060

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 Power Systems II**
Academic Year	: 2020/21
Date	:22nd January 2022
Time	: 09.30-12.30
Duration	**: 3 hours**

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **six (06)** questions in **six (06)** pages.
3. Answer **only five** questions. 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 handwriting.
8. Do not use Red color pen.

Q1.

a) A lossless transmission line is connected to a pure resistive load. The load resistance is equal to the surge impedance. Prove that the voltage magnitude at both ends of the line are equal.

[6 marks]

b) A Power plant connects a grid substation using 300 km long transmission line. The line has series reactance of j0.32 Ω km^{-1} and shunt admittance of j 4.5 x 10-6 S km^{-1}. The line is open at the grid substation end, while the voltage at the power plant end is 500 kV. It was found that at this situation the voltage at the grid substation end is beyond the permissible maximum voltage.

i. Explain the reason for the voltage increase during open circuit condition, [3 marks]

ii. Calculate the voltage at the grid substation end, [6 marks]

iii. To bring this voltage up-to the maximum permissible voltage, a shunt reactor is to be installed at the receiving end. Calculate the minimum MVAr rating (per-phase) of this reactor. [5 marks]

[total:20 marks]

Q2.

a) Write three properties of bus admittance matrix of network of real power systems

[3 marks]

b) Bus admittance matrix (Y_{BUS}) of a three -bus power system is given below. Type and its known data of the three buses are given in Table Q2. Base power is 100 MVA.

$$Y_{BUS} = \begin{bmatrix} -j12 & j4 & j8 \\ j4 & -j10 & j6 \\ j8 & j6 & -j14 \end{bmatrix}$$

Table Q1

Bus number	Bus type	V p.u.	δ degree	P load MW	Q load MVAr	P gen MW	Q gen MVAr
1	Slack	1.03	0^0	--	--	--	--
2	Load	1.00	--	90	40	-	--
3	PV	1.02	--	--	--	80	--

i. Calculate voltage of buses 2 and 3 after the first iteration of Gauss-Seidel method, [8 marks]

ii. Calculate power flow of the line between buses 2 and 3. Sketch this line and indicate the directions of active and reactive power flow, [5 marks]

iii. Calculate power loss of the line 2-3 [2 marks]

iv. Determine power and power factor of the slack bus [2 marks]

[total:20 marks]

Q3.

a) Which blocks of Jacobean matrix is made zero in decouple load flow calculation. Explain why [4 marks]

b) Compare Newton-Raphson method with the Gauss-Seidel method for the following properties of load flow calculation
   i. Convergence,
   ii. Computational time per iteration,
   iii. Sensitiveness to the initial estimation.

[3 marks]

c) The total number of buses of a power system is hundred (100). There are ten (10) PV buses in the system. Determine order of each block of Jacobean matrix. [5 marks]

d) A large system which is represented by Thevenin's equivalent is connected to a bus k, as shown in figure Q3. Let the active and reactive power of the bus k are given as below

$$P_k = \frac{V_k^2}{Z_{th}} Cos\theta - \frac{V_k V_{th}}{Z_{th}} Cos(\theta + \delta_k)$$

$$Q_k = \frac{V_k^2}{Z_{th}} Sin\theta - \frac{V_k V_{th}}{Z_{th}} Sin(\theta + \delta_k)$$

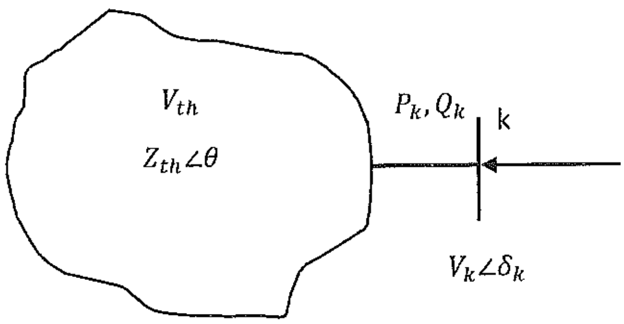

Figure Q3

Derive expressions for following elements of Jacobian matrix:

$$\frac{\partial P_k}{\partial \delta_k}, \frac{\partial P_k}{\partial V_k}, \frac{\partial Q_k}{\partial \delta_k}, \frac{\partial Q_k}{\partial V_k}$$

