Gokaraju Rangaraju Institute of Engineering and Technology (Autonomous)

Bachupally, Kukatpally, Hyderabad – 500 090, Telangana, India. (040) 6686 4440

VISION AND MISSION

Vision of the Institute

To be among the best of the institutions for engineers and technologists with attitudes, skills and knowledge and to become an epicentre of creative solutions.

Mission of the Institute

To achieve and impart quality education with an emphasis on practical skills and social relevance.

Vision of the Department

To impart technical knowledge and skills required to succeed in life, career and help society to achieve self sufficiency.

Mission of the Department

- To become an internationally leading department for higher learning.
- To build upon the culture and values of universal science and contemporary education.
- To be a center of research and education generating knowledge and technologies which lay groundwork in shaping the future in the fields of electrical and electronics engineering.
- To develop partnership with industrial, R&D and government agencies and actively participate in conferences, technical and community activities.

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ACADEMIC CALENDER

2022-23

GRIET/DAA/1H/G/22-23 19 July 2022

Academic Calendar
Academic Year 2022-23

III B.Tech. –First Semester

S. No.	EVENT	PERIOD	DURATION
1	Commencement of First Semester class work	08-08-2022	
2	I Spell of Instructions	08-08-2022 to 08-10-2022	9 Weeks
3	I Mid-term Examinations	10-10-2022 to 13-10-2022	3 Days
4	II Spell of Instructions	14-10-2022 to 12-12-2022	9 Weeks
5	II Mid-term Examinations	13-12-2022 to 15-12-2022	3 Days
6	Preparation	16-12-2022 to 22-12-2022	1 Week
7	End Semester Examinations (Theory/ Practical) Regular/ Supplementary	23-12-2022 to 13-01-2023	3 Weeks
8	Commencement of Second Semester, AY 2022-23	16-01-2023	

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2022-23 II sem Subject Allocation sheet

2022 -23 I sem Subject allocation sheet

II YEAR(GR20)	Section-A	
Electrical Circuit Analysis	G Sandhya Rani	
Principles of Analog Electronics	P Ravikanth	
DC Machines and Transformers	Dr Phaneedra Babu B	
Electromagnetic Fields	Dr T Suresh Kumar	
Power Generation and Transmission	V Vijaya Rama Raju	
Java Programming for Engine	CSE Dept. Staff	
Constitution of India	D Karuna Kumar	
Value Ethics and Gender Culture	M Prashanth	
Principles of Analog Electronics Lab	U Vijaya Lakshmi/ M Prashanth	
DC Machines and Transformers Lab	V Vijaya Rama Raju / M Rekha	
III YEAR (GR20)	Section-A	
Power System Analysis	Dr J Sridevi	
Power Electronics	Dr Pakkiraiah B	
Microproces sors and Microcontrol lers	Dr D Raveedhra	
Electrical and Hybrid Vehicles (PE-1)	Dr D G Padhan	
Cloud Computing (NPTEL)	P Ravikanth	
Power Systems Lab	Dr J Sridevi / V Usha Rani/ U Vijaya Lakshmi	
Power Electronics Lab	Dr Pakkiraiah B/ G Sandhya Rani	
Microproces sors and Microcontrol lers Lab	Dr P Srividya Devi/ M N Sandhya Rani	
IV YEAR(GR18)	Section-A	Section-B
Power Systems – III	Dr P Srividya Devi	P Prashanth Kumar
Electronics Design	Dr D S N M Rao	Dr D S N M Rao
Electrical and Hybrid Vehicles (PE-III)	D Srinivasa Rao	D Srinivasa Rao
High Voltage Engineering (PE-IV)	A Vinay Kumar	A Vinay Kumar
Robotics	Anitha (Mech)	
Database Management Systems	D Swathi (CSE)	

Electronics Design Lab	P Ravikanth /Dr DSNM Rao	D Karuna Kumar/ V Usha Rani
Project work - (PhaseI)	A Vinay Kumar/ D Srinivasa Rao	M N Sandhya Rani / G Sandhya Rani
I/I BEE(GR20)	Theory	LAB
EEE (1) BEE	R Anil Kumar/ P Praveen Kumar / P Prashanth Kumar/ K Sudha	
ECE (3) BEE		
IT (3) BEE		
CSBS (1) PEE		
Design Thinking	Dr D G Padhan	
Mech II/I (GR20)	A	
BEEE	M N Sandhya Rani	

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Time Table

GRIET/PRIN/06/G/01/22-23 Wef : 08th Jul 2022

BTech - EEE - A III Year - I Semester

DAY/ HOUR	9:00 - 9:55	9:55- 10:50	10:50 - 11:45	11:45 -12:25	12:25-1:15	1:15 - 2:05	2:05 -2:55
MONDAY	PE	PE	EHV	BREAK	PE Lab (A1)/PS Lab (A2)		
TUESDAY	CC	MC	MC		PSA	PSA	Library
WEDNESDAY	MC	PSA	Mentoring		PS Lab (A1)/MC Lab (A2)		
THURSDAY	PSA	PSA	PE		MC Lab (A1)/PE Lab (A2)		
FRIDAY	EHV	EHV	CC		Library	MC	MC
SATURDAY	CC	PE	PE		Library	EHV	EHV

ROOM NO	
Theory/Tutorial	4402
Lab	PE Lab (4405) MC Lab (4502) PS Lab (4504)
Class Incharge:	G. Sandhya Rani

Subject Code	Subject Name	Faculty Code	Faculty Name
GR20A3012	Power Systems Analysis (PSA)	Dr JSD	Dr J. Sridevi
GR20A3013	Power Electronics (PE)	Dr PB	Dr Pakkiraiah B
GR20A3014	Microprocessors and Microcontrollers (MC)	Dr DR	Dr D Raveendhra
GR20A3015	Electrical and Hybrid Vehicles (EHV)	Dr DGP	Dr D. G. Padhan
	Cloud Computing (CC)	PRK	P. Ravikanth
GR20A3020	Power Systems Lab (PS Lab)	Dr JSD/ VUR/UVL	Dr J. Sridevi/ V. Usharani/ U. Vijayalakshmi
GR20A3021	Power Electronics Lab (PE Lab)	Dr PB/GSR/MRE	Dr. B. Pakkiraiah/G. Sandhya Rani/M Rekha
GR20A3022	Microprocessors and Microcontrollers Lab (MC Lab)	Dr PSVD/MNSR	Dr. P. Srividya Devi/ M. N. Sandhya Rani

Almanac	
1st Spell of Instructions	08-08-2022 to 08-10-2022
1st Mid-term Examinations	10-10-2022 to 13-10-2022
2nd Spell of Instructions	14-10-2022 to 18-12-2022
2nd Mid-term Examinations	09-12-2022 to 13-12-2022
Preparation	14-12-2022 to 20-12-2022
End Semester Examinations (Theory/ Practicals) Regular / Supplementary	21-12-2022 to 10-01-2023
Commencement of Second Semester, A.Y 2022-2023	16-01-2023

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POWER SYSTEM ANALYSIS

Course Code:GR20A3012 **L/T/P/C:2/1/0/3**

UNIT I
POWER FLOW STUDIES-1

Per-Unit System of Representation. Per-Unit equivalent reactance network of a three phase Power System, Numerical Problems. Ybus formation by Direct Inspection Method, Numerical Problems. Necessity of Power Flow Studies – Data for Power Flow Studies – Derivation of Static load flow equations – Load flow solutions using Gauss Seidel Method: Acceleration Factor, Load flow solution with and without P-V buses, Algorithm and Flowchart. Numerical Load Flow Solution for Simple Power Systems (Max. 3-Buses): Determination of Bus Voltages, Injected Active and Reactive Powers (One Iteration only) and finding Line Flows/Losses for the given Bus Voltages.

UNIT II
POWER FLOW STUDIES-2

Newton Raphson Method in Rectangular and Polar Co-Ordinates form, Load Flow Solution with and without PV Busses- Derivation of Jacobian Elements, Algorithm and Flowchart. Decoupled and Fast Decoupled Methods. - Comparison of Different Load flow Methods – DC load Flow.

UNIT III
FORMATION OF ZBUS

Partial network, Algorithm for the Modification of Zbus Matrix for addition of an element for the following cases: Addition of an element from a new bus and reference, Addition of element from a new bus to an old bus, Addition of element between an old bus to reference and Addition of element between two old buses (Derivations and Numerical Problems)-Modification of Zbus for the changes in network (Problems).

SHORT CIRCUIT ANALYSIS

Symmetrical fault Analysis: Short Circuit Current and MVA Calculations, Fault levels, Application of Series Reactors, Numerical Problems. Symmetrical Component Theory: Symmetrical Component Transformation, Positive, Negative and Zero sequence components: Voltages, Currents and Impedances. Sequence Networks: Positive, Negative and Zero Sequence Networks, Numerical Problems.

Unsymmetrical Fault Analysis: LG, LL, LLG faults with and without fault impedance, Numerical Problems.

UNIT IV

STEADY STATE STABILITY ANALYSIS

Elementary concepts of Steady State, Dynamic and Transient Stability. Description of: Steady State Stability Power Limit, Transfer Reactance, Synchronizing

Power Coefficient, Power Angle Curve and Determination of steady state stability and Methods to improve steady state stability.

UNIT V

POWER SYSTEM TRANSIENT STABILITY ANALYSIS

Derivation of Swing Equation. Determination of Transient Stability by Equal Area Criterion, Application of Equal Area Criterion, Critical Clearing Angle Calculation - Solution of Swing Equation: Point-by-Point Method and Modified Euler's method. Multi machine stability. Methods to improve Transient Stability.

TEXT BOOKS

1. Electric Power Systems by C. L. Wadhwa, New Age International.
2. Modern Power System Analysis by I.J.Nagrath & D.P.Kothari, Tata McGraw- Hill.
3. P.Kundur, "Power System Stability and Control" McGraw Hill Education, 1994

REFERENCES

1. Power System Analysis by Grainger and Stevenson, Tata McGraw Hill.
2. Power System Analysis by Hadi Saadat, TMH Edition.
3. A. R. Bergen and V. Vittal, "Power System Analysis", Pearson Education Inc., 1999.
4. B. M. Weedy, B. J. Cory, N. Jenkins, J. Ekanayake and G. Strbac, "Electric Power Systems", Wiley, 2012.

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CO’S AND PO’S MAPPINGS

Academic **Y**ear : 2022-23

Semester : II

Name of the Program: B.Tech……..… Year: ……**I**……….. Section: A& B

Course/Subject: …**Power System Analysis**…Course Code..GR20A3012

Name of the Faculty: ……**Dr J.Sridevi**..........…………………………..Dept.: …**EEE**………

Designation: .PROFESSOR

Course Code : GR20A3012 Course Title: Power System Analysis

Course Outcomes	Program Outcomes													
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
1. Outline the analysis of power system at different concepts, states and conditions.	M			M	M				M		M		M	
2. Formulate the Impedance and admittance matrices and necessity of Power Flow Studies.	M	M		M		M		M	M	M		M		M
3. Solve Power Flow equations using different numerical methods.	H	M	M		H		M			M	M		M	H
4. Evaluate fault currents for different types of faults and analyze short circuit studies.		H		M	M	H		M	M		M	H	M	H
5. Analyze a power system in Transient state, steady state and Stability Constraints in a grid.	H	H		M		H	M	M		M	M	H		H

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COURSE OBJECTIVES

Academic **Y**ear : 2022-23

Semester : I

Name of the Program: B.Tech……..… Year: ……**I**……….. Section: A& B

Course/Subject: …**Power System Analysis**…Course Code..GR20A3012

Name of the Faculty: ……**Dr J.Sridevi**...........…………………………..Dept.: …**EEE**………

Designation: .PROFESSOR

The objective of this course is to provide the student:

S.No.	Course Objectives
1.	Basic concepts of Power flow analysis.
2.	Concepts related to Power flow equations and numerical analysis.
3.	Illustrate about the formation of Z buses and short circuit analysis.
4.	Solve faults current for different types of faults.
5.	Stability constraints in a synchronous grid.

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COURSE OUTCOMES

Academic **Y**ear : 2022-23

Semester : I

Name of the Program: B.Tech……..… Year: ……**I**……….. Section: A& B

Course/Subject: …**Power System Analysis**…Course Code..GR20A3012

Name of the Faculty: ……**Dr J.Sridevi**..........…………………………..Dept.: …**EEE**………

Designation: .PROFESSOR

The expected outcomes of the Course/Subject are:

S.No	Outcomes
1.	Outline the analysis of power system at different concepts, states and conditions.
2.	Formulate the Impedance and admittance matrices and necessity of Power Flow Studies.
3.	Solve Power Flow equations using different numerical methods.
4.	Evaluate fault currents for different types of faults and analyze short circuit studies.
5.	Analyze a power system in Transient state, steady state and Stability Constraints in a grid.

Signature of faculty

Date:

Note: Please refer to Bloom's Taxonomy, to know the illustrative verbs that can be used to state the outcomes.

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GUIDELINES TO STUDY THE COURSE/SUBJECT

Academic **Y**ear : 2022-23

Semester : I

Name of the Program: B.Tech……..… Year: ……**I**……….. Section: A& B

Course/Subject: …**Power System Analysis**…Course Code..GR20A3012

Name of the Faculty: ……**Dr J.Sridevi**...........…………………………..Dept.: …**EEE**………

Designation: .PROFESSOR
Guidelines to study the Course/ Subject: Power System Analysis

<u>Course Design and Delivery System (CDD):</u>

- The Course syllabus is written into number of learning objectives and outcomes.
- Every student will be given an assessment plan, criteria for assessment, scheme of evaluation and grading method.
- The Learning Process will be carried out through assessments of Knowledge, Skills and Attitude by various methods and the students will be given guidance to refer to the text books, reference books, journals, etc.

The faculty be able to –

- Understand the principles of Learning
- Understand the psychology of students
- Develop instructional objectives for a given topic
- Prepare course, unit and lesson plans
- Understand different methods of teaching and learning
- Use appropriate teaching and learning aids
- Plan and deliver lectures effectively
- Provide feedback to students using various methods of Assessments and tools of Evaluation
- Act as a guide, advisor, counselor, facilitator, motivator and not just as a teacher alone

Signature of faculty

Date:

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COURSE SCHEDULE

Academic **Y**ear : 2022-23

Semester : I

Name of the Program: B.Tech……..… Year: ……**I**……….. Section: A& B

Course/Subject: …**Power System Analysis**…Course Code..GR20A3012

Name of the Faculty: ……**Dr J.Sridevi**..........…………………………..Dept.: …**EEE**………

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The Schedule for the whole Course / Subject is:

S. No.	**Description**	**Total No. Of Periods**
1.	Power Flow Studies-1	12
2.	Power Flow Studies-2	15
3.	Formation Of Zbus	15
4.	Steady State Stability Analysis	15
5.	Power System Transient Stability Analysis	15

Total No. of Instructional periods available for the course: ..……72……. Hours / Periods

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SCHEDULE OF INSTRUCTIONS

COURSE PLAN

Academic **Y**ear : 2022-23

Semester : I

Name of the Program: B.Tech……..… Year: ……**I**……….. Section: A& B

Course/Subject: …**Power System Analysis**…Course Code..GR20A3012

Name of the Faculty: ……**Dr J.Sridevi**..........…………………………..Dept.: …**EEE**………

Designation: .PROFESSOR

Unit No.	No. of Periods	Topics / Sub-Topics	Outcomes Nos.	References (Text Book, Journal…) Page Nos.: ____to_
1	12	Power Flow Studies-1	CO1	Modern Power System Analysis by I.J.Nagrath & D.P.Kothari,
2	15	Power Flow Studies-2	CO2	Modern Power System Analysis by I.J.Nagrath & D.P.Kothari,
3	15	Formation Of Zbus	CO3	Modern Power System Analysis by I.J.Nagrath & D.P.Kothari,
4	15	Steady State Stability Analysis	CO4	Modern Power System Analysis by I.J.Nagrath & D.P.Kothari,
5	15	Power System Transient Stability Analysis	CO5	Modern Power System Analysis by I.J.Nagrath & D.P.Kothari,

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SCHEDULE OF INSTRUCTIONS
SESSION PLAN

Academic **Y**ear : 2022-23

Semester : I

Name of the Program: B.Tech…….…. Year: ……**I**……….. Section: A& B

Course/Subject: …**Power System Analysis**…Course Code..GR20A3012

Name of the Faculty: ……**Dr J.Sridevi**...........…………………………..Dept.: …**EEE**………

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S.No	Unit No	No.of periods	Date	Topics
1	1	2	09.08.2022	Per-Unit System of Representation.
2	1	2	11.08.2022	Ybus formation by Direct Inspection Method, Numerical Problems. Necessity of Power Flow Studies
3	1	2	16.08.2022	Load flow solutions using Gauss Seidel Method: Acceleration Factor, Load flow solution without P-V buses
4	1	2	23.08.2022	Load flow solutions using Gauss Seidel Method: Acceleration Factor, Load flow solution with P-V buses
5	1	2	25.08.2022	Numerical Load Flow Solution for Simple Power Systems (Max. 3-Buses)
6	2	2	30.08.2022	Newton Raphson Method in Rectangular Co-Ordinates form
7	2	2	01.09.2022	Newton Raphson Method in Polar Co-Ordinates form
8	2	2	06.09.2022	Load Flow Solution with and without PV Busses,Derivation of Jacobian Elements
9	2	2	08.09.2022	Decoupled and Fast Decoupled Methods. - Comparison of Different Load flow Methods – DC load Flow.
10	3	2	13.09.2022	Algorithm for the Modification of Zbus Matrix for addition of an element for all cases
11	3	2	15.09.2022	Modification of Zbus for the changes in network (Problems).
12	3	2	20.09.2022	Symmetrical fault Analysis: Short Circuit Current and MVA Calculations
13	3	2	22.09.2022	Symmetrical Component Transformation, Positive, Negative and Zero sequence components

14	3	2	27.09.2022	Sequence Networks: Positive, Negative and Zero Sequence Networks,
15	3	2	29.09.2022	LG, LL faults with and without fault impedance
16	3	2	13.10.2022	LLG faults with and without fault impedance
17	4	2	18.10.2022	Elementary concepts of Steady State, Dynamic and Transient Stability.
18	4	2	20.10.2022	Description of: Steady State Stability Power Limit
19	4	2	25.10.2022	Transfer Reactance, Synchronizing Power Coefficient,
20	4	2	27.10.2022	Numerical Problems
21	4	2	01.11.2022	Power Angle Curve
22	4	2	02.11.2022	Determination of steady state stability
23	4	2	03.11.2022	Methods to improve steady state stability.
24	5	2	10.11.2022	Derivation of Swing Equation
25	5	2	15.11.2022	Determination of Transient Stability by Equal Area Criterion,
26	5	2	17.11.2022	Application of Equal Area Criterion
27	5	2	22.11.2022	Critical Clearing Angle Calculation
28	5	2	23.11.2022	Solution of Swing Equation: Point-by-Point Method and Modified Euler’s method.
29	5	2	24.11.2022	Methods to improve Transient Stability
30	5	2	08.12.2022	Revison

Signature of faculty

Date:

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ASSIGNMENT SHEET – 1

Academic **Y**ear : 2022-23

Semester : I

Name of the Program: B.Tech……..… Year: ……**I**……….. Section: A& B

Course/Subject: …**Power System Analysis**…Course Code..GR20A3012

Name of the Faculty: ……**Dr J.Sridevi**..........…………………………..Dept.: …**EEE**………

Designation: .PROFESSOR

This Assignment corresponds to Unit No. ………………**1**………………………….

1. The data for 2-bus system is given below. SG1=Unknown; SD1=UnknownV1=1.0p.u. ; S1= To be determined. SG2=0.25+jQG2 p.u.; SD2=1+j0.5 p.u. The two buses are connected by a transmission line p.u. reactance of 0.5 p.u. Find Q2 and angle of V2. Neglect shunts susceptance of the tie line. Assume |V2|=1.0, perform two iterations using GS method.
2. Derive static load flow equations?
3. What is the importance of slack bus in Load flow studies?
4. What is acceleration factor? What is its role in GS method for power flow studies?
5. Line data:

Line code	data:	Bus Admittance(p.u.)
1-2		1+j6
1-3		2-j3
2-3		0.8-j2.2
2-4		1.2-j2.3
3-4		2.1-j4.2

Load Data:

Bus No.	P (p.u.)	Q (p.u.)	V (p.u.)	Remarks

1	-	-	1.03	Slack
2	0.52	0.23	1.0	PQ
3	0.42	0.32	1.0	PQ
4	0.4	0.12	1.0	PQ

Determine the voltages at all the buses at the end of first iteration using GS method

Outcome Nos.: ……………………1…………………………………………………………….

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ASSIGNMENT SHEET – 2

Academic **Y**ear : 2022-23

Semester : I

Name of the Program: B.Tech…….… Year: ……**I**……….. Section: A& B

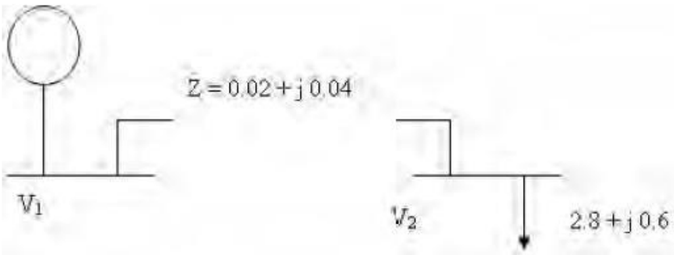
Course/Subject: …**Power System Analysis**…Course Code..GR20A3012

Name of the Faculty: ……**Dr J.Sridevi**..........…………………………..Dept.: …**EEE**………

Designation: .PROFESSOR

This Assignment corresponds to Unit No: ………………**2**………………………….

1. The magnitude of voltage at bus-1 is adjusted to 1.05 p.u. The scheduled loads at Buses 2 and 3 (PQ-Buses) are 2.566 p.u, 1.102 p.u and 1.386 p.u, 0.452 p.u. Using NR-method determine the phase values of the voltage at the load buses 2 and 3.Given Y12= 10 -j20 p.u., Y13=10-j30 p.u., Y23=16 -j32 p.u.
2. Compare GS-method, NR, decoupled and FDLF methods with respect to
   i. Number of equations
   ii. Memory
   iii. Time for iteration
3. In the power system network shown in figure, bus-1 is slack bus with V1=1.0 p.u.and bus-2 is a load bus with S2=2.8+j0.6 p.u. The line impedance is 0.02+j0,.04 p.u. using NR method, determine V2.



4. Are Decoupled and Fast decoupled methods of power flow analysis mathematical methods? What are the assumptions for reducing the NR-method to DLF and FDLF methods?

Outcome Nos.: ……………………2…………………………………………………………

Signature of faculty
Date:

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ASSIGNMENT SHEET – 3

Academic **Y**ear : 2022-23

Semester : I

Name of the Program: B.Tech…….… Year: ……**I**……….. Section: A& B

Course/Subject: …**Power System Analysis**…Course Code..GR20A3012

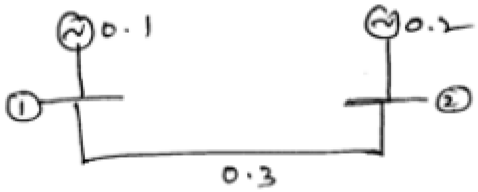
Name of the Faculty: ……**Dr J.Sridevi..........**…………………………..Dept.: …**EEE**………

Designation: .PROFESSOR

This Assignment corresponds to Unit No. / Lesson ………………**3**………………………….

1. Write an algorithm for the Modification of Zbus Matrix for different cases.

2. Determine the ZBus using building algorithm for the network shown in below figure. The values are in p.u reactance.



3. What do you understand by sequence networks? What is their importance in unsymmetrical fault calculations?

4. An 11Kv, 25MVA synchronous generator has positive, negative and zero sequence reactance of 0.12, 0.12 and 0.08 per unit respectively. The generator neutral is grounded through a reactance of 0.03 pu. A single line to ground fault occurs at the generator terminals. Determine the fault current and line to line voltages. Assume that the generator was unloaded before the fault

5. A 25 MVA, 13.2 kV alternator with solidly grounded neutral has a subtransient reactance of 0.25 p.u. The negative and zero sequence reactance's are 0.35 and 0.1 p.u. respectively. A single line to ground fault occurs at the terminals of an unloaded alternator; determine the fault current and the line-to-line voltages. Neglect resistance.

6. Derive an expression for the fault current of the three different phases of an alternator, when a LLG fault occurs at the R-phase. Assume that the alternator neutral is isolated

Outcome Nos.: ……………………3………………………………………………………….

Signature of faculty

Date:

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ASSIGNMENT SHEET – 4

Academic **Y**ear : 2022-23

Semester : I

Name of the Program: B.Tech……..… Year: ……**I**……….. Section: A& B

Course/Subject: …**Power System Analysis**…Course Code..GR20A3012

Name of the Faculty: ……**Dr J.Sridevi**...........…………………………..Dept.: …**EEE**………

Designation: .PROFESSOR

This Assignment corresponds to Unit No. ………………**4**………………………….

1. Derive an expression for steady state stability limit of a short transmission line having sending end and receiving end voltages Vs and Vr an impedance Z.

2. A 4-pole, 50 Hz, 26 kV turbo alternator has a rating of 100 MVA, p.f 0.8 lag. The moment of inertia of rotor is 8000 kg-m2. Determine M and H

3. A 50 Hz, four pole generators rated 100 MVA, 11 kV has an inertia constant of 8MJ/MVA.

   i) Find the stored energy in the rotor at synchronous speed.

   ii) If the mechanical input is suddenly raised to 80 MW for an electrical load of 50 MW, find rotor acceleration.

   iii) If the acceleration calculated in (ii) is maintained for 10 cycles, find the change in torque angle and rotor speed in rpm at the end of this period.

4. Explain the point by point method of solving the swing equation. Compare this method with the equal area criterion method.

5. A salient pole synchronous generator is connected to an infinite bus via a line. Derive an expression for electrical power output of the generator and draw p-δ curve.

Outcome Nos.: ……………………4………………………………………………………….

Signature of faculty

Date:

Gokaraju Rangaraju Institute of Engineering and Technology (Autonomous)

Bachupally, Kukatpally, Hyderabad – 500 090, Telangana, India. (040) 6686 4440

ASSIGNMENT SHEET – 5

Academic **Y**ear : 2022-23

Semester : I

Name of the Program: B.Tech…….… Year: ……**I**……….. Section: A& B

Course/Subject: …**Power System Analysis**…Course Code..GR20A3012

Name of the Faculty: ……**Dr J.Sridevi**..........…………………………..Dept.: …**EEE**………

Designation: .PROFESSOR

This Assignment corresponds to Unit No. / Lesson ………………**5**………………………….

1. Derive the expression for critical clearing angle for a system having a generator feeding a large system through a double circuit line.
2. Draw a diagram to illustrate the application of equal area criterion to study Transient stability when there is a sudden increase in the input of generator.
3. A 50 Hz, 4 pole turbo alternator rated 150 MVA, 11 KV has an inertia constant of 9MJ/MVA. Find the a) stored energy at synchronous speed b) the rotor acceleration if the input mechanical power is raised to 100 MW when the electrical load is 75 MW. C) The speed at the end of 10 cycles if acceleration is assumed constant at the initial value
4. Give details of assumptions made in the study of steady state and transient stability solution techniques.

Outcome Nos.: …………………………………………5……………………………………….

Signature of faculty

Date:

Gokaraju Rangaraju Institute of Engineering and Technology (Autonomous)
Bachupally, Kukatpally, Hyderabad – 500 090, Telangana, India. (040) 6686 4440

EVALUATION STRATEGY

Academic **Y**ear : 2022-23

Semester : I

Name of the Program: B.Tech……..… Year: ……**I**……….. Section: A& B

Course/Subject: …**Power System Analysis**…Course Code..GR20A3012

Name of the Faculty: ……**Dr J.Sridevi**...........…………………………..Dept.: …**EEE**………

Designation: .PROFESSOR

1. TARGET:

A) Percentage for pass100%

b) Percentage of class: 100%

2. COURSE PLAN& CONTENT DELIVERY:

- LCD presentation of the Lectures
- Solving exercise problems
- Model questions

3. METHOD OF EVALUATION

3.1 Continuous Assessment Examinations (CAE-I, CAE-I)

3.2 Assignments

3.3 Seminars

3.4 Quiz

3.5 Semester/End Examination

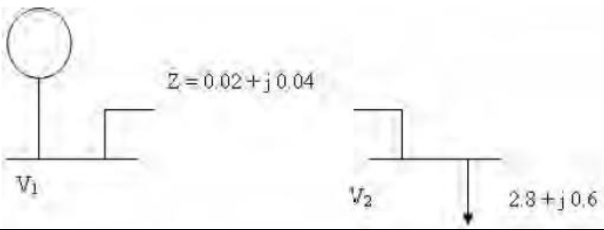
Signature of HOD   Signature of faculty

Date: Date

GOKARAJU RANGARAJU INSTITUTE OF ENGINEERING AND TECHNOLOGY
(Autonomous)
Department of Electrical and Electronics Engineering

Academic Year: **2022-23**	**MID Exam – I (Descriptive)**	Date: 10/10/2022
Year:**III**	**Subject Name: Power System Analysis**	Duration:**90 min**
Semester:**I**	**Subject Code: GR20A3012**	Max Marks: **15**

Note: Answer any ALL questions. All questions carry equal marks.

Q.No	Questions	Marks	CO	BL
1.	The data for 2-bus system is given below. SG1=Unknown; SD1=UnknownV1=1.0p.u.;S1= To be determined. SG2=0.25+jQG2 p.u.; SD2=1+j0.5 p.u. The two buses are connected by a transmission line p.u. reactance of 0.5 p.u. Find Q2 and angle of V2. Neglect shunts susceptance of the tie line. Assume |V2|=1.0, perform two iterations using GS method.	**[5M]**	**CO1**	**BL3**
	OR			
2.	**(a)** Derive static load flow equations	**[3M]**	**CO1**	**BL2**
	(b) What is the importance of slack bus in Load flow studies?	**[2M]**	**CO1**	**BL2**
3.	Are Decoupled and Fast decoupled methods of power flow analysis mathematical methods? What are the assumptions for reducing the NR-method to DLF and FDLF methods?	**[5M]**	**CO2**	**BL4**
	OR			
4.	In the power system network shown in figure, bus-1 is slack bus with V1=1.0 p.u.and bus-2 is a load bus with S2=2.8+j0.6 p.u. The line impedance is 0.02+j0,.04 p.u. using NR method, determine V2. 	**[5M]**	**CO2**	**BL4**
5.	Discuss about algorithm for the modification of Z bus matrix for addition of element between old bus to reference bus.	**[5M]**	**CO3**	**BL3**
	OR			

6.	Form ZBUS by building algorithm for the power system network, data given in the table below. Bus Code / Self Impedance (p.u.) / Bus Code / Mutual Impedance (p.u.) 1-2 / 0.15 / 3-4 / 0.15 2-3 / 0.65 3-4 / 0.35 4-1 / 0.75 2-4 / 0.25	**[5M]**	**CO3**	**BL4**

Bus Code	Self Impedance (p.u.)	Bus Code	Mutual Impedance (p.u.)
1-2	0.15	3-4	0.15
2-3	0.65		
3-4	0.35		
4-1	0.75		
2-4	0.25		

GOKARAJU RANGARAJU INSTITUTE OF ENGINEERING AND TECHNOLOGY
(Autonomous)
Department of Electrical and Electronics Engineering

Academic Year: **2022-23** Year:**III** Semester:**I**	**MID Exam – I (Objective)** **Subject Name: Power System Analysis** **Subject Code: GR20A3012**	Date: 10/10/2022 Duration: **10 min** Max Marks:**5M**

Roll No:

Note: Answer ALL questions. All questions carry equal marks.

Q.No	Questions	Option	CO	BL
1	Base impedance in ohms is mathematically expressed as: A) [Base voltage in kV (line to line)] * 1000 / Base kVA B) [Base voltage in kV (line to line)]^2 * 1000 / Base kVA C) [Base voltage in kV (line to line)]^3 * 1000 / Base kVA D) None of these	[ ]	**CO1**	**BL1**
2	On slack bus __________ and ____________ are specified: A) Voltage Magnitude, Real power B) Voltage Magnitude, Phase angle C) Active, Reactive power D) Active power, phase angle	[ ]	**CO1**	**BL1**
3	Which among the following buses constitute the maximum number in a power system? A) Slack bus B) P Q bus C) P V bus D) None of these	[ ]	**CO1**	**BL1**
4	In load flow studies of a power system, a voltage control bus is specified by A) Real power and reactive power B) Reactive power and voltage magnitude C) Voltage and voltage phase angle D) Real power and voltage magnitude	[ ]	**CO1**	**BL2**
5	In a load flow study a PV bus is treated as a PQ bus when A) Voltage limit is violated B) Active power limit is violated C) Phase angle is high D) Reactive power limit is violated	[ ]	**CO1**	**BL2**
6	Gauss-Seidel interative method can be used for solving a set of A. Linear differential equations only	[ ]	**CO1**	**BL1**

	B. Linear algebraic equations only C. Both linear and nonlinear algebraic equations D. Both linear and nonlinear algebraic differential equations			
7	Determine the order of the Jacobian matrix (with one slack bus) for a 10 bus power system? (Assume 2 buses as PV bus) A) 16 X 18 B) 16 X 18 C) 18 X 16 D) 18 X 18	**[ ]**	**CO2**	**BL3**
8	The impedance per phase of 3-phase transmission line on a base of 100MVA, 100KV is 2 p.u. The value of this impedance on a base of 400MVA and 400KV would be A) 1.5 p.u B) 1.0 p.u C) 0.5 p.u D) 0.25 p.u	**[ ]**	**CO1**	**BL3**
9	The dimension of Z bus matrix for addition of element between old bus to reference bus will be A) Constant B) Increase by 1 C) Decrease by 1 D) None	**[ ]**	**CO3**	**BL2**
10	The dimension of Z bus matrix for addition of element between new bus to old bus will be A) Constant B) Increase by 1 C) Decrease by 1 D) None	**[ ]**	**CO3**	**BL2**

BL – Bloom’s Taxonomy Levels
CO – Course Outcomes
PI – Performance Indicator Code3

GOKARAJU RANGARAJU INSTITUTE OF ENGINEERING AND TECHNOLOGY
(Autonomous)
Department of Electrical and Electronics Engineering

Academic Year: **2022-23**
Year:**III**
Semester:**I**

MID Exam – II (Descriptive)
Subject Name: Power System Analysis
Subject Code: GR20A3012

Date:_13/12/2022
Duration:**90 min**
Max Marks: **15**

Q.No	Questions	Marks	CO	BL
1.	An 11Kv, 25MVA synchronous generator has positive, negative and zero sequence reactance of 0.12, 0.12 and 0.08 per unit respectively. The generator neutral is grounded through a reactance of 0.03 pu. A single line to ground fault occurs at the generator terminals. Determine the fault current and line to line voltages. Assume that the generator was unloaded before the fault	**[5M]**	**CO3**	**BL4**
	OR		**OR**	
2.	Derive an expression for the fault current of the three different phases of an alternator, when a LLG fault occurs at the R-phase. Assume that the alternator neutral is isolated	**[5M]**	**CO3**	**BL3**
3.	A salient pole synchronous generator is connected to an infinite bus via a line. Derive an expression for electrical power output of the generator and draw p-δ curve.	**[5M]**	**CO4**	**BL4**
	OR			
4.	A 50 Hz, four pole generators rated 100 MVA, 11 kV has an inertia constant of 8MJ/MVA. i) Find the stored energy in the rotor at synchronous speed. ii) If the mechanical input is suddenly raised to 80 MW for an electrical load of 50 MW, find rotor acceleration. iii) If the acceleration calculated in (ii) is maintained for 10 cycles, find the change in torque angle and rotor speed in rpm at the end of this period.	**[5M]**	**CO4**	**BL5**

5.	Draw a diagram to illustrate the application of equal area criterion to study Transient stability when there is a sudden increase in the input of generator.	**[5M]**	**CO5**	**BL4**
	OR			
6.	Derive the expression for critical clearing angle for a system having a generator feeding a large system through a double circuit line.	**[5M]**	**CO5**	**BL3**

Academic Year: **2022-23**
Year:**III**
Semester:**I**

MID Exam – II (Objective)
Subject Name
Subject Code: GR20A3012

Date: ___/06/2022
Duration: **10 min**
Max Marks:**5M**

Roll No:

Note: Answer ALL questions. All questions carry equal marks.

Q.No	Questions	Option	CO	BL
1	If all the sequence voltages at the fault point in a power system are equal, then fault is ___________ a) LLG fault b) Line to Line fault c) Three phase to ground fault d) LG fault	**[ ]**	**CO3**	**BL1**
2	For a three-bus network elements in the first colum of bus impedance matrix in p.u. areZbus(1,1) = j 0.08, Zbus(2,1) = j 0.03 and Zbus(3,1) = j 0.05. Symmetrical three phase fault with zerofault impedance occurs at bus 1. Faulted bus current I1 (F) is (a) j 6.25 p.u. (b) – j 6.25 p.u. (c) - j 12.5 p.u (d) j 12.5 p.u	**[ ]**	**CO3**	**BL2**
3	In the case of synchronous machine which one of the following is correct? (a) Xd >Xd'>Xd" (b) Xd <Xd'<Xd" (c) Xd >Xd'<Xd" (d) Xd<Xd'>Xd''	**[ ]**	**CO3**	**BL1**
4	Positive component $Ia^{(1)} = 5\angle 2000$ A when the phase sequence is ACB. Then $Ib^{(1)}$ is (a) $5\angle -400$ A (b) $5\angle 800$ A (c) $-5\angle -400$ A (d) $-5\angle 800$ A	**[ ]**	**CO3**	**BL2**
5	Which one of the followings is not correct in transient stability analysis? (a) $\theta = \omega s\ t + \delta$ (b) $d\theta/dt = \omega s + d\delta/dt$ (c) $d^2\theta/dt^2 = M\ d^2\delta/dt^2$ (d) $d^2\theta/dt^2 = d^2\delta/dt^2$	**[ ]**	**CO5**	**BL1**
6	Swing equation used in transient stability analysis is (a) Non-linear algebraic equation (b) Linear algebraic equation (c) Non-linear differential equation (d) Linear differential equation	**[ ]**	**CO5**	**BL1**
7	Critical clearing time of a generator can be obtained by knowing (a) power output curves corresponding to pre-fault, during fault and post-fault conditions (b) input power and power output curves corresponding to pre-fault, during fault and post-fault conditions (c) critical clearing angle and swing curve for sustained fault (d) initial rotor angle and swing curve for sustained fault	**[ ]**	**CO5**	**BL2**

8	Value of M required in the swing equation M $d^2\delta/dt^2$= Pa is obtained from (a) M = π f/G H (b) M = π f/G I (c) M = G H/π f (d) M = G I/π f	**[ ]**	**CO4**	**BL1**
9	Load on a synchronous motor is suddenly increased. It will be stable if at one point of time (a) $\delta = 0$ (b) $d\delta/dt = 0$ (c) $d^2\delta/dt^2 = 0$ (d) $d\omega/dt = 0$	**[ ]**	**CO4**	**BL1**
10	By using which component can the transient stability limit of a power system be improved? (a) Series resistance (b) Series capacitor (c) Series inductor (d) Shunt resistance	**[ ]**	**CO5**	**BL1**

BL – Bloom's Taxonomy Levels
CO – Course Outcomes
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B.Tech EEE IIIYEAR I SEM **RESULT ANALYSIS OF 2020-2024 BATCH**

ACADEMIC YEAR 2022-2023   TOTAL. NO. OF STUDENTS REGISTERED = 65

Overall pass (passed in all subjects) = 50/65 (77%)

HOD,EEE

CODE: GR20A	GR 20	SET - 1

III B.Tech I Semester Regular Examinations, December/January 2022/23

MODEL PAPER

Power System Analysis

(Electrical and Electronics Engineering)

Time: 3 hours **Max Marks: 70**

< **Note:** Type the questions in the given format only, Times New Roman font , size 12 >

Instructions:

1. Question paper comprises of **Part-A** and **Part-B**
2. **Part-A** (for 20 marks) must be answered at one place in the answer book.
3. **Part-B** (for 50 marks) consists of **five questions with internal choice,** answer all questions.

PART – A

(Answer ALL questions. All questions carry equal marks)

10 * 2 = 20 Marks

1. a.	What are the advantages of per unit system?	**[2]**	**CO1**	**BL1**
b.	Write static load flow equations.	**[2]**	**CO1**	**BL2**
c.	What are the assumptions made in the FDLF method?	**[2]**	**CO2**	**BL1**
d.	In a load flow study, when PV bus is treated as PQ bus?	**[2]**	**CO2**	**BL2**
e.	Write impedance matrix if adding branch to the reference bus	**[2]**	**CO3**	**BL1**
f.	Write short notes on symmetrical component transformation?	**[2]**	**CO3**	**BL1**
g.	Write short notes on power angle curve.	**[2]**	**CO4**	**BL1**
h.	Define Transfer reactance	**[2]**	**CO4**	**BL1**
i.	Write short notes on Auto Reclosing	**[2]**	**CO5**	**BL1**
j.	Write swing equation during Fault and post fault.	**[2]**	**CO5**	**BL2**

PART – B

(Answer ALL questions. All questions carry equal marks)

5 * 10 = 50 Marks

2.	For the system shown below obtain i) primitive admittance matrix ii) bus incidence matrix Select ground as reference. Line num Bus code Admittance in pu 1 1-4 1.4 2 1-2 1.6 3 2-3 2.4 4 3-4 2.0 5 2-4 1.8	**[10]**	**CO1**	**BL4**

OR

3.	Explain Gauss-Seidal iterative method for power flow analysis of any given power system with a flow chart.	**[10]**	**CO1**	**BL3**
4.	Discuss about load flow solution with PV bus by using FDLF method	**[10]**	**CO2**	**BL3**
	OR			
5.	a) What are the assumptions made in reducing Decoupled method to fast decoupled method of power flow solution? (b) The voltage at bus-1 is V1 = 1.06 p.u. The scheduled loads on bus-2 is PD2=4.0p.u., QD2 = 3.2 p.u. Given the line admittances Y12= j30 p.u, Y13=j80 p.u. and Y23= j20p.u using FDLF-method with initial at voltage start. Find V2 and V3	**[10]**	**CO2**	**BL2 and BL4**
6.	(a) What are the advantages of ZBUS building algorithm? (b)Z bus matrix elements are given by Z11= 0.2, Z22= 0.6, Z12=0 find the modified ZBUS if a branch having an impedance 0.4 p.u. is added from the reference bus (Bus -1) to new bus? Also find the modified ZBUS if a branch having an impedance 0.4 p.u. is added from existing bus (other than reference bus) to new bus?	**[10]**	**CO3**	**BL2 And BL4**
	OR			
7.	Give a step by step procedure of analyzing a L-G fault on a power system by bus impedance matrix method and explain	**[10]**	**CO3**	**BL3**
8.	Derive the power angle equation of single machine connected to infinite bus	**[10]**	**CO4**	**BL4**
	OR			
9.	A 120 MVA, 19.5 kV generator has Xs = 0.15 per unit and is connected to a transmission line by a transformer rated 150 MVA, 230 Y/18Δ kV with X = 0.1 per unit. If the base to be used in the calculation is 100 MVA, 230 kV for the transmission line, find the per unit values to be used for the transformer and the generator reactance's	**[10]**	**CO4**	**BL4**
10.	A 200 MVA 11 KV 50 Hz 4 pole turbo generator has an inertia constant of 6 MJ/MVA. (a) Find the stored energy in the rotor at synchronous speed. (b) The machine is operating at a load of 120 MW. When the load suddenly increases to 160 MW, find the rotor retardation. Neglect losses. The retardation calculated above is maintained for 5 cycles, find the change in power angle and rotor speed in rpm at the end of this period	**[10]**	**CO5**	**BL4**
	OR			
11.	Derive the transient stability by Equal Area Criterion, What are the application of Equal Area Criterion	**[10]**	**CO5**	**BL3**

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Gokaraju Rangaraju Institute of Engineering and Technology

(Autonomous)

Bachupally, Kukatpally, Hyderabad – 500 090

Direct Internal CO Attainments

Academic Year	2022-23	Department	EEE	Name of the Programme	B.Tech		
Year - Semester	III-I	Course Name :	Power System Analysis	Course Code	GR20A2034	Section	

	Mid -I								Mid -II							Assignment Marks					Assessment
	Q.No 1(a)	Q.No 2(a)	Q.No 2(b)	Q.No 3	Q.No 4	Q.No 5	Q.No 6	Objective Marks	Q.No 1	Q.No 2	Q.No 3	Q.No 4	Q.No 5	Q.No 6	Objective Marks	I	II	III	IV	V	Marks
Enter CO Number → 1,2,3,4,5,6,7	1	1	1	2	2	3	3	1,2,3	3	3	4	4	5	5	3,4,5	1	2	3	4	5	1,2,3,4,5
Marks →	5	3	2	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
S.No/Roll No.	***Note :*** Enter Marks Between Two Green rows. ***Another Note :*** Additional Columns if Required should be inserted after column H and appropriately rename the Q. Nos. For Calculations consult Departments CO-PO Incharge																				
First Record / 1	0				0		0	2			3		3		4	5	5	5	5	5	5
2									0			1		1	2	4	5	5	5	5	5
3									0			1			3	4	4	4	4	4	4
4		1	1		2	1	1	2	4	3		4		4	2	5	5	5	5	5	5
5		1	2		4		0	2	5			5	1		2	5	5	5	5	5	5
6		2	1	2		0		2			0	2	3		2	4	5	5	5	5	5
7	0			1		0		1	0		0		1		2	4	4	4	4	4	4
8		2	1	0		1		4			2		2		1	5	5	5	5	5	5
9															3	4	4	4	4	4	4
10				2		0		1		0				0	2	4	4	4	4	4	5
11		2	2	2		1		2	0			2	2		1	4	4	4	4	4	5
12		2	1	2			1	2	4		2	4		5	2	5	5	5	5	5	5
13																4	5	5	5	5	5
14																4	4	4	4	4	4
15		2	1		1		0	2	0			3	0		3	4	5	5	5	5	5
16		2	1	2	3		0	1	5			4	1		1	5	5	5	5	5	4
17	0			0		0		2	0			2	0		1	4	5	5	5	5	5
18		2	2	2			0	2	3	4	1	4		4	2	5	5	5	5	5	5
19		1	1	1			0	3		0	0			0	2	4	4	4	4	4	4
20		2	1	3			0	1	0			0			3	5	5	5	5	5	4
21		2	1	1		0		1	2					1	1	4	4	4	4	4	5
22		2	1				0	2				0	0		1	5	5	5	5	5	4
23	2	2	1	3	4		0	3	5			5	4		2	5	5	5	5	5	5
24	0			2	0			3				0	0		3	5	5	5	5	5	5
25	0							3		0	0				1	4	4	4	4	4	4
26	2	0	1			1		3								4	4	4	4	4	5
27	0				0		0	3	0			1	0		1	4	4	4	4	4	4
28			1					3				4	1		2	4	4	4	4	4	5
29		2	1		5		0	3		5		5	3		2	5	5	5	5	5	5
30		2	1		0			3				3	3		2	5	5	5	5	5	4
31																					
32																5	5	5	5	5	5
33		3	2		4.5		0	3			5	4	1	5	2	5	5	5	5	5	5
34		0						3	0			0			2	4	4	4	4	4	4
35		2	1	5			0	3	2	3		5	5		2	5	5	5	5	5	5
36		2	0					4	3	2	3			0	2	5	5	5	5	5	4
37		2	0	2		1		3	0			2	3		2	4	4	4	4	4	5
38		2	1	0				3	2		3		2		2	4	4	4	4	4	4
39		2	1	3				3	4		0	2	5		2	4	4	4	4	4	5
40		2	1	3		1		4	1			3			1	5	5	5	5	5	5
41		2	1		0		0	3								4	4	4	4	4	5
42		2	1	1		1		3	4	1	0	2	0	3	2	5	5	5	5	5	5
43		2	1	2		2		4	4		4	3	5	3	2	5	5	5	5	5	4
44	0							3	3		3		2		2	4	4	4	4	4	4
45		2	1		5		0	3		0		2		2	3	5	5	5	5	5	5
46		2	1	2	0		0	2	5			5	3		2	5	5	5	5	5	5
47				2			0	2	4			5			2	4	4	4	4	4	4
48	5	2	1		3		0	3	4	4		3		5	2	5	5	5	5	5	5
49			1	1				4	0			4			4	5	5	5	5	5	4
50		2	1	2			0	4		0					2	4	4	4	4	4	5
51		0	1					3				2	0		2	4	4	4	4	4	4

52										3		0		0		2		5	5	5	5	5	4
53	0	1	1	1				3		0		0			0	2		4	4	4	4	4	4
54	5	3	2	4	5		0	2			4		3	3	4	2		5	5	5	5	5	5
55																		4	4	4	4	4	4
56		2	1	1				4		5		0		0		2		5	5	5	5	5	4
57		2	1		2	4		5		4			4		5	2		5	5	5	5	5	5
58		0	1	0	0		0	4		2	0		2		4	2		5	5	5	5	5	5
59	3				3			3		4			5	2		3		4	4	4	4	4	5
60		2	1	4			0	3		5			5	3		2		5	5	5	5	5	5
61		2	1		4	4		2		4			5	5		2		5	5	5	5	5	5
62		2	1		5		0	4		4			4		4	3		5	5	5	5	5	5
63		2	1	2		2		5		4			4		4	3		5	5	5	5	5	5
64							0	3		4			5		3	2		5	5	5	5	5	5
65	0				1			3		2		0		0		2		4	4	4	4	4	4
Last Record 66		2	1		4		0	3		5		3				2		5	5	5	5	5	5
if your class strength is > 60 then *insert rows above the green row(last record)* , Similarly *delete the empty rows above green row* if the class strenght is < 60)																							
Total number of students appeared for the examination (NST)	66	66	66	66	66	66	66	66		66	66	66	66	66	66	66		66	66	66	66	66	66
Total number of students attempted the question (NSA)	14	43	44	31	23	16	27	57		42	14	20	42	33	20	59		65	65	65	65	65	65
Attempt % (TAP) = (NSA/NST)*100	21.21	65.15	66.67	46.97	34.85	24.24	40.91	86.36		63.64	21.21	30.30	63.64	50.00	30.30	89.39		98.48	98.48	98.48	98.48	98.48	98.48
Total number of Students who got more than 60% marks (NSM)	3	35	5	7	12	2	0	38		24	6	7	26	13	13	11		65	65	65	65	65	65
Attainment % (TMP) = (NSM/NST)*100	4.55	53.03	7.58	10.61	18.18	3.03	0.00	57.58		36.36	9.09	10.61	39.39	19.70	19.70	16.67		98.48	98.48	98.48	98.48	98.48	98.48
Score(S)	0	2	0	0	0	0	0	2		1	0	0	1	0	0	0		3	3	3	3	3	3
Note : CO attainment is considered to be zero if the attempt % is less than 30%																							
CO Validation	**1**	**1**	**1**	**2**	**2**	**3**	**3**	**1,2,3**		**3**	**3**	**4**	**4**	**5**	**5**	**3,4,5**		**1**	**2**	**3**	**4**	**5**	**1,2,3,4,5**
Course Outcome	**CO1**	**CO1**	**CO1**	**CO2**	**CO2**	**CO3**	**CO3**	**CO1,CO2, CO3**		**CO3**	**CO3**	**CO4**	**CO4**	**CO5**	**CO5**	**CO3,CO4, CO5**		**CO1**	**CO2**	**CO3**	**CO4**	**CO5**	**CO1,CO2,CO3,CO4,CO5**
Marks (Y)	**5**	**3**	**2**	**5**	**5**	**5**	**5**	**5**		**5**	**5**	**5**	**5**	**5**	**5**	**5**		**5**	**5**	**5**	**5**	**5**	**5**
No. of COs Shared (Z)	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**3**		**1**	**1**	**1**	**1**	**1**	**1**	**3**		**1**	**1**	**1**	**1**	**1**	**5**
Y/Z	**5**	**3**	**2**	**5**	**5**	**5**	**5**	**1.66667**		**5**	**5**	**5**	**5**	**5**	**5**	**1.66667**		**5**	**5**	**5**	**5**	**5**	**1**
S*Y/Z	**0**	**6**	**0**	**0**	**0**	**0**	**0**	**3.33333**		**5**	**0**	**0**	**5**	**0**	**0**	**0**		**15**	**15**	**15**	**15**	**15**	**3**
CO1	**1**	**1**	**1**	**0**	**0**	**0**	**0**	**1**		**0**	**0**	**0**	**0**	**0**	**0**	**0**		**1**	**0**	**0**	**0**	**0**	**1**
CO2	**0**	**0**	**0**	**1**	**1**	**0**	**0**	**1**		**0**	**0**	**0**	**0**	**0**	**0**	**0**		**0**	**1**	**0**	**0**	**0**	**1**
CO3	**0**	**0**	**0**	**0**	**0**	**1**	**1**	**1**		**1**	**1**	**0**	**0**	**0**	**0**	**1**		**0**	**0**	**1**	**0**	**0**	**1**
CO4	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**		**0**	**0**	**1**	**1**	**0**	**0**	**1**		**0**	**0**	**0**	**1**	**0**	**1**
CO5	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**		**0**	**0**	**0**	**0**	**1**	**1**	**1**		**0**	**0**	**0**	**0**	**1**	**1**

Weighted Average for Attainment relevance (Internal CODn)	CO1	CO2	CO3	CO4	CO5	CO6	CO7
	2.55	2.21	1.90	2.30	2.02		

!!

!! Caution !! For CO Values < 2.25 should be justified with Remidial Action Report.

raju Rangaraju Institute of Engineering and Technology

(Autonomous)

Bachupally, Kukatpally, Hyderabad – 500 090

Indirect CO Attainments

Academic Year	2022-23	Department	EEE
Year - Semester	III-I	Course Name :	Power System Analysis

Course Outcomes survey on Scale 1 (Low) to 5 (High)					
Enter Course Outcomes →					
CO Number → 1,2,3,4,5	1	2	3	4	5
Marks →	5	5	5	5	5
S.No/Roll No.	Note : Enter Marks Between Two Green rows.				
First Record / 1	3	3	3	3	3
2	1	1	1	1	3
3	5	5	5	5	5
4	5	4	4	4	4
5	5	5	5	5	5
6	5	4	2	2	3
7	5	4	4	4	4
8	5	4	4	4	5
9	5	5	5	5	5
10	5	5	5	5	5
11	5	5	5	5	5
12	5	5	5	5	5
13	5	5	5	5	5
14	5	2	3	5	5
15	5	5	5	5	5
16	5	5	5	5	5
17	5	5	5	5	5
18	5	5	5	5	5
19	2	5	5	5	5
20	5	5	3	5	5
21	2	2	5	2	5
22	5	5	5	5	2
23	2	5	5	5	2
24	5	5	5	5	3
25	2	5	5	5	3
26	2	5	5	5	3
27	2	5	5	5	3
28	5	5	5	5	5
29	5	5	5	5	5

30	5	5	5	5	5
31	2	5	5	5	5
32	5	5	5	5	5
33	5	5	5	5	5
34	4	4	4	4	3
35	4	4	4	4	3
36	4	4	4	4	3
37	4	4	4	4	3
38	4	4	4	4	3
39	4	4	4	4	3
40	4	4	4	4	3
41	4	4	4	4	3
42	4	4	4	4	3
43	4	4	4	4	3
44	4	4	4	4	3
45	4	4	4	4	3
46	4	4	4	4	1
47	4	4	4	4	3
48	4	4	4	4	3
49	4	4	4	4	4
50	4	4	4	4	3
51	3	2	1	3	2
52	3	2	1	3	2
53	3	2	1	3	2
54	3	2	1	1	2
55	4	4	4	4	1
56	4	4	4	4	3
57	4	4	4	4	1
58	4	4	4	4	3
59	4	4	4	4	3
60	3	2	2	1	2
61	3	2	2	1	2
62	2	2	2	1	2
63	4	4	4	4	3
64	2	2	2	3	2
65	2	2	2	3	2
Last Record 66	5	5	2	2	2
if your class strength is > 60 then *insert rows above the green row(Last Record)* , Similarly *delete the empty rows above green row* if the class strenght is < 60)					
Total number of students appeared for the examination (NST)	66	66	66	66	66
Total number of students attempted the question (NSA)	66	66	66	66	66
Attempt % (TAP) = (NSA/NST)*100	100.00	100.00	100.00	100.00	100.00
Total number of Students who got more than 60% marks (NSM)	55	54	54	58	51

Attainment % (TMP) = (NSM/NST)*100	83.33	81.82	81.82	87.88	77.27
Score(S)	3	3	3	3	3

CO attainment is considered zero if the attempt % is less than 30%

Indirect CO (COIn)	CO1	CO2	CO3	CO4	CO5
	3	3	3	3	3

Gokaraju Rangaraju Institute of Engineering and Technology

(Autonomous)

Bachupally, Kukatpally, Hyderabad – 500 090

Direct External CO Attainment

Academic Year	2022-23	Department	EEE	Name of the Programme	
Year - Semester	III-I	Course Name :	Power System Analysis	Course Code	

Section: A

	Part A										Part B																		
	Q.No 1 (a) Marks	Q.No 1 (b) Marks	Q.No 1 (c) Marks	Q.No 1 (d) Marks	Q.No 1 (e) Marks	Q.No 1 (f) Marks	Q.No 1 (g) Marks	Q.No 1 (h) Marks	Q.No 1 (i) Marks	Q.No 1 (j) Marks	Q.No 2A Marks	Q.No 2B Marks	Q.No 3A Marks	Q.No 3B Marks	Q.No 4A Marks	Q.No 4B Marks	Q.No 5A Marks	Q.No 5B Marks	Q.No 6A Marks	Q.No 7A Marks	Q.No 7B Marks	Q.No 8A Marks	Q.No 8B Marks	Q.No 9A Marks	Q.No 9B Marks	Q.No 10A Marks	Q.No 10B Marks	Q.No 11A Marks	Q.No11B Marks
Enter CO Number → 1,2,3,4,5	1	1	2	2	3	3	4	4	5	5	1	1	1	1	2	2	2	2	3	3	3	4	4	4	4	5	5	5	5
Marks →	2	2	2	2	2	2	2	2	2	2	5	5	5	5	5	5	5	5	10	5	5	5	5	5	5	5	5	5	5
S.No/Roll No.	***Note :*** **Enter Marks Between Two Green rows.** ***Another Note :*** **Additional Columns if Required should be inserted after column H and appropriately rename the Q. Nos. For Calculations consult Departments CO-PO Incharge**																												
First Record / 1	1	1	2	2	2	2	2	1	2	2			4	3	4	3			7					3	2	3	3		
2	1	1	2	1	2	1	2	1	1	1			3	3	2				5			2	0			2	0		
3	1	2	2	1	2	2	1	1	2	2			2	3	3	1			6					1	2	3	5		
4	0	0	0	0	0	0	0	0	0	0			1	0			0	0		0	0	1	0	0				0	0
5													3	2								2				3			
6	2	2	1	2	2	1	1	1	1	1			2	2	3	2				0	2	3	0			3	2	2	4
7	0	1	0	0	0	0	0	0	0	0			2	0			2	1		0	0	0		2	0			0	0
8	1	1	1	1	1	1	1	1	1	2			1	1	2	1			2					2	0	3	2		
9	2	2	2	2	2	2	1	1	2	2			4	3	4	4			8					2	4			2	3
10	1	1	1	1	1	1	1		1	1			0	1			3	2	7					2	0			2	0
11	2	1	2	2	2	1	2	2	0	1	2	0	3	3	3	2			0	0	2			0	2	2	2	0	2
12	1	0	1	1	2	0	1	0	1	0		2	2						2		1	3			2	3			
13	2	2	2	1	2	2	2	2	2	2			4	3	4	2			8					3	4			3	5
14	2	1	0	1	1	1	1	2	1	1			2	3	3	3				2	1	1	1				5	3	3
15	0	0	0	1	1	1	2	2	1	2	0	0					3	3		2	0	4	1			2	3	3	4
16	1	2	2		1	2	2	2	2	2	4	3			3	2			7			4	3		2		5	4	3
17	0	1	0	0	1	0	1	2	0	1			4	3			1	0	7			3	1	3	2	3	3		
18	1	2	1	0	1	1	1	2	1	1			4	2	3	2			5					3	2			2	2
19	2	2	1	0	2	1	2	1	1	1	1	2					1	0	9			4	1					1	3
20	1	1	0	0	1	1	1	0	0	0			2	2			1	0		0	1	3	0					3	2
21	1	1	1	1	1	0	1	1	1		1			2					0			2		2		2			3
22	1	2	2	2	2	1	2	1	2	1	2	3	2	2	2	2			4					3	2	2			3
23	2	2	1	2	2	1	2	2	2	1	2	3			4	2			6					2	0			3	2
24	1	0	2	2	2	1		0	1	2			3	3	4	3			4					0	5	5	0		
25	1	1	2	0	0	1	0	1	1	2			3	3	3	1			2	5	0			3	4			3	3
26	2	1	2	2	0	1	0	1	0	1			2	1			0	2	4	4					2			2	
27	2	2	2	2	2	1	0	0	1	1			5	1	7	3				5	0			3	3	2	5		
28	2	0	2	2	2	1	1	0	2	2			1	0	6	3				5	0	1	0			4	5		
29	1	1	2	0	1	1	1	0	0	2			4	4			3	2		2				3	3	3	4		
30	1	2	2	0	1	1	0	0	1	0			3	4	4	1				5	1			2	3			2	1
31			2	2	0		2	0	1	0	2	4			4	2			3						3			2	3
32	2	2	2	2	2	1	0	0	1	2			4	3	4	2			6	1					5	3	1		
33	2	1	2	0	0	1	2	0	0	0			3	2	4	2			6					2	3			1	2
34	2	2		2	2	1	1		2	1			3	4	2	2			8	2	0			1	1			3	3
35													0	2						0				2	2				
36	2	2	2	2	2	2	2	1	1	1			3	3	4				6	4	2	2	0					5	2
37	1	2	2	2	2	0	1	1	1	2			3	2			3	2	7	5				5	3			3	4
38	1	1	2	2	1	1	1	0	1	2			2	1	3	1			2	5	1	4	3			2	5		
39	2	1	2	2	2		1			0			3	3	2	1			7				4			3	0	2	
40	1	2	2	2	2	2	1	1	2	2			2	3	4	2			7						4			3	2
41	1	2	1	2	1	0	1	0	1				2	0	3	0			0							2			
42	2	1	2	2	2	1	1	1	1	2			3	1						0				1	1			1	1
43	1	0	2	2	0	2	1	1	1	2			3	3			2	2		1	0	2	2					2	2
44	2	2	2	2	2	1	1	0	1	2			2	2			2	1	3	2				1	2	3	4		
45	1	1	2	2	0	0	1	1	2	1	2	2	4	3				3	8			3				3	3	2	
46	1	1	2	2	0	0	1	1	1	0			3	2	2				3					3	1			4	3
47	1	1	2	2	0	1	1	0	1	2			3	3			2	2	2			2	2	2	0	3	2		
48	2	2	2	2	0	2	2	1	2	1	1	5			3	2		1	8	3	0		0	3		4	5		
49	1	1	2	2	2	2	1	1	2	2			3	4	3	1			6	0	0	2	2	2	4			3	4
50	1	1	2	2	2	2	2	1	1	2			3	4	4	3			5					3	2			3	2
51	1	2	2	2	1	1	0	0	1	0			4	4			3	2	5	1				4	2	3	3		
52	2	1	2	2	2	2	1	1	0	0			4	4			3	2	9					3	5			3	2
53	2	1	2	2		2	1	1	1	2			3	4	4	2				0	3			3	3			4	5
54	1	1	2	2	0	1	2	0	2	1			3	2	2	0				0	1	0	1					2	3
55	1	0	0	2	0	0	1			2	1	3			4	3			6										
56	1	1	2	2	0	0	1	0	1	0			2	4	5	3			7	5	1			2	2	2	0		
57	0	0	0	0		0	0	0	0	0	0				0	0		0	0	0						0	0		
58	1	1	0	2	2	1	0	1	1	0			4	3	3	3			9					1	2	5	2		

59	2	2	2	1	2	1	2	0	2	1			4	2	4	2			0	2	0			5	5	4	3		
60	2			2	2	2	2	2	2	2			4	4					9			4	1					3	5
61	1	1	0	1	1	0	2	2	1				3	4	5				8					2	4	3	4		
62	2	2	2	2	2	2	1	2	2				4	3			5	2	8			4	3					3	3
63	2	2	1	2	2	2	2	1	2	2			4	4	5	3				4	2			3	4	4	5		
64																													
Last Record 65																													
if your class strength is > 60 then *insert rows* *above the green row (Last Record)* , Similarly *delete the* *empty rows above green row* if the class strenght is < 60)																													
Total number of students appeared for the examination (NST)	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65
Total number of students attempted the question (NSA)	60	59	59	60	59	59	60	57	59	57	12	11	54	54	40	36	16	19	46	31	23	23	20	38	41	31	28	35	34
Attempt % (TAP) = (NSA/NST)*100	92.31	90.77	90.77	92.31	90.77	90.77	92.31	87.69	90.77	87.69	18.46	16.92	83.08	83.08	61.54	55.38	24.62	29.23	70.77	47.69	35.38	35.38	30.77	58.46	63.08	47.69	43.08	53.85	52.31
Total number of Students who got more than 60% marks (NSM)	24	23	39	38	30	16	19	11	18	25	1	6	36	31	32	11	7	2	26	11	1	11	4	17	18	21	17	18	19
Attainment % (TMP) = (NSM/NST)*100	36.92	35.38	60.00	58.46	46.15	24.62	29.23	16.92	27.69	38.46	1.54	9.23	55.38	47.69	49.23	16.92	10.77	3.08	40.00	16.92	1.54	16.92	6.15	26.15	27.69	32.31	26.15	27.69	29.23
Score(S)	1	1	3	2	1	0	0	0	0	1	0	0	2	1	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0
CO attainment is considered zero if the attempt % is less than 30%																													
CO Validation	1	1	2	2	3	3	4	4	5	5	1	1	1	1	2	2	2	2	3	3	3	4	4	4	4	5	5	5	5
Course Outcome	CO1	CO1	CO2	CO2	CO3	CO3	CO4	CO4	CO5	CO5	CO1	CO1	CO1	CO1	CO2	CO2	CO2	CO2	CO3	CO3	CO3	CO4	CO4	CO4	CO4	CO5	CO5	CO5	CO5
Marks (Y)	2	2	2	2	2	2	2	2	2	2	5	5	5	5	5	5	5	5	10	5	5	5	5	5	5	5	5	5	5
No. of COs Shared (Z)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Y/Z	2	2	2	2	2	2	2	2	2	2	5	5	5	5	5	5	5	5	10	5	5	5	5	5	5	5	5	5	5
S*Y/Z	2	2	6	4	2	0	0	0	0	2	0	0	10	5	5	0	0	0	10	0	0	0	0	0	0	5	0	0	0
CO1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CO2	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
CO3	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0
CO4	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0
CO5	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1

Weighted Average for Attainment relevance	CO1	CO2	CO3	CO4	CO5		
	2.11	2.15	2.50	1.50	2.29		

!! Caution !! For CO Values < 2.25 should be justified with Remidial Action Report.

Gokaraju Rangaraju Institute of Engineering and Technology
(Autonomous)
Bachupally, Kukatpally, Hyderabad – 500 090

Summary Sheet CO Attainments

Academic Year:	2022-23
Course/Subject:	Power System Analysis
Department:	EEE
Section	#REF!

Name of the Program:	B.Tech
Course Code:	GR20A2034
Year - Semester :	III-I

Attainment/CO	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**
Attainment for Direct Internal CO (Mid I & II, Assignments, Tutorials, Assessments, etc.)	2.55	2.21	1.90	2.30	2.02
Attainment for Direct External CO (End Semester Exam)	2.11	2.15	2.50	1.50	2.29
Direct CO (0.3*Internal + 0.7*External)	2.24	2.17	2.32	1.74	2.21
Indirect CO	3.00	3.00	3.00	3.00	3.00
Final CO (COFn) = (0.9 x Direct CO + 0.1 x Indirect CO)	**2.32**	**2.25**	**2.39**	**1.87**	**2.29**

CO	**Course Outcome**	**Remedial Action for COs Less than 75% (2.25)**
CO1	Outline the analysis of power system at different concepts, states and conditions.	
CO2	Formulate the Impedance and admittance matrices and necessity of Power Flow Studies.	
CO3	Solve Power Flow equations using different numerical methods.	
CO4	Evaluate fault currents for different types of faults and analyze short circuit studies.	Conducted Tutorial classes to solve more problems.
CO5	Analyze a power system in Transient state, steady state and Stability Constraints in a grid.	

ID No.	Name of the Faculty	Department	Signature

HOD **DAA**

Copy to: IQAC

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Bachupally, Kukatpally, Hyderabad – 500 090

Direct Internal CO Attainments

Academic Year	2022-23
Year - Semester	III-I

Department	EEE
Course Name :	Power System Anaysis

P-Outcomes / C-Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
1	M			M	M				M		M		M	
2	M	M		M		M		M	M	M		M		M
3	H	M	M		H		M			M	M		M	H
4		H		M	M	H		M	M		M	H	M	H
5	H	H		M		H	M	M		M	M	H		H

Convert above mappings to scale 1-3

P-Outcomes / C-Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	2			2	2				2		2		2	
CO2	2	2		2		2		2	2	2		2		2
CO3	3	2	2		3		2			2	2		2	3
CO4		3		2	2	3		2	2		2	3	2	3
CO5	3	3		2		3	2	2		2	2	3		3
Expected Attainment	2.50	2.50	2.00	2.00	2.33	2.67	2.00	2.00	2.00	2.00	2.00	2.67	2.00	2.75

Fill the below table with obtained attainments in mids, external and Tutorial/Attendence

Final Cos CoF	CO1	CO2	CO3	CO4	CO5				
	2.32	2.25	2.39	1.87	2.29				

	Attained PO 1	Attained PO 2	Attained PO 3	Attained PO 4	Attained PO 5	Attained PO 6	Attained PO 7	Attained PO 8	Attained PO 9	Attained PO 10	Attained PO 11	Attained PO 12	Attained PSO1	Attained PSO2
CO1	1.55			1.55	1.55				1.55		1.55		1.55	
CO2	1.50	1.50		1.50		1.50		1.50	1.50	1.50		1.50		1.50
CO3	2.39	1.59	1.59		2.39		1.59			1.59	1.59		1.59	2.39
CO4		2.39		1.59	1.59	2.39		1.59	1.59		1.59	2.39	1.59	2.39
CO5	2.39	2.39		1.59		2.39	1.59	1.59		1.59	1.59	2.39		2.39
Attained	1.96	1.97	1.59	1.56	1.84	2.09	1.59	1.56	1.55	1.56	1.58	2.09	1.58	2.17

Note : If Average Attainment of a PO is #Div/0! Relace the corresponding PO with blank.

	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO 8**	**PO 9**	**PO 10**	**PO 11**	**PO 12**	**PSO 1**	**PSO 2**
Expected	2.50	2.50	2.00	2.00	2.33	2.67	2.00	2.00	2.00	2.00	2.00	2.67	2.00	2.75
Attained	1.96	1.97	1.59	1.56	1.84	2.09	1.59	1.56	1.55	1.56	1.58	2.09	1.58	2.17

Faculty Co-Ordinator

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the base value in the same unit. The percent value is 100 times the pu value. Both the pu and percentage methods are simpler than the use of actual values. Further, the main advantage in using the pu system of computations is that the result that comes out of the sum, product, quotient, etc. of two or more pu values is expressed in per unit itself.

Per unit value.

The per unit value of any quantity is defined as the ratio of the actual value of the any quantity to the base value of the same quantity as a decimal.

Advantages of per unit system

i. Per unit data representation yields valuable relative magnitude information.
ii. Circuit analysis of systems containing transformers of various transformation ratios is greatly simplified.
iii. The p.u systems are ideal for the computerized analysis and simulation of complex power system problems.
iv. Manufacturers usually specify the impedance values of equivalent in per unit of the equipment rating. If the any data is not available, it is easier to assume its per unit value than its numerical value.
v. The ohmic values of impedances are refereed to secondary is different from the value as referee to primary. However, if base values are selected properly, the p.u impedance is the same on the two sides of the transformer.
vi. The circuit laws are valid in p.u systems, and the power and voltages equations are simplified since the factors of $\sqrt{3}$ and 3 are eliminated.

In an electrical power system, the parameters of interest include the current, voltage, complex power (VA), impedance and the phase angle. Of these, the phase angle is dimensionless and the other four quantities can be described by knowing any two of them. Thus clearly, an arbitrary choice of any two base values will evidently fix the other base values.

Normally the nominal voltage of lines and equipment is known along with the complex power rating in MVA. Hence, in practice, the base values are chosen for complex power (MVA) and line voltage (KV). The chosen base MVA is the same for all the parts of the system. However, the base voltage is chosen with reference to a particular section of the system and the other base voltages (with reference to the other sections of the systems, these sections caused by the presence of the transformers) are then related to the chosen one by the turns-ratio of the connecting transformer.

If Ib is the base current in kilo amperes and Vb, the base voltage in kilo volts, then the base MVA is, Sb = (VbIb). Then the base values of current & impedance are given by

Base current (kA), Ib = MVAb/KVb

= Sb/Vb

Base impedance, Zb = (Vb/Ib)

= $(KVb^2 / MVAb)$

Hence the per unit impedance is given by

Zpu = Zohms/Zb

= Zohms $(MVAb/KVb^2)$

In 3-phase systems, KVb is the line-to-line value & MVAb is the 3-phase MVA. [1-phase MVA = (1/3) 3-phase MVA].

1.11. CHANGE OF BASE.

It is observed from equation (3) that the pu value of impedance is proportional directly to the base

MVA and inversely to the square of the base KV. If Zpunew is the pu impedance required to be calculated on a new set of base values: MVAbnew & KVbnew from the already given per unit impedance Zpuold, specified on the old set of base values, MVAbold & KVbold , then we have

Zpunew = Zpu old (MVAb new/MVAbold) $(\text{KVbold}/\text{KVbnew})^2$
On the other hand, the change of base can also be done by first converting the given pu impedance to its ohmic value and then calculating its pu value on the new set of base values.

Merits and Demerits of pu System
Following are the advantages and disadvantages of adopting the pu system of computations in electric power systems:
Merits:

- The pu value is the same for both 1-phase and & 3-phase systems
- The pu value once expressed on a proper base, will be the same when refereed to either side of the transformer. Thus the presence of transformer is totally eliminated
- The variation of values is in a smaller range 9nearby unity). Hence the errors involved in pu computations are very less.
- Usually the nameplate ratings will be marked in pu on the base of the name plate ratings, etc.

Demerits:

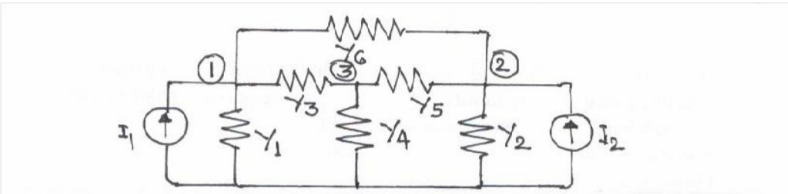
- If proper bases are not chosen, then the resulting pu values may be highly absurd (such as 5.8 pu, -18.9 pu, etc.). This may cause confusion to the user. However, this problem can be avoided by selecting the base MVA near the high-rated equipment and a convenient base KV in any section of the system.

PU Impedance / Reactance Diagram
For a given power system with all its data with regard to the generators, transformers, transmission lines, loads, etc., it is possible to obtain the corresponding impedance or reactance diagram as explained above. If the parametric values are shown in pu on the properly selected base values of the system, then the diagram is referred as the per unit impedance or reactance diagram. In forming a pu diagram, the following are the procedural steps involved:
1. Obtain the one line diagram based on the given data
2. Choose a common base MVA for the system
3. Choose a base KV in any one section (Sections formed by transformers)
4. Find the base KV of all the sections present
5. Find pu values of all the parameters: R,X, Z, E, etc.
6. Draw the pu impedance/ reactance diagram.

1.12 FORMATION OF Y BUS & Z BUS
The performance equations of a given power system can be considered in three different frames of reference as discussed below:
Frames of Reference:
Bus Frame of Reference: There are b independent equations (b = no. of buses) relating the bus vectors of currents and voltages through the bus impedance matrix and bus admittance matrix:
EBUS = ZBUS IBUS
IBUS = YBUS EBUS

Bus Frame of Reference: There are b independent equations (b = no. of buses) relating the bus vectors of currents and voltages through the bus impedance matrix and bus admittance matrix:
EBUS = ZBUS IBUS
IBUS = YBUS EBUS
Branch Frame of Reference: There are b independent equations (b = no. of branches of a selected Tree sub-graph of the system Graph) relating the branch vectors of currents and voltages through the branch impedance matrix and branch admittance matrix:
EBR = ZBR IBR
IBR = YBR EBR
Loop Frame of Reference: There are b independent equations (b = no. of branches of a selected Tree sub-graph of the system Graph) relating the branch vectors of currents and voltages through the branch impedance matrix and branch admittance matrix:
ELOOP = ZLOOP ILOOP
ILOOP = YLOOP ELOOP
Of the various network matrices refered above, the bus admittance matrix (YBUS) and the bus impedance matrix (ZBUS) are determined for a given power system by the rule of inspection as explained next.

Rule of Inspection
Consider the 3-node admittance network as shown in figure5. Using the basic branch relation: I = (YV), for all the elemental currents and applying Kirchhoff's Current Law principle at the nodal points, we get the relations as under:
At node 1: I1 =Y1V1 + Y3 (V1-V3) + Y6 (V1 – V2)
At node 2: I2 =Y2V2 + Y5 (V2-V3) + Y6 (V2 – V1)
At node 3: 0 = Y3 (V3-V1) + Y4V3 + Y5 (V3 – V2)



i.

These are the performance equations of the given network in admittance form and they can be represented in matrix form as:

$$\begin{vmatrix} I_1 \\ I_2 \\ 0 \end{vmatrix} \begin{matrix} = \\ = \\ = \end{matrix} \begin{vmatrix} (Y_1+Y_3+Y_6) & -Y_6 & -Y_3 \\ -Y_6 & (Y_2+Y_5+Y_6) & -Y_5 \\ -Y_3 & -Y_5 & (Y_3+Y_4+Y_5) \end{vmatrix} \begin{vmatrix} V_1 \\ V_2 \\ V_3 \end{vmatrix}$$

In other words, the relation of equation (9) can be represented in the form IBUS = YBUS EBUS

Where, YBUS is the bus admittance matrix, IBUS & EBUS are the bus current and bus voltage vectors respectively.
By observing the elements of the bus admittance matrix, YBUS of equation (9), it is observed that the matrix elements can as well be obtained by a simple inspection of the given system diagram:

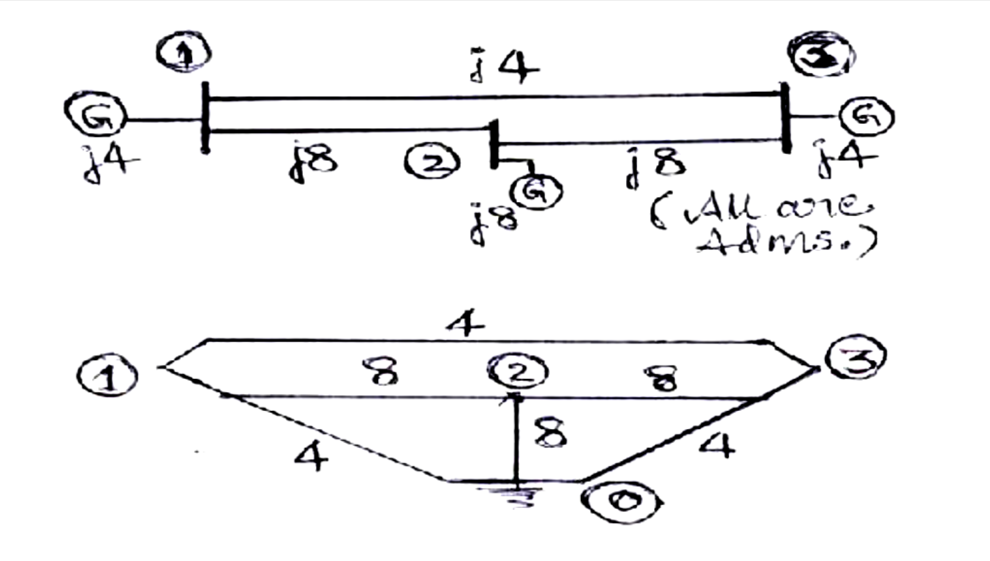
Diagonal elements: A diagonal element (Yii) of the bus admittance matrix, YBUS, is equal to the sum total of the admittance values of all the elements incident at the bus/node i,

Off Diagonal elements: An off-diagonal element (Y_{ij}) of the bus admittance matrix, YBUS, is equal to the negative of the admittance value of the connecting element present between the buses I and j, if any.
This is the principle of the rule of inspection. Thus the algorithmic equations for the rule of inspection are obtained as:
Y_{ii} = □□y_{ij} (j = 1,2,…….n)
Y_{ij} = - y_{ij} (j = 1,2,…….n)
For i = 1,2,….n, n = no. of buses of the given system, y_{ij} is the admittance of element connected between buses i and j and y_{ii} is the admittance of element connected between bus i and ground (reference bus).

Bus impedance matrix
In cases where, the bus impedance matrix is also required, then it cannot be formed by direct inspection of the given system diagram. However, the bus admittance matrix determined by the rule of inspection following the steps explained above, can be inverted to obtain the bus impedance matrix, since the two matrices are inter-invertible.

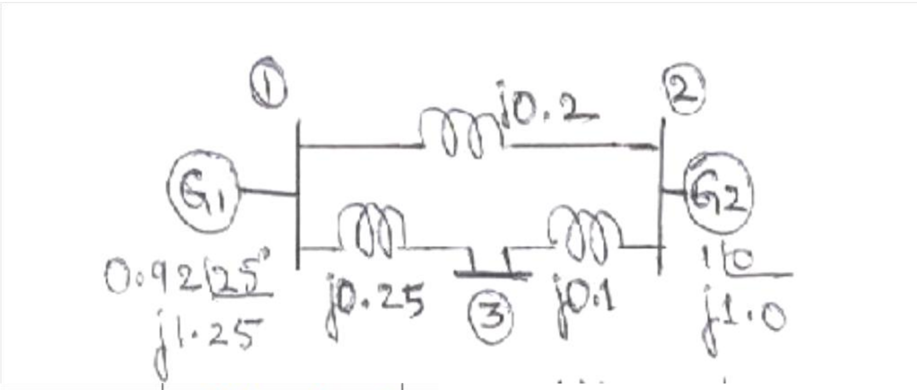
Note: It is to be noted that the rule of inspection can be applied only to those power systems that do not have any mutually coupled elements.

EXAMPLES ON RULE OF INSPECTION:
Problem #1: Obtain the bus admittance matrix for the admittance network shown aside by the rule of inspection



$$Y_{BUS} = \begin{vmatrix} 16 & -8 & -4 \\ -8 & 24 & -8 \\ -4 & -8 & 16 \end{vmatrix}$$

Problem #2: Obtain YBUS and ZBUS matrices for the impedance network shown aside by the rule of inspection. Also, determine YBUS for the reduced network after eliminating the eligible unwanted node. Draw the resulting reduced system diagram.



$$Y_{BUS} = \begin{vmatrix} -9.8 & 5 & 4 \\ 5 & -16 & 10 \\ 4 & 10 & -14 \end{vmatrix}$$

$$Z_{BUS} = Y_{BUS}^{-1}$$

EXAMPLES ON PER UNIT ANALYSIS:

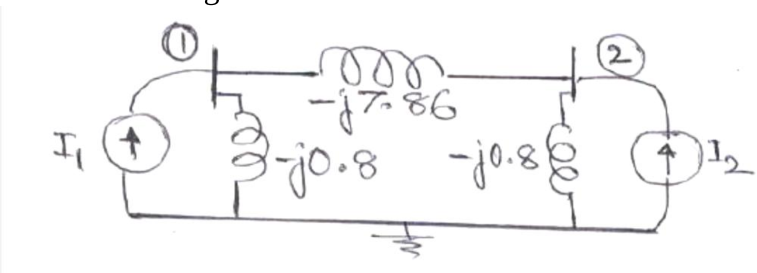
Problem #1:

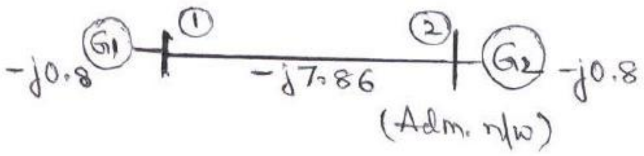
Two generators rated 10 MVA, 13.2 KV and 15 MVA, 13.2 KV are connected in parallel to a bus bar. They feed supply to 2 motors of inputs 8 MVA and 12 MVA respectively.

The operating voltage of motors is 12.5 KV. Assuming the base quantities as 50 MVA, 13.8 KV, draw the per unit reactance diagram. The percentage reactance for generators is 15% and that for motors is 20%.

Solution:

The one line diagram with the data is obtained as shown in figure





$$Y_{BUS}^{New} = Y_A - Y_B Y_D^{-1} Y_C$$

$$Y_{BUS} = \begin{vmatrix} -8.66 & 7.86 \\ 7.86 & -8.86 \end{vmatrix}$$

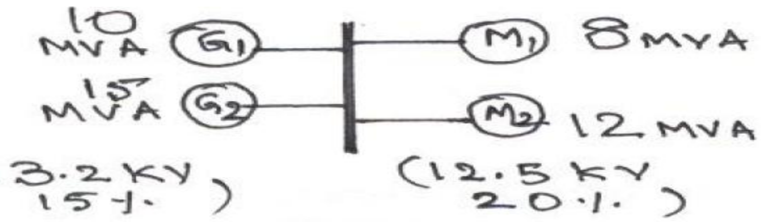
EXAMPLES ON PER UNIT ANALYSIS:

Problem #1:

Two generators rated 10 MVA, 13.2 KV and 15 MVA, 13.2 KV are connected in parallel to a bus bar. They feed supply to 2 motors of inputs 8 MVA and 12 MVA respectively. The operating voltage of motors is 12.5 KV. Assuming the base quantities as 50 MVA, 13.8 KV, draw the per unit reactance diagram. The percentage reactance for generators is 15% and that for motors is 20%.

Solution:

The one line diagram with the data is obtained as shown in figure P1

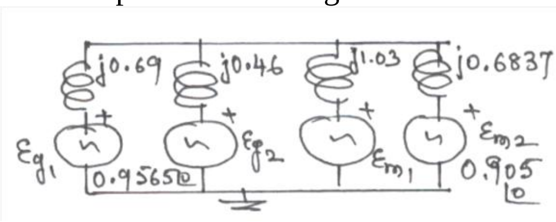


Selection of base quantities: **50** MVA, **13.8** KV (Given)

Calculation of pu values*:*

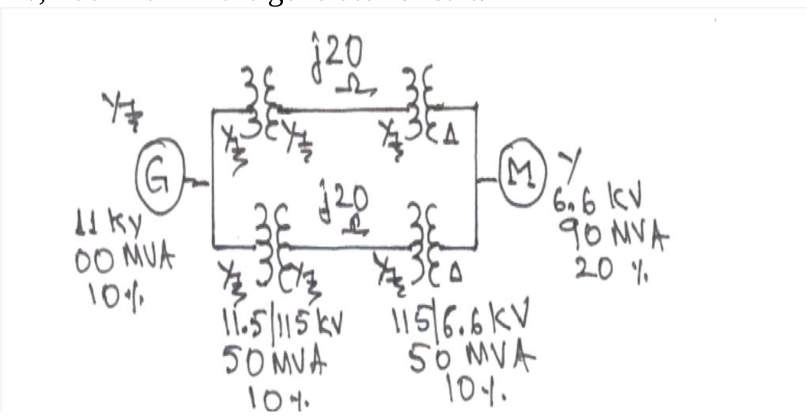
XG1 = j 0.15 (50/10) (13.2/13.8)2 = j 0.6862 pu.
XG2 = j 0.15 (50/15) (13.2/13.8)2 = j 0.4574 pu.
Xm1 = j 0.2 (50/8) (12.5/13.8)2 = j 1.0256 pu.
Xm2 = j 0.2 (50/12) (12.5/13.8)2 = j 0.6837 pu.
Eg1 = Eg2 = (13.2/13.8) = 0.9565 □00 pu
Em1 = Em2 = (12.5/13.8) = 0.9058 □00 pu

Thus the pu reactance diagram can be drawn as shown in figure P1



Problem #2:

Draw the per unit reactance diagram for the system shown in figure below. Choose a base of 11 KV, 100 MVA in the generator circuit.

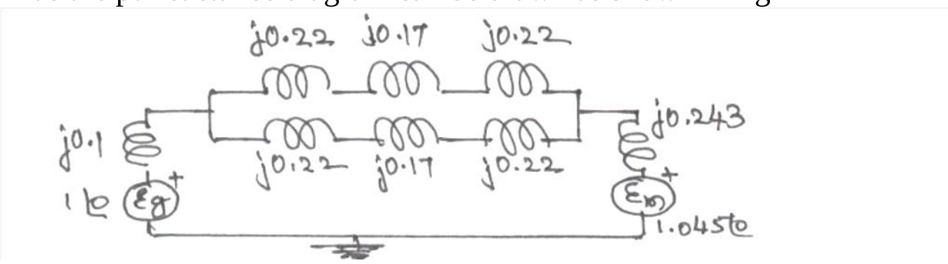


Solution:

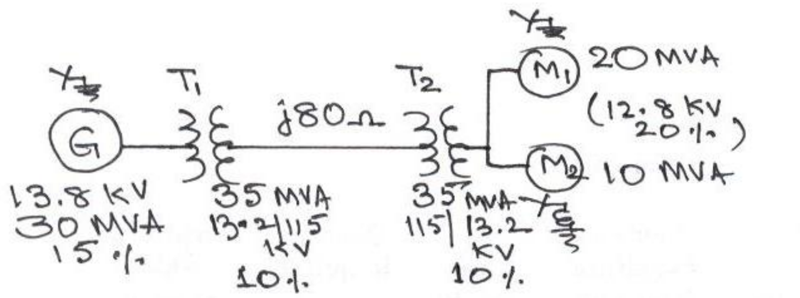
The one line diagram with the data is considered as shown in figure.
Selection of base quantities:
100 MVA, **11** KV in the generator circuit(Given); the voltage bases in other sections are: 11 (115/11.5) = **110** KV in the transmission line circuit and 110 (6.6/11.5) = **6.31** KV in the motor circuit.

Calculation of pu values:
XG = j 0.1 pu, Xm = j 0.2 (100/90) (6.6/6.31)2 = j 0.243 pu.
Xt1 =Xt2 = j 0.1 (100/50) (11.5/11)2 = j 0.2185 pu.
Xt3 =Xt4 = j 0.1 (100/50) (6.6/6.31)2 = j 0.219 pu.
Xlines = j 20 (100/1102) = j 0.1652 pu.
Eg = 1.0□□00 pu, Em = (6.6/6.31) = 1.045□□00 pu

Thus the pu reactance diagram can be drawn as shown in fig



Problem #3:
A 30 MVA, 13.8 KV, 3-phase generator has a sub transient reactance of 15%. The generator supplies 2 motors through a step-up transformer - transmission line – step down transformer arrangement. The motors have rated inputs of 20 MVA and 10 MVA at 12.8 KV with 20% sub transient reactance each. The 3-phase transformers are rated at 35 MVA, 13.2 KV-□□/115 KV-Y with 10 % leakage reactance. The line reactance is 80 ohms. Draw the equivalent per unit reactance diagram by selecting the generator ratings as base values in the generator circuit.
Solution:
The one line diagram with the data is obtained as shown in figure P3

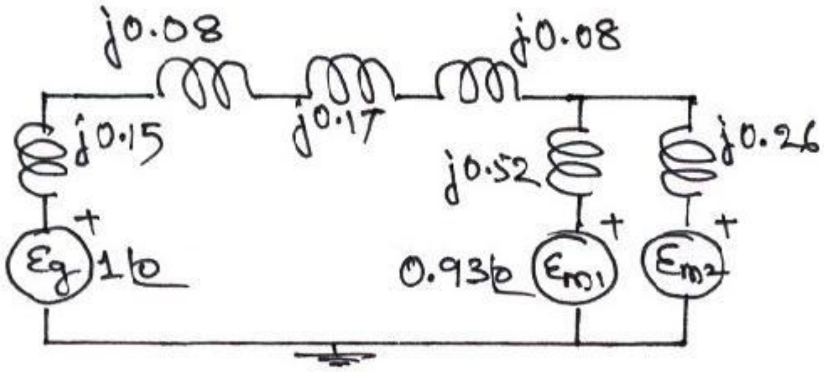


Selection of base quantities:
30 MVA, **13.8** KV in the generator circuit (Given);
The voltage bases in other sections are:
13.8 (115/13.2) = **120.23** KV in the transmission line circuit and
120.23 (13.26/115) = **13.8** KV in the motor circuit.

Calculation of pu values:
XG = j 0.15 pu.
Xm1 = j 0.2 (30/20) (12.8/13.8)2 = j 0.516 pu.
Xm2 = j 0.2 (30/10) (12.8/13.8)2 = j 0.2581 pu.
Xt1 =Xt2 = j 0.1 (30/35) (13.2/13.8)2 = j 0.0784 pu.
Xline = j 80 (30/120.232) = j 0.17 pu.

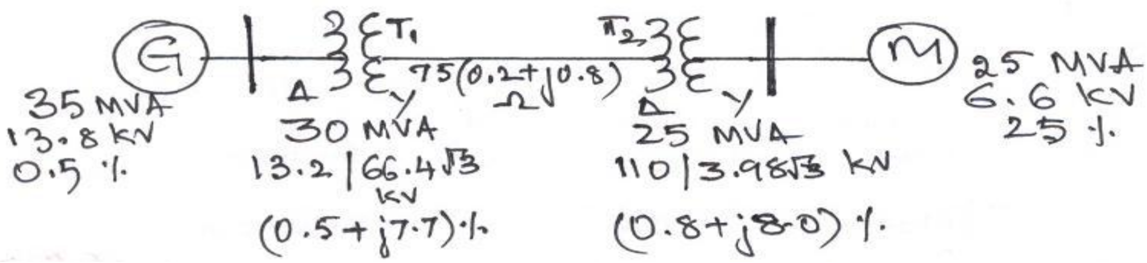
Eg = 1.0□00 pu; Em1 = Em2 = (6.6/6.31) = 0.93□00 pu

Thus the pu reactance diagram can be drawn as shown in figure P3



Problem #4:
A 33 MVA, 13.8 KV, 3-phase generator has a sub transient reactance of 0.5%. The generator supplies a motor through a step-up transformer - transmission line – step-down transformer arrangement. The motor has rated input of 25 MVA at 6.6 KV with 25% sub transient reactance. Draw the equivalent per unit impedance diagram by selecting 25 MVA (3□), 6.6 KV (LL) as base values in the motor circuit, given the transformer and transmission line data as under:

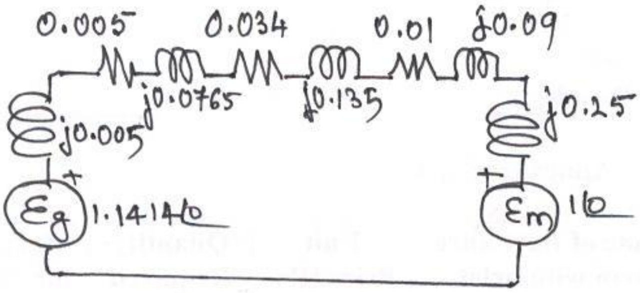
Step up transformer bank: three single phase units, connected □–Y, each rated 10 MVA, 13.2/6.6 KV with 7.7 % leakage reactance and 0.5 % leakage resistance;
Transmission line*:* 75 KM long with a positive sequence reactance of 0.8 ohm/ KM and a resistance of 0.2 ohm/ KM; and
Step down transformer bank: three single phase units, connected □–Y, each rated 8.33 MVA, 110/3.98 KV with 8% leakage reactance and 0.8 % leakage resistance;
Solution:
The one line diagram with the data is obtained as shown in figure P4



3-phase ratings of transformers:
T1: 3(10) = 30 MVA, 13.2/ 66.4□3 KV = 13.2/ 115 KV, X = 0.077, R = 0.005 pu.
T2: 3(8.33) = 25 MVA, 110/ 3.98□3 KV = 110/ 6.8936 KV, X = 0.08, R = 0.008 pu.

Selection of base quantities:
25 MVA, **6.6** KV in the motor circuit (Given); the voltage bases in other sections are: 6.6 (110/6.8936) = **105.316** KV in the transmission line circuit and 105.316 (13.2/115) = **12.09** KV in the generator circuit.
Calculation of pu values:
Xm = j 0.25 pu; Em = 1.0□00 pu.
XG = j 0.005 (25/33) (13.8/12.09)2 = j 0.005 pu; Eg = 13.8/12.09 = 1.414□00 pu.
Zt1 = 0.005 + j 0.077 (25/30) (13.2/12.09)2 = 0.005 + j 0.0765 pu. (ref. to LV side)
Zt2 = 0.008 + j 0.08 (25/25) (110/105.316)2 = 0.0087 + j 0.0873 pu. (ref. to HV side)
Zline = 75 (0.2+j 0.8) (25/ 105.3162) = 0.0338 + j 0.1351 pu.

Thus the pu reactance diagram can be drawn as shown in figure



1.13. Exercises for Practice

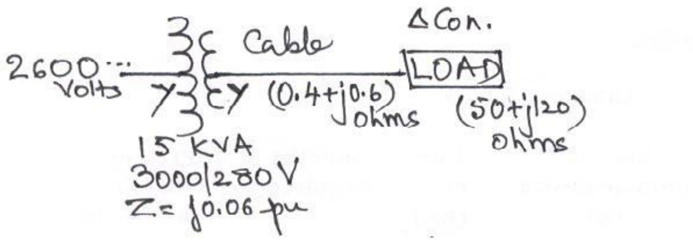
Problems

1. Determine the reactances of the three generators rated as follows on a common base of 200 MVA, 35 KV: Generator 1: 100 MVA, 33 KV, sub transient reactance of 10%; Generator 2: 150 MVA, 32 KV, sub transient reactance of 8% and Generator 3: 110 MVA, 30 KV, sub transient reactance of 12%.
[*Answers*: XG1 = j 0.1778, Xg2 = j 0.089, Xg3 = j 0.16 all in per unit]

2. A 100 MVA, 33 KV, 3-phase generator has a sub transient reactance of 15%. The generator supplies 3 motors through a step-up transformer - transmission line – step down transformer arrangement. The motors have rated inputs of 30 MVA, 20 MVA and 50 MVA, at 30 KV with 20% sub transient reactance each. The 3-phase transformers are rated at 100 MVA, 32 KV-□□/110 KV-Y with 8 % leakage reactance. The line has a reactance of 50 ohms. By selecting the generator ratings as base values in the generator circuit, determine the base values in all the other parts of the system. Hence evaluate the corresponding pu values and draw the equivalent per unit reactance diagram.
[*Answers*: XG = j 0.15, Xm1 = j 0.551, Xm2 = j 0.826, Xm3 = j 0.331, Eg1=1.0 □00, Em1 = Em2= Em3 = 0.91□00, Xt1 = Xt2 = j 0.0775 and Xline = j 0.39 all in per unit]

3. A 80 MVA, 10 KV, 3-phase generator has a sub transient reactance of 10%. The generator supplies a motor through a step-up transformer - transmission line – step-down transformer arrangement. The motor has rated input of 95 MVA, 6.3 KV with 15% sub transient reactance. The step-up 3-phase transformer is rated at 90 MVA, 11 KV-Y /110 KV-Y with 10% leakage reactance. The 3-phase step-down transformer consists of three single phase Y-□□connected transformers, each rated at 33.33 MVA, 68/6.6 KV with 10% leakage reactance. The line has a reactance of 20 ohms. By selecting the 11 KV, 100 MVA as base values in the generator circuit, determine the base values in all the other parts of the system. Hence evaluate the corresponding pu values and draw the equivalent per unit reactance diagram.
[*Answers*: XG = j 1.103, Xm = j 0.165, Eg1=0.91□00, Em= 1.022□00, Xt1 = j 0.11, Xt2 = j0.114 and Xline = j 0.17 all in per unit]

4. For the three-phase system shown below, draw an impedance diagram expressing all impedances in per unit on a common base of 20 MVA, 2600 V on the HV side of the transformer. Using this impedance diagram, find the HV and LV currents.



[*Answers*: Sb = 20 MVA; Vb=2.6 KV (HV) and 0.2427 KV (LV); Vt=1.0□00, Xt = j 0.107, Zcable = 0.136 +j 0.204 and Zload = 5.66 + j 2.26, I = 0.158 all in per unit, I (hv)= 0.7 A and I (lv) = 7.5 A]

UNIT II POWER FLOW ANALYSIS

2.1. IMPORTANCE OF POWER FLOW ANALYSIS IN PLANNING AND OPERATION OF POWER SYSTEMS.

POWER FLOW STUDY OR LOAD FLOW STUDY

The study of various methods of solution to power system network is referred to as load flow study. The solution provides the voltages at various buses, power flowing in various lines and line losses.

Information's that are obtained from a load flow study

The information obtained from a load flow study is magnitude and phase angle of voltages, real and reactive power flowing in each line and the line losses. The load flow solution also gives the initial conditions of the system when the transient behavior of the system is to be studied.

Need for load flow study

The load flow study of a power system is essential to decide the best operation of existing system and for planning the future expansion of the system. It is also essential for designing a new power system.

2.2. STATEMENT OF POWER FLOW PROBLEM

Quantities associated with each bus in a system

Each bus in a power system is associated with four quantities and they are real power (P), reactive power (Q), magnitude of voltage (V), and phase angle of voltage (δ).

Work involved (or) to be performed by a load flow study

(i). Representation of the system by a single line diagram
(ii). Determining the impedance diagram using the information in single line diagram
(iii). Formulation of network equation
(iv). Solution of network equations

Iterative methods to solve load flow problems

The load flow equations are non linear algebraic equations and so explicit solution as not possible. The solution of non linear equations can be obtained only by iterative numerical techniques.

Mainly used for solution of load flow study

The Gauss seidal method, Newton Raphson method and Fast decouple methods.

Flat voltage start

In iterative method of load flow solution, the initial voltages of all buses except slack bus assumed as 1+j0 p.u. This is referred to as flat voltage start

2.3. CLASSIFICATION OF BUSES

Bus

The meeting point of various components in a power system is called a bus. The bus is a conductor made of copper or aluminum having negligible resistance .At some of the buses power is being injected into the network, whereas at other buses it is being tapped by the system lods.

Bus admittance matrix

The matrix consisting of the self and mutual admittance of the network of the power system is called bus admittance matrix ($\mathbf{Y_{bus}}$).

Methods available for forming bus admittance matrix

Direct inspection method.
Singular transformation method.(Primitive network)

Different types of buses in a power system

Types of bus	Known or specified quantities	Unknown quantities or quantities to be determined
Slack or Swing or Reference bus	V, δ	P,Q
Generator or Voltage control or PV bus	P, V	Q, δ
Load or PQ bus	P, Q	V, δ

Need for slack bus

The slack bus is needed to account for transmission line losses. In a power system the total power generated will be equal to sum of power consumed by loads and losses. In a power system only the generated power and load power are specified for buses. The slack bus is assumed to generate the power required for losses. Since the losses are unknown the real and reactive power are not specified for slack bus.

Effect of acceleration factor in load flow study

Acceleration factor is used in gauss seidal method of load flow solution to increase the rate of convergence. Best value of A.F=1.6

Generator buses are treated as load bus

If the reactive power constraint of a generator bus violates the specified limits then the generator is treated as load bus.

2.4. ITERATIVE SOLUTION USING GAUSS-SEIDEL METHOD - ALGORITHM

Algorithm of Gauss seidal method

Step1: Assume all bus voltage be 1+ j0 except slack bus. The voltage of the slack bus is a constant voltage and it is not modified at any iteration

Step 2: Assume a suitable value for specified change in bus voltage which is used to compare the actual change in bus voltage between K th and (K+1) th iteration

Step 3: Set iteration count K = 0 and the corresponding voltages are V_1^0, V_2^0, V_3^0, …… V_n^0 except slack bus

Step 4: Set bus count P = 1

Step 5: Check for slack bus. It is a slack bus then goes to step 12 otherwise go to next step

Step 6: Check for generator bus. If it is a generator bus go to next step. Otherwise go to step 9

Step 7: Set $|V_P^K| = |V_P|$ specified and phase of $|V_P^K|$ as the K th iteration value if the bus P is a generator bus where $|V_P|$ specified is the specified magnitude of voltage for bus P. Calculate reactive power rating

$$Q_P{}^{K+1}{}_{Cal} = (-1)\ \mathrm{Imag}\left[(V_P{}^K)^A \left(\sum_{q=1}^{P-1} Y_{pq} Vq^{k+1} + \sum_{q=P}^{n} Y_{pq} V_q{}^K\right.\right.$$

Step 8: If calculated reactive power is within the specified limits then consider the bus as generator bus and then set $Q_P = Q_P{}^{K+1}{}_{Cal}$ for this iteration go to step 10

Step 9 : If the calculated reactive power violates the specified limit for reactive power then treat this bus as load bus

If $QP^{K+1}{}_{Cal} < Q_{P\,min}$ then $Q_P = Q_{P\,min}$

$Q_P{}^{K+1}{}_{Cal} > Q_{P\,max}$ then $Q_P = Q_{P\,max}$

Step10: For generator bus the magnitude of voltage does not change and so for all iterations the magnitude of bus voltage is the specified value. The phase of the bus voltage can be calculated using

V_P^{K+1} temp = $1 / Y_{PP} [(P_P - jQ_P / V_P^{K*}) - \sum Y_{pq} V_q^{K+1} - \sum Y_{pq} V_q^K]$

Step 11: For load bus the (k+1)th iteration value of load bus P voltage VPK+1 can be calculated using V_P^{K+1} temp = $1 / Y_{PP} [(P_P - jQ_P / V_P^{K*}) - \sum Y_{pq} V_q^{K+1} - \sum Y_{pq} V_q^K]$

Step 12: An acceleration factor α can be used for faster convergence. If acceleration factor is specified then modify the $(K+1)^{th}$ iteration value of bus P using

$V_{Pacc}^{K+1} = V_P^K + \alpha (V_P^{K+1} - V_P^K)$ then

Set $V_P^{K+1} = V_{Pacc}^{K+1}$

Step 13: Calculate the change in bus-P voltage using the relation $\Delta V_P^{K+1} = V_P^{K+1} - V_P^K$

Step 14: Repeat step 5 to 12 until all the bus voltages have been calculated. For this increment the bus count by 1 go to step 5 until the bus count is n

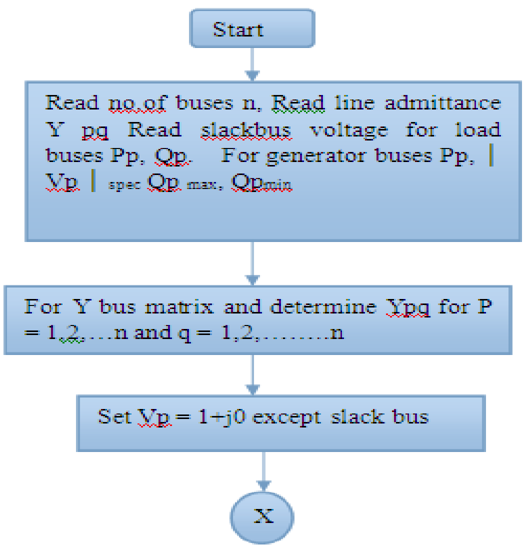
Step 15: Find the largest of the absolute value of the change in voltage

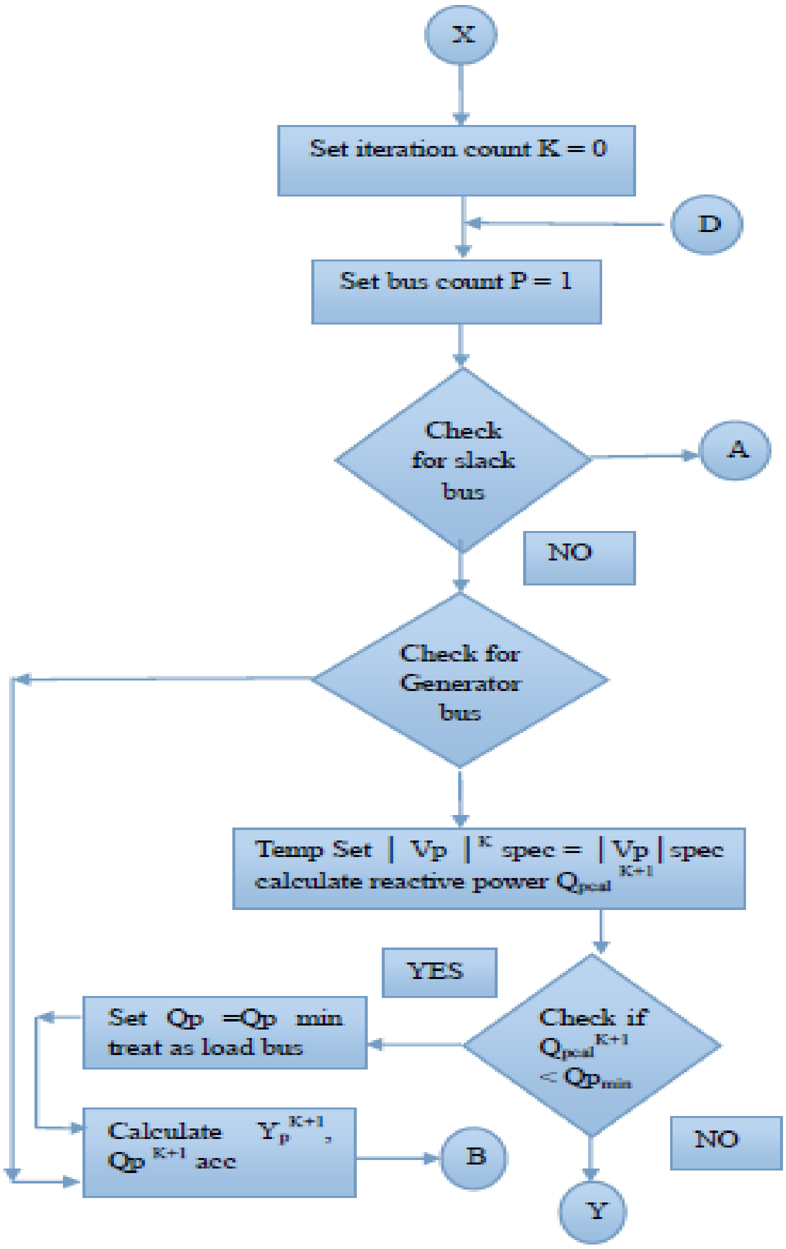
$|\Delta V_1^{K+1}|, |\Delta V_2^{K+1}|, |\Delta V_3^{K+1}|, \ldots\ldots\ldots\ldots, |\Delta V_n^{K+1}|$

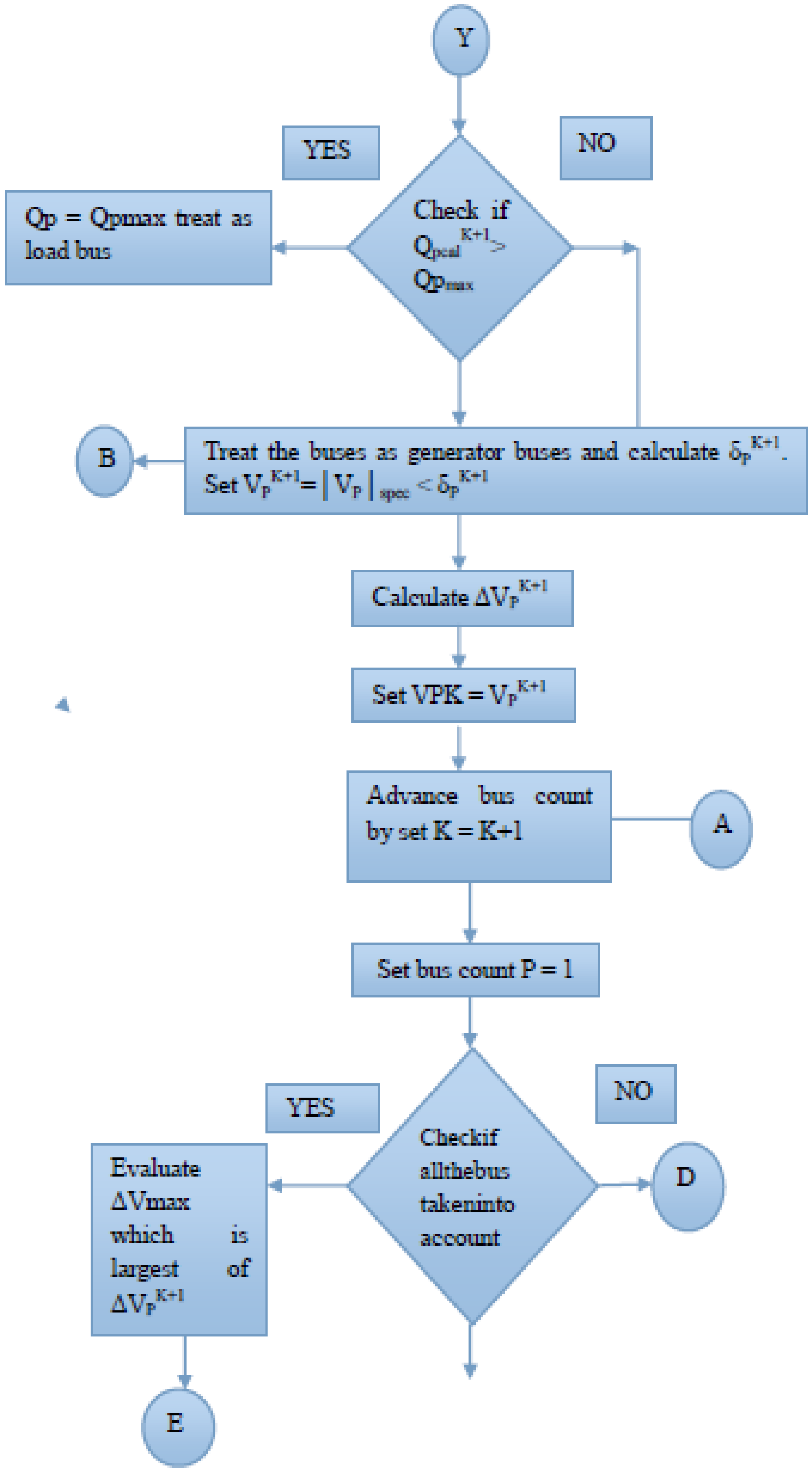
Let this largest value be the $|\Delta V_{max}|$. Check this largest change $|\Delta V_{max}|$ is less than pre specified tolerance. If $|\Delta V_{max}|$ is less go to next step. Otherwise increment the iteration count and go to step 4

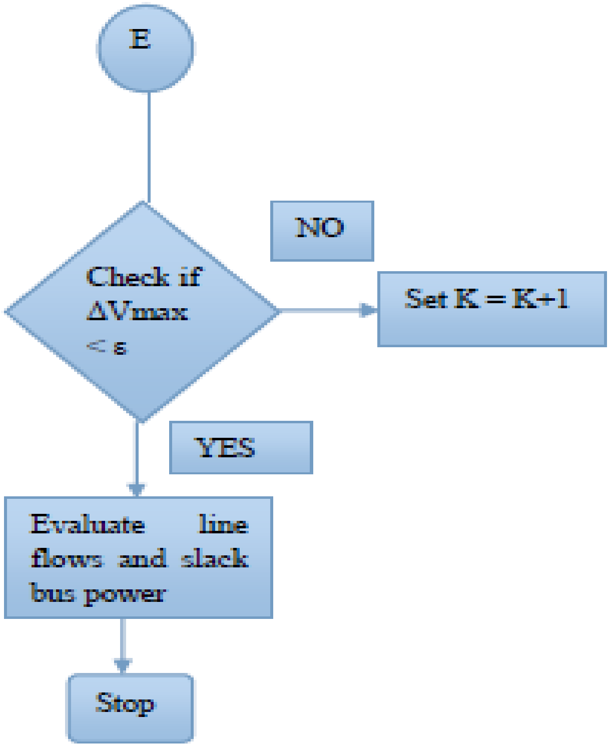
Step 16: Calculate the line flows and slack bus power by using the bus voltages

Gauss - Seidal method flow chart




X
Set iteration count K = 0
D
Set bus count P = 1
Check for slack bus
A
NO
Check for Generator bus
Temp Set | Vp |^K spec = | Vp | spec calculate reactive power Q_{pcal}^{K+1}
YES
Set Qp =Qp min treat as load bus
Check if Q_{pcal}^{K+1} < Qp_{min}
NO
Calculate Y_p^{K+1}, Qp^{K+1} acc
B
Y


Y
YES
NO
Check if Q_{pcal}^{K+1} > Qp_{max}
Qp = Qpmax treat as load bus
B
Treat the buses as generator buses and calculate δ_P^{K+1}. Set $V_P^{K+1} = |V_P|_{spec} < \delta_P^{K+1}$
Calculate ΔV_P^{K+1}
Set VPK = V_P^{K+1}
Advance bus count by set K = K+1
A
Set bus count P = 1
YES
NO
Checkif allthebus takeninto account
Evaluate ΔVmax which is largest of ΔV_P^{K+1}
D
E



2.5. ITERATIVE SOLUTION USING NEWTON-RAPHSON METHOD – ALGORITHM

Step 1: Assume a suitable solution for all buses except the slack bus. Let $V_p = a+j0$ for P = 2,3,……n $V_1 = a+j0$

Step 2 : Set the convergence criterion = ε0

Step 3 : Set iteration count K= 0

Step 4 : Set bus count P = 2

Step 5 : Calculate Pp and Qp using

$$Pp = \sum_{q=1}^{n} \{ e_p(e_pG_{pq}+f_pB_{qp})+f_p(f_pG_{pq} - e_pB_{pq})\}$$

$$Qp = \sum_{q=1}^{n} \{ f_p(e_pG_{pq}+f_pB_{qp})+e_p(f_pG_{pq} - e_pB_{pq})\}$$

Step 6 : Evaluate $\Delta P_P^K = P_{spec} - P_P^K$

Step 7 : Check if the bus is the question is a PV bus. If yes compare Q_P^K with the limits. If it exceeds the limit fix the Q value to the corresponding limit and treat the bus as PQ for that iteration and go to next step (or) if the lower limit is not violated evaluate $|\Delta V_P|^2 = |V_{spec}|^2 - |V_P^K|^2$ and go to step 9

Step 8: Evaluate $\Delta Q_P^K = Q_{spec} - Q_P^K$

Step 9 : Advance bus count P = P+1 and check if all buses taken in to account if not go to step 5

Step 10 : Determine the largest value of $|\Delta V_P|^2$

Step 11: If $\Delta V_P < \varepsilon$ go to step 16

Step 12: Evaluate the element of Jacobin matrices J_1, J_2, J_3, J_4, J_5 and J_6

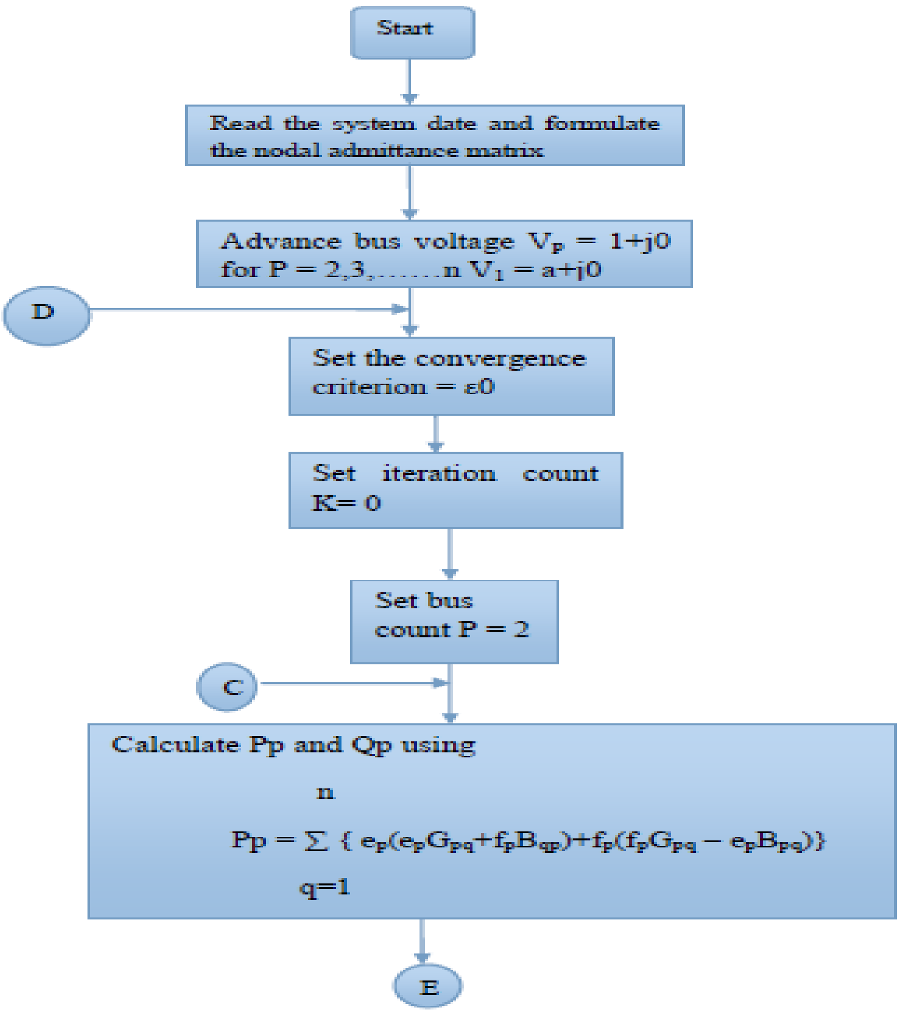
Step 13: Calculate Δe_P^K and Δf_P^K

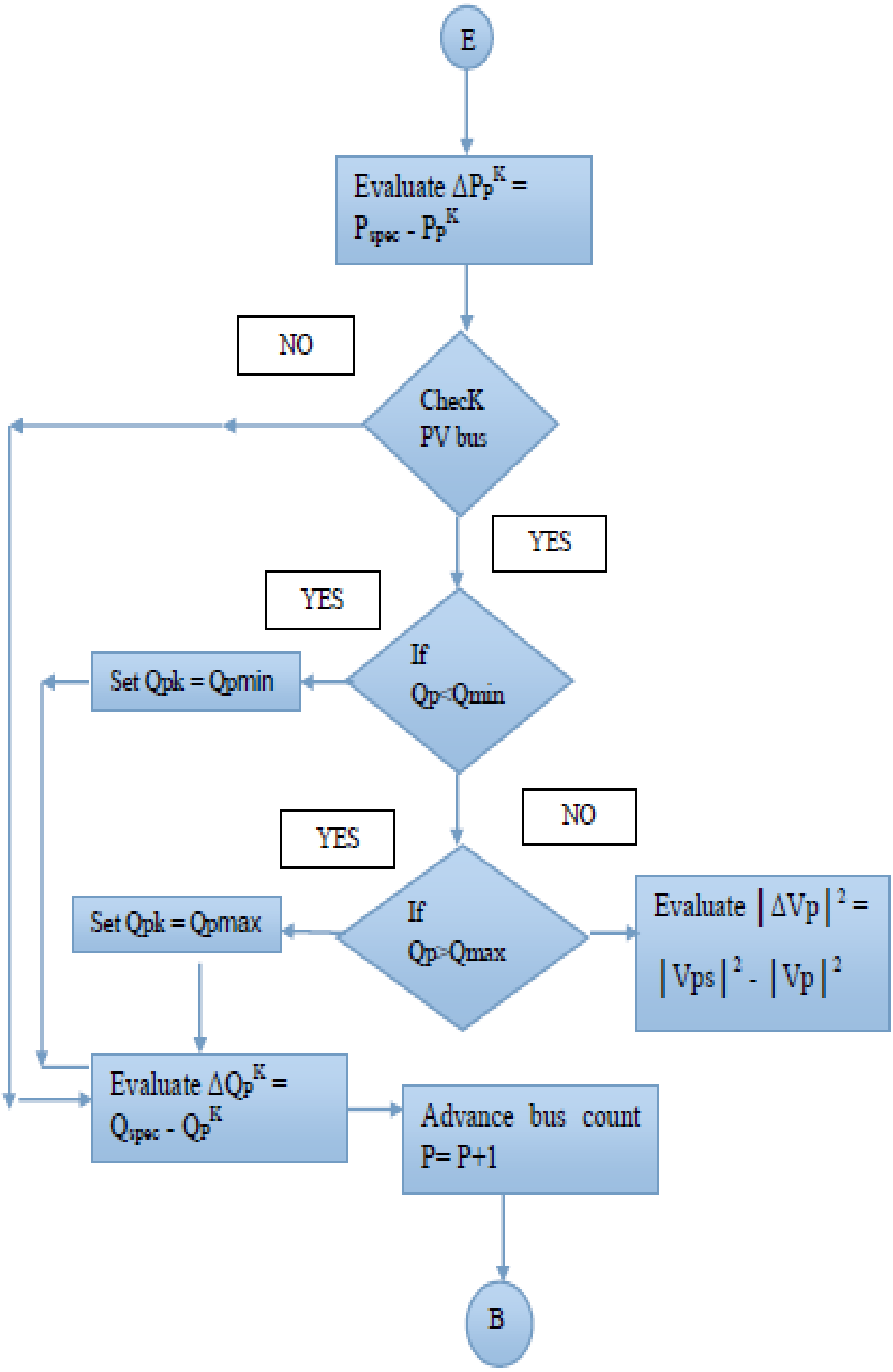
Step 14: Calculate $e_P^{K+1} = e_P^K + \Delta e_P^K$ and $f_P^{K+1} = f_P^K + \Delta f_P^K$

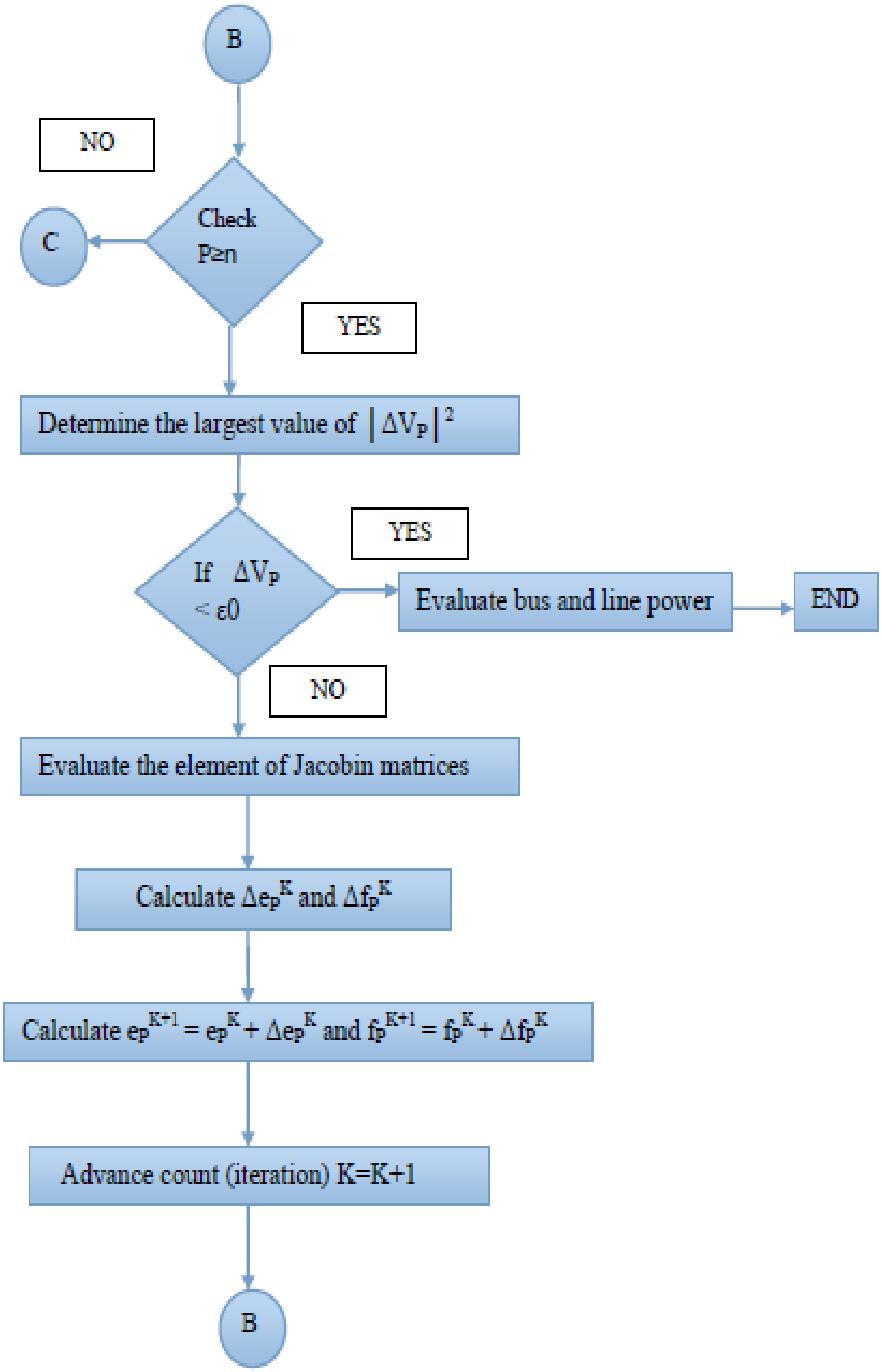
Step 15 : Advance count (iteration) K=K+1 and go to step 4

Step 16: Evaluate bus and line power and print the result

Iterative solution using Newton-Raphson method – Flow chart




E
Evaluate ΔPp^K = P_spec - Pp^K
NO
Check PV bus
YES
YES
If Qp<Qmin
Set Qpk = Qpmin
YES
NO
If Qp>Qmax
Set Qpk = Qpmax
Evaluate |ΔVp|^2 = |Vps|^2 - |Vp|^2
Evaluate ΔQp^K = Q_spec - Qp^K
Advance bus count P= P+1
B



2.6. ITERATIVE SOLUTION USING FAST DECOUPLED LOAD FLOW METHOD – ALGORITHM

Step 1: Assume a suitable solution for all buses except the slack bus. Let Vp =1+j0 for P=2,3,..................n and V=a+j0

Step2: Set the convergence criterion = ε0

Step3: Set iteration count K = 0

Step 4: Set bus count P = 2

Step 5: Calculate Pp and Qp using

$$Pp = \sum_{q=1}^{n} |VpVqYpq| \cos(\theta pq+\delta P-\delta q)$$

$$Qp = \sum_{q=1} |VpVqYpq| \sin(\theta pq+\delta P-\delta q)$$

Step 6: Compute the real and reactive power mismatches ΔP^K and ΔQ^K. If the mismatches Are with in desirable tolerance the iteration end

Step 7: Normalize the mismatches by dividing each entry by its respective bus voltage magnitude $\Delta P^K = \Delta P_2^K / V_2^K$

$\Delta P_3^K / V_3^K$

.

.

$\Delta P_n^K / V_n^K$

$\Delta Q^K = \Delta Q_2^K / V_2^K$

$\Delta Q_3^K / V_3^K$

.

.

$\Delta Q_n^K / V_n^K$

Step 8: Solve for the voltage magnitude and the correction factors ΔV^K and $\Delta\delta^K$ by using the constant matrices B' and B" which are extracted from the bus admittance matrix Y Bus

$[B'] \Delta\delta^K = \Delta P^K$

$[B'']\Delta Q^K = \Delta Q^K$

Step 9: Up date the voltage magnitude and angel vectors

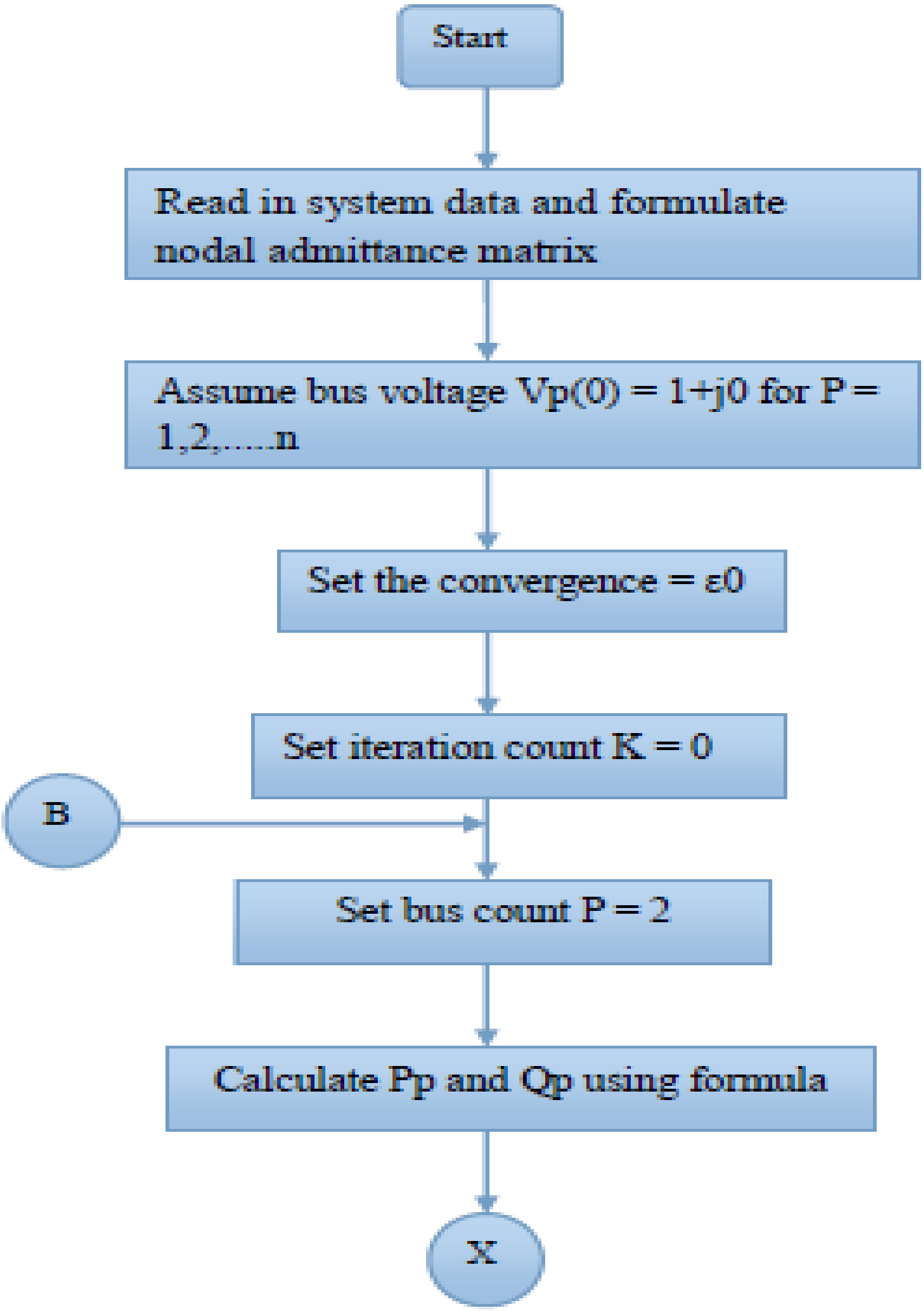
$\delta^{K+1} = \delta^K + \Delta\delta^K$

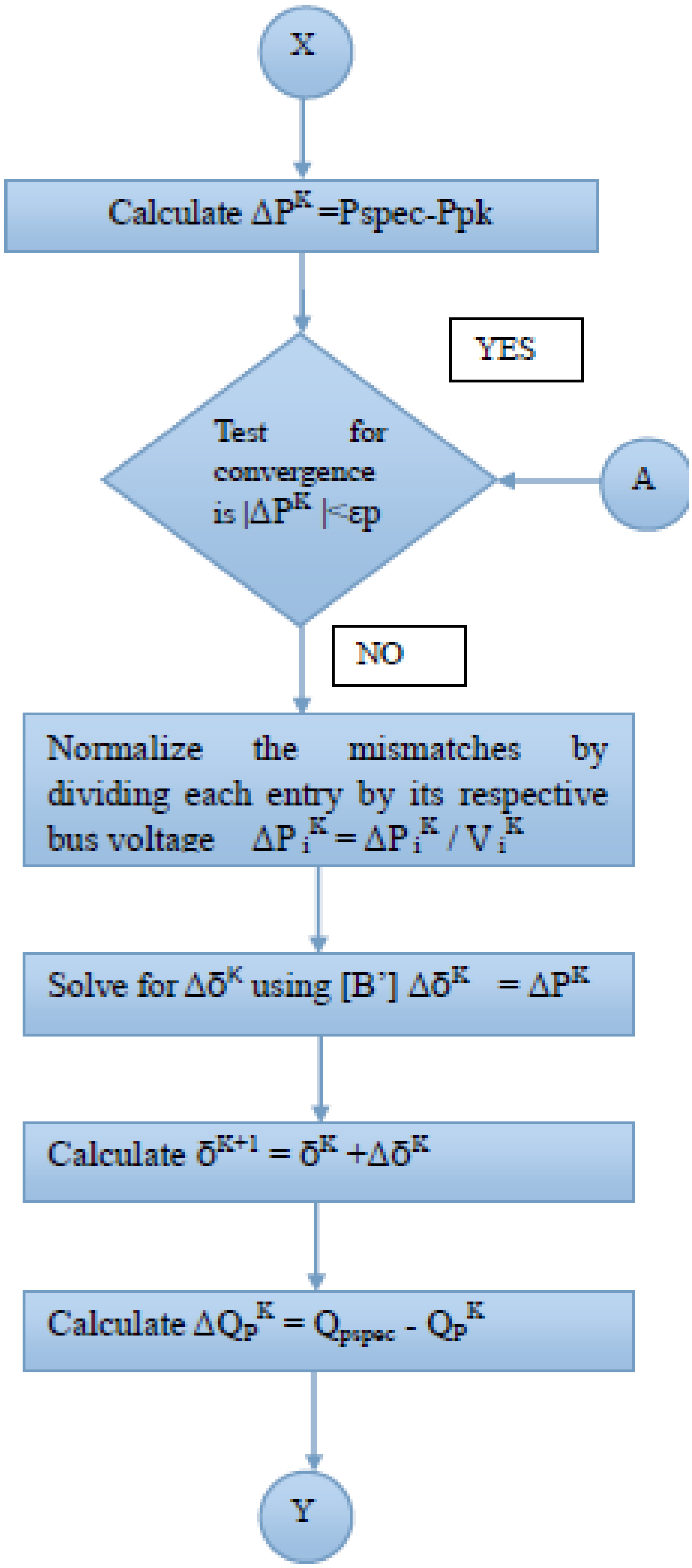
$V^{K+1} = V^K + \Delta V^K$

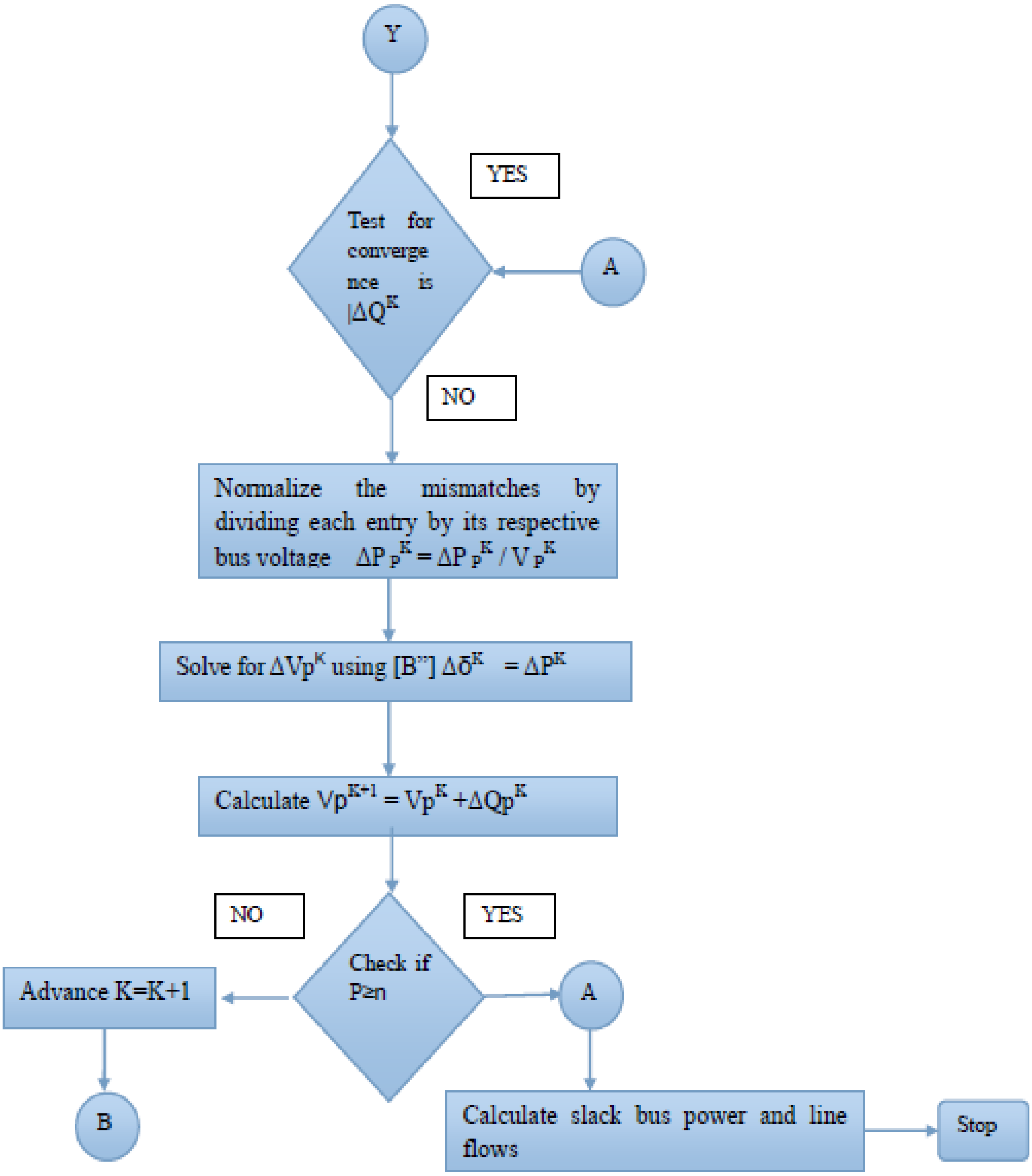
Step 10: Check if all the buses are taken into account if yes go to next step otherwise go to next step. Otherwise go to step 4

Step 11: Advance iteration count K = K+1 go to step 3

Step 12: Evaluate bus and load powers and print the results


Start
Read in system data and formulate nodal admittance matrix
Assume bus voltage Vp(0) = 1+j0 for P = 1,2,.....n
Set the convergence = ε0
Set iteration count K = 0
B
Set bus count P = 2
Calculate Pp and Qp using formula
X


X
Calculate ΔP^K =Pspec-Ppk
YES
Test for convergence is |ΔP^K |<εp
A
NO
Normalize the mismatches by dividing each entry by its respective bus voltage ΔP_i^K = ΔP_i^K / V_i^K
Solve for Δδ^K using [B'] Δδ^K = ΔP^K
Calculate δ^(K+1) = δ^K +Δδ^K
Calculate ΔQ_P^K = Q_pspec - Q_P^K
Y



2.7 ITERATIVE SOLUTION USING FAST DECOUPLED LOAD FLOW METHOD – FLOW CHART

Advantages and disadvantages of Gauss-Seidel method

Advantages: Calculations are simple and so the programming task is lessees. The memory requirement is less. Useful for small systems;
Disadvantages: Requires large no. of iterations to reach converge .Not suitable for large systems. Convergence time increases with size of the system

Advantages and disadvantages of N.R method

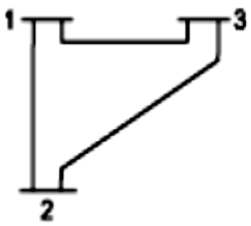
Advantages: Faster, more reliable and results are accurate, require less number of iterations;
Disadvantages: Program is more complex, memory is more complex.

2.8 COMPARE THE GAUSS SEIDEL AND NEWTON RAPHSON METHODS OF LOAD FLOW STUDY

S.No	G.S	N.R	FDLF
1	Require large number of iterations to reach convergence	Require less number of iterations to reach convergence.	Require more number of iterations than N.R method
2	Computation time per iteration is less	Computation time per iteration is more	Computation time per iteration is less
3	It has linear convergence characteristics	It has quadratic convergence characteristics	….
4	The number of iterations required for convergence increases with size of the system	The number of iterations are independent of the size of the system	The number of iterations are does not dependent of the size of the system
5	Less memory requirements	More memory requirements.	Less memory requirements than N.R.method.

Y matrix of the sample power system as shown in fig. Data for this system is given in table.

Bus code i-k	Impedance Z_{ik}	Line charging $y'_{ik}/2$
1-2	$0.02 + j0.06$	$j0.03$
1-3	$0.08 + j0.24$	$j0.025$
2-3	$0.06 + j0.18$	$j0.020$



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UNIT III FAULT ANALYSIS – BALANCED FAULTS

3.1. IMPORTANCE SHORT CIRCUIT (OR) FOR FAULT ANALYSIS

Fault

A fault in a circuit is any failure which interferes with the normal flow of current. The faults are associated with abnormal change in current, voltage and frequency of the power system.

Faults occur in a power system

The faults occur in a power system due to

(i). Insulation failure of equipment

(ii). Flashover of lines initiated by a lighting stroke

(iii). Due to permanent damage to conductors and towers or due to accidental faulty operations.

Various types of faults

(i) Series fault or open circuit fault

One open conductor fault

Two open conductor fault

(ii) Shunt fault or short circuit fault.

Symmetrical fault or balanced fault

- Three phase fault

Unsymmetrical fault or unbalanced fault

- Line to ground (L-G) fault
- Line to Line (L-L) fault
- Double line to ground (L-L-G) fault

Relative frequency of occurrence of various types of fault

Types of fault	**Relative frequency of occurrence of faults**
Three phase fault	5%
Double line to ground fault	10%
Line to Line fault	15%
Line to ground fault	70%

Symmetrical fault or balanced three phase fault

This type of fault is defined as the simultaneous short circuit across all the three phases. It occurs infrequently, but it is the most severe type of fault encountered. Because the network is balanced, it is solved by per phase basis using Thevenins theorem or bus impedance matrix or KVL, KCL laws.

3.2. BASIC ASSUMPTIONS IN FAULT ANALYSIS OF POWER SYSTEMS.

(i). Representing each machine by a constant voltage source behind proper reactance which may be X”, X’, or X

(ii). Pre-fault load current are neglected

(iii). Transformer taps are assumed to be nominal

(iv). Shunt elements in the transformers model that account for magnetizing current and core loss are neglected

(v). A symmetric three phase power system is conducted

(vi). Shunt capacitance and series resistance in transmission are neglected (vii). The negative sequence impedances of alternators are assumed to be the same as their positive sequence impedance $Z^+ = Z^-$

Need for short circuit studies or fault analysis

Short circuit studies are essential in order to design or develop the protective schemes for various parts of the system .To estimate the magnitude of fault current for the proper choice of circuit breaker and protective relays.

Bolted fault or solid fault

A Fault represents a structural network change equivalent with that caused by the addition of impedance at the place of a fault. If the fault impedance is zero, the fault is referred as bolted fault or solid fault.

Reason for transients during short circuits

The faults or short circuits are associated with sudden change in currents. Most of the components of the power system have inductive property which opposes any sudden change in currents, so the faults are associated with transients.

Doubling effect

If a symmetrical fault occurs when the voltage wave is going through zero then the maximum momentary short circuit current will be double the value of maximum symmetrical short circuit current. This effect is called doubling effect.

DC off set current

The unidirectional transient component of short circuit current is called DC off set current.

3.3. SYMMETRICAL FAULT

In symmetrical faults all the three phases are short circuited to each other and to earth also. Such faults are balanced and symmetrical in the sense that the voltage and current of the system remains balanced even after the fault and it is enough if we consider any one phase

Short circuit capacity of power system or fault level.

Short circuit capacity (SCC) or Short circuit MVA or fault level at a bus is defined as the product of the magnitude of the pre fault bus voltage and the post fault current

$$\text{SCC or Short circuit MVA} = |V_{prefault}| \times |I_f|$$

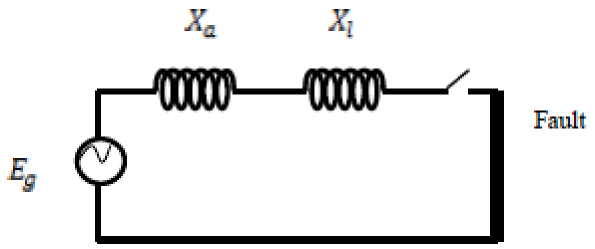
(OR)

$$\text{SCC} = \frac{1}{X_{th}} \; p.u \; MVA$$

Synchronous reactance or steady state condition reactance

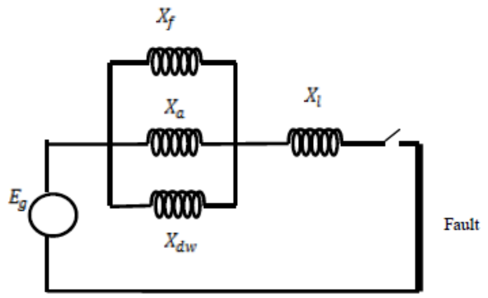
The synchronous reactance is the ratio of induced emf and the steady state rms current. It is the sum of leakage reactance (X_l) and the armature reactance (X_a).

$$X_d = X_a + X_l$$



Sub transient reactance

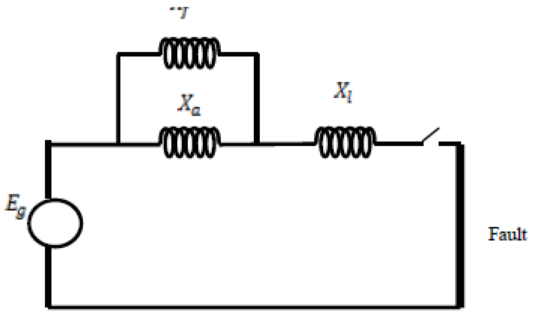
The synchronous reactance is the ratio of induced emf on no load and the sub transient symmetrical rms current.



$$X_d'' = X_l + \frac{1}{\frac{1}{X_a} + \frac{1}{X_f} + \frac{1}{X_{dw}}}$$

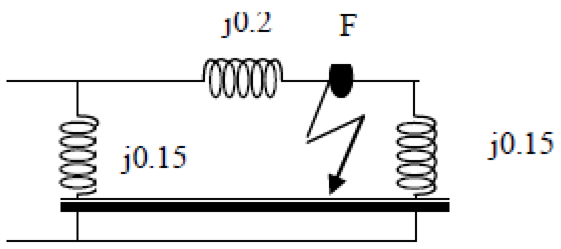
Transient reactance

The synchronous reactance is the ratio of induced emf on no load and the transient symmetrical rms current.



$$X_d' = X_l + \frac{1}{\frac{1}{X_a} + \frac{1}{X_f}}$$

Fault current in fig., if the Pre-fault voltage at the fault point is 0.97 p.u.



Thevenin's theorem:
(i). Fault current = E_{th} / $(Z_{th}+Z_f)$
(ii). Determine current contributed by the two generators $IG_1 = I_f * (Z_2/(Z_1+Z_2))$
$IG_2 = If * (Z_1 / (Z_1+Z_2))$
(iii). Determine Post fault voltage $V_{if} = V_i°+\Delta V = V°+(-Z_{i2}*IG_i)$
(iv). Determine post fault voltage line flows $I_{ij} = (V_i - V_j) / Z_{ij}$ series
(v). Short circuit capacity $I_f = |E_{th}|^2 / X_{th}$

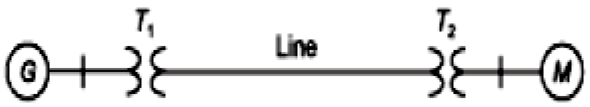
3.4. FAULT ANALYSIS USING Z-BUS MATRIX – ALGORITHM AND FLOW CHART.

Bus impedance matrix
Bus impedance matrix is the inverse of the bus admittance matrix. The matrix consisting of driving point impedance and transfer impedances of the network is called as bus impedance matrix. Bus impedance matrix is symmetrical.

Methods available for forming bus impedance matrix
(i). Form bus admittance matrix and take the inverse to get bus impedance matrix.
(ii). Using bus building algorithm.
(iii). Using L-U factorization of Y-bus matrix.

3.5 SOLVED PROBLEMS

Problem 1
A synchronous generator and a synchronous motor each rated 20MVA, 12.66KV having 15% reactance are connected through transformers and a line as shown in fig. the transformers are rated 20MVA,12.66/66KV and 66/12.66KV with leakage reactance of 10% each. The line has a reactance of 8% on base of 20MVA, 66 KV. The motor is drawing 10MW at 0.8 leading power factors and a terminal voltage 11KV when symmetrical three phase fault occurs at the motors terminals. Determine the generator and motor currents. Also determine the fault current.



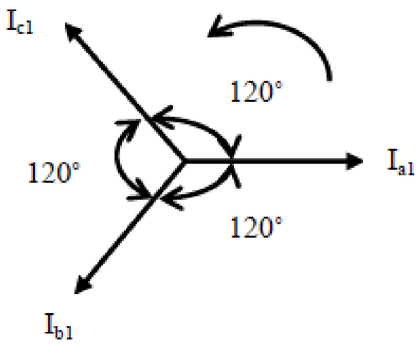
UNIT- IV

SYMMETRICAL COMPONENTS AND UNBALANCED FAULT ANALYSIS

4.1. INTRODUCTION TO SYMMETRICAL COMPONENTS

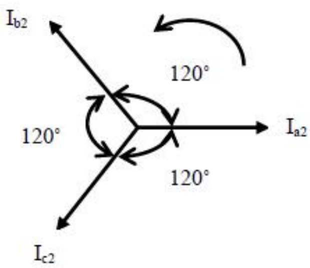
Symmetrical components of a 3 phase system
In a 3 phase system, the unbalanced vectors (either currents or voltage) can be resolved into three balanced system of vectors.
They are Positive sequence components
Negative sequence components
Zero sequence components
Unsymmetrical fault analysis can be done by using symmetrical components.

Positive sequence components
It consists of three components of equal magnitude, displaced each other by 120° in phase and having the phase sequence abc .



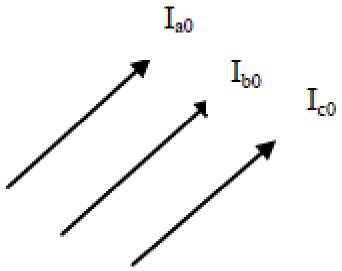
$$I_{a1} = I_{a1}\angle 0^\circ$$
$$I_{b1} = I_{a1}\angle 240^\circ = I_{a1}\angle -120^\circ$$
$$I_{c1} = I_{a1}\angle 120^\circ$$

Negative sequence components
It consists of three components of equal magnitude, displaced each other by 120° in phase and having the phase sequence acb .



$$I_{a2} = I_{a2}\angle 0^\circ$$
$$I_{b2} = I_{a2}\angle 120^{\circ\circ}$$
$$I_{c1} = I_{a2}\angle 240^\circ = I_{a2}\angle -120^\circ$$

Zero sequence components
It consists of three phasors equal in magnitude and with zero phase displacement from each other.



$I_{a0} = I_{b0} = I_{c0}$

Sequence operator

In unbalanced problem, to find the relationship between phase voltages and phase currents, we use sequence operator ***'a'***.

$a = 1\angle 120^{\circ} == -0.5+j0.866$

$$a^2 = 1\angle 240^{\circ} = -0.5 - j0.866$$

$$1 + a + a^2 = 0$$

Unbalanced currents from symmetrical currents

Let, I_a, I_b, I_c be the unbalanced phase currents

Let, I_{a0}, I_{a1}, I_{a2} be the symmetrical components of phase a

$$\begin{bmatrix} I_a \\ I_b \\ I_b \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{bmatrix}$$

Determination of symmetrical currents from unbalanced currents.

Let, I_a, I_b, I_c be the unbalanced phase currents

Let, I_{a0}, I_{a1}, I_{a2} be the symmetrical components of phase a

$$\begin{bmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_b \end{bmatrix}$$

4.2. SEQUENCE IMPEDANCES SEQUENCE NETWORKS

The sequence impedances are the impedances offered by the power system components or elements to +ve, -ve and zero sequence current.

The single phase equivalent circuit of power system consisting of impedances to current of any one sequence only is called sequence network.

The phase voltage across a certain load are given as

$$V_a = (176 - j132)\ Volts$$

$$V_b = (-128 - j96)\ Volts$$

$$V_c = (-160 + j100)\ Volts$$

Compute positive, negative and zero sequence component of voltage

Solution:

$$V_{a1} = \frac{1}{3}\left(V_a + \beta V_b + \beta^2 V_c\right)$$

$$V_{a2} = \frac{1}{3}\left(V_a + \beta^2 V_b + \beta V_c\right)$$

$$V_{a0} = \frac{1}{3}\left(V_a + V_b + V_c\right)$$

$$V_{a1} = \frac{1}{3}\left\{176 - j132 + 1\angle 120^\circ \times (-128 - j96) + 1\angle 240^\circ (-160 + j100)\right\}$$

$$V_{a1} = (163.24 - j35.10) \text{ Volts}$$

$$V_{a2} = \frac{1}{3}\left\{176 - j132 + 1\angle 240^\circ (-128 - j96) + 1\angle 120^\circ (-160 + j100)\right\}$$

$$V_{a2} = (50.1 - j53.9) \text{ Volts}$$

$$V_{a0} = \frac{1}{3}(176 - j132 - 128 - j96 - 160 + j100) \text{ Volts}$$

A balanced delta connected load is connected to a three phase system and supplied to it is a current of 15 amps. If the fuse is one of the lines melts, compute the symmetrical components of line currents.

Solution:

$$I_a = -I_c, \quad I_b = 0$$

$$I_a = 15\angle 0^\circ; \quad I_c = 15\angle 180^\circ = -15$$

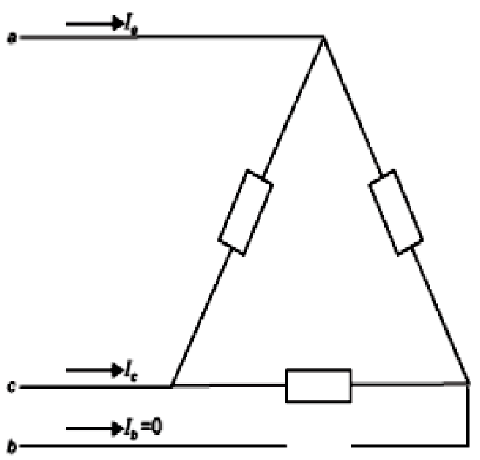
$$\therefore \quad I_{a1} = \frac{1}{3}\left(I_a + \beta I_c + \beta^2 I_b\right)$$

$$= (7.5 + j4.33) \text{ Amp.}$$

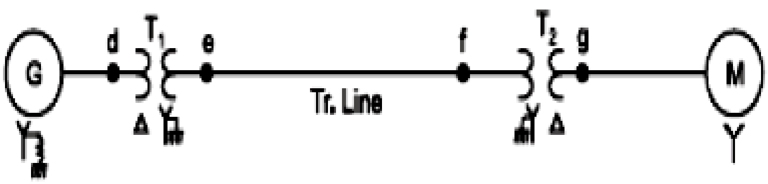
$$I_{a2} = \frac{1}{3}\left(I_a + \beta^2 I_c + \beta I_b\right)$$

$$= (7.5 + j4.33) \text{ Amp.}$$

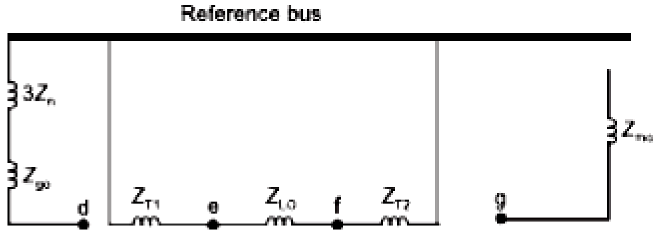
$$I_{a0} = \frac{1}{3}\left(I_a + I_b + I_c\right) = 0.0$$



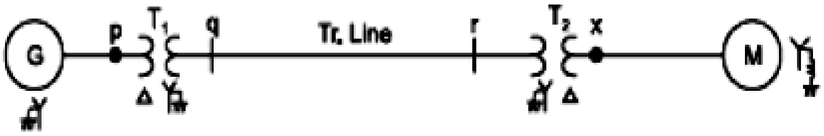
Draw zero sequence network of the power system as shown in fig.



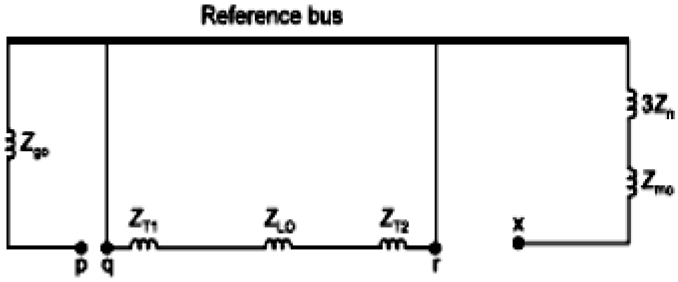
Solution:



Draw zero sequence network of the power system as shown in fig.

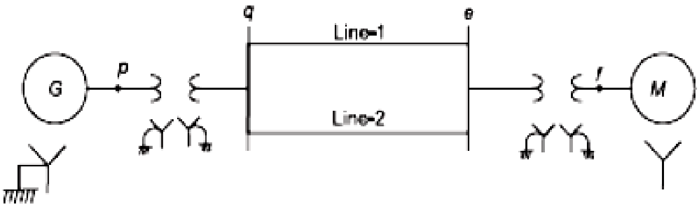


Solution:

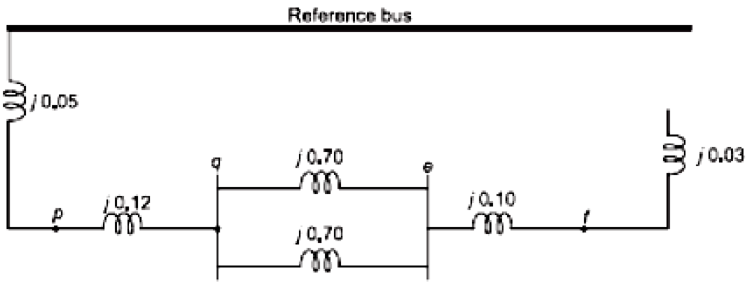


Draw zero sequence network of the power system as shown in fig. Data are given below.

G: $x_{g0} = 0.05$ pu
M: $x_{m0} = 0.03$ pu
T_1: $x_{T1} = 0.12$ pu
T_2: $x_{T2} = 0.10$ pu
Line-1: $x_{L10} = 0.70$ pu
Line-2: $x_{L20} = 0.70$ pu

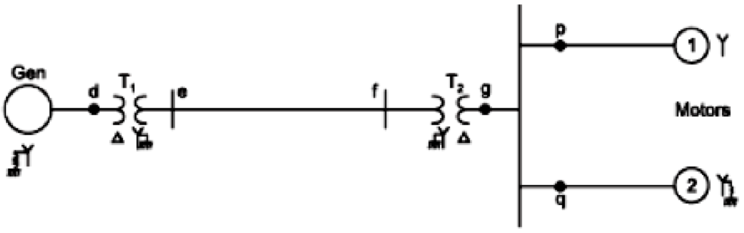


Solution:



4.3. REPRESENTATION OF SINGLE LINE TO GROUND, LINE TO LINE AND DOUBLE LINE TO GROUND FAULT CONDITIONS.

A 50MVA, 11KV, synchronous generator has a sub transient reactance of 20%.The generator supplies two motors over a transmission line with transformers at both ends as shown in fig. The motors have rated inputs of 30 and 15 MVA, both 10KV, with 25% sub transient reactance. The three phase transformers are both rated 60MVA, 10.8/121KV, with leakage reactance of 10% each. Assume zero sequence reactance for the generator and motors of 6% each. Current limiting reactors of 2.5 ohms each are connected in the neutral of the generator and motor number 2. The zero sequence reactance of the transmission line is 300 ohms. The series reactance of the line is 100 ohms. Draw the positive, negative and zero sequence networks.



Assume that the negative sequence reactance of each machine is equal to its subtransient reactance.

Solution:

Assume base power = 50 MVA

base voltage = 11 KV

Base voltage of transmission line

$$= 11 \times \frac{121}{10.8} = 123.2 \text{ KV}$$

$$\text{Motor base voltage} = 123.2 \times \frac{10.8}{121} = 11 \text{ KV}$$

Transformer reactance,

$$x_{T1} = x_{T2} = 0.10 \times \frac{50}{60} \times \left(\frac{10.8}{11}\right)^2 = 0.0805 \text{ pu}$$

Line reactance (positive & negative sequence)

$$= \frac{100 \times 50}{(123.2)^2} \text{ pu} = 0.33 \text{ pu}$$

Line reactance (zero sequence)

$$= \frac{300 \times 50}{(123.2)^2} = 0.99 \text{ pu}$$

Reactance of motor 1(positive and negative sequence)

$$= 0.25 \times \frac{50}{30} \times \left(\frac{10}{11}\right)^2 = 0.345 \text{ pu}$$

Zero-sequence reactance of motor 1

$$= 0.06 \times \frac{50}{30} \times \left(\frac{10}{11}\right)^2$$

$$= 0.082 \text{ pu}$$

Reactance of motor 2 (positive and negative sequence)

$$= 0.25 \times \frac{50}{15} \times \left(\frac{10}{11}\right)^2 = 0.69 \text{ pu}$$

Zero-sequence reactance of motor 2

$$= 0.06 \times \frac{50}{15} \times \left(\frac{10}{11}\right)^2 = 0.164 \text{ pu}$$

$$\text{Reactance of reactors} = 2.5 \times \frac{50}{(11)^2} = 1.033 \text{ pu}$$

Positive, negative and zero-sequence diagram are given below:

Fig. 9.10(a): Positive sequence network.

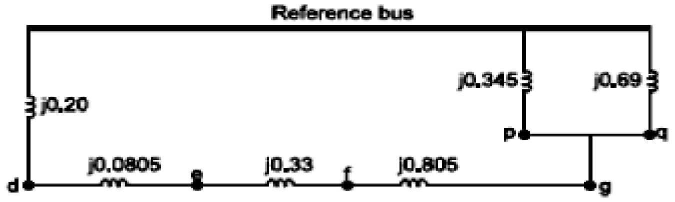


Fig. 9.10(b): Negative sequence network.

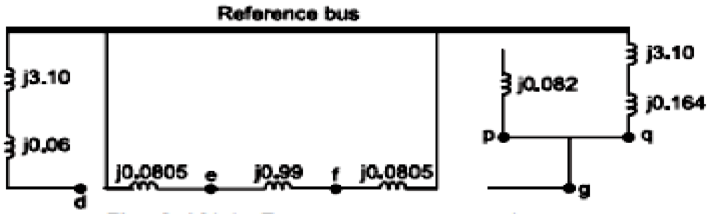


Fig. 9.10(c): Zero-sequence network.

4.4. UNBALANCED FAULT ANALYSIS PROBLEM FORMULATION

A 30 MVA, 13.2KV synchronous generator has a solidly grounded neutral. Its positive, negative and zero sequence impedances are 0.30, 0.40 and 0.05 p.u respectively. Determine the following:

a) What value of reactance must be placed in the generator neutral so that the fault current for a line to ground fault of zero fault impedance shall not exceed the rated line current?

b) What value of resistance in the neutral will serve the same purpose?

c) What value of reactance must be placed in the neutral of the generator to restrict the fault current to ground to rated line current for a double line to ground fault?

d) What will be the magnitudes of the line currents when the ground current is restricted as above?

e) As the reactance in the neutral is indefinitely increased, what are the limiting values of the line currents?

UNIT V STABILITY ANALYSIS

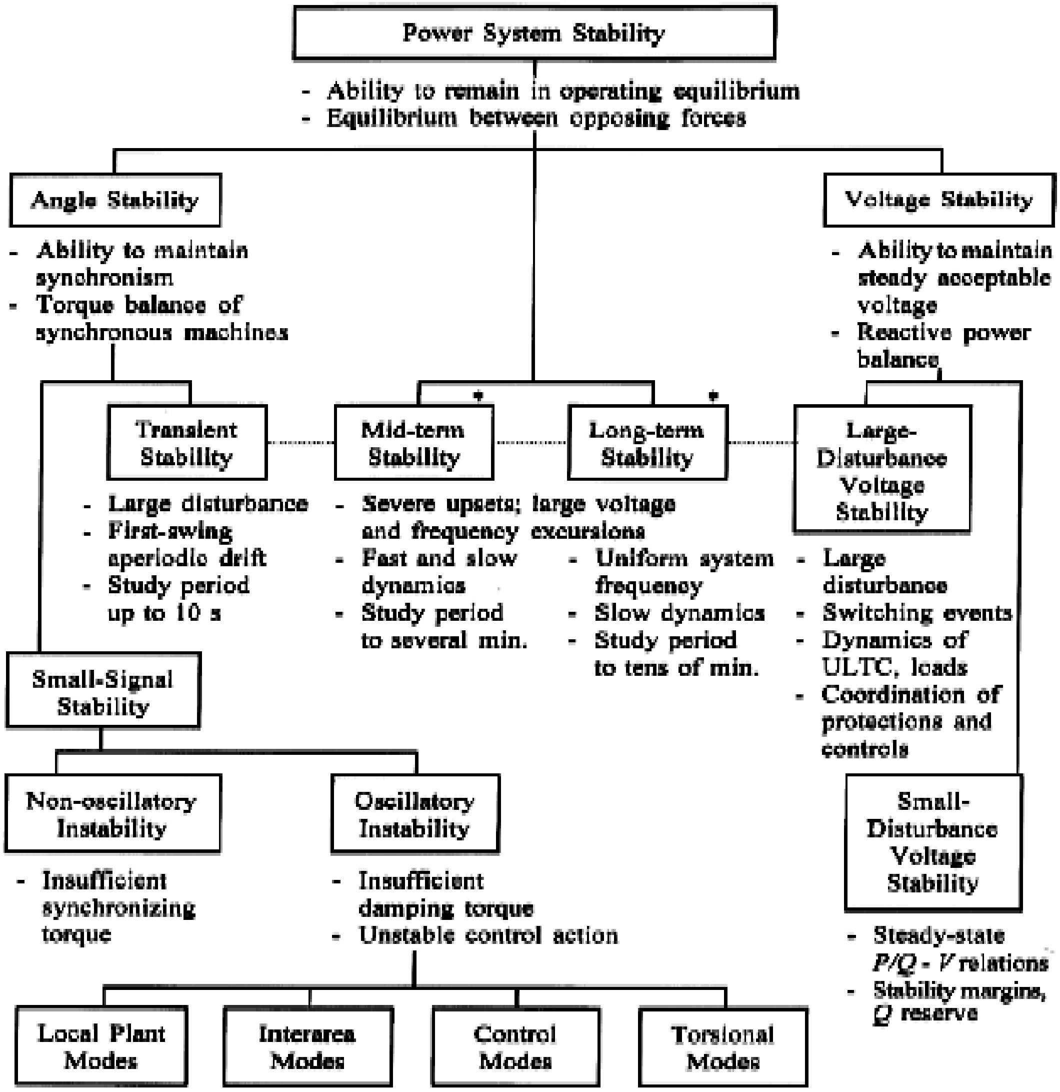
5.1. IMPORTANCE OF STABILITY ANALYSIS IN POWER SYSTEM PLANNING AND OPERATION

Power system stability

The stability of an interconnected power system means is the ability of the power system is to return or regain to normal or stable operating condition after having been subjected to some form of disturbance.

5.2. CLASSIFICATION OF POWER SYSTEM STABILITY - ANGLE AND VOLTAGE STABILITY

Power system stability is classified



5.3 ANGLE AND VOLTAGE STABILITY

Rotor angle stability
Rotor angle stability is the ability of interconnected synchronous machines of a power system to remain in synchronism.

Steady state stability
Steady state stability is defined as the ability of the power system to bring it to a stable condition or remain in synchronism after a small disturbance.

Steady state stability limit
The steady sate stability limit is the maximum power that can be transferred by a machine to receiving system without loss of synchronism

Transient stability
Transient stability is defined as the ability of the power system to bring it to a stable condition or remain in synchronism after a large disturbance.

Transient stability limit
The transient stability limit is the maximum power that can be transferred by a machine to a fault or a receiving system during a transient state without loss of synchronism.Transient stability limit is always less than steady state stability limit

Dynamic stability
It is the ability of a power system to remain in synchronism after the initial swing (transient stability period) until the system has settled down to the new steady state equilibrium condition

Voltage stability
It is the ability of a power system to maintain steady acceptable voltages at all buses in the system under normal operating conditions and after being subjected to a disturbance.

Causes of voltage instability
A system enters a state of voltage instability when a disturbance, increase in load demand, or change in system condition causes a progressive and uncontrollable drop in voltage. The main factor causing instability is the inability of the power system to meet the demand for reactive power.

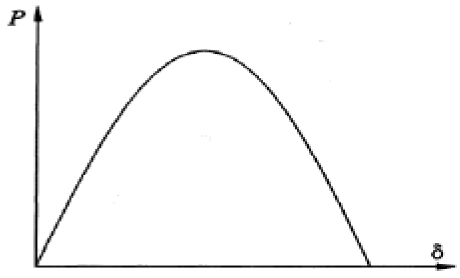
Determination of critical clearing angle and time

Power angle equation and draw the power angle curve

$$P = \frac{V_s V_r}{X_T} \sin \delta$$

Where, P – Real Power in watts
V_s – Sending end voltage; V_r- Receiving end voltage
X_T - Total reactance between sending end receiving end
δ- Rotor angle.

Power angle curve



Maximum power transfer.

$$P_{max} = \frac{V_s V_r}{X_T}$$

Swing equation for a SMIB (Single machine connected to an infinite bus bar) system.

$$\frac{H}{\pi f}\frac{d^2\delta}{dt^2} = P_m - P_e$$

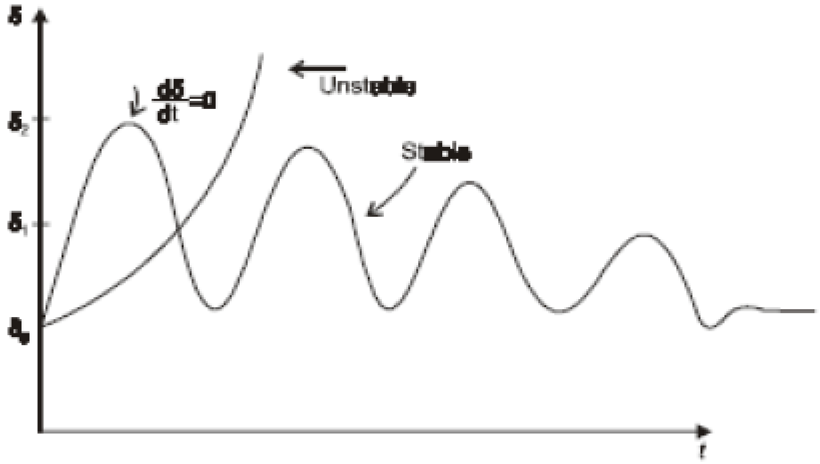
Since M in p.u = $H/\pi f$

$$M\frac{d^2\delta}{dt^2} = P_m - P_e$$

Where H = inertia constant in MW/MVA
f = frequency in Hz
M = inertia constant in p.u

Swing curve

The swing curve is the plot or graph between the power angle δ and time t. From the nature of variations of δ the stability of a system for any disturbance can be determined.



3 machine system having ratings G_1, G_2 and G_3 and inertia constants M_1, M_2 and M_3.What is the inertia constants M and H of the equivalent system.

$$M_{eq} = \frac{M_1 G_1}{G_b} + \frac{M_2 G_2}{G_b} + \frac{M_3 G_3}{G_b}$$

$$H_{eq} = \frac{\pi f M_{eq}}{G_b}$$

Where G_1, G_2, G_3 – MVA rating of machines 1, 2, and 3
G_b = Base MVA or system MVA

Assumptions made in stability studies.

(i). Machines represents by classical model

(ii). The losses in the system are neglected (all resistance are neglected)

(iii). The voltage behind transient reactance is assumed to remain constant.

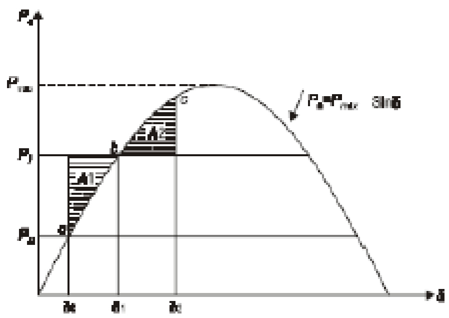
(iv). Controllers are not considered (Shunt and series capacitor)

(v). Effect of damper winding is neglected.

Equal Area Criterion

The equal area criterion for stability states that the system is stable if the area under P – δ curve reduces to zero at some value of δ.

This is possible if the positive (accelerating) area under P – δ curve is equal to the negative (decelerating) area under P – δ curve for a finite change in δ. hence stability criterion is called equal area criterion.



Critical clearing angle.

The critical clearing angle , is the maximum allowable change in the power angle δ before clearing the fault, without loss of synchronism.

The time corresponding to this angle is called critical clearing time, .It can be defined as the maximum time delay that can be allowed to clear a fault without loss of synchronism.

Methods of improving the transient stability limit of a power system.

(i).Reduction in system transfer reactance

(ii).Increase of system voltage and use AVR

(iii).Use of high speed excitation systems

(iv). Use of high speed reclosing breakers

Numerical integration methods of power system stability

i. Point by point method or step by step method

ii. Euler method

iii. Modified Euler method

iv. Runge-Kutta method(R-K method)

5.4 SINGLE MACHINE INFINITE BUS (SMIB) SYSTEM: DEVELOPMENT OF SWING EQUATION.

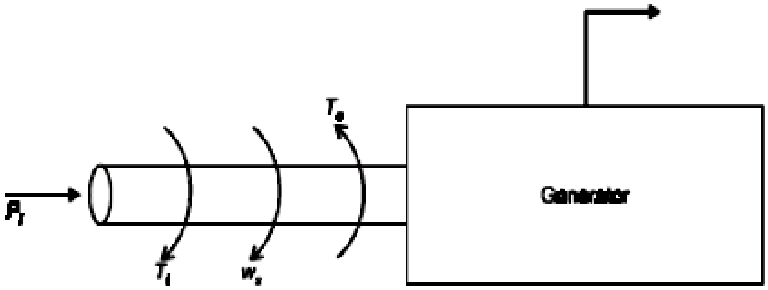


Fig. 11.1: Flow of powers in a synchronous generator.

Consider a synchronous generator developing an electromagnetic torque T_e (and a corresponding electromagnetic power P_e) while operating at the synchronous speed w_s. If the input torque provided by the prime mover, at the generator shaft is T_i, then under steady-state conditions (i.e., without any disturbance)

$$T_e = T_i \quad ...(11.10)$$

Here we have neglected any retarding torque due to rotatianal losses. Therefore we have

$$T_e w_s = T_i w_s \quad ...(11.11)$$

and $$T_i w_s - T_e w_s = P_i - P_e = 0 \quad ...(11.12)$$

If there is a departure from steady-state occurs, for example, a change in load or a fault, then input power P_i is not equal to P_e, if the armature resistance is neglected. Therefore left-side of eqn. (11.12) is not zero and an accelerating torque comes into play. If P_a is the corresponding accelerating (or decelerating) power, then

$$P_i - P_e = M.\frac{d^2\theta_e}{dt^2} + D.\frac{d\theta_e}{dt} = P_a \quad ...(11.13)$$

Where M has been defined in eqn. (11.8) or eqn. (11.9). D is a damping coefficient and θ_e is the electrical angular position of the rotor. It is more convenient to measure the angular position of the rotor with respect to a synchronously rotating frame of reference. Let

$$\delta = \theta_e - w_s.t \quad ...(11.14)$$

$$\therefore \quad \frac{d^2\theta_e}{dt^2} = \frac{d^2\delta}{dt^2} \quad ...(11.15)$$

Where δ is the power angle of the synchronous machine. Neglecting damping (i.e., $D = 0$) and substituting eqn. (11.15) in eqn. (11.13), we get,

$$M.\frac{d^2\delta}{dt^2} = P_i - P_e \;\; MW \quad ...(11.16)$$

$$\frac{GH}{\pi f}\frac{d^2\delta}{dt^2} = P_i - P_e\ MW \quad \text{...(11.17)}$$

Dividing throughout by G, the MVA rating of the machine,

$$M\,(\text{pu})\frac{d^2\delta}{dt^2} = (P_i - P_e)\ \text{pu} \quad \text{...(11.18)}$$

where $$M(\text{pu}) = \frac{H}{\pi f} \quad \text{...(11.19)}$$

or $$\frac{H}{\pi f}\frac{d^2\delta}{dt^2} = (P_i - P_e)\ \text{pu} \quad \text{...(11.20)}$$

Eqn. (11.20) is called swing equation. It describes the rotor dynamics for a synchronous machine. Although damping is ignored but it helps to stabilizer the system. Damping must be considered in dynamic stability study.

A 400 MVA synchronous machine has H_1=4.6 MJ/MVA and a 1200 MVA machines H_2=3.0 MJ/MVA. Two machines operate in parallel in a power plant. Find out H_{eq} relative to a 100MVA base.

Solutions:

Total kinetic energy of the two machines is

$$KE = 4.6 \times 400 + 3 \times 1200 = 5440\ \text{MJ}.$$

Using the formula given in eqn. (11.28),

$$H_{eq} = \left(\frac{400}{100}\right) \times 4.6 + \left(\frac{1200}{100}\right) \times 3$$

$$\therefore \quad H_{eq} = 54.4\ \text{MJ/MVA}$$

or, equivalent inertia relative to a 100 MVA base is

$$H_{eq} = \frac{\text{KE}}{\text{System base}} = \frac{5440}{100} = 54.4\ \text{MJ/MVA} \quad \textbf{Ans.}$$

A 100 MVA, two pole, 50Hz generator has moment of inertia 40 x 10^3 kg-m^2.what is the energy stored in the rotor at the rated speed? What is the corresponding angular momentum? Determine the inertia constant h.