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

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Study Programme	: Bachelor of Technology Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	**: EEX5352 Power Systems II**
Academic Year	: 2022/23
Date	: 02nd February 2024
Time	: 14:00-17:00
Duration	: **3 hours**

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **five (05)** questions in **four (04)** pages.
3. Answer **all** the **questions**
4. Answer to each question should commence from a new page.
5. Graph papers are available on request.
6. This is a Closed Book Test (CBT).
7. Answers should be in clear handwriting.
8. Do not use red color pen.

Question 1

A generator delivers power to a system via a transmission line as shown in figure Q1. Voltage at system bus is 1.0 pu and transmission line reactance is 0.3 p.u. Under the steady state condition generator's emf is 1.8 pu and its sub-transient reactance is 1.2 p.u. Input mechanical power to the generator is 0.45 p.u.

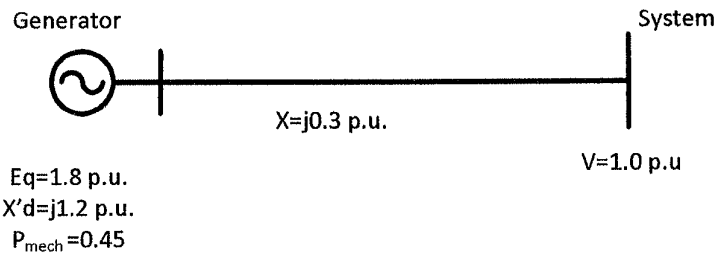

Figure Q1

I. Determine maximum possible power that can be delivered to the system. [2 marks]

II. Calculate initial power angle. [2 marks]

Now, the input mechanical power is doubled.

III. Sketch power angle curve and indicate acceleration and deacceleration areas. [4 marks]

IV. Write the swing equation and show that there is an acceleration of the rotor just after increase of the input mechanical power. [2 marks]

V. Use equal area criterion to show that the generator becomes stable after the transient period. [8 marks]

VI. Without any calculations, identify the range of maximum swing angle. [2 marks]

Question 2

A power plant connects to a grid substation via 300 km, 50 Hz transmission line. The substation receives 600 MW while keeping magnitudes of the voltage at both ends at 510 kV. Per-unit length series reactance and shunt susceptance of the line are j0.32 Ω/km and 5.2 x 10^{-6} S/km.

I. Calculate surge impedance and propagation constant of the line. [4 marks]

II. Calculate surge impedance loading and express the power delivered by the line as a percentage of the surg impedance loading. [2 marks]

III. Using long length transmission line model determine

a. Current at the receiving end of the line [5 marks]

b. Reactive power requirement at the receiving end of the line [5 marks]

IV. Without any calculations, sketch the voltage and current variation along the line. [4 marks]

Question 3

Figure Q3 shows a single -line diagram of a power system. Known voltages and power of the respective buses are given in the figure (All the parameters are given in p.u. on common base). The elements of bus admittance matrix are :

Y12=j10 p.u.; Y13=j8 p.u.; Y23=j8 p.u

Y22=-j18 p.u; Y33=-j16 p.u

It was proposed to solve this system using a combination of Gauss -Seidel method and Newton

Raphson method. The first iteration is carried out using the Gauss-Seidel method and from the second iteration onwards Newton- Raphson method is used.