[8 marks]

[total:20 marks]

Q4

A 50 Hz three-phase synchronous generator (G) delivers power of 1.5 p.u. at 0.9 power factor lagging to a system (S) via transformer (T) and transmission network as shown in figure Q4. Voltage at system bus is maintained at 1.0 p.u. Reactance of the generator, transformer, transmission lines in p.u. on common base are indicated in the figure. H constant of the generator is 6 s.

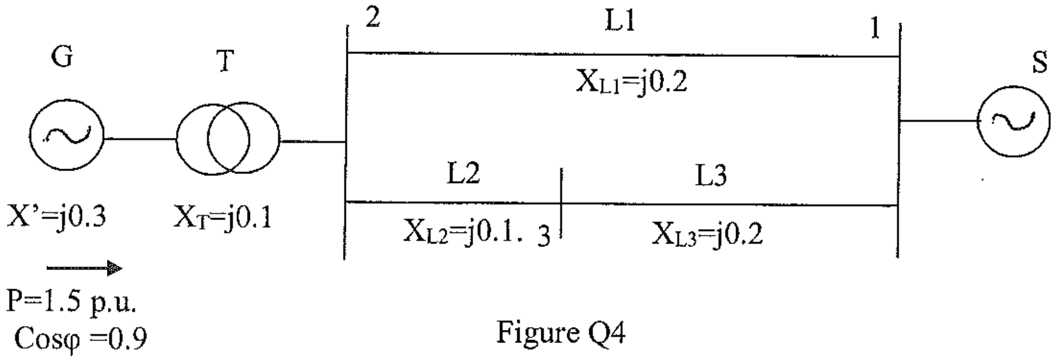

Figure Q4

i. Calculate excitation voltage of the generator (Eq), and initial power angle (δ_0), [7 marks]

ii. A three-phase short circuit occurs at the bus 2 and the fault is cleared after 60 ms without tripping any of the line.

   a. Calculate the rotor angle at the moment of clearing the fault, [5 marks]
   b. Derive an equation to determine maximum swing angle (solving of equation is not required). [8 marks]

[total:20 marks]

Q5.

a. A radial distribution system shown in figure Q5.1 is protected by IDMT relays at circuit breakers locations A, B, and C (shown in figure Q5.1). Pick-up value, maximum short circuit current and CT ratio at circuit breaker's location is given in table Q5. Time current characteristic of the relay is given in in the appendix A.

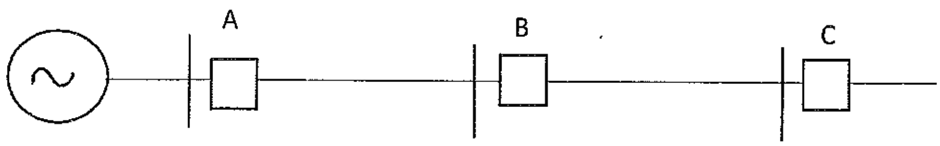

Figure Q5.1

Table Q5

Parameter	A	B	C
Pick-up value (A)	7.5	5	2.5
CT ratio	600:5	300:5	200:5
Max, short circuit current	5000	3250	2000

i. What is the TMS of the relay at C? Ggive reason(s). [3 marks]

ii. If the relay at B provides the remote back-up for the relay at C, determine TMS of the relay at B, [5 marks]

iii. If the relay at A provides the remote back-up for the relay at B, determine the TMS of the relay at A. [5 marks]

b. Power system shown in figure Q5.2 is protected by over current relays at circuit breakers locations A, B, C, D, E, and F.
   - Identify the directional and non-directional relays? [2 marks]
   - Indicate the directions of the directional relays in the system (redraw the system in the answer sheet and indicate them). [5 marks]

[total:20 marks]

