UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 3 Examination in Engineering: October 2019

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

[Three Hours]

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

Q1. a) i) State three favorable characteristics of a typical power system.

iii) Briefly explain the role of electric machines in a power system.

iii) Consider a power system with four generators and two loads. Rated output power of each generator is 50 MW. Power rating of L_1 and L_2 loads are 125 MW and 85 MW respectively. Four hour average power demand profile of the two loads for a day is given in Table Q1. Calculate the demand factor, the load factor, the diversity factor, the plant capacity factor and the utilization factor of the system for the given day. Neglect the reactive power flow in the system.

[6.0 Marks]

b) Single line diagram of a single-phase power system is shown in Figure Q1. T_1, T_2 and T_3 are transformers, and TX1 and TX2 are transmission lines. Take 10 MVA and 5 kV as base values at the generator G.

i) Draw the per-unit circuit diagram.

ii) Calculate the output current of the generator G in per-unit and amperes if the generator output voltage is 4.5 kV.

iii) Calculate the current drawn by Load 01 in amperes.

[6.0 Marks]

Q2 a) i) What are the major hydro power complexes in Sri Lanka? Name two power plants in each complex.

ii) Briefly discuss four strategies used in Sri Lanka to fulfill the increasing electricity demand in the recent past.

iii) Describe the organizational structure which controls the electricity market in Sri Lanka.

iv) Discuss how the percentage contributions of hydro power plants and thermal power plants in electricity generation have changed over the years in Sri Lanka.

[6.0 Marks]

b) i) State the four main energy supply forms in Sri Lanka.

ii) What is the objective of energy reforms?

iii) What is the economic model of the electricity sector in Sri Lanka? List three characteristics of this model.

iv) State the differences between a Small Power Producer (SPP) and an Independent Power Producer (IPP) in Sri Lanka.

v) Briefly explain why income elasticity of energy demand in a developing country is relatively low compared to that of a developed country.

[6.0 Marks]

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

ii) Briefly explain the operation and application of a pumped storage type hydro-electric power station.

iii) A hydro-electric power station is to be operated at a mean head of 200 m and it is supplied from a reservoir having a catchment area of 1200 km^2. The average annual rainfall in the catchment area is 145 cm and 75% of the rainfall is available for power generation. The expected load factor at the plant is 65%. Take the efficiencies of the turbine and the generator as 85% and 92% respectively. Calculate a suitable MW rating for this power station and comment on the type of water turbine suitable for this power station.

[6.0 Marks]

b) i) Briefly explain why a starting system is needed in a diesel power plant.

ii) State two commonly used starting systems in a diesel power plant.

iii) Draw the basic schematic diagram of a diesel power plant.

iv) Briefly describe two filtering mechanisms used to control the harmful emissions of coal-fired power stations.

[6.0 Marks]

Q4 a) i) Discuss the importance of Demand Side Management (DSM) in managing the increasing electricity demand.

ii) Explain the difference between direct load controlling and indirect load controlling in DSM.

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

iv) Briefly explain two methods that can be used to increase the efficiency of a system with electrical motors.

[6.0 Marks]

b) i) What is an energy audit?

ii) Name 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, 60 Hz, 415 V motor develops an output of 120 hp at a power factor of 0.6 lagging and efficiency of 88%. A bank of capacitors is connected in delta across the supply terminals where each of the branch is built with six 3.8 mF capacitors connected in series. The total power loss in the capacitor bank is 10 kW. Calculate the new power factor, and the electricity bill saving if the charge per kVA is Rs. 42.00.

[6.0 Marks]

Q5 a) i) State four attributes expected from a protection scheme in a power system.

ii) Discuss the advantages of using discrimination by both current and time for proper relay coordination in a protection system.

iii) A Very Inverse (VI) type over current relay is connected through a 500/5 current transformer. The current setting and the time setting multiplier of the relay are 75% and 0.8 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 1.5 s during an over current fault.

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

[6.0 Marks]

b) i) What is a TN-C-S earthing system?

ii) State three soil improvement techniques used in power system earthing.

iii) Briefly explain the Wenner method used in measuring earth resistivity.

iv) An earth electrode contains 6 earth rods in a linear arrangement with a rod spacing of 5 m. Each rod has a length of 2.0 m and outer radius of 10 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 the each rod is fully driven into the soil with a resistivity of 155 Ω m, 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]

Table Q1: Four hour average power demand profile of the two loads

Time slot	L_1 (MW)	L_2 (MW)
6.00 am – 10.00 am	65	40
10.00 am – 2.00 pm	50	60
2.00 pm – 6.00 pm	75	75
6.00 pm – 10.00 pm	100	35
10.00 pm – 2.00 am	70	20
2.00 am – 6.00 am	15	60

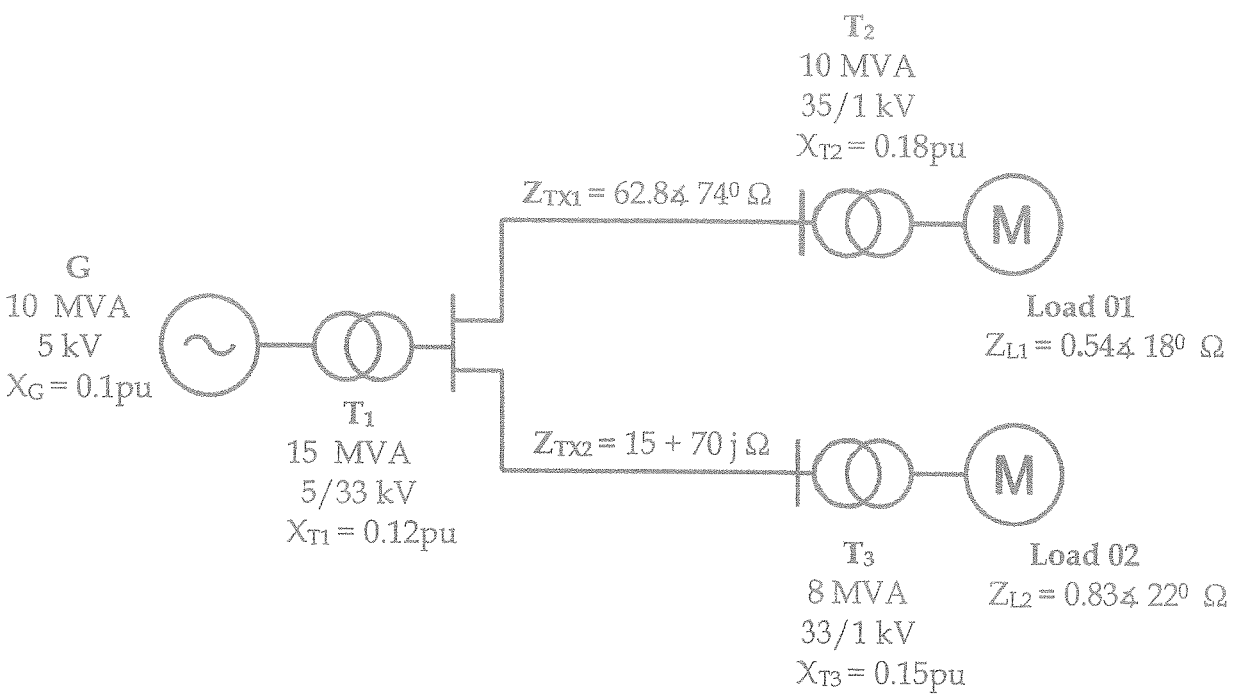

Figure Q1: Single line diagram of the single-phase power system