00140

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The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Electrical and Computer Engineering

Study Programme	: Bachelor of Technology Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	**: EEX5832/ECX5332 Power Systems II**
Academic Year	: 2017/18
Date	:13th February 2019
Time	: 0930-1230hrs
Duration	**: 3 hours**

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **Eight (08)** questions in **six (06)** pages.
3. Answer any **Five (05)** questions only. All questions carry equal marks.
4. Answer for each question should commence from a new page.
5. Relevant charts/ codes are provided.
6. This is Closed Book Test (CBT).
7. Answers should be in clear hand writing.
8. Do not use Red colour pen.

Question 1

A synchronous generator delivers power of 1.5 p.u. to an infinite bus via transmission line as shown in Figure Q1.1. Excitation voltage and the transient reactance of the generator are 1.12 p.u. and 0.12 p.u. respectively. Reactance of the transmission line is 0.2 p.u. and the infinite bus voltage is 1.0 p.u. H constant of the generator is 4 MJ/MVA and frequency is 50 Hz.

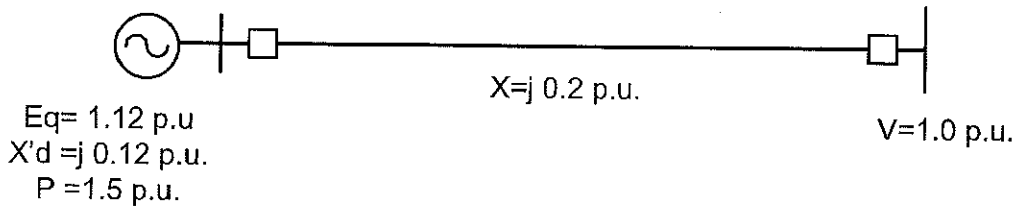

Figure Q1.1

a) Calculate the maximum power that can be delivered by the generator [3 marks]
b) Determine the initial power angle (δ_0) [2 marks]

c) While delivering the power, suddenly the line is switched off by the circuit breakers at the ends of the line and is re-energized after time of T=0.1 s (the corresponding angle is δ_1). The time T is less than the critical clearing time ($T < t_{cr}$). Variation of δ with the time for this situation is shown in Figure Q1.2

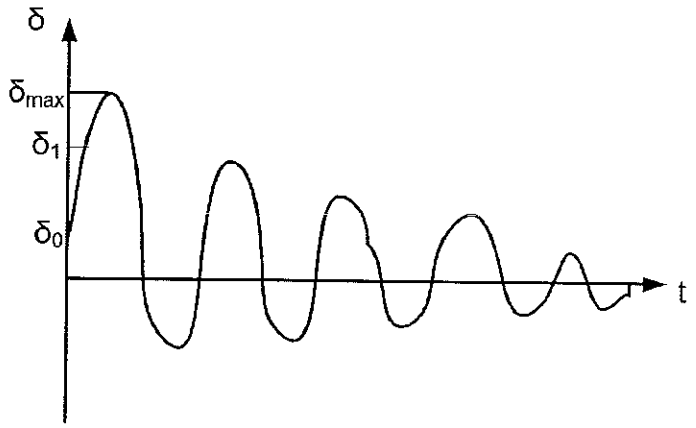

Figure Q1.2

i. Sketch the power angle curve and clearly indicate P_{mech}, δ_0, δ_1, δmax, acceleration area, deacceleration area for the above situation [5 marks]
ii. Calculate the angle (δ_1) at which the line is re-energized [4 marks]
iii. Derive an equation to determine maximum swing angle δmax [4 marks]
iv. Find an approximate value for maximum swing angle (simple iterative method is recommended) [2 marks]

Question 2

A power plant delivers power to a system via 500 kV, 450 km long transmission line. Per phase reactance and susceptance of the line are 0.308 Ωkm^{-1} and 3.6 x 10^{-6} Skm^{-1}respectively.

a) Calculate surge impedance, propagation constant and surge impedance loading [5 marks]

b) During the peak hours, the load at the receiving end of the line is 1.2 times of the surge impedance loading. Voltage at the receiving end is 500 kV. Determine the voltage at the sending end of the line, when receiving end power factor is unity. [7 marks]

c) During the off-peak hours load at the receiving end is 0.15 of the surge impedance loading. Voltage at the both ends of the line is equal 495 kV.

i. Determine
- Phase difference between the voltages at the ends of line
- Reactive power at the receiving end of the line [6 marks]

[hint: $I_R = \frac{P_R}{\sqrt{3}V_R}(1 + jtan\varphi)$*]*

ii. Without any calculation, state whether the voltage at the midpoint of the line is greater or less than the voltage at the ending points. Explain your answer [2 marks]

Question 3

Consider a power system shown in Figure Q3. Reactance of the lines and shunt susceptance at bus 3 are given in p.u. on common base of 100 MVA as indicated in the Figure Q3. Voltage at bus 4 is fixed at 1.02 p.u. and voltage magnitude at generator bus 2 is 1.05 p.u.

