UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 4 Examination in Engineering: December 2016

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

[Three Hours]

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

Q1 a) Two impedances, $Z_1 = 0.8 + j5.6\ \Omega$ and $Z_2 = 8 - j16\ \Omega$, and a single phase motor are connected in parallel across a 200 Vrms, 50 Hz supply as shown in Figure Q1 (a). The motor draws 5 kVA at 0.8 power factor lagging.

(i) Determine the total current and the power supplied by the source.

(ii) What is the overall power factor?

(iii) A capacitor is connected in parallel with the loads in order to improve the overall power factor to unity. Find the capacitance of the required capacitor.

[5 Marks]

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

G:	60 MVA	20 kV	X = 9%
T1:	50 MVA	20/200 kV	X = 10%
T2:	50 MVA	200/20 kV	X = 10%
M:	43.2 MVA	18 kV	X = 8%
Line:		200 kV	Z = 120+j200 Ω

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

(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 in kV.

[5 Marks]

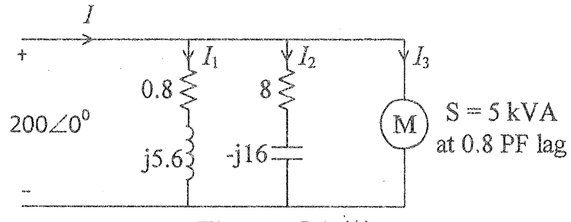

Figure Q1 (a)

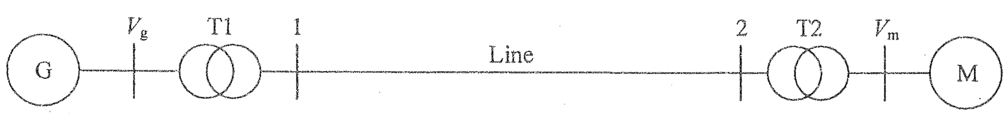

Figure Q1 (b)

Q2 a) Let $ABCD$ constants of a transmission line model be $A = |A|\angle\theta_A$, $B = |B|\angle\theta_B$, $C = |C|\angle\theta_C$, $D = |D|\angle\theta_D$ and the supplying and the receiving ends phase voltages to be $V_S = |V_S|\angle\delta$ and $V_R = |V_R|\angle 0^0$. Show that the active and reactive power received at the receiving end are given by

$$P_R = \frac{3|V_S||V_R|}{|B|}\cos(\theta_B - \delta) - \frac{3|A||V_R|^2}{|B|}\cos(\theta_B - \theta_A)$$

$$Q_R = \frac{3|V_S||V_R|}{|B|}\sin(\theta_B - \delta) - \frac{3|A||V_R|^2}{|B|}\sin(\theta_B - \theta_A).$$

[2 Marks]

b) A 230 kV, three-phase transmission line has a per phase series impedance of $z = 0.05 + j0.45\ \Omega$ per km and a per phase shunt admittance of $y = j3.4 \times 10^{-6}$ siemens per km. The line is 80 km long and supplies a 200 MVA, 0.8 lagging power factor load at 220 kV. Using the nominal π model, determine

i) the transmission line $ABCD$ constants.

ii) sending end voltage, current and power.

iii) voltage regulation

iv) the efficiency of the transmission line.

[8 Marks]

Q3 The single-line diagram of a three-bus power system with generation at buses 1 and 3 is shown in Figure Q3. The voltage at bus 1 is $V_1 = 1.05\angle 0^0$ per unit. Voltage magnitude at bus 3 is fixed at 1.03 per unit with a real power generation of 300 MW. A load draws 400 MW and 200 Mvar from bus 2. The line impedances and charging susceptances are given in Table Q3 in per units based on 100 MVA.

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

[2Marks]

b) Using Gauss-Seidel method and initial estimates of $V_2^{(0)} = 1.0 + j0$ and $V_3^{(0)} = 1.03 + j0$ 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 (1.0683-j0.0358) and (1.0297+j0.0239) per unit respectively. Determine the active and reactive power supplied from the generator at bus 1 and comment on the results.

[2 Marks]

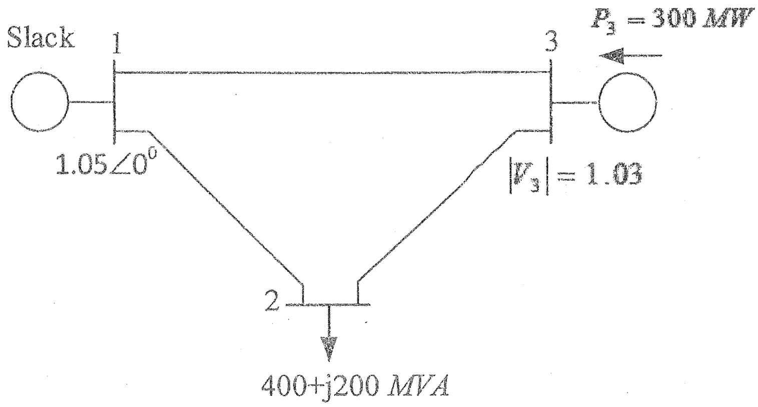

Figure Q3

Table Q3: Line data

Bus (from-to)	Impedance (ohm)	Charging Susceptance (Seimens)
1-2	j 0.025	j 4.0
1-3	j 0.050	j 8.0
2-3	j 0.025	j 4.0

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 the thermal generators while coordinating the network transmission line losses.

[3 Marks]

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

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

The total system loss of the above network is given by

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

The total demand of the network is 160 MW. Using the Lambda iteration method, find the economic scheduling of the two plants or perform three iteration of the process to find the economic scheduling of the plants. Consider $\lambda = 3.0$ as the initial estimate and 1 MW of power mismatch as the acceptable tolerance.

[7 Marks]

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

[2 Marks]

b) Flux linkages of a conductor in a group of n number of conductors carrying currents $I_1, I_2, \dots\dots, I_n$ such that $I_1 + I_2 + \cdots + I_n = 0$ is given by

$$\lambda_i = 2 \times 10^{-7}\left(I_i ln\frac{1}{r_i'} + \sum_{j=1}^{n} I_j ln\frac{1}{D_{ij}}\right)\ \text{Wb/m} \quad j \neq i$$

Using the above result, show that the inductance per phase per unit length of a three phase transmission line, whose three conductors are equilaterally spaced with distance D is given by

$$L = 0.2\, ln\frac{D}{r'} \text{ mH/km}.$$

All notations carry their usual meanings.

The permeability of free space $\mu_0 = 4\pi \times 10^{-7}\text{H/m}$ and permittivity of free space $\varepsilon_0 = 8.85 \times 10^{-12}\text{F/m}$.

[2 Marks]

c) A transposed three-phase line consisting of three-conductor bundles is shown in Figure Q5. The conductors have a diameter of 2.1793 cm and a GMR of 0.8839 cm. 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 100 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]

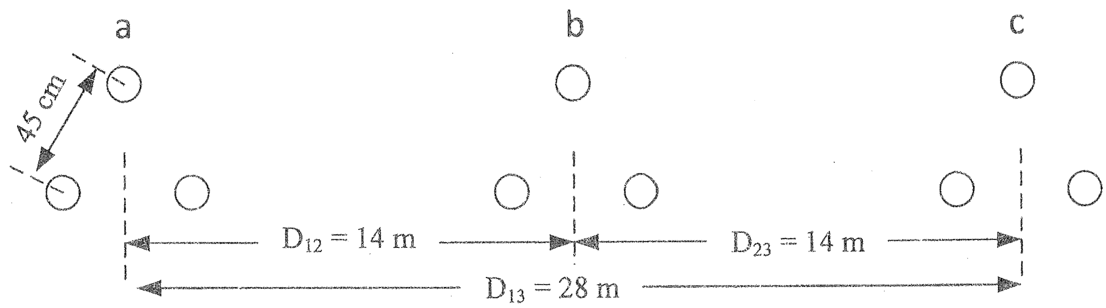

Figure Q5

Q6 a) Show that the arrangement of a transmission line supported with two different elevations at the ends depends on the mechanical parameters of the line. Draw the arrangements and give the conditions for which these arrangements are valid. Assume parabolic configuration for the line shape.

[4 Marks]

b) A transmission line conductor at a river crossing is supported from two towers at heights of 30 m and 90 m respectively above water level. The horizontal distance between the towers is 270 m. If the tension in the conductor is 1800 kgf and the conductor weights 1.0 kgf per meter, find the clearance between the conductor and the water at a point midway between the towers. Assume parabolic configuration for the line shape.

[6 Marks]