UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 4 Examination in Engineering: November 2017

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

[Three Hours]

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

Q1 a) A three-phase line has an impedance of $0.4 + j\,2.7\ \Omega$ per phase. The line feeds two star connected balanced three-phase loads that are connected in parallel. The first load is absorbing 560.1 kVA at 0.707 power factor lagging. The second load absorbs 132 kW at unity power factor. The line-to-line voltage at the load end of the line is 3810.5 V. Determine,

(i) The magnitude of the line voltage at the source end of the line.

(ii) Total real and reactive power loss in the line.

(iii) Real power and reactive power supplied at the sending end of the line.

[6 Marks]

b) The three-phase power ratings, line-to-line voltage ratings and the impedances of the components of the electric power system shown in Figure Q1 are given as

G:	60 MVA	~~12 kV~~ 24 kV	X = 9%
T1:	50 MVA	20/200 kV	X = 10%
T2:	50 MVA	200/20 kV	X = 10%
M:	40 MVA	18 kV	X = 8%
Line:	60 MVA	200 kV	Z = 120+j200 Ω

A 20 MVA 0.8 lagging power factor load at 20 kV is connected to the load bus V_L as shown in Figure Q1.

(i) Draw an impedance diagram showing all impedances in per-unit on a 100 MVA base. Choose 20 kV as the voltage base for load bus (V_L).

(ii) The motor M is drawing 45 MVA, 0.8 power factor lagging at a line-to-line terminal voltage of 18 kV. Determine the terminal voltage of the generator V_G in kV.

[6 Marks]

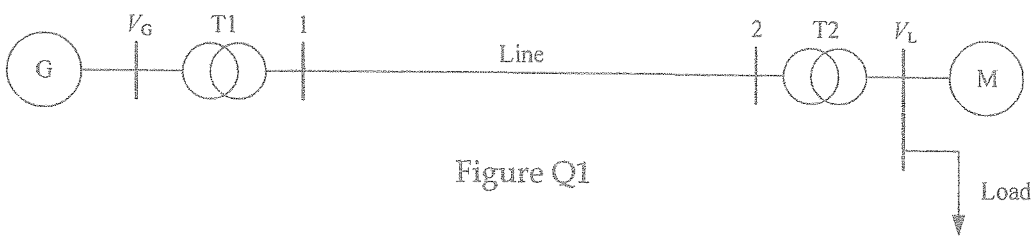

Figure Q1

Q2 a) Different models can be realized for power transmission lines based on their length. Give the ABCD parameters of the models that can be realized for a short length, a medium length and a long length transmission line respectively in terms of their line parameters. Clearly define any symbols used.

[4 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 1000 MVA unity 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 ABCD constants of the transmission line model.

iv) The load current.

v) The sending end line to line voltage.

Hint:

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

[8 Marks]

Q3 The single-line diagram of a three-bus power system with generation at buses 1 and 2 is shown in Figure Q3. System parameters are given in per unit based on 100 MVA base. The voltage at bus 1 is $V_1 = 1.03\angle 0^0$ per unit. Voltage magnitude at bus 2 is fixed at 1.05 per unit with a real power generation of 2 per unit. A load draws (5+j 4) per unit from bus 3. The per unit line impedances and charging susceptances are given in Table Q3.

a) Calculate the bus admittance matrix for the three-bus network in Figure Q3.

[3 Marks]

b) Using Gauss-Seidel method and initial estimates of $V_2^{(0)} = 1.0 + j\,0$ and $V_3^{(0)} = 1.03 + j\,0$ and keeping $|V_3| = 1.03$, perform one iteration in the process of calculating the voltages at bus 2 and bus 3.

[6 Marks]

c) After several iterations, voltages at bus 2 and bus 3 converge to $1.05\angle -0.71^0$ and $0.994\angle -3.82^0$ per unit respectively. Determine the reactive power supplied from the generator at bus 2.

