UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 4 Examination in Engineering: December 2018

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 a 12.47 kV three-phase supply are given below.

Load 1: Inductive load, 60 kW and 660 kVar.

Load 2: Capacitive load, 240 kW at 0.8 power factor.

Load 3: Pure resistive load of 60 kW.

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

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

(iii) Calculate the supply current.

(iv) A Y-connected capacitor bank is expected to be connected in parallel with the loads in order to improve the overall power factor to 0.8 lagging. Calculate the capacitance of a capacitor of the required capacitor bank.

(v) Calculate the supply current after the power factor is improved to 0.8 lagging.

[6 Marks]

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

G1:	90 MVA	20 kV	X = 9%
T1:	80 MVA	20/200 kV	X = 16%
T2:	80 MVA	200/20 kV	X = 20%
G2:	90 MVA	18 kV	X = 9%
Line:		200 kV	X = 120 Ω
Load:		200 kV	S=48 MW+ j 64 MVar

[6 Marks]

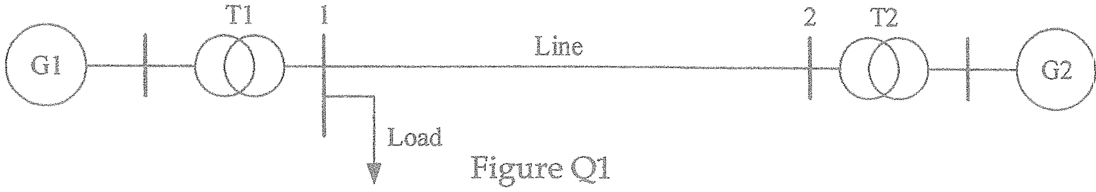

Figure Q1

Q2 a) $ABCD$ parameters of a long transmission line model in usual notation are given as

$A = \cosh(\gamma l) = D$

$B = Z_C \sinh(\gamma l)$

$C = \frac{1}{Z_C}\sinh(\gamma l)$, where $\gamma = \sqrt{zy} = \alpha + j\beta$.

(i) Obtain the $ABCD$ parameters for a lossless line.
Hint: $\cosh(jx) = \cos(x)$; $\sinh(jx) = j\sin(x)$

(ii) Show that the voltage at any point along a lossless transmission line remains constant if the line is terminated by its surge impedance.

[4 Marks]

b) With the appropriate notations, give the equivalent π model of a long transmission line. Define any symbol used.

[2 Marks]

c) A 250 km, 400 kV, 50 Hz three-phase lossless transmission line has a per phase series impedance of $z = j\,0.35\ \Omega$ per km and a per phase shunt admittance of $y = j\,3.5 \times 10^{-6}$ siemens per km.

(i) Calculate the $ABCD$ parameters of the above line.

(ii) Obtain the equivalent π model of the above transmission line.

(iii) Hence or otherwise, find the sending end voltage, current and power if the line supplies a 200 MVA at 0.8 power factor lagging at 400 kV.

[6 Marks]

Q3 a) Defining any symbols used, write the polar form expressions for active power P_i and reactive power Q_i drawn by the i^{th} bus bar in a n bus power system.

[2 Marks]

b) In a two-bus system shown in Figure Q3, bus 1 is a slack bus with $V_1 = 1.0\angle 0^0$ pu. A load of 100 MW and 50 MVar is taken from bus 2. The line impedance $Z_{12} = 0.12 + j0.16$ pu on a base of 100 MVA.

(i) Derive the bus admittance matrix for above power system.

(ii) Obtain the expressions for active power P_2 and reactive power Q_2 drawn from bus 2 in terms of the system parameters.

(iii) It is expected to carry out the load flow analysis on above system using Newton-Raphson method. Obtain the expressions for the elements of the respective Jacobian matrix.

(iv) Starting with the initial estimates of $|V_2|^0 = 1.0$ and $\delta_2{}^0 = 0$, calculate the power residual matrix and the Jacobian matrix during the first iteration of the process.

(v) Perform one iteration of the load flow analysis and find the bus bar 2 voltages after first iteration.