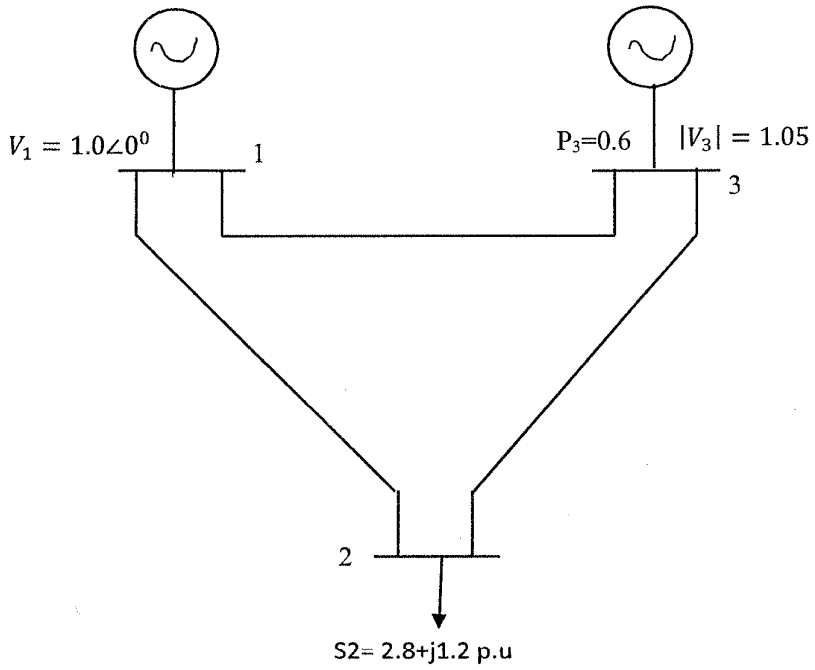

Figure Q3

I. Calculate unknown voltages of the buses after the first iteration of Gauss-Seidel method.

[8 marks]

II. Determine active and reactive power mismatch of bus 2 after the first iteration.

[6 marks]

III. Determine the order of sub-matrices $\left[\frac{\partial P}{\partial V}\right], \left[\frac{\partial P}{\partial \delta}\right], \left[\frac{\partial Q}{\partial V}\right], \left[\frac{\partial Q}{\partial \delta}\right]$ of the Jacobean matrix. Hence, calculate the order of the Jacobean matrix. (do not calculate the elements of the Jacobean matrix) [6 marks]

Question 4

I. Figure Q4 shows 33 kV distribution system which is protected by identical over current relays at circuit breaker locations A, B, C, D, and E. Operating time-current characteristic of the relay on any plug setting with the time leaver set at 1.0 is given below

Operating time (s)	15	4.5	3.9	2.65	2.0
Multiples of the plug setting	1.5	4.0	5	10	20

The plug settings of the relay are at 2.5, 3.75, 5.00, 6.25, 7.5, 8.75 and 10 A and the time leaver is continuously adjustable from 0.1 to 1.0.
The maximum and minimum fault currents at relay locations are 4500 A and 1000 A respectively. The current transformer used at E has 500:5 ratio. The pick-up value of the relay at E is 2.5 A whilst its time leaver setting is 0.1 s.
The relays at A and B provide back-up protection for the relay at E.

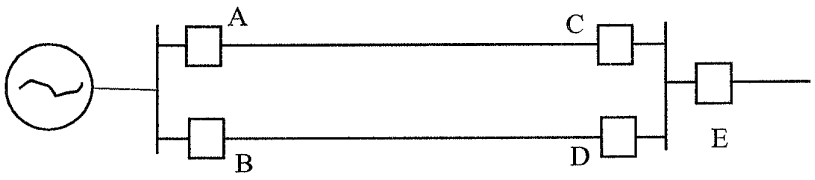

Figure Q4

a. Select suitable CT for the relay A among CTs which have the ratios of 100:1 and 100:5 [5 marks]
b. Determine pick-up value and time leaver setting for the relays A and B. (graph papers are available on request) [8 marks]

II. A 132 kV transmission line has an impedance of 20+ j100 Ω. This line is protected by a Mho rely. Zone 1 setting of the relay has maximum reach of 1.01 Ω, at an angle making 75^0 with the R-axis on the R-X plane. Current transformer and voltage transformer ratios at the circuit breaker location are 100 A:5 A and 132 kV: 120 V respectively.

a. Determine the impedance of the line seen by the relay [3 marks]
b. Calculate the fraction of the line protected by this relay [4 marks]

Question 5

I. Explain the significance of direction over-current protection using an appropriate example. [4 marks]

II. What are the two conditions to be satisfied by the current transformers that are used in two sides of D-Y connected power transformers in differential protection? [4 marks]

III. Describe how the series compensation in transmission line is used for increasing the steady-state stability limit. [4 marks]

IV. A power plant consists of two units. Their incremental fuel cost characteristics and minimum and maximum power outputs are given bellow

$$\lambda_1 = 0.008P_1 + 8 \ \$/MWh \quad 120 \leq P_1 \leq 600 \ MW$$
$$\lambda_2 = 0.009P_2 + 9 \ \$/MWh \quad 120 \leq P_2 \leq 600 \ MW$$

a. Which of the units should be loaded first, while keeping the other unit at its minimum load? [2 marks]
b. What is the load of the power plant at which both the units start to parallelly increase their power dispatch? [2 marks]
c. Calculate optimum power dispatch between the plants when the load is 500 MW. [4 marks]