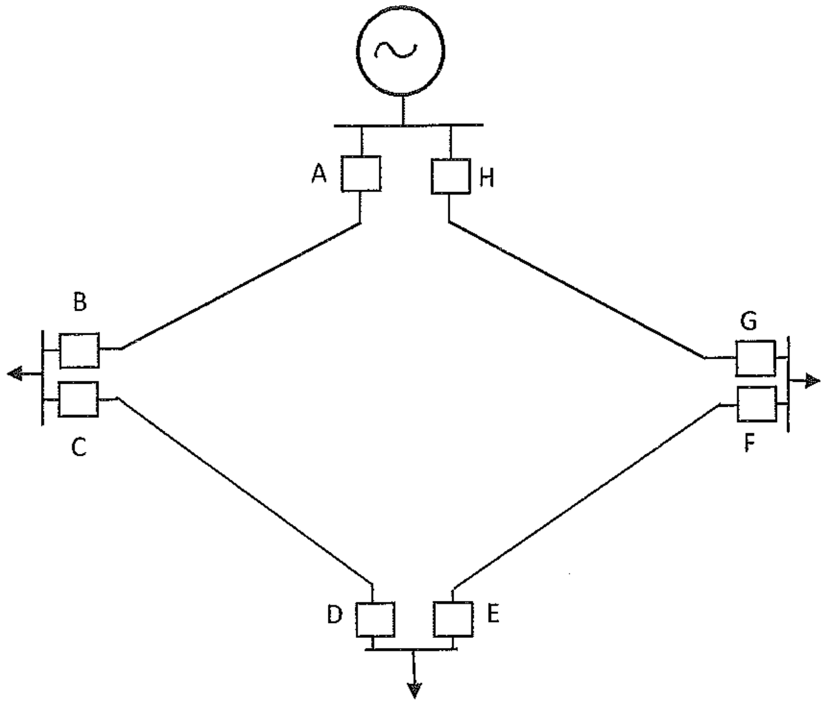

Figure Q5.2

Q6

a. Figure Q6 shows a transmission network protected by the distance relays installed at circuit breakers X and Y. Zone I settings of relays at X and Y are 200 Ω. During a fault at point P, fault currents through the circuit breakers X and Y are 600 A and 250 A respectively. Line impedances are indicated in the figure.

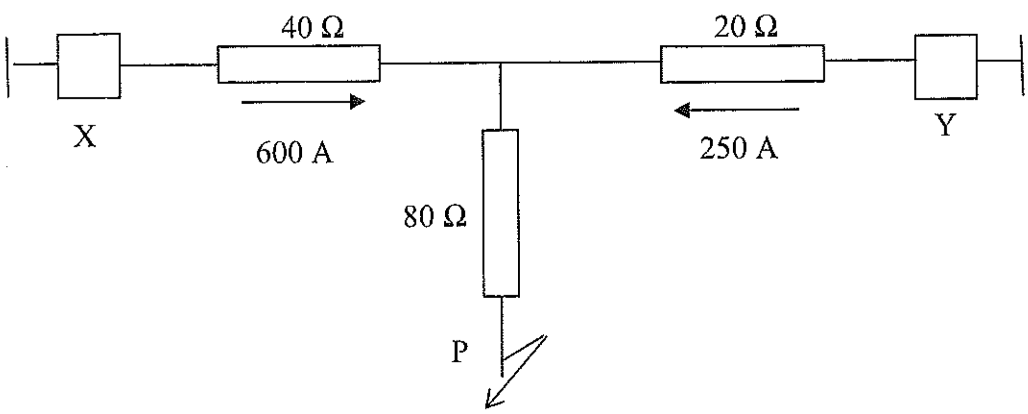

Figure Q6

i. Determine the impedances seen by the relay X and Y during the fault,
ii. Which relay (or both the relays) will detect the fault? Give reason.

[10 marks]

b. State method of protection used for bus bar protection. Briefly explain your answer with the aid of suitable figure/diagram. [5 marks]
c. Explain why the fuel cost characteristics of thermal power plants have minimum and maximum power limits. [5 marks]

[total:20 marks]

APPENDIX A

Time Current characteristics for different time settings of relay