[10 Marks]

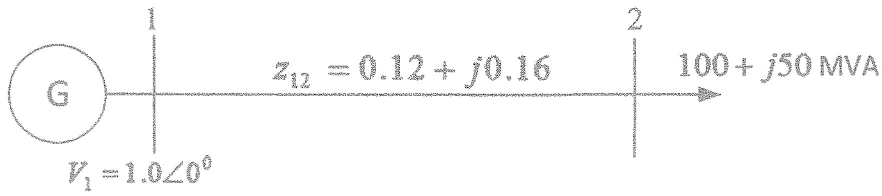

Figure Q3

Q4 a) Using the Lagrange multiplier method, show that the incremental fuel cost of each plant should be kept the same for optimal load dispatch, if the real power losses in the transmission lines and the generator limits are neglected.

[4 Marks]

b) Consider the two bus system shown in Figure Q4. If 100 MW is transmitted from plant 1 to the load, a transmission loss of 10 MW is incurred. The incremental fuel costs of the plants are given as

$$\frac{dF_1}{dP_1} = 0.02P_1 + 16 \quad \text{Rs/MWh}$$

$$\frac{dF_2}{dP_2} = 0.04P_2 + 20 \quad \text{Rs/MWh.}$$

The load demand is 235 MW.

(i) Find an expression for transmission loss P_L.

(ii) Using the equal incremental cost criteria, find the optimum load distribution between the two plants when the losses are included but not coordinated.

(iii) Using the Lamda iteration technique, perform three iterations in the process of finding the optimum load dispatch while the losses are included and coordinated. Use $\lambda = 25$ as the initial estimate.

(iv) When the losses are included and coordinated, the optimal scheduling is found to be $P_1 = 127.912$ MW and $P_2 = 123.45$ MW. Hence, find the savings in rupees per hour by switching the operation from the method described in (ii) to the method described above.

[8 Marks]

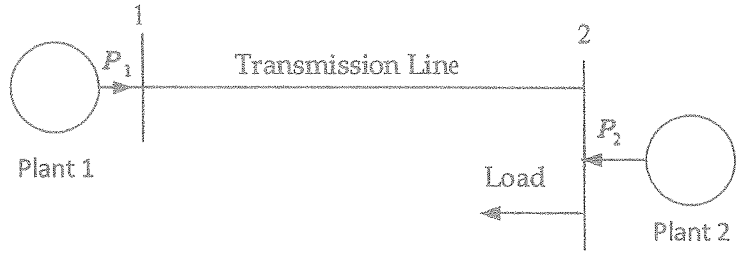

Figure Q4

Q5 a) A 220 kV, 50 Hz double circuit line with hexagonal spacing is shown in Figure Q5. The radius of a conductor is r and the space between two adjacent conductors is D. Two lines are fully transposed and 200 km long.

i) Using the method of GMD or otherwise, find an expression for per phase inductance per km in terms of r and D.

ii) Using the method of GMD or otherwise, find an expression for per phase equivalent capacitance to neutral per km length in terms of r and D.

iii) If r is 1.5 cm and D is 1m, calculate the per phase line reactance and the per phase charging current.

[6 Marks]

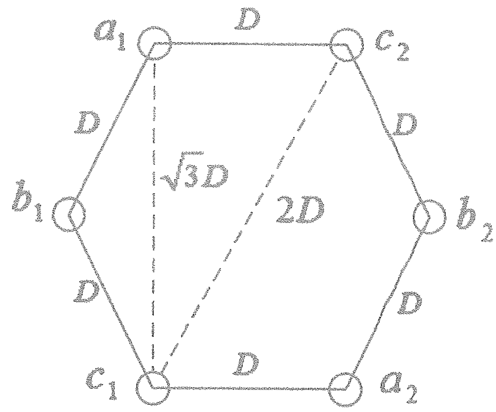

Figure Q5

b) An overhead transmission line is supported on two towers 300 m apart having a difference in level of 10 m. The conductor radius is 1 cm and weighs 2.3 kg/m. Determine the sag with respect to the lower support when the line is subjected to a wind pressure of 55 kg/m^2 on projected area. The maximum tensile strength of the conductor material is 422x10^5 kg/m^2. Assume a factor of safety of 2.3.

[6 Marks]