operates in 2 s during an overcurrent fault.

$$t = T.S.M \times \frac{0.14}{P.S.M.^{0.02} - 1}$$

[6.0 Marks]

b) i) State the difference between neutral earthing and equipment earthing?

ii) Briefly explain how soil resistivity varies with soil temperature and moisture content.

iii) Explain the fall of potential method used in measuring earth resistance.

iv) An earth electrode contains 8 earth rods in a linear arrangement with a rod spacing of 4 m. Each rod has a length of 1.5 m and outer radius of 8 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 135 Ωm, determine the earthing resistance.

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

[6.0 Marks]

Time slot	L_1 (MW)	L_2 (MW)	L_2 (MW)
12.00 midnight – 6.00 am	5	8	37
6.00 am – 12.00 noon	12	20	20
12.00 noon – 6.00 pm	8	30	25
6.00 pm – 12.00 midnight	18	10	10

Table Q1

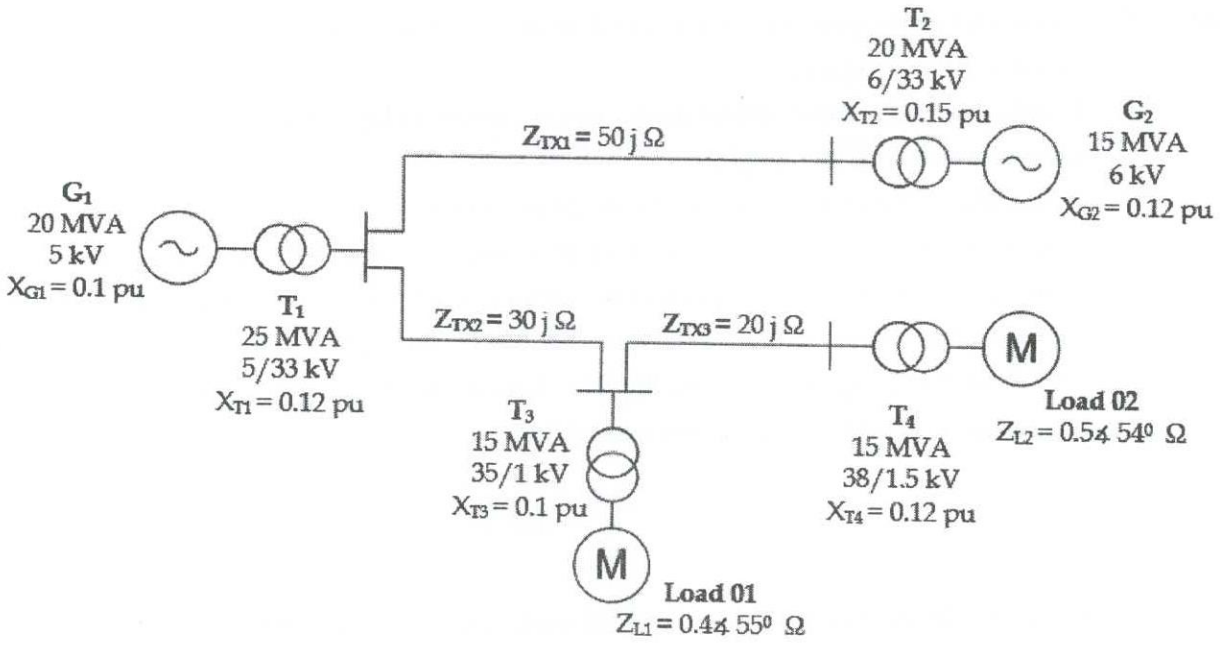

Figure Q1

Year	Country A	Country B
2015	Energy Intensity = 4.1 toe/ LKR million	Energy Intensity = 7.2 toe/ LKR million
2020	Energy consumption = 1.5×10^7 toe GDP = LKR billion 4,150	Energy consumption = 3.85×10^7 toe GDP = LKR billion 9,450

Table Q2