[3 Marks]

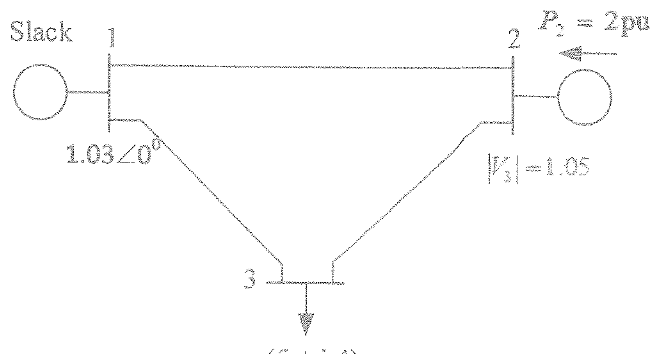

Figure Q3

Table Q3: Line data (in per unit)

Bus (from-to)	Impedance	Charging Susceptance
1-2	j 0.025	j 0.5
1-3	j 0.050	j 1.0
2-3	j 0.025	j 0.5

Q4 a) With the appropriate notations, state the coordination equations and the power balance equation which need to be solved in order to find the economic scheduling of thermal generators while coordinating the network transmission line losses.

[4 Marks]

b) Consider the two generator system shown in Figure Q4. Both generators are thermal units and have the same fuel cost function given as

$F = 400 + 7P + 0.002P^2$ \$/h where P is the power output of the generator.

The generators have maximum and minimum limits of 400 MW and 70 MW respectively. The losses in the transmission line depend on the line flows and given by

$P_L = 0.0002{P_1}^2$ MW where P_1 is the power supplied by the first generator, G1.

The total demand of the load is 500 MW.

(i) Calculate the generating cost per hour, if the maximum allowable power is supplied by generator 2 (G2) while the rest of the demand is supplied by generator 1 (G1).

(ii) Calculate the generating cost per hour, if the load demand is equally shared by both generators.

(iii) Calculate the generating cost per hour if two generators economically share the demand while coordinating the losses. Use the Lamda iteration method and take $\lambda = 8.0$ as the initial estimate. Consider 1 MW of power mismatch as the acceptable tolerance for convergence.

[8 Marks]

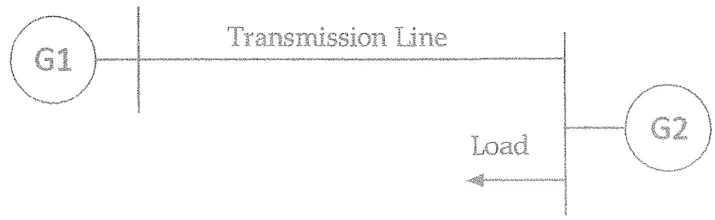

Figure Q4

Q5 a) A transposed three-phase line consisting of four-conductor bundles is shown in Figure Q5. The conductors have a diameter of 3.45 cm and placed at the corner of a square with 50 cm on one side. The line has a flat horizontal configuration with a spacing of 14 m as measured from the center of the bundle as shown in Figure Q5.

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.

[6 Marks]

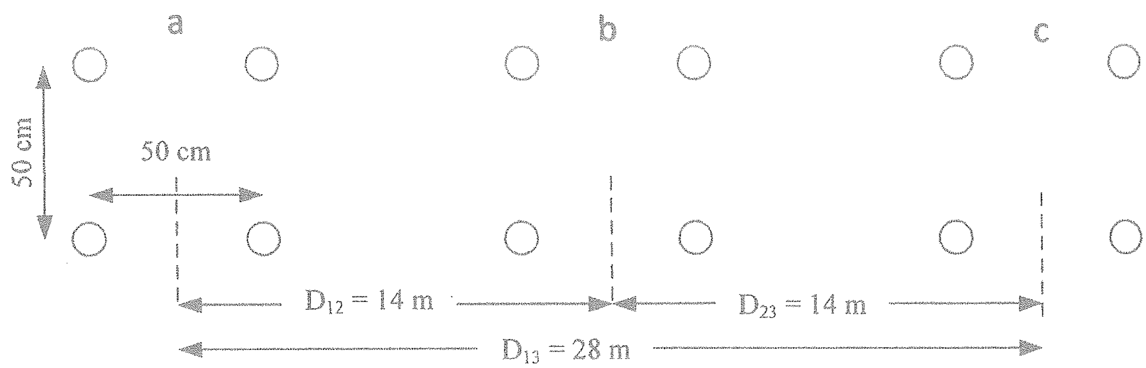

Figure Q5

b) An overhead transmission line at a river crossing is supported from two towers at heights of 30 m and 70 m above the water level. The horizontal distance between the towers is 250 m. If the required clearance between the conductors and the water midway between the towers is 45 m and if both the towers are on the same side of the point of maximum sag, find the tension in the conductor. The weight of the conductor is 0.8 kg/m.

[6 Marks]