



UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 5 Examination in Engineering: March 2026

Module Number: EE5304

Module Name: Power Systems II (C-18)

[Three Hours]

[Answer all questions, each question carries 10 marks]

- Q1 a) i) What is the effect of unsymmetrical spacing of conductors in a 3-phase transmission line?
- ii) Consider a system of n conductors carrying charges $q_1, q_2, \dots, q_n$, where

$$\sum_{m=1}^n q_m = 0$$

Due to the charge on all conductors, the potential difference between conductor k and i is given by

$$V_{ki} = \frac{1}{2\pi\epsilon_0} \sum_{m=1}^n q_m \ln \frac{D_{im}}{D_{km}}$$

where all the notations have their usual meanings.

Using the above expression, derive the capacitance of a single-phase line with identical conductors, each having a radius r and a spacing d between them, as shown in Figure Q1a).

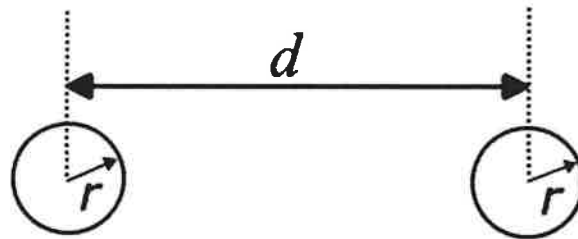


Figure Q1 a).

[4.0 Marks]

- b) Determine the inductance of a single-phase transmission line consisting of three conductors of 2 cm radii in the 'go' conductor and two conductors of 4 cm radii in the return conductor as shown in Figure Q1b).

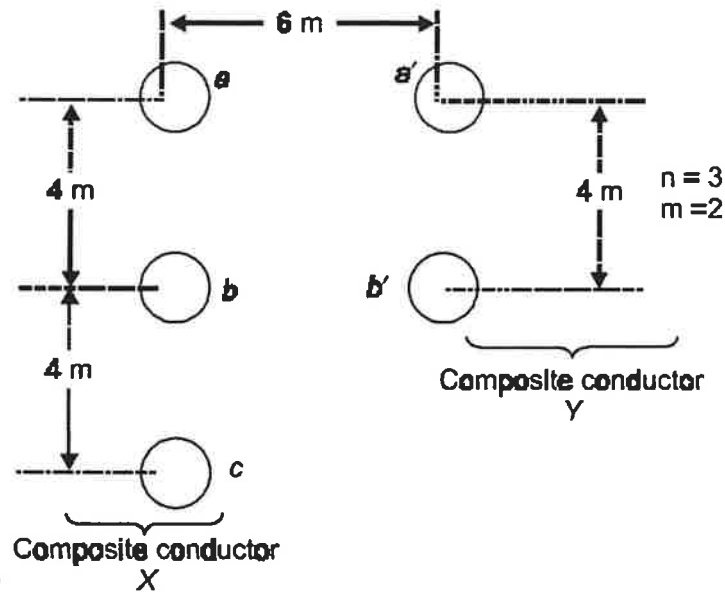


Figure Q1b).

[6.0 Marks]

- Q2 a) i) Draw the equivalent per-phase representation of a long length transmission line. Clearly indicate all the line parameters in the figure and name them.
- ii) Derive the ABCD parameters for a medium-length transmission line of length l , given the per-kilometer values: Line resistance - r (Ω/km), Line reactance - x (Ω/km), and Line susceptance - y (S/km)
- iii) Define the term voltage regulation for a transmission line.

[4.0 Marks]

- b) A 50 Hz, three-phase transmission line with 150 km of length, supplies a three-phase, Y connected, balanced load of 100 MVA at 0.9 power factor lagging. The load voltage is 220 kV (line-to-line). The line parameters are as follows.

Resistance: $0.22 \Omega/\text{km}$, Inductance: $2.56 \text{ mH}/\text{km}$, and Capacitance to neutral: $0.002 \mu\text{F}/\text{km}$.

- i) Calculate the ABCD parameters of the line.
- ii) Calculate the load current.
- iii) Calculate sending-end voltage, sending-end current, and sending-end power factor.
- iv) Calculate the transmission line efficiency.
- v) Calculate the voltage regulation.

[6.0 Marks]

- Q3 a) Consider a portion OP of a curved length l of the overhead conductor shown in Figure Q3 which is hanging in still air with O as the lowest point on the conductor. Let the weight of the conductor per meter length be w kg.

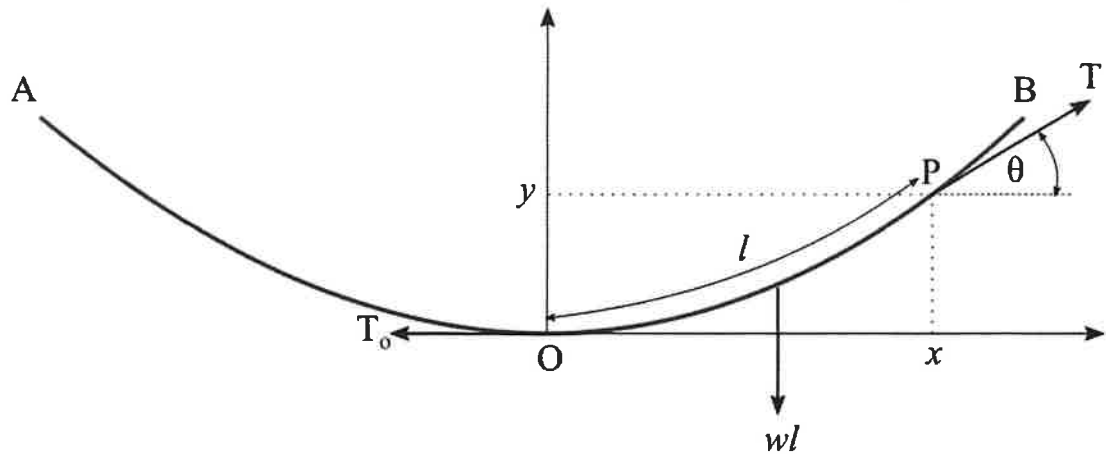


Figure Q3.

- i) Derive the parabolic approximation of the catenary formed by the conductor.
- ii) Derive an expression for the maximum tension of the conductor.

[4.0 Marks]

- b) An overhead transmission line has a span of 275 m between level supports. The conductor has a radius of 0.9765 cm and weighs 0.844 kg/m and has an ultimate breaking strength of 11925 kg. Conductor has a radial covering of ice 0.953 cm thick and is subjected to a horizontal wind pressure of 40 kg/m² of the ice covered projected area. Factor of safety is 3.0. Density of the ice is 913.5 kg/m³.

- i) Determine the vertical sag of the transmission line.
- ii) Calculate the length of the transmission line.

[6.0 Marks]

- Q4 a) i) Define the following types of buses in a power system for load flow analysis, stating the specified and unknown quantities for each bus.

- Slack bus
- Load bus
- PV bus

- ii) State the key properties and assumptions of a power system that are utilized in the Fast Decoupled Load Flow (FDLF) method to reduce computational complexity compared to the Newton-Raphson method.

[3.0 Marks]

- b) Consider the three-bus power system shown in Figure Q4. Bus 1 is the slack bus, Bus 2 is a PQ bus, and Bus 3 is a PV bus. The line impedances and bus data are provided in the figure. All quantities are expressed in per unit on a common base of 100 MVA.

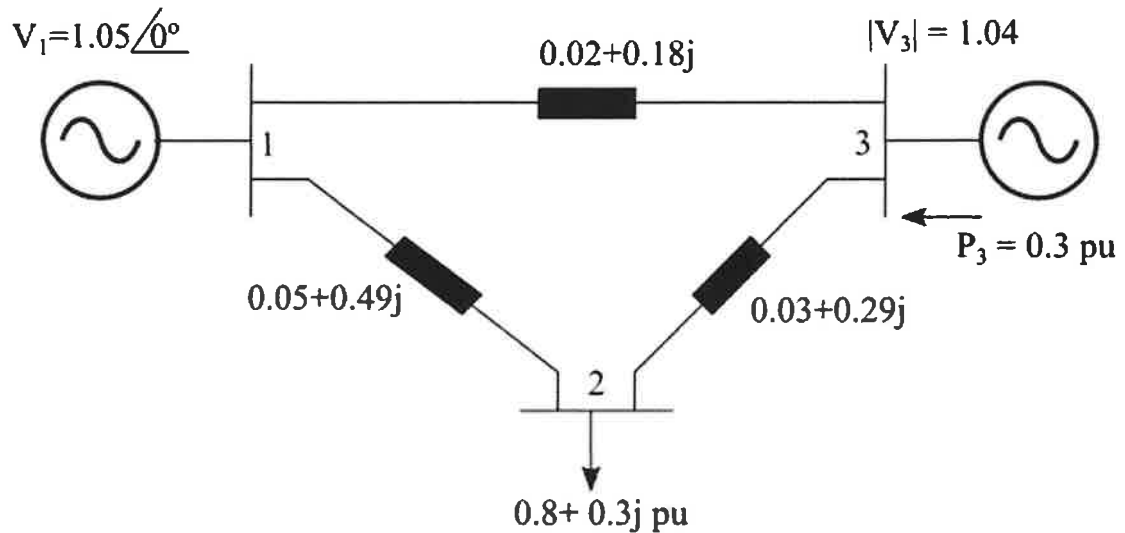


Figure Q4.

- i) Using the Gauss-Seidel load flow method, perform one iteration and determine:

- The voltage magnitude and angle at Bus 2
- The voltage angle at Bus 3

Clearly show all calculation steps. Assume a flat start (i.e., initial voltages of $1 \angle 0^\circ$ p.u. for all buses except the slack bus, and PV bus whose voltage magnitudes are specified).

- ii) During the iterative process, it is observed (e.g., at the 10th iteration) that the reactive power generated at the Bus 2 exceeds its specified limits. Explain how this situation is handled in load flow analysis.
- iii) Explain how the choice of the pre-specified tolerance (convergence criterion) affects the convergence rate and the accuracy of the final solution.
- iv) After convergence, the solution yields the following bus voltages:

$$V_2 = 0.961 \angle -0.158 \text{ rad}$$

$$V_3 = 1.04 \angle -0.028 \text{ rad}$$

Using these values, calculate the active and reactive power supplied by the slack bus.

- v) Determine the total real power loss in the transmission lines of the system.

[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 power generation? 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 in 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 α .

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

[6.0 Marks]