UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 4 Examination in Engineering: February 2020

Module Number: EE4305 **Module Name: Power Systems**

[Three Hours]

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

Q1 a) Three three-phase loads that are connected in parallel across an 11 kV three-phase supply are given below.

Load 1: 80 kVA load at 0.8 power factor lagging

Load 2: 20 kVA load at 0.7 power factor leading

Load 3: Pure resistive load of 15 kW

(i) Find the total complex power drawn from the supply.

(ii) Find the overall power factor of the load.

(iii) Calculate the supply current.

(iv) A Δ-connected capacitor bank is expected to be connected in parallel with the loads in order to improve the overall power factor to 0.98 lagging. Calculate the capacitance of a capacitor of the required capacitor bank.

[6 Marks]

b) Draw the per unit impedance diagram for the electric power system shown in Figure Q1 giving all impedances in per unit on a 100 MVA base. Choose 20 kV as the voltage base for generator G1. The reactance, three-phase power rating and line to line voltage rating of the power system elements are given below.

G1:	70 MVA	20 kV	X = 9%
T1:	80 MVA	20/200 kV	X = 10%
G2:	70 MVA	20 kV	X = 9%
T2:	80 MVA	200/20 kV	X = 10%
Line 1-2:		200 kV	X = 120 Ω
Line 2-3:		200 kV	X= 100 Ω
Line 3-1:		200 kV	X= 60 Ω
Load:	48 MW+j 64 MVar	200 kV	

[6 Marks]

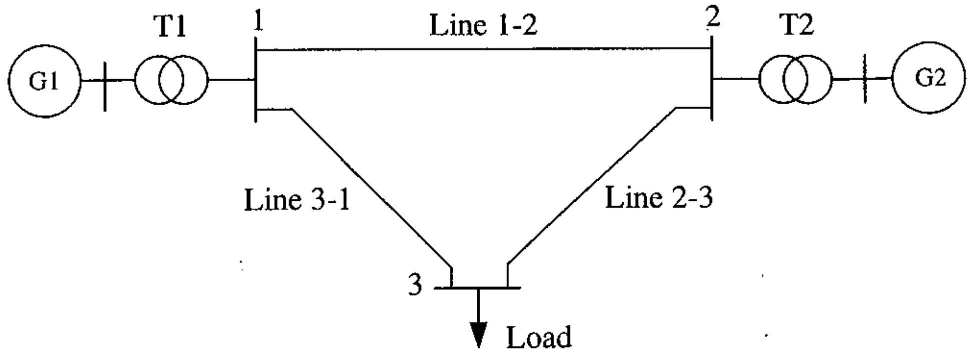

Figure Q1

Q2 a) Clearly defining any symbols used, give the two port network model of a long length transmission line.

[2 Marks]

b) A 400 km, 500 kV, 50 Hz three-phase transmission line has a per phase series impedance of $z = 0.03 + j\,0.35\ \Omega$ per km and a per phase shunt admittance of $y = j\,4.4 \times 10^{-6}$ siemens per km. The line supplies a 200 MVA at 0.8 lagging power factor load at 475 kV. Using the long length line model, determine,

i) The propagation constant of the transmission line.

ii) The characteristic impedance of the transmission line.

iii) The A, B, C and D constants of the transmission line model.

iv) The load current.

v) The sending end line to line voltage.

Hint:

$\cosh(\gamma l) = \frac{e^{\gamma l} + e^{-\gamma l}}{2}$; $\sinh(\gamma l) = \frac{e^{\gamma l} - e^{-\gamma l}}{2}$; $e^{\gamma l} = e^{(\alpha l + j\beta l)} = e^{\alpha l} e^{j\beta l} = e^{\alpha l}\angle \beta l$

[10 Marks]

Q3 a) A typical bus of a power system (bus-i) is shown in Figure Q3 (a) in which the transmission lines are represented by their per unit admittances on a common MVA base. Show that in the iterative process of calculating the bus bar voltages, the i^{th} bus bar voltage at $(k+1)$ iteration can be given as

$$V_i^{k+1} = \frac{\frac{P_i^{sch} - jQ_i^{sch}}{V_i^{*(k)}} + \sum_{j=1}^{n} y_{ij} V_j^{(k)}}{\sum_{j=0}^{n} y_{ij}} \qquad j \neq i$$

All notations have their usual meanings.

[4 Marks]

b) The single-line diagram of a three-bus power system with generation at buses 1 is shown in Figure Q3 (b). System parameters are given in per unit based on a 100 MVA base. The voltage at bus 1 is $V_1 = 1.03\angle 0^0$ per unit. The load connected to bus 2 draws (2.5+j1.1) per unit power from bus 2 while the load connected to bus

3 draws (1.3+j0.45) per unit power from bus 3. The per unit line impedances are given in Table Q3. The line charging susceptances can be neglected.

i) Using Gauss-Seidel method and initial estimates of $V_2^{(0)} = 1.0 + j\,0$ and $V_3^{(0)} = 1.0 + j\,0$, perform two iteration in the process of calculating the voltages at bus 2 and bus 3. Expected accuracy of the bus bar voltages is up to four decimal places.

ii) After several iterations, voltages at bus 2 and bus 3 converge to $0.9617\angle{-3.5^0}$and $0.9814\angle{-2.83^0}$per unit respectively. Determine the active and reactive power supplied from the generator at bus 1.

iii) Determine the line current and power losses in Line 1 -2 in per unit.