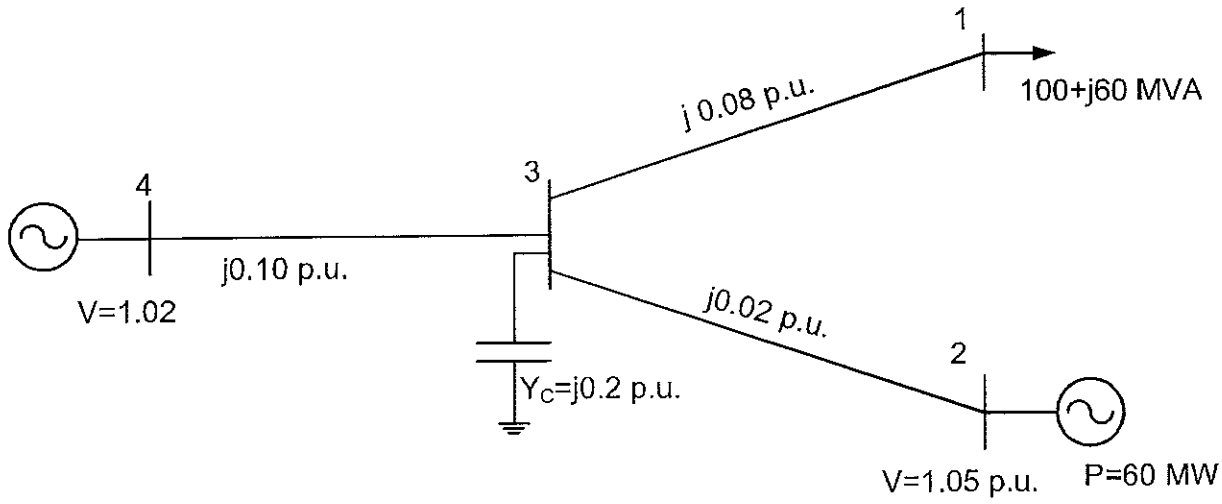

Figure Q3

a) Form the Bus admittance matrix [6 marks]

b) Calculate;

i. voltage at buses using Gauss-Seidel method. One iteration is sufficient [8 marks]

ii. active power (in MW) and reactive power (in Mvar) of the slack bus [5 marks]

iii. reactive power generated by shunt capacitor at bus 3 [1 mark]

Question 4

a) Explain why in Newton- Raphson method, the iterative process starts with "flat start" is not always converged to the solution. [4 marks]

b) Figure Q4 shows a generator connected to a system bus via transmission line. The generator delivers 250 +j 75 MVA and a load of 20 +j5 MVA is connected at the generator bus. Line reactance is 0.4 p.u on common base of 100 MVA. Voltage at the system bus is 1.1 p.u.

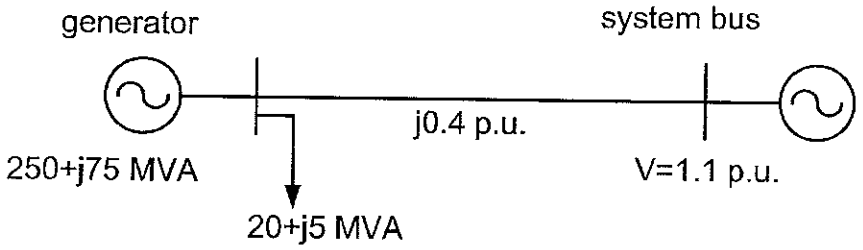

Figure Q4

i. Calculate voltage at the generator bus using Newton-Raphson method. One iteration is sufficient [14 marks]

ii. What is the accuracy of your result obtained? [2 marks]

Active and reactive power at any bus can be calculated as

$$P_i = V_i \sum_{j=1}^{n} V_j Y_{ij} Cos\left(\theta_{ij} + \delta_j - \delta_i\right);\ Q_i = -V_i \sum_{j=1}^{n} V_j Y_{ij} Sin(\theta_{ij} + \delta_j - \delta_i)$$

