Reg. No.														

B.Tech. DEGREE EXAMINATION, NOVEMBER 2023
Fifth Semester

18EEC303T – POWER SYSTEM ANALYSIS
(For the candidates admitted from the academic year 2020-2021 to 2021-2022)

Note:
(i) **Part - A** should be answered in OMR sheet within first 40 minutes and OMR sheet should be handed over to hall invigilator at the end of 40^{th} minute.
(ii) **Part - B & Part - C** should be answered in answer booklet.

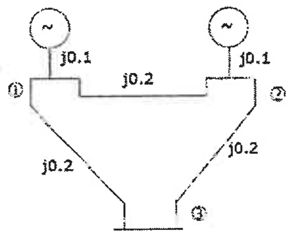
Time: 3 hours — Max. Marks: 100

PART – A (20 × 1 = 20 Marks)
Answer **ALL** Questions

Marks BL CO

1. The per unit impedance of a circuit element is 0.15 p.u. If the base kV and base MVA are halved, then the new value of the per unit impedance of the circuit element will be — 1 1 1
   (A) 0.075 p.u (B) 0.15 p.u
   (C) 0.30 p.u (D) 0.6 p.u

2. A sample power system network is shown in figure. The reactances marked are in p.u. The p.u value of Y_{22} of the bus admittance matrix is: — 1 2 1



   (A) j10.0 (B) j0.4
   (C) -j0.1 (D) -j20.0

3. A three phase 100 MVA, 10 kV generator has winding reactance of 1.0 Ω. Its per unit reactance is: — 1 2 1
   (A) 0.01 (B) 0.1
   (C) 1.0 (D) 10

4. Corresponding to a load power of ($P_L + j\,Q_L$) p.u. and a load voltage of V_L p.u., the per unit load impedance is — 1 1 1
   (A) $\dfrac{P_L - jQ_L}{|V|^2}$ (B) $\dfrac{P_L + jQ_L}{|V|^2}$
   (C) $\dfrac{|V_L|^2}{P_L + jQ_L}$ (D) $\dfrac{|V_L|^2}{P_L - jQ_L}$

5. For a 15 bus power system with 3 voltage controlled buses, the size of Jacobian matrix is: — 1 1 2
   (A) 11 × 11 (B) 12 × 12
   (C) 19 × 19 (D) 19 × 21

6. In load flow analysis, the load connected at a bus is represented as: — 1 1 2
   (A) constant current drawn from the bus (B) constant impedance connected at the bus
   (C) voltage and frequency dependent source at the bus (D) constant real and reactive power drawn from the bus

7. In the load flow analysis, Jacobian is represented as $\begin{bmatrix} H & N \\ M & L \end{bmatrix}$ For decoupled load flow analysis the assumptions made are 1 1 2

(A) M = 0; L = 0 (B) H = 0; L = 0
(C) M=0; N=0 (D) H = 0; N = 0

8. While carrying out fast decoupled power flow analysis at every iteration two sets of linear equations are to be solved. One set is: 1 1 2

(A) $B'' \Delta\delta = \frac{\Delta P}{|V|}$ (B) $B'' \Delta|V| = \frac{\Delta P}{|V|}$
(C) $B'' \Delta\delta = \frac{\Delta Q}{|V|}$ (D) $B'' \Delta|V| = \frac{\Delta Q}{|V|}$

9. A power system network consists of 3 elements 0 - 1, 1 - 2 and 2 - 0 of per unit impedances j0.2, j0.4 and j0.4 p.u respectively. Its bus impedance matrix is given by: 1 2 3

(A) $j\begin{bmatrix} 7.5 & -2.5 \\ -2.5 & 5.0 \end{bmatrix}$ (B) $j\begin{bmatrix} 0.16 & 0.08 \\ 0.08 & 0.24 \end{bmatrix}$
(C) $j\begin{bmatrix} 0.16 & -0.08 \\ -0.08 & 0.24 \end{bmatrix}$ (D) $j\begin{bmatrix} 0.6 & 0.4 \\ 0.4 & 0.8 \end{bmatrix}$

10. What is the value of the zero sequence impedance? 1 1 3

(A) $Z_0 = Z$ (B) $Z_0 = Z + 2Z_n$
(C) $Z_0 = Z + 3Z_n$ (D) $Z_0 = 0$

11. For a three-bus network elements in the first column of bus impedance matrix in p.u. are $Z_{bus}(1,1) = j\,0.08$, $Z_{bus}(2,1) = j\,0.03$ and $Z_{bus}(3,1) = j\,0.05$. Symmetrical three phase fault with zero fault impedance occurs at bus 1. Faulted bus current $I_{1\,(F)}$ is 1 2 3

(A) j 6.25 p.u (B) −j 6.25 p.u
(C) -j 12.5 p.u (D) j 12.5 p.u

12. In the case of a synchronous machine which one of the following is correct? 1 1 3

(A) $X_d > X_d' > X_d''$ (B) $X_d < X_d' < X_d''$
(C) $X_d > X_d' < X_d''$ (D) $X_d < X_d' > X_d''$

13. An unloaded, solidly grounded 10 MVA, 11 kV generator has positive, negative and zero sequence per unit impedances as j 1.175, j 0.3 and j 0.1 respectively. A bolted double line to ground fault occurs at the terminals of the generator. Taking generator voltage as 1.0 pu, determine the current $I_a^{(1)}$ is 1 2 4

(A) -j 0.8 p.u (B) j 0.8 p.u
(C) -j 0.635 p.u (D) j 0.635 p.u

14. A fault occurs at bus p in a three phase-power system. The fault conditions are $I_{fb} = I_{fc} = 0$ and $V_{pa} = Z_f I_{fa}$. The fault type is 1 1 4

(A) Symmetrical three phase fault (B) Single line to ground fault
(C) Line to line fault (D) Double line to ground fault

15. In a solidly grounded alternator, double line to ground fault occurs and I_b= j 8.0 p.u and I_C= - j 3.0 p.u. Fault current is 1 1 4

(A) - j 5.0 p.u (B) j 5.0 p.u
(C) −j 11.0 p.u (D) j 11.0 p.u

16. A power system is subjected to a fault which makes the zero sequence component of current equal to zero. The nature of fault is: 1 1 4

(A) Double line to ground fault (B) Double line fault
(C) Line to ground fault (D) Three-phase to ground fault

17. At what value of 'δ' the maximum power transfer takes place? 1 1 4

(A) 45° (B) 90°
(C) 120° (D) 180^0

18. An alternator is connected to an infinite bus-bar and operating at steady state. Which one of the following is correct? 1 1 5

(A) Output power=Pmax sinδ, Input power= Pmax cosδ
(B) Output power=a constant, input power=another constant
(C) Output power=a constant, input power= Pmax sinδ
(D) Output power= Pmax sinδ, Input power=a constant

19. By observing the swing curve of the alternator after time $t = 0^+$ we can say that the machine is stable when we notice a point wherein 1 1 5

(A) $\frac{d\delta}{dt}$ = constant
(B) $\frac{d\delta}{dt} > 0$
(C) $\frac{d\delta}{dt}$ is close to zero
(D) $\frac{d\delta}{dt} = 0$

20. When damping is included swing equation $M\frac{d^2\delta}{dt^2} = P_a$ will be modified as 1 1 5

(A) $M\frac{d^2\delta}{dt^2} - D\frac{d\delta}{dt} = P_a$
(B) $M\frac{d^2\delta}{dt^2} + D\frac{d\delta}{dt} = P_a$
(C) $(M + D)\frac{d^2\delta}{dt^2} = P_a$
(D) $(M - D)\frac{d^2\delta}{dt^2} = P_a$

PART – B (5 × 4 = 20 Marks)

Answer **ANY FIVE** Questions

Marks BL CO

21. Form new Ybus matrix after the elimination of node 3 in the given Ybus matrix. 4 2 1

Ybus= -j 7.611 j1.389 j6.222

j1.389 -j6.11 j4.722

j 6.222 j4.722 -j10.944

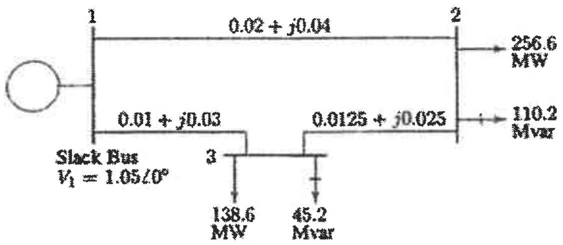
22. List out the advantages of per-unit computation. 4 1 1

23. For the sample power system, determine the reactive power for PV bus. 4 3 2

$$Y_{BUS} = \begin{bmatrix} 3-j9 & -2+j6 & -1+j3 & 0 \\ -2+j6 & 3.666-j11 & -0.666+j2 & -1+j3 \\ -1+j3 & -0.666+j2 & 3.666-j11 & -2+j6 \\ 0 & -1+j3 & -2+j6 & 3-j \end{bmatrix}$$

Bus	P_i pu	Q_i pu	V_i pu	Remarks
1	–	–	1.04 ∠0°	Slack bus
2	0.5	- 0.2	1.04 pu	PV bus
3	- 1.0	0.5	–	PQ bus
4	0.3	- 0.1	–	PQ bus

24. Using Gauss seidel method, determine the phasor value of voltage at bus 2. Y_{12}=10-j20, Y_{13}=10-j30, Y_{23}=16-j32. Assume 100 MVA base. 4 3 2



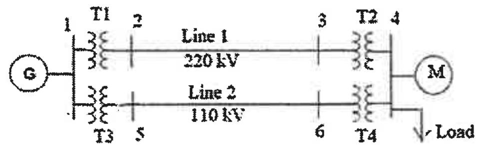
25.	Determine voltage at all buses during the fault at bus 3, if fault impedance is j 0.16 p.u and fault current is : - j2 p.u. $$Z_{bus} = \begin{bmatrix} j0.16 & j0.08 & j0.12 \\ j0.08 & j0.24 & j0.16 \\ j0.12 & j0.16 & j0.34 \end{bmatrix}$$	4	3	3
26.	Draw the zero sequence network for the power system shown below.	4	4	4

27.	Obtain the derivation of the swing equation in transient stability analysis.	4	2	5

PART – C (5 × 12 = 60 Marks)

Answer **ALL** Questions

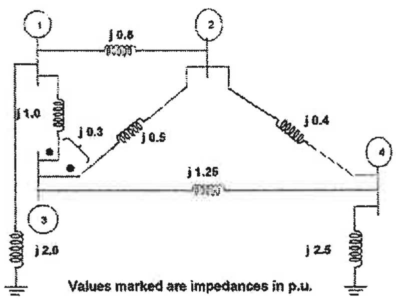
		Marks	BL	CO
28. a.	The one line diagram of three phase power system is shown in Figure below. Select a common base of 100 MVA, 22 kV on the generator side. Draw an impedance diagram with all impedances in p.u.	12	3	1



G: 90 MVA, 22 kV X=18%
T1: 50MVA, 22 kV/220 kV X=10%
T2: 40 MVA, 220 kV/11 kV X=6%
T3: 40 MVA, 22 kV/110 kV X=6.4%
T4: 40 MVA, 110 kV/11 kV X=8%
M: 66.5 MVA, 10.45 kV X=18.5%
The load at bus 4 absorbs 57 MVA, 0.6 power factor lagging at 10.45 kV. Line 1 and 2 have reactances of 48.4 and 65.3 ohms respectively.

(OR)

b.	For the network shown in Figure, compute Y_{bus} matrix using the bus incidence matrix and the primitive admittance matrix. Take the orientation of elements as from 1 to 2; from 3 to 1; from 3 to 2; from 4 to 2; from 3 to 4; from 0 to 1 and from 0 to 4.	12	3	1



29. a.	Consider the power system with the following data. Perform power flow analysis for the power system with the data given below, using Newton Raphson method and obtain the bus voltages at the end of first iterations.	12	3	6

Line data (p.u. quantities)

Line No.	Between buses	Line impedances
1	1–2	0 + j0.1
2	2–3	0 + j0.2
3	1–3	0 + j0.2

Bus data (p.u. quantities)

Bus No	Type	Generator P	Generator Q	Load P	Load Q	|V|	δ	Q_{min}	Q_{max}
1	Slack	---	---	0	0	1.0	0	---	---
2	P - V	5.3217	---	0	---	1.1	---	0	3.5
3	P - Q	0	0	3.6392	0.5339	---	---	---	---

(OR)

b. Perform power flow analysis using Fast decoupled load flow method and determine the voltage and angle at all buses at the end of first iteration. 12 3 6

Line No.	Between buses	Line impedances
1	1–2	0 + j0.1
2	2–3	0 + j0.2
3	1–3	0 + j0.2

Bus data (p.u. quantities)

Bus No	Type	Generator P	Generator Q	Load P	Load Q	|V|	δ	Q_{min}	Q_{max}
1	Slack	—	—	0	0	1.0	0	—	—
2	P-V	1.8184	—	0	—	1.1	—	0	3.5
3	P-Q	0	0	1.2517	1.2574	—	—	—	—

30. a. For the network with the following data construct the bus impedance matrix. 12 3 3

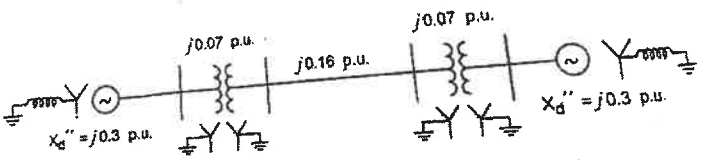
Element No.	Between buses		p.u. impedance
1	0	1	j 0.3
2	2	3	j 0.5
3	4	1	j 0.44
4	0	3	j 0.3
5	2	1	j 0.6
6	1	3	j 0.4

(OR)

b. In the power system, symmetrical three-phase fault occurs at bus 4. Using the bus impedance matrix, calculate the fault current, voltages at all the buses and currents in all the elements. 12 3 3

$$Z_{bus} = j \begin{array}{c|ccccc} & 1 & 2 & 3 & 4 & 5 \\ \hline 1 & 0.112082 & 0.055798 & 0.55494 & 0.090224 & 0.055251 \\ 2 & 0.055798 & 0.066727 & 0.052762 & 0.050333 & 0.041591 \\ 3 & 0.055798 & 0.052762 & 0.084031 & 0.056861 & 0.059046 \\ 4 & 0.090224 & 0.050333 & 0.056861 & 0.110170 & 0.062083 \\ 5 & 0.055252 & 0.041591 & 0.059046 & 0.062083 & 0.073011 \end{array}$$

31. a.i. Draw the positive, negative and zero sequence diagram for the power system shown in Figure below. 4 2 4



Zero sequence line reactance is 40%. Machines $X_0 = 5\%$, $X_n = 4\%$.

ii. A 20 MVA, 13.8 kV alternator has the following reactances: 8 2 4

$X_1 = 0.25$ p.u. $X_2 = 0.35$ p.u. $X_{g0} = 0.04$ p.u. $X_n = 0.02$ p.u.

A line-to-line fault with fault impedance j 0.125 p.u. occurs at its terminals. Draw the interconnections of the sequence networks and calculate

1) the current in each line
2) the fault current
3) the line to neutral voltages
4) the line to line voltages

(OR)

b. The positive sequence, negative sequence and zero sequence bus impedance matrices of a power system are shown below. 12 2 4

$$Z_{bus}^{(1)} = Z_{bus}^{(2)} = j \begin{array}{c c} & \begin{array}{cccc} 1 & 2 & 3 & 4 \end{array} \\ \begin{array}{c} 1 \\ 2 \\ 3 \\ 4 \end{array} & \begin{bmatrix} 0.1437 & 0.1211 & 0.0789 & 0.0563 \\ 0.1211 & 0.1696 & 0.1104 & 0.0789 \\ 0.0789 & 0.1104 & 0.1696 & 0.1211 \\ 0.0563 & 0.0789 & 0.1211 & 0.1437 \end{bmatrix} \end{array}$$

$$Z_{bus}^{(0)} = j \begin{array}{c c} & \begin{array}{cccc} 1 & 2 & 3 & 4 \end{array} \\ \begin{array}{c} 1 \\ 2 \\ 3 \\ 4 \end{array} & \begin{bmatrix} 0.1553 & 0.1407 & 0.0493 & 0.0347 \\ 0.1407 & 0.1999 & 0.0701 & 0.0493 \\ 0.0493 & 0.0701 & 0.1999 & 0.1407 \\ 0.0347 & 0.0493 & 0.1407 & 0.1553 \end{bmatrix} \end{array}$$

A bolted single line to ground fault occurs on phase 'a' at bus 3. Determine the fault current and the voltage at buses 3 and 4.

32. a.i. A 60 Hz generator having H = 6.0 MJ / MVA is delivering power of 1.0 p.u. to an infinite bus through a purely reactive network when the occurrence of a fault reduces the generator output power to zero. The maximum power that could be delivered is 2.5 p.u. When the fault is cleared the original network condition again exist. Determine the critical clearing angle and critical clearing time. 8 2 5

ii. Illustrate and explain equal area criterion for sudden change in mechanical input. 4 2 5

(OR)

b. A 60 Hz synchronous generator having inertia constant H = 4 MJ / MVA is connected to infinite bus through transformer and a transmission network. Mechanical input power is 1.0 p.u. Its prefault and during fault maximum power output are 1.6667 p.u. and 0.4167 p.u. respectively. Using Runga Kutta method obtain its swing curve up to 0.1 s taking time step of 0.05 s. 12 2 5

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