[8 Marks]

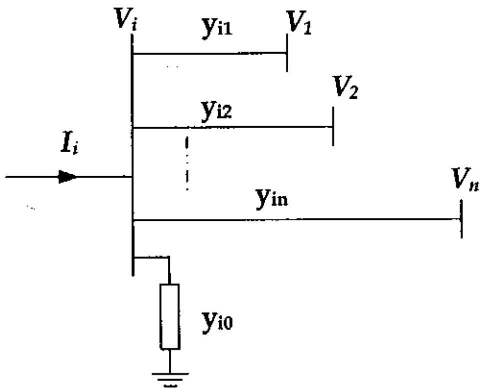

Figure Q3 (a)

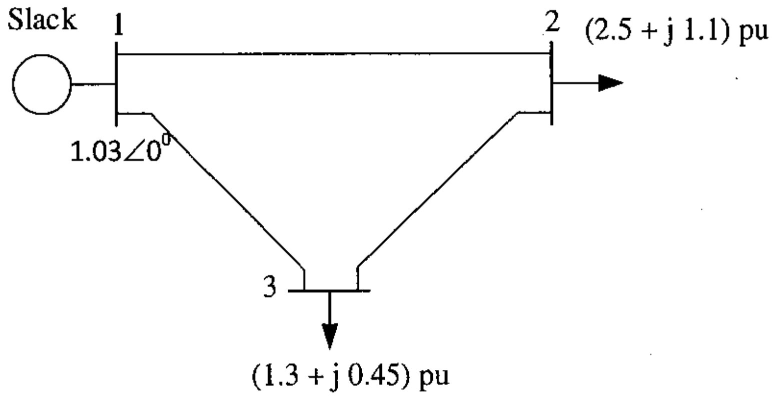

Figure Q3 (b)

Table Q3: Line data (in per unit)

Bus (from-to)	Impedance
1-2	0.02+j 0.04
1-3	0.01+j 0.03
2-3	0.0125+j 0.025

Q4 a) Starting from the first principles, obtain the coordination equations to be solved in order to obtain the economic load dispatch among the thermal generators when the transmission line losses are also coordinated among the generators.

[4 Marks]

b) Fuel cost curves of two thermal plants of a simple two-plant network are given as

$$F_1 = 4 + 2P_1 + 0.006P_1^{\,2} \quad \text{Rs/h}$$
$$F_2 = 3 + 1.5P_2 + 0.0075P_2^{\,2} \quad \text{Rs/h}$$

where P_1 and P_2 are the generation of the two plants in MW.

The total system loss of the above network is given by

$$P_L = 0.0015P_1^{\,2} + 0.0025P_2^{\,2} \text{ MW}$$

The total demand of the network is 160 MW.

(i) Using the equal incremental cost criteria and neglecting the transmission line losses, find the optimum load distribution among the two plants.

(ii) Using the Lambda iteration method, find the economic scheduling of the two plants or perform three iteration of the above process. Take $\lambda = 3.0$ as the initial estimate and 1 MW of power mismatch as the acceptable tolerance.

[8 Marks]

Q5 a) What are the advantages of bundle conductors compared to single conductors with the same cross sectional area?

[2 Marks]

b) A 220 kV, 50 Hz three phase line consisting of two- conductor bundle per phase is shown in Figure Q5. The conductors have a radius of 1.5 cm and GMR of 0.8839 cm and placed 45 cm apart in a bundle. The line is fully transposed and placed in the vertices of a triangle as shown in Figure Q5. The distances are measured from the center of the bundle.

i) Determine the inductance per phase per km of the line.

ii) If the line is 200 km long, calculate the charging capacitance per phase with respect to neutral.

iii) If the operating voltage of the line is 220 kV (line to line), calculate the line charging current.

[5 Marks]

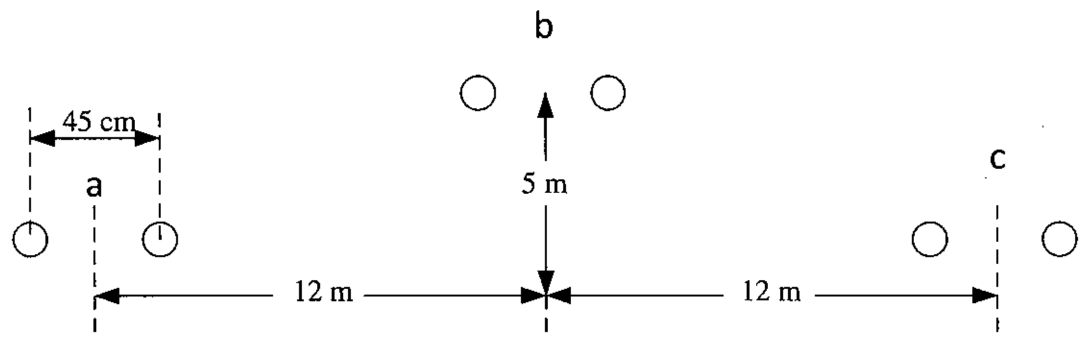

Figure Q5

c) An overhead transmission conductor having weight of 1.16 kg/m has an ultimate tensile strength of 32×10^6 kg/m^2. Its diameter is 1.7 cm. It is erected between two supports 300 m apart and 12 m difference in height. The conductor is loaded with 1 kg of ice per meter. Calculate the sag of the line with respect to the taller of the two supports. Take the factor of safety as 2.0.

[5 Marks]