Question 5

A 22 kV radial distribution system (shown in figure Q5) is protected by over current relays installed at circuit breaker locations A and B. Maximum load currents at bus 2 and 3 are indicated in the Figure Q5. Current transformer ratio at circuit breakers' locations A and B are 600 A: 5 A and 400 A: 5 A respectively. Maximum and minimum three -phase short circuit currents at line L2 are 5000 A and 3500 A respectively. Pick-up settings of the over current relay can be adjustable by taps at 2.5, 3.75, 5.0, 6.25, 7.5, 8.75 and 10.0 A. time-multiplier can be adjustable from 0.1 to 1 continuously. Time current characteristic of the relay is given in Appendix A.

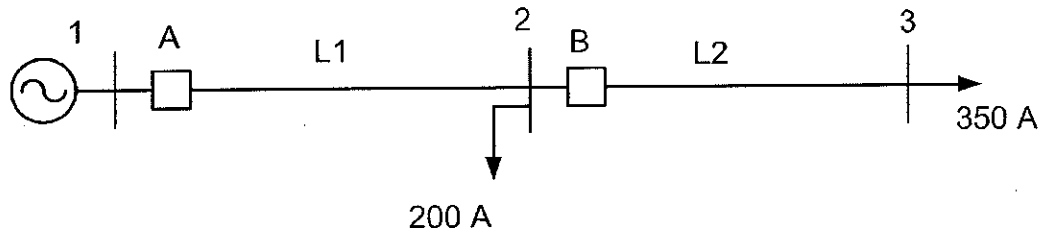

Figure Q5

i. Select suitable pick up values for the relays at A and B [4 marks]

ii. If relay at A provides the remote back up for the relay at B, what should be the time dial setting of the relay at A [6 marks]

iii. If a three-phase fault of 4275 A occurred in line L2, calculate the operating time of the relay at B [7 marks]

iv. Suppose, the relay at B did not respond for the fault given in (iii), how long does it take to operate the relay at A [3 marks]

Question 6

a) With the help of necessary sketches explain how the differential relays are used for bus bar protection [5 marks]

b) Explain how does distributed parameters of the long length line affect the voltage variation along the line [5 marks]

c) Explain how series capacitance improve the steady state stability limit [5 marks]

d) What is the role of slack bus in electrical power system? [5 marks]

Question 7

a) "Distance relays are more suitable than over current relays in the transmission line protection". Explain why [3 marks]

b) With the help of suitable example, explain why the zone of the distance relay is used to cover only a portion of the transmission line, but not the entire line. [4 marks]

c) Figure Q7 shows 132 kV transmission system. Line impedances are indicated in the figure. Mho relay is installed at the circuit breaker X. Current and voltage transformer ratio at the circuit breaker location are 600 A: 1 A and 132000 V: 120 V respectively.

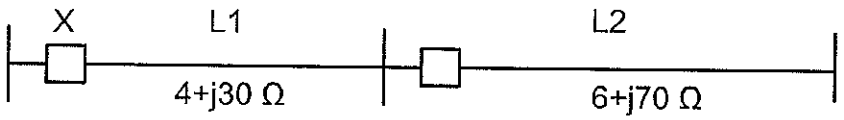

Figure Q7

i. Determine the line impedance L1 as seen by the relay at X [8 marks]

ii. Determine zone 1 and zone 2 settings for the relay at X [5 marks]

Question 8

a) Define term "incremental fuel cost" [2 marks]

b) Explain why fuel cost characteristics have minimum and maximum limits [4 marks]

c) A power plant consists of two generating units. Operating cost characteristic of the units are given bellow

$$C_1 = 8P_1 + 0.006P_1^2 \ \frac{\$}{hr}, \qquad 200 \leq P_1 \leq 600\ MW$$

$$C_2 = 5P_2 + 0.008P_2^2 \ \frac{\$}{hr}, \quad 250 \leq P_2 \leq 1000\ MW$$

i. Determine incremental fuel cost characteristics of the units [2 marks]

ii. Calculate optimum power sharing between the units for following loads (transmission losses are neglected)

-500 MW

-1000 MW [8 marks]

iii. Calculate the total operating cost of the plant for each of the above loads given in iii [4 marks]

APPENDIX A

Time current characteristic of relay