Children's Education Society ®

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

THE OXFORD COLLEGE OF ENGINEERING

Hosur Road, Bommanahalli, Bengaluru-560 068

Website:www.theoxford.edu Email : enghodcse@theoxford.edu

(Approved by AICTE, New Delhi, Accredited by NBA, NAAC, New Delhi & Affiliated to VTU, Belgaum)

INSTITUTION

Vision

To be a Respected and Most Sought after Engineering Educational Institution Engaged in Equipping Individuals Capable of Building Learning Organizations in the New Millennium.

Mission

To Develop Competent Students with Good Value Systems to Face Challenges of the Continuously Changing World.

DEPARTMENT

Vision

To establish the department as a renowned center of excellence in the area of scientific education, research with industrial guidance, and exploration of the latest advances in the rapidly changing field of computer science.

Mission

To produce technocrats with creative technical knowledge and intellectual skills to sustain and excel in the highly demanding world with confidence.

Program Educational Objectives (PEO)

1. To create graduates equipped with life-long learning skills and have a successful professional career in IT industry.
2. To prepare graduates to pursue higher education and get inclined towards research & development in computer science engineering.
3. To provide adequate training and opportunities, with exposure to emerging cutting edge technologies and to work in teams on multidisciplinary projects with effective communication skills and leadership qualities.

Program Specific Outcomes (PSO)

1. To design efficient algorithms and develop effective code for real-time computations.
2. To apply software engineering principles in developing optimal software solutions.

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING
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Hosur Road, Bommanahalli, Bengaluru-560 068
Website:www.theoxford.edu Email : engprincipal@theoxford.edu
(Approved by AICTE, New Delhi, Accredited by NBA, New Delhi & Affiliated to VTU, Belgaum)

Academic Semester: Aug 2016 to Nov 2016

Subject: 15CS32 **Sub Code: Analog and Digital Electronics**

Course Objectives

This course will enable the students to

- Recall and Recognize construction and characteristics of JFETs and MOSFETs and differentiate with BJT
- Evolve and Analyze Operational Amplifier circuits and their applications
- Describe, Illustrate and Analyze Combinational Logic circuits, Simplification of Algebraic Equations using Karnaugh Maps and Quine McClusky Techniques.
- Describe and Design Decoders, Encoders, Digital multiplexers, Adders and Subtractors, Binary comparators, Latches and Master-Slave Flip-Flops.
- Describe, Design and Analyze Synchronous and Asynchronous Sequential
- Explain and design registers and Counters, A/D and D/A converters.

Faculty Sign

HOD, CSE

HEAD OF THE DEPARTMENT
DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING
THE OXFORD COLLEGE OF ENGINEERING
BENGALURU - 560 068

Academic Semester: Aug 2016 to Nov 2016

Subject: Analog and Digital Electronics Sub Code: 15CS32

Course Outcomes (COs)

C202.1: To understand the basic concepts of digital logic and simplify the Boolean expression and types of simplification

C202.2: To understand the basics of Multiplexer design from SOP and POS.

C202.3: Describe and Design Decoders, Encoders, Digital multiplexers, Adders and Subtractors, Binary comparators, Latches and Master slave Flip Flop.

C202.4: Describe and Analyze Synchronous and Asynchronous Sequential circuit.

C202.5: Learn about Op-amp and comparator with hysteresis.

CO-PO Mapping

PO CO	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
C202.1	3	3	2	2								1
C202.2	2	2	1	1								1
C202.3	2	2	2	2								1
C202.4	3	3	2	2	1							1
C202.5	2	2	2	2	1							1

CO-PSO Mapping

CO	PSO1	PSO2
C202.1	2	2
C202.2	1	1
C202.3	1	1
C202.4	2	2
C202.5	2	2

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BENGALURU - 560 068

PARTMENT OF COMPUTER SCIENCE / ENGINEERING
THE OXFORD COLLEGE OF ENGINEERING

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Website:www.theoxford.edu Email : engprincipal@theoxford.edu
(Approved by AICTE, New Delhi, Accredited by NAAC & NBA, New Delhi & Affiliated to VTU, Belgaum)

COURSE: BE | **SEM & SECTION: 3 A** | **ROOM NO: 316** | **CLASS TEACHER :Ms. Beena**

DAY/ TIME	9:00 – 9:55	9:55 – 10:50	11:00 - 11:55	11:55 – 12:50	12:50 - 1:30	1:30 – 2:25	2:25 – 3:20	3:20 – 4:15
MON	DS	ADE	MAT	USP	LUNCH BREAK	DMS	CO	Library
TUE	ADE	DMS	CO	DS		<------------LD & DS LAB------------⊠		
WED	MAT	<------------LD & DS LAB------------⊠				←	TOGGLE	→
THU	DS	MAT	DMS	USP		~~CO~~	~~DS~~	Tutorial
FRI	DMS	USP	CO	ADE		MAT	CREAM & REMEDIAL	
SAT	CO	USP	ADE	DS				

SUBJECT CODE	SUBJECT	FACULTY NAME
15CS31	Engineering Mathematics - III	Ms. Sandya Rani
15CS32	Analog and Digital Electronics	Ms. Florence
15CS33	Data Structures and Applications	Ms. Shilpa
15CS34	Computer Organization	Ms.Chandanitha
15CS35	Discrete Mathematical Structures	Ms.Moumitha
15CS361	Unix and Shell Programming	Ms.Beena
15CSL37	Analog and Digital Electronics Laboratory	Ms. Florence
15CSL38	Data Structures with C Laboratory	Ms.Shilpa

Anandhi 26/7/16.
HOD/CSE

28/7/16
Time Table Coordinator
Professor & HOD of E & C Engineering
The Oxford College of Engineering
Bommanahalli, Bangalore-560 068.

Dr. R. KARIBASAPPA
PRINCIPAL
The Oxford College of Engineering
Bommanahalli, Hosur Road
Bangalore-560 068

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ACADEMIC YEAR 2016-2017: ODD SEMESTER [AUG 2016-DEC 2016]

Individual Time Table

STAFF: **Florance**

	1	2	3	4	5	6	7
MON							
TUE		ADE			LD/DS LAB		
WED	ADE	LD/DS LAB					
THU							
FRI				ADE			
SAT			ADE				

HOD/CSE

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To access the VTU Scheme and Syllabus of CBCS 15Scheme, kindly follow this below link.

15 Scheme VTU Scheme and Syllabus

https://drive.google.com/file/d/1jAoQEMzAuPNsglKoYMljR9dRKrg2h6y0/view?usp=sharing

To access the VTU Scheme and Syllabus of CBCS 15Scheme, kindly follow this below link.

15 Scheme VTU Scheme and Syllabus

https://drive.google.com/file/d/1jAoQEMzAuPNsglKoYMljR9dRKrg2h6y0/view?usp=sharing

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Lesson Plan

Date: 28/07/2016

Subject code : 15CS32
Subject Title : ANALOG AND DIGITAL ELECTRONICS
Course / Branch : COMPUTER SCIENCE and ENGINEERING
Semester : 3 SEM
Academic Year : 2016-2017
Objective of Course: To learn the analog and digital system concept
PREREQUISITE: Should have knowledge about Basic electronics and digital system

Module	Topic No.	Topic	Books Referred & Pages
1	1	**Module 1: Field Effect Transistors:** Junction field transistors, MOSFETs, Differences Between JFETs and MOSFETs	T1 165
	2	Biasing MOSFETs, FET Applications, CMOS Devices	T1 192
	3	Wave shaping Circuits: integrated circuit, multivibrators.	T1 503
	4	Introduction to operational Amplifier: ideal v/s practical opamp, performance parameters	T1 627
	5	operational amplifier application circuits: peak detector circuit	T1 671
	6	comparator, Active filters, nonlinear amplifier	T1 672
	7	Relaxation oscillator, current to voltage converter, voltage to current converter.	T1 690
2	8	The basic gates: Review of basic logic gates, positive and negative logic, Introduction to HDL.	T2 41
	9	Combinational logic circuit: Sum of product method, Truth table to karnaugh map, pairs, Quads and Octets.	T2 77
	10	Karnaugh simplification, Don't care conditions, Product of sum method, Product of Sum simplification,	T2 92
	11	Simplification by Quine Mc-clusky method	T2107
	12	Hazards and Hazard covers	T2 110
	13	HDL implementation models.	T2 113
3	15	Data processing circuits: Multiplexers, Demultiplexers, 1 of 16 decoder	T2 123
	16	BCD to decimal decoders, & segment decoders. Encoders, Exclusive OR gates.	T2 138
	17	Parity generators and checkers, Magnitude comparator.	T2 149
	18	Programmable array logic, Programmable Logic array.	T2 159
	19	HDL implementation of data processing circuit. Arithmetic building blocks.	T2 156
	20	Arithmetic logic unit, Flipflops: RS flip flops, Gated flip flops, Edge triggered RS flip flop.	T2 239
	21	Edge triggered D and JK flip flops.	T2 285
4	22	Flip Flops: Flip flop timing, JK master slave flip flop,	T2 288
	23	switch contact bounce circuits, Various representation of flip flops,	T2 291
	24	HDL implementation of flip flop.	T2 301
	25	Registers: Types of registers, Serial in serial out, Serial in parallel out, parallel in serial out, parallel in parallel out, Universal shift register, Application of shift register	T2 310

	26	Register implementation of HDL, Counter: Asynchronous counters,	T2 333
	27	Decoding gates, synchronous counters,	T2 345
	28	Changing the counter modules.	T2 356
5	29	Counters: Decade counters, Pre settable counters, counter design as a synthesis problem.	T2 363
	30	A digital clock, Counter design using HDL, D/A conversion and A/D Conversion,	T2 381
	31	Variable register networks, Binary ladders, D/A converters, D/A Accuracy and resolution,	T2 431
	32	A/D converter- simultaneous conversion, A/D converter	T2 448
	33	Counter method, continuous A/D conversion, A/D techniques,	T2 455
	34	Dual slope A/D conversion, A/D accuracy and resolution.	T2 461

Self-study Topics (Not included in Syllabus)

Sl. No.	Self –study Topics	Suggested Reference
1.	Changing the counter modules above 16	T1
2.	Counter design using HDL design and implementation	T2

Assignment Topics

Sl. No.	Assignment Topics	Submission due on
1.	Simplification by Quine Mc-cluskymethod	1/9/16
2.	Counter and D/A conversion and A/D Conversion,	9/10/16

Student Feedback about the course from Last Year:

1. Need more Example problems on K-Map and Counter design.

Action Plan proposed to accommodate the Feedback:

1. Conducting extra class, unit-wise class test after each unit completion and_incorporating more example programs.

Faculty

HOD

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DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING
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BENGALURU - 560 068

CBCS Scheme

USN ☐☐☐☐☐☐☐☐☐☐ 15CS32

Third Semester B.E. Degree Examination, Dec.2016/Jan.2017
Analog and Digital Electronics

Time: 3 hrs. Max. Marks: 80

Note: ***Answer FIVE full questions, choosing one full question from each module.***

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

Module-1

1 a. Explain the working of N – channel DE – MOSFET, with the help of neat diagram. **(08 Marks)**
b. With circuit diagram, explain any two application of FET. **(06 Marks)**
c. How CMOS can be used as inverting switch? **(02 Marks)**

OR

2 a. Design a voltage divider bias network using a DEMOSFET with supply voltage $V_{DD} = 16V$, $I_{DSS} = 10mA$ and $V_P = 5V$ to have a quiescent drain current of 5mA and gate voltage of 4V. (Assume the drain resistor R_D to be four times the source resistor R_S and $R_2 = 1k\Omega$). **(08 Marks)**
b. Explain the performance parameters of Op-amp. **(08 Marks)**

Module-2

3 a. Minimize the following Boolean function using K – map method
$f(a, b, c, d) = \Sigma m\ (5, 6, 7, 12, 13) + \Sigma d\ (4, 9, 14, 15)$. **(06 Marks)**
b. Apply Quine Mc – Clusky method to find the essential prime implicants for the Boolean expression $f(a, b, c, d) = \Sigma m\ (1, 3, 6, 7, 9, 10, 12, 13, 14, 15)$. **(10 Marks)**

OR

4 a. A digital system is to be designed in which the month of the year is given as input is four bit form. The month January is represented as '0000', February as '0001' and so on. The output of the system should be '1' corresponding to the input of the month containing 31 days or otherwise it is '0'. Consider the excess number in the input beyond '1011' as don't care conditions for the system of four variables. (ABCD) find the following :
i) Write truth table and Boolean expression in SOP Σm and POS ΠM form.
ii) Using K – map simplify the Boolean expression of canonical mini term form.
iii) Using Basic gates implement logical circuit. **(10 Marks)**
b. What is Hazard? List the type of hazards and explain static 0 and static – 1 hazard. **(06 Marks)**

Module-3

5 a. Implement the following function using 8:1 multiplexer $f(a, b, c, d) = \Sigma m\ (0, 1, 5, 6, 8, 10, 12, 15)$. **(06 Marks)**
b. Realize the following function using 3:8 decoder
i) $f(a, b, c) = \Sigma m\ (1, 2, 3, 4)$ ii) $f(a, b, c) = \Sigma m(3, 5, 7)$. **(04 Marks)**
c. What is Magnitude Comparator? Explain 1 bit magnitude comparator. **(06 Marks)**

OR

6 a. Design 7 – segment decoder using PLA. **(08 Marks)**
b. Differentiate between Combinational and Sequential circuit. **(04 Marks)**

c. Write VHDL code for given circuit. **(04 Marks)**

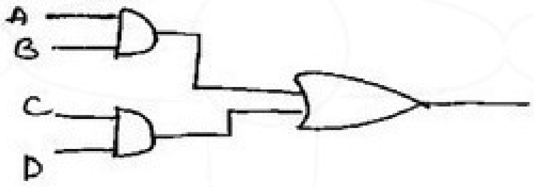

Fig.Q6(c)

Module-4

7 a. What is Race around condition? With block diagram and truth table, explain the working of JK master – slave flip – flop. **(10 Marks)**

b. Give State transition diagram and characteristics equation for JK and SR Flip Flop. **(06 Marks)**

OR

8 a. With neat diagram, explain Ring counter. **(04 Marks)**

b. What is Shift Register? With neat diagram, explain 4 bit parallel in serial out shift resisters. **(08 Marks)**

c. Compare Synchronous and Asynchronous counter. **(04 Marks)**

Module-5

9 a. Define Counter. Design A synchronous counter for the sequence 0 → 4→1→ 2→ 6 → 0→4 using JK Flip – Flop. **(12 Marks)**

b. Explain Digital clock, with neat diagram. **(04 Marks)**

OR

10 a. Explain the Binary ladder with Digital input of 1000. **(06 Marks)**

b. Explain 2 bit simultaneous A/D converter. **(10 Marks)**

* * * * *

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Academic Semester: Aug 2016 to Nov 2016

Subject: Analog and Digital Electronics   Sub Code: 15CS32

DIRECT ATTAINMENT

CO Attainment

CO	IA Attainment %	IA Attainment	Ext Attainment	Final Co Attainment
C202.1	80.39	3	1	1.8
C202.2	77.57	3	1	1.8
C202.3	79.23	3	1	1.8
C202.4	65	2	1	1.4
C202.5	53.77	1	1	1

PO Attainment

CO/PO	CO Attainment	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
C202.1	1.8	2	3	3	2	1	1	1	1	1	1	1	1
C202.2	1.8	2	3	3	2	1	1	1	1	1	1	1	1
C202.3	1.8	2	3	3	2	1	1	1	1	1	1	1	1
C202.4	1.4	2	3	3	3	1	1	1	1	1	1	1	1
C202.5	1	2	3	3	3	1	1	1	1	1	1	1	1
PO Attainment		1.4	1.4	1.4	1.37	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4

PSO Attainment

CO/PO	CO Attainment	PSO1	PSO2
C202.1	1.8	2	2
C202.2	1.8	1	1
C202.3	1.8	1	1
C202.4	1.4	2	2
C202.5	1	2	2
PSO Attainment		1.32	1.32

Faculty Sign

HOD, CSE

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CHILDREN'S EDUCATION SOCIETY (Regd.)
THE OXFORD COLLEGE OF ENGINEERING
DEPARTMENT OF INFORMATION SCIENCE AND ENGINEERING
(Recognized by the Govt. of Karnataka, Affiliated to Visvesvaraya Technological University, Belagavi. Approved by A.I.C.T.E. New Delhi. Recognized by UGC Under Section 2(f))
Bommanahalli, Hosur Road, Bangalore - 560 068. Ph: 080-61754601/602, Fax: 080 - 25730551
E-mail: engprincipal@theoxford.edu Web: www.theoxfordengg.org

Course File
2017-2018

1. **Vision & Mission (Institution)**

VISION

With a vision to be a respected and sought after group of educational institutions, we are very much engaged in equipping individuals to be capable of building learning organization in the new millennium

MISSION

Our mission is to develop competent students with good value systems to face challenges of the continuously changing world.

2. **Vision & Mission (Department Level)**

VISION

To meet the educational, research & service needs of the region through collaboration with academic, technical institutions, businesses, government agencies & cultural organizations, thereby, providing a platform that encourages students & faculty to continue their intellectual & professional growth.

MISSION

To develop the best Information Science Professionals, who work creatively, communicate effectively & become technologically competent and also to mould them into good citizens by inculcating sense of ethical values in them.

3. **Course Outcome (Computer Network -15CS52)**
   - Explain principles of application layer protocols
   - Recognize transport layer services and infer UDP and TCP protocols
   - Classify routers, IP and Routing Algorithms in network layer
   - Understand the Wireless Networks covering IEEE 802.11 Standard
   - Understand the Mobile Networks covering IEEE Standard
   - Describe Multimedia Networking and Network Management
4. **Program Outcome**
   1. **Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
   2. **Problem analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
   3. **Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
   4. **Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
   5. **Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
   6. **The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
   7. **Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
   8. **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

9. **Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. **Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11. **Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12. **Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

5. Program Specific Outcome

1. Provide effective and efficient real time solutions with the application of knowledge in IT, ITES, Networking and Software domains.
2. Demonstrate the ability to work in a team, with professional ethics, good communication and documentation skills in designing, implementation and management of software products and services, at optimal cost.
3. Proven capability to exchange views/concepts, incubate ideas and to carryout lifelong learning with zeal, to be aware of the state of art technologies and their development.

6. CO-POMapping with CO Statement

CO/PO	CO Attainment	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
C355.1	**1**	2	2	2									
C355.2	**1**	2	2	2									
C355.3	**1.4**	3			3	3							3
C355.4	**1.4**	3			3	3							3
C355.5	**1**				3	3		3			3		3
C355.6	**1.4**				3	3		3			3		3
	PO Attainement	**1.24**	**1**	**1**	**1.3**	**1.3**		**1.2**			**1.2**		**1.3**

CO/PO	CO Attainment	PSO1	PSO2	PSO3
C355.1	**1**	2	1	2
C355.2	**1**	1	2	2
C355.3	**1.4**	2		
C355.4	**1.4**	1	2	1
C355.5	**1**	1		1
C355.6	**1.4**	1	2	1
	PSO Attainement	**1.2**	**1.23**	**1.11**

Course name:Computer Network **Course Code 15CS52**

C355.1	An ability to understand the Principles of application layer protocols.RBT:1,2
C355.2	An ability to recognize transport layer services and infer UDP and TCP protocolsRBT:2
C355.3	An ability to classify routers,IP and routing algorithms in network layer RBT:2
C355.4	An ability to understand the wirelss networks covering IEEE802.11 standards.RBT:1,2
C355.5	An ability to identify , analyze and solve multimedia network and Network management. RBT:5

7. Department Time Table/Individual Time Table

The Oxford College of Engineering					
Department of Information Science & Engineering					
		ACADEMIC YEAR 2017-2018 ODD SEMESTER[AUG-JAN]			
COURSE:B.E			V SEMESTER/SECTION: B		ROOM NO:N 419

CLASS TEACHER:Ms.Kokila/Ms.Keerthi

TIMETABLE w.e.f:07-08-2017

Day / Time	9.00-9.55	9.55-10.50	10.50-11.00	11.00-11.55	11.55-12.50	12.50-1.30	1.30-2.25	2.25-3.20	3.20-4.15
Mon	C#	AT	**SHORT BREAK**	JAVA	DBMS(T)	**LUNCH BREAK**	C#(T)	CN(T)	AT(T)
Tue	DBMS	AT		CN	JAVA		EPM	DBMS	MINI PROJECT
Wed	EPM	CN		DBMS	CN		DBMS LAB(B1) / CN LAB(B2)		
Thu	C#	EPM		DBMS	JAVA		CN	EPM	MINI PROJECT
Fri	JAVA	AT		C#	EPM(T)		C#	JAVA(T)	MINI PROJECT
Sat	AT	DBMS LAB(B2) / CN LAB(B1)							

Sub Code	**Subject**	**Faculty**
15CS51	Management and Entreprenurship (EPM)	Ms.Keerthi
15CS52	Computer Networks (CN)	MS.Kokila
15CS53	Database Management System (DBMS)	Ms.Suganya
15CS54	Automata Theory & Computational Intelligence (AT)	Ms.Amaresha
15CS553	Advanced JAVA and J2EE (JAVA)	Mr.Nalinakshi
15CS564	Dot Net framework for application development(C#)	Mr.Channappa gowda
15CSL57	Database Applications Laboratory (DBMS LAB)	B1:Ms.Suganya & Ms.Sindhuja B2:Ms.Suganya & Ms.Nalinakshi
15CSL58	Computer Networks Laboratory (CN LAB)	B1:Ms.Kokila & Mr.YadhuKrishna B2:Ms.Kokila & Mr.Karthik
	Miniproject	Ms.Keerthi/Mr.Vinodha/Ms.Kokila

TT INCHARGE	CHIEF TT COORDINATOR	HOD-ISE	PRINCIPAL

Faculty name: Ms. P KOKILA

	I HR.	II HR.	III HR.	IV HR.	V HR.	VI HR.	VII HR.
MON			DM			CN (T)	
TUE	DM		CN		ADE LAB(3A - B2)		
WED		CN		CN	CN LAB(5B - B2)		
THU					CN		DM(T)
FRI	DM				DM		MINI PROJ(5B)
SAT		CN LAB(5B - B1)					

8. **Syllabus and Schemes**
   https://drive.google.com/file/d/1f7ISctG_jicIQg4W6ArF8hxQ51AvAZns/view?usp=sharing
9. **Lesson Plan**

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Lesson Plan **Date: 19/08/2017**

Subject code /Title : **15CS52 / COMPUTER NETWORKS**
Course / Branch : **B.E / ISE**
Semester / Academic Year : **V - B / 2017 – 2018 (ODD)**
Faculty Name : **P KOKILA**

COURSE OBJECTIVES

This course will enable students to

1. Demonstration of application layer protocols
2. Discuss transport layer services and understand UDP and TCP protocols
3. Explain routers, IP and Routing Algorithms in network layer
4. Disseminate the Wireless and Mobile Networks covering IEEE 802.11 Standard
5. Illustrate concepts of Multimedia Networking, Security and Network Management

COURSE OUTCOMES

The students should be able to:

1. Explain principles of application layer protocols
2. Recognize transport layer services and infer UDP and TCP protocols
3. Classify routers, IP and Routing Algorithms in network layer
4. Understand the Wireless Networks covering IEEE 802.11 Standard
5. Understand the Mobile Networks covering IEEE Standard
6. Describe Multimedia Networking and Network Management

Prerequisites: Data communication

Module/ Unit	**Topic No.**	**Date**	**Topic**	**Books Referred &**
I	1	7/8/17	Module:1-Application Layer: Principles of Network Applications, Network Application Architectures	**Text book1: 83 - 183**
	2	8/8/17	Processes Communicating, Transport Services Available to Applications, Transport Services Provided by the Internet	
	3	9/8/17	Application-Layer Protocols, The Web and HTTP: Overview of HTTP, Non-persistent and Persistent Connections,	
	4	10/8/17	HTTP Message Format, User-Server Interaction: Cookies, Web Caching, The Conditional GET	
	5	14/8/17	File Transfer: FTP Commands & Replies, Electronic Mail in the Internet: SMTP, Comparison with HTTP	
	6	16/8/17	Mail Message Format, Mail Access Protocols, DNS, Mail Message Format, Mail Access Protocols, DNS	
	7	17/8/17	The Internet's Directory Service: Services Provided by DNS, Overview of How DNS Works	

	8	21/8/17	DNS Records and Messages, Peer-to-Peer Applications: P2P File Distribution	
	9	22/8/17	Distributed Hash Tables, Socket Programming: creating Network Applications	
	10	23/8/17	Socket Programming with UDP, Socket Programming with TCP.	
II	11	24/8/17	**Module-2: Transport Layer :** Introduction and Transport-Layer Services: Relationship between Transport and Network Layers, Overview of the Transport Layer in the Internet	**Text book 1: 185 - 279**
	12	26/8/17	Multiplexing and Demultiplexing: Connectionless Transport: UDP,UDP Segment Structure, UDP Checksum	
	13	28/8/17	Principles of Reliable Data Transfer: Building a Reliable Data Transfer Protocol, Pipelined Reliable Data Transfer Protocols,	
	14	29/8/17	Go-Back-N, Selective repeat	
	15	20/8/17	Connection-Oriented Transport TCP: The TCP Connection, TCP Segment Structure	
	16	31/8/17	Round-Trip Time Estimation and Timeout, Reliable Data Transfer	
	17	3/9/17	Flow Control, TCP Connection Management	
	18	4/9/17	Principles of Congestion Control: The Causes and the Costs of Congestion, Approaches to Congestion Control	
	19	5/9/17	Network-assisted congestion-control example, ATM ABR Congestion control	
	20	6/19/17	TCP Congestion Control: Fairness.	
III	21	7/9/17	**Module-3: The Network layer:** What's Inside a Router?	**Text book 1: 320 - 405**
	22	10/9/17	Input Processing: The Distance-Vector (DV) Routing Algorithm, Hierarchical Routing, Switching	
	23	11/9/17	Output Processing, Where Does Queuing Occur? Routing control plane	
	24	12/9/17	IPv6, A Brief foray into IP Security, Algorithm,	
	25	13/9/17	Routing Algorithms: The Link-State (LS) Routing	
	26	14/9/17	Routing in the Internet	
	27	17/9/17	Intra-AS Routing in the Internet: RIP	
	28	18/9/17	Intra-AS Routing in the Internet: OSPF,	
	29	20/9/17	Inter/AS Routing: BGP	
	30	21/9/17	Broadcast and Multicast Routing: Broadcast Routing Algorithms and Multicast	
IV	31	22/9/17	**Module-4: Mobile and Multimedia Networks:** Cellular Internet Access: An Overview of Cellular Network Architecture	**Text book 1: 546 - 572**

	32	25/9/17	3G Cellular Data Networks: Extending the Internet to Cellular subscribers	
	33	26/9/17	On to 4G:LTE	
	34	27/9/17	Mobility management: Principles Addressing,	
	35	28/9/17	Routing to a mobile node	
	36	30/9/17	Mobile IP	
	37	1/10/17	Managing mobility in cellular	
	38	3/10/17	Routing calls to a Mobile user	
	39	4/10/17	Handoffs in GSM	
	40	5/10/17	Wireless and Mobility: Impact on Higher-layer protocols.	
V	41	7/10/17	**Module-5: Multimedia Networking Applications:** Properties of video, properties of Audio, Per-connection Quality-of Service (QoS)	**Text book 1: 588 – 608 632 – 652**
	42	8/10/17	Types of multimedia Network Applications	
	43	9/10/17	Streaming stored video: UDP Streaming, HTTP Streaming	
	44	10/10/17	Adaptive streaming and DASH	
	45	11/10/17	Content distribution Networks	
	46	12/10/17	case studies: Netflix, You Tube and Kankan	
	47	16/10/17	case studies: You Tube and Kankan	
	48	17/10/17	Network Support for Multimedia : Dimensioning Best-Effort Networks	
	49	19/10/17	Providing Multiple Classes of Service, Diffserv	
	50	2/11/17	Guarantees: Resource Reservation and Call Admission.	
	51	9/11/17	Revision 1,2,3	
	52	15/11/17	Revision 4, 5	

Self-study Topics (Not included in Syllabus)

Sl. No.	Self –study Topics	Suggested Reference
1	Types of Multiplexing and Demultiplexing methods	R1
2	Noisy and Noiseless Channel	R1

Assignment Topics

Sl. No.	Assignment Topics	Submission due on
1	P2P File Distribution, UDP Segment Structure	
2	Hierarchical Routing, Broadcast Routing Algorithms and Multicast	
3	On to 4G:LTE, Mobile IP, Adaptive streaming	

Quiz

Sl. No.	Quiz	Scheduled date
1	Module 1 ,2	

2	Module 3,4	
3	Module 5	

Text Books:

1. James F Kurose and Keith W Ross, Computer Networking, A Top-Down Approach, Sixth edition, Pearson, 2017.

Reference Book:

1. Behrouz A Forouzan, Data and Communications and Networking, Fifth Edition, McGraw Hill, Indian Edition
2. Larry L Peterson and Brusce S Davie, Computer Networks, fifth edition, ELSEVIER
3. Andrew S Tanenbaum, Computer Networks, fifth edition, Pearson
4. Mayank Dave, Computer Networks, Second edition, Cengage Learning

Faculty HOD

10. **Regulation Link**
    https://drive.google.com/file/d/1hzpLVj86EA2dVVpedxrRDoBW5mpI3Wzf/view?usp=sharing
11. **Model QP(VTU-QP)**
    https://drive.google.com/drive/folders/1_f9m08NJ15Zpa84Dz8lmBHVF4biXFTZD?usp=sharing
12. **CO Attainment(IA,External)**

CO	**IA Attainmet %**	**IA Attainment**	**Ext Attainment**	**Final Co Attainment**
C355.1	65	1	1	1
C355.2	46	1	1	1
C355.3	84	2	1	1.4
C355.4	82	2	1	1.4
C355.5	77	1	1	1
C355.6	87	2	1	1.4

Children's Education Society ®
THE OXFORD COLLEGE OF ENGINEERING
DEPARTMENT OF CIVIL ENGINEERING
Hosur Road, Bommanahalli, Bengaluru-560 068
080-30219601/02, Fax : 080-25730551,30219629,
Website:www.theoxford.edu Email : theoxfordcivil@gmail.com
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VISION OF THE INSTITUTE

To be a respected and most sought after engineering educational institution engaged in equipping individuals capable of building institutions of higher learning in the current millennium.

MISSION OF THE INSTITUTE

To develop competent students with good value systems and face challenges of the continuously changing world.

VISION OF THE DEPARTMENT

To impart very high quality education to the students to make them do innovative sustainable engineering relevant to industry and people at large.

MISSION OF THE DEPARTMENT

M1: To emphasize on basics of engineering as well as their applications relevant to the industry.

M2: To serve the society with due consideration of economy, ecology and ethical issues of nation.

M3: To sensitize the students and faculty to take up research and consultancy to be on par with international standards.

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PROGRAM EDUCATIONAL OBJECTIVES

After the graduation the graduates are able to

PEO1: Apply fundamental concepts of civil engineering in developing economically viable and sustainable sound solutions.

PEO2: To work collaboratively on multidisciplinary problems.

PEO3: To achieve their professional aims keeping good ethics.

PROGRAM SPECIFIC OUTCOMES

Graduates will be able

PSO1: To apply technical skills and modern engineering tools for civil engineering day to day practice.

PSO2: To participate in critical thinking and problem solving of civil engineering field that needs analytical and design requirements.

PSO3: To pursue lifelong learning and professional development to face the challenging and emerging needs of our society.

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PROGRAM OUTCOMES

Engineering Graduates will be able to:

1. **Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. **Problem analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. **Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. **Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
6. **The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7. **Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. **Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. **Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11. **Project management and finance:** To demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and also as a leader in a team, to manage projects in multidisciplinary environments.
12. **Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broad context of technological change.

CHILDREN'S EDUCATION SOCIETY (REGD.)
Administrative Office:
1st Phase JP Nagar, Bengaluru – 560 078
☎: 080-3041 0501 – 502 Fax: 080-2654 8658

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Bommanahalli, Hosur Road, Bengaluru –560068.
☎: 080-30219601/602/604/736, Fax 080 – 25730551/ 30219629 E-mail engprincipal@theoxford.edu Web www.theoxford.edu

TENTATIVE CALENDAR OF EVENTS FOR ODD SEMESTERS – 2018 - 19

Week No.	Month	Day						No. of working days	Activities
		Mon	Tue	Wed	Thu	Fri	Sat		
1	Aug		-	01 FWD	02	03	04	4	1st – First Working Day
2	Aug	06	07	08	09	10	11	6	
3	Aug	13	14	15 (H)	16	17	18	5	15th – Independence Day
4	Aug	20	21	22 (H)	23	24	25	5	22nd – Bakrid
5	Aug/Sep	27	28	29	30 T	31	1	6	
6	Sep	03 (T1)	04 (T1)	05 (T1)	06	07	08 (PTM)	6	03, 04 & 05th – First Internal Assessment
7	Sep	10	11	12	13 (H)	14	15	5	13th – Varasiddhi Vinayaka Vrata
8	Sep	17	18	19	20	21 (H)	22	5	21st - Last day of Moharam
9	Sep	24	25	26	27	28	29	6	
10	Oct	01	02 (H)	03	04 T	05	06	5	2nd – Gandhi Jayanthi
11	Oct	08 (H)	09	10	11	12	13	5	08th – Mahalaya Amavasye
12	Oct	15 (T2)	16 (T2)	17 (T2)	18 (H)	19 (H)	20 (PTM)	4	15th, 16th & 17th – Second Internal Assessment 18th – Maha Navami Ayudapooja 19th - Vijayadasami
13	Oct	22	23	24 (H)	25	26	27	5	24th – Maharshi Valmiki Jayanthi
14	Oct /Nov	29	30	31	01 (H)	02	03	5	1st – Kannada Rajyothsava
15	Nov	05	06 (H)	07	08 (H) T	09	10	4	06th – Naraka Chaturdashi 08th – Balipadyami Deepavali
16	Nov	12 (T3)	13 (T3)	14 (T3)	15	16	17 (PTM)	6	12, 13 &14 – Third Internal Assessment
17	Nov	19	20 (LWD)	-	-	-	-	-	- ---------

Dr. R V Praveena Gowda
Principal, TOCE

Dr. R V Praveena Gowda
Principal
The Oxford College of Engineering
Bommanahalli, Hosur Road

Academic Year Aug 2019-Nov 2019 (Odd Sem)

W.E.F : 29/07/2019

COURSE: B.E

CLASS TEACHER: Ms. Kavya S K (KSK) / Mrs. Akshatha K B(AKB)

SEM: V CV 'A'
ROOM NO: N210

DAY/ TIME	9.00 to 9.55	9.55 to 10.50		11.00 to 11.55	11.55 to 12.50		1.30 to 2.25	2.25 to 3.20	3.20 to 4.15
MON	TE(KM)	AGT(PTS)	SHORT BREAK	RCC(AM)	RCC(AM)	LUNCH BREAK	GT LAB A1 (MKS+PN) C & HM LAB A2 (KM+PHV)		
TUE	AIS(SJ)	AIS(SJ)		CAD(AKR+SNK)					
WED	RCC(AM)	AGT(PTS)		TE(KM)	RCC(AM)		AGT(PTS)		
THU	APC(KSK)	GT LAB-1 C&HM LAB		GT LAB A1 (MKS+PN) C & HM LAB A2 (KM+PHV)			TE(KM)	APC(KSK)	
FRI	CAD(AKR+SNK)			APC(KSK)	AIS(SJ)				
SAT	AGT(PTS)	AIS(SJ)		TE(KM)	APC(KSK)				

SUB CODE	SUBJECT	FACULTY
17CV51	Design Of Rc Structural Elements	Ms. Amrutha M (AM)
17CV52	Analysis Of Indeterminate Structures	Ms. Shradha J (SJ)
17CV53	Applied Geotechnical Engineering	Mr. Prashanth Hathwar T S (PTS)
17CV54	Computer Aided Building Planning & Drawing	Mrs. Akshatha K R(AKR) / Mrs. Sunanda Nanda Kumar (SNK)
17CV551	Air Pollution And Control	Ms. Kavya S K (KSK)
17CV561	Traffic Engineering	Ms. Krithika M (KM)
17CVL57	Geotechnical Engineering Laboratory	Mr. Mahesh Kumar S(MKS) / Mr. Prakash N (PN)
17CVL58	Concrete And Highway Materials Laboratory	Ms. Krithika M(KM) / Ms. Premanjali H V(PHV

TIMETABLE INCHARGE

HOD

Head of the Department
Department of Civil Engineering
The Oxford College of Engineer
Bangal

CHIEF TIMETABLE COORDINATOR

HOD of E&C Engineering
The Oxford College of Engineering
Bommanahalli, Bangalo

PRINCIPAL

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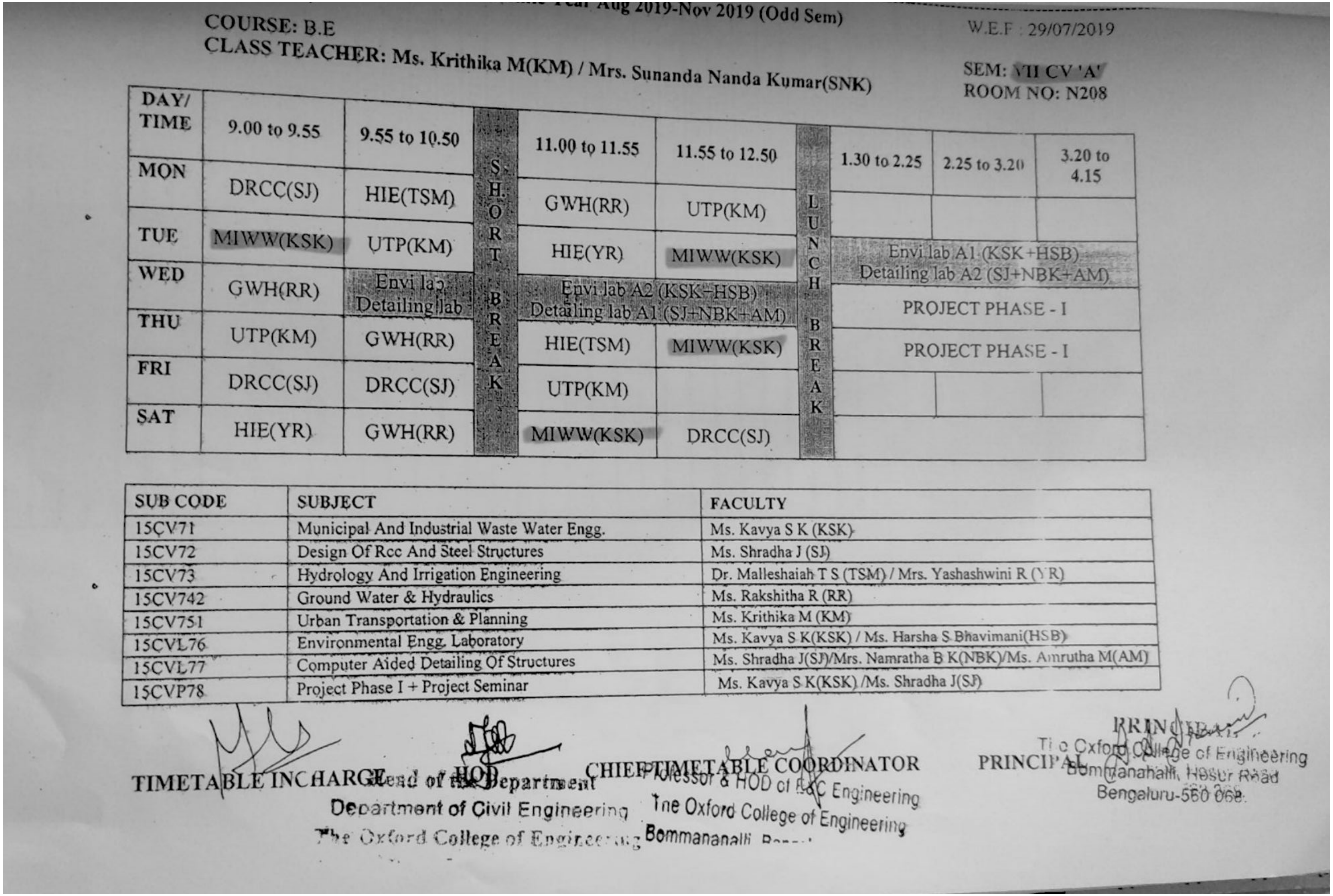
The Oxford College of Engineering
Bommanahalli, Hosur Road
Bengaluru-560 068



Aug 2019-Nov 2019 (Odd Sem)

COURSE: B.E
W.E.F : 29/07/2019

CLASS TEACHER: Ms. Krithika M(KM) / Mrs. Sunanda Nanda Kumar(SNK)

SEM: VII CV 'A'
ROOM NO: N208

DAY/ TIME	9.00 to 9.55	9.55 to 10.50		11.00 to 11.55	11.55 to 12.50		1.30 to 2.25	2.25 to 3.20	3.20 to 4.15
MON	DRCC(SJ)	HIE(TSM)	SHORT BREAK	GWH(RR)	UTP(KM)	LUNCH BREAK			
TUE	MIWW(KSK)	UTP(KM)		HIE(YR)	MIWW(KSK)		Envi lab A1 (KSK+HSB) Detailing lab A2 (SJ+NBK+AM)		
WED	GWH(RR)	Envi lab Detailing lab		Envi lab A2 (KSK+HSB) Detailing lab A1 (SJ+NBK+AM)			PROJECT PHASE - I		
THU	UTP(KM)	GWH(RR)		HIE(TSM)	MIWW(KSK)		PROJECT PHASE - I		
FRI	DRCC(SJ)	DRCC(SJ)		UTP(KM)					
SAT	HIE(YR)	GWH(RR)		MIWW(KSK)	DRCC(SJ)				

SUB CODE	SUBJECT	FACULTY
15CV71	Municipal And Industrial Waste Water Engg.	Ms. Kavya S K (KSK)
15CV72	Design Of Rcc And Steel Structures	Ms. Shradha J (SJ)
15CV73	Hydrology And Irrigation Engineering	Dr. Malleshaiah T S (TSM) / Mrs. Yashashwini R (YR)
15CV742	Ground Water & Hydraulics	Ms. Rakshitha R (RR)
15CV751	Urban Transportation & Planning	Ms. Krithika M (KM)
15CVL76	Environmental Engg. Laboratory	Ms. Kavya S K(KSK) / Ms. Harsha S Bhavimani(HSB)
15CVL77	Computer Aided Detailing Of Structures	Ms. Shradha J(SJ)/Mrs. Namratha B K(NBK)/Ms. Amrutha M(AM)
15CVP78	Project Phase I + Project Seminar	Ms. Kavya S K(KSK) /Ms. Shradha J(SJ)

TIMETABLE INCHARGE

HOD
Head of the Department
Department of Civil Engineering
The Oxford College of Engineering

CHIEF TIMETABLE COORDINATOR
Professor & HOD of E&C Engineering
The Oxford College of Engineering
Bommanahalli

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THE OXFORD COLLEGE OF ENGINEERING
HOSUR ROAD , BOMMANHALLI, BANGLORE
ENTOR LIST - ACADEMIC YEAR 2019-20
BRANCH : CIVIL ENGG.
SEMESTER : VII Sem SECTION A

Student List 7 'A'

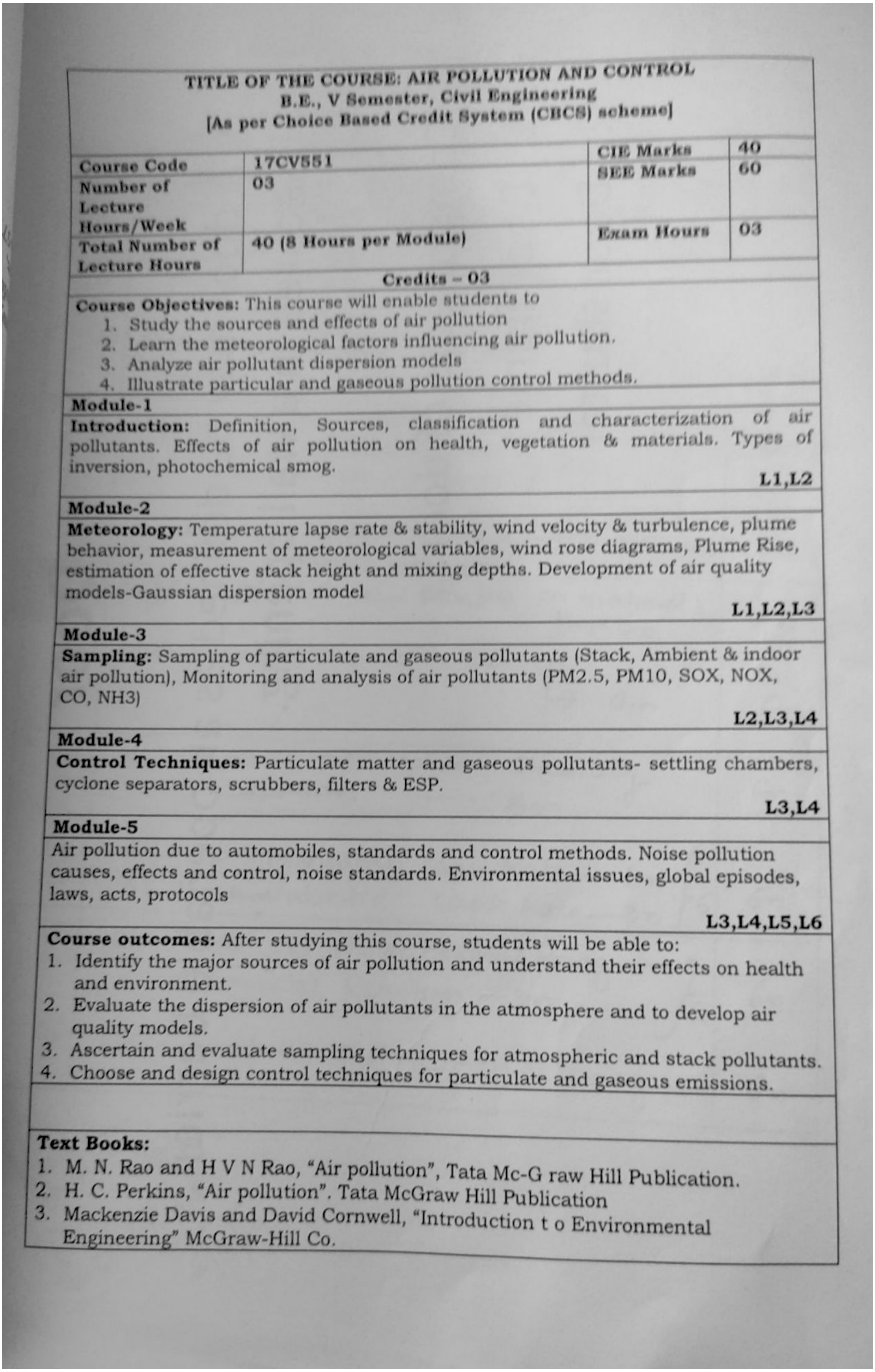
Sl. No.	USN	NAME
1	1OX16CV001	ABHISHEK
2	1OX16CV002	ABHISHEK NANDAKUMAR
3	1OX16CV004	ABRAR AHMAD NATH
4	1OX16CV006	AKASH SONAR
5	1OX16CV008	AMAL ANIYAN KUNJU
6	1OX16CV009	AMARANATHA REDDY R
7	1OX16CV010	AMRUTHA H L
8	1OX16CV011	ANILKUMAR
9	1OX16CV012	ANITHA V R
10	1OX16CV013	ANUGRAHA K
11	1OX16CV014	APOORVA PATIL G M
12	1OX16CV015	ASHWINI R
13	1OX16CV019	CHARAN K
14	1OX16CV020	CHETHANA H S
15	1OX16CV021	DARSHAN JAIN C B
16	1OX16CV022	DARSHAN N
17	1OX16CV024	DEEKSHITH K M
18	1OX16CV025	DIVYASREE C
19	1OX16CV026	G NANDA KUMAR
20	1OX16CV027	GEETA SULIKERI
21	1OX16CV029	GOVINDRAJ M
22	1OX16CV030	GOWTHAM S
23	1OX16CV031	HARISH CHANDRA
24	1OX16CV032	HARSHITHA C V
25	1OX16CV033	IMTIPONG IMSONG
26	1OX16CV034	ISHFAQ MANZOOR RATHER
27	1OX16CV037	KARTHIK
28	1OX16CV038	KARTHIK R
29	1OX16CV040	LIGITH P
30	1OX16CV042	MADHAN KUMAR M
31	1OX16CV415	RAKESH L KAMMAR
32	1OX17CV400	ABDUL RAHMAN SHOAIB
33	1OX17CV401	ABHILASH H
34	1OX17CV402	ADDAGALA ROHITH
35	1OX17CV403	AMRUTHA D H
36	1OX17CV406	BALAJI DS
37	1OX17CV407	CHAITHRA M V
38	1OX17CV408	DEEPAK S N
39	1OX17CV409	GURUDATTA TL
40	1OX17CV410	GURUPRASAD T
41	1OX17CV411	HEMANTH HM
42	1OX17CV413	KESHAPPA P RATHOD
43	1OX17CV414	KHUSHBOO A

44	1OX17CV415	LAMBANI KIRTI RAMCHANDRA
45	1OX17CV417	MOHAMMED ZEESHAN
46	1OX17CV418	MOULAHUSSAIN
47	1OX17CV419	NAVEEN B
48	1OX17CV420	NAVEENKUMAR GOTUR
49	1OX17CV422	NISHANTH V
50	1OX17CV423	PRADEEP BS
51	1OX17CV425	PRUTHVI D JAIN
52	1OX17CV426	RACHAYYA HIREMATH
53	1OX17CV427	RANJITH KUMAR M
54	1OX17CV428	RATISH GOWDA AS
55	1OX17CV429	ROHITH M

HOD

Air pollution and Control

(17CV551)



TITLE OF THE COURSE: AIR POLLUTION AND CONTROL
B.E., V Semester, Civil Engineering
[As per Choice Based Credit System (CBCS) scheme]

Course Code	17CV551	**CIE Marks**	40
Number of Lecture Hours/Week	03	**SEE Marks**	60
Total Number of Lecture Hours	40 (8 Hours per Module)	**Exam Hours**	03

Credits – 03

Course Objectives: This course will enable students to
1. Study the sources and effects of air pollution
2. Learn the meteorological factors influencing air pollution.
3. Analyze air pollutant dispersion models
4. Illustrate particular and gaseous pollution control methods.

Module-1

Introduction: Definition, Sources, classification and characterization of air pollutants. Effects of air pollution on health, vegetation & materials. Types of inversion, photochemical smog.

L1,L2

Module-2

Meteorology: Temperature lapse rate & stability, wind velocity & turbulence, plume behavior, measurement of meteorological variables, wind rose diagrams, Plume Rise, estimation of effective stack height and mixing depths. Development of air quality models-Gaussian dispersion model

L1,L2,L3

Module-3

Sampling: Sampling of particulate and gaseous pollutants (Stack, Ambient & indoor air pollution), Monitoring and analysis of air pollutants (PM2.5, PM10, SOX, NOX, CO, NH3)

L2,L3,L4

Module-4

Control Techniques: Particulate matter and gaseous pollutants- settling chambers, cyclone separators, scrubbers, filters & ESP.

L3,L4

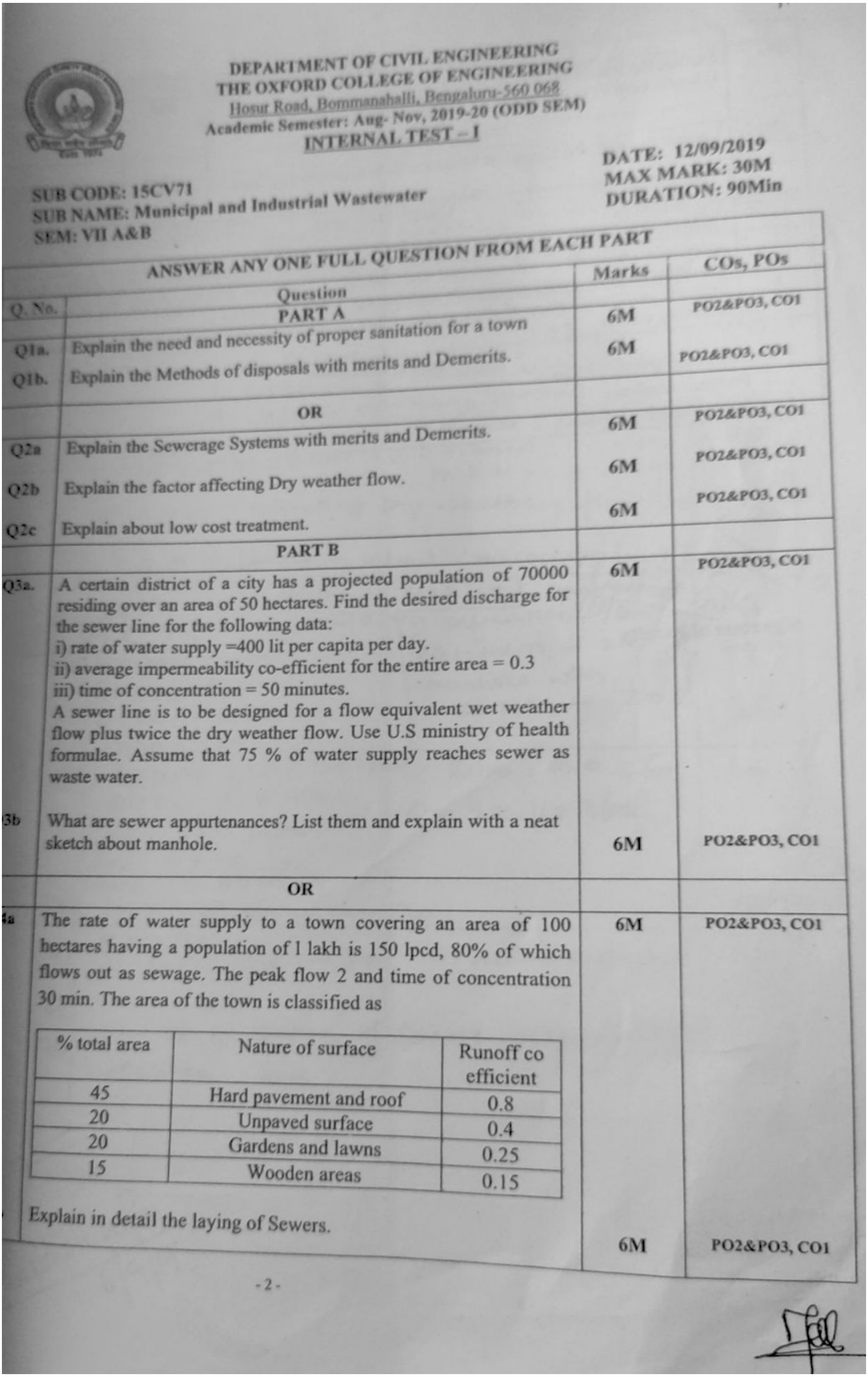
Module-5

Air pollution due to automobiles, standards and control methods. Noise pollution causes, effects and control, noise standards. Environmental issues, global episodes, laws, acts, protocols

L3,L4,L5,L6

Course outcomes: After studying this course, students will be able to:
1. Identify the major sources of air pollution and understand their effects on health and environment.
2. Evaluate the dispersion of air pollutants in the atmosphere and to develop air quality models.
3. Ascertain and evaluate sampling techniques for atmospheric and stack pollutants.
4. Choose and design control techniques for particulate and gaseous emissions.

Text Books:
1. M. N. Rao and H V N Rao, "Air pollution", Tata Mc-G raw Hill Publication.
2. H. C. Perkins, "Air pollution". Tata McGraw Hill Publication
3. Mackenzie Davis and David Cornwell, "Introduction t o Environmental Engineering" McGraw-Hill Co.



DEPARTMENT OF CIVIL ENGINEERING
THE OXFORD COLLEGE OF ENGINEERING
Hosur Road, Bommanahalli, Bengaluru-560 068
Academic Semester: Aug- Nov, 2019-20 (ODD SEM)
INTERNAL TEST – I

SUB CODE: 15CV71
SUB NAME: Municipal and Industrial Wastewater
SEM: VII A&B

DATE: 12/09/2019
MAX MARK: 30M
DURATION: 90Min

<table>
<tr><th colspan="4">ANSWER ANY ONE FULL QUESTION FROM EACH PART</th></tr>
<tr><th>Q. No.</th><th>Question</th><th>Marks</th><th>COs, POs</th></tr>
<tr><td></td><td>PART A</td><td></td><td></td></tr>
<tr><td>Q1a.</td><td>Explain the need and necessity of proper sanitation for a town</td><td>6M</td><td>PO2&PO3, CO1</td></tr>
<tr><td>Q1b.</td><td>Explain the Methods of disposals with merits and Demerits.</td><td>6M</td><td>PO2&PO3, CO1</td></tr>
<tr><td></td><td>OR</td><td></td><td></td></tr>
<tr><td>Q2a</td><td>Explain the Sewerage Systems with merits and Demerits.</td><td>6M</td><td>PO2&PO3, CO1</td></tr>
<tr><td>Q2b</td><td>Explain the factor affecting Dry weather flow.</td><td>6M</td><td>PO2&PO3, CO1</td></tr>
<tr><td>Q2c</td><td>Explain about low cost treatment.</td><td>6M</td><td>PO2&PO3, CO1</td></tr>
<tr><td></td><td>PART B</td><td></td><td></td></tr>
<tr><td>Q3a.</td><td>A certain district of a city has a projected population of 70000 residing over an area of 50 hectares. Find the desired discharge for the sewer line for the following data:
i) rate of water supply =400 lit per capita per day.
ii) average impermeability co-efficient for the entire area = 0.3
iii) time of concentration = 50 minutes.
A sewer line is to be designed for a flow equivalent wet weather flow plus twice the dry weather flow. Use U.S ministry of health formulae. Assume that 75 % of water supply reaches sewer as waste water.</td><td>6M</td><td>PO2&PO3, CO1</td></tr>
<tr><td>3b</td><td>What are sewer appurtenances? List them and explain with a neat sketch about manhole.</td><td>6M</td><td>PO2&PO3, CO1</td></tr>
<tr><td></td><td>OR</td><td></td><td></td></tr>
<tr><td>4a</td><td>The rate of water supply to a town covering an area of 100 hectares having a population of 1 lakh is 150 lpcd, 80% of which flows out as sewage. The peak flow 2 and time of concentration 30 min. The area of the town is classified as
<table>
<tr><th>% total area</th><th>Nature of surface</th><th>Runoff co efficient</th></tr>
<tr><td>45</td><td>Hard pavement and roof</td><td>0.8</td></tr>
<tr><td>20</td><td>Unpaved surface</td><td>0.4</td></tr>
<tr><td>20</td><td>Gardens and lawns</td><td>0.25</td></tr>
<tr><td>15</td><td>Wooden areas</td><td>0.15</td></tr>
</table></td><td>6M</td><td>PO2&PO3, CO1</td></tr>
<tr><td></td><td>Explain in detail the laying of Sewers.</td><td>6M</td><td>PO2&PO3, CO1</td></tr>
</table>

- 2 -

	PART C		
Q5a.	Explain the following with sketches: i) Septic tank ii) Oxidation pond.	6M	PO
	OR		
Q5b.	Explain in detail the Shapes of Sewers with neat sketch any four.	6M	PO

Course Outcomes

Students will be able to

1.	Understand sewerage network and influencing parameters, Understand and design
2.	operations involved in conventional and biological treatment process, Apply the Industrial effluent treatment process for different industrial wastes
3.	Evaluate self-purification of streams depending on hydraulic and organic loading of receiving waters

Program Outcomes

1. Engineering Knowledge
2. Problem Analysis
3. Interpretation of data

1) Kay

2) Parshitha R 06/09/19

Signature of Faculty

Signature of

7A+B.

Academic Year: 2019-2020 (ODD SEMESTER)

INTERNAL TEST – I

SCHEME OF VALUATION

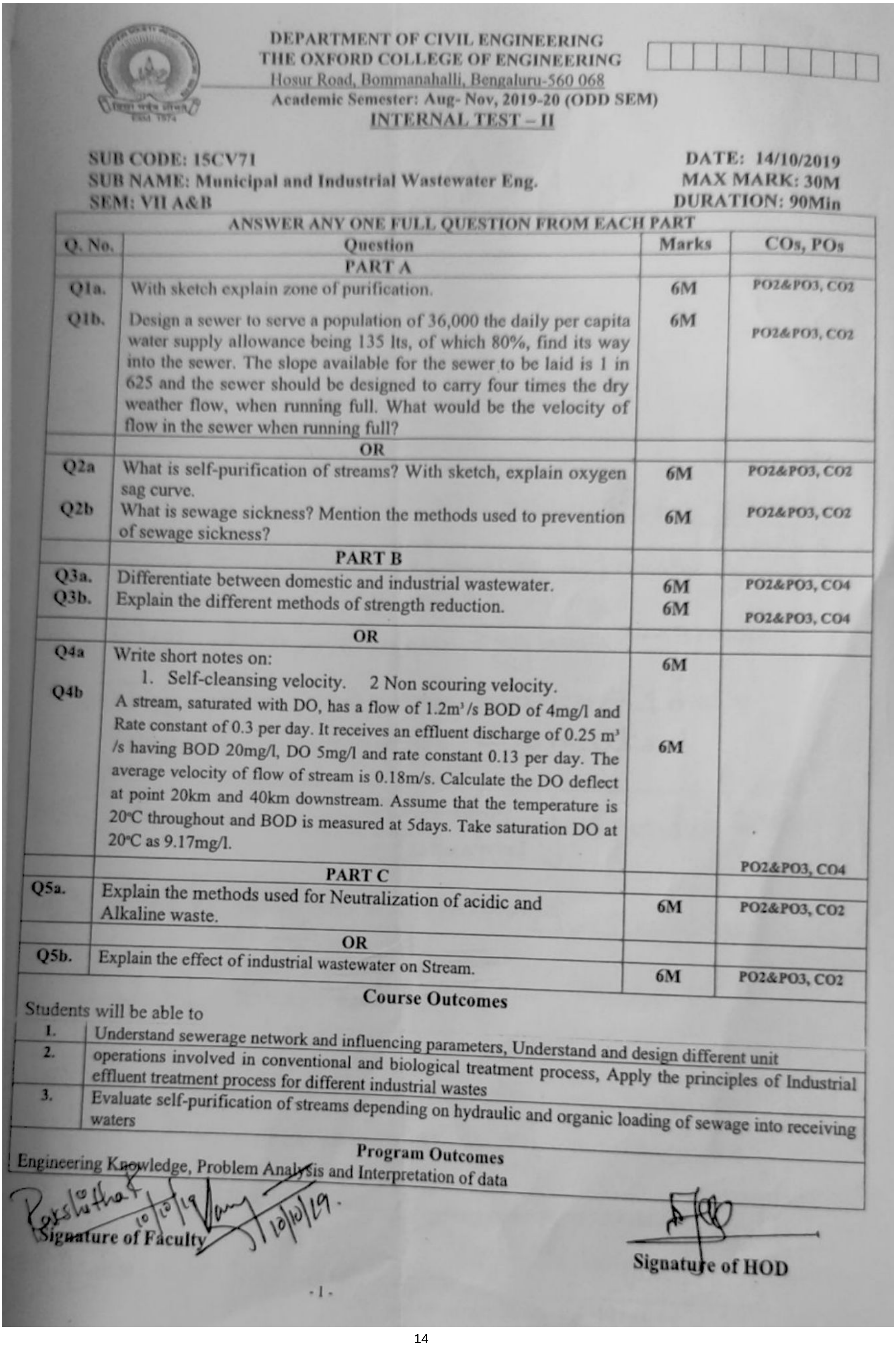
SUB CODE: 15CV71 **SEM:** 7th 'A' and

SUB NAME: Municipal & Industrial w/w. **MAX MARK: 30M**

Q. No	DESCRIPTION OF ANSWER	MARKS
1 (a)	Minimum Six points on need & necessity of proper Sanitation. 1×6 = 6m.	6m.
(b)	Methods of Disposal (3+3) = 6m 1. Conservancy method with adv & disadv 2. Water carriage method "	6m
2 (a)	Sewerage System with adv & disadv 1. Separate system – 2m 2. Combined " – 2m 3. Partial " " – 2m	6m
(b)	(4) Factors Affecting Dry weather flow – 3m	6m
(c)	Detail Explanation about Low cost treatment – 3	
3 (a)	DWF = 243.05 lts/sec, Sewage flow = 300 lts/c/d Ri = 14.5 mm/hrs. Q = 609 lts/sec Q = 1095.1 lts/sec Ratio = 0.39 6×1 = 6m	
(b)	Sewer appurtenances Definition – 2m List them – 1m manhole with Sketch – 3m	6m
4 (a)	Sewage flow = 120 lpcd, Ration = 18.0 – 6m DWF = 138.8 lts/sec. Ri = 20.32 mm/hrs. Q = 280.49 lts/sec I_{Av} = 0.5125 WWF = 2.89 m^3/sec	6m
(b)	Laying of Sewers — 6m with Sketch	6m
5 (a)	(i) Septic tank — 3m, ii) oxidation pond – 3m	6m
OR		
(b)	Any Four Shape of Sewers with neat Sketches.	6m

6/9/19

Harshitha R
6/9/19



DEPARTMENT OF CIVIL ENGINEERING
THE OXFORD COLLEGE OF ENGINEERING
Hosur Road, Bommanahalli, Bengaluru-560 068
Academic Semester: Aug- Nov, 2019-20 (ODD SEM)

INTERNAL TEST – II

SUB CODE: 15CV71
SUB NAME: Municipal and Industrial Wastewater Eng.
SEM: VII A&B

DATE: 14/10/2019
MAX MARK: 30M
DURATION: 90Min

ANSWER ANY ONE FULL QUESTION FROM EACH PART

Q. No.	Question	Marks	COs, POs
	PART A		
Q1a.	With sketch explain zone of purification.	6M	PO2&PO3, CO2
Q1b.	Design a sewer to serve a population of 36,000 the daily per capita water supply allowance being 135 lts, of which 80%, find its way into the sewer. The slope available for the sewer to be laid is 1 in 625 and the sewer should be designed to carry four times the dry weather flow, when running full. What would be the velocity of flow in the sewer when running full?	6M	PO2&PO3, CO2
	OR		
Q2a	What is self-purification of streams? With sketch, explain oxygen sag curve.	6M	PO2&PO3, CO2
Q2b	What is sewage sickness? Mention the methods used to prevention of sewage sickness?	6M	PO2&PO3, CO2
	PART B		
Q3a.	Differentiate between domestic and industrial wastewater.	6M	PO2&PO3, CO4
Q3b.	Explain the different methods of strength reduction.	6M	PO2&PO3, CO4
	OR		
Q4a	Write short notes on: 1. Self-cleansing velocity. 2 Non scouring velocity.	6M	
Q4b	A stream, saturated with DO, has a flow of 1.2m³/s BOD of 4mg/l and Rate constant of 0.3 per day. It receives an effluent discharge of 0.25 m³ /s having BOD 20mg/l, DO 5mg/l and rate constant 0.13 per day. The average velocity of flow of stream is 0.18m/s. Calculate the DO deflect at point 20km and 40km downstream. Assume that the temperature is 20°C throughout and BOD is measured at 5days. Take saturation DO at 20°C as 9.17mg/l.	6M	PO2&PO3, CO4
	PART C		
Q5a.	Explain the methods used for Neutralization of acidic and Alkaline waste.	6M	PO2&PO3, CO2
	OR		
Q5b.	Explain the effect of industrial wastewater on Stream.	6M	PO2&PO3, CO2

Course Outcomes

Students will be able to

1.	Understand sewerage network and influencing parameters, Understand and design different unit
2.	operations involved in conventional and biological treatment process, Apply the principles of Industrial effluent treatment process for different industrial wastes
3.	Evaluate self-purification of streams depending on hydraulic and organic loading of sewage into receiving waters

Program Outcomes

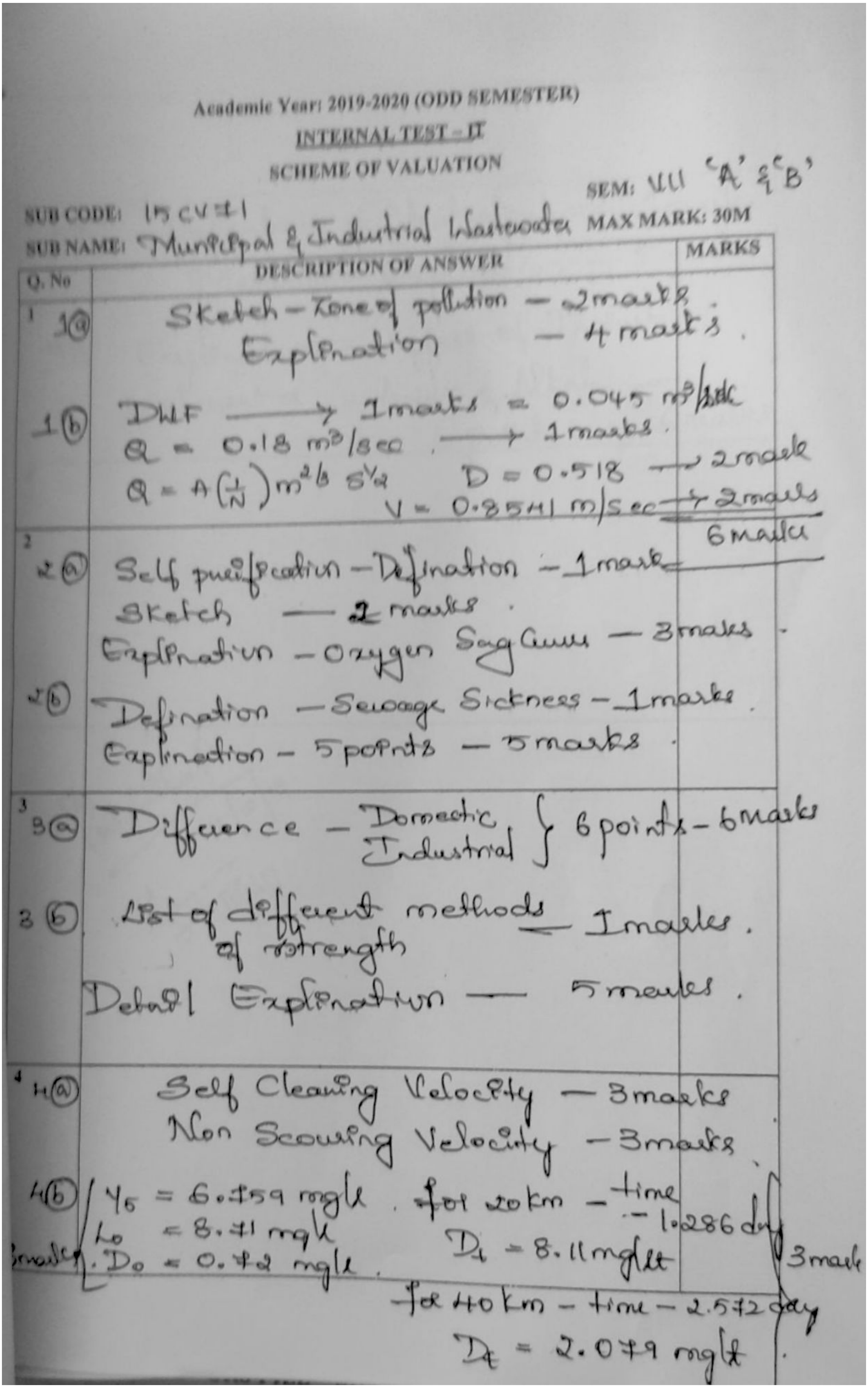
Engineering Knowledge, Problem Analysis and Interpretation of data

Purushotham 10/10/19 10/10/19.

Signature of Faculty

Signature of HOD

- 1 -



Academic Year: 2019-2020 (ODD SEMESTER)

INTERNAL TEST – II

SCHEME OF VALUATION

SEM: VII 'A' & 'B'

SUB CODE: 15 CV71

SUB NAME: Municipal & Industrial Wastewater

MAX MARK: 30M

Q. No	DESCRIPTION OF ANSWER	MARKS
1 1(a)	Sketch – Zone of pollution – 2 marks. Explination – 4 marks.	
1(b)	DWF ⟶ 1 marks = 0.045 m³/sec Q = 0.18 m³/sec ⟶ 1 marks. $Q = A\left(\frac{1}{N}\right) m^{2/3} S^{1/2}$ D = 0.518 → 2 marks V = 0.8541 m/sec → 2 marks	6 marks
2 2(a)	Self purification – Defination – 1 mark Sketch – 2 marks. Explination – Oxygen Sag Curve – 3 marks.	
2(b)	Defination – Sewage Sickness – 1 marks. Explination – 5 points – 5 marks.	
3 3(a)	Difference – Domestic / Industrial } 6 points – 6 marks	
3(b)	List of different methods of strength – 1 marks. Detail Explination – 5 marks.	
4 4(a)	Self Cleaning Velocity – 3 marks Non Scouring Velocity – 3 marks	
4(b)	3 marks { Y_5 = 6.759 mg/l L_0 = 8.71 mg/l D_0 = 0.72 mg/l. for 20 km – time – 1.286 day D_t = 8.11 mg/lt for 40 km – time – 2.572 day D_t = 2.079 mg/lt } 3 mark	

5	5 (a). Defination – Neutralization – 1 marks Method – Explination – 5 marks. 5 (b) Explination – Effect of Industrial wastewater – Acidic & Alkali – 6 points – 6 marks.	

15/10/19

15/10/19

Course Title: Environmental Engineering Laboratory
As per Choice Based Credit System (CBCS) scheme
SEMESTER:VII

Subject Code	15CVL76	IA Marks	20
Number of Lecture Hours/Week	1I+2P	Exam Marks	80
Total Number of Lecture Hours	40	Exam Hours	03
	CREDITS –02	**Total Marks- 100**	

Course objectives: This course will enable students,
1. To learn different methods of water & waste water quality
2. To conduct experiments to determine the concentrations of water and waste water
3. To determine the degree and type of treatment
4. To understand the environmental significance and application in environmental engineering practice

Experiments	**Teaching Hours**	**Revised Bloom's Taxonomy (RBT) Level**
1. Determination of pH, Acidity and Alkalinity	02 Class	L1,L2,L3
2. Determination of Calcium, Magnesium and Total Hardness.	02 Class	L1,L2,L3
3. Determination of Dissolved Oxygen. 4. Determination of BOD.	02 Class	L1,L2,L3
5. Determination of Chlorides	01 Class	L1,L2,L3
6. Determination of percentage of available chlorine in bleaching powder, Determination of Residual Chlorine	01 Class	L1,L2,L3
7. Determination of Solids in Sewage: I) Total Solids, II) Suspended Solids, III) Dissolved Solids, IV) Volatile Solids, Fixed Solids, V) Settle able Solids. 8. Determination of Turbidity by Nephelometer 9. Determination of Optimum Dosage of Alum using Jar test apparatus.	02 Class	L1,L2,L3
10. Determination of sodium and potassium using flame photometer.	01 Class	L1,L2,L3
11. Determination Nitrates by spectrophotometer. 12. Determination of Iron & Manganese.	01 Class	L1,L2,L3
13. Determination of COD.	Demonstration	L1,L2,L3
14. Air Quality Monitoring (Ambient, stack monitoring , Indoor air pollution)	Demonstration	L1,L2,L3
15. Determination of Sound by Sound level meter at different location	Demonstration	L1,L2,L3

Course Outcomes: After studying this course, students will be able to:
1. Acquire capability to conduct experiments and estimate the concentration of different parameters.
2. Compare the result with standards and discuss based on the purpose of analysis.
3. Determine type of treatment, degree of treatment for water and waste water.
4. Identify the parameter to be analyzed for the student project work in environmental stream.

Program Objectives:
1. Evaluation of the test results and assesses the impact on water and waste water treatment.
2. Train student to undertake student project work in 8th semester in the field of environmental engineering.

Question paper pattern:

Two experiments shall be asked from the above set
One experiment to be conducted and for the other student should write detailed procedure.

Reference Books:
1. Lab Manual, ISO 14001 Environmental Management, Regulatory Standards for Drinking Water and Sewage disposal
2. Clair Sawyer and Perry McCarty and Gene Parkin, "Chemistry for Environmental Engineering and Science" , McGraw-Hill Series in Civil and Environmental Engineering

	USN	STUDENT NAME	
1	1OX16CV001	ABHISHEK	BATCH I
2	1OX16CV002	ABHISHEK NANDAKUMAR	
3	1OX16CV004	ABRAR AHMAD NATH	
4	1OX16CV006	AKASH SONAR	
5	1OX16CV008	AMAL ANIYAN KUNJU	
6	1OX16CV009	AMARNATH REDDY.R	
7	1OX16CV010	AMRUTHA H L	
8	1OX16CV011	ANILKUMAR	
9	1OX16CV012	ANITHA V R	
10	1OX16CV013	ANUGRAHA K	
11	1OX16CV014	APOORVA PATIL G M	
12	1OX16CV015	ASHWINI R	
13	1OX16CV019	CHARAN K	
14	1OX16CV020	CHETHANA H S	
15	1OX16CV021	DARSHAN JAIN C B	
16	1OX16CV022	DARSHAN N	
17	1OX16CV024	DEEKSHITH K M	
18	1OX16CV025	DIVYASREE C	
19	1OX16CV026	G NANDA KUMAR	
20	1OX16CV027	GEETA SULIKERI	
21	1OX16CV029	GOVINDRAJ M	
22	1OX16CV030	GOWTHAM S	
23	1OX16CV031	HARISH CHANDRA	
24	1OX16CV032	HARSHITHA CV	
25	1OX16CV033	IMTIPONG IMSONG	
26	1OX16CV034	ISHFAQ MANZOOR RATHER	
27	1OX16CV037	KARTHIK	

VII A (BATCH II)			
SL. No	USN	STUDENT NAME	
1	1OX16CV038	KARTHIK R	
2	1OX16CV040	LIGITH P	BATCH II
3	1OX16CV042	MADHAN KUMAR M	
4	1OX17CV400	ABDUL RAHMAN SHOAIB	
5	1OX17CV401	ABHILASH .H	
6	1OX17CV402	ADDAGALA ROHITH	
7	1OX17CV403	AMRUTHA D.H	
8	1OX17CV406	BALAJI D S	
9	1OX17CV407	CHAITHRA . MV	
10	1OX17CV408	DEEPAK S N	
11	1OX17CV409	GURUDATTA T L	
12	1OX17CV410	GURUPRASAD .T	
13	1OX17CV411	HEMANTH H M	
14	1OX17CV413	KESHAPPA P RATHOD	
15	1OX17CV414	KHUSHBOO .A	
16	1OX17CV415	LAMBANI KIRTI RAMCHANDRA	
17	1OX17CV417	MOHAMMED ZEESHAN	
18	1OX17CV418	MOULA HUSSAIN	
19	1OX17CV419	NAVEEN .B	
20	1OX17CV420	NAVEEN KUMAR GOTUR	
21	1OX17CV422	NISHANT	
22	1OX17CV423	PRADEEP.B.S	
23	1OX17CV425	PRUTHVI. D JAIN	
24	1OX17CV426	RACHAYYA HIREMATH	
25	1OX17CV427	RANJITH KUMAR .M	
26	1OX17CV428	RATISH GOWDA A S	
27	1OX17CV429	ROHITH M	
28	1OX16CV415	RAKESH KAMMAR	

CBCS SCHEME

USN

15CV/CT551

Fifth Semester B.E. Degree Examination, June/July 2018
Air Pollution and Control

Time: 3 hrs. Max. Marks: 80

Note: 1. *Answer any FIVE full questions, choosing one full question from each module.*
2. *Assume the required data if necessary.*

Module-1

1 a. Explain the classification of air pollutants. Give examples. **(08 Marks)**
b. Explain effects of air pollutants on plants. **(08 Marks)**

OR

2 a. With a neat sketch, explain inversion occurs due to high pressure system. **(06 Marks)**
b. Define : (i) Fog, (ii) Mists (iii) Smoke (iv) Soot **(04 Marks)**
c. Explain the effects of carbon monoxide on human beings. **(06 Marks)**

Module-2

3 a. Define DALR and ELR. **(02 Marks)**
b. Calculate the minimum stack height required for a thermal power plant which burns 100 tonnes of coal with 5.5%, Sulphur content. The particulate concentration in flue gases is 8000 mg/m^3 and gas flow rate is 20 m^3/s. **(08 Marks)**
c. Explain the application of wind rose diagram. **(06 Marks)**

OR

4 a. A thermal plant burns 5.45 tonnes with 4.2% sulphur per hour and discharge through a stack of effective height 75 m. The average wind speed at top of stack is 6 m/s. Atmosphere is slightly to moderately stable. Find Ground Level Concentration (GLC) at 3 km downwind and 0.4 km crosswind distance. Take $\sigma_z = 170$ and $\sigma_y = 280$. **(08 Marks)**
b. With neat sketches, explain different types of plume behavior. **(08 Marks)**

Module-3

5 a. With neat sketches, explain the components of sampling train. **(10 Marks)**
b. Explain the gravitational method for estimating particulate matter. **(06 Marks)**

OR

6 a. Explain the factors influencing indoor air quality. **(06 Marks)**
b. With a neat sketch, explain Pollution Standard Index (PSI). **(06 Marks)**
c. What is meant by super Isokinetic sampling? **(04 Marks)**

Module-4

7 a. With a neat sketch, explain the working of cyclones in particulate removal. **(08 Marks)**
b. Calculate the settling velocity of fog with a particle size of 1 μm. **(08 Marks)**

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

OR

8 a. With a neat sketch, explain working principle of electrostatic precipitator. **(10 Marks)**

b. A fabric filter is to be constructed using bags of 0.3 m in diameter and 6 m long. The bag house is to receive 800 m^3/min of air. Determine the number of bags required for cleaned operation. **(06 Marks)**

Module-5

9 a. Explain the types of emissions due to automobiles. **(09 Marks)**

b. How noise can be reduced at source? Explain. **(07 Marks)**

OR

10 a. Define acid rain. Explain the sources and effects of acid rain. **(08 Marks)**

b. List Air Pollution Control Acts. **(04 Marks)**

c. Explain the reason for Bhopal gas tragedy. **(04 Marks)**

* * * * *

Examiner 2 Sign.

Examiner 1 Sign.

Student Sign.

USN :

CBCS Scheme

USN ☐☐☐☐☐☐☐☐☐☐

15CV/CT551

Fifth Semester B.E. Degree Examination, Dec.2017/Jan.2018
Air Pollution and Control

Time: 3 hrs. Max. Marks: 80

Note: *Answer FIVE full questions, choosing one full question from each module.*

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

Module-1

1 a. Define Air Pollution. Explain Primary and Secondary air pollutants. **(08 Marks)**
b. With respect to Air pollution, explain air borne contaminants. **(08 Marks)**

OR

2 a. Enumerate the effects of Air pollution on Human Health and Vegetation. **(08 Marks)**
b. Define Inversion. Briefly explain the different types of inversion with the aid of neat sketches. **(08 Marks)**

Module-2

3 a. Explain the structure and the companion of atmosphere. **(08 Marks)**
b. Define Lapse rate. Explain the different types of lapse rate. **(08 Marks)**

OR

4 a. What are the assumptions and limitations of the Gaussian Plume dispersion model? **(08 Marks)**
b. A Thermal power plant releases SO_2 at a rate of 138.8 g/s. The stack height is 120m. While the temperature of the stack gas is 150^0C and the ambient air temperature is 35^0C. The wind velocity at the stack height is 8.5m/s. While the stack gas velocity is 10m/s. The stack diameter is 3.5m. The atmospheric pressure is 1.005 bar. Estimate the effective stack height. **(08 Marks)**

Module-3

5 a. What is meant by Air sampling? Explain briefly sampling train. **(08 Marks)**
b. With eh help of the neat sketch, explain the measurement of SPM in ambient air. **(08 Marks)**

OR

6 a. With the help of neat sketch, explain high volume air sampler for measurement of particulate matter. **(08 Marks)**
b. Briefly explain any one method of measuring SO_2 in the stack. **(08 Marks)**

Module-4

7 a. Explain the factors affecting the selection of the particulate air control devices. **(08 Marks)**
b. Briefly explain the particulate matter removal by gravity Sattler, with the help of neat sketch. **(08 Marks)**

OR

8 a. With the help of neat sketch, explain the working principle of Electro Static Precipitation. **(08 Marks)**
b. A cement plant was emitting flue gas at the rate of 20,000 m^3/h. Assuming inlet gas velocities of 2m/s. Design a tubular ESP with 0.20m diameter with 7 cylinders to achieve the efficiency of 90% and 95%. **(08 Marks)**

KLE Dr. M.S. Sheshgiri College

Module-5

9 a. Explain briefly the emission of the gasoline driven vehicles and diesel driven vehicles. (08 Mar

b. Define Noise Pollution. Explain the sources and control methods of Noise - Pollution. (08 Marks

OR

10 Write short notes on any Four of the following :

a. Acid rain and its effects.
b. Bhopal gas tragedy.
c. Air quality standards.
d. Noise Pollution standards.
e. Environmental policy.
f. Kyoto protocol.

(16 Marks)

* * * * *

Children's Education Society ®
THE OXFORD COLLEGE OF ENGINEERING
DEPARTMENT OF CIVIL ENGINEERING
Hosur Road, Bommanahalli, Bengaluru-560 068
080-30219780/81, Fax : 080-25730551,30219629,
Website:www.theoxford.edu Email : theoxfordcivilworks@gmail.com
(Approved by AICTE, New Delhi, Accredited by NBA, New Delhi & Affiliated to VTU, Belgaum)

CORSE OUTCOMES

WATER SUPPLY AND TREATMENT ENGINERRING (15CV64)

Course Outcomes: After studying this course, students will be able to:

CO1: Analyze the variation of water demand and to estimate water requirement for a community.

CO2: Evaluate the sources and conveyance systems for raw and treated water.

CO3: Study drinking water quality standards and to illustrate qualitative analysis of water.

CO4: Design physical, chemical and biological treatment methods to ensure safe and potable water Supply.

CO5: Purification of water using Rapid sand Filtration method.

CO6: Testing of water samples correlated with pH scale, using different methods of population forecasting to design the water treatment plant.

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CO MAPPING WITH PO'S

Course Title : **WATER SUPPLY AND TREATMENT ENGINEERING**
Course Code : 15CV64
Semester : SIXTH

Course Outcome	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
364.1	1	2	1	-	-	-	-	-	-	-	-	-
364.2	1	2	1		-	-	-	-	-	-	-	-
364.3		2	-	-	1	1	-	-	-	-	-	-
364.4	-	-	2		2	1	1	-	-	-	-	-
364.5	-	-	-	-	2	1	1	-	-	-	-	-
364.6	-	-	-	1	2	1		-	-	-	-	-
AVG	1	2	1.33	1	1.75	2	1	0	0	0	0	0

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CO MAPPING WITH PSO

ACADEMIC YEAR 2017-2018

CO	PSO-1	PSO-2	PSO-3
232	1.833	1.5	1.16
233	1.33	0.5	-
234	1.5	0.66	1.33
235	0.33	1.16	2.5
236	1.16	0.66	1.33
237	2	2	-
238	1.5	1.16	1.16
242	1	1.66	0.33
243	1	1.833	0.5
244	1.5	1	1.66
245	1.33	1.33	1.66
246	2	2.16	2
247	1.66	2	1.33
248	0.83	1	2.5
351	1.16	1.83	1
352	1	1.83	0.16
353	1.33	1.83	0.16
354	1.33	1.5	1.33
355	1	1.5	1
356	1.16	1.5	0.5
357	0.16	1.16	1
358	0	1	1
361	0.16	1.16	1.5
362	1.16	2.66	0.5
363	0.5	1.66	2
364	**0.66**	**2**	**1**
365	0.83	1.66	2
366	0.66	2	1

THE OXFORD COLLEGE OF ENGINEERING BANGALORE

DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

NAME OF THE FACULTY

B.DEVI VIGHNESHWARI

SEMESTER/SECTION

VI B

SUBJECT NAME

POWER SYSTEM ANALYSIS

SUBJECT CODE

18EE62/ 17EE62 / 15EE62

YEAR

2019 – 2020 (EVEN)

THE OXFORD COLLEGE OF ENGINEERING BANGALORE

DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

INDEX SHEET

SL.NO	CONTENTS
1	VISION , MISSION, PEO's, PSO's
2	SYLLABUS COPY
3	TIME TABLE
4	LESSON PLAN
5	NAME LIST
6	MODULE WISE CLASS NOTES
7	INTERNAL QUESTION PAPERS WITH ANSWER KEY
8	UNIVERSITY QUESTION PAPERS
9	QUESTION BANK
10	INTERNAL & EXTERNAL MARKS
11	SAMPLE ASSIGNMENT / TUTORIAL
12	RESULT ANALYSIS FOR 3 YEARS

THE OXFORD COLLEGE OF ENGINEERING BANGALORE

DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

Vision: To meet the educational and research needs of the student community and staff through collaboration with other academic and technical institutions, industry and government agencies and make the students to face problems of the country and society as a whole.

Mission:

M1-To develop and train competent Electrical and Electronics Engineers with adequate practical skills.

M2-To provide state-of-the-art resources that contribute to achieve excellence in teaching-learning, research and development activities.

M3-To inculcate, ethics, leadership, moral values and social activities.

Programme Educational Objectives: Graduate of the programme will

1 Be able to apply the fundamental knowledge of mathematics, science, electrical and electronics engineering to analyze and solve the complex problem in electrical, electronics and allied interdisciplinary areas.

2 Possess good leadership skills, function ethically in multidisciplinary areas to develop sustainable solutions for global, environmental and social issues.

3 Be able to inculcate lifelong learning to maintain and enhance professional skills.

Program Outcomes: Electrical Engineering Program helps the students to attain the following outcomes:

a) An ability to apply the engineering science knowledge acquired in creating good projects and solutions to problems faced by the industry.

b) An ability to analyze, design and innovate products, solutions for day to day problems.

c) An ability to design, implement and evaluate Hardware / software components to meet desired needs with constraint related to economic, environment, social, health and safety.

d) An ability to apply research based knowledge and methods in designing / analysing complex problems.

e) A good knowledge about simulation and design on various packages relevant to their specialization like MATLAB, PSPICE, MiPower, ECAD etc and also to apply them in relevant designs.

f) An ability to design and develop specialized instrumentation required for monitoring the health of the aged people and developing devices which can help people having various form of disabilities.

g) An ability to find solutions related to problems created by usage of technology.

h) An ability to understand ethical, legal professional and social issues in Electrical Engineering Practice.

i) An ability to work in a team with good understanding and also to lead a team.

j)An ability to communicate effectively.

k)An ability to manage both people and finance information.

l) Recognition of the need for and an ability to engage in Life – Long Learning.

Programme Specific Outcome

PSO1: Apply fundamental knowledge to identify, formulate, design and investigate various problems of electrical and electronic circuits, power electronics, control systems and power systems.

PSO2: Apply modern software tools for design, simulation and analysis of electrical systems to engage in life- long learning and to successfully adapt in multi-disciplinary environments.

PSO3: Solve ethically and professionally various Electrical Engineering problems in societal and environmental context and communicate effectively by applying project management techniques to complex engineering problems.

THE OXFORD COLLEGE OF ENGINEERING BANGALORE

DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

POWER SYSTEM ANALYSIS – 1 (Core Subject)

B.E., VI Semester, Electrical and Electronics Engineering [As per Choice Based Credit System (CBCS) scheme]

Course Code	17EE62	CIE Marks	40
Number of Lecture Hours/Week	04	SEE Marks	60
Total Number of Lecture Hours	50	Exam Hours	03
Credits - 04			

Course objectives:

- To introduce the per unit system and explain its advantages and computation.
- To explain the concept of one line diagram and its implementation in problems.
- To explain the necessity and conduction of short circuitanalysis.
- To explain analysis of three phase symmetrical faults on synchronous machine and simple power systems.
- To discuss selection of circuit breaker.
- To explain symmetrical components, their advantages and the calculation of symmetrical components of voltages and currents in un-balanced three phase circuits.
- To explain the concept of sequence impedance and its analysis in three phase unbalanced circuits.
- To explain the concept of sequence networks and sequence impedances of an unloaded synchronous generator, transformers and transmission lines.
- To explain the analysis of synchronous machine and simple power systems for different unsymmetrical faults using symmetrical components.
- To discuss the dynamics of synchronous machine and derive the power angle equation for a synchronous machine
- Discuss stability and types of stability for a power system and the equal area criterion for the evaluation of stability of a simple system.

		Teaching Hours
Module-1		
Representation of Power System Components: Introduction, Single-phase Representation of Balanced Three Phase Networks, One-Line Diagram and Impedance or Reactance Diagram, Per Unit (PU) System, Steady State Model of Synchronous Machine, Power Transformer, Transmission of electrical Power, Representation ofLoads.		10
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	
Module-2		
Symmetrical Fault Analysis: Introduction, Transient on a Transmission Line, Short Circuit of a Synchronous Machine(On No Load), Short Circuit of a Loaded Synchronous Machine, Selection of Circuit Breakers.		10
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	
Module-3		
Symmetrical Components: Introduction, Symmetrical Component Transformation, Phase Shift in Star-Delta Transformers, Sequence Impedances of Transmission Lines, Sequence Impedances and Sequence Network of Power System, Sequence Impedances and Networks of Synchronous Machine, Sequence Impedances of Transmission Lines, Sequence Impedances and Networks of Transformers, Construction of Sequence Networks of a Power System, Measurement of sequence Impedance of Synchronous Generator.		10
Revised Bloom's Taxonomy Level	L_2 – Understanding, L_3 – Applying, L_4 – Analysing, L_5 - Evaluating.	
Module-4		

Unsymmetrical Fault Analysis: Introduction, Symmetrical Component Analysis of Unsymmetrical Faults. Single Line-To-Ground (LG) Fault, Line-To-Line (LL) Fault, Double Line-To-Ground (LLG) Fault, Open Conductor Faults. ■		**10**
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	

B.E ELECTRICAL AND ELECTRONICS ENGINEERING(EEE)
CHOICE BASED CREDIT SYSTEM (CBCS)
SEMESTER -VI

17EE62 POWER SYSTEM ANALYSIS – 1 (Core Subject) (continued)

Module-5		Teaching Hours
Power System Stability: Introduction, Dynamics of a Synchronous Machine, Power Angle Equation Salient and Non – Salient pole Synchronous Machines, Simple Systems, Steady State Stability, Transient Stability, Equal Area Criterion, Factors Affecting Transient Stability. ■		10
Revised Bloom's Taxonomy Level	L_1 – Remembering, L_2 – Understanding, L_3 – Applying, L_4 – Analysing.	

Course outcomes:

At the end of the course the student will be able to:

- Show understanding of per unit system, its advantages and computation.
- Show the concept of one line diagram and its implementation in problems
- Perform short circuit analysis on a synchronous machine and simple power system to select a circuit breaker for the system.
- Evaluate symmetrical components of voltages and currents in un-balanced three phase circuits.
- Explain the concept of sequence impedance and sequence networks of power system components and power system.
- Analyze three phase synchronous machine and simple power systems for different unsymmetrical faults using symmetrical components.

Graduate Attributes (As per NBA)

Engineering Knowledge, Problem analysis, The Engineer and Society, Ethics

Question paper pattern:

- The question paper will have ten full questions carrying equal marks. Each full question consisting of 16 marks.
- There will be two full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub question covering all the topics under a module.

Textbook

1.	Modern Power System	D. P. Kothari	McGraw Hill	4th Edition, 2011

ReferenceBooks

1	Elements of Power System	William D. StevensonJr	McGraw Hill	4th Edition, 1982
2	Power System Analysis and Design	J.Duncan Glover et al	Cengage	4th Edition, 2008
3	Power System Analysis	Hadi Sadat	McGraw Hill	1st Edition, 2002

B. E. ELECTRICAL AND ELECTRONICS ENGINEERING
Choice Based Credit System (CBCS) and Outcome Based Education (OBE)
SEMESTER - VI

POWER SYSTEM ANALYSIS – 1 (Core Subject)

Course Code	18EE62	CIE Marks	4
Number of Lecture Hours/Week (L:T:P)	3:2:0	SEE Marks	6
Credits	04	Exam Hours	0

Course Learning Objectives:

- To introduce the per unit system and explain its advantages and computation.
- To explain the concept of one line diagram and its implementation in problems.
- To explain the necessity and conduction of short circuit analysis.
- To explain analysis of three phase symmetrical faults on synchronous machine and simple power systems.
- To discuss selection of circuit breaker.
- To explain symmetrical components, their advantages and the calculation of symmetrical components of voltages and currents in un-balanced three phase circuits.
- To explain the concept of sequence impedance and its analysis in three phase unbalanced circuits.
- To explain the concept of sequence networks and sequence impedances of an unloaded synchronous generator, transformers and transmission lines.
- To explain the analysis of synchronous machine and simple power systems for different unsymmetrical faults using symmetrical components.
- To discuss the dynamics of synchronous machine and derive the power angle equation for a synchronous machine.
- Discuss stability and types of stability for a power system and the equal area criterion for the evaluation of stability of a simple system. ■

Module-1

Representation of Power System Components: Introduction, Single-phase Representation of Balanced Three Phase Networks, One-Line Diagram and Impedance or Reactance Diagram, Per Unit (PU) System, Steady State Model of Synchronous Machine, Power Transformer, Transmission of Electrical Power, Representation of Loads. ■

Module-2

Symmetrical Fault Analysis: Introduction, Transient on a Transmission Line, Short Circuit of a Synchronous Machine(On No Load), Short Circuit of a Loaded Synchronous Machine, Illustrative simple examples on power systems. Selection of Circuit Breakers. ■

Module-3

Symmetrical Components: Introduction, Symmetrical Component Transformation, Phase Shift in Star-Delta Transformers, Sequence Impedances of Transmission Lines, Sequence Impedances and Sequence Network of Power System, Sequence Impedances and Networks of Synchronous Machine, Sequence Impedances of Transmission Lines, Sequence Impedances and Networks of Transformers, Construction of Sequence Networks of a Power System. ■

Module-4

Unsymmetrical Fault Analysis: Introduction, Symmetrical Component Analysis of Unsymmetrical Faults, Single Line-To-Ground (LG) Fault, Line-To-Line (LL) Fault, Double Line-To-Ground (LLG) Fault, Open Conductor Faults. ■

Module-5

Power System Stability: Introduction, Dynamics of a Synchronous Machine, Review of Power Angle Equation, Simple Systems, Steady State Stability, Transient Stability, Equal Area Criterion, Factors Affecting Transient Stability, Multi machine stability studies, classical representation. ■

Course Outcomes: At the end of the course the student will be able to:

- Model the power system components & construct per unit impedance diagram of power system.
- Analyze three phase symmetrical faults on power system.
- Compute unbalanced phasors in terms of sequence components and vice versa, also develop sequence networks.
- Analyze various unsymmetrical faults on power system.
- Examine dynamics of synchronous machine and determine the power system stability. ■

Question paper pattern:

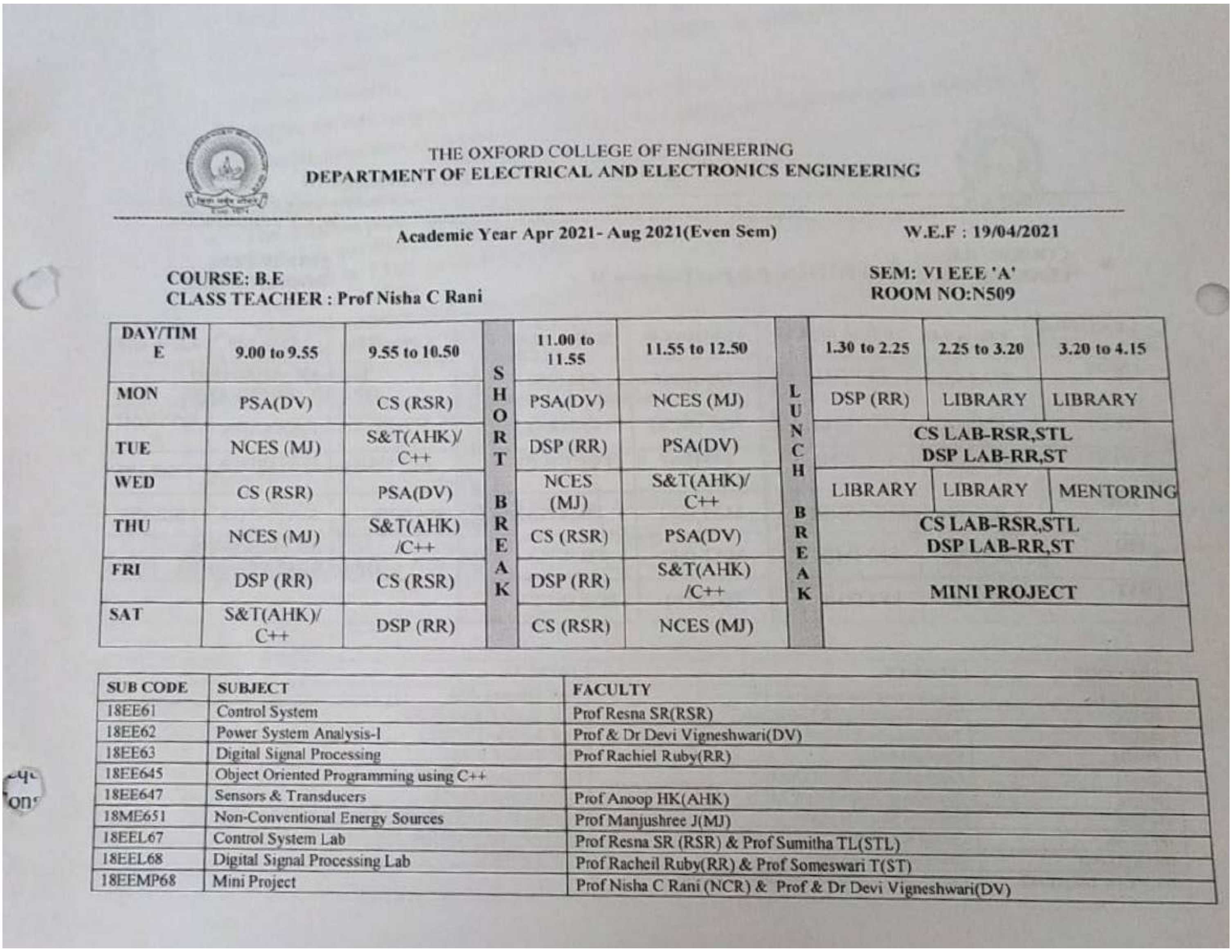
- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of three sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Text Book

1.	Elements of Power System	William D. StevensonJr	McGraw Hill	4th Edition, 1982

Reference Books

1	Modern Power System	D. P. Kothari	McGraw Hill	4th Edition, 2011
2	Power System Analysis and Design	J.Duncan Glover et al	Cengage	4th Edition, 2008
3	Power System Analysis	Hadi Sadat	McGraw Hill	1st Edition, 2002



THE OXFORD COLLEGE OF ENGINEERING

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

Academic Year Apr 2021- Aug 2021(Even Sem) W.E.F : 19/04/2021

COURSE: B.E
CLASS TEACHER : Prof Nisha C Rani

SEM: VI EEE 'A'
ROOM NO:N509

DAY/TIME	9.00 to 9.55	9.55 to 10.50		11.00 to 11.55	11.55 to 12.50		1.30 to 2.25	2.25 to 3.20	3.20 to 4.15
MON	PSA(DV)	CS (RSR)	SHORT BREAK	PSA(DV)	NCES (MJ)	LUNCH BREAK	DSP (RR)	LIBRARY	LIBRARY
TUE	NCES (MJ)	S&T(AHK)/ C++		DSP (RR)	PSA(DV)		CS LAB-RSR,STL DSP LAB-RR,ST		
WED	CS (RSR)	PSA(DV)		NCES (MJ)	S&T(AHK)/ C++		LIBRARY	LIBRARY	MENTORING
THU	NCES (MJ)	S&T(AHK) /C++		CS (RSR)	PSA(DV)		CS LAB-RSR,STL DSP LAB-RR,ST		
FRI	DSP (RR)	CS (RSR)		DSP (RR)	S&T(AHK) /C++		MINI PROJECT		
SAT	S&T(AHK)/ C++	DSP (RR)		CS (RSR)	NCES (MJ)				

SUB CODE	SUBJECT	FACULTY
18EE61	Control System	Prof Resna SR(RSR)
18EE62	Power System Analysis-I	Prof & Dr Devi Vigneshwari(DV)
18EE63	Digital Signal Processing	Prof Rachiel Ruby(RR)
18EE645	Object Oriented Programming using C++	
18EE647	Sensors & Transducers	Prof Anoop HK(AHK)
18ME651	Non-Conventional Energy Sources	Prof Manjushree J(MJ)
18EEL67	Control System Lab	Prof Resna SR (RSR) & Prof Sumitha TL(STL)
18EEL68	Digital Signal Processing Lab	Prof Racheil Ruby(RR) & Prof Someswari T(ST)
18EEMP68	Mini Project	Prof Nisha C Rani (NCR) & Prof & Dr Devi Vigneshwari(DV)

The Oxford College of Engineering
Bommanahalli, Bangalore-560068

LESSON PLAN
Academic Year: 2020-21

CLASS: VI SEM (A)	Course Instructors: Mrs.B.Devi Vighneshwari	Course Name: Power System Analysis – I	Course Code: 18EE62/17EE62/ 15EE62

COURSE OBJECTIVE:

To explain analysis of three phase symmetrical faults on synchronous machine and simple power systems.
To discuss selection of circuit breaker.
To explain symmetrical components, their advantages and the calculation of symmetrical components of voltages and currents in un-balanced three phase circuits.
To explain the concept of sequence impedance and its analysis in three phase unbalanced circuits.
To explain the concept of sequence networks and sequence impedances of an unloaded synchronous generator, transformers and transmission lines.
To explain the analysis of synchronous machine and simple power systems for different unsymmetrical faults using symmetrical components.
To discuss the dynamics of synchronous machine and derive the power angle equation for a synchronous machine
Discuss stability and types of stability for a power system and the equal area criterion for the evaluation of stability of a simple system.

PREREQUISITE(s) : Knowledge about Machines, Switch gear components

COURSE OUTCOME:

At the end of the course the student will be able to:
C362.1 – Show understanding of per unit system, its advantages and computation.
C362.2 - Perform short circuit analysis on a synchronous machine and simple power system to select a circuit breaker for the system.
C362.3 – Evaluate symmetrical components of voltages and currents in un-balanced three phase circuits.
C362.4 - Explain the concept of sequence impedance and sequence networks of power system components and power system.
C362.5 - Analyse three phase synchronous machine and simple power systems for different unsymmetrical faults using symmetrical components.
C362.6 - Discuss the dynamics of synchronous machine, stability and types of stability.

IT IS BASIC SUBJECT FOR: Electrical & Electronics Engineering

SUBJECT APPLICATIONS: Power Quality issues, Load flow analysis

Sl. No	Topics	Planned Date	Execution date	Deviation Due to (CL/UPL/OOD/ HOL/Other)	CO's (No. only)	PO's(No. only)	PSO's(No. only)	Remarks
				Module 1				
1	Representation of Power System Components: Introduction	19/04/21						
2	Single phase representation of balanced three phase networks, One line diagram	19/04/21						
3	Impedance or reactance Diagram	20/04/21			1,2	a,b,,c,d,e,i, j,l	1,2	
4	Problems	21/04/21						

5	Per unit system – problems	22/04/21						
6	Problems on per unit system	26/04/21						
7	Problems	26/04/21						
8	Problems	27/04/21						
9	Problems	28/04/21						
10	Steady state model of synchronous machine, Power transformer, Transmission	29/04/21						
11	Revision of Problems in Module 1	03/05/21						
12	Revision of Problems in Module 1	03/05/21						
13	Revision of Problems in Module 1	04/05/21						
			Module 2					
1	**Symmetrical Fault Analysis: Introduction**	05/05/21			2,3	a,b,c,d,e	1,2,3	
2	Transient Studies	06/05/21						
3	Short Circuit on no load	10/05/21						
4	Problems	10/05/21						
5	Short circuit on Loaded condition	11/05/21						
6	Problems	12/05/21						
7	Selection of Circuit Breakers	13/05/21						
8	Problems	17/05/21						
9	Problems on transient studies	17/05/21						
10	Problems on short circuit	18/05/21						
11	Revision of Problems in Module 2	19/05/21						
12	Revision of Problems in Module 2	20/05/21						
13	Revision of Problems in Module 2	31/05/21						
			Module 3					
1	Symmetrical Components: Introduction	31/05/21			3,4	a,b,c,d,e	1,3	
2	Symmetrical component transformation	01/06/21						
3	Phase shift in Star delta	02/06/21						

	Problems							
5	Sequence Impedance of transmission lines	03/06/21						
6	Sequence networks of Power system	07/06/21						
7	Sequence networks of machines	07/06/21						
8	Sequence networks of Transformers	08/06/21						
9	Problems on sequence networks	09/06/21						
10	Revision of Problems in Module 3	10/06/21						
11	Revision of Problems in Module 3	14/06/21						
12	Revision of Problems in Module 3	14/06/21						
		15/06/21						
			Module 4					
1	Unsymmetrical Fault Analysis: Introduction	16/06/21			5,6	b,e	1,2,3	
2	Symmetrical component analysis of unsymmetrical faults	17/06/21						
3	Single line to ground fault	21/06/21						
4	Problems	21/06/21						
5	Line to Line fault	22/06/21						
6	Problems	23/06/21						
7	Double Line to ground fault	24/06/21						
8	Problems	01/07/21						
9	Open conductor faults	05/07/21						
10	Problems	05/07/21						
11	Problems	06/07/21						
12	Revision of Problems in Module 4	07/07/21						
13	Revision of Problems in Module 4	08/07/21						
14	Revision of Problems in Module 4	12/07/21						
			Module 5					
1	**Power System Stability:** Introduction	12/07/21			5,6	b,e	1,2,3	
2	Dynamics of synchronous Machine	13/07/21						
3	Power angle – Salient pole	14/07/21						

4	Power angle problems	15/07/21						
5	Power Angle non salient pole	19/07/21						
6	Problems	19/07/21						
7	Steady state stability	20/07/21						
8	Problems	21/07/21						
9	Transient stability	22/07/21						
10	Question Paper Discussion - Module 1 &2	26/07/21						
11	Question Paper Discussion - Module 3 & 4	27/07/21						
12	Question Paper Discussion - Module 5	28/07/21						

ABBREVIATIONS: CL: Casual Leave; UPL: Unplanned Leave; OOD: On Office Duty; HOL: Unscheduled Holiday

1ST INTERNAL - 24/05/2021 - 26/05/2021
2ND INTERNAL - 28/06/2021 - 30/06/2021
3RD INTERNAL - 29/07/2021 - 31/07/2021

Activities planned for the Course

(Like Assignments, Tutorials, Class Test, Mini Projects, Lab exercise, Quiz, Seminar etc.)

Activity	**Unit**	**Planned date**	**Execution date**	**Remarks** (Mention the bridging of curriculum gap for the course)
Problems on Per unit calculations - by Simulink	Module 1	05/03/2020		
Problems on Symmetrical fault analysis - by Simulink	Module - 2	13/04/2020		
Problems on Unsymmetrical fault analysis - by Simulink	Module – 4	11/05/2020		

Literature to be referred for the Course:

Book Type	Code	*Title & Author*	*Publication Information*		
			Edition	Publisher	Year
Text Books	T1	Modern Power System Analysis by D.P.Kothari	4th	Mc Graw Hill	2011
	T2	Power system Analysis Hadisadat	1st	Mc Graw Hill	2002
Reference Books	R1	R1: Power System Analysis by V.Neelakantan	1st	Shiva Book Centre	2016
	R2	R2: Power System analysis by Nagoorkani	1st	RBA Publication	2013

Comments by Faculty:

Faculty in-charge

Comments by HOD:

HOD

ASSESSMENT PLAN / PROCESS:

- The additional activities like assignments, tutorial classes, additional/class test, mini-projects, seminars, quiz, group discussion, project making, technical article, lab exercise, educational CD's/ video etc. are planned during the course by the course instructor to bridge the curriculum gap identified for the course.
- Feedback for the activity conducted by the course instructor will be taken and assessed as follows: 1. Low 2. Medium 3. High.
- The course instructor needs to map the activity with CO's, PO's/PSO's. in the correlation matrix.

QUESTIONNAIRE FOR FEEDBACK

1) Usefulness of the activity in terms of understanding:

a) Concepts/ Design/ Problem analysis
1. Low 2. Medium 3. High

b) Communication/ Presentation skills
1. Low 2. Medium 3. High

c) Working as team/ Individual
1. Low 2. Medium 3. High

Approved By

NBA coordinator

Principal

C Education Society ®
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(Approved by AICTE, New Delhi, Accredited by NBA, New Delhi & Affiliated to VTU, Belgaum)

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

ELIGIBILITY LIST of VI semester EEE (A section)- Academic year 2020-21

SI NO	USN	NAME
1	1OX18EE001	A.S JEEVITHA
2	1OX18EE002	AKHILA B.G
3	1OX18EE004	AKSHAY KUMAR B S
4	1OX18EE005	AMITH K N
5	1OX18EE006	ANURAG TIWARI
6	1OX18EE008	ASHWINI M R
7	1OX18EE009	THRIGUNYESHWARI
8	1OX18EE011	D PALLAVI
9	1OX18EE012	DARSHAN K B
10	1OX18EE013	DEEPA K
11	1OX18EE014	DILDAR BASHIR KUMAR
12	1OX18EE015	G SANJAYRAJU
13	1OX18EE016	GAGANA S M
14	1OX18EE018	GURURAJ
15	10X18EE021	HARSHITH J G
16	1OX18EE023	KARTHIK G
17	1OX18EE024	KHAN SHADAB SARFARAZ
18	1OX18EE025	KOUSHIK BABU REDDY B
19	1OX18EE026	KUMAR P
20	1OX18EE027	KUSHAL R S
21	1OX18EE028	KUSUMA G NAIK
22	1OX18EE030	MALLESH K
23	1OX18EE031	MANIK BELURE
24	1OX18EE032	MANOJ R
25	1OX18EE034	NAVEEN C
26	1OX18EE040	NITHYA N
27	1OX18EE062	SUHARSHA L
28	1OX18EE063	SURAJ R
29	1OX18EE061	SUDARSHAN BHAT
30	1OX18EE066	SUSHMA BILIDALE
31	1OX16EE409	MANJULA
32	1OX19EE402	GOUTHAM M R

33	1OX19EE404	KOUSHIK K NAIK
34	1OX19EE406	NOOTAN SURESH D
35	1OX15EE004	ALDRIN LEONARD VIPIN. B
36	1OX17EE009	AMAN SINGH R
37	1OX17EE018	DHANUSH J
38	1OX17EE038	MOHAMMED MUBARAK
39	1OX18EE401	LOKESH
40	1OX18EE405	RAGHUNANDAN

Children's Education Society ®

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DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

ELIGIBILITY LIST of VI semester EEE (B section)- Academic year 2020-21

SLNO	USN	NAME
1	1OX18EE003	AKSHATA
2	1OX18EE017	GOVARDHAN REDDY H
3	1OX18EE019	HARIKRISHNA P.A
4	1OX18EE020	HARSHAVARDHANA REDDY.KS
5	1OX18EE035	NAVYA
6	1OX18EE037	NISHA H N
7	1OX18EE041	PAVITHRA
8	1OX18EE042	POOJA M
9	1OX18EE043	POOJA
10	1OX18EE044	PREETHI B
11	1OX18EE045	RAKESH NAIK K
12	1OX18EE046	RAKSHITHA S
13	1OX18EE047	RISHIKA S R
14	1OX18EE049	ROHIT NAYAK S
15	1OX18EE050	ROSHAN S TELIGI
16	1OX18EE051	SAHANA
17	1OX18EE052	SANDEEP K
18	1OX18EE053	SANJANA K G

19	1OX18EE054	SATHISH REDDY N
20	1OX18EE055	SHASHI KUMAR M
21	1OX18EE057	SHIVAPRASAD L KULKARNI
22	1OX18EE058	SINGAMSETTI JAYAHARI
23	1OX18EE059	SNEHA V
24	1OX18EE064	SURYA B
25	1OX18EE065	SUSHMA S
26	1OX18EE067	VIDYA SHREE J
27	1OX18EE068	VIJETHA M G
28	1OX18EE069	VIKRANT
29	1OX18EE070	YATHEESH M
30	1OX18EE071	YOUSUF AHMED
31	1OX17EE066	SUPRIYA A J
32	1OX17EE047	PREETHA S
33	1OX19EE400	ABHILASH D S
34	1OX19EE401	AISHWARYA A K
35	1OX19EE403	JAVERIYA SADAF
36	1OX19EE405	MAMATHA G
37	1OX15EE103	VINUSHA N
38	1OX16EE041	NIKHIL ARALI
39	1OX16EE043	POORNA CHANDRA
40	1OX16EE053	RAKSHITH R

15EE62/18EE62/17EE62 - PSA-2

MODULE-1

Representation of Power System Components:-

- → Introduction
- → Single Phase Representation of Balance three Phase Networks
- → One Line Diagram
- → Impedance Diagram
- → Reactance Diagram
- → Perunit (PU) System
- → Steady State Model of Synchronous Machine
- → Power Transformes
- → Transmission of Electrical Power Lines
- → Representation of Loads

Dec 2018/Jan 2019

Page No 7-8 1ⓐ Show that the pu Impedance of a T/F is the Same when refered to either py (or) Sy side [4 Marks].

Page no 32-39 1ⓑ Draw the Circuit Model of synchronous Gen, Transmission line and Transformes [4 Marks]-

Page No 5&6 2ⓐ What is perunit Quantity? Mention its advantages [4 Marks]

Page 6&7 2ⓑ How is the Perunit Impedance Value in a given base are Changed to per unit Impedance on new base [4 Marks]

June/July 2019

1ⓐ Same as 1ⓐ [6 Marks]-in above Q paper

2ⓐ Same as 2a in above QP [4 Marks]

June/July 2018

Page 3&4 1ⓐ With suitable example explain one single line diagram and discuss the elements represented [6 Marks]

Page 3&4 ⓑ With the help of typical electrical power system explain Impedance & Reactance diagram & mention its assumptions made [6 Marks].

Dec 2019/ Jan 2020

1(a) Define Per unit quantity. Mention the advantages Of Per unit System [4 Marks] page 5&6

1(b) Show that the Per unit impedance of a Transformer remains same whether it is referred to HV or LV winding [4 marks]. page 7&8

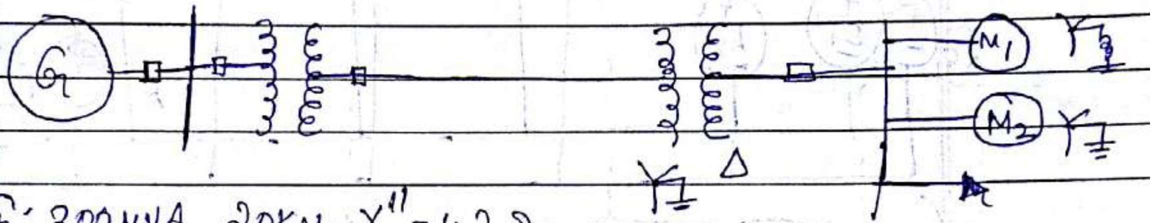
2(a) Draw Single Line diagram of a power System Indicating the Various components of it. Obtain the impedance diagram and Reactance Diagram. Explain each Component and the assumptions Made to draw the reactance diagram. (8 Marks). page 3&4

One Line Diagram

Definition:-

One line diagram (or) Single line diagram do not show all the three phases. It consist of one of the three lines and a neutral return. Also the diagram represents the components of the system by standard symbols rather than by their equivalent circuits.

Eg:-



G: 300MVA, 20KV, $X'' = 1.2\,\Omega$

T1: 350MVA, 230V-Y/20KV-Δ, $X = 15.2\,\Omega/Ph$.

T2: 300 MVA, 230V-Y/13.2KV-Δ, $X = 16\,\Omega/Ph$.

TL: $l = 64\,Km$; $X_{TL} = 0.5\,\Omega/Km$

M1: 200MVA, 13.2KV, $X'' = 1.6\,\Omega$

M2: 100MVA, 13.2KV, $X'' = 1.6\,\Omega$

Static Load:

Impedance Diagram

The impedance diagram is obtained by replacing each component of the power system by its single phase equivalent circuit.

Use:-

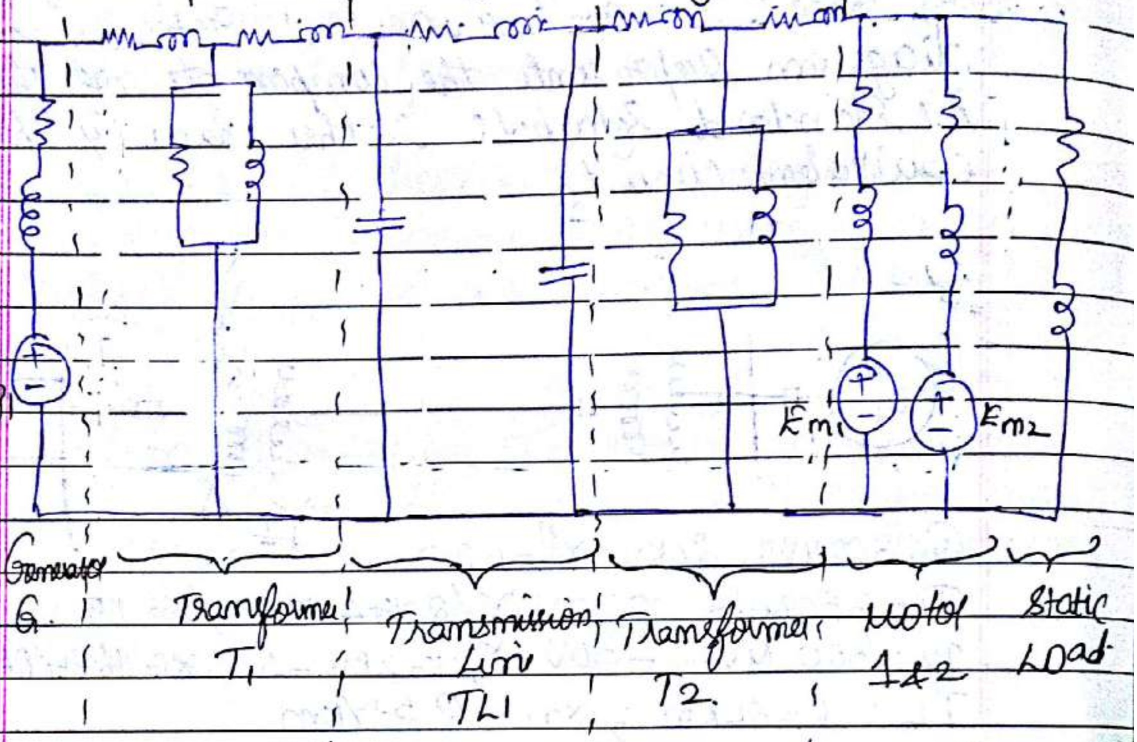
i) To calculate the performance of a system under load conditions (or) upon the occurrence of a fault.

Assumptions made:-

i) Resistance and reactance used for grounding the neutral of the generator is not shown - Assumption made is :- During balanced state no current flows through the neutral

③

Eg:- For the above one line diagram the Impedance diagram is given below.



Reactance Diagram

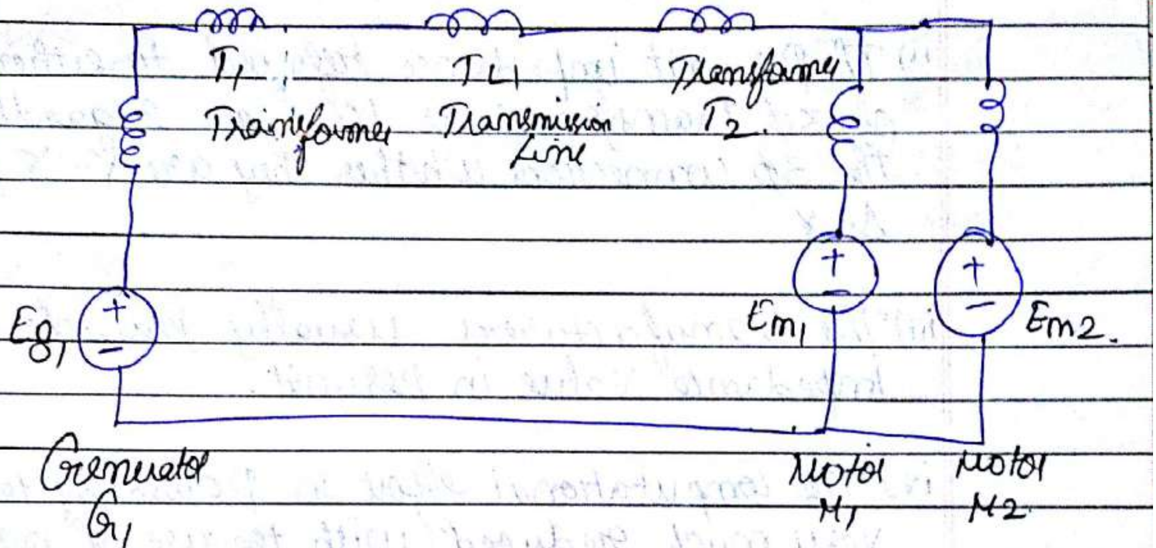
Assumptions Made:-

i) While doing fault calculations, resistance values can be omitted, since the impedance is not so different from the inductive reactance as the resistance is small.

ii) Loads which do not involve rotating machinery have little effect on the total line current during a fault and hence they are omitted.

iii) Magnetizing components of transformers are also neglected as magnetizing ~~current~~ current is less compared to full load current

(iv) The capacitance of the transmission line is also neglected as only less current will flow through the capacitance.



PER UNIT SYSTEM

Per unit value of any quantity is defined as

$$P.U = \frac{\text{Actual Value of the quantity}}{\text{Base (or) Reference Value of the given quantity.}}$$

Eg If $I_{Base} = 100 A$

$I_{current\ Actual} = 80 A$.

$$I_{pu} = \frac{80}{100} = 0.8 \text{ pu}.$$

Advantages of Per unit System:-

i) The Per unit impedance Refered to either side of a single Phase Transformer is the Same.

ii) The Per unit impedance refered to either side of 3ϕ Transformer is the Same regardless of the 3ϕ connections whether they are Y-Y, Δ-Δ, Δ-Y

iii) The Manufacturers usually Provide the impedance value in per unit.

iv) The Computational effort in Power system is very much reduced with the use of per unit quantities.
Eg Calculation manually is simple as Per unit values are < or close to 1.

(v) Line to Phase or Phase to Line Conversions are reduced.

Changing the base of Per unit Quantities

If the values given are already in pu values refered by their own ratings, then to convert them to the selected base values.

$$Z_{pu\,given} = \frac{Z_{actual}}{Z_{Base}} = \frac{Z_{actual}}{\frac{V_{Base\,given}^2}{S_{Base\,given}}} \quad ①$$

$$Z_{Base} = \frac{V_{Base}}{I_{Base}} = \frac{V_{Base}}{\frac{S_{Base}}{V_{Base}}} = \frac{V_{Base}^2}{S_{Base}}$$

III^ly $$Z_{punew} = \frac{Z_{actual}}{Z_{Basenew}} = \frac{Z_{actual}}{\frac{(V_{Basenew})^2}{S_{Basenew}}} \quad ②$$

$$\div \frac{②}{①}$$

$$\frac{Z_{punew}}{Z_{pugiven}} = \frac{\frac{Z_{actual}}{(V_{Basenew})^2} * S_{Basenew}}{\frac{Z_{actual}}{V_{Basegiven}^2} * S_{Basegiven}}$$

$$\boxed{Z_{punew} = Z_{pugiven} * \frac{S_{Basenew}}{S_{Basegiven}} * \frac{V_{Basegiven}^2}{V_{Basenew}^2}}$$

Show that the Perunit impedance of a Transformer is the same irrespective of the side on which it is Calculated [Pu Impedance referred to Py = Pu Impedance referred to Sy].

Let S_B = Rated MVA of the Transformer
V_{B1} = Base voltage in the primary side.
V_{B2} = Bar voltage in the Secondary side.

Z_{eq1} = Impedance refered to primary side.

Z_{eq2} = Impedance refered to secondary side.

$$Z_{eq1\,pu} = Z_{eq1\,in\,\Omega} * \frac{S_B}{V_{B1}^2} \quad — ①$$

and $$Z_{eq2\,pu} = Z_{eq2\,in\,\Omega} * \frac{S_B}{V_{B2}^2} \quad — ②$$

By Transformation ratio,

$$Z_{eq2}(\text{in }\Omega) = Z_{eq1}(\text{in }\Omega) * \frac{V_{B2}^2}{V_{B1}^2} \quad — ③$$

Sub ③ in ②

$$Z_{eq2}(pu) = \left[Z_{eq1}(\text{in }\Omega) * \frac{V_{B2}^2}{V_{B1}^2} * \frac{S_B}{V_{B2}^2} \right]$$

$$= Z_{eq1}(\text{in }\Omega) * \frac{S_B}{V_{B1}^2}$$

= eq ①

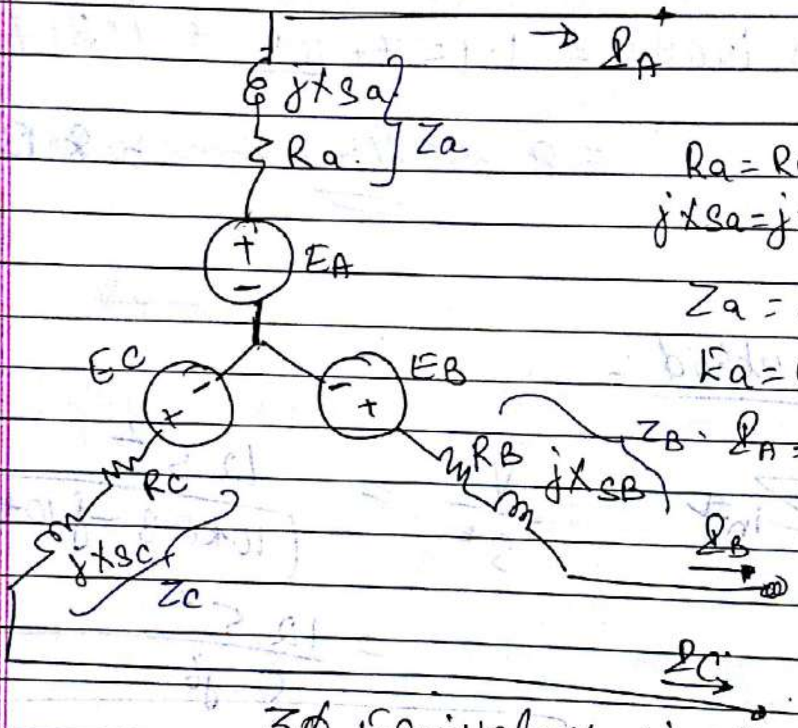
Hence proved.

$$\boxed{Z_{eq2}(pu) = Z_{eq1}(pu)}$$

Steady State models of Synchronous Machines

Generator

It consists of a source representing induced emf per phase, a series reactance representing the armature reactance and leakage reactance and a series resistance representing the armature winding.



$R_a = R_B = R_C = R_a$

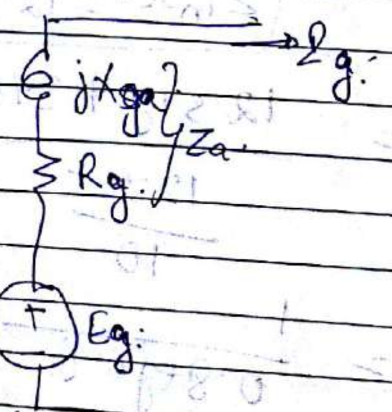
$jX_{sa} = jX_{sb} = jX_{sc} = jX_{sa}$

$Z_a = Z_B = Z_C = Z_a$

$E_a = E_b = E_c = E_a$.

$I_A = I_B = I_C = I_A$

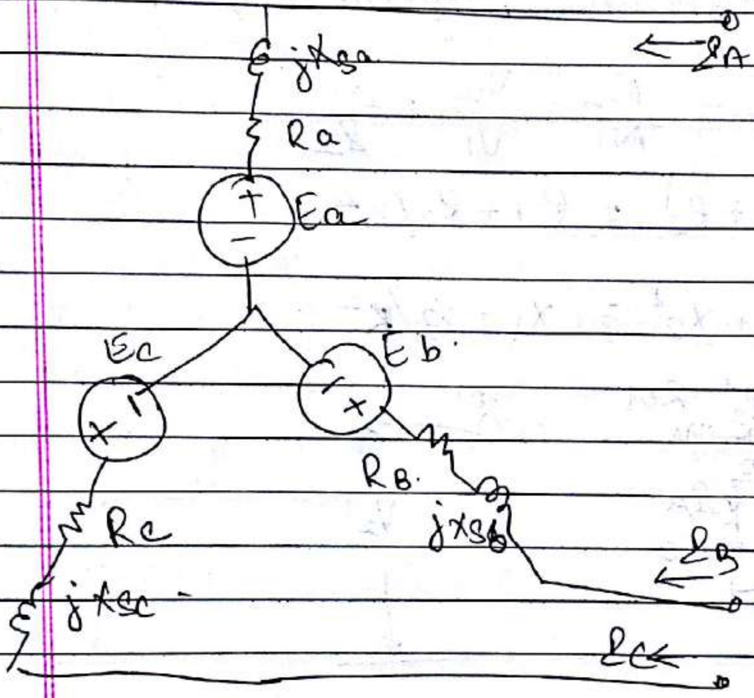
3φ Equivalent circuit



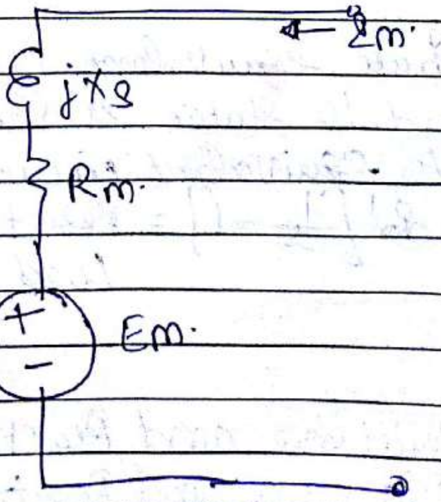
1φ Equivalent circuit.

MOTOR

The Synchronous Motor is similar to a generator in Constuction, but it performs the reverse, action of the generator. A generator converts mechanical energy to electrical energy, but the motor converts electrical energy to Mechanical energy. Therefore the direction of current in motor is opposite to that of Generator



3ϕ Equivalent of Motor



1ϕ Equivalent of Motor

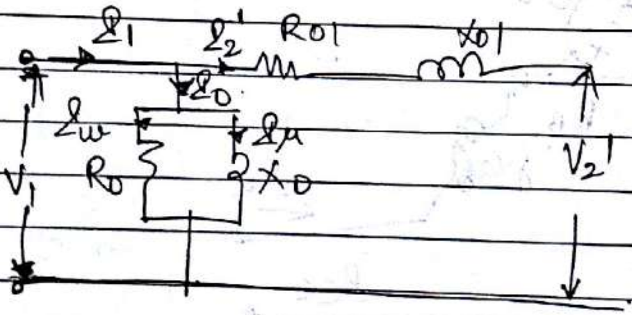
Transformer

The equivalent circuit of a 1ϕ, two winding transformer refered to primary. It consists of shunt branches to represent magnetising current and core loss, series resistance representing winding resistance refered to primary and the series reactance representing leakage reactance refered to primary.

$$K = \frac{E_2}{E_1} = \frac{N_2}{N_1} = \frac{V_2}{V_1} = \frac{I_1}{I_2}$$

$$R_{01} = R_1 + R_2' = R_1 + R_2/K^2$$

$$X_{01} = X_1 + X_2' = X_1 + X_2/K^2$$



Induction Motor

The single phase equivalent circuit of Induction motor refered to stator is shown in figure. It is similar to equivalent circuit of Transformer.

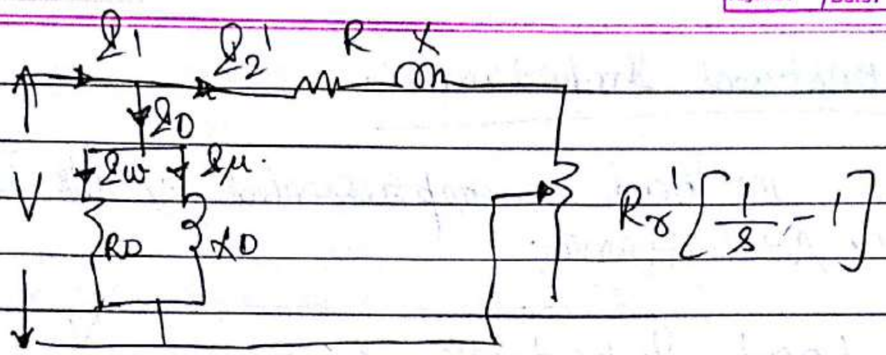
S = Slip $R_r'\left[\frac{1}{s} - 1\right]$ = Resistance Representing Load.

$R = R_s + R_r'$

$X = X_s + X_r'$

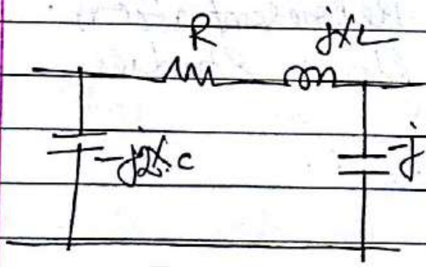
R_s, X_s = Resistance and Reactance of Stator

R_r, X_r = Resistance and Reactance of Rotor.

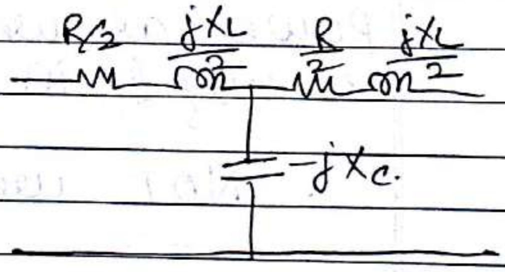


Transmission Line

The transmission line can be represented by it's resistance, Inductance and capacitance. The 1Ø equivalent π-type and T-type model of the transmission line is shown in figure. The elements R, X_L and X_c are resistance, Inductive Reactance and capacitive Reactance per phase Respectively.



π-Type.



T-Type.

Representation of Resistive & Reactive Loads

The resistive and Reactive Loads can be represented in the equivalent circuit by any one of the

I Constant Power Representation
II Constant current Representation
III Constant Impedance Representation.

Constant Impedance:-

The load is represented by it's Impedance (or) Admittance.

$$\text{Load Impedance}, Z = V/I = \frac{V}{\frac{S^*}{V}} = \frac{V^2}{S^*}$$

Where $S = P + jQ$.

$$|||^{ly} \text{ Load Admittance} = \frac{1}{Z} = \frac{S^*}{V^2}.$$

(Used by Series (or) parallel representation)
Refer Problems ⑦

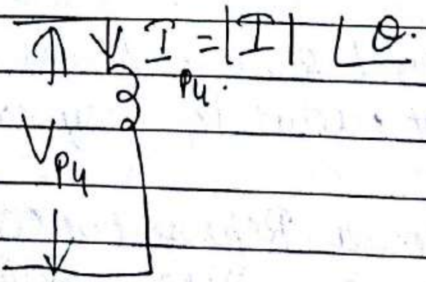
Constant power:-

The Load active power and reactive Power are used for Representation. This is useful in Load flow Studies

" NOT used here ".

Constant current:-

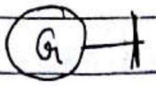
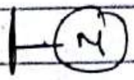
$$I = \frac{S^*}{V} = \frac{P - jQ}{V}.$$

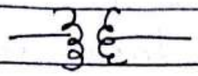


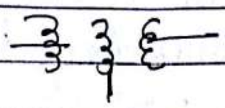
Load is Represented in terms of Magnitude of current

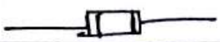
[Refer Problem -4]

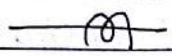
Symbols used in One Line Diagram :-

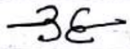
1) Rotating M/C →  (or) 

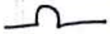
2) Two winding T/f → 

3) Three Winding T/f → 

4) Fuse → 

5) Current T/f → 

6) Potential T/f → 

7) Circuit Breaker →  (or) 

8) Delta Connection → Δ

9) Star Connection → Y

10) Star with grounded → 

11) Static Load → 

12) Bus Bar → 

Three Winding Transformer

In addition to the primary and secondary winding, the transformer may be constructed with a third winding called tertiary winding. In three winding transformers, the two windings are connecting in star and one winding in delta (or two windings in delta and one winding in star.

Purpose of Tertiary winding:-

i) To get supply voltage for the substation auxiliary devices.

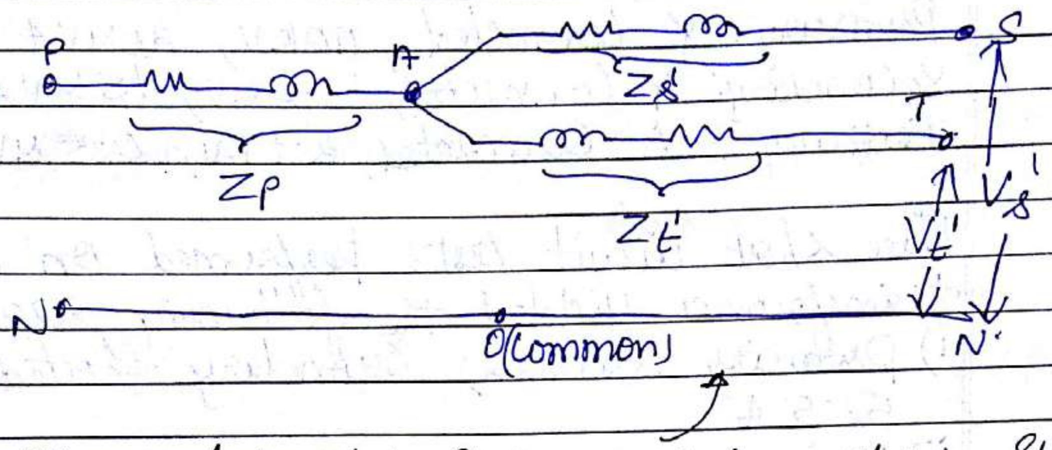
ii) Static capacitors (or) Synchronous condensers may be connected to the tertiary winding for reactive power injection into the system for voltage control.

iii) A delta connected tertiary reduces the impedance offered to the zero sequence currents thereby allowing a large earth fault current to flow for proper protection of protective equipments. Further it limits voltage imbalance when the load is unbalanced. It also permits the third harmonic current to flow thereby reducing third harmonic voltages. For these reasons the tertiary winding is also called stabilization winding.

iv) Three windings may be used for interconnecting 3 transmission line at different voltages.

v) Tertiary can serve the purpose of measuring voltage on a HV testing T/F.

Single phase equivalent of 3 wdg T/F



All are referred to Primary & Connected in Star

Z_p - Impedance of Primary Winding

Z_s' - Impedance of Secondary Winding referred to py.

Z_t' - Impedance of Tertiary winding referred to py.

Z_{ps} = Leakage Impedance Measured in py with secondary Short circuited & tertiary open.

Z_{pt} = Leakage Impedance Measured in py with tertiary Short circuited and Secondary open

Z_{st}' - Leakage Impedance Measured in Secondary with tertiary short circuited and Primary open and then referred to Primary.

$$Z_{ps} = Z_p + Z_s' \quad \text{—①}$$

$$Z_{pt} = Z_p + Z_t' \quad \text{—②}$$

$$Z_{st}' = Z_s' + Z_t' \quad \text{—③}$$

① + ② − ③ yield, ⇒ $Z_{ps} + Z_{pt} - Z_{st}' = 2Z_p$

$$\boxed{Z_p = \frac{1}{2}\left(Z_{ps} + Z_{pt} - Z_{st}'\right)}$$

①+③−② gives

$Z_{ps} + Z_{st}' - Z_{pt} = 2Z_s'$

$$\boxed{Z_s' = \frac{1}{2}\left[Z_{ps} + Z_{st}' - Z_{pt}\right]}$$

$$\text{111}^{ly}\ \boxed{Z_t' = \frac{1}{2}\left[Z_{st}' + Z_{pt} - Z_{ps}\right]}$$

⑮ The three phase ratings a a 3-winding Transformer are

Primary: Y Connected, 110kV, 20MVA
Secondary: Y Connected, 13.2kV, 15MVA
Tertiary: Δ Connected, 2.1kV, 0.5MVA

Three short circuit tests performed on this transformer yielded the following results

i) primary excited, secondary shorted: 2290V, 52.5A
ii) Primary excited, Tertiary Shorted: 1785V, 52.5A
iii) Secondary excited, Tertiary Shorted: 148V, 32.8A.

Find the pu impedances of the Star Connected single phase equivalent circuit for a base of 20MVA, 110kV in the primary circuit. Neglect resistance.

Solution :-

i) Zps [Primary excited tertiary opened, Secondary shorted

$$Z_{ps} = \frac{V_L/\sqrt{3}}{I_{ph}} = \frac{2290/\sqrt{3}}{52.5} = 25.1835\,\Omega/ph. \quad \Big\}\ Y\ V_{ph} = V_L/\sqrt{3}$$

(ii) Py excited Ty shorted, Sy open $Z_{pt} = \frac{1785/\sqrt{3}}{52.5}$
Py is star
$= 19.6299\,\Omega/ph.$

(iii) Sy excited, Ty SC, Py open $Z_{st} = \frac{148/\sqrt{3}}{32.8}$
$= 0.2605\,\Omega/ph$

$$Z_{ps}\ \text{in pu} = \frac{25.1835}{Z_{Base\,in\,pu}} = \frac{25.1835}{\frac{110^2}{20}} = 0.0416\,pu.$$

$$Z_{pt} = \frac{19.6299}{\frac{110^2}{20}} = 0.0324\,pu$$

~~Zsy in~~ Z_{st} in pu $= \frac{Z_{st}}{Z_{Base,sy}} = \frac{0.2605}{\frac{13.2^2}{20}}$

$= 0.0299\,pu$

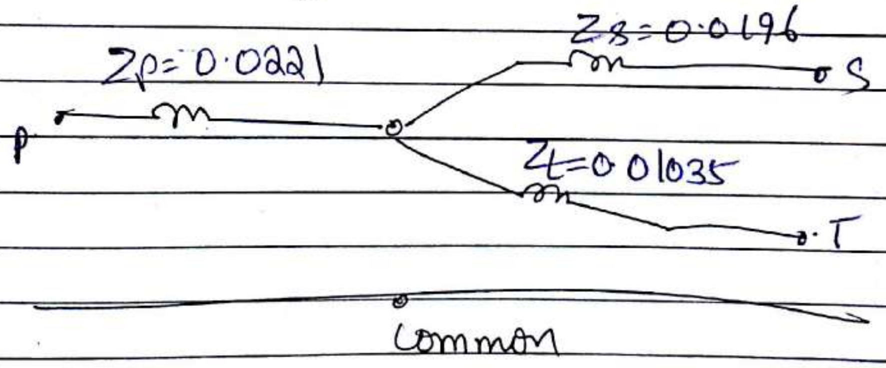
Equivalent Impedance:-

$$Z_p = \frac{1}{2}\left[Z_{ps} + Z_{pt} - Z_{st}'\right]$$

$$= \frac{1}{2}\left[0.0416 + 0.0324 - 0.0299\right] = 0.0221\,pu$$

$$Z_s' = \frac{1}{2}\left[0.0416 + 0.0299 - 0.0324\right] = 0.0196\,pu$$

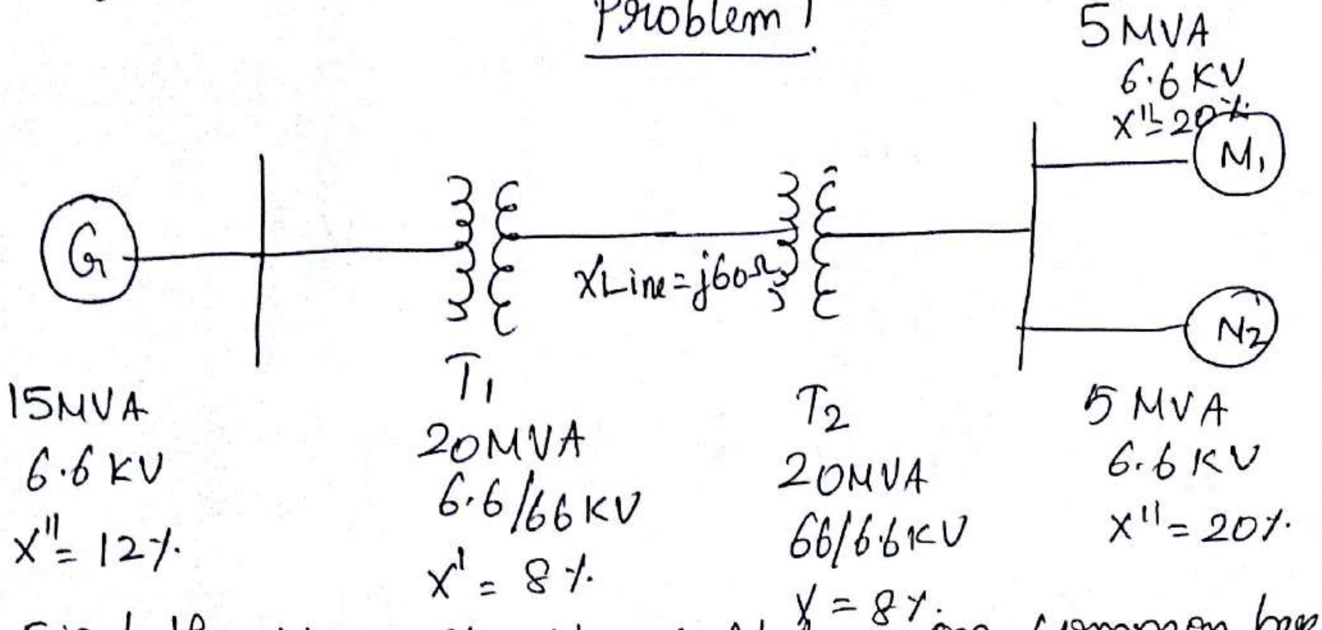
$$Z_t' = \frac{1}{2}\left[0.0324 + 0.0299 - 0.0416\right] = 0.01035$$



← MODULE-1 Completed →

Single Line Diagram – Base Value Calculation

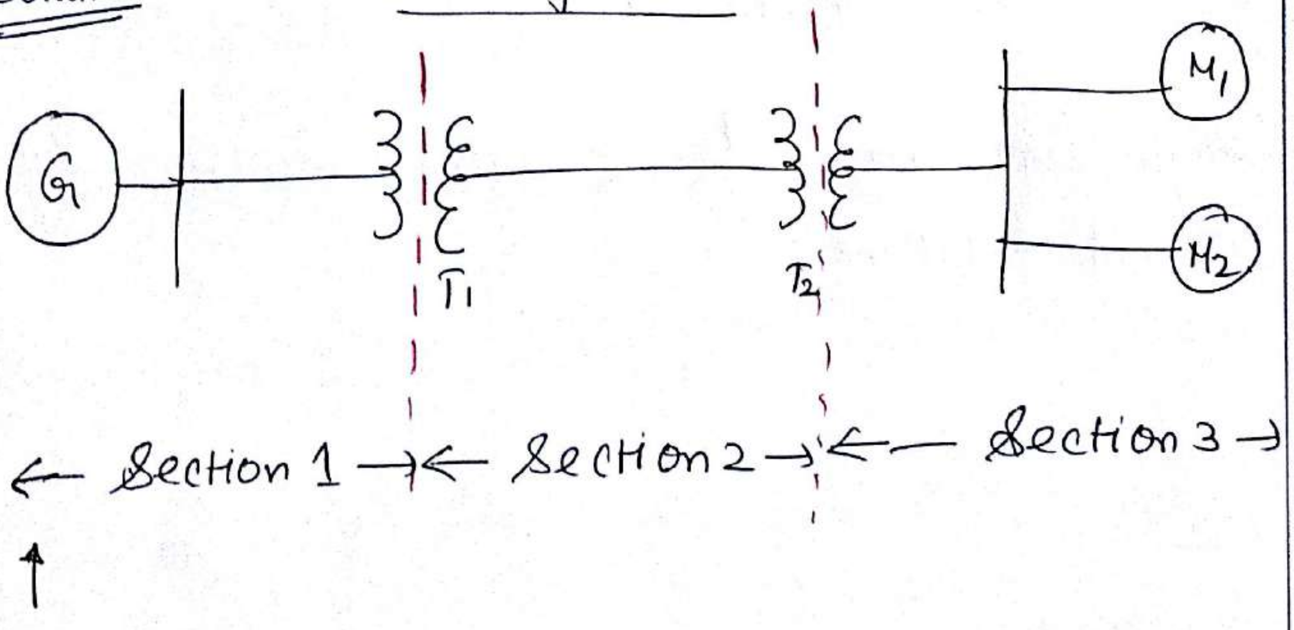
Problem 1



Find the New Reactance Values on common base.

Solution

Dividing Section



Default

generator becomes the base value (ie) $S_B = 15MVA$

$V_B = 6.6KV$.

Section 1	Section 2	Section 3
$S_B = 15 MVA$	$S_B = 15 MVA$	$S_B = 15 MVA$
$V_B = 6.6 KV$	$V_B = 66 KV$	$V_B = 6.6 KV.$

T1 6.6/66KV $V_B = 66 KV$ T2 66/6.6KV $V_B = 6.6 KV$

Step2:- **Section 1**

Generator - 1 :- G1 : 15 MVA, 6.6 KV $x'' = 12\% = 0.12$ [Given / old values].

$$X''_{g1}(new) = X''_{g1}(old/given) * \frac{S_{Bnew}}{S_{Bold}} * \frac{(V_{Bold})^2}{(V_{Bnew})^2}.$$

$$= 0.12 * \frac{15 MVA}{15} * \frac{6.6^2}{6.6^2}.$$

$$= 0.12 \text{ pu}.$$

Transformer (Py. - Primary) lies in Section 1

Transformer 1 (Sy - Secondary) lies in Section 2.

Step3:- Primary Side - Section 1

old $\{ T_1 = 20MVA$; 6.6 KV Py Side Voltage , $X_{t1} = 8\% = 0.08pu$.

New $\{$ Section 1 - Base MVA $S_B = 15MVA$; $V_B = 6.6KV$

$$X_{t1}\,new = X_{t1}(old) * \frac{S_B new}{S_B old} * \frac{V_B old^2}{V_B new^2}.$$

$$= 0.08pu * \frac{15}{20} * \frac{6.6^2}{6.6^2}.$$

$$= j0.06pu.$$

Secondary Side - Present in Section 2.

old $\{ T_1 = 20MVA$; 66KV Sy Side Voltage ; $X_{t1} = 8\% = 0.08pu$

New $\{$ Section 2 - Base MVA, $S_B = 15MVA$ $V_B = 66KV$.

$$X_{t1}new = X_{t1}(old) * \frac{S_B new}{S_B old} * \frac{V_B old^2}{V_B new^2}.$$

$$= 0.08 * \frac{15}{20} * \frac{66^2}{66^2}.$$

$$= j0.06pu$$

Step4 :- Transmission line — Lies in Section 2.

$X_{Line} = j60\Omega$ $\quad$ (X) Given in Ω.

For Ω. formula is :-

$$X_{Line}(pu) = \frac{X_{Line}(actual)}{X_{Line}(base)}$$

$$X_{Line\,base}(\Omega) = \frac{V_{Base}^2}{S_{Base}} = \frac{66^2}{15} = j290.4\Omega.$$

$$X_{line}(actual)(\Omega) = j60\Omega.$$

$$X_{Line\,pu} = \frac{j60}{j290.4} = \underline{\underline{j0.207\,pu.}}$$

Step5:- ~~Motors M1, M2 both have same rating~~

Transformer T_2 → Py Lies in Section2

→ Sy Lies in Section1.

T2 Py :- 20MVA, 66 KV $X = 8\% = 0.08$.

Section 2 base ⇒ 15MVA, 66 KV.

$$X\,T_2\,new = 0.08 * \frac{15}{20} * \frac{66^2}{66^2} = j0.06\,pu.$$

Step6:-

Reactance of Motors M1, M2.

Both Motors are in Section-3, Ratings are Same

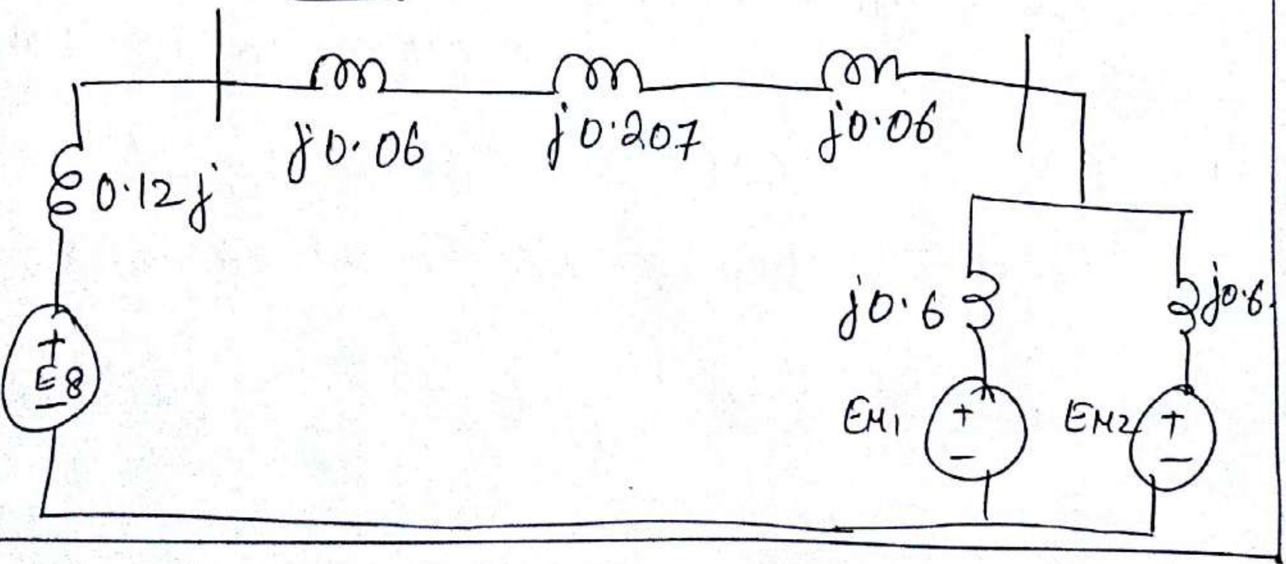
$\therefore$ M_1, M_2 : 5MVA, 6.6KV, $X'' = 20\% = 0.2$ } old value

Section-3 (base) => $S_B = 15 MVA$ $V_B = 6.6 KV$

$$\left.\begin{matrix} X''_{M1}\,new \\ (or) \\ X''_{M2}\,new \end{matrix}\right\} = X_{mold} * \frac{S_{Bnew}}{S_{Bold}} * \frac{V_{Bold}^2}{V_{Bnew}^2}$$

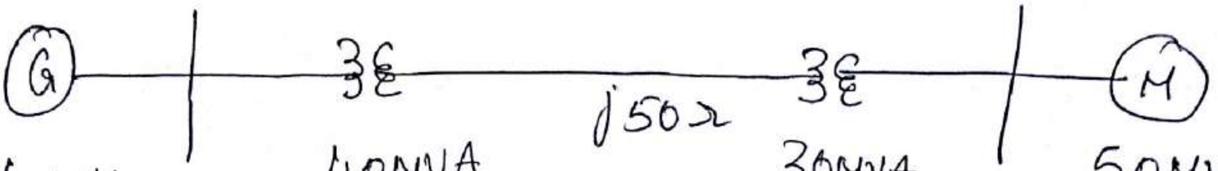
$$= 0.2 * \frac{15}{5} * \frac{6.6^2}{6.6^2}$$

$$= \underline{j0.6pu}$$



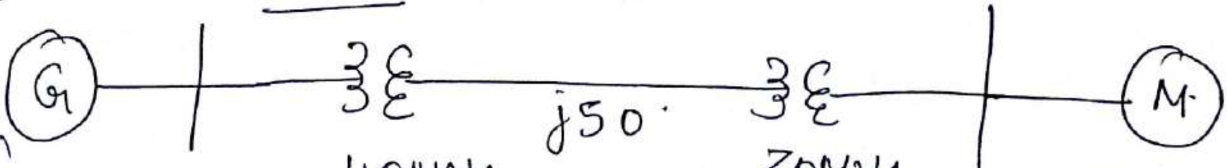
Problem-2:

Draw the perunit impedance diagram for the Power System Shown below. use 100MVA, 220KV in 50Ω line base.



40MVA	40MVA	30MVA	50MVA
25KV	33/220KV	220/11KV	11KV
X = 20%	X = 15%	X = 15%	X = 30%

Solution :- Step1



Given (or) old Values	40MVA	40MVA	30MVA	50MVA
	25KV	33/220KV	220/11KV	11KV
	X = 20%	X = 15%	X = 15%	X = 30%
	= 0.20	= 0.15	= 0.15	= 0.30

Step2

	Section 1	Section2	Section 3
		Base is given for Section-2 is 50Ω Line	
New Values	$S_B = 100MVA$	$V_B = 220KV$	$S_B = 100MVA$
	$V_B = 33KV$	$S_B = 100MVA$	$V_B = 11KV$.

33/220KV.   220/11KV

Step 3:- Section 1 :- $S_{Bnew} = 100MVA$

$V_{Bnew} = 33\ KV.$

$$X_{g1(new)} = X_{g1}(\text{given (pu) old}) * \frac{S_{Bnew}}{S_{B(old)}} * \left(\frac{V_{Bold}}{V_{Bnew}}\right)^2$$

$$= 0.20 * \frac{100}{40} * \left(\frac{25}{33}\right)^2$$

$$= 0.2869\ pu$$

For T1 -> consider primary side it is in Section 1.

$$X_{T1(new)} = 0.15 * \frac{100}{40} * \left(\frac{33}{33}\right)^2$$

$$= 0.375\ pu.$$

Step 4: Section 2 - $S_{Base\,new} = 100MVA$

$V_{Base\,new} = 220KV.$

Transmission line lies in Section 2.

$$X_{L1(new)} = \frac{j50\Omega}{X_{Base}} = \frac{X_{Actual/given}}{X_{Base\ of\ that\ section}} = \frac{X_{(Actual/given)}}{\frac{V^2_{Base\,new}}{S_{Base\,new}}}$$

$$= \frac{j50}{\frac{220^2}{100}} = 0.1033\ pu.$$

Py of Transformer-2 lies in Section 2.

$$X_{T2(new)} = 0.15 * \frac{100}{30} * \frac{220^2}{220^2} = 0.5\ PU.$$

Steps:- **Section-3** $S_{Bnew} = 100MVA$

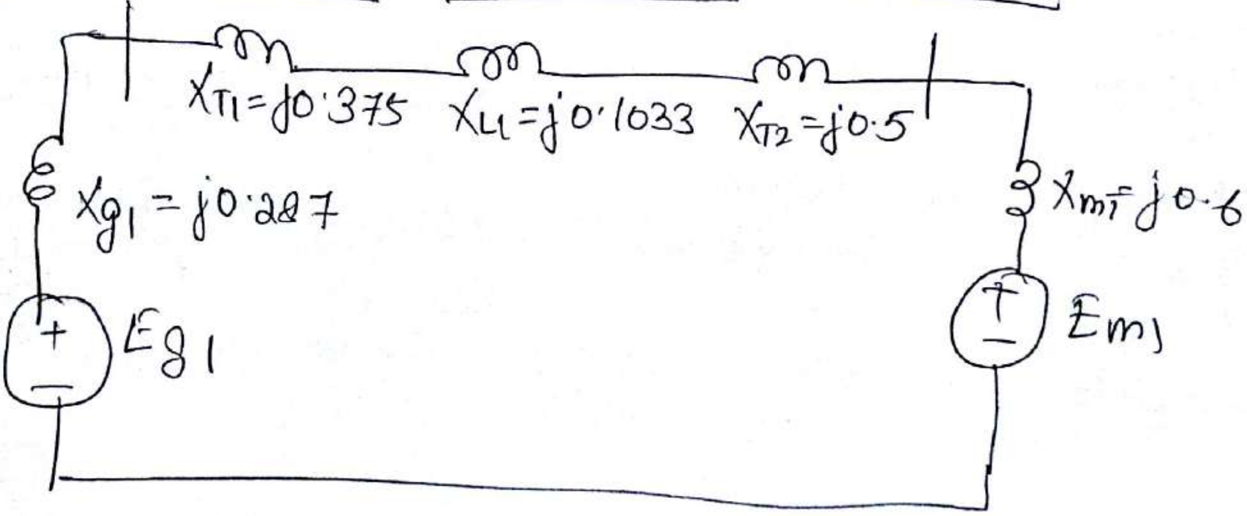
$V_{BaseNew} = 11kV$.

Motor lies in Section-3.

$$\therefore X_{m_1 (new)} = 0.30 * \frac{100}{50} * \left(\frac{11}{11}\right)^2.$$

$$= \underline{\underline{0.6 pu}}$$

Perunit Reactance / Impedance Diagram:-



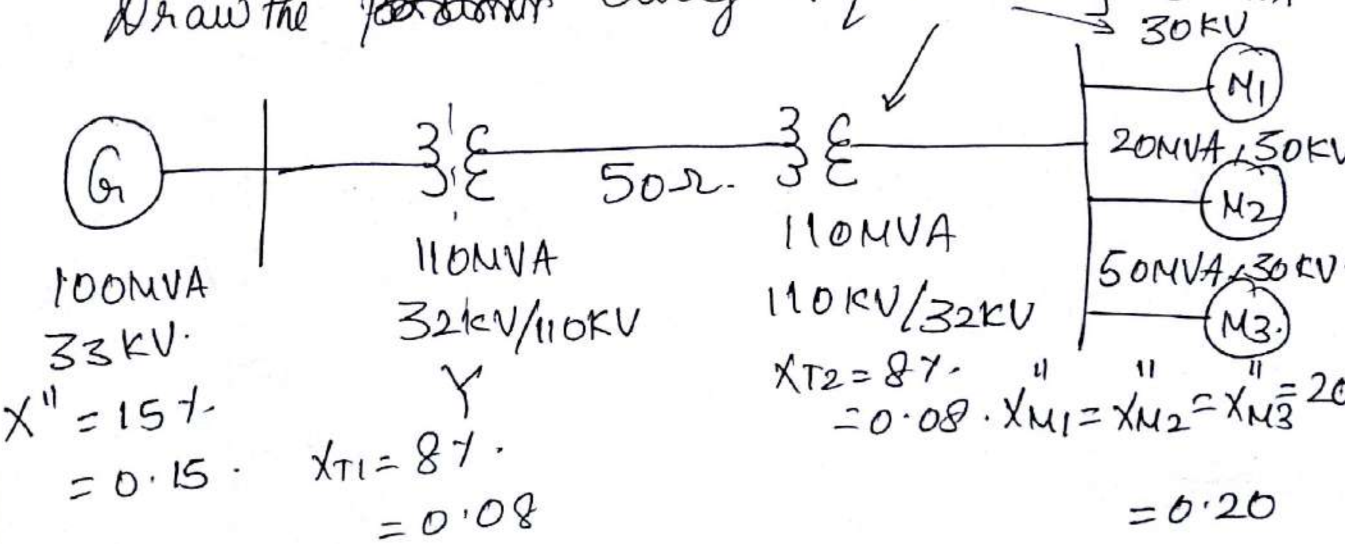
Problem 3

A 100MVA, 33kV, 3ϕ generator has a subtransient reactance of 15%. The generator is connected to three motors through a transmission line and two Transformers. The Motor have rated inputs of 30MVA, 20MVA and 50MVA at 30kV with 20% Subtransient Reactance. The 3ϕ Transformer are rated at 110MVA, 32kV/110kV Y with leakage reactance 8%. The line has a reactance of 50Ω. Selecting the generator rating as the base quantities in the generator circuit. Determine the base quantities in other parts of the system and evaluate the corresponding pu values.

Solution:-

Step1:-

Draw the ~~per unit~~ one line diagram [old Values]



Step2:- Dividing into Sections

Section 1 | T_1 32/110KV | **Section 2** | T_2 110/32KV. | **Section 3**

Section 1:
$S_B = 100MVA$ (New)
$V_B = 33KV$. (New)

Section 2:
~~New section~~
$S_B = 100MVA$ (new)
$V_{B new} = ?$

Section 3:
$S_B = 100MVA$ (new)
$V_{B new} = ?$

In Section 2 (Secondary of T1)

T1
32/110KV.
primary/secondary

Section 1 (Primary of T1)
$V_{Bnew} = 33KV$.

To find V_{Bnew} in Section 2 ((ie) V_{Bnew} in Sy of T1) = V_{Bnew} in Section1 $\ast \frac{\text{Sy Voltage}}{\text{Py Voltage}}$.

$$V_{Bnew\,in\,Section2} = 33 + \frac{110}{32} = 113.4375\ KV.$$

(or)

For 32 KV Py volt T/F 1 gives → 110KV

For 33 KV Py volt T/F 1 gives = $\frac{110 \times 33}{32}$

$= 113.4375$

∴ Section 2:- $S_{B\,new} = 100MVA$

$V_{Bnew} = 1134375\ KV$.

Section 3. $T_2 \rightarrow 110/32\,KV$.
Py/Sy.
Section2 Section3.

Section 2 (Py)
$V_{Bnew} = 113.4375kV$

∴ V_{Bnew} in Section 3 = V_{Bnew} in Section 2 $\ast \frac{\text{Sy Voltage}}{\text{Py Voltage}}$

$= 113.4375 \ast \frac{32}{110} = 33KV$

$S_{Bnew} = 100MVA$; $V_{Bnew} =$ 33 KV.

Step3:- **Generator-1** G1: 100MVA, 33KV, $X_g'' = 0.15$ [old]

$S_{Bnew} = 100MVA$ $V_{Bnew} = 33KV$.

$$X_{g1(new)} = \cancel{X}g_1(old) * \frac{S_{Bnew}}{S_{Bold}} * \left[\frac{V_{Bold}}{V_{Bnew}}\right]^2.$$

$$= 0.15 * \frac{100}{100} * \left[\frac{33}{33}\right]^2 = 0.15\ pu$$

Transformer 1 :- $\{T1 = 110MVA\ \ 32KV/\ 110KV\ X_{T1} = 0.08\}$ old.

$S_{BNew} = 100MVA$; $V_{Bnew} = 33KV$. For Section1

$$X_{T1(new)}\ (in\ pu) = 0.08 * \frac{100}{110} * \left[\frac{32}{33}\right]^2$$

$$= 0.0684\ Pu.$$

Line $X_{L1} = j50\Omega$ (old) Section2 → $S_{Bnew} = 100MVA$

$V_{Bnew} = 113.44kV$

$$X_{L1}\ new = \frac{X_{L1}\ Actual}{X_{L1}\ Base(new)} = \frac{X_{L1}\ Actual}{\frac{V_{Basenew}^2}{S_{Bnew}}} = \frac{j50}{\frac{113.44^2}{100}}$$

$$X_{L1new} = 0.3885\ Pu.$$

Transformer 2 :- P4 lies in section-2

T2 = 110MVA , 110KV/32KV XT2=0.08 } old.

SBnew = 100MVA VBnew = 113.44 KV in section2

$$\therefore X_{T_2}(new) = 0.08 * \frac{100}{110} * \left(\frac{\cancel{1}10}{113.44}\right)^2$$

$= 0.06833$ pu.

M1 :- Motor Lie in section-3

Section-3 baseNew

SBnew = 100MVA

VBnew = 33KV.

M1 = 30MVA, 30KV, $X_{M1}'' = 20\% = 0.20$ } given (or) old.

$$X_{M_1}(new) = 0.20 * \frac{100}{30} * \left[\frac{30}{33}\right]^2$$

$= 0.55096$ pu.

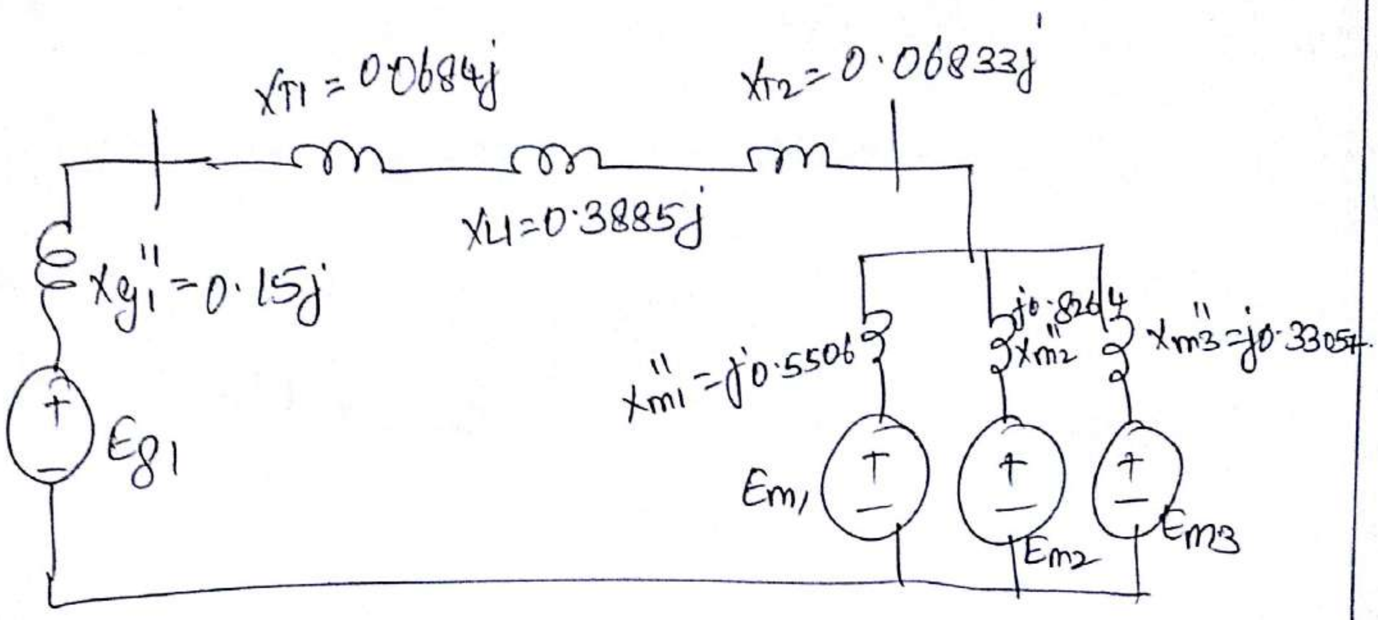
M2 : 20MVA, 30KV $X_{M2}'' = 0.20$ } given (or) old

$$X_{M2}(new) = 0.20 * \frac{100}{20} * \left[\frac{30}{33}\right]^2$$

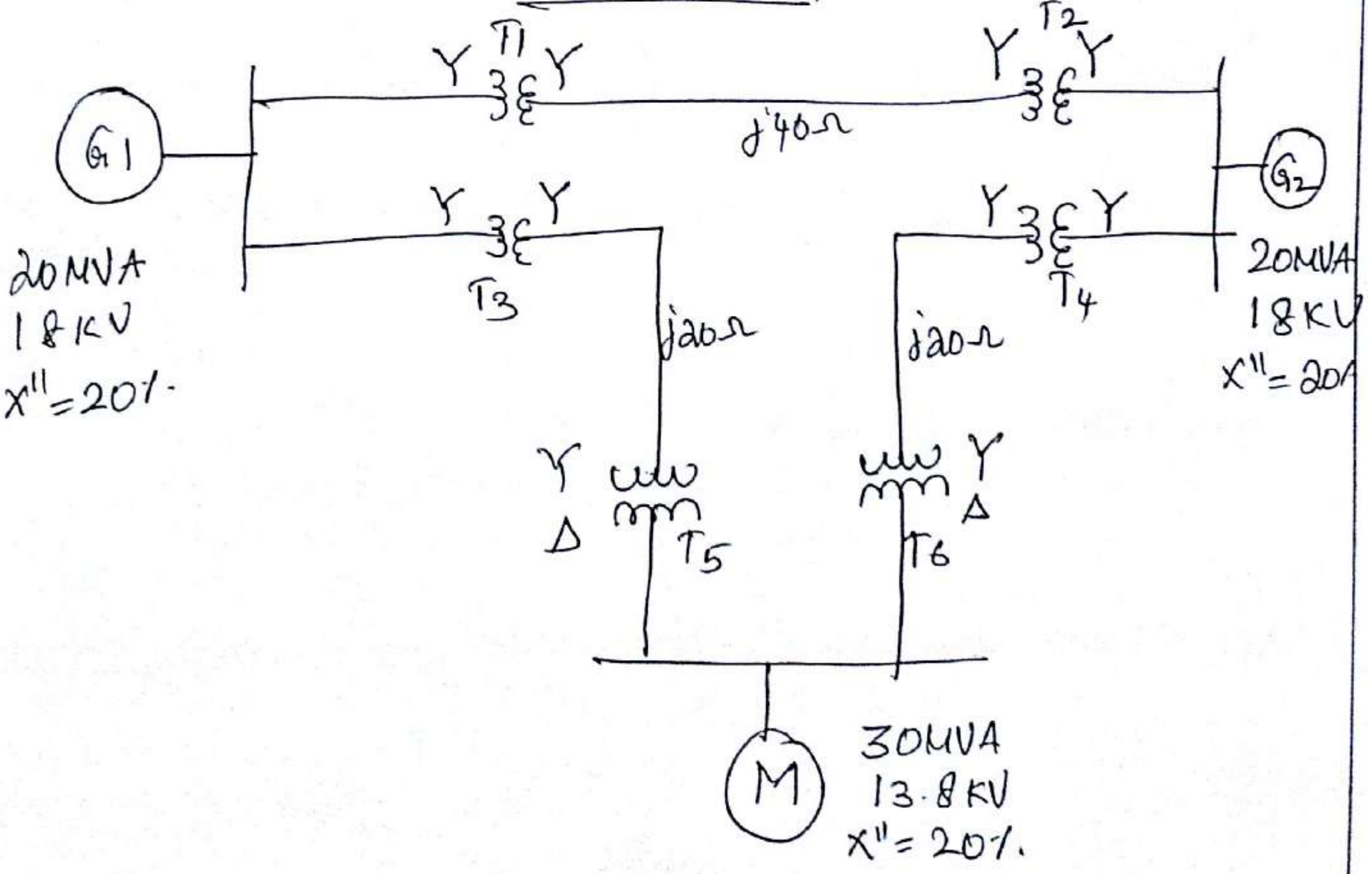
$= 0.8264$ pu.

M3 : 50MVA, 30KV, $X_{M3}'' = 0.20$ } given (or) old.

$$X_{M3}(new) = 0.20 * \frac{100}{50} * \left[\frac{30}{33}\right]^2 = 0.33057 pu$$



Problem 4



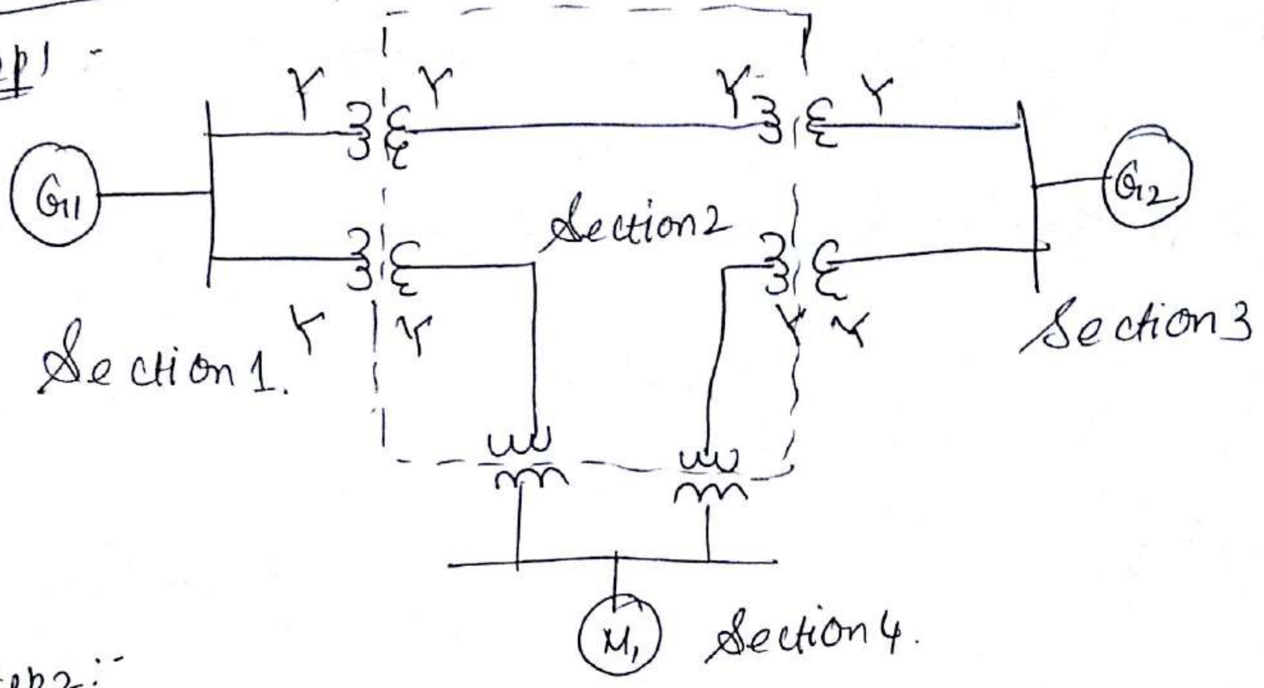
T/F - Y-Y → 20MVA, 138/20KV X = 10%.

Y-Δ → 15MVA, 138/13.8 KV X = 10%.

Select base as 50KVA, 138 KV in 40Ω line

Solution :-

Step1 -



Step2:-

Section 1	Section2 (Given Base New)	Section3	Section4
S(NEW) = 50KVA = 0.05MVA	S_B = 50KVA = S_{Bnew} = 0.05MVA	S_B(new) = 50KVA = 0.05MVA	S_BNew = 50KVA = 0.05MVA.
V_{Bnew} = 20KV	V_B = 138 KV = V_{Bnew}	V_B(new) = 20KV.	V_{Bnew} = 13.8KV.

20/138 KV.
T_1, T_3

T_2, T_4.
138/20KV.

T_5, T_6
138/13.8KV

Step3:- G_1 : 20MVA, 18KV, $x'' = 20\% = 0.20$ } given old.

Section1:-

$$X_{g1}(new) = X_{g1}(old) * \frac{S_{Bnew}}{S_{Bold}} * \left(\frac{V_{Bold}}{V_{Bnew}}\right)^2.$$

$$= 0.20 * \frac{0.050}{20} * \left[\frac{18}{20}\right]^2 = 0.000405 \text{ pu}$$

Both are in Section1 – PY of T/F.

$$X_{T1(new)} = X_{T3(new)} = 0.10 * \frac{0.05}{20} * \left(\frac{20}{20}\right)^2 = 0.00025pu$$

Both PY are in Section2.

$$X_{T2(new)} = X_{T4(new)} = 0.10 * \left[\frac{0.05}{20}\right] * \left[\frac{138}{138}\right]^2$$

$$= 0.00025pu.$$

Both PY are in Section2.

$$X_{T5(new)} = X_{T6(new)} = 0.10 * \left[\frac{0.05}{15}\right] * \left[\frac{138}{138}\right]^2$$

$$= 0.00033pu.$$

G2 in Section 3 — $S_{Bnew} = 0.05MVA$, $V_{Bnew} = 20KV$.

$$X_{g2(new)} = 0.20 * \frac{0.05}{20} * \left[\frac{18}{20}\right]^2$$

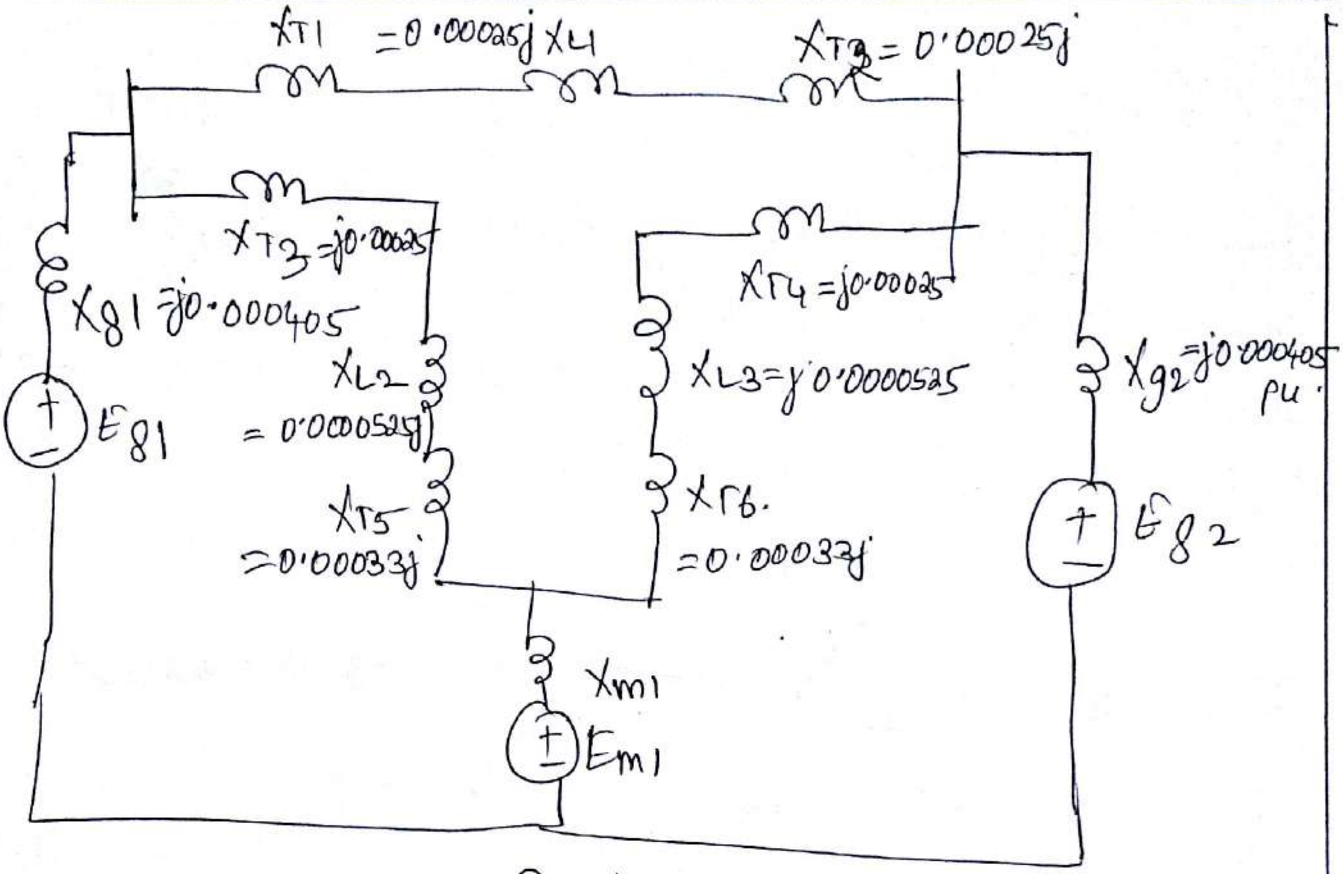
$$= 0.000405pu.$$

M1 in Section 4 — $S_{Bnew} = 0.05MVA$, $V_{Bnew} = 13.8 KV$

$$X_{m1(new)} = 0.20 * \frac{0.05}{30} * \left[\frac{13.8}{13.8}\right]^2 = 0.00033pu$$

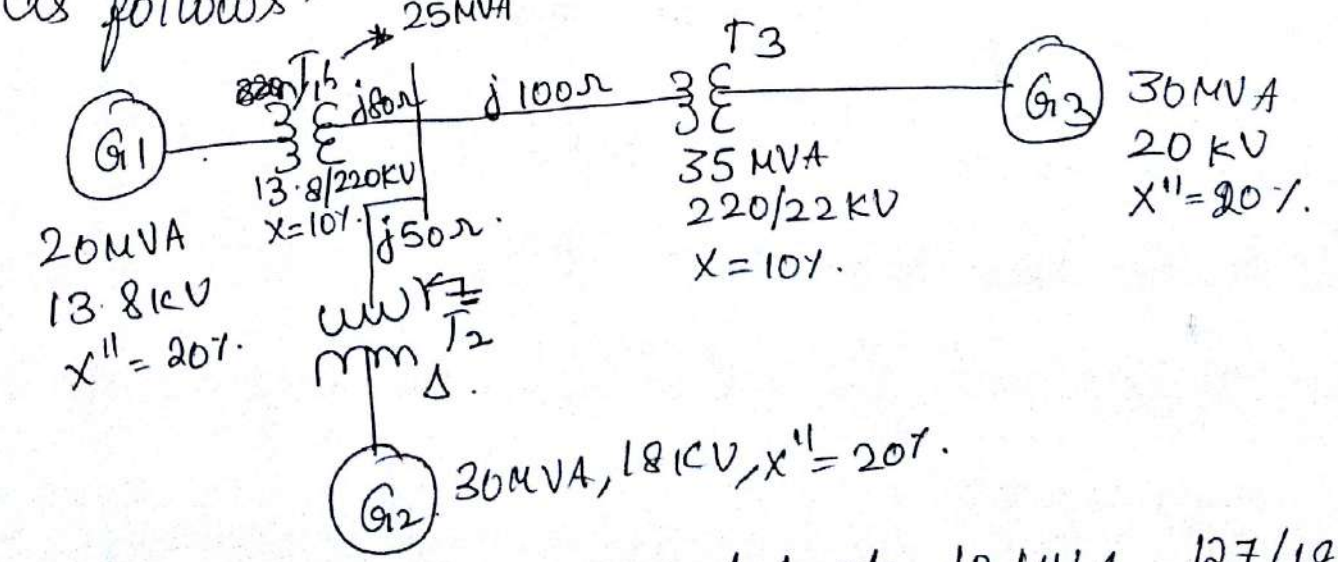
$$X_{L1(pu)} = \frac{j40}{\frac{138^2}{0.05}} = j0.000105 pu \quad \left[X_L \text{ in } pu = \frac{X_{Actual}}{X_{Base}} = \frac{X_{Actual}}{\frac{V_{Base}^2}{S_{Base}}} \right]$$

$$X_{L2} = \frac{j20}{\frac{138^2}{0.05}} = j0.0000525pu = X_{L3}$$



Problem-5

The Single Line diagram of an unloaded power System. The generator and transformer are rated as follows :-

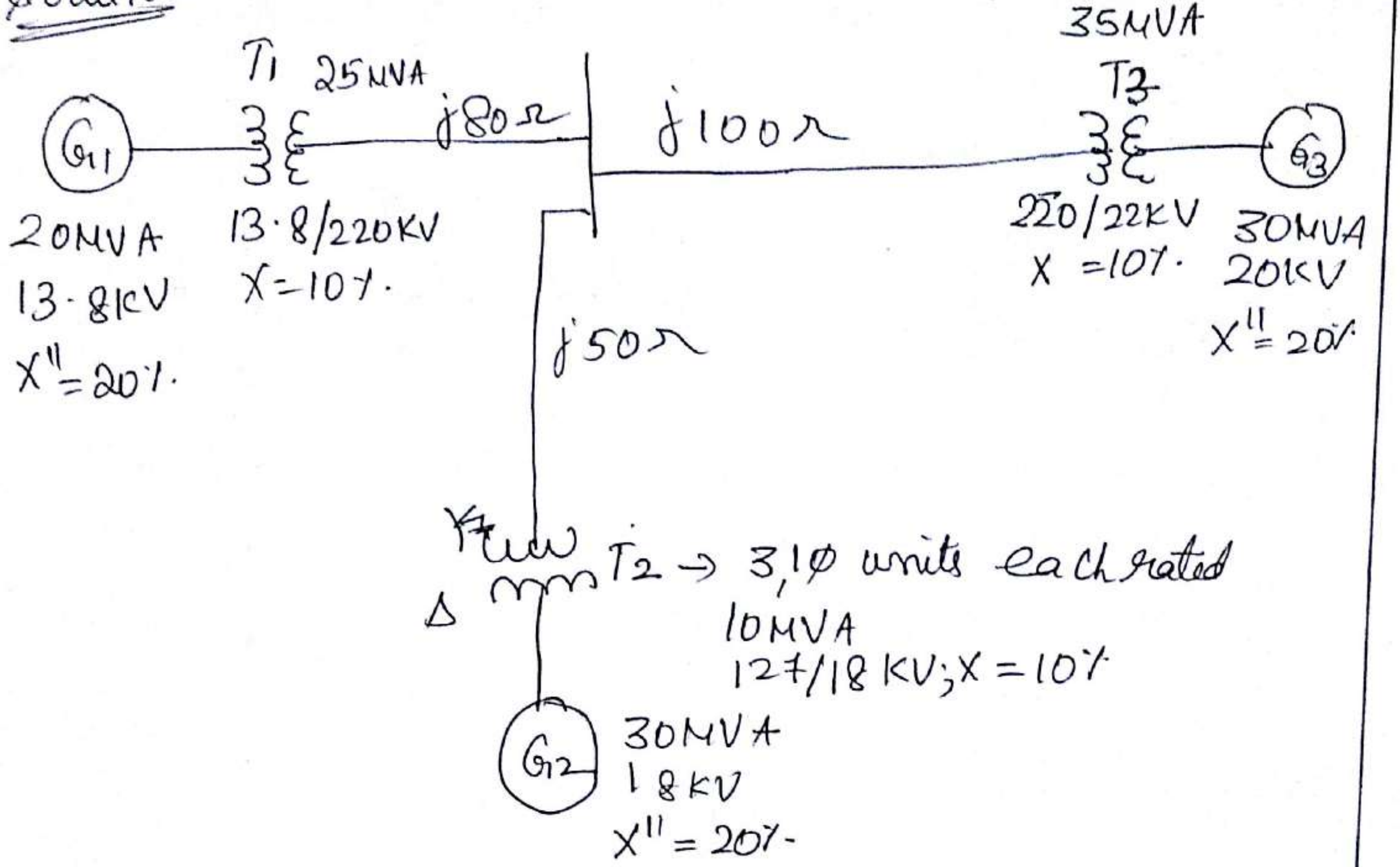


T2 → 3, 1φ units each rated at 10 MVA 127/18KV X=10%

Draw the reactance diagram using 50MVA, 13·8KV on Gen 1

Page 27

Solution:-



For T2 $\quad 3 - 1\phi$ units

So total MVA $= 10 * 3 = 30$MVA.

$Y \Rightarrow V_L = \sqrt{3}\, V_{ph} = \sqrt{3} * 127 = 220V$

$\Delta \Rightarrow V_L = V_{ph} = 18$ KV.

$X' = 10\%$. remains same.

$\therefore T_2 = 30$MVA, 220/18kV $X = 10\%$.

Step2:- Section 1	Section 2	Section 3
G_1, T_1 (PY)	T_1 Sy, T_3(PY) T_2 (PY)	T_3 (Sy), G_3.
$S_{B\,new} = 50MVA$	$S_{B\,New} = 50MVA$	$S_{B\,new} = 50MVA$
$V_{B\,new} = 13.8KV$.	$V_{B\,new} = 220K$	$V_{B\,new} = 22KV$

T_1
13.8/220.

T_3
220/22KV

Section4

T_2 Sy & G_2.

$S_{B\,new} = 50MVA$ $T_2 \rightarrow 220/18\ KV$.

$V_{B\,new} = 18KV$

$$X_{new} = X_{given/old} * \frac{S_{B\,new}}{S_{B\,given\,old}} * \left(\frac{V_{B\,old/given}}{V_{Base\,new}}\right)^2$$

Step3:-

$$X_{g1}\ new = 0.20 * \frac{50}{20} * \left(\frac{13.8}{13.8}\right)^2 = j0.5pu$$

$$X_{T1}(PY)-new = 0.10 * \frac{50}{25} * \left[\frac{13.8}{13.8}\right]^2 = 0.20j\ pu.$$

$$X_{T3}(PY)-new = 0.10 * \frac{50}{35} * \left[\frac{220}{220}\right]^2 = j0.1428pu.$$

$$X_{T2}(PY)\ new = 0.10 * \frac{50}{30} * \left[\frac{220}{220}\right]^2 = j0.1667j$$

$$X_{G3}\ new = 0.20 * \frac{50}{30} * \left[\frac{20}{22}\right]^2 = 0.27548j$$

$$X_{g2}\ new = 0.20 * \frac{50}{30} * \left[\frac{18}{18}\right]^2 = j0.3333.$$

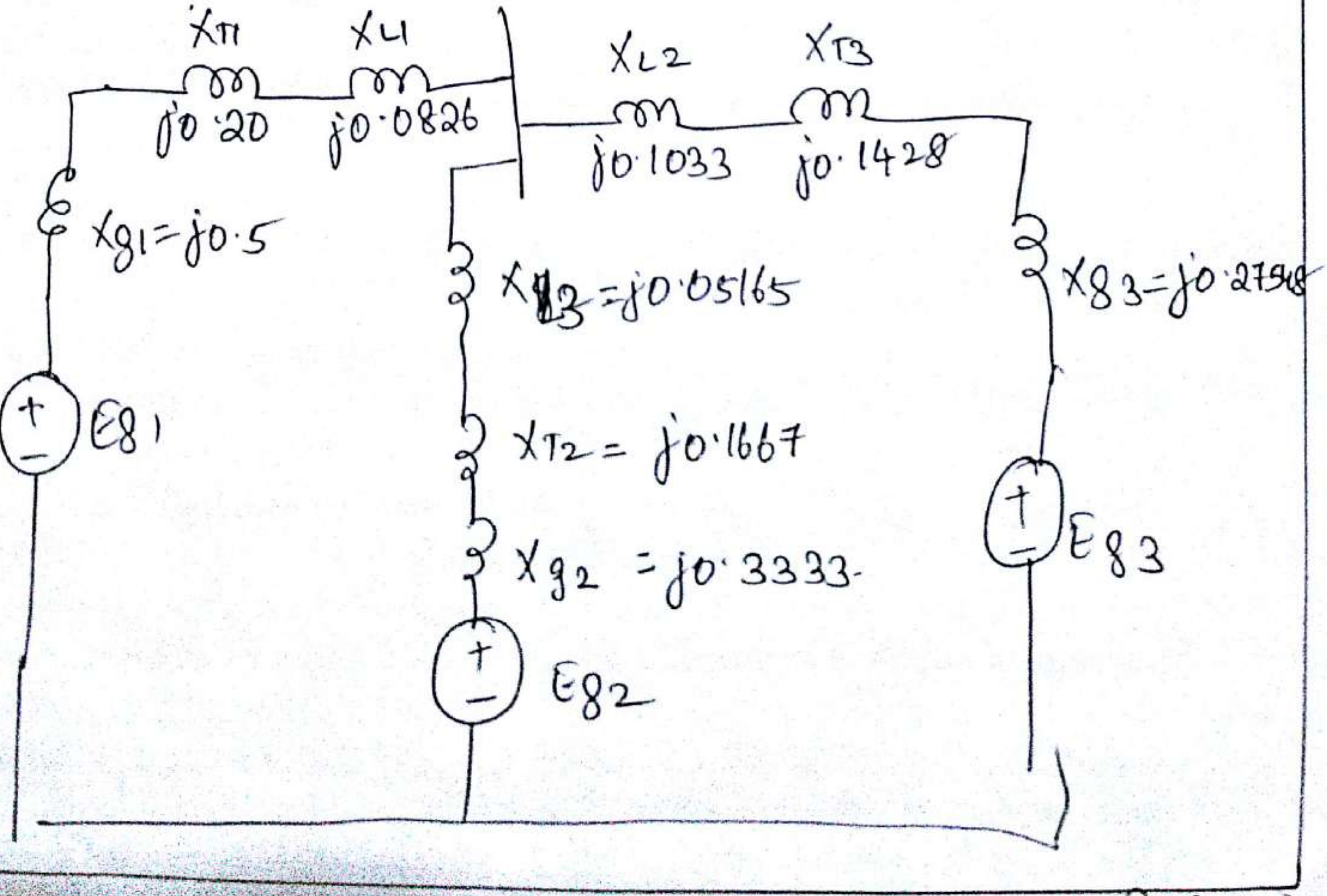
$$X_L(\text{in PU}) = \frac{X_L \text{ Actual}}{X_{base}}$$

$$X_{L1}\text{ (new)} \text{ (Section 2)} = \frac{j80\Omega}{\frac{220^2}{50}} = j0.0826\text{PU}$$

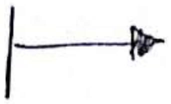
$$X_{L2}\text{(new)} \text{ Section 2} = \frac{j100\Omega}{\frac{220^2}{50}} = j0.1033\text{PU}$$

$$X_{L3}\text{(new)} \text{ Section 2} = \frac{j50\Omega}{\frac{220^2}{50}} = j0.05165\text{PU}$$

Reactance Diagram



Static Loads

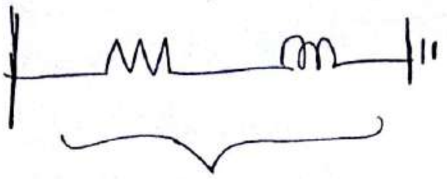


S(kVA), φ(PF) at V(kV)

$$S = VI^*$$
$$= \cancel{V}\left[\frac{S}{\cancel{V}}\right]^*$$
$$Z = V/I = \frac{V}{(S/V)^*} = \frac{V^2}{S^*}$$

Series

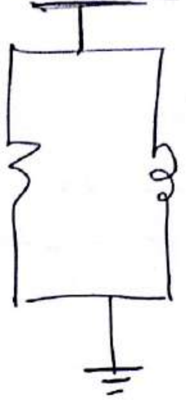
$$S = VI^*$$



Z in Ω.

$$Z \text{ in } \Omega = \frac{V^2}{S^*}$$
$$= \frac{V^2}{(S\cos\phi + jS\sin\phi)^*}$$
$$\cancel{= \frac{(2.4)^2}{[50^*}}$$

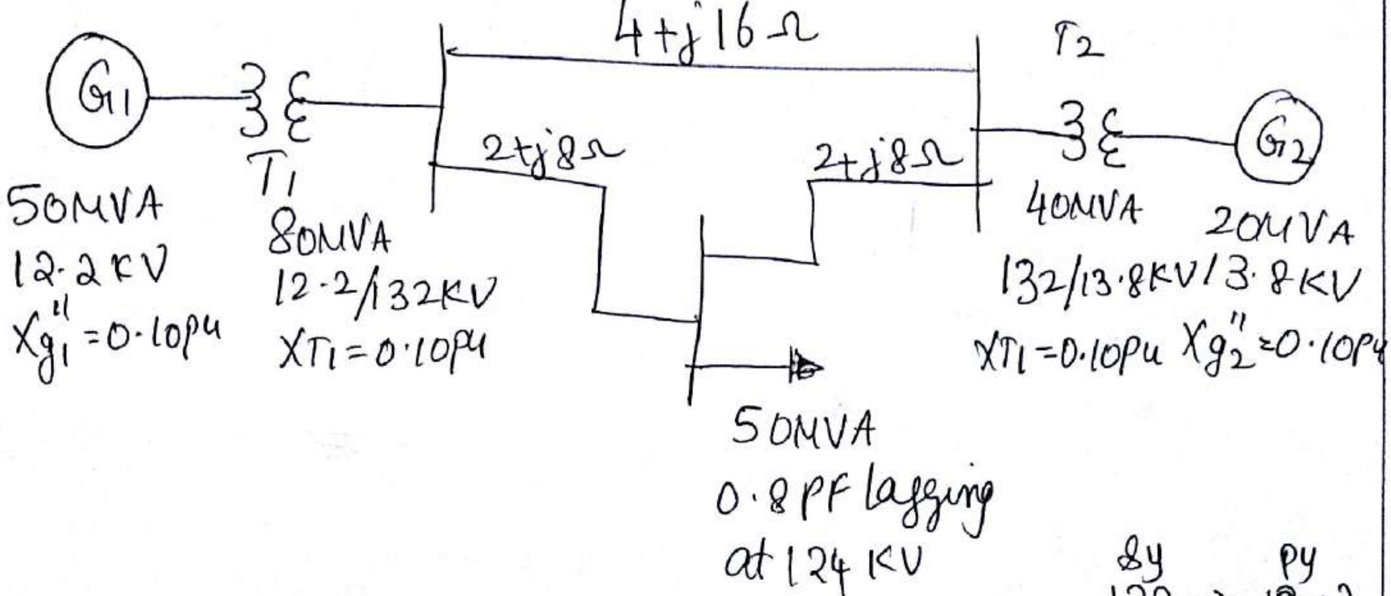
Parallel



$$R \text{ in } \Omega = \frac{V^2}{P}$$
$$P = S\cos\phi.$$
$$X \text{ in } \Omega = \frac{V^2}{Q}$$
$$Q = S\sin\phi.$$

Problem-6

Draw the perunit Impedance Diagram for the System Shown in figure. Assume 100MVA and 100kV as base.



Solution:- $V_{B\,new}$ in section1 = $V_{B\,new}$ in section2 * $\frac{Py\ Voltage}{Sy\ voltage}$

sy → py
132 → 12.2
100 → $\frac{12.2 * 100}{132}$

Step1

Section1	Section2	Section3
G1, Ty1 Py	Ty1(sy), Lines, Static load, T2 (Py	G2.
SBnew = 100MVA	100MVA = SBNew	SBnew = 100MVA
VBnew = 9.24KV	100kV = VBnew	VBnew = 10.45KV

132/13.8

12.2/132

Step 2:- $X_{g\,new} = X_g(\text{given}) * \frac{S_{B\,new}}{S_{B\,old}} * \left(\frac{V_{B\,old}}{V_{B\,new}}\right)^2$

$$X_{g1}'' = 0.10 * \frac{100}{50} * \left(\frac{12.2}{9.24}\right)^2 = 0.3486\,pu$$

$$X_{T1} = 0.10 * \frac{100}{80} * \left(\frac{12.2}{9.24}\right)^2 = 0.2179\,pu$$

$$X_{L1} = \frac{4+j16}{\frac{100^2}{100}} = 0.04 + j0.16\,pu$$

$$X_{L2} = \frac{2+j8}{\frac{100^2}{100}} = 0.02 + j0.08\,pu = X_{L2}$$

$$X_{T2} = 0.1 * \frac{100}{40} * \left[\frac{13.8}{10.45}\right]^2 = 0.4359\,pu$$

$$X_{g2} = 0.10 * \frac{100}{20} * \left[\frac{13.8}{10.45}\right]^2 = 0.8719\,pu$$

Load in Serei

$$Z_{in\,\Omega} = \frac{V^2}{S^*} = \frac{124^2}{[50*0.8+j50*0.6]^*}$$

$$= \frac{124^2}{40-j30} = 246+j184.512$$

$$Z_{in\,pu} = \frac{246+j184.52}{\frac{100^2}{100}} = 2.46+j1.8452$$

Load in parallel

$$R_{in\,\Omega} = \frac{V^2}{P}$$

$$= \frac{124^2}{50*0.8}$$

$$= 384.4\,\Omega$$

$$X_{in\,\Omega} = V^2/Q$$

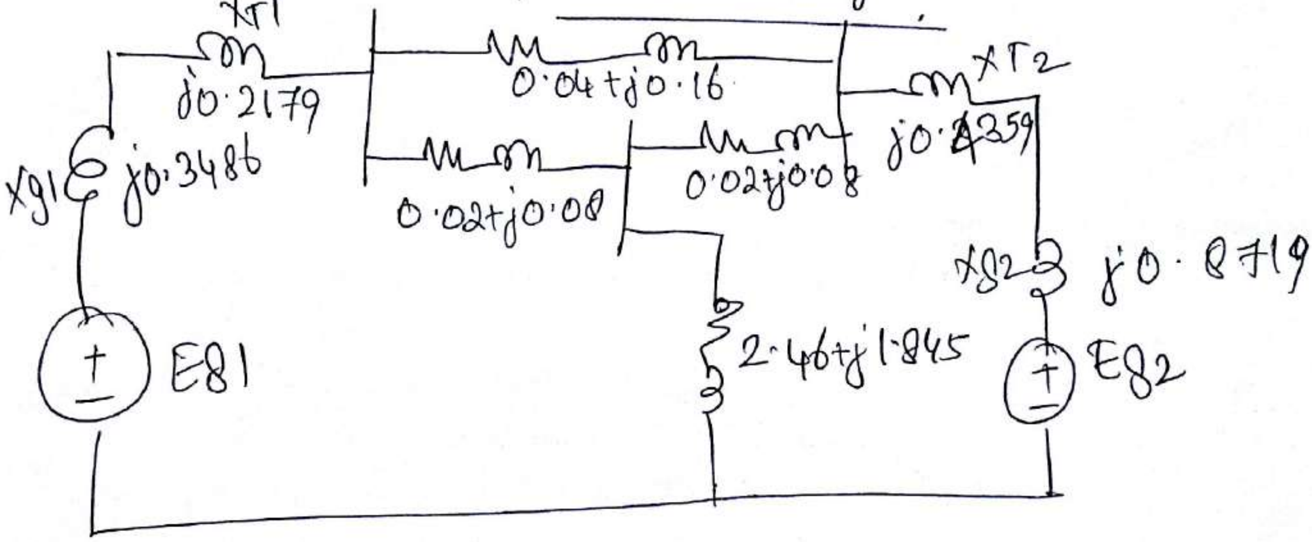
$$= \frac{124^2}{50*0.6} = 512.53\,\Omega$$

Parallel

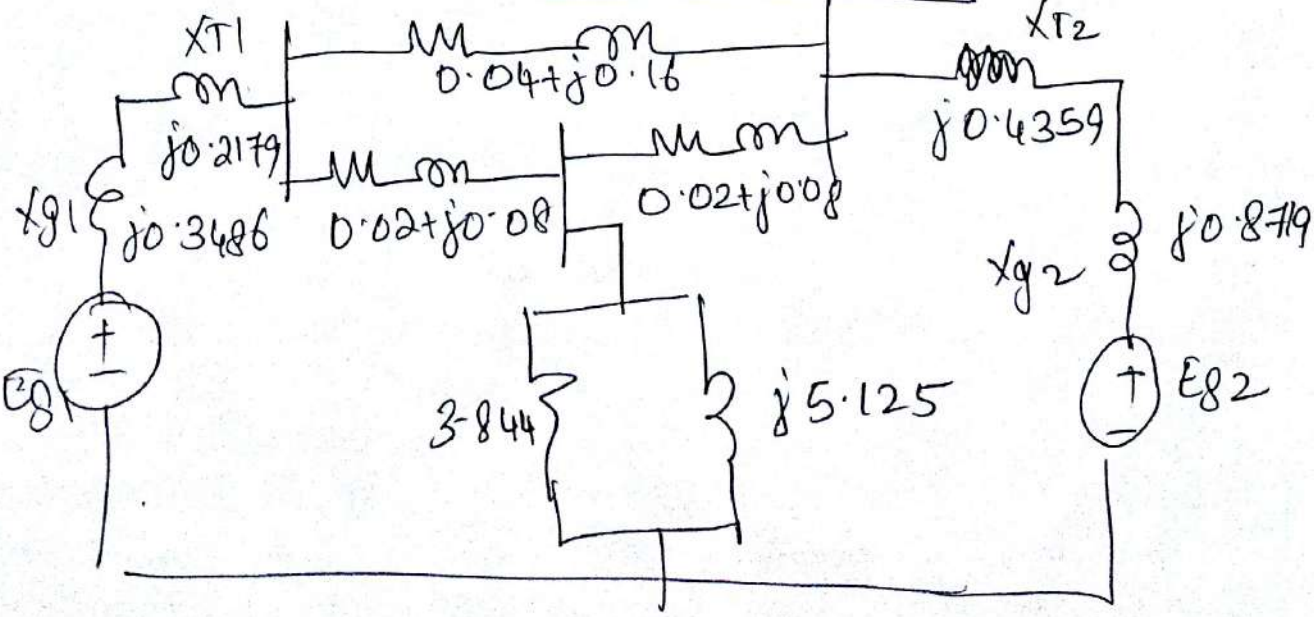
$$R\,in\,pu = \frac{384.4}{\frac{100^2}{100}} = 3.844\ pu$$

$$X\,in\,pu = \frac{512.53}{\frac{100^2}{100}} = 5.1253\,pu-$$

For Series Type



For Parallel type



Show that the Perunit Impedance of a Transformer is the Same irrespective Of the Side on which it is Calculated:- [(ie) Perunit Impedance referred to Py is equal to perunit Impedance referred to Sy]

Solution:-

Let

S_B = Rated MVA of the Transformer (or) SBase.

V_{B1}= Rated Voltage of primary Side (or) VBase (Primary)

V_{B2} = Rated Voltage of Secondary Side (or) VBase (Secondary)

Z_{eq1} = Impedance referred to primary Side (in Ω)

Z_{eq2} = Impedance referred to Secondary Side.

Step1:

$$Z_{eq1}(Pu) = \frac{Z_{eq1}(\text{in } \Omega)}{\frac{V_{B1}^2}{S_B}} \qquad \left[\therefore Z_{Pu} = \frac{Z_{actual}}{Z_{Base}} = \frac{Z_{actual}}{\frac{V_B^2}{S_B}} \right.$$

$$Z_{eq1}^{(pu)} = Z_{eq1}(\text{in } \Omega) * \frac{S_B}{V_{B1}^2} \quad — ①$$

$$III^{ly} \quad Z_{eq2}(pu) = Z_{eq2}(in\ \Omega) * \frac{S_B}{V_{B2}^2} \quad — ②$$

~~By Transformation Ratio :-~~

$$\cancel{\frac{Z_{eq2}(in\ \Omega)}{Z_{eq1}(in\ \Omega)} = V_{B2}}$$

By Transformation Ratio :-

$$\frac{N_2}{N_1} = \frac{V_2}{V_1} = \frac{I_1}{I_2}.$$

PY MVA = SY MVA.

$S_1 = S_2$

$$\frac{N_2}{N_1} = \frac{V_{B2}}{V_{B1}} = \frac{I_1}{I_2}.$$

$$\cancel{Z = \frac{V}{I} = \frac{V}{I}}$$

$$\frac{Z_2}{Z_1} = \frac{V_2^2}{V_1^2} = \frac{N_2^2}{N_1^2}.$$

$$\therefore \frac{Z_{eq2}(in\ \Omega)}{Z_{eq1}(in\ \Omega)} = \frac{V_{B2}^2}{V_{B1}^2} \quad — ③$$

$$Z_{eq2}(\text{in }\Omega) = Z_{eq1}(\text{in }\Omega) * \frac{V_{B2}^2}{V_{B1}^2} \quad \text{— ④}$$

Sub ④ in ②

$$\text{eq ②} \Rightarrow Z_{q2}(\text{pu}) = Z_{eq2}(\text{in }\Omega) * \frac{S_B}{V_{B2}^2}$$

$$\text{Sub ④ in ②} \Rightarrow Z_{eq2}(\text{pu}) = \left[Z_{eq1}(\text{in }\Omega) * \frac{V_{B2}^2}{V_{B1}^2}\right] * \frac{S_B}{V_{B2}^2}$$

$$= \underbrace{Z_{eq1}(\text{in }\Omega) * \frac{S_B}{V_{B1}^2}}_{\Rightarrow \text{eq ①}}$$

$$\boxed{Z_{eq2}(\text{pu}) = Z_{eq1}(\text{pu})}$$

Problem 1:-

The Primary and Secondary Sides of a 1ϕ 1 MVA, 4 KV/2 KV Transformer have a leakage reactance of 2Ω each. Find the perunit reactance of the Transformer referred to the Primary and Secondary Side.

Solution

$X_1 = 2\Omega$ $X_2 = 2\Omega.$ $V_1 = 4KV$ $V_2 = 2KV$

Step 1:- Primary Side:

$$X_{1eq} = X_1 + X_2'$$

$$= X_1 + X_2\left[\frac{V_1}{V_2}\right]^2$$

$$= 2 + 2\left[\frac{4}{2}\right]^2 = 2 + 8$$

$$\boxed{X_{1eq} = 10\Omega.}$$

$$X_{1eq}(\text{in pu}) = \frac{X_{1eq}\text{ in }\Omega}{\frac{V_B^2(\text{in section Py})}{S_B(\text{in Pu})}} = \frac{10}{\frac{4^2}{1}} = 0.625\ \text{pu}$$

Secondary Side :-

$$X_{2eq} = X_2 + X_1'$$

$$= 2 + \left[X_1\right] * \left[\frac{V_2}{V_1}\right]^2$$

$$= 2 + 2 * \left(\frac{2}{4}\right)^2$$

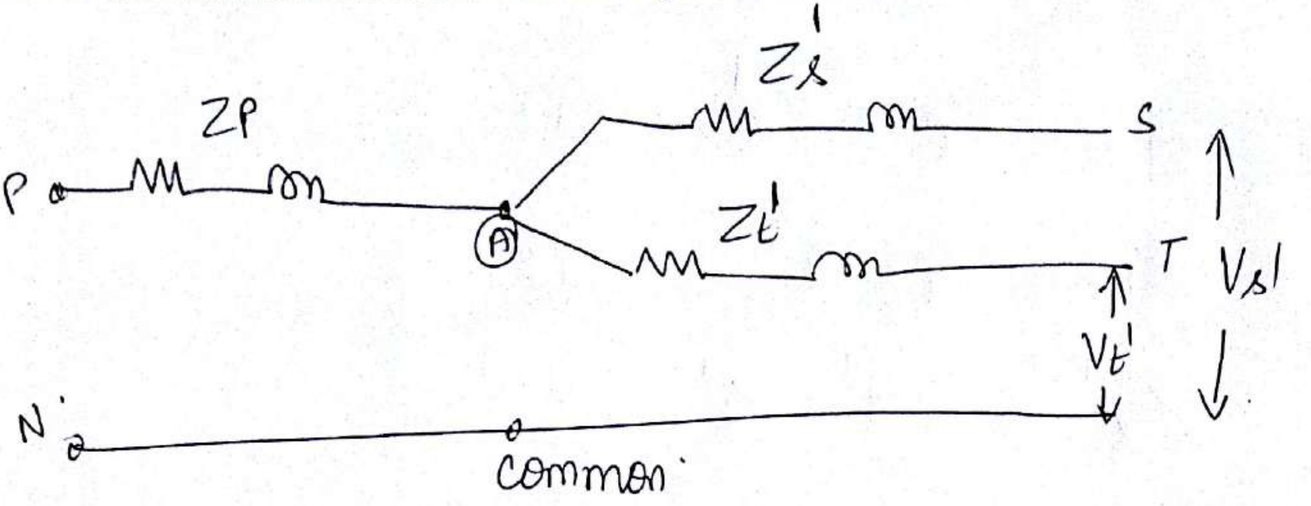
$$= 2 + 0.5 = 2.5\Omega$$

$$X_{2eq}(\text{in pu}) = \frac{X_{2eq} \text{ in } \Omega}{\frac{V_B^2 (\text{in Sy})}{S_B (\text{in Sy})}} = \frac{2.5}{\frac{2^2}{1}}$$

$$= \underline{\underline{0.625 \text{ pu}}}$$

$$\therefore \boxed{Py = Sy}$$

3 wdg T/F Derivation



1 ϕ equivalent of 3 wdg T/F.

Where:-

ZP - Impedance of Primary winding

Z_s' - Impedance of Secondary winding referred to Py.

Z_t' - Impedance of Tertiary winding referred to Py.

Z_{PS} = Leakage Impedance Measured in Py with Secondary Short circuited & Tertiary Opened

Z_{Pt} = Leakage Impedance Measured in Py with tertiary Short circuited and Secondary open.

Z_{st}' - Leakage Impedance Measured in Sy with tertiary Short circuited and Primary open and Referred to Primary

$$Z_{ps} = Z_p + Z_s' \quad \text{—①}$$

$$Z_{pt} = Z_p + Z_t' \quad \text{—②}$$

$$Z_{st}' = Z_s' + Z_t' \quad \text{—③}$$

① + ② − ③.

$$\Rightarrow Z_{ps} + Z_{pt} - Z_{st}' = 2Z_p + Z_s' + Z_t' - Z_s' - Z_t'$$

$$\therefore Z_p = \frac{1}{2}\left[Z_{ps} + Z_{pt} - Z_{st}'\right].$$

|||ly $Z_s' = \frac{1}{2}\left[Z_{ps} + Z_{st}' - Z_{pt}\right].$

|||ly $Z_t' = \frac{1}{2}\left[Z_{pt} + Z_{st}' - Z_{ps}\right]$

Problem in 3wdg T/F

The Three phase ratings of a 3 winding Transformer are

Primary : Y connected, 110 KV, 20 MVA
Secondary : Y connected, 13.2 KV, 15 MVA
Tertiary : Δ connected, 2.1 KV, 0.5 MVA

Three short circuit tests performed on this Transformer yielded the following results.

i) Primary excited, Secondary shorted : 2290 V, 52.5 A

ii) Primary excited, Tertiary shorted : 1785 V, 52.5 A.

iii) Secondary excited Tertiary shorted : 148 V, 328 A

Find the PU Impedances of the star connected 1ϕ equivalent circuit for a base of 20 MVA, 110 KV in Primary circuit. Neglect resistances.

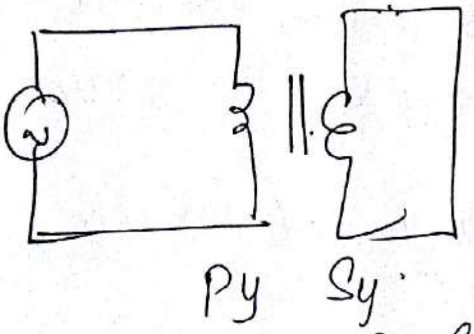
Solution

Note Y $V_{Ph} = \frac{V_L}{\sqrt{3}}$; $I_{Ph} = I_L$.

Δ $V_{Ph} = V_L$; $I_{Ph} = \frac{I_L}{\sqrt{3}}$

Note2 ⇒ Whichever winding is excited that Connection should be Considered.

Step2



$$\therefore \left.\begin{matrix} Z_{PS} \\ (\text{or}) \\ Z_{12} \end{matrix}\right\} = \frac{V_L/\sqrt{3}}{I_{ph}}$$

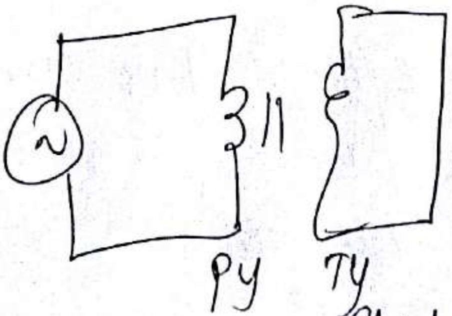
Pyexcited SC Shorted.

Y Y [given in Question]

$$= \frac{2290/\sqrt{3}}{52.5}$$

$$\boxed{\begin{matrix} Z_{PS}(\text{or}) \\ Z_{12} \end{matrix} = 25.1835 \ \Omega/\text{ph}}$$

Step3:- Py excited, Tertiary Shorted



$$Z_{13} (\text{or}) Z_{PT} = \frac{1785/\sqrt{3}}{52.5}$$

$$= 19.6299 \ \Omega/\text{ph}.$$

1 or P. Shorted

3 (or) T

Y Δ.

Step4: Z_{ST} (or $Z_{23} = \frac{148/\sqrt{3}}{328} = 0.2605 \ \Omega/\text{ph}$.

~~Step4 :- Exited winding we wont measure any loading~~

Step4:- Z_{PS} & Z_{PT} Measurements are done in Primary

$$\therefore Z_{PS} \text{ (or) } Z_{12} \text{ (Pu)} = \frac{Z_{PS} \text{ (or) } Z_{12} \text{ [Actual]}}{Z_{Base} \text{(in Py)}}$$

$$= \frac{Z_{PS} \text{ (or) } Z_{12} \text{ [Actual]}}{\frac{V_{Base(Py)}^{2}}{S_{Base(Py)}}}$$

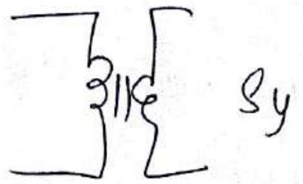
Py Base => $S_B = 20 \text{MVA}$ $V_B = 110 \text{KV}$

$$\therefore Z_{PS} \text{ (or) } Z_{12} \text{ (Pu)} = \frac{25.1835}{\frac{110^2}{20}} = 0.0416 \text{ pu}$$

||ly

$$Z_{Pt} \text{ (or) } Z_{13} \text{ (Pu)} = \frac{19.6299}{\frac{110^2}{20}} = 0.0324 \text{Pu}$$

Step5:- For Z_{st} (or) Z_{23} :- we need to use equivalent Sy Side Base.



Py

110KV : 13.2KV.

$\downarrow$

use this V_B

Sy Base

$\therefore V_B = 13.2KV$

$S_B = 110\ KV$

$$\therefore Z_{st}' \text{ (or) } Z_{23}' (pu) = \frac{Z_{st} \text{ (or) } Z_{23} \text{ (in } \Omega / \text{actual)}}{Z_{Base(in\ Sy)}}$$

$$= \frac{Z_{st} \text{ (or) } Z_{23} \text{ (Actual)}}{\frac{V^2_{Base(Sy)}}{S_B Sy}}$$

$$= \frac{0.2605}{\frac{13.2^2}{20}}$$

$$= 0.0299\ pu$$

Step6:-

Equivalent Impedance

Step6:

Z_1 (or) $Z_p = \frac{1}{2}\left[Z_{ps} + Z_{pt} - Z'_{st}\right]$ (or $\frac{1}{2}\left[Z_{12} + Z_{13} - Z'_{23}\right]$.

$= \frac{1}{2}\left[0.0416 + 0.0324 - 0.0299\right]$

$= 0.0221$ PU

Z'_2 (or) $Z'_s = \frac{1}{2}\left[Z_{ps} + Z'_{st} - Z_{pt}\right]$ (or) $\frac{1}{2}\left[Z_{12} + Z'_{23} - Z_{13}\right]$

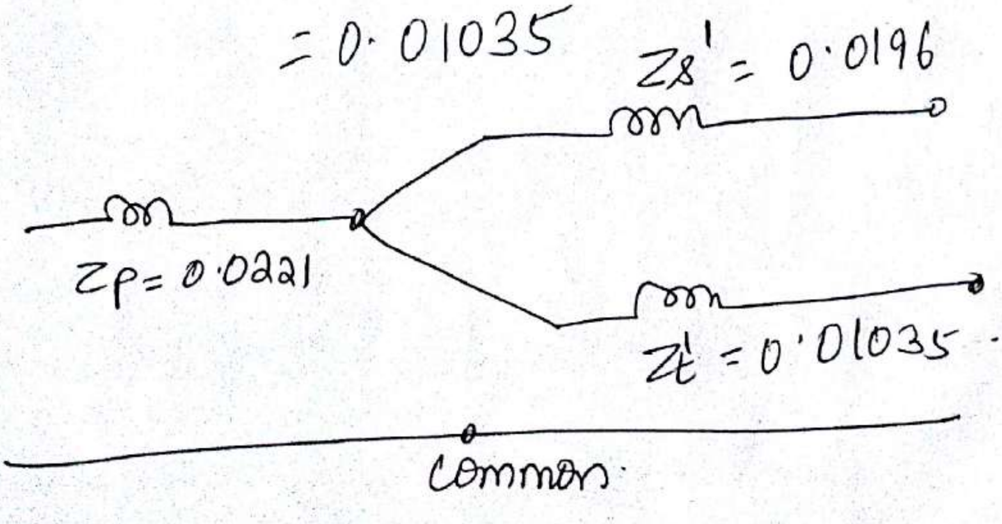
$= \frac{1}{2}\left[0.0416 + 0.0299 - 0.0324\right]$

$= 0.0196$ PU.

Z'_3 (or) $Z_t' = \frac{1}{2}\left[Z_{13} + Z'_{23} - Z_{12}\right]$ (or) $\frac{1}{2}\left[Z_{pt} + Z'_{st} - Z_{ps}\right]$

$= \frac{1}{2}\left[0.0324 + 0.0299 - 0.0416\right]$

$= 0.01035$



7c

Module 2 - Symmetrical Fault Analysis

Introduction:-

* A fault in a circuit is any failure which Interfers with the normal flow of current.

Causes:-

1) Insulation failure of equipments
2) Flash over of lines initiated by a lightning stroke.
3) Due to Permanent damage to conductors.
4) Due to permanent damage of towers.
5) Due to accidental faulty operations.

* The Faults can be broadly classified into Shunt faults (Short circuits) and series faults (open conductors)

Shunt Fault:-

i) It involves Short Circuit between Conductors and ground. (or) Short circuit between two (or) more Conductors.

ii) The Shunt faults are characterized by increase in current and fall in voltage and frequency.

iii) The Shunt faults can be classified as
   1) Line to ground fault
   2) Line to Line Fault
   3) Double Line to Ground fault.
   4) Three Phase fault

Series Fault:-

i) It occur with one or two broken conductors whic
creates open circuits.

2) It also happens in circuits controlled by fuses (or)
Breakers which do not open all the three Phases.

3) Series faults are characterized by increase in Voltag
and frequency, fall in current in the faulted Phase.

4) The Series faults may be classified as one open
Conductor fault and two open Conductor fault.

Symmetrical Fault:-

- These faults are Characterized by Short circuit of all Phases.

- They are analyzed on per Phase basis using Thevenin's Theorem (or using Bus Impedance matrix.

Unsymmetrical Fault:-

- The unsymmetrical faults are analyzed using Symmetrical Components.

- Eg. Single Line to Ground fault - 70 - 80% Fault
  3φ Fault - 5% fault.
  Double Line to Ground fault - LLG - 10% fault.
  Line to Line Fault - LLF - 15%.

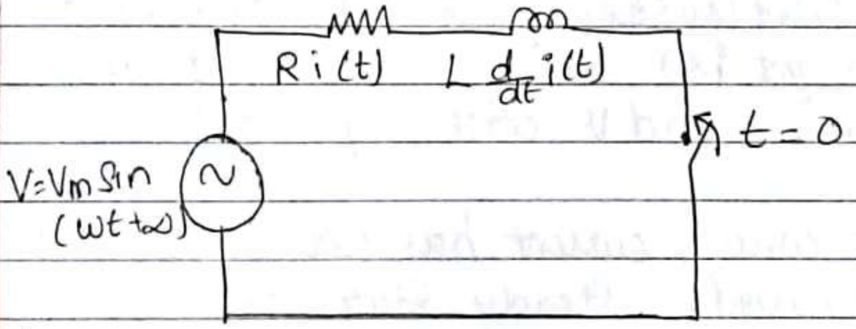
Transients due to Short circuits:-

Most of the components of the power system have inductive property which give rise to transients when there is a sudden change in current. Faults on the power system are accompanied by sudden change in current which give rise to transient conditions in power system.

Transients due to short circuit in Transmission Line:-

An unloaded transmission line can be represented by an R-L circuits excited by a sinusoidal source as shown in figure.

The capacitance of the transmission line is neglected.



Let

$i(t)$ = Current in Transmission line under short circuit condition.

Z = Impedance of the transmission line.

$$Z = R + j\omega L = \sqrt{R^2+\omega^2 L^2}\,\angle \tan^{-1}\frac{\omega L}{R} = |Z|\angle\theta$$

where, $|Z| = \sqrt{R^2+\omega^2L^2}$ and $\theta = \tan^{-1}\left(\frac{\omega L}{R}\right)$

The fault condition can be simulated by closing the switch at $t=0$. When the switch is closed at $t=0$, fault current (short circuit current) flows in the circuit.

The differential equation governing the circuit can be obtained using KVL

$$Ri(t) + L\frac{di(t)}{dt} = V_m \sin(\omega t + \alpha)$$

Solving this,

$$i(t) = \underbrace{\frac{V_m}{|Z|}\sin(\omega t + \alpha - \theta)}_{\substack{\text{Symmetrical Short Circuit} \\ \text{Current (or Steady state} \\ \text{Current } (i_s)}} + \underbrace{\frac{V_m}{|Z|}\sin(\theta - \alpha)e^{-R/L\, t}}_{\substack{\text{DC offset current} \\ \text{(or Transient} \\ \text{current } (i_t).}}$$

Plot i_s, i_t and v with respect to 't'.

The Short circuit current has two Component and they are sinusoidal Steady State Component and unidirectional transient Component.

The Steady state current is called Symmetrical Short circuit current and the transient component is called DC offset current

In the Short circuit current $i(t)$ the Value Corresponding to the first peak is Called the maximum momentary Short circuit current (i_{mm})

The first peak value is Obtained when $\sin(\omega t+\alpha-\theta)=1$

$$i_{mm}=\frac{V_m}{|Z|}+\frac{V_m}{|Z|}\sin(\theta-\alpha)e^{-R/L\,t}$$

If the decay of transient Current in the interval between $t=0$ and time at which first peak Occurs is neglected then eqn can be written as Shown below:-

(ie) $e^{-R/L\,t}\simeq e^{0}=1$

$$I_{mm}=\frac{V_m}{|Z|}+\frac{V_m}{|Z|}\sin(\theta-\alpha)$$

In transmission lines, the resistance is very low when compared to reactance and so $\theta=90^\circ$ (ie) $\tan^{-1}\omega L/R\simeq\tan\alpha=90^\circ$.

Hence by taking $\theta=90^\circ$

$$i_{mm}=\frac{V_m}{|Z|}+\frac{V_m}{|Z|}\sin(90-\alpha)$$

$$\boxed{i_{mm}=\frac{V_m}{|Z|}+\frac{V_m}{|Z|}\cos\alpha}$$

i_{mm} Maximum Value when $\alpha=0$

This Implies that the effect of Short circuit will be severe if the fault occurs when the Voltage wave is going through zero.

When $\alpha = 0$

$$i_{mm}(\text{Max Possible}) = \frac{V_m}{|Z|} + \frac{V_m}{|Z|} \doteq 2\frac{V_m}{|Z|}.$$

→ Maximum Value of Symmetical Short circuit current as $V_m/|Z|$

→ Maximum Possible Value of Maximum momenta Short circuit is double the Value of Maximum Symmetical Short circuit current.

→ If such a condition exists in a transmission line Then this effect is called Doubling effect.

→ A safer choice of momentary current rating of Circuit Breaker can be maximum possible value of maximum momentary Short circuit current.

→ The Interrupting current rating of the Circuit Breake can be Obtained by multiplying the Symmetical Short circuit current by a Suitable factor.

→ The multiplication by a constant is necessary to account for the DC offset current at the time of Interruption.

Transients due to a Short circuit in 3ϕ Alternator.

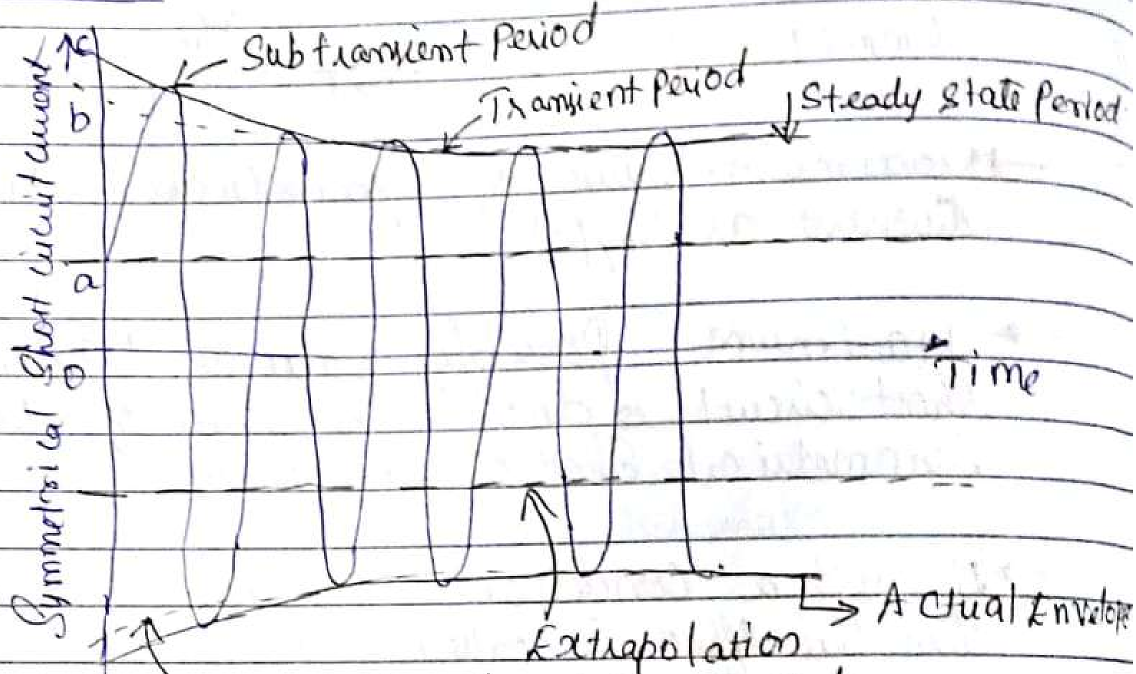


Fig1 - Extrapolation of transient envelope

On No Load Symmetrical Short circuit armature current in an alternator / oscillogram of Short circuit current

- Consida a Three Phase alternator running on noload.

- If a 3ϕ fault occur at the terminals of the alternator then a heavy short circuit current flows in the armature circuit.

- The oscillogram of Short circuit current after removing the Dc offset current.

- At the time of Short circuit in a 3ϕ M/c, the Voltage wave of the Three Phases will have different Phase.

* Therefore the DC offset current will be different in each Phase of a 3φ Machine & so it is accounted seperately on an empirical basis.

* The AC Component of the Short circuit current is called Symmetrical Short circuit current.

* The Symmetrical Short circuit Can be divided into Three Regions

i) SubTransient

ii) Transient

iii) Steady State

Under Steady State:-

* The armature reaction of a Synchronous generator produces a demagnetizing flux.

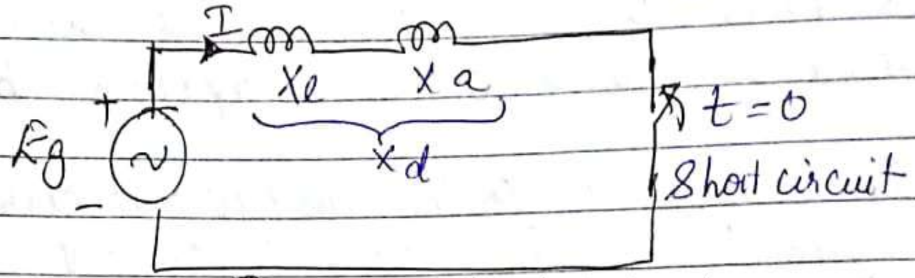
* This effect is represented as a reactance called armature reaction reactance Xa.

* The Sum of leakage reactance Xl and Xa is called synchronous reactance, Xs.

* In case of salient pole Machines the synchronous reactance is called Direct axis Reactance and denoted by Xd.

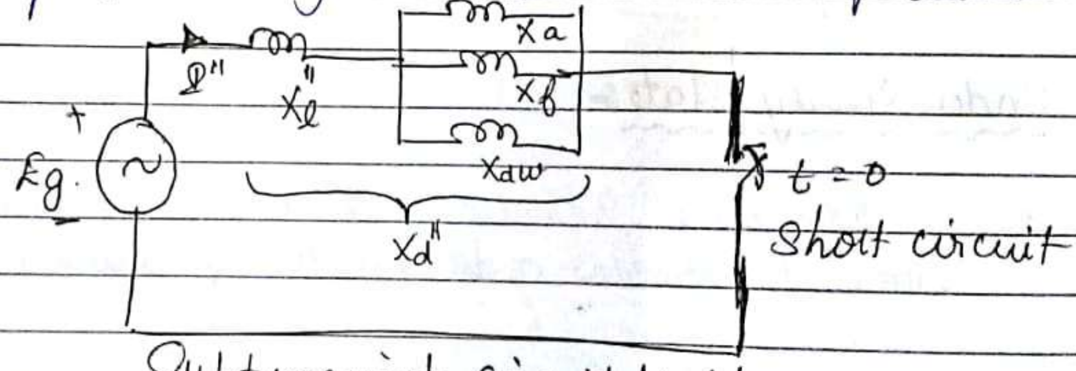
* On neglecting the armature resistance the steady

State Short circuit model of an alternator



Steady State short circuit

At any instant of Short circuit the DC offset current appears in all the 3 Phases of Stator. This DC offset current can induce currents in rotor field winding and damper winding by Transformer action. The Increase in field current and damper winding Current will set up flux in a direction to augment the main flux. This effect can be represented by two reactances in parallel with Xa



Subtransient circuit Model

Where,

X_f = Flux Created by Induced current in the field winding

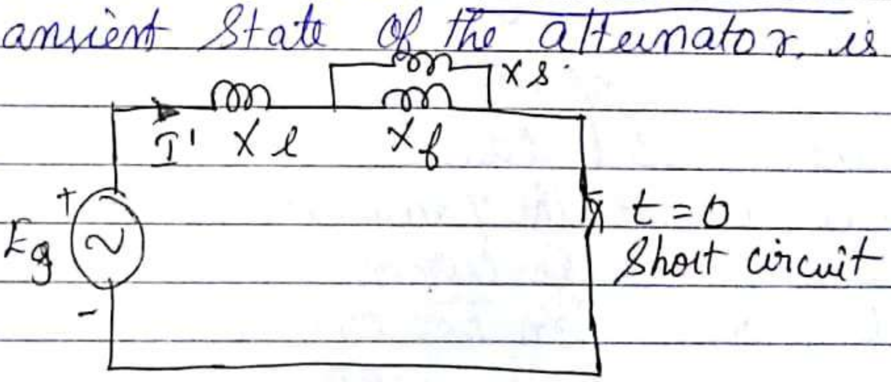
X_{dw} = Flux Created by Induced Currents in the Damper winding.

The combined effect of all the three reactances is to reduce the total reactance of the machine and so the short circuit current is very hight in this state which is called as Subtransient State.

The total reactance under this condition is called the Sub transient reactance and denoted by X_d''.

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

The Induced currents in the damper winding disappears after few cycles from the instant of fault. Because the time constant of the damper winding is smaller than the field winding. This effect is equivalent to open circuted X_{dw} and this state is called Transient State. The transient state of the alternator is given below



The total reactance in transient state is called transient reactance and is denoted by X_d'

$$X_d' = X_l + \frac{1}{\frac{1}{X_a} + \frac{1}{X_f}} \quad \text{—} ②$$

The transient State will exist for few cycles and then Steady State Conditions are achieved. Because the effect of field winding current will also die out in a Short time depending on its time constant. This effect is equivalent to open circuiting x_f and this State is referred to as Steady State.

In a Steady State the total Reactance is given by sum of x_l and x_a

$$\boxed{x_d = x_l + x_a} \quad -③$$

From ①, ② & ③. we can say that the subtransient reactance of the Machine is Smallest and Steady State reactance of the machine is highest among the reactances. Therefore $X_d'' < X_d' < X_d$

From the oscillogram shown above in Fig1

The envelope of the current wave during transient period can be extrapolated backwards in time to meet the y axis at point b. Similarly the envelope of the current wave during Steady State period can be extrapolated backwards in time to meet the y axis at point a.

Let $|I|$ = RMS Value of Steady State current.

$|I'|$ = RMS Value of Transient current excluding Dc component.

$|I''|$ = RMS Value of Subtransient current excluding Dc component.

From the wave form, we get,

$$|I| = \frac{Oa}{\sqrt{2}} \; ; |I'| = \frac{Ob}{\sqrt{2}} \; ; |I''| = \frac{OC}{\sqrt{2}}$$

$$X_d'' = \frac{|Eg|}{|I''|} = \frac{|Eg|}{Oa/\sqrt{2}}$$

$$X_d' = \frac{|Eg|}{|I'|} = \frac{|Eg|}{Ob/\sqrt{2}}$$

$$X_d = \frac{|Eg|}{|I|} = \frac{|Eg|}{Oc/\sqrt{2}}$$

The momentary current rating of the circuit breakers used for generators and synchronous motors are determined using subtransient reactances. The Interrupting Capacity of the Circuit Breakers are determined using subtransient reactance for generators and transient reactance for motors.

During Loading

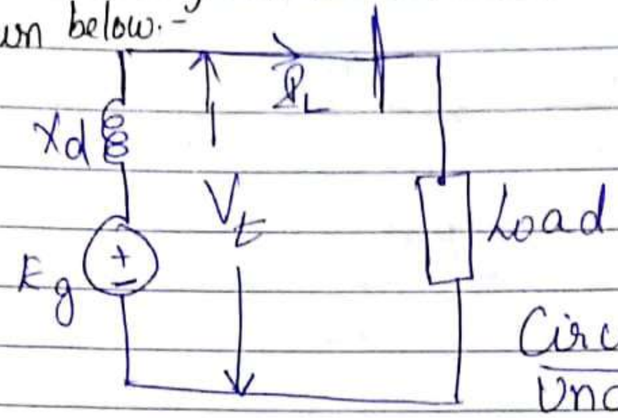
Internal Voltages Of Loaded Synchronous Machines Under Transient Conditions:-

* Consider a generator connected to a bus with Voltage V_t.

* Let I_L be the current delivered by the generator

* The equivalent circuit of a loaded generator

Under Steady State Condition supplying a load current is shown below:-



Circuit of a loaded generator Under Steady State Condition

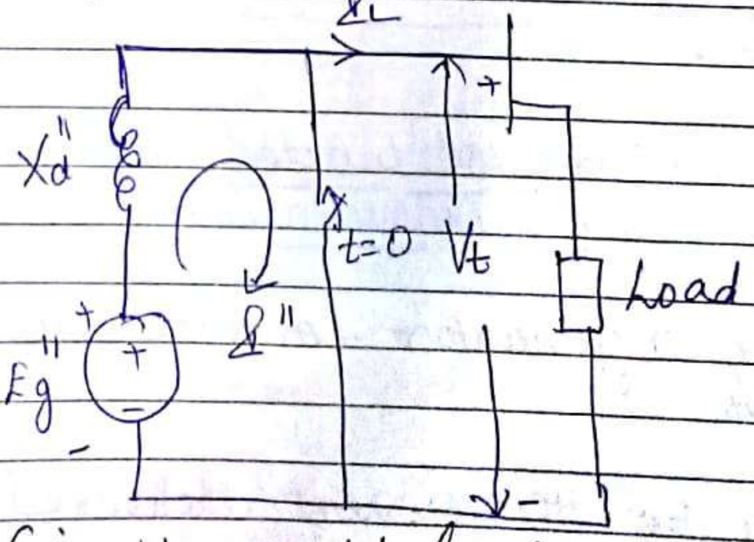
Here,

E_g - Induced Emf under loaded Condition

X_d - Direct axis Synchronous reactance of the machine.

$$E_g = V_t + jX_d I_L$$

Let a Short circuit occur at the terminals of the generator while delivering the load current I_L. Now in order to study the Subtransient State the E_g and X_d should be replaced by E_g'' and X_d''



Circuit model for Computing Subtransient current.

In order to Study the transient State the E_g and X_d of Should be replaced by

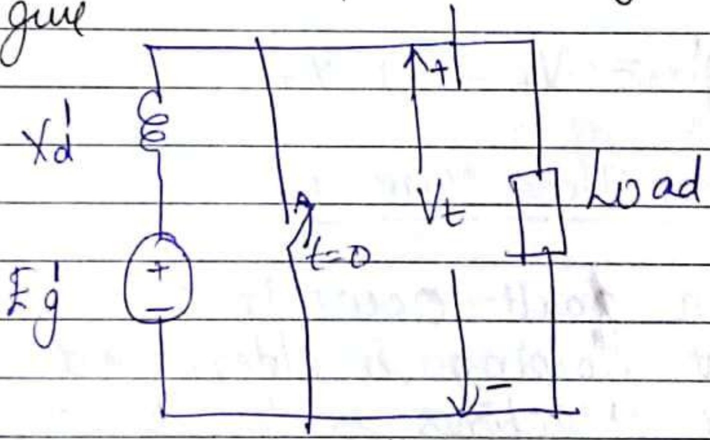
Here, $E_g'' =$ Subtransient Internal Voltage

$X_d'' =$ Subtransient Reactance.

When Switch is Closed subtransient fault current will flow in the fault path.

$$E_g'' = V_t + j I_L X_d''$$

Let us Study the transient State the E_g and X_g should be replaced by E_g' and X_d' as shown in figure



Circuit Model for Computing transient Current

Here $E_g' =$ Transient Internal Voltage
$X_d' =$ Transient Reactance.

When Switch is Closed, Transient fault current will flow in the fault path.

$$E_g' = V_t + j I_L X_d'$$

E_g'' & E_g' are functions of Prefault load current. Therefore E_g'' and E_g' have to be estimated for each value of load current.

The Synchronous Motors have internal emfs and reactances similar to that of a generator except that the current direction is reversed.

Hence for short circuit studies the circuit models similar to ~~that~~ above can be used for synchronous motor with reversed direction of current. Therefore for synchronous motor,

$$E_g'' = V_t - j I_L X_d''$$

$$E_g' = V_t - j I_L X_d'$$

Symmetrical Three Phase Faults:-

→ When a fault occurs in a power system network the current flowing is determined by the internal emf of the machines in the system, by their internal impedances and by impedances in the network between machine and the fault.

→ When the fault current is equal in all the phases, the fault is called Symmetrical Fault

→ The Fault current will be symmetrical only in 3ϕ faults in which all the three Phases are shunted to ground.

The symmetrical fault can be analysed on per phase basis using reactance diagram (or) by using per unit reactance diagram.

→ The Symmetrical fault can be analysed on per phase basis using reactance diagram (or) by using

→ The Symmetrical fault analysis has to be performed separately for subtransient, transient and steady state conditions of the fault, because the reactances and internal emfs of the synchronous machines will be different in each state.

→ In symmetrical fault Analysis, the reactance diagram of the Power system is formed using the informations in single line diagram.

For estimation of subtransient fault current, the synchronous machine is represented by its subtransient internal emf in series with subtransient reactance.

IIIly for estimation of transient fault current, the synchronous machine is represented by its transient internal emf in series with transient reactance and for steady state fault analysis steady state internal emfs and reactance are used for synchronous machines.

Once the per unit reactance diagram of the power system is formed for a particular state (ie) either subtransient / transient / steady state) of fault

Condition, then the currents and voltages in the various parts of the system can be determined by any one of the following method:-

i) Using KVL & KCL

ii) Using Thevenin Theorem.

Symmetrical Fault current Estimation Using [illegible] Law:-

i) Choose appropriate base values and determine the prefault condition reactance diagram of the given power system (The prefault condition reactance diagram is separately formed for subtransient, transient and steady state condition of the fault).

ii) Calculate the Internal emfs of synchronous machines and the prefault voltage at the fault point using prefault current (Load current).

Note:- If the power system is unloaded (i.e) If there is no prefault current then prefault voltage at the fault point is 1pu. Also the Internal emf's for subtransient and transient state are same as steady state induced emf.

iii) Draw the fault condition reactance diagram of the system. This diagram is same as prefault reactance diagram except that the fault is represented by a short circuit or by the specified fault impedance. The currents in this reactance diagram are fault condition currents.

(iv) Calculate the pu value of fault currents in the various parts of the system and in the fault

v) The actual values of the fault currents are obtained by multiplying the pu values by the respective base currents.

Note:- When T/F are used in the power system, the base currents will be different for various sections of power system.

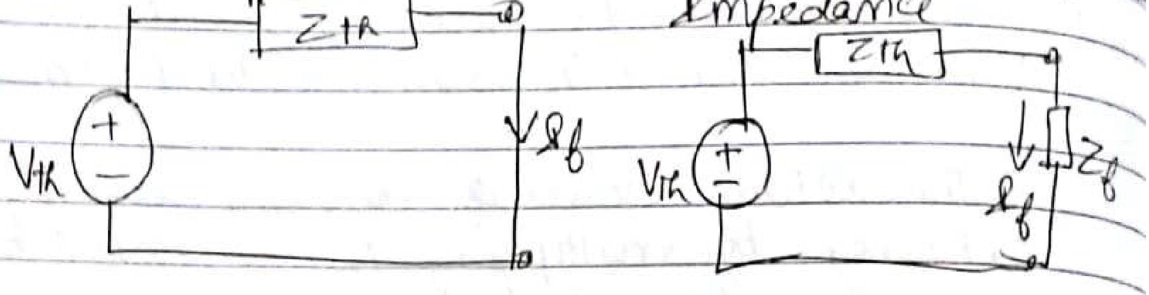
Symmetrical fault current estimation using Thevenin's Theorem

i) Choose appropriate base values and determine the prefault condition reactance diagram of the given power system.

ii) Calculate the prefault voltage at the fault point using the prefault current (load current) If the system is unloaded, then the prefault voltage is 1 pu. The prefault voltage at the fault point is the thevenin's voltage.

iii) Determine the thevenin's Impedance of the system at the fault point (This is given by looking back Impedance at the fault point) To determine the thevenin's impedance, replace all the sources by zero value source and then reduce the resultant N/w to single equivalent Impedance.

iv) Draw the thevenin's equivalent at the fault point F as shown in fig below. Here the fault can be represented by a short circuit or by Fault Impedance



Thevenin's equivalent at fault point

Now the pu value of fault current, $I_f = V_{th}/Z_{th}$

The actual value of fault current is obtained by multiplying the pu value with base current.

v) The fault currents in other parts of the Network are determined from the knowledge of change in current due to fault and prefault current. The fault current (i.e) Post fault current in any part of the system is given by sum of prefault current and change in current due to fault.

vi) The change in current due to fault can be estimated by connecting the thevenin's source with reversed polarity (i.e) negative of thevenin's voltage at the fault. Replace all other sources by zero value sources. Now the currents in various parts of the system are the change in currents due to fault. Calculate these currents by any conventional Technique.

Selection of Circuit Breakers:-

* The circuit Breakers are Protective devices which are used in Power System to automatically open the faulty part of the system in the event of a fault.

* In normal working condition they can be used as a switch.

* Hence the two functions of CB are
i) TO act as switch for normal load conditions.
ii) TO automatically Isolate (or) open the faulty part in the event of a fault.

* The circuit breakers are normally used in power system at places where the power level is Veryhigh.

* They are used in high voltage transmission lines, Substations, generating Stations and for heavy loads in Industries.

* Since the circuit breakers are employed in places where the Power level is high, Whenever its contacts open it has to interrupt heavy currents both during load conditions and faulty conditions.

* Since the power System is Predominantly inductive in nature, the Interruption of current when the Circuit Breaker open it's Contanct is associated with large ~~induced~~ Voltages induced across its contacts which Inturn results in sparking at the contacts.

* Hence in circuit Breakers the amount of current it has to interrupt is an important criteria.

The circuit breaker for a particular application (or location) is selected based on the following ratings:-

1. Normal working Power level specified as rated interrupting current or rated interrupting KVA.

2. The Fault level specified as either the rated Short circuit interrupting current (or rated Short circuit interrupting MVA.

3. Momentary current rating.

4. Normal working Voltage.

5. Speed of Circuit Breaker.

Momentary Current Rating:-

→ It is the maximum current that may flow through a circuit breaker for a short duration.

→ It is the current that may flow during subtransient period of fault condition.

→ In fault analysis the subtransient fault current calculated using subtransient circuit model is the Symmetrical subtransient current.

→ It is then multiplied by a factor of 1·6 to get the maximum momentary current during fault. [The factor 1·6 accounts for DC offset current during Subtransient Period].

→ The circuit breaker is chosen such that it's momentary current rating is less than the calculated value.

Short circuit Interrupting current :-

→ Usually the circuit breaker will open its contacts in the transient period and so the short circuit interrupting current rating depends on transient period currents.

→ In fault Analysis the transient fault current calculated using transient circuit model is the symmetrical transient fault current.

→ It is then multiplied by a factor 1·0 to 1·5 to get the maximum interrupting current. (The factor 1·0 to 1·5 accounts for DC offset current during transient period).

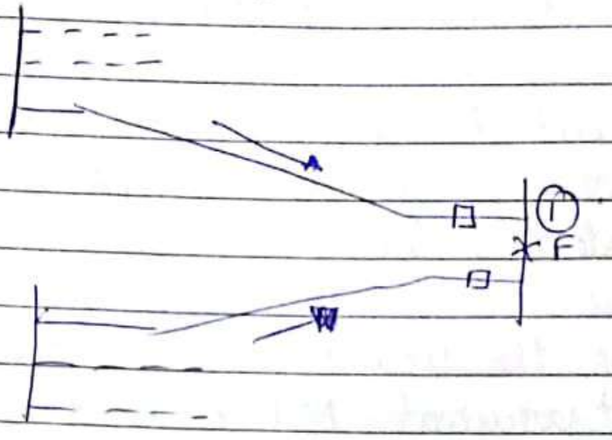
→ The circuit Breaker is chosen such that its short circuit interrupting current rating is less than the calculated value.

Multiplying factor to find the short circuit Interrupting current

Speed of Circuit Breaker	Multiplying factor
8 cycles (or) more	1·0
5 cycles	1·1
3 cycles	1·2
2 cycles	1·4
1½ cycles	1·5

Short circuit Interrupting MVA:-

Consider the system shown below.



*Assume that a symmetrical short circuit occurs at bus 1.

* The Prefault Voltage of the bus is 1 pu and as soon as the fault takes place, the Voltage of this bus reduces to almost zero.

* The Voltage of the other buses will sag during the short circuit and the reduction in Voltage of Various buses is an Indication of the strength of the N/W.

* We normally are interested in knowing this strength and the severity of the short circuit stresses.

* This is met by Short circuit Capacity (Or Fault Level of the bus.

* Higher the Short circuit capacity of a bus more is its Strength

(c) It is able to Maintain its Voltage in case of a fault on any other bus.

Short circuit capacity:- It is the Product of the magnitude of Prefault voltage and post fault current

It is the fault current is measured in Amperes and the system Voltage in Volts.

Then in 3ϕ system,

$$(MVA)_{SC} = \sqrt{3}\ V_{PF}\ I_f \times 10^{-6}$$

Where, V_{PF} - Prefault Voltage (L-L) in Volts.
I_f - post fault current (A)

$V_{PF} \simeq V_B$ (Base voltage in that section)

$$|MVA)_{SC} = \sqrt{3}\ |V_B|\ |I_f| \times 10^{-6}$$

$$|I_f| = \frac{|V_B/\sqrt{3}|}{|Z|}$$

Where Z - Impedance in Ω in the circuit upto the point of fault.

$$(MVA)_{SC} = \frac{|V_B|^2}{|Z|} \times 10^{-6} = \frac{(KV_B)^2}{|Z|}$$

We have, $|Z_{pu}| = |Z| \times \frac{MVA_B}{(KV_B)^2}$

$$\therefore \ |MVA|_{SC} = \frac{|MVA|_B}{|Z_{pu}|}.$$

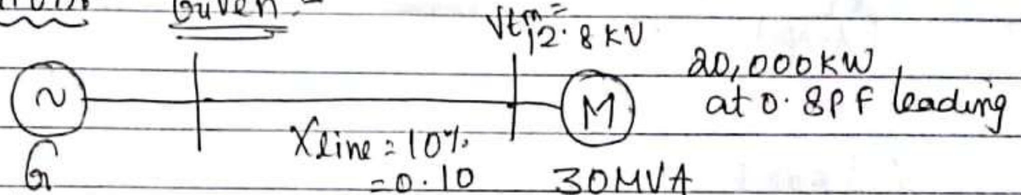
Where, $|MVA|_B$ – Total 3ϕ MVA.

$|KV|_B$ – Line to Line Voltage in kV.

Problems :-

1) A synchronous generator and motor are rated for 30,000 KVA, 13.2 KV and both have subtransient reactance of 20% The line connecting them has a reactance of 10% on the base of machine ratings. The motor is drawing 20,000 KW at 0.8 PF leading The terminal voltage of the motor is 12.8 KV. When a symmetrical 3ϕ fault occur at motor terminals, Find the subtransient current in generator, motor and at the fault point?

Solution:- Given :-



30MVA
13.2KV
$x_d'' = 20\%$

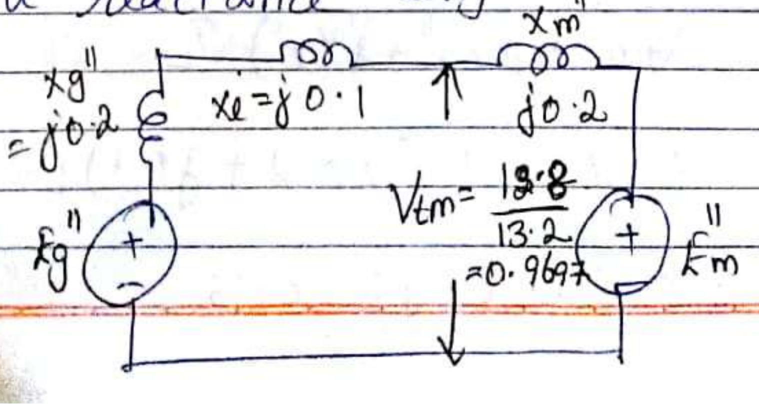
$X_d'' = 20\%$
30 MVA
13.2KV

Fault — at Motor terminals — 3ϕ symmetrical

To find:- Subtransient current in generator, $I_g'' = ?$
" " " motor, $I_m'' = ?$
Fault current = ?

Step1.- Base values (Assumed) → $S_B = 30MVA$ $V_B = 13.2KV$

pu reactance Dig



$x_g'' = j0.20$ (no change)
$X_l = 0.10$
$X_m'' = 0.20$

$V_{tm} = 12\cdot8$ kV   Base $= 13\cdot2$ kV.

$V_{tm}(pu) = \frac{12\cdot8}{13\cdot2} = \underline{0\cdot9697}$ pu

Step 2:-

$I_L = \frac{S}{\sqrt{3}\,V}$ ~~ϕ~~ $V = V_{tm} = 12\cdot8$ across Motor.

$S = \frac{P}{PF} = \frac{20{,}000 \text{ KW}}{0\cdot8} = \underline{25 \text{ MVA}}$

$I_{L\,(Amps)} = \frac{25\times10^{6}}{\sqrt{3} * 12\cdot8\times10^{3}} = 1127\cdot6\,(A)$

$I_L(Base) = \frac{S_B}{\sqrt{3}\,V_B} = \frac{30\times10^{6}}{\sqrt{3}\times13\cdot2\times10^{3}} = 1312\,A$

$I_L(pu) = \frac{I_L(Amps)}{I_L(Base)} = \frac{1127\cdot6}{1312} = \underline{0\cdot859\,A}$

$\phi = \cos^{-1}(0\cdot8) = 36\cdot87$

It is a leading load ∴ $I_L\,pu = 0\cdot859 \angle +36\cdot87$

$\boxed{I_L(\text{in complex}) = 0\cdot6872 + j\,0\cdot5154}$

Method-I - KVL+KCL Approach.

Step3:- PreFault:-

$E_g'' = V_{tm} + (jX_g'' + jX_l)\,I_L$

$= 0\cdot9697 + (j0\cdot2 + j0\cdot1)(0\cdot6872 + j0\cdot5154)$

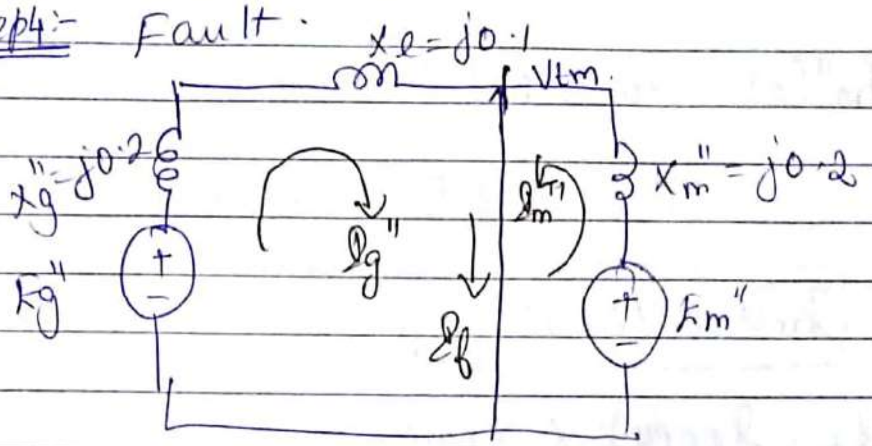
$\boxed{E_g'' = 0\cdot81508 + j0\cdot20616}$

$E_m'' = V_m - j0.2 I_e.$

$E_m'' = 0.9697 - j0.2(0.6872 + j0.5154)$

$\boxed{E_m'' = 1.07278 - j0.13744}$

Step4:- Fault.



$I_g'' = \frac{E_g''}{jx_g'' + jx_e} = \frac{0.81508 + j0.20616}{j0.2 + j0.1}$

$\boxed{I_g'' = 0.6872 - j2.7169}$

$I_m'' = \frac{E_m''}{jX_m} = \frac{1.07278 - j0.13744}{j0.2}$

$\boxed{I_m'' = 0.6872 - j5.3638}$

$I_f = I_g'' + I_m'' = 0.6872 - j2.7169 + 0.6872 - j5.3638.$

$\boxed{I_f = -j8.081}$

Step5:- In Amps $I_{(Amps)} =$ ~~I_{pu}~~ $I_{pu} \times I_{base}$.

$I_g''(A) = I_g''(pu) \times I_{base}$.

$= (0{\cdot}6872 - j2{\cdot}716) \times 1312$.

$\boxed{I_g''(A) = \cancel{0{\cdot}687}\ 901{\cdot}344 - j\,3563{\cdot}39}$

$I_m''(A) = I_m''(pu) \times I_{Base}$.

$= (0{\cdot}6872 - j\,5{\cdot}3638) \times 1312$

$\boxed{I_m''(A) = 901{\cdot}606 - j\,7037{\cdot}31}$

$I_f(A) = I_f(pu) \times I_{base}$.

$= (-j\,8{\cdot}081) \times 1312$

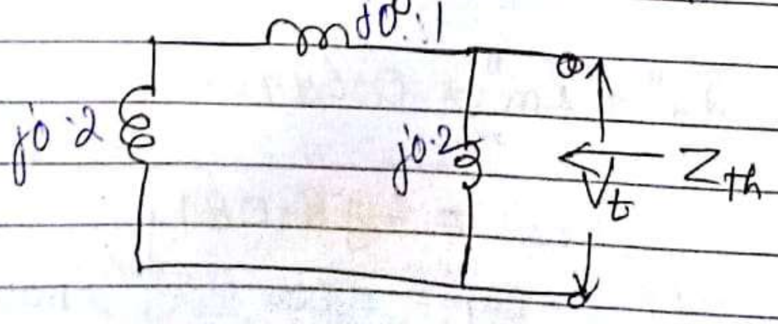
$\boxed{I_f = 10602{\cdot}27j\ (A)}$

Method-2 - Thevenins

Till step 2 is same for both method.

Step3:- Finding Z_{th} at fault location

Short all voltage sources.



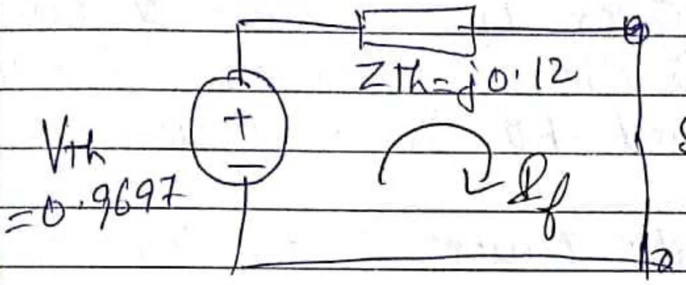
$$Z_{th} = \frac{(j0.1+j0.2)\times j0.2}{(j0.1+j0.2)+j0.2} = \underline{j0.12} //$$

Step 4:-

V_{th} = Voltage across the faulted terminal

$= V_{tm} = \underline{0.9697}$

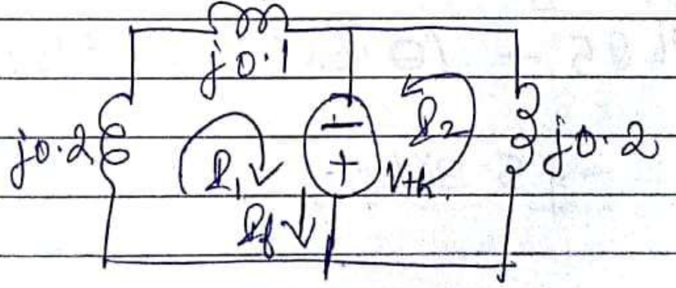
Step 5:- Thevenin circuit.



$$I_f = \frac{V_{th}}{Z_{th}} = \frac{0.9697}{j0.12} = -8.0808j$$

Step 6:-

To find the change in current due to fault.



The change in current due to fault can be calculated by connecting the thevenin's generator with reversed polarity at the fault as shown in figure. [All other sources are replaced by zero value sources (ie) by short circuit].

Now, $I_1 = \frac{V_{th}}{j0.2 + j0.1} = \frac{0.9697}{j0.3} = -j3.2323$

$I_2 = \frac{V_{th}}{j0.2} = \frac{0.9697}{j0.2} = -j4.8485$

Step6 :- To find subtransient fault current in motor and generator.

Subtransient fault current of Motor and generator are given by the sum of prefault current and the change in current due to fault current delivered by the various generators.

Here the Prefault current is the load current

$I_g'' = I_1 + I_L.$

$I_g'' = I_1 + I_L = -j3.2323 + 0.6872 + j0.515$

$= 0.6872 - j2.7163$

$I_m'' = I_2 - I_L.$

$I_m'' = -j4.8485 - (0.6872 + j0.516).$

$= -0.6872 - j5.3645.$

Result :-

$I_g''(A) = 901.344 - j3563.39\ (A)$

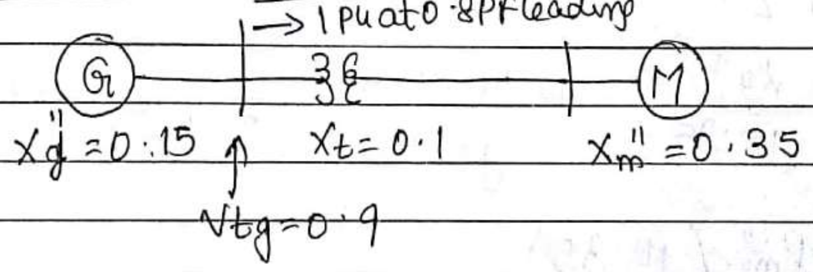
$I_m''(A) = 901.606 - j7037.31\ (A)$

$I_f = 10602.27j\ (A)$

Refer in

② A generator is connected through a Transformer to a synchronous motor. The Subtransient reactance of generator and motor are 0.15 and 0.35 respectively. The leakage reactance of the T/F is 0.1 PU. All the reactance are calculated on a common base. A three phase fault occurs at the terminals of the motor. When the terminal voltage of the generator is 0.9 PU the output current of generator is 1PU and 0.8 PF leading. Find the subtransient current in PU in the fault, generator and motor. Use the terminal voltage of generator as reference vector.

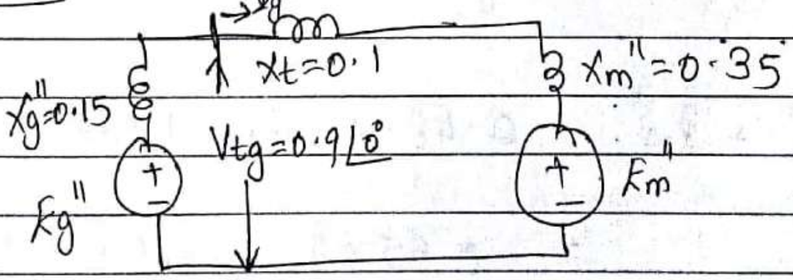
Solution:- Given:-



Terminal Voltage of generator as Reference Vector.

To find:- $I_F = ?$ $I''_g = ?$ $I''_m = ?$

Step 1:- All reactance are calculated on a common base



$\phi = \cos^{-1}(0.8)$
$= 36.87$

$I''_g = 1 \angle 36.87$

$E''_g = V_{tg} + I''_g X''_g$

$= 0.9 + j0 + 1\angle 36.87\,(j0.15) = \underline{0.8099 + j0.12}$

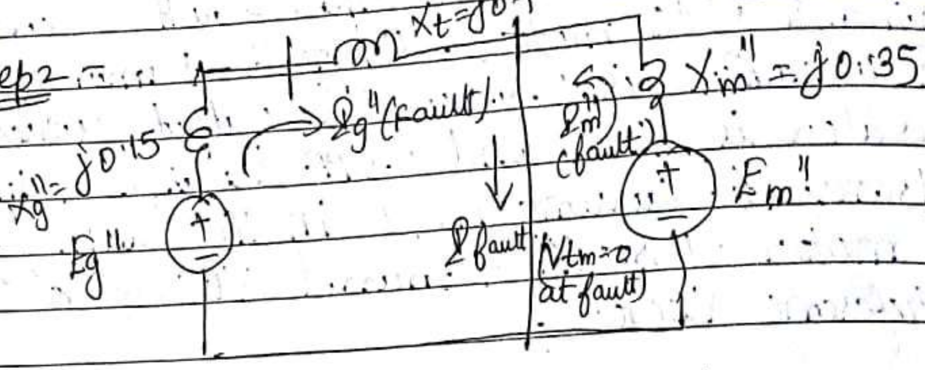
$E_m'' = V_{tg} - j\cancel{I_g}(jX_t + jX_m'')\, I_g$

$= 0.9 + j0 - (j0.1 + j0.35)\; 1\angle 36.9$

$\boxed{E_m'' = 1.1702 - j0.3599}$

KCL & KVL Method

Step 2 :



$E_g'' = I_g''\,[j0.15 + j0.1] + \cancel{V_{tm}}^{\,0}$

$I_g'' = \dfrac{E_g''}{j0.25} = \dfrac{0.8099 + j0.12}{j0.25} = \underline{\underline{0.48 - j3.24}}$

$E_m'' = I_m''\,(j0.35)$

$I_m'' = \dfrac{E_m''}{j0.35} = \dfrac{1.1702 - j0.3599}{j0.35} = \underline{\underline{-1.028 - j3.343}}$

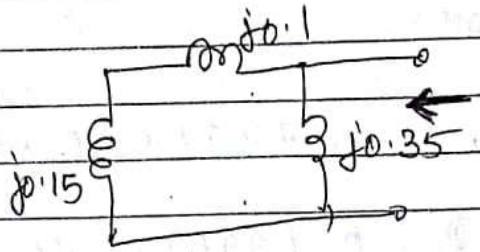
$I_f = I_g'' + I_m'' = 0.48 - j3.24 - 1.028 - j3.343$

$= \underline{\underline{-0.5502 - j6.5831}}$

Thevenin's Theorem:-

Step 1 is same.

Step 2:- Z_{th}

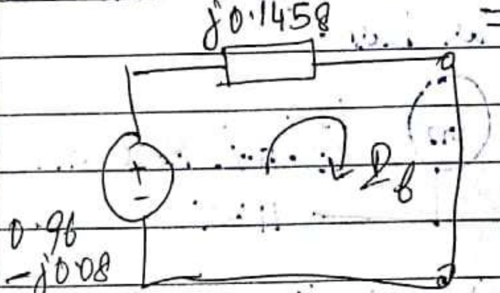


$$Z_{th} = \frac{(j0.1 + j0.15) \times j0.35}{(j0.15 + j0.1 + j0.35)} = j0.1458 \text{ pu}$$

$$V_{th} = V_{fault\,point} = \cancel{V_g}'' - j(\cancel{X} + jX_t)\, I_g''$$

$$= (\cancel{0.8099 + j0.42}\ \overset{0.9+j0}{}) - (\cancel{j0.118} \times j0.1) \times (1\angle 36.87)$$

$$= 0.96 - j0.08$$



$$I_f = \frac{V_{th}}{Z_{th}} = \frac{0.96 - j0.08}{j0.1458}$$

$$\boxed{I_f = -0.5502 - j6.5831}$$

Step 3:- To find the change in current due to fault

$$\Delta I_g = \frac{V_{th}}{j0.15 + j0.1} = \frac{0.9633 - j0.08}{j0.25} = -0.3224 - j3.8396$$

$$\Delta I_{g_2} = \frac{V_{th}}{j0.35} = \frac{0.9633 - j0.08}{j0.35} = -0.2303 - j2.7421$$

Step4:-

To find the subtransient fault current in motor and generator:-

$$I_1 = I_2 = 0.7997 + j0.6004$$

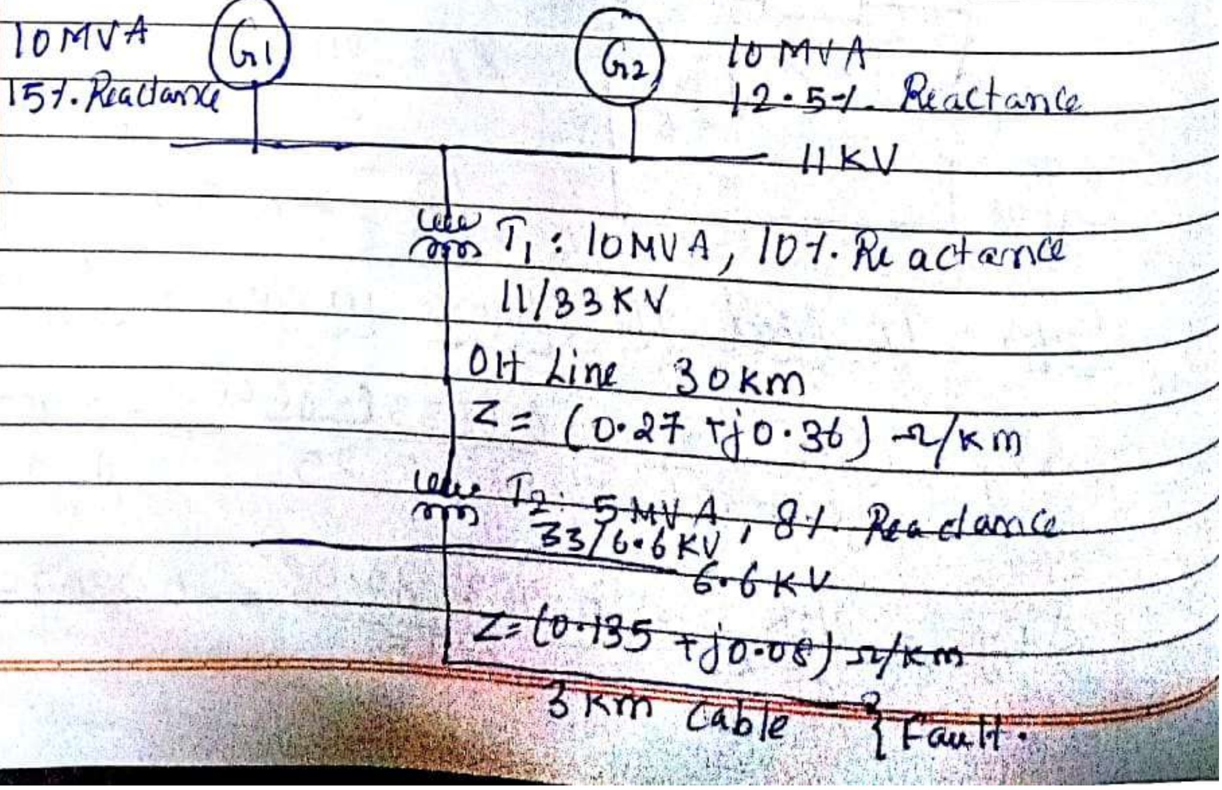
$$I_g'' = \Delta I_1 + I_L = 0.7997 + j0.6004 - 0.3224 - j3.8396$$

$$= \underline{0.4773 - j3.2393}$$

$$I_m'' = +\Delta I_2 - I_L = -(-0.2303 - j2.7426) - (0.7997 + j0.6004)$$

$$= \underline{-1.03 - j3.343}$$

③ For the radial N/w shown in figure, a 3φ fault occurs at F. Determine the fault current and the line Voltage at 11KV bus under fault conditions. Choose 100MVA, 33KV as base.



Solution:- By Thevenin's Theorem

Step1:- Selecting base values

Tr. line Sect 2 – $S_B = 100MVA$, $V_B = 33KV$

Sec 1 – $S_B = 100 MVA$, $V_B = 11 KV$

Sec 3 – $S_B = 100MVA$, $V_B = 6.6 KV$

Step2:- Doing PU in common base,

$X_{g1} = 0.15 \times \frac{100}{10} = j1.5$ pu

$X_{g2} = 0.125 \times \frac{100}{10} = j1.25$ pu

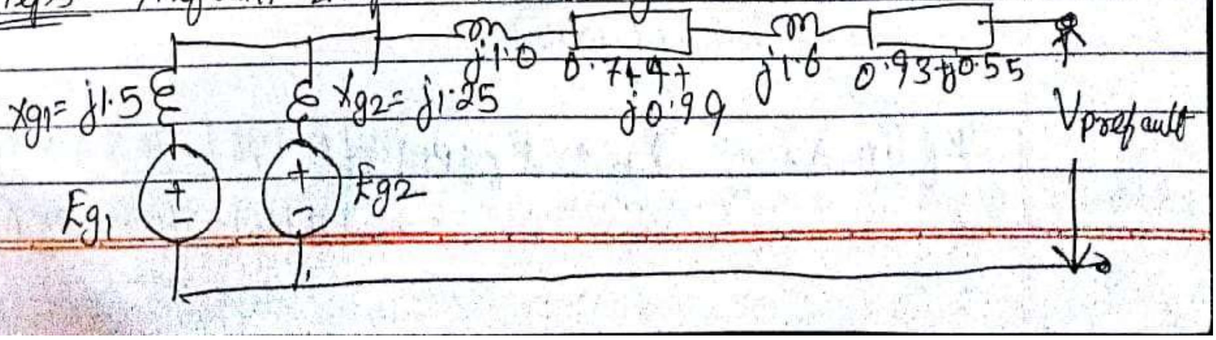
$X_{T1} = j0.1 \times \frac{100}{10} = j1.0$ pu

$X_{T2} = j0.08 \times \frac{100}{5} = j1.6$ pu

$Z_{Line} = \dfrac{30(0.27 + j0.36)}{\frac{33^2}{100}} = 0.744 + j0.99$ pu

$Z_{cable} = \dfrac{3(0.135 + j0.08)}{\frac{6.6^2}{100}} = 0.93 + j0.55$ pu

Step3:- Prefault Impedance Diagram-

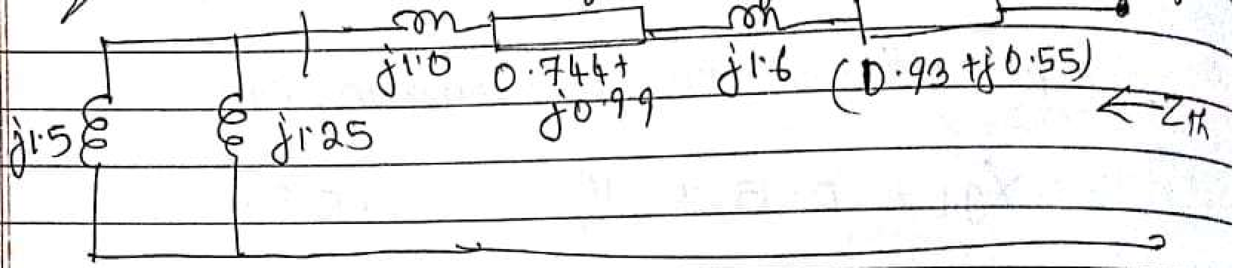


Vprefault = 1.0 Since the system is unloaded prior to occurrence of fault.

VPF is assumed to be 1 pu & Vth = Vprefault = 1.0 pu

Step4 :- Zth

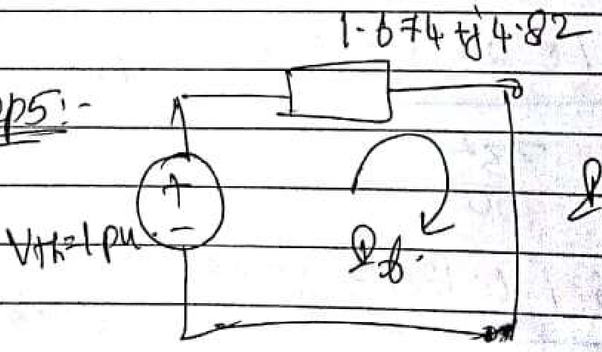
Shorting the generated voltage we obtain the equivalent circuit of the system prior to the fault



$$Z_{th} = \left(\frac{j1.5 \times j1.25}{j1.5 + j1.25}\right) + \left(j1.0 + 0.744 + j0.99 + j1.6 + 0.93 + j0.55\right)$$

$$= \underline{1.674 + j4.82}$$

Step5 :-



$$I_f = \frac{1.0}{1.674 + j4.82}$$

$$= \underline{0.196 \angle -70.8 \text{ pu}}$$

$$I_b = \frac{100 \times 10^6}{\sqrt{3} \times 6.6 \times 10^3} = \underline{8747 \text{ (A)}}$$

$$I_f \text{(in A)} = I_b * I_{f(pu)} = (0.196 \angle -70.8)\, 8747$$

$$= \underline{1714 \angle -70.8 \text{ (A)}}$$

Step 6:-

$Z_{\text{+ill}}$ (11 KV bus) $= (0.93 + j0.55) + j1.6 + (0.744 + j0.99) + j1.0$

$= 1.674 + j4.14.$

Voltage at 11 KV bus $= (1.674 + j4.14) \times (0.196 \angle -70.8)$

$= 0.875 \angle -2.82$ pu.

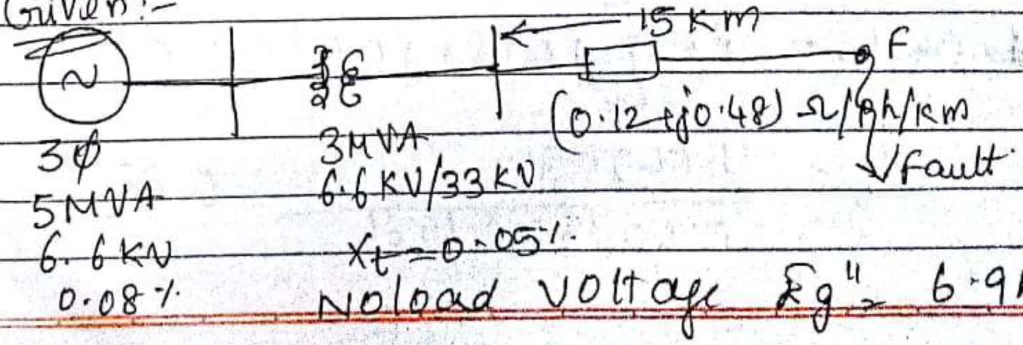
V at 11 KV bus = Vinpu × V_B

$= 0.875 \angle -2.82 \times 11$

$= 9.625 \angle -2.82$ KV

(4) A 3φ, 5MVA, 6.6KV alternator with a reactance of 8% is connected to a feeder of series impedance of $0.12 + j0.48\ \Omega$/Ph/Km. The Transformer is rated at 3MVA, 6.6KV/33KV and has a reactance of 5%. Determine the fault current supplied by the generator operating under noload with a voltage of 6.9KV when a 3φ symmetrical fault occurs at a point 15km along the feeder.

Given:-



Noload voltage $E_g'' = 6.9$KV (given)

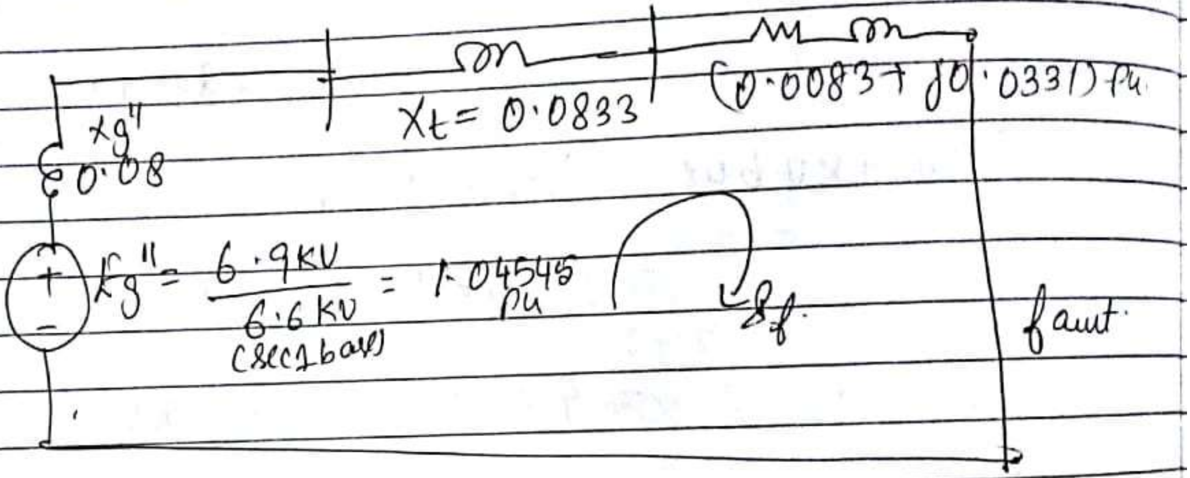
To find :-

$I_f = ?$

Step1 :-

Converting all to pu values on common base of $S_B = 5\,MVA$ $V_B = 6.6\,kV$ on section 1

$S_B = 5\,MVA$ $V_B = 33\,kV$ on section 2. [Gen is taken as base]



$X_{tn} = 0.05 \times \frac{5}{3} = 0.0833$ pu

Z_{feeder} in pu $= \frac{(0.12 + j0.48) \times 15}{\frac{33^2}{5}} = 0.0083 + j0.0331$ pu

Step2 :-

$$E_g'' = I_f \left[jX_g'' + jX_t + jX_{feeder} \right]$$

$$1.04545 = I_f \left[j0.08 + j0.0833 + 0.0083 + j0.0331 \right]$$

$$I_f = \frac{1.04545}{0.0083 + j0.1964} = 0.2226 - j5.313$$

Step3 :-

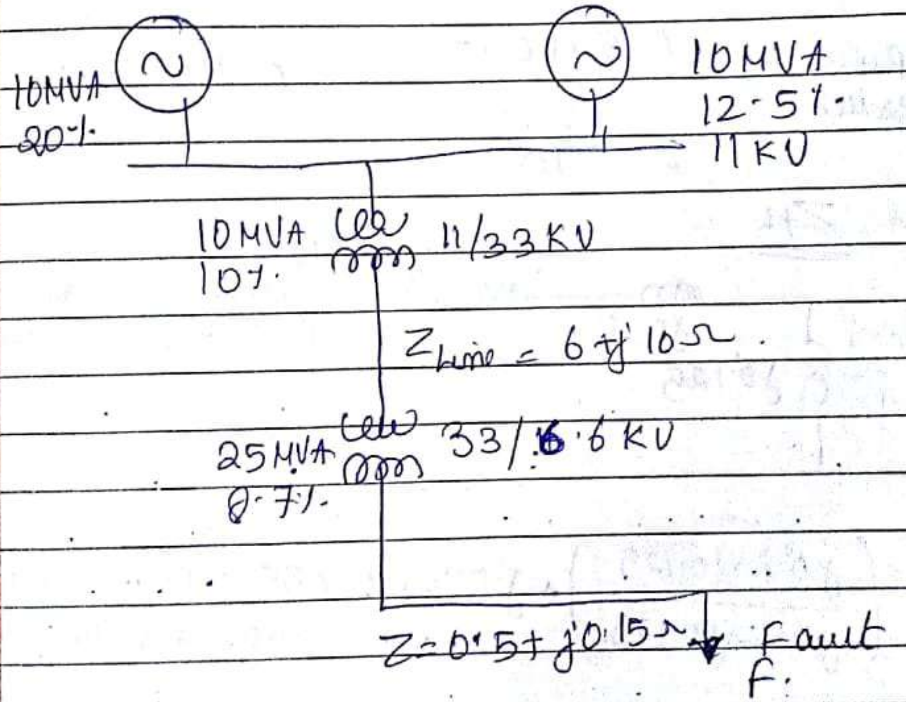
$I_{base} = \frac{S_B}{\sqrt{3} V_B} = \frac{5\times10^6}{\sqrt{3}\times33\times10^3} = 87.4773(A)$

Step4 :- I_f (in A) = I_f(pu) × I_{Base}.

$= (0.2226 - j5.313) \times 87.4473$

$= 19.76 - j\,464.607$ (A)

⑤ For the radial N/W A 3φ fault Occurs at point F Determine the fault current.



Solution :Step1 Select the base as Generator

$S_B = 10$ MVA $V_B = 11$ KV in section1
$S_B = 10$ MVA $V_B = 33$ KV in section2
$S_B = 10$ MVA $V_B = 6.6$ KV in Section3

Step2:- Convertion of all to same base in Pu.

$X_{g_1} = 0.20 \quad X_{g_2} = 0.125$ } No change.

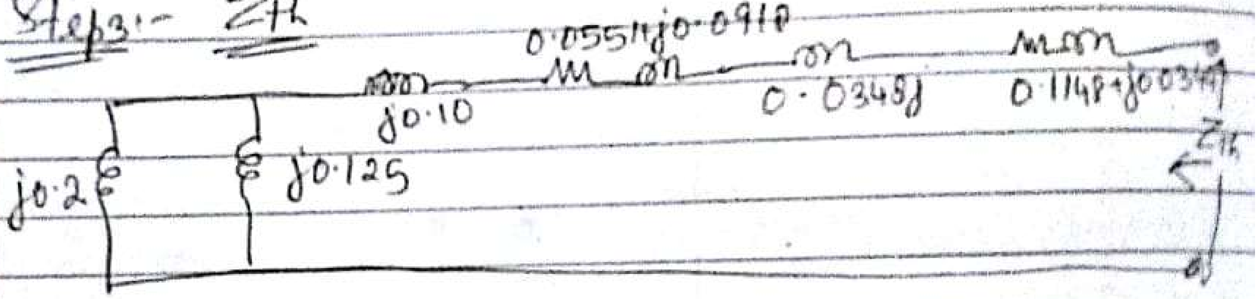
$X_{t1} = 0.10$

$$Z_{in}\,pu = \frac{6+j10}{\frac{33^2}{10}} = 0.0551 + j0.0918 \text{ pu}$$

$$X_{T2}(n) = 0.087 * \frac{10}{25} = 0.0348 \text{ pu}$$

$$\underset{(\text{Feeder})}{Z_{in}\,pu} = \frac{0.5+j0.15}{\frac{6.6^2}{10}} = 0.1148 + j0.0344 \text{ Pu}$$

Step3:- Zth



$$Z_{th} = \left(\frac{j0.2 \times j0.125}{j0.2 + j0.125}\right) + j0.10 + 0.0551 + j0.0918 + 0.0348j + 0.1148 + j0.0344$$

$$\boxed{Z_{th} = 0.1699 + j0.3379}$$

$V_{th} = 1\angle 0^\circ$ pu.

Step4.-

$$I_{fault} = \frac{V_{th}}{Z_{th}} = \frac{1+j0}{0.1699 + j0.3379} = 1.18776 - j2.366$$

$$I_{base} = \frac{S_B}{\sqrt{3} V_B} = \frac{10 \times 10^6}{\sqrt{3} \times 6.6 \times 10^3} = 874.47 \text{ (A)}$$

$$I_{fault} (A) = I_{fault} (pu) * I_{base}$$

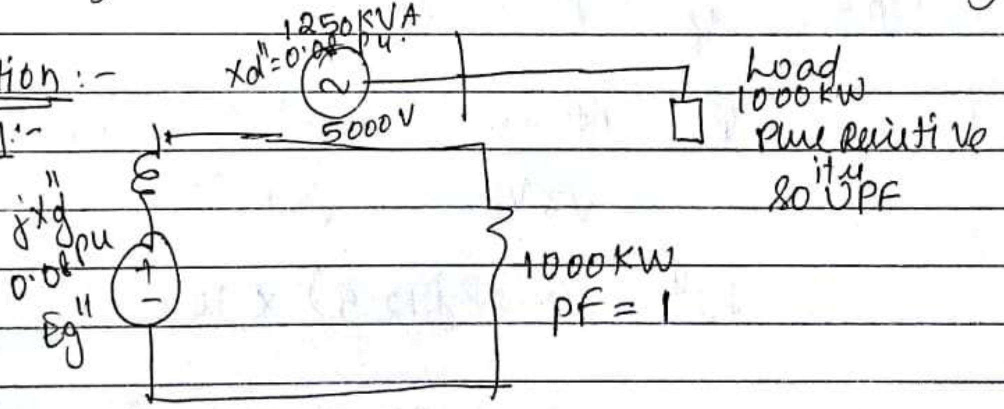
$$= (1.18776 - j2.36622) \times 874.47$$

$$= 1038.66 - j2069.188 \text{ (A)}.$$

⑥ A 1250 kVA, 5000V generator with $X_d'' = 0.08$ pu supplies a purely resistive load of 1000 kW at rated voltage. The load is connected directly across the terminals of the generator. If all the three Phases of the load are short circuited simultaneously find initial symmetrical short circuit current in the generator.

Solution :-

Step1:-



Step2:- $S_B = 1250$ kVA $= 1.25$ MVA $V_B = 5000 V = 5 kV$

$$\text{Load in MVA} = \frac{1000 \text{ kW}}{PF} = \frac{1000}{1} = 1000 \text{ kVA}$$

$$(\text{Load in MVA}) \text{ in pu} = \frac{1000}{S_B} = \frac{1000}{1.250} = 0.8 \text{ pu}$$

$V_t = 1 \cdot 0$ pu (assume)

Step 3:-

$$I_L = \frac{P}{V} = \frac{0\cdot 8}{1\cdot 0} = 0\cdot 8 \text{ pu } \angle 0^\circ$$ (since pure resistive).

Step 4:- $$E_g'' = V_{PF} + j I_L X_g''$$

$$= 1 + j0 + j0\cdot 08 \times 0\cdot 8$$

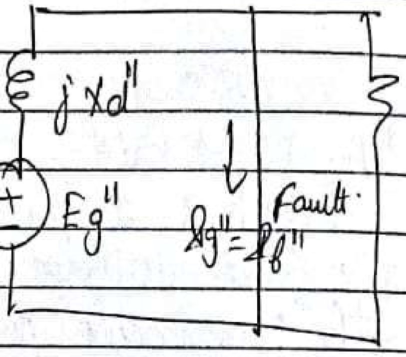
$$= 1 + j0\cdot 064 \text{ pu}.$$

Step 5:-

$$I_g'' = \frac{E_g''}{jX_d''}$$

$$= \frac{1 + j0\cdot 064}{j0\cdot 08}$$

$$= 0\cdot 8 - j12\cdot 5.$$



Step 6:- $$I_f'' = I_g'' = 0\cdot 8 - j12\cdot 5$$

$$I_b = \frac{MVA_b}{\sqrt{3} V_b} = \frac{125 \times 10^6}{\sqrt{3} * 5 \times 10^3} \; 144\cdot 34 (A)$$

$$I_f'' = (0\cdot 8 - j12\cdot 5) \times 144\cdot 34 = 115\cdot 472 - j1804\cdot 25$$

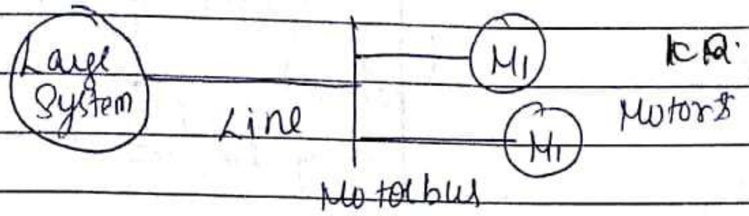
⑦ Two synchronous motors are connected to the bus of a large system through a transmission line. The ratings of the various components are,

Motor each: 1 MVA, 440 V, 0·1 pu transient reactance

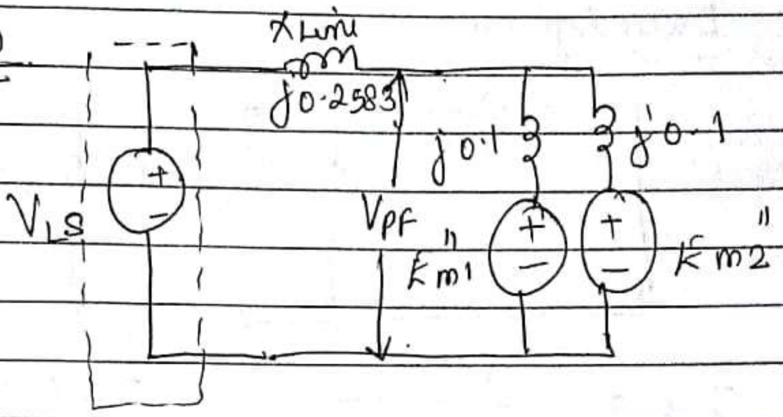
Line 0·05 Ω reactance

Large system: Short circuit MVA at its bus at 440 V is 8.

When the motors are operated at 400V, Calculate the Short circuit current (Symmetrical) fed into a three Phase fault at motor bus.



Solution



Large System.

Step1 :-

In Large system is an infinite bus and so its voltage and fuquency will not Change due to a fault in the motor bus.

$$MVA_b = 1MVA \qquad V_B = 440\ V = 0.44KV$$

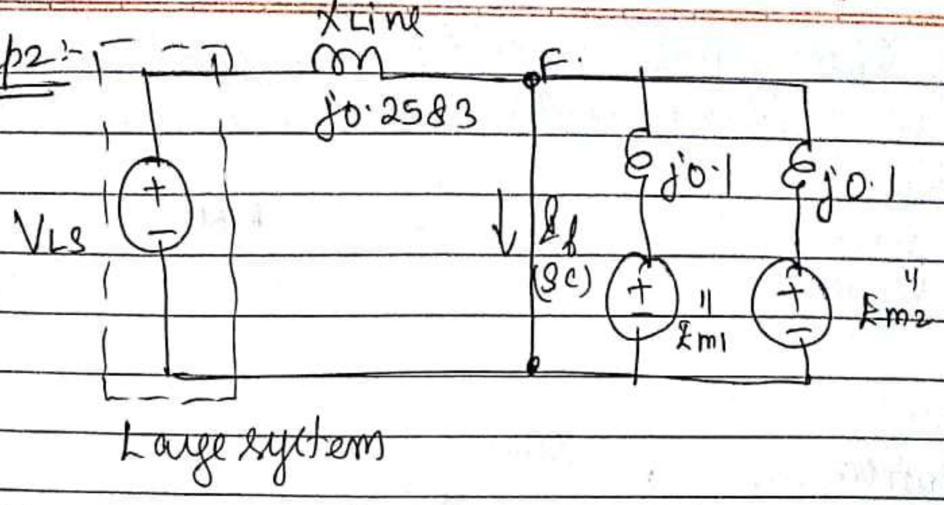
$$Z_b = \frac{KV_b^2}{MVA_b} = \frac{0.44^2}{1} = 0.1936$$

$$X_{Line}(pu) = \frac{0.05}{0.1936} = 0.2583\ pu$$

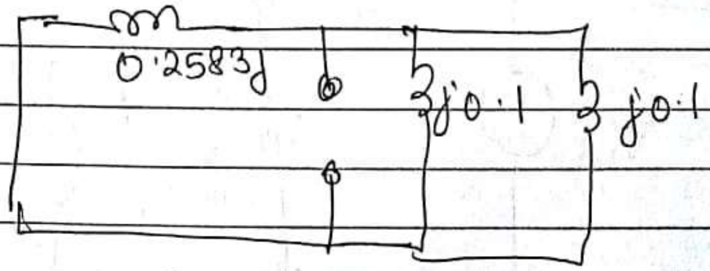
$$V_{pf} = \frac{400}{440} = 0.9091\ pu.$$

$$V_{LS} = \frac{440}{440} = 1\ pu.$$

Step2:-



Zth



$$\Rightarrow Z_{th} = \frac{1}{\frac{1}{j0.2583} + \frac{1}{j0.1} + \frac{1}{j0.1}} = j0.04194 \text{ pu}$$

Step3:- $$I_f = \frac{V_{th}}{Z_{th}} = \frac{0.9091}{j0.0419} = j21.6969 \text{ pu}$$

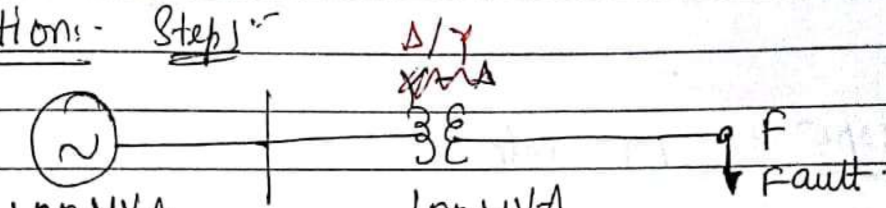
Step4:- $$I_b = \frac{KVA_b}{\sqrt{3}\, V_b} = \frac{1 \times 10^6}{\sqrt{3} \times 0.44 \times 10^3} = 1312.16 \text{ (A)}.$$

$$\underset{(A)}{I_f} = \underset{(A)}{I_b} * I_{f(pu)} = 1312.16 * j21.6969.$$

$$I_{f(A)} = j28.469 \text{ KA}$$

⑧ A generator is connected through a circuit Breaker to a transformer. The ratings of the generator are 100 MVA, 18 KV, $x_d'' = 19\%$, $x_d' = 26\%$ and $X_d = 130\%$. The transformer ratings are 100 MVA, 240/18 KV, Y-Δ, X = 10% with 18 KV on Δ side. If a 3φ short circuit occurs on the high tension side of a Transformer at rated Voltage and noload, Find
(a) Initial symmetrical rms current in the Transformer winding on the high tension side.
(b) The Initial symmetrical rms current in the line on the low tension side.

Solution:- Step 1:-

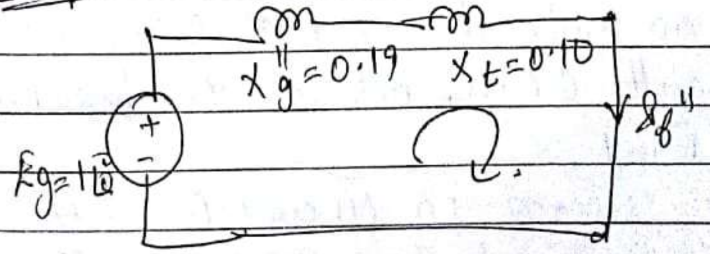


100 MVA
18 KV
$x_d'' = 0.19$
$x_d' = 0.26$
$x_d = 1.30$

100 MVA
18/240 KV
$X_t = 0.10$

To find
(a) Initial symmetrical rms current in T/F (HT) side = ?
(b) Initial symmetrical rms current in T/F (LV side) = ?

Step 2:- $S_B = 100\,MVA$ $V_B = 18\,KV$.



$$I_f'' = \frac{E_g}{j0.19 + j0.10} = -3.44827j \text{ pu}$$

$KV_B(HT) = 240$ V　　　KV_B on LT = 18 KV
$S_B = 100$ MVA　　　$S_B = 100$ MVA

Step3:-

$$I_{base}(HT) = \frac{KVA_b}{\sqrt{3}\ KV_b} = \frac{100\times10^6}{\sqrt{3}\times 240\times10^3} = 240.56(A)$$

$$I_{base}(LT) = \frac{KVA_b}{\sqrt{3}\ KV_b} = \frac{100\times10^6}{\sqrt{3}\times 18\times10^3} = 3207.5(A)$$

Step4:-

I_f'' (in Amps) HT $= -j3.4482 \times 240.56$

$= j\,829.5$ A

Step5:- LT side.

I_f'' (in Amps) LT $= -j3.4482 \times 3207.5$

$= 11060.4(A)$

⑨ A generator connected through a five cycle circuit breaker to a Transformer is rated at 100MVA, 18kV with reactances $X_d'' = 20\%$. $X_d' = 25\%$ and $X_d = 110\%$. It is operated on noload and at rated voltage. When a 3φ fault occurs between the breaker and the transformer Find.

(a) Short circuit current in circuit Breaker.

(b) The Initial symmetrical rms current in the circuit Breaker

(c) the maximum possible Dc component of the short circuit current in the breaker.

(d) The current to be interrupted by the breaker

(e) The Interrupting MVA.

Symmetrical Components & Sequence Networks

* The analysis of unsymmetrical polyphase Network by the method of symmetrical components was introduced by Dr. C. Fortesque.

* He proved that an unbalanced system of 'n' related Vectors can be resolved into 'n' system of balanced Vectors called Symmetrical Components of original Vectors.

* The n vectors of each set of components are equal in length and the Phase angles between adjacent Vectors of the set are equal.

* In a three phase system, the three unbalanced Vectors either V_a, V_b, V_c or I_a, I_b, I_c can be resolved into three balanced system of Vectors.

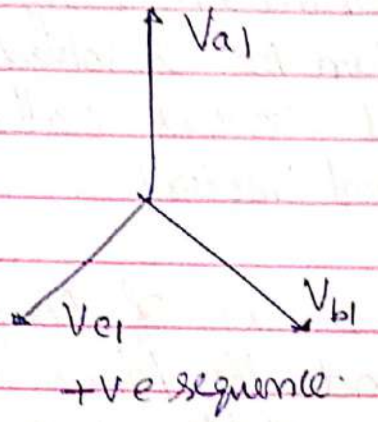
* The Vectors of the balanced system are called Symmetrical Components of the original system.

* The Symmetrical Components of three phase system are

i) Positive Sequence Components
ii) Negative Sequence Component
iii) Zero Sequence Component.

Positive Sequence components:

It consists of three vectors equal in magnitude, displayed from each other in Phase by 120° having the same Phase sequence as the original vectors.



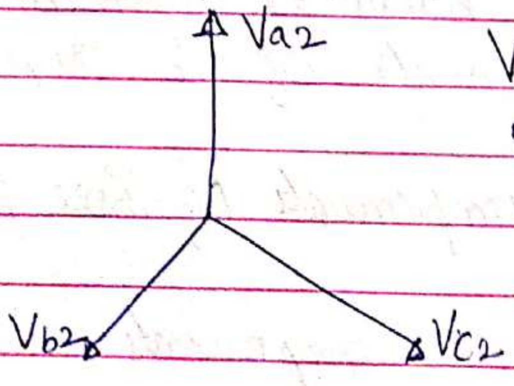
V_{a1}, V_{b1}, V_{c1} → 'C' phase +ve sequence compon

↳ 'B' phase +ve sequence Component

↓ 'A' phase +ve sequence component

Negative Sequence Component:

It consists of three Vectors equal in Magnitude, displaced from each other by 120° in Phase sequence opposite of original vectors.



V_{a2} → 'A' Phase -Ve sequence Compon

V_{b2} → 'B' Phase -Ve Sequence componen

V_{c2} → 'C' Phase -Ve sequence componen

Zero Sequence Components:-

It consists of three Vectors equal in magnitude and with zero phase displacement from each other.

$\longrightarrow V_{a0}$ → Zero sequence Component of Phase 'a'

$\longrightarrow V_{b0}$ → Zero Sequence Component of Phase 'b'

$\longrightarrow V_{c0}$ → Zero Sequence Component of Phase 'c'

Define:-

$a = 1\angle 120^\circ = -0.5 + j0.866 = -\frac{1}{2} + \frac{\sqrt{3}}{2} j$

$$\left.\begin{array}{l} a^2 = 1\angle 240^\circ \\ \quad = 1\angle -120^\circ \end{array}\right\} = -0.5 - j0.866 = -\frac{1}{2} - \frac{\sqrt{3}}{2} j$$

$a^3 = 1\angle 360^\circ = 1$

$a^4 = 1\angle 360^\circ + 120^\circ = a\angle 480 = -0.5 + j0.866 = a$

Proof:-

* $1 + a + a^2 = 1 + (-0.5 + j0.866) + (-0.5 - j0.866)$.

$$\boxed{1 + a + a^2 = 0}$$

* $(a - a^2) = (-0.5 + j0.866) - (-0.5 - j0.866)$

$= -0.5 + j0.866 + 0.5 + j0.866$

$= (+2) * j0.866)$

$= (+2) * \left(\frac{\sqrt{3}}{2}\right) j = \underline{\sqrt{3} j}$

(iii) $(a^2 - a) = (-0.5 - j0.866) - (-0.5 + j0.866)$

$= -j0.866 - j0.866$

$= -2 * j0.866$

$= -2 * \left(\frac{\sqrt{3}}{2} j\right)$

$= \underline{\underline{-j\sqrt{3}}}$

Derivation - I :-

① Compute unbalanced Vectors from their Symmetrical Components:-

{phase values in terms of symmetrical Components}.

$\boxed{\{ V_{(a,b,c)} = A \; V_{(0,1,2)} \}}$ S.T.

Each of the original unbalanced Vector is the sum of its +ve, -ve and zero sequence Component. Therefore the original unbalanced 3φ Voltage Vectors Can be expressed in terms of their Components as shown below.

$$\left.\begin{aligned} V_a &= V_{a0} + V_{a1} + V_{a2} \\ V_b &= V_{b0} + V_{b1} + V_{b2} \\ V_c &= V_{c0} + V_{c1} + V_{c2} \end{aligned}\right] - ①$$

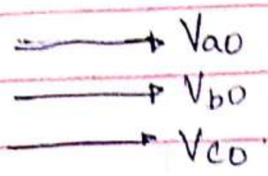
where,

V_{a0}, V_{b0}, V_{c0} → zero sequence component

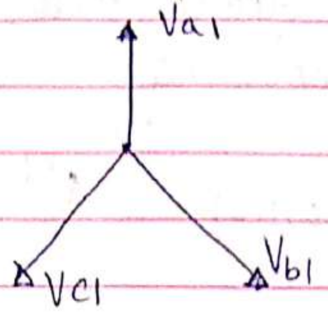
V_{a1}, V_{b1}, V_{c1} → +ve sequence component

V_{a2}, V_{b2}, V_{c2} → -ve sequence component

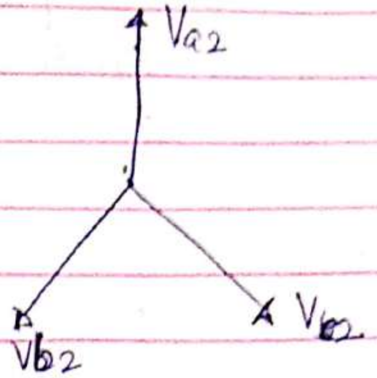
From vector Dig:-



Zero sequence



+ve sequence



-ve sequence.

V_{a0} is reference V_{a1} is reference V_{a2} is reference

A → Phase taken as Reference for all sequence components.

$V_{b0} = V_{a0}$

$V_{c0} = V_{a0}.$

$V_{b1} = V_{a1} * 1\angle -120^\circ$

$V_{b1} = V_{a1}\, a^2$

III^ly $V_{c1} = V_{a1} * 1\angle +120^\circ$

$V_{c1} = V_{a1} * a$

$V_{b2} = V_{a2} * 1\angle 120^\circ$

$V_{b2} = V_{a2}\, a$

$V_{c2} = V_{a2} * 1\angle -120^\circ$

$V_{c2} = a^2 V_{a2}.$

Now substitute above in eq ①

$V_a = V_{a0} + V_{a1} + V_{a2}$ → No change as this is reference

$V_b = V_{a0} + (a^2 V_{a1}) + a V_{a2}$ → in terms of Reference

$V_c = V_{a0} + a V_{a1} + a^2 V_{a2}$ → in terms of Reference

In matrix form,

$$\boxed{\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix}} \quad \text{—②}$$

$$\left[V_{a,b,c}\right] = A \left[V_{0,1,2}\right]$$

III^ly current $I_{(a,b,c)} = A\, I_{(0,1,2)}$

(II) Compute Symmetrical components in terms of Phase Components

$$\left\{ S.T \rightarrow V_{(0,1,2)} \overset{(or)}{=} A^{-1} V_{(a,b,c)} \right\}$$

Proof:-

~~From~~ We know that,

$$V_{(a,b,c)} = A \, V_{seq\,(0,1,2)}$$

$$V_{seq} = A^{-1} V_{(a,b,c)}$$

A^{-1}:-

$$A = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix}$$

$$A^{-1} = \frac{1}{\Delta} \text{ Cofactor of } A$$

Δ:-

$$\Delta = 1(a^4 - a^2) - 1(a^2 - a) + 1(a - a^2).$$

$$= a^4 - a^2 + (a - a^2) + (a - a^2)$$

$$\downarrow$$

$$= a - a^2 + a - a^2 + a - a^2 \quad [\because a^4 =$$

$$= 3a - 3a^2$$

$$\boxed{\Delta = 3(a - a^2)}$$

Cofactor of A :-

$$\text{Cofactor} = \begin{vmatrix} +1(a^4-a^2) & -1(a^2-a) & +1(a-a^2) \\ -1(a^2-a) & +(a^2-1) & -(a-1) \\ +(a-a^2) & -(a-1) & +(a^2-1) \end{vmatrix}$$

$$= \begin{vmatrix} (a-a^2) & (a-a^2) & (a-a^2) \\ (a-a^2) & (a^2-1) & (1-a) \\ (a-a^2) & (1-a) & (a^2-1) \end{vmatrix}$$

$$\therefore A^{-1} = \frac{1}{\Delta} \text{ Cofactor of } A.$$

$$= \frac{1}{3(a-a^2)} \begin{vmatrix} (a-a^2) & (a-a^2) & (a-a^2) \\ (a-a^2) & (a^2-1) & (1-a) \\ (a-a^2) & (1-a) & (a^2-1) \end{vmatrix}$$

$$A^{-1} = \frac{1}{3} \begin{bmatrix} \frac{1}{\cancel{(a-a^2)}} & 1 & 1 \\ 1 & \frac{a^2-1}{a-a^2} & \frac{1-a}{a-a^2} \\ 1 & \frac{1-a}{a-a^2} & \frac{a^2-1}{a-a^2} \end{bmatrix}$$

$$\left[\frac{a^2-1}{a-a^2} = \frac{a^2-a^3}{a-a^2} = \frac{a[a-a^2]}{[a-a^2]} \quad \because 1 = a^3 \right.$$

$$\boxed{\frac{a^2-1}{a-a^2} = a}$$

$$\frac{1-a}{a-a^2} = \frac{a^3-a^4}{a-a^2} = \frac{a^2(a-a^2)}{(a-a^2)} \quad \because a^4 = a$$

$$\left. \boxed{\frac{1-a}{a-a^2} = a^2} \right].$$

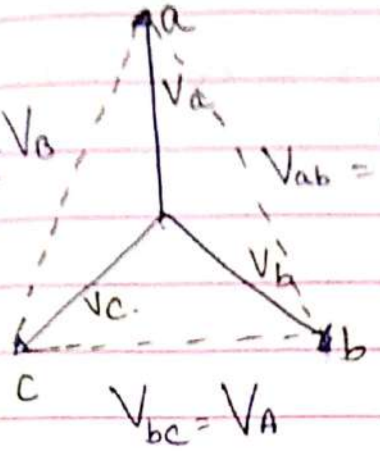
$$A^{-1} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}$$

$$\therefore \begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix} = \underbrace{\frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}}_{} \quad \text{—①}$$

$$\boxed{V_{(0,1,2)} = A^{-1} V_{(a,b,c)}}$$

Illy for current $I_{(0,1,2)} = A^{-1} I_{(a,b,c)}$

(iii) Relation between Sequence Components of Phase and line Voltages in Y connected System:-



where,
A, B, C → Capital letters denote Line Values
a, b, c → Small letters denote Phase Values.

- If the sequence components of the Phase Voltages are known, it is possible to determine the sequence components of the line Voltages
- Let V_a, V_b, V_c ⇒ Phase Values of the Voltages
- V_{ab}, V_{bc}, V_{ca} ⇒ Voltages b/w two phases

From Vector Algebra,

$$\left.\begin{aligned} V_{bc} = V_A &= V_c - V_b \\ V_{ca} = V_B &= V_a - V_c \\ V_{ab} = V_c &= V_b - V_a \end{aligned}\right] \text{—}①$$

→ Line Voltages

$V_{ab} = V_c$ → Opposite Vertex.

~~we get~~, Now consider

$$\begin{bmatrix} V_{A0} \\ V_{A1} \\ V_{A2} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}\begin{bmatrix} V_A \\ V_B \\ V_C \end{bmatrix} \text{—}②$$

$$V_{A0} = \frac{1}{3}\left(V_A + V_B + V_c\right).$$

$$= \frac{1}{3}\left[(V_c - V_b) + (V_a - V_c) + (V_b - V_a)\right]$$

$$= \frac{1}{3}(0)$$

$$\boxed{V_{A0} = 0}$$

$$V_{A1} = \frac{1}{3}\left[V_A + aV_B + a^2 V_c\right]$$

$$= \frac{1}{3}\left[(V_c - V_b) + a(V_a - V_c) + a^2(V_b - V_a)\right]$$

$$= \frac{1}{3}\left[\underline{\underline{V_c}} - \underset{\sim}{V_b} + \underline{\underline{aV_a}} - \underset{\sim}{aV_c} + \underline{\underline{a^2V_b}} - \underset{\sim}{a^2V_a}\right].$$

$$= \frac{1}{3}\left[(aV_a + a^2V_b + \underset{\substack{\downarrow\\1=a^3}}{V_c}) - (a^2V_a + V_b + \underset{\substack{\downarrow\\a=a^4}}{aV_c})\right]$$

$$= \frac{1}{3}\left[a(V_a + aV_b + a^2V_c) - a^2(V_a + aV_b + a^2V_c)\right]$$

$$V_{A1} = \frac{1}{3}\left[(a - a^2)(V_a + aV_b + a^2V_c)\right].$$

From page ③

$$a - a^2 = j\sqrt{3}$$

$V_{A1} = j\sqrt{3}\,V_{a1}$

$$\boxed{V_{A1} = j\sqrt{3}\,V_{a1}}$$

From page (8) eq (1)

$V_{a1} = \frac{1}{3}\underbrace{\left[V_a + aV_b + a^2V_c\right]}_{\text{is Replaced with } V_{a1}}$

|||ly

$V_{A2} = \frac{1}{3}\left[V_A + a^2V_B + aV_C\right]$

$= \frac{1}{3}\left[(V_c - V_b) + a^2(V_a - V_c) + a(V_b - V_a)\right]$

$= \frac{1}{3}\left[\underline{\underline{V_c}} - \underline{V_b} + \underline{\underline{a^2V_a}} - \underline{a^2V_c} + \underline{\underline{aV_b}} - \underline{aV_a}\right]$

$= \frac{1}{3}\left[(a^2V_a + \underset{a=a^4}{\underset{\downarrow}{aV_b}} + \underset{1=a^3}{\underset{\downarrow}{V_c}}) - (aV_a + \underset{1=a^3}{\underset{\downarrow}{V_b}} + a^2V_c)\right]$

$= \frac{1}{3}\left[a^2(V_a + a^2V_b + aV_c) - a(V_a + a^2V_b + aV_c)\right]$

$= \frac{1}{3}\left[(a^2 - a)(V_a + a^2V_b + aV_c)\right]$

$V_{A2} = (a^2 - a)\,V_{a2}$

From page (8) eq (1) $V_{a2} = \frac{1}{3}\left[V_a + a^2V_b + aV_c\right]$

$a^2 - a = -j\sqrt{3}$ From page (4)

$$\boxed{\therefore V_{A2} = -j\sqrt{3}\,V_{a2}}$$

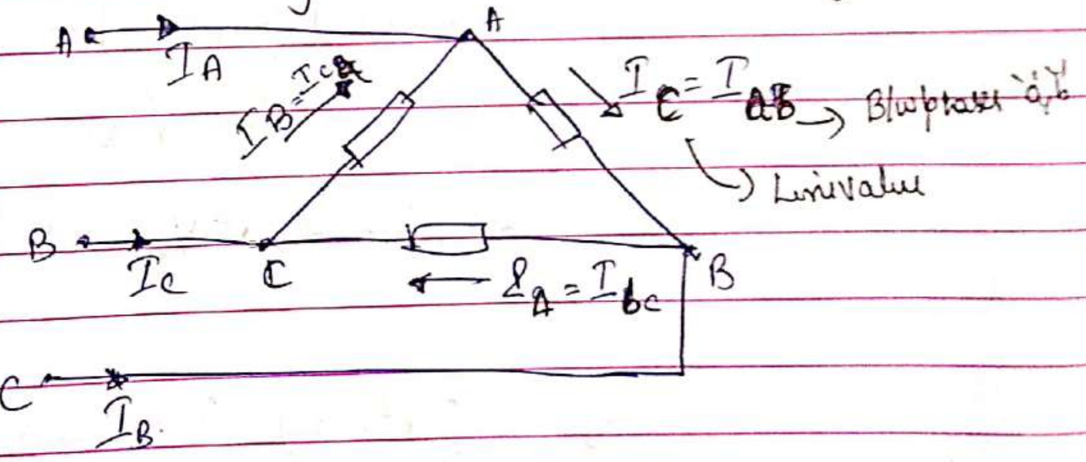
$$\therefore \boxed{\begin{aligned} V_{A0} &= 0 \\ V_{A1} &= j\sqrt{3}\,V_{a1} \\ V_{A2} &= -j\sqrt{3}\,V_{a2} \end{aligned}}$$

For Y Connected System

IV Relationship between Sequence Components of Phase and Line currents in Δ Connected System:-

→ In delta connected System, the Phase currents are diffrent from line currents.

→ Consider a delta connected 3ϕ System where in the line currents I_A, I_B and I_C are entering Delta Connected System.



Let I_A, I_B, I_C → Line currents (denoted by Capital letter).

I_a, I_b, I_c → Phase currents (denoted by Small letter).

$$I_A = I_{bc} = I_c - I_b$$

$$I_B = I_{ca} = I_a - I_c$$

$$I_C = I_{ab} = I_b - I_a$$

Now Consider,

$$\begin{bmatrix} I_{A0} \\ I_{A1} \\ I_{A2} \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \begin{bmatrix} I_A \\ I_B \\ I_C \end{bmatrix}$$

IIIr to page ⑧ eq ①

$$I_{A0} = \frac{1}{3}\left[I_A + I_B + I_C \right].$$

$$= \frac{1}{3}\left[I_c - I_b + I_a - I_c + I_b - I_a \right]$$

$$= \frac{1}{3}\left[0 \right]$$

$$\boxed{I_{A0} = 0}$$

$$I_{A1} = \frac{1}{3}\left[I_A + a I_B + a^2 I_C \right].$$

$$= \frac{1}{3}\left[\underline{I_c} - \underline{\underline{I_b}} + \underline{a I_a} - \underline{\underline{a I_c}} + \underline{a^2 I_b} - \underline{\underline{a^2 I_a}} \right]$$

$$= \frac{1}{3}\left[\left(a I_a + a^2 I_b + \underset{\underset{1=a^3}{\downarrow}}{I_c} \right) - \left(a^2 I_a + \underset{\underset{1=a^3}{\downarrow}}{I_b} + \underset{\underset{a^4=a}{\downarrow}}{a I_c} \right) \right]$$

$$= \frac{1}{3}\left[a(I_a + aI_b + a^2 I_c) - a^2(I_a + aI_b + a^2 I_c \right.$$

$$= \frac{1}{3}\left[(a-a^2)(I_a + aI_b + a^2 I_c)\right].$$

$$I_{A1} = \frac{1}{3}\, j\sqrt{3}\,(I_a + aI_b + a^2 I_c)$$

$$\boxed{I_{A1} = j\sqrt{3}\, I_{a1}}$$

$$I_{A2} = \frac{1}{3}\left[I_{A2} + a^2 I_{B2} + a I_{C2} \right]$$

$$= \frac{1}{3}\left[\underline{I_c} - \underline{\underline{I_b}} + \underline{a^2 I_a} - \underline{\underline{a^2 I_c}} + \underline{a I_b} - \underline{\underline{a I_a}} \right]$$

$$= \frac{1}{3}\left[(a^2 I_a + \underset{\substack{\downarrow \\ a^4 = a}}{a I_b} + \underset{\substack{\downarrow \\ a^3 = 1}}{I_c}) - (a I_a + \underset{\substack{\downarrow \\ 1 = a^3}}{I_b} + a^2 I_c)\right]$$

$$= \frac{1}{3}\left[a^2(I_a + a^2 I_b + a I_c) - a(I_a + a^2 I_b + a I_c) \right]$$

$$= \frac{1}{3}(a^2 - a)(I_a + a^2 I_b + a I_c)$$

$$\boxed{I_{A2} = -j\sqrt{3}\, I_{a2}}$$

$$\boxed{\begin{aligned} I_{A0} &= 0 \\ I_{A1} &= j\sqrt{3}\, I_{a1} \\ I_{A2} &= -j\sqrt{3}\, I_{a2} \end{aligned}}$$

For Δ connected System

Complex Power in Terms of Symmetrical Components:-

The total Complex Power flowing through three Phase circuit is Given as:

$$S = P + jQ = V_a I_a^* + V_b I_b^* + V_c I_c^*$$

Where,

S = Total Complex Power
P = Active Power
Q = Reactive Power

$$S = P + jQ = [V_a \ V_b \ V_c] \begin{bmatrix} I_a^* \\ I_b^* \\ I_c^* \end{bmatrix}.$$

$$[V_a V_b V_c] = \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}^T = \left\{ \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix} \right\}^T$$

$$= \begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix}^T \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix}^T$$

Since $\{[A] \cdot [B]\}^T = [B]^T [A]^T$

and

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

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

$a^* = a^2 \quad (a^2)^* = a$

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

$$\therefore S = P + jQ = \begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix}^T \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \begin{bmatrix} I_{a0}^* \\ I_{a1}^* \\ I_{a2}^* \end{bmatrix}$$

$$= \begin{bmatrix} V_{a0} & V_{a1} & V_{a2} \end{bmatrix} \begin{bmatrix} 1+1+1 & 1+a+a^2 & 1+a^2+a \\ 1+a^2+a & 1+a^3+a^3 & 1+a^4+a^2 \\ 1+a+a^2 & 1+a^2+a^4 & 1+a^3+a^3 \end{bmatrix} \begin{bmatrix} I_{a0}^* \\ I_{a1}^* \\ I_{a2}^* \end{bmatrix}$$

$$= \begin{bmatrix} V_{a0} & V_{a1} & V_{a2} \end{bmatrix} \cdot \begin{bmatrix} 3 & 0 & 0 \\ 0 & 3 & 0 \\ 0 & 0 & 3 \end{bmatrix} \begin{bmatrix} I_{a0}^* \\ I_{a1}^* \\ I_{a2}^* \end{bmatrix}$$

$1 + a^4 + a^2 = 1 + a + a^2 = 0.$

$1 + a^3 + a^3 = 1 + 1 + 1 = 3$

$$S = \begin{bmatrix} V_{a0} & V_{a1} & V_{a2} \end{bmatrix} \begin{bmatrix} 3 & 0 & 0 \\ 0 & 3 & 0 \\ 0 & 0 & 3 \end{bmatrix} \begin{bmatrix} I_{a0}^* \\ I_{a1}^* \\ I_{a2}^* \end{bmatrix}$$

$$S = 3 \left\{ V_{a0} I_{a0}^* + V_{a1} I_{a1}^* + V_{a2} I_{a2}^* \right\}$$

$$S_{inpu} = \frac{S}{S_B} = \frac{S}{3 V_B I_B}$$

$$= \frac{\cancel{3} \left\{ V_{a0} I_{a0}^* + V_{a1} I_{a1}^* + V_{a2} I_{a2}^* \right\}}{\cancel{3} V_B I_B}$$

$$\boxed{S_{inpu} = V_{a0pu} I_{a0pu}^* + V_{a1pu} I_{a1pu}^* + V_{a2pu} I_{a2pu}^*}$$

$\boxed{S_{inpu} = S_{in3\phi}}$ Hence proved.

Problems

① The Voltages across a 3ϕ unbalanced load are $V_a = 300\angle 20^\circ$ V; $V_b = 360\angle 90^\circ$ V and $V_c = 500\angle -140^\circ$. Determine the Symmetrical Components of Voltages.

" $[V_{0,1,2} = A^{-1} V_{a,b,c}]$ → using this derivation

Solution:-

Given:- $V_a = 300\angle 20^\circ$; $V_b = 360\angle 90^\circ$, $V_c = 500\angle -140^\circ$

Required:- $V_{a0} = ?$ $V_{a1} = ?$ $V_{a2} = ?$

Step 1:- $V_{a0} = \frac{1}{3}[V_a + V_b + V_c]$

$$= \frac{1}{3}[300\angle 20^\circ + 360\angle 90^\circ + 500\angle -140^\circ]$$

$$\boxed{V_{a0} = -33.70 + j\,47.07}$$

$$V_{a1} = \frac{1}{3}[V_a + a\,V_b + a^2 V_c]$$

$$= \frac{1}{3}[300\angle 20^\circ + (1\angle 120^\circ * 360\angle 90^\circ) + (1\angle 240^\circ)(500\angle -140^\circ)]$$

$$\boxed{V_{a1} = -38.89 + j\,138.34}$$

$$V_{a2} = \frac{1}{3}\left[V_a + a^2 V_b + a V_c\right]$$

$$= \frac{1}{3}\left[300\angle 20^\circ + \left(1\angle 240 * 360\angle 90^\circ\right) + \left(1\angle 120 * 500\angle -140\right)\right].$$

$$V_{a2} = 354.51 - j82.80$$

We know $V_{a0} = V_{b0} = V_{c0} = -33.70 + j47.07$

$$V_{b1} = a^2 V_{a1} = 1\angle 240 * \left[-38.89 + j138.34\right].$$

$$V_{b1} = 143.70 \angle 346^\circ$$

$$V_{c1} = aV_{a1} = 1\angle 120^\circ \left(-38.89 + j138.34\right)$$

$$V_{c1} = 143.70 \angle 226^\circ$$

$$V_{b2} = a V_{a2} = 1\angle 120^\circ * \left(354.51 - j82.80\right).$$

$$= 364.05 \angle 107$$

$$V_{c2} = a^2 V_{a2} = 1\angle 240 \left(354.51 - j82.80\right).$$

$$= 364.05 \angle 227^\circ \text{ V}.$$

② The symmetrical components of Phase Voltage in a 3φ unbalanced system are $V_{a0} = 10\angle 180^\circ$ V; $V_{a1} = 50\angle 0^\circ$ V and $V_{a2} = 20\angle 90^\circ$. Determine the Phase Voltages V_a, V_b and V_c.

Solution:-

using I derivation $V_{a,b,c} = A V_{0,1,2}$

$V_a = V_{a0} + V_{a1} + V_{a2}$

$= -10+j0 + 50+j0 + 0+j20$

$= 40+j20$

$V_b = V_{a0} + a^2 V_{a1} + a V_{a2}$

$= -10+j0 + \{1\angle 240 \cdot (50+j0)\} + (1\angle 120 \cdot (0+j20))$

$= -52.32 - j53.30$

$V_c = V_{a0} + a V_{a1} + a^2 V_{a2}$

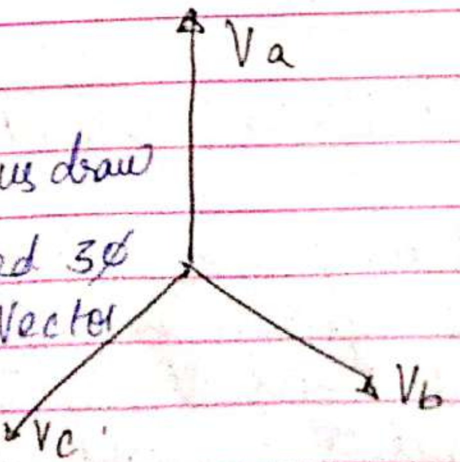
$= (-10+j0) + (1\angle 120° \times (50+j0)) + (1\angle 240° (0+j20))$

$= -17.68 + j33.33$

③ Prove that a balanced set of three phase Voltages will have only +Ve sequence Components of voltages only.

Solution

Let us draw the balanced 3ϕ Voltage Vector



Va is ref.

$V_b = V_a(1\angle -120°) = 1\angle 240°$

$V_b = a^2 V_a$

$V_c = V_a(1\angle 120°)$

$V_c = V_a a$

$$\begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}$$

$$\begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} \cancel{V_a +}\; 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}\begin{bmatrix} V_a \\ a^2 V_a \\ a V_a \end{bmatrix}$$

$$= \frac{1}{3}\begin{bmatrix} V_a + a^2 V_a + a V_a \\ V_a + a^3 V_a + a^3 V_a \\ V_a + a^4 V_a + a^2 V_a \end{bmatrix}$$

$$= \frac{1}{3}\begin{bmatrix} (1 + a^2 + a) V_a \\ V_a (1 + a^3 + a^3) \\ V_a (1 + a^4 + a^2) \end{bmatrix}$$

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

$a^3 = 1$

$a^4 = a$

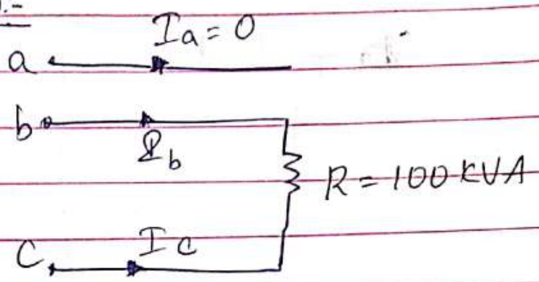
$$= \frac{1}{3}\begin{pmatrix} 0 * V_a \\ (1+1+1) V_a \\ V_a (1 + a + a^2) \end{pmatrix}$$

$$= \frac{1}{3}\begin{pmatrix} 0 \\ 3V_a \\ V_a \end{pmatrix}.$$

$\therefore \boxed{V_{a1} = V_a}$ // Only +ve sequence is present

④ A 1ϕ Resistive load of 100KVA is connected across lines bc of a balanced supply of 3KV. Compute the symmetrical components of line currents

Solution:-



$I_a = 0$; $I_b = -I_c = \frac{100*10^3}{3*10^3} = 33.33(A)$.

$I_a = 0$; $I_b = 33.33$ $I_c = -33.33$

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

$= \frac{1}{3}(0 + 33.33 - 33.33) = 0$

$I_{a1} = \frac{1}{3}(I_a + aI_b + a^2 I_c)$.

$= \frac{1}{3}(0 + 33.33(1\angle 120) + (1\angle 240^\circ)(-33.33))$

$= j19.24$

$I_{a2} = \frac{1}{3}(I_a + a^2 I_b + aI_c)$

$= \frac{1}{3}(0 + 1\angle 240 * 33.33 + 1\angle 120 * -33.33)$

$= -j19.24$

⑤ The currents in a 3ϕ unbalanced system are $\bar{I}_R = (12+j6)$ A ; $\bar{I}_y = (12-j12)$ A ; $\bar{I}_B = (-5+j10)$ A. The phase sequence is RYB. Calculate the zero, +ve, −ve sequence of the currents

$$I_{R0} = \frac{1}{3}(I_R + I_y + I_B).$$

$$= \frac{1}{3}(12+j6+12-j12-5+j10)$$

$$= 6.47\angle 11.88 \ (A)$$

$$I_{R1} = \frac{1}{3}(I_R + aI_y + a^2 I_B).$$

$$= \frac{1}{3}(12+j6+1\angle 120\,(12-j12)+1\angle 240^\circ(-5+j10)).$$

$$= 11.69\angle 38.26^\circ \ (A)$$

$$I_{R2} = \frac{1}{3}(I_R + a^2 I_y + aI_B).$$

$$= \frac{1}{3}(12+j6+1\angle 240^\circ(12-j12)+1\angle 120^\circ(-5+j10)).$$

$$= 4.35\angle -143.8^\circ \ (A).$$

6) The positive and Negative sequence components of Phase Voltages of a 3ϕ system are $V_{a1} = 230\angle 30^\circ$ and $V_{a2} = 60\angle 60^\circ$ V. Determine the +Ve, −Ve sequence components and hence the line Voltages

$V_{A1} = j\sqrt{3}\,V_{a1} = j\sqrt{3}\,(230\angle 30^\circ) = -199.19 + j\,345\ (V)$

$V_{A2} = -j\sqrt{3}\,V_{a2} = (-j\sqrt{3})(60\angle 60^\circ) = 90 - j\,51.96\,(V)$

$V_A = V_{A0} + V_{A1} + V_{A2}.$

$= 0 + (-199.19 + j345) + (90 - j\,51.96)$

$= -109.19 + j\,293.04\,(V).$

$V_B = V_{A0} + a^2 V_{A1} + a V_{A2}$

$= 0 + 1\angle 240\ (-199.19 + j345) + 1\angle 120\,(90 - j51.96)$

$= 398.37 + j103.92\ (V)$

$V_C = V_{A0} + a V_{A1} + a^2 V_{A2}$

$= 0 + 1\angle 120^\circ\,(-199.19 + j34) + 1\angle 240\ (90 - j\,51.96)$

$= -289.19 - j\,396.96\ (V)$

⑦ In a 3ϕ, 3 wire system, the line current $I_a = 100\angle 0^\circ$ A and $I_b = 100\angle -100^\circ$ A. Determine the sequence components of line currents.

$I_a + I_b + I_c = 0$

$I_c = -(I_a + I_b) = -(100\angle 0^\circ + 100\angle -100^\circ).$

$I_c = -[(100+j0)+(-17.36-j98.48)]$

$\boxed{I_c = -(82.64+j98.48)(A)}$

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

$= \frac{1}{3}[100\angle 0^\circ + 100\angle -100 + (-82.64+j98.48)]$

$= 0$

$I_{a1} = \frac{1}{3}(I_a + a I_b + a^2 I_c)$.

$= \frac{1}{3}(100\angle 0^\circ + 1\angle 120 * 100\angle -100 + 1\angle 240 (-82.64 + j98.48))$

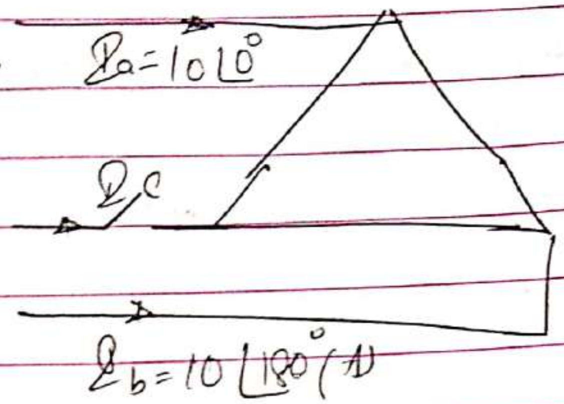
$= 106.86 + j18.84$

$I_{a2} = \frac{1}{3}(I_a + a^2 I_b + a I_c)$.

$= \frac{1}{3}(100\angle 0^\circ + 1\angle 240 * 100\angle -100 + 1\angle 120^\circ(-82.64 + j98.48)]$

$= \underline{\underline{-6.86 - j18.84}}$

⑧ A balanced delta Connected load is Connected to a 3ϕ symmetrical supply. The line currents are each 10A in magnitude. If fuse in one of the lines blows out, Determine the sequence Components of line current.



Solution:-

$$I_a + I_b + I_c = 0$$

$$I_c = 0 \quad \{\because \text{ Fuse Blows out}\}$$

$$I_b = -I_a.$$
$$I_b = -10$$

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

$$= \frac{1}{3}(10 - 10 + 0) = 0.$$

$$I_{a1} = \frac{1}{3}(I_a + a I_b + a^2 I_c).$$

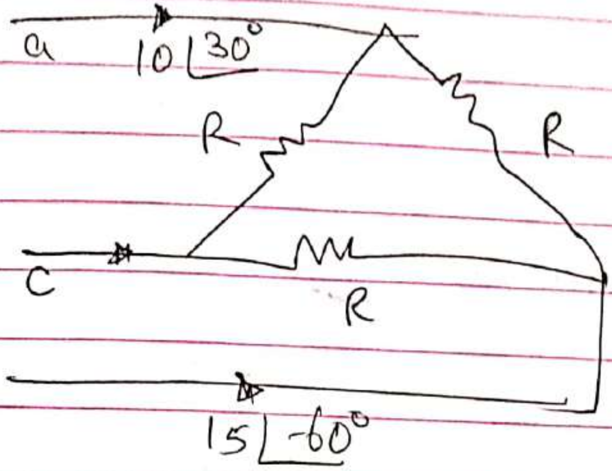
$$= \frac{1}{3}(10 + 1\angle 120 (-10) + 1\angle 240 \times 0)$$

$$= 5 - j2.89$$

$$I_{a2} = \frac{1}{3}(I_a + a^2 I_b + a I_c) = \frac{1}{3}(10 + 1\angle 120°(-10) + 1\angle 120° \times 0)$$

$$= 5 + j2.89$$

⑨ A Delta connected balanced resistive load is connected across an unbalanced 3ϕ supply. Find the symmetrical components of line current and delta current



Solution:-

It is given line current $I_A = 10\angle 30^\circ$

$I_B = 15\angle -60^\circ$

$I_C = -(I_A + I_B)$

$= -(10\angle 30^\circ + 15\angle -60^\circ) = -16.16 + j8$

$I_{A1} = \frac{1}{3}(I_A + aI_B + a^2 I_C)$

$= \frac{1}{3}(10\angle 30^\circ + 1\angle 120 * 15\angle -60 + 1\angle 240 * (-16.16 + j8))$

$= 10.38 + j\,9.3$

$I_{A2} = \frac{1}{3}(I_A + a^2 I_B + a I_C)$

$= \frac{1}{3}(10\angle 30^\circ + 1\angle 240 * 15\angle -60^\circ + 1\angle 120^\circ(-16.16 + j8))$

$= -1.7 + j\,4.3$

$$I_{A0} = \frac{1}{3}\left(10\angle 30^\circ + 15\angle -60^\circ + (-16.16+j8)\right)$$

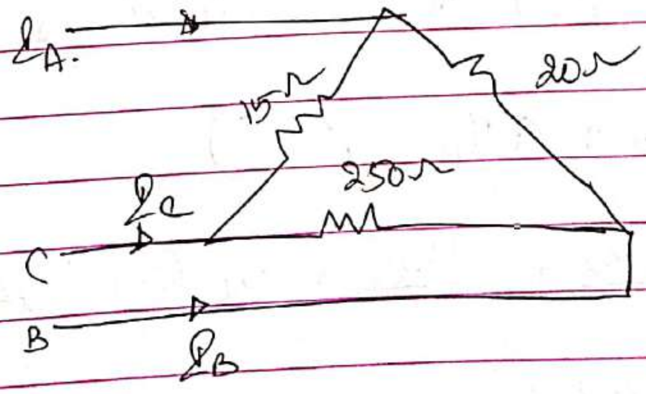
$$= 0 .$$

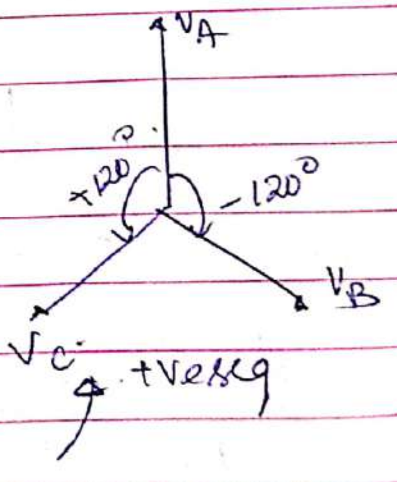
$$I_{a1} = \frac{I_{A1}}{j\sqrt{3}} = \frac{10.38+j9.3}{\sqrt{3}}$$

Phase (or) Delta Current

$$I_{a2} = \frac{I_{A2}}{-j\sqrt{3}} = \frac{-1.7+j4.3}{-j\sqrt{3}}$$

10) A delta Connected resistive load is connected across a balanced 3ϕ supply of 400V. Find the Symmetrical components of line currents and Delta currents.



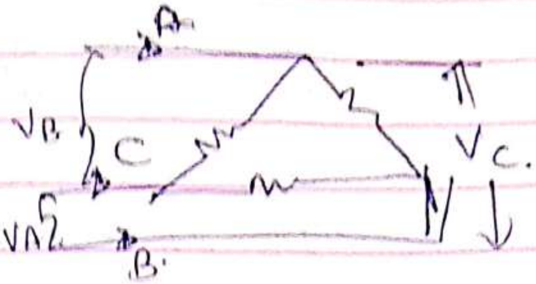


Solution:-

$V_A = 400V\angle 0^\circ$ (L-L) $V_B = 400\angle 240^\circ$

$V_C = 400\angle 120^\circ$

$$I_A = \frac{V_A}{Z_A} = \frac{400\angle 0^\circ}{250}$$



$$I_B = \frac{V_B}{Z_B} = \frac{400\angle 240^\circ}{15}$$

$$= 26.67\angle 240^\circ (A)$$

$$I_C = \frac{V_C}{Z_C} = \frac{400\angle 120^\circ}{20} = 20\angle 120^\circ (A)$$

$$I_{A0} = \frac{1}{3}(I_A + I_B + I_C).$$

$$= \frac{1}{3}(1.6\angle 0^\circ + 26.67\angle 240^\circ + 20\angle 120^\circ).$$

$$= -7.25 - j1.93$$

$$I_{A1} = \frac{1}{3}(I_A + aI_B + a^2 I_C).$$

$$= \frac{1}{3}(1.6\angle 0^\circ + 26.67\angle 240^\circ * 1\angle 120^\circ + 1\angle 240^\circ * 20\angle 120^\circ)$$

$$= 16.11 A$$

$$I_{A2} = \frac{1}{3}(I_A + a^2 I_B + I_C a).$$

$$= \frac{1}{3}(1.6\angle 0^\circ + 1\angle 240^\circ * 26.67\angle 240^\circ + 20\angle 120^\circ * 1\angle 120^\circ).$$

$$= -7.25 + j1.93 A$$

$$I_{a1} = j\sqrt{3}\, I_{A1} = j\sqrt{3} * 161.1 = 27.89\angle 90^\circ$$

$$I_{a2} = -j\sqrt{3}\, I_{A2} = j\sqrt{3} * (-7.25 + j1.93) = 13\angle 75^\circ.$$

11) The symmetrical Components of phase 'A' fault current in a 3ϕ unbalanced system are $I_{a0} = 350\angle 90^\circ$ A, $I_{a1} = 600\angle -90^\circ$ A and $I_{a2} = 250\angle 90^\circ$ A. Determine the phase current I_a, I_b and I_c

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

$I_a = I_{a0} + I_{a1} + I_{a2} = 0 + j350 + 0 - j600 + j250 = 0$

$I_b = I_{a0} + a^2 I_{a1} + a I_{a2}$

$= (0 + j350) + (1\angle 240 \times 600\angle -90^\circ) + (1\angle 120 \times 250\angle 90^\circ)$

$= j350 - 519.62 + j300 - 216.51 - j125$

$I_b = 904.16\angle 145^\circ$ A $= -736.13 + j525$

$I_c = I_{a0} + a I_{a1} + a^2 I_{a2}$

$= (0 + j350) + (1\angle 120^\circ \times 600\angle -90^\circ) + (1\angle 240^\circ \times 250\angle 90^\circ)$

$= (0 + j350) + (519.62 + j300) + (216.51 - j125)$

$= 736.13 + j525$

$I_c = 904.16\angle 35^\circ$

12) Determine the Symmetrical Components of the unbalanced 3ϕ currents $I_a = 10\angle 0^\circ$ (A) $I_b = 12\angle 23$ and $I_c = 10\angle 130^\circ$ (A)

Solution:-

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

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

$$= \frac{1}{3}\left[10 - 7.71 - j\,9.19 - 6.43 + j\,7.66\right]$$

$$I_{a0} = -1.38 - j0.51 = 1.47\angle -160^\circ$$

$$I_{a1} = \frac{1}{3}(I_a + aI_b + a^2 I_c).$$

$$= \frac{1}{3}\left(10 + (1\angle 120^\circ * 12\angle 230^\circ) + (1\angle 240^\circ * 10\angle 130^\circ)\right)$$

$$= \frac{1}{3}(10 + 11.82 - j2.08 + 9.85 + j1.74).$$

$$= 10.56 - j0.11$$

$$= 10.56\angle -0.6$$

$$I_{a2} = \frac{1}{3}(I_a + a^2 I_b + a I_c).$$

$$= \frac{1}{3}\left(10 + (1\angle 240^\circ * 12\angle 230^\circ) + (1\angle 120^\circ * 10\angle 130)\right).$$

$$= \frac{1}{3}\left(10 + (-4.10 + j11.28) + (-3.46 - j\,9.40)\right)$$

$$= 0.83 + j0.63 = 1.04\angle 37^\circ$$

$$I_{a0} = I_{b0} = I_{c0} = 1.47\angle -160 = -1.38 - j0.51$$

$I_{a1} = 10.56 \angle -0.6$

$I_{b1} = a^2 I_{a1} = 1\angle 240 * 10.56 \angle 0^\circ$
$= 10.56 \angle 240^\circ$

$I_{c1} = a I_{a1} = 1 \angle 120^\circ * 10.56 \angle 0^\circ$
$= 10.56 \angle 120^\circ$ (A).

$I_{a2} = 1.04 \angle 37^\circ$ $I_{b2} = a I_{a2}$
$= 1\angle 120^\circ * 1.04 \angle 37^\circ$
$= 1.04 \angle 157^\circ$ (A)

$I_{c2} = a^2 I_{a2} = 1 \angle 240^\circ * 1.04 \angle 37^\circ$
$= 1.04 \angle 277^\circ$ (A).

13) A balanced Y connected load takes 30A from a balanced 3ϕ, 4wire supply. If the fuses in two lines are removed. Find the symmetrical components of the line currents before and after the fuses are removed.

i) Before Fuse Removal:-

$I_a = 30\,A \angle 0^\circ$ ref $I_b = 30 \angle 240^\circ$; $I_c = 30 \angle 120^\circ$

$I_{a0} = \frac{1}{3}(I_a + I_b + I_c) = \frac{1}{3}(30 \angle 0^\circ + 30 \angle 240^\circ + 30 \angle 120^\circ)$

$I_{a0} = 0$

$$I_{a1} = \frac{1}{3}(I_a + aI_b + a^2 I_c).$$

$$= \frac{1}{3}(30\angle 0^\circ + 30\angle 360^\circ + 30\angle 360^\circ)$$

$$= \frac{1}{3}(30 + 30 + 30) = 30(A)$$

$$I_{a2} = \frac{1}{3}(I_a + a^2 I_b + aI_c)$$

$$= \frac{1}{3}(30\angle 0^\circ + 30\angle 480^\circ + 30\angle 240^\circ) = 0$$

(ii) <u>After fuse removal</u>:-

$I_a = 30\angle 0^\circ$ $I_b = 0$ $I_c = 0.$

$$I_{a0} = \frac{1}{3}(I_a + I_b + I_c) = \frac{1}{3}(30\angle 0^\circ + 0 + 0)$$

$$= 10\angle 0^\circ (A)$$

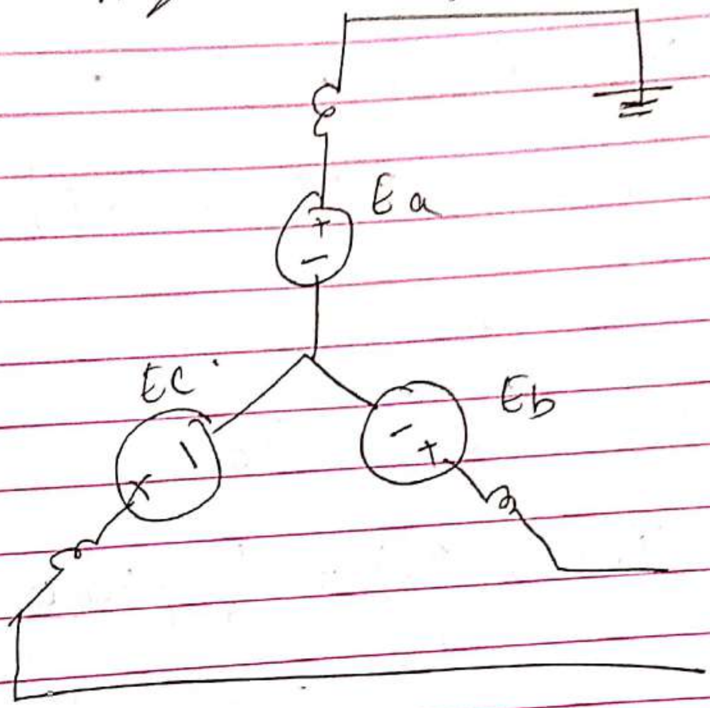
$$I_{a1} = \frac{1}{3}(I_a + aI_b + a^2 I_c)$$

$$= \frac{1}{3}(30\angle 0^\circ + 0 + 0) = 10\angle 0^\circ (A).$$

$$I_{a2} = \frac{1}{3}(I_a + a^2 I_b + aI_c).$$

$$= \frac{1}{3}(30\angle 0^\circ + 0 + 0) = 10\angle 0^\circ (A)$$

14) For a grounded 3ϕ Generator, the three sequence Voltages are E_{a1}, E_{a2} and E_{a0}. If the ground is removed and the terminal of Phase 'A' is grounded. Determine the new sequence Voltage.



Solution :- $V_a = 0$ $V_b = E_b - E_a$ $V_c = E_c - E_a$

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

$$= \frac{1}{3}\left[0 + (E_b - E_a) + (E_c - E_a)\right]$$

$$= \frac{1}{3}\left[(E_a + E_b + E_c) - 3E_a\right]$$

$$\boxed{V_{a0} = E_{a0} - E_a}$$

$$V_{a1} = \frac{1}{3}\left(V_a + aV_b + a^2V_c\right).$$

$$= \frac{1}{3}\left(0 + aE_b - aE_a + a^2E_c - a^2E_a\right)].$$

$$= \frac{1}{3}\left[\left(E_a + aE_b + a^2E_c\right) - E_a\left(1+a+a^2\right)\right]$$

$$= \frac{1}{3}\left[3E_{a1} + 0\right]$$

$$\boxed{V_{a1} = E_{a1}}$$

$$V_{a2} = \frac{1}{3}\left(V_a + a^2V_b + aV_c\right).$$

$$= \frac{1}{3}\left[0 + a^2\left(E_b - E_a\right) + a\left(E_c - E_a\right)\right]$$

$$= \frac{1}{3}\left[\left(E_a + a^2E_b + aE_c\right) - E_a\left(1+a+a^2\right)\right].$$

$$= \frac{1}{3}\left(3E_{a2} + 0\right)$$

$$\boxed{V_{a2} = E_{a2}.}$$

⑮ The sequence components of the phase voltages are $V_{a1} = 200\angle 30°$; $V_{a2} = 60\angle 60°$ and $V_{a0} = 20\angle -30°$ V. The line currents are $I_{a1} = 20\angle 10°$; $I_{a2} = 5\angle 20°$ A & $I_{a0} = 3\angle -10°$ A Determine the 3ϕ power in KVA and pu if the base power is 1 KVA.

Solution:-

* (conjugate meaning) {-ve sign for Angle}

$$S = 3\left(V_{a1}I_{a1}^* + V_{a2}I_{a2}^* + V_{a0}I_{a0}^*\right)$$

$$S = 3\left[200\angle 30^\circ * 20\angle -10^\circ + 60\angle 60^\circ * 5\angle -20^\circ + 20\angle -30^\circ * 3\angle 10^\circ\right]$$

$$= 3\left[4000\angle 20^\circ + 300\angle 40^\circ + 60\angle -20^\circ\right]$$

$$S = 12.13 + j4.62 \text{ KVA}$$

$$S_{in\,pu} = \frac{S}{S_B} = \frac{(12.13 + j4.62)\text{ KVA}}{1 \text{ KVA}}$$

$$\boxed{S_{in\,pu} = 12.13 + j4.62 \text{ pu}}$$

⑯ In a 3ø system, the sequence quantities are $V_{a1} = (0.9 + j0.2)$ pu; $V_{a2} = (0.2 + j0.1)$ pu; $V_{a0} = (0.1 + j0.05)$ pu and $I_{a1} = (0.9 - j0.1)$ pu $I_{a2} = (0.2 - j0.1)$ pu $I_{a0} = (0.05 - j0.02)$ pu. Find the 3ø complex power in pu and in MVA on a base of 100MVA. Also compute active and reactive powers.

Solution Since V & I are in pu use Sin(pu) formula:

$$S_{in\,pu} = V_{a1} I_{a1}^* + V_{a2} I_{a2}^* + V_{a0} I_{a0}^*$$

conjugate

conjugate

$$= \left[(0.9 + j0.2)(0.9 + j0.1) + (0.2 + j0.1)(0.2 + j0.1) + (0.1 + j0.05)(0.05 + j0.02)\right].$$

$S = (0.817 + j0.3126)\ pu$

$S = S_{pu} * S_B = (0.817 + j0.3126) * 100\ MVA$

$$\boxed{S = \underset{\overset{\downarrow}{P}}{81.7} + j\underset{\overset{\downarrow}{Q}}{31.26}\ MVA}$$

17) In a 3ϕ, 4 wire system, the sequence Voltages and currents are $V_{a1} = 0.9\angle 110°\ Pu$; $V_{a2} = 0.25\angle 110°\ Pu$, $V_{a0} = 0.2\angle 300°\ Pu$, $I_{a1} = 0.75\angle 25°\ Pu$, $I_{a2} = 0.15\angle 170°\ Pu$, $I_{a0} = 0.1\angle 330°\ pu$. Find the complex power in pu. If the neutral gets disconnected find the new Power.

Solution:-

$$S_{pu} = V_{a0} I_{a0}^* + V_{a1} I_{a1}^* + V_{a2} I_{a2}^*$$

$$= (0.12\angle 300° * 0.1\angle -330° + 0.9\angle 110° * 0.75\angle -25° + 0.25\angle 110° * 0.15\angle -170°)$$

$S_{pu} = 0.68 - j0.212\ pu$

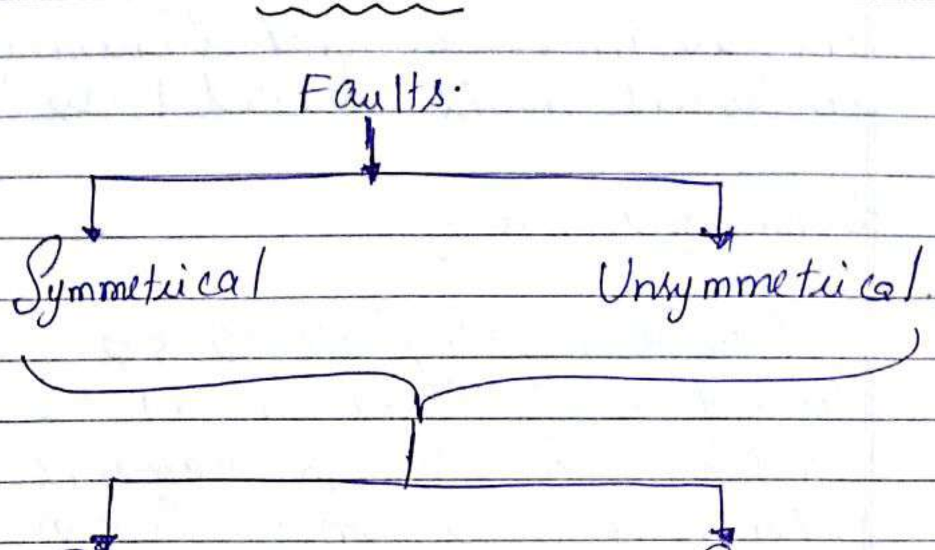
When Neutral gets opened, Zero sequence component $I_{a0} = 0$

$$\therefore S_{pu\,(new)} = V_{a1} I_{a1}^* + V_{a2} I_{a2}^*$$

$$= 0.9\angle 110° * 0.75\angle -25 + 0.25\angle 110° * 0.15\angle -170°$$

$S_{pu(new)} = (0.67 - j0.206)\ pu$

UNSYMMETRICAL FAULTS



Shunt	Series
1) Single Line Ground (SLG) (or(LG))	1) One Conductor open fault.
2) Line to Line Fault (LL)	2) Two conductors open faut.
3) Double Line to Line fault (LLG).	3) Three conductors open fault.
4) 3ϕ fault (3L)(or(3LG).	

Shunt Fault:-

Short circuit between Conductors (or between the conductors and ground. They are characterized by an increase in current and fall in Voltage and frequency in the faulted phase.

Series Fault:-

When one (or) two lines in a 3ϕ system get Opened while the other lines or line remain intact such faults are called as

Series faults. They are Characterized by an increase in voltage and frequency and fall in current in the faulted Phase

Symmetrical Faults:-

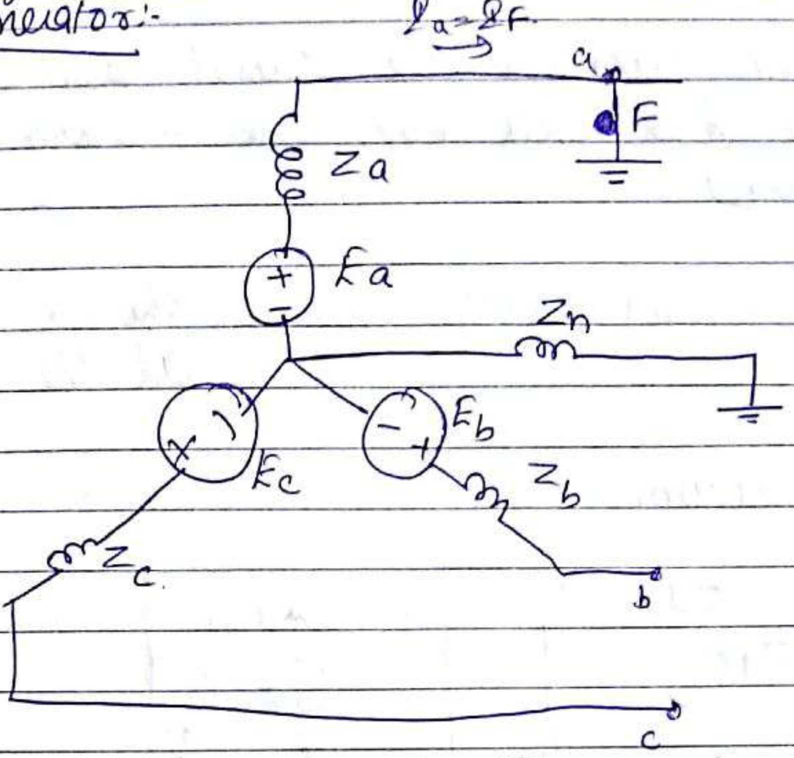
Faults involving all the 3ϕ. The fault current is the same in all the three phases and hence the System remains balanced even after occurrence. The knowledge of Voltage and current in one Phase is sufficient to determine the Voltages and currents in the other two Phases. Real Power and Reactive Power is three times the Corresponding per phase value.

Unsymmetrical Faults:-

All other faults leaving out the 3ϕ faults are unsymmetrical, the fault current is not the same in all Phases and the system is rendered Unbalanced. It involves Phasors of different magnitude and Phase angles in each Phase. Analysis under unbalanced conditions can be Carried Out on a 3ϕ basis, but it is Very ~~an~~ difficult Process.

So we use the Symmetrical components and Sequence Networks for determining the Voltages and currents in all parts of the system after the occurrence of the fault.

Single line to Ground fault on an unloaded Generator:-



SLG → Phase-a is Shorted to ground directly.

Terminal Conditions:-

$$V_a = 0 \;;\; I_b = 0 \;;\; I_c = 0$$

Symmetrical Component relations:-

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

$$\begin{bmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}\begin{bmatrix} I_a \\ \cancel{I_b} \to 0 \\ \cancel{I_c} \to 0 \end{bmatrix}$$ Apply Initial Conditions

$$I_{a0} = I_{a1} = I_{a2} = \frac{1}{3} I_a$$

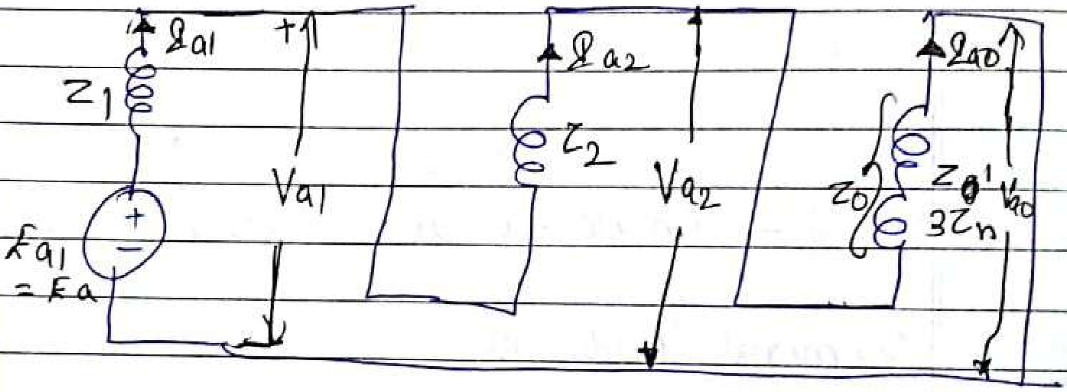
$\therefore V_{a0} + V_{a1} + V_{a2} = 0$ as per Initial Condition.

So the sequence N/w becomes,

Since currents are equal $I_{a0} = I_{a1} = I_{a2}$
The Three ckts +ve, -ve & zero are in series

$V_a = V_{a1} + V_{a2} + V_0 = 0$ ⇒ Shows Short ckt at the end

Interconnection Of Sequence Networks:-



From N/w :-

$$I_{a1} = I_{a2} = I_{a0} = \frac{E_a}{Z_1 + Z_2 + Z_0}$$

$$V_{a1} = E_{a1} - I_{a1} Z_1 = E_a - \left(\frac{E_a}{Z_1 + Z_2 + Z_0} \right) Z_1$$

$$= E_a \left[\frac{Z_1 + Z_2 + Z_0 - Z_1}{Z_1 + Z_2 + Z_0} \right]$$

$$\boxed{V_{a1} = E_a \frac{Z_2 + Z_0}{Z_1 + Z_2 + Z_0}}$$

$$V_{a2} = -I_{a2} Z_2 = -E_a \frac{Z_2}{Z_1+Z_2+Z_0}$$

$$V_{a0} = -I_{a0} Z_0 = -E_a \frac{Z_0}{Z_1+Z_2+Z_0}.$$

Fault current:-

$$I_f = I_a = 3 I_{a0} = 3 \frac{E_a}{Z_1+Z_2+Z_0}.$$

In case:-

1) The Neutral of the generator is not grounded Then,

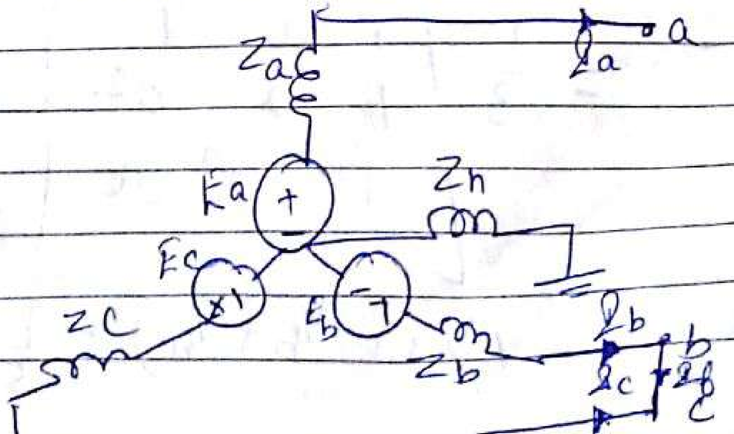
$$Z_0 = Z_{g0} + 3Z_n = Z_{g0} + \infty = \infty.$$

$$\therefore I_f = 3 \left(\frac{E_a}{Z_1+Z_2+\infty} \right) = 0$$

Fault current = 0 if Neutral is not grounded in case of a LG Fault.

Line to Line fault of an unloaded Generator:-

LL Fault → b, c Phases are Shorted.



Terminal Conditions:-

$$I_a = 0 \; ; \; I_b + I_c = 0 \; ; \; V_b = V_c$$

$$I_c = -I_b$$

Symmetrical Component Relations:-

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

$$\begin{bmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \begin{bmatrix} \cancel{I_a}\,0 \\ I_b \\ \cancel{I_c}\,-I_b \end{bmatrix}$$

$$I_{a0} = \frac{1}{3}(I_b - I_b) = 0$$

$$I_{a1} = \frac{1}{3}\left[a I_b - a^2 I_b\right] = \frac{1}{3}(a - a^2) I_b.$$

$$I_{a2} = \frac{1}{3}\left[a^2 I_b - a I_b\right] = -\frac{1}{3}(a - a^2) I_b$$

$$\therefore \boxed{I_{a0} = 0} \qquad \boxed{I_{a1} = -I_{a2}}$$

$$\begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}$$

$$= \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ \cancel{V_c}\,V_b \end{bmatrix}$$

$$V_{a0} = \frac{1}{3}(V_a + V_b + V_b) = \frac{1}{3}(V_a + 2V_b)$$

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

$$V_{a1} = \frac{1}{3}\left(V_a - V_b\right).$$ $a + a^2 = -1$

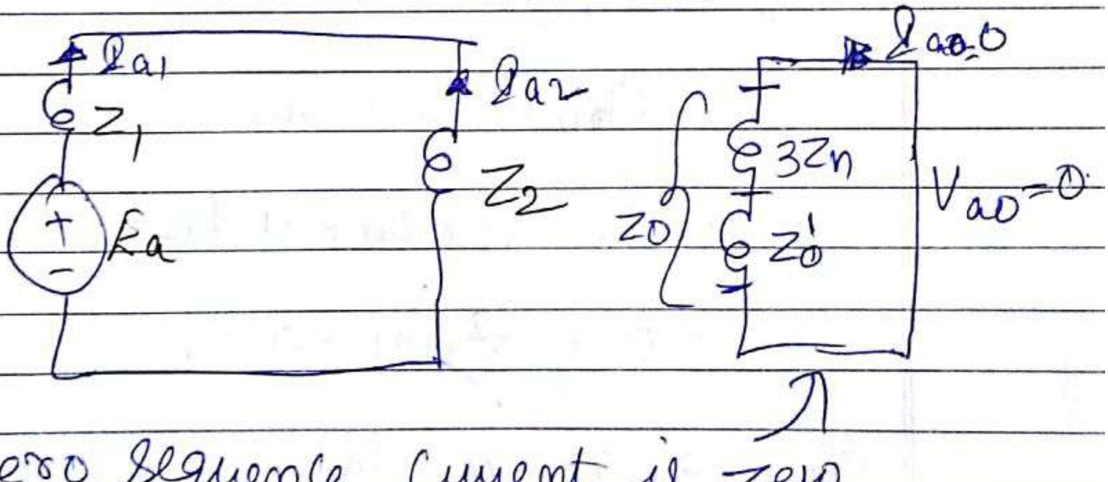
$$V_{a2} = \frac{1}{3}\left(V_a + (a^2+a)V_b\right)$$

$$= \frac{1}{3}\left(V_a - V_b\right).$$

$$\therefore \boxed{V_{a1} = V_{a2}}$$

N/w is parallel since $V_{a1} = V_{a2}$ (+ve & -ve N/w is in parallel)

& both currents I_{a1} & I_{a2} are opposite in direction.



zero sequence current is zero
∴ ckt is seperate with short ckt as no emf is present in zero sequence. current is zero.

From N/w :- $I_{a0} = 0$ ∴ $V_{a0} = -I_{a0} Z_0$

$V_{a0} = 0$

From N/W,

$$I_{a1} = -I_{a2} = \frac{E_a}{Z_1 + Z_2}$$

$$V_{a1} = V_{a2} = E_a - I_{a1} Z_1$$

$$= E_a - \left(\frac{E_a}{Z_1+Z_2}\right) Z_1.$$

$$= E_a \left[\frac{\cancel{Z_1}+Z_2-\cancel{Z_1}}{Z_1+Z_2}\right]$$

$$\boxed{V_{a1} = V_{a2} = E_a \frac{Z_2}{Z_1+Z_2}.}$$

Fault current :-

$$I_f = I_b \text{ (or) } (-I_c).$$

$$= I_{b0} + I_{b1} + I_{b2}.$$

$$= I_{a0} + a^2 I_{a1} + a I_{a2}$$

$$= 0 + a^2 I_{a1} - a I_{a1}$$

$$= (a^2 - a) I_{a1}$$

$$I_f. = -j\sqrt{3} \left[\frac{E_a}{Z_1+Z_2}\right].$$

$$\boxed{I_f = \sqrt{3}\, I_{a1}}$$ //.

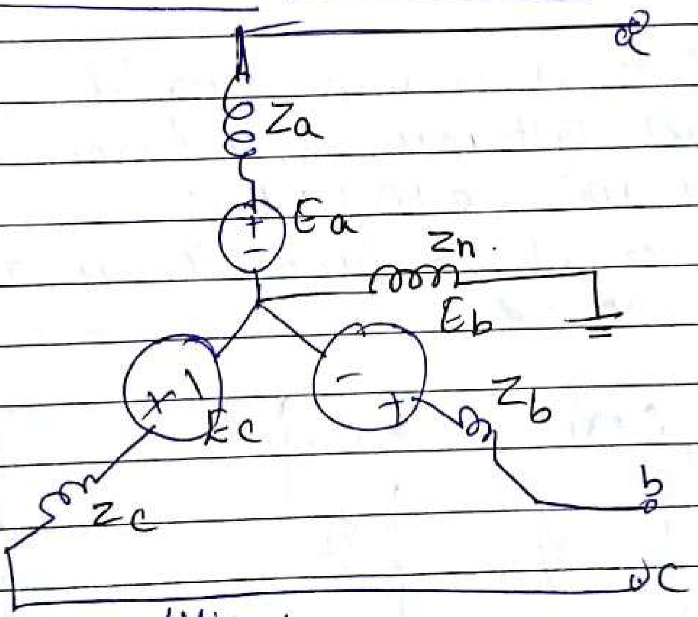
Incase:-

Neutral is not grounded, then

$Z_0 = Z_{g0}' + 3Z_n = Z_{g0} + \infty = \infty$

The Fault current is independent of the value of Z_0, the presence or absense of a grounded neutral at the generator does not affect the fault current.

Double Line to Ground (LLG) fault on an Unloaded Generator:-



Initial conditions,

$V_b = 0 \; ; \; V_c = 0 \; ; \; I_a = 0$

Symmetrical Component relations:-

$$\begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}$$

$$\begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}\begin{bmatrix} V_a \\ V_b = 0 \\ V_c = 0 \end{bmatrix}$$

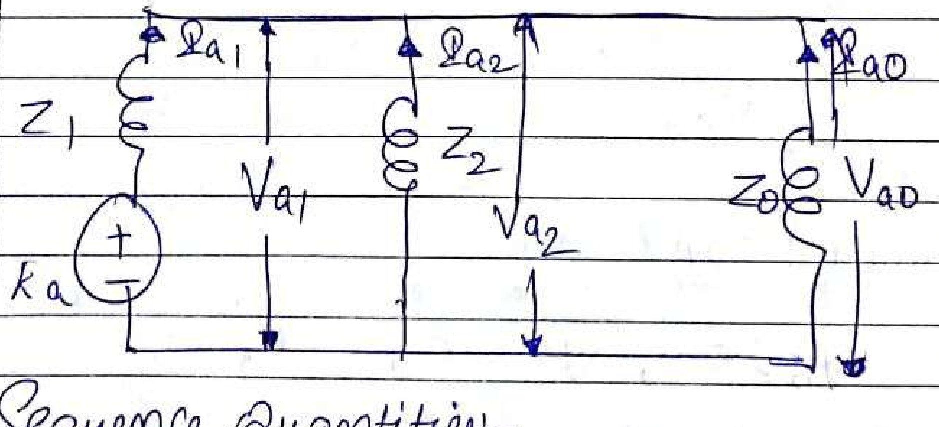
$V_{a0} = \frac{1}{3} V_a$; $V_{a1} = \frac{1}{3} V_a$; $V_{a2} = \frac{1}{3} V_a$

$$\boxed{V_{a0} = V_{a1} = V_{a2} = \frac{1}{3} V_a}$$

$$\boxed{I_a = I_{a1} + I_{a2} + I_{a0} = 0}$$

So ckt is drawn parallel. All three phase voltages are same so all three N/w's will be in parallel.

Since all the currents are addition & they are shorted



Sequence Quantities:-

$$V_{a1} = V_{a2} = V_{a0} = E_a - I_{a1} Z_1$$

$$I_{a1} = \frac{E_a}{Z_1 + \left(\frac{Z_2 Z_0}{Z_2 + Z_0}\right)}$$

by reducing the N/w we will get

$$\left.\begin{aligned} I_{a2} &= -I_{a1}\left(\frac{Z_0}{Z_2+Z_0}\right) \\ I_{a0} &= -I_{a1}\left(\frac{Z_2}{Z_2+Z_0}\right) \end{aligned}\right\}$$

By 'I' division rule.

Fault current:-

$$I_f = I_b + I_c$$

$$= (I_{a0} + a^2 I_{a1} + a I_{a2}) + (I_{a0} + a I_{a1} + a^2 I_{a2})$$

$$= 2I_{a0} + (a+a^2) I_{a1} + (a+a^2) I_{a2}$$

$$= 2I_{a0} - I_{a1} - I_{a2} \quad \{\because (a+a^2) = -1\}$$

$$I_f = 2I_{a0} - (I_{a1} + I_{a2}).$$

$$= 2I_{a0} - (-I_{a0}) \quad \left\{\begin{aligned} &\because I_{a1} + I_{a2} + I_{a0} = 0 \\ &I_{a1} + I_{a2} = -I_{a0} \end{aligned}\right.$$

$$\boxed{I_f = 3I_{a0}}$$

$$I_f = 3\left[-I_{a1}\left(\frac{Z_2}{Z_2+Z_0}\right)\right\}$$

$$\boxed{I_f = -3I_{a1}\left(\frac{Z_2}{Z_0+Z_2}\right)}$$

Incase:- If Neutral Grounding is Absent

Then $Z_n = \infty$

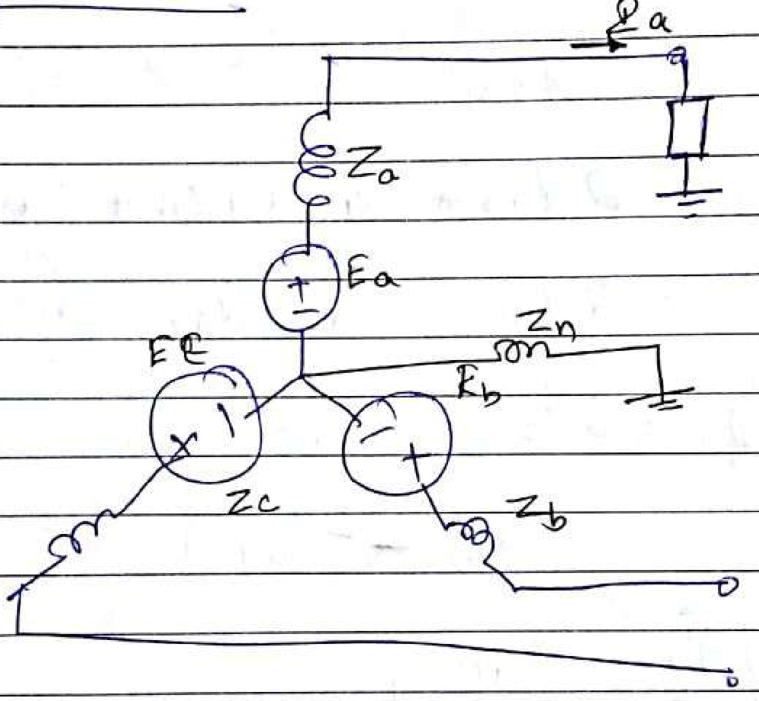
$$Z_0 = Z_{g0} + 3Z_n = Z_{g0} + \infty = \infty$$

Hence, $I_f = -3I_{a1}\left(\frac{Z_2}{Z_2+\infty}\right) = 0.$

Fault Through Impedance :-

Fault impedance is included at appropriat points in the circuits.

Single line to ground (LG) fault on an unloaded Generator through a fault Impedance :-



Terminal Condition :-

$$V_a = I_a Z_f \; ; \; I_b = 0 \; ; \; I_c = 0$$

Symmetrical Component Relations :-

$$\begin{bmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}\begin{bmatrix} I_a \\ \cancelto{0}{I_b} \\ \cancelto{0}{I_c} \end{bmatrix}$$

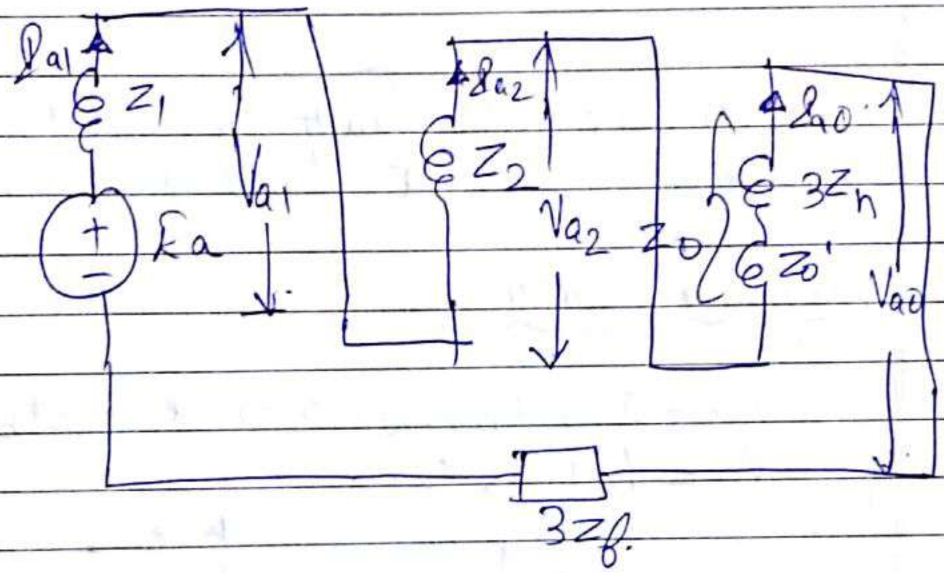
$$I_{a0} = \frac{1}{3} I_a = \frac{1}{3} I_a = I_{a1} = I_{a2}$$

$$V_{a0}+V_{a1}+V_{a2} = I_a Z_f = 3 I_{a0} Z_f$$

All sequence currents are equal and the sum of sequence voltages equals $3I_{a0}Z_f$.

∴ It is a series connection of sequence Networks through an impedance $3Z_f$.

Interconnection of sequence nw:



$$I_{a0} = I_{a1} = I_{a2} = \frac{E_a}{Z_1+Z_2+Z_0+3Z_f}$$

$$V_{a1} = E_a - I_{a1}Z_1 = E_a\left[\frac{Z_2+Z_0+3Z_f}{Z_1+Z_2+Z_0+3Z_f}\right]$$

$$V_{a2} = -I_{a2}Z_2 = \frac{-E_aZ_2}{Z_1+Z_2+Z_0+3Z_f}$$

$$V_{a0} = -I_{a0}Z_0 = \frac{-E_aZ_0}{Z_1+Z_2+Z_0+3Z_F}$$

Fault current:-

$$I_f = I_a = 3 I_{a0} = 3\left(\frac{E_a}{Z_1+Z_2+Z_0+3Z_f}\right).$$

Note:-

If Neutral is ungrounded, $Z_n=\infty$

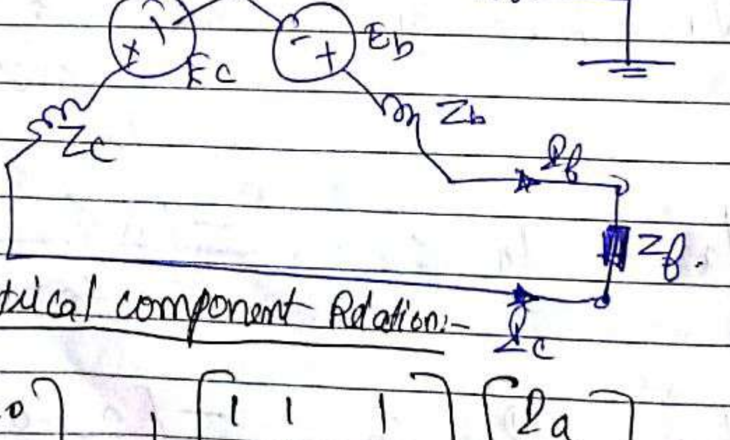
$\Rightarrow Z_0=\infty$ & hence $I_f = 0$.

Line to Line (LL) fault on an Unloaded Generator through a fault Impedance:-

Terminal Conditions:-

$I_a=0$; $I_b+I_c=0 \Rightarrow I_c=-I_b$

$V_b = V_c + I_b Z_f$.



Symmetrical component Relation:-

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

$$= \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}\begin{bmatrix} \cancel{I_a}^{\,0} \\ I_b \\ \cancel{I_c} - I_b \end{bmatrix}$$

$I_{a0} = \frac{1}{3}(I_b - I_b) = 0.$

$I_{a1} = \frac{1}{3}(a - a^2) I_b$

$I_{a2} = -\frac{1}{3}(a - a^2) I_b.$

$$\boxed{\begin{matrix} I_{a0} = 0 \\ I_{a1} = -I_{a2} \end{matrix}}$$

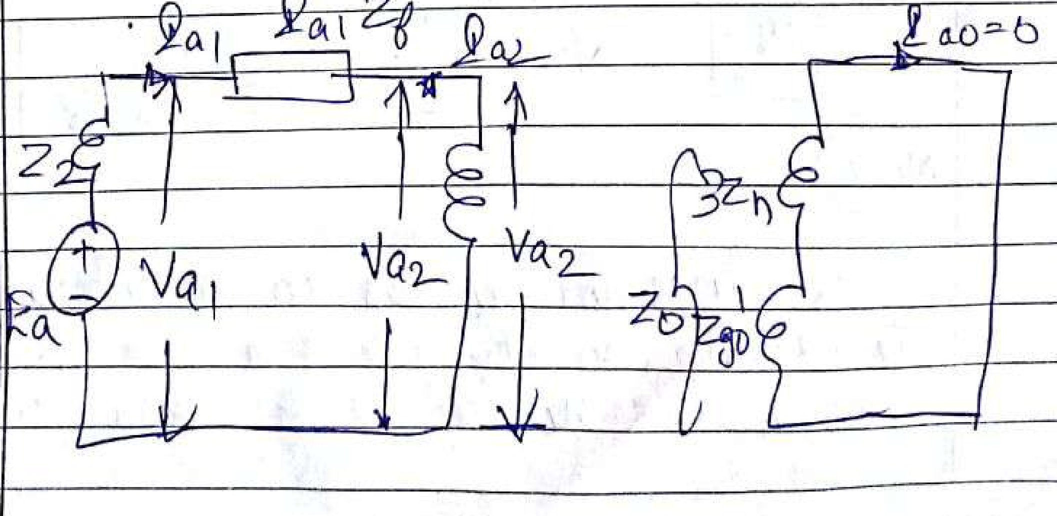
$V_{a1} - V_{a2} = \frac{1}{3}\left[(a - a^2) V_b + (a^2 - a) V_c\right]$

$= \frac{1}{3}(a - a^2)(V_b - V_c)$

$= \underbrace{\frac{1}{3}(a - a^2)(I_b}_{I_{a1}} Z_f)$ $\left[V_b - V_c = I_b Z_b \text{ from Initial Condition}\right]$

$= ~~\frac{1}{3}(a-a^2)~~\; I_{a1} Z_f.$

$$\boxed{V_{a1} - V_{a2} = I_{a1} Z_f}$$



From N/w -

$$I_{a1} = -I_{a2} = \frac{E_a}{Z_1 + Z_2 + Z_f}$$

$$I_{a0} = V_{a0} = 0$$

$$V_{a1} = E_a - I_{a1} Z_1 = E_a \left(\frac{Z_2 + Z_f}{Z_1 + Z_2 + Z_f} \right).$$

$$V_{a2} = -I_{a2} Z_2 = -E_a \left(\frac{Z_2}{Z_1 + Z_2 + Z_f} \right)$$

Fault current :-

$$I_f = I_b = I_{a0} + a^2 I_{a1} + a I_{a2}$$

$$= 0 + a^2 I_{a1} - a I_{a1}$$

$$= (a^2 - a) I_{a1}$$

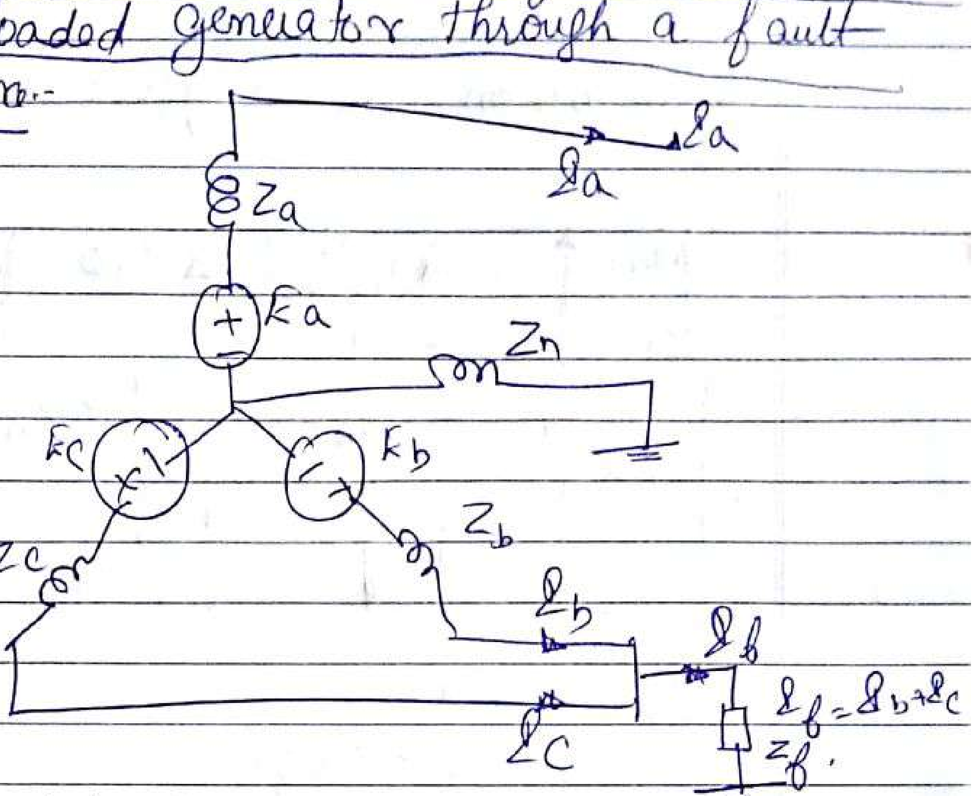
$$= -j\sqrt{3} I_{a1}$$

$$\boxed{|I_f| = \sqrt{3} I_{a1}} \boxed{= \sqrt{3} \frac{E_a}{Z_1 + Z_2 + Z_f}}$$

Note :-

Z_0 does not appear in the above equation, the presence (or) absence of a grounded neutral does not affect the fault current.

Double Line to Ground fault (LLG) on an unloaded generator through a fault Impedance:-



Terminal Conditions:-

$$I_a = 0 \; ; \; V_b = (I_b + I_c) Z_f \; ; \; V_c = (I_b + I_c) Z_f$$

Symmetrical component Relations:-

$$V_{a1} = \frac{1}{3}(V_a + aV_b + a^2 V_c) = \frac{1}{3}[V_a + (a+a^2)V_b]$$

$$V_{a1} = \frac{1}{3}[V_a - V_b].$$

$$V_{a2} = \frac{1}{3}(V_a + a^2 V_b + aV_c) = \frac{1}{3}(V_a + (a^2+a)V_b)$$

$$V_{a2} = \frac{1}{3}(V_a - V_b)$$

$$V_{a0} = \frac{1}{3}(V_a + V_b + V_c) = \frac{1}{3}(V_a + 2V_b).$$

$$\therefore \boxed{V_{a1} = V_{a2}} \qquad V_{a0} - V_{a2} = \frac{1}{3}(3V_b)$$

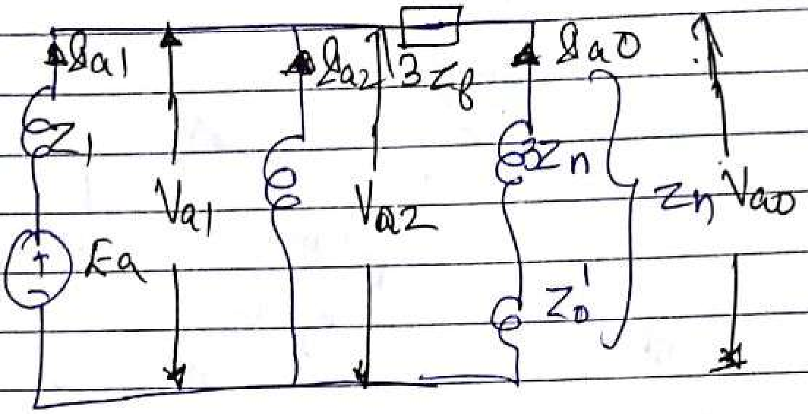
$$= V_b$$

$$= (I_b + I_c) Z_f.$$

$$\boxed{V_{a0} = 3I_{a0} Z_f}$$

$V_{a0} = V_{a2} + 3 I_{a0} Z_f$.

The condition $I_a = 0$ gives $I_{a0} + I_{a1} + I_{a2} = 0$.



$$I_{a1} = \frac{E_a}{Z_1 + \frac{Z_2(3Z_f+Z_0)}{Z_2+3Z_f+Z_0}}$$

$$I_{a2} = -\frac{I_{a1}(Z_0+3Z_f)}{(Z_0+Z_2+3Z_f)}$$

$$I_{a0} = \frac{-I_{a1} Z_2}{(Z_0+Z_2+3Z_f)}$$

Fault current:

$$I_f = I_b + I_c = (I_{a0} + a^2 I_{a1} + a I_{a2}) + (I_{a0} + a I_{a1} + a^2 I_{a2})$$

$$= 2 I_{a0} + (a^2+a) I_{a1} + (a+a^2) I_{a2}$$

$$= 2 I_{a0} - I_{a1} - I_{a2}$$

$$= 2 I_{a0} - (I_{a1} + I_{a2}).$$

$$I_f = 2 I_{a0} - (-I_{a0})$$

$$\boxed{I_f = 3 I_{a0} = -3 I_{a1}\left(\frac{Z_2}{Z_0+Z_2+3Z_f}\right)}$$

Note :-

$Z_n = \infty \Rightarrow Z_0 = \infty$ Hence $I_f = 0$.

Unsymmetrical Faults on Power Systems:-

* For unsymmetrical faults on the Power System are analysed using Thevenin's equivalent is obtained with respect to fault point and reference.

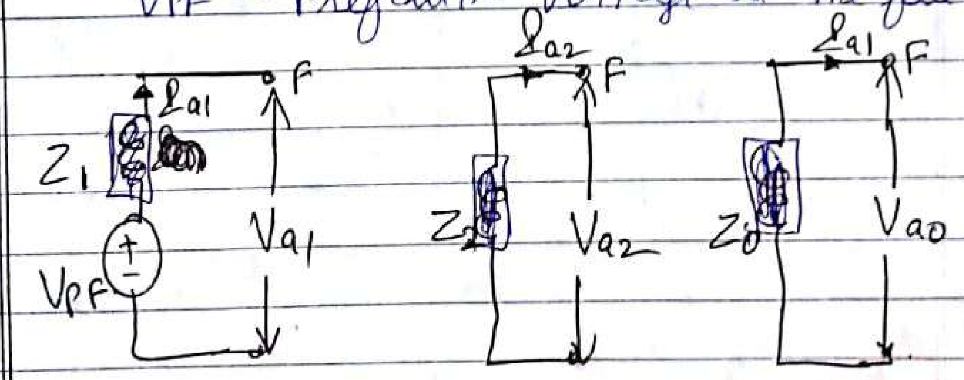
* The Prefault Voltage at the Power System at the fault Point is the V_{Th} of +ve seq components

Let Z_1 - Thevenin's Impedance Of +ve seq N/w

Z_2 - Thevenin's Impedance Of -ve seq N/w

Z_0 - Thevenin's Impedance of zero seq N/w

V_{PF} - Prefault Voltage at the fault Point



No Zn since it is Tr line

Using KCL

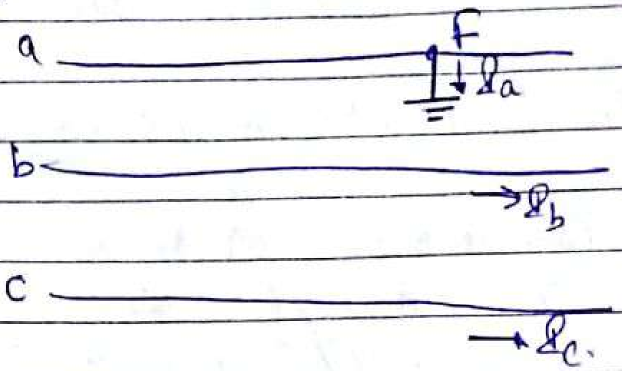
$V_{a0} = Z_0 I_{a0}$

$V_{a1} = V_{PF} - Z_1 I_{a1}$

$V_{a2} = -Z_2 I_{a2}$

$$\begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix} = \begin{bmatrix} 0 \\ V_{PF} \\ 0 \end{bmatrix} - \begin{bmatrix} Z_0 & 0 & 0 \\ 0 & Z_1 & 0 \\ 0 & 0 & Z_2 \end{bmatrix} \begin{bmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{bmatrix}$$

Single Line to Ground (LG) Fault:-



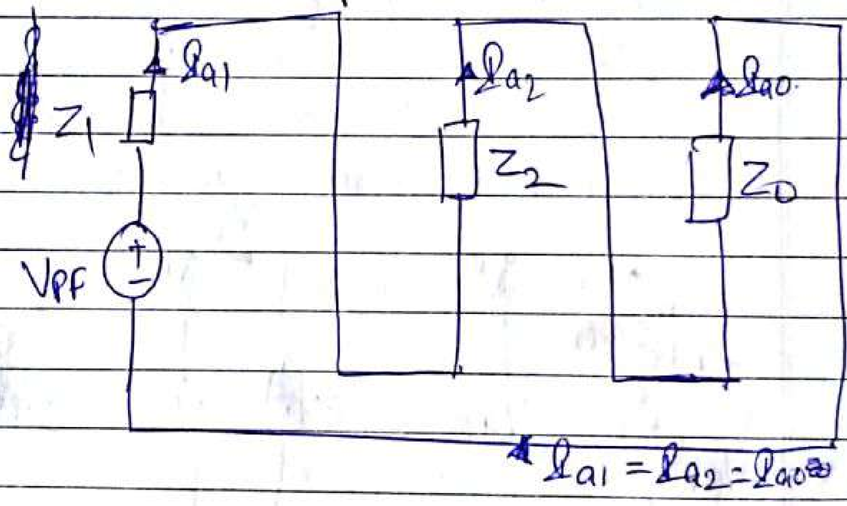
Initial Conditions:-

$$I_b = 0 \quad I_c = 0 \; ; \; V_a = 0 .$$

Derivation is Same as Generator.

page NO - 3-5

N/W

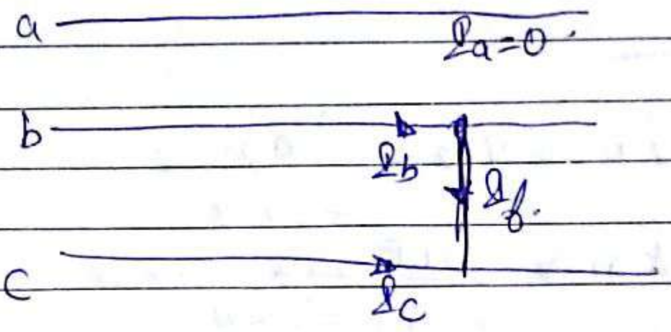


$$I_{a1} = I_{a2} = I_{a0} = \frac{I_a}{3}$$

$$\& \; I_{a1} = \frac{V_{PF}}{Z_1 + Z_2 + Z_0} .$$

$$I_f = 3 \frac{V_{PF}}{Z_1 + Z_2 + Z_0}$$

Line to Line Fault on ~~th~~ a power System:-

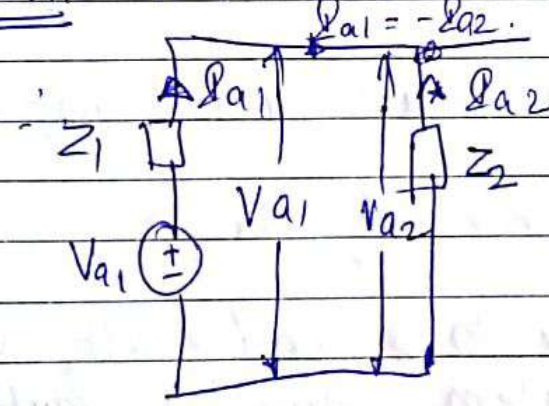


Initial Conditions:-

$I_a = 0$; $I_b = -I_c$; $V_b = V_c$

Same Derivation as L-L fault on page NO 5-8.

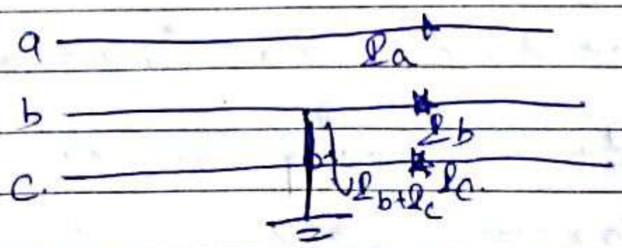
Ckt $V_{a1} = V_{a2}$



$$I_{a1} = \frac{V_{PF}}{Z_1+Z_2}$$

$$I_f = \sqrt{3}\, I_{a1}.$$

Double Line to Ground fault on a Power System:-



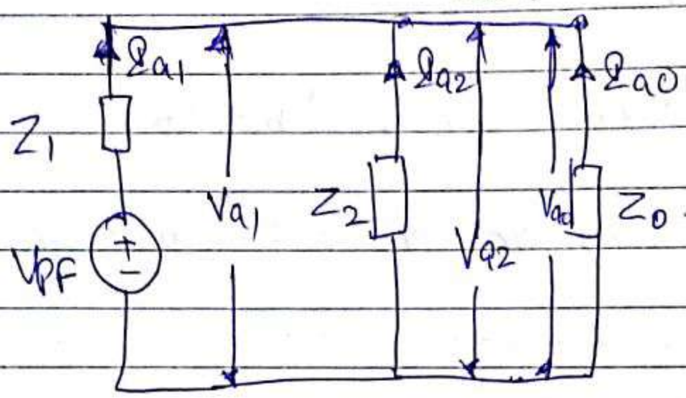
Initