UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 4 Examination in Engineering: December 2015

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

[Three Hours]

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

Q1 a) List the advantages of using per unit calculations in power system analysis.

[2 Marks]

b) The three-phase power and line-line ratings of the electric power system shown in Figure Q1 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
Z_{Load}:	4+j3 MVA at 18 kV		

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.

[5 Marks]

c) 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 and the internal emf of the generator in per unit and in kV.

[5 Marks]

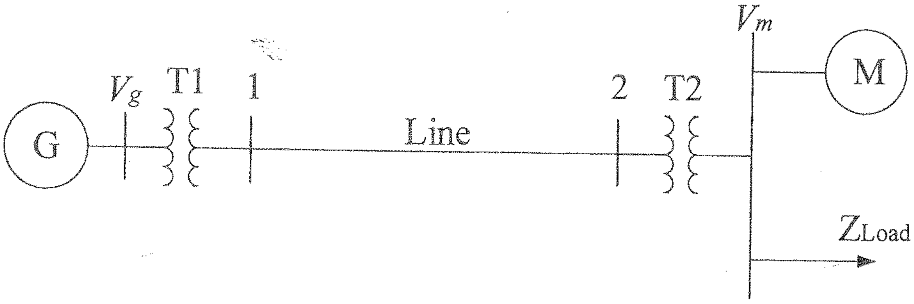

Figure Q1

Q2 A 50 Hz, 300 km long three phase transmission line has a total series impedance of 40+j125 Ω per phase and a total shunt admittance of 0.001 Ω^{-1} per phase. The receiving end load is 50 MW at 220 kV line-to-line voltage with 0.8 lagging power factor.

a) Calculate the $ABCD$ parameters of the line.

[3 Marks]

b) Hence, calculate the sending end voltage, sending end current and the voltage regulation of the line.

[4 Marks]

c) If the sending end line-to-line voltage is 230 kV, calculate the receiving end voltage assuming the load draws the same current as in part b) and the phase difference between the sending end and receiving end voltages is 6.365^0.

[3 Marks]

d) Suggest a method to improve the receiving end voltage back to 220 kV, if the sending end voltage is fixed at 230 kV due to system constraints.

[2 Marks]

Hint:
$$\cosh(x+jy) = \frac{1}{2}(e^x\angle y + e^{-x}\angle -y)$$
$$\sinh(x+jy) = \frac{1}{2}(e^x\angle y - e^{-x}\angle -y)$$

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 equivalent π model. The impedances have been converted to per unit admittances on a common MVA base. Derive an expression for current I_i and hence expressions for the active and reactive power at bus i in terms of bus voltages and line admittances.

[4 Marks]

b) In the power system network shown in Figure Q3 (b), bus 1 is a slack bus with $V_1 = 1 + j0$ per unit and bus 2 is a load bus with S_2=280MW+j60Mvar. The line impedance on a base 100 MVA is Z_{12}=0.02+j0.04 per unit.

i) Using Gauss-Seidel method, calculate the voltage at bus 2 up to four iterations. Use initial estimate for bus 2 voltage as (1+j0) per unit.

ii) After several iterations voltage at bus 2 converges to (0.90-j0.10) per unit. Determine the active and reactive power supplied from the generator at bus 1.

iii) Calculate the real and reactive power loss in the line.

[8 Marks]

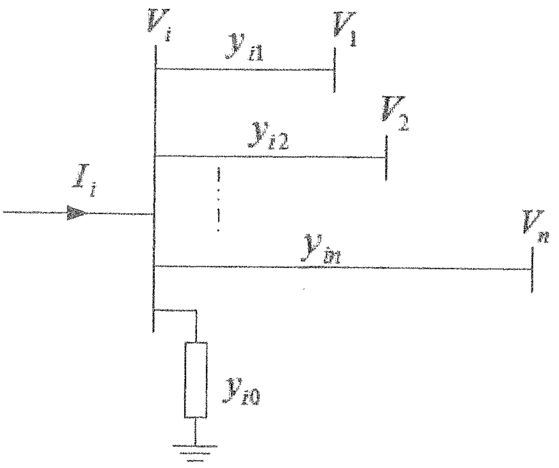

Figure Q3 (a)

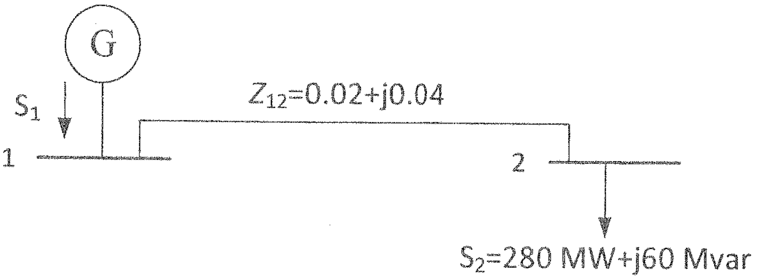

Figure Q3 (b)

Q4 a) For a n-bus system, the following terms are defined with their usual notations.

F_n	Cost function of the nth generator
F_T	Total production cost
P_n	Generation of the n^{th} generator connected to the nth bus bar
P_D	Total demand of the system
λ	Lagrangian multiplier
$\frac{\partial F_n}{\partial P_n} = F_{nn}P_n + f_n$	Incremental production cost of the n^{th} generator.
$P_L = \sum_m \sum_n P_n B_{mn} P_M$	Total transmission loss
$\frac{\partial P_L}{\partial P_n} = 2\sum_m B_{mn}P_m$	Incremental transmission loss.

i) State the optimal load dispatch problem including transmission line losses. Define any additional symbols used.

ii) Derive the coordination equation for optimal load dispatch for a lossy system with n busses with the help of Lagrangian multiplier λ.

iii) Solve the coordination equation to find the generation of the n^{th} generator P_n in terms of the parameters defined above.

[6 Marks]

b) Incremental production cost of the plants and the total system loss of a simple two plant system are given as

$$\frac{dF_1}{dP_1} = 0.01P_1 + 2.0 \text{ Rs/MWhr}$$

$$\frac{dF_2}{dP_2} = 0.01P_2 + 1.5 \text{ Rs/MWhr}$$

$$P_L = 0.0015{P_1}^2 + 0.0025{P_2}^2 - 0.0005P_1P_2 \text{ MW}$$

Using method of successive approximation, calculate the generation schedule for λ=2.6, if 0.01 MW is considered as the convergence criteria. Use the generation corresponding to equal incremental cost of production as the initial values.

[6 Marks]

Q5 a) A three-phase 50 Hz transmission line consists of three equal conductors of radii 12.5 mm, placed in a horizontal plane, with a spacing of 6 m between the middle and each outer conductor as shown in Figure Q5. (Note that permeability of free space $\mu_0 = 4\pi \times 10^{-7}\text{H/m}$ and permittivity of free space $\varepsilon_0 = 8.85 \times 10^{-12}\text{F/m}$).

i) Determine the inductive reactance per phase per km of the transposed line.

ii) Find the capacitance per km to neutral and the capacitive reactance per phase per km of the transposed line.

[6 Marks]

b) The transmission line shown in Figure Q5 has been suspended freely from two towers and has taken the form of a catenary curve. The span between the two towers is 250 m, and the weight of the conductor is 0.85 kgf/m. The ultimate breaking strength of the conductor is 3000 kgf. Each conductor is subjected to a horizontal wind pressure of 40 kgf/m². Assuming a factor safety of 2 and using the approximate method, calculate

i) the deflected sag and

ii) the length of the conductor.

[6 Marks]

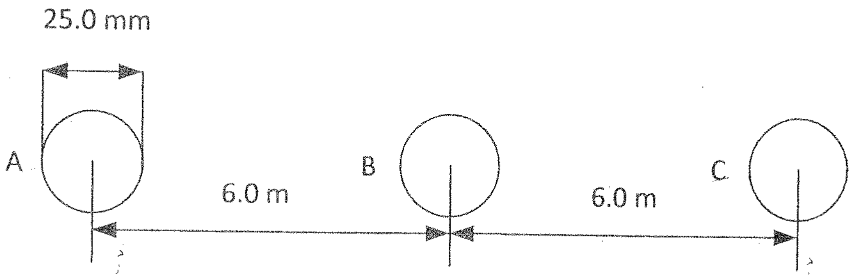

Figure Q5