UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 05 Examination in Engineering: May 2023

Module Number: EE5304 **Module Name: Power Systems II**

[Three Hours]

[Answer **all questions**, each question carries 10 marks]

Q1 a) i) What is the effect of higher inductance value in a transmission line.

ii) Show that the inductance per unit length of an overhead line due to internal flux linkages is a constant and is independent of the size of the conductor.

iii) What is the need of transposition in a transmission line?

[4 Marks]

b) i) A 3-phase transmission line uses triple bundle conductors as shown in figure Q1)b)i). There are three identical conductors each of radius 2 cm placed as an equilateral triangle of side 10 cm in a bundle. Other distances are indicated on the figure itself. Assuming that the line is regularly transposed, calculate the per phase inductance per unit length of the transmission line.
Use $L = 0.4605 \log (Deq/Ds)\ mH/km$; where Deq is equivalent mutual Geometric Mean Distance (GMD) and Ds is self GMD.

ii) What will be the new per phase inductance if the triple conductor bundles are replaced with twin conductor bundles each having same conductor radius and a distance of 15 cm between conductors of a bundle as shown in figure Q1)b)ii).

iii) Briefly explain the effect of using bundled conductors for power transmission, using the above calculated results.

[6 Marks]

Q2 a) i) The voltage V(x) and the current I(x) of a long transmission line measured at a distance of "x" from the receiving end are given by the following equations, where "γ" is the propagation constant, "z" is the series impedance per unit length, C_1 and C_2 are constants.

$$V(x) = C_1 e^{\gamma x} + C_2 e^{-\gamma x}$$
$$I(x) = (1/z)\, dV(x)/dx$$

Determine the constants C_1 and C_2 in terms of receiving end voltage "V_R" and receiving end current "I_R". Hence, determine the A, B, C, D constants of the transmission line if the length of the line is "l".

ii) Explain the scenario of Ferranti effect using the equations in part i).

[4 Marks]

b) i) A lossless, 3-phase, 50 Hz, 400 kV transmission line is 350 km long. The line inductance is 1.2 mH/km and the capacitance is 0.012 μF/km. Determine the line phase constant, characteristic impedance, velocity of propagation and line wavelength.

ii) If the receiving end is connected to a load of 900 MW, 0.8 pf lagging at 400 kV, determine the sending end voltage (Vs), current (Is), apparent power at sending end and the voltage regulation.

[6 Marks]

Q3 a) i) State four factors effecting the tension of an overhead transmission line.

ii) Plot a typical sag template and briefly explain the three curves of the template.

iii) What is meant by the equivalent span of a transmission line.

[4 Marks]

b) i) Let the conductor be strung between the supports A and B as shown in Figure Q3. Consider a portion OP of a curved length l of a wire hanging in still air. w is the weight per unit length of the wire, T_0 is the tension in the wire at the lowest point O of the wire and T is the tension at point P in kg. Θ is the angle subtended by T with the horizontal axis.
Derive expressions for the parabolic approximation of the catenary and tension at point P.

ii) A transmission line conductor having a diameter of 15 mm weights 0.65 kg/m. The span is 200 m. Determine the sag which must be allowed if the tension is not to exceed one-fourth of the ultimate tensile strength 8000 kg, under following situations.

(I) In still air

(II) With a wind pressure of 35 kg/m² with an ice coating of 13.5 mm. Density of ice is 910 kg/m³.

Determine the vertical sag in Case (II).

[6 Marks]

Q4 a) i) Explain what is load flow study and its importance in designing and maintaining the power system.

ii) Consider the three-bus power system shown in Figure Q4. The admittance matrix of the system is given below.

$$Y = \begin{bmatrix} Y_{11} & Y_{12} & Y_{13} \\ Y_{21} & Y_{22} & Y_{23} \\ Y_{31} & Y_{32} & Y_{33} \end{bmatrix}$$

Derive the load flow equations for the bus No-3 of this power system.

[3.0 Marks]

b) Consider the 3-bus power system shown in Figure Q4. Bus-1 is the slack bus, and its voltage is $1.04 \angle 0$ pu. The voltage magnitude at bus-2 is 1.00 pu and the active power generation at this bus is 3.5 pu. The active and reactive load at bus-3 is 2.0 pu and 0.95 pu respectively. The line impedances are as follows.

$$z_{12} = 0.218j \text{ pu}$$
$$z_{13} = 0.204j \text{ pu}$$
$$z_{23} = 0.132j \text{ pu}$$

In the following calculations, consider the angle is in radians and the numbers are up to three decimal points.

i) Calculate the admittance matrix of the power system.

ii) Take the initial guess for the voltage at bus-3 is 1.00 pu and 0 rad as the initial guess for the voltage angles at bus-2 and -3. Calculate the active and reactive power at bus-2 and -3 and the reactive power at bus-3.

iii) Use the Fast Decoupled Load flow (FDLF) method and calculate the voltage magnitude at bus-3 and the voltage angles at bus-2 and -3 after the first iteration.

iv) Calculate the active and reactive power at the slack bus after the first iteration.

v) In FDLF, what is the criteria used to determine whether the final solution has reached.

[7.0 Marks]

Q5 a) i) What is meant by economic load dispatch?

ii) State three factors affecting the total energy generation cost.

iii) What are the three ways to represent the cost of thermal generators? Plot the corresponding curves.

[4.0 Marks]

b) Consider a power system with two generators G1 and G2. The cost functions of the two generators are as follows.

$$C_{G1}(P_1) = 320 + 7.2\, P_1 + 0.003\, P_1^2 \quad \$/h$$
$$C_{G2}(P_2) = 290 + 6.9\, P_2 + 0.004\, P_2^2 \quad \$/h$$

P_1 and P_2 are power output of the G1 and G2 generators in MW.
The minimum power output limits of the two generators $G1$ and $G2$ are 250 MW and 300 MW respectively. The system load is 620 MW.

i) Determine the economic dispatch for the generators neglecting the losses.

ii) Calculate the total generation cost for the operation in part i).

iii) The power loss function of the above power system is given by

$$P_{loss} = \alpha P_1^2 + 0.0003\, P_2^2 \quad \text{MW}.$$

When the load on the system is 620 MW, the optimum power output of generator 2 that results minimum total generation cost is found to be **300** MW and the incremental fuel cost of generator 1 is found to be 11.12 \$/MWh. Calculate the power output of generator 1 and the system loss coefficient $\boldsymbol{\alpha}$.

iv) Calculate the losses in the system for the operation in part iii).

[6.0 Marks]

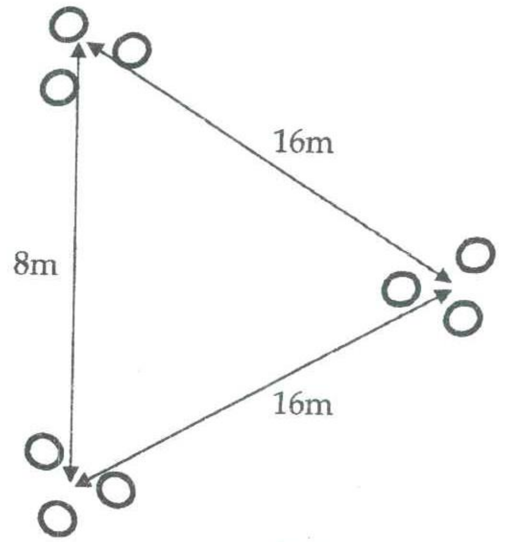

Figure Q1)b)i).

Figure Q1)b)ii).

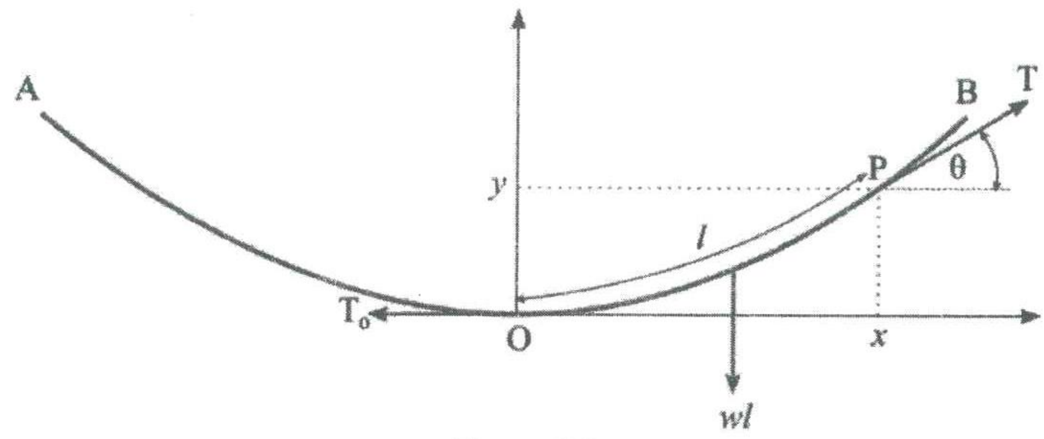

Figure Q3.

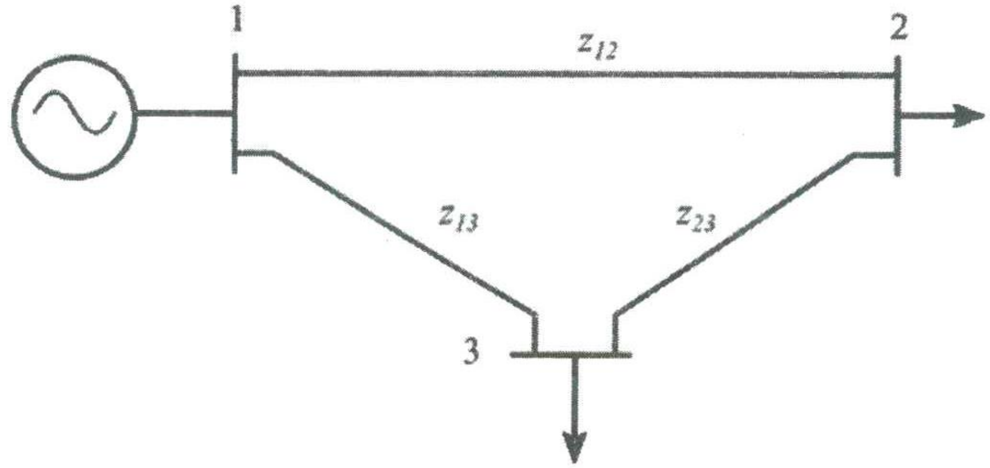

Figure Q4: 3-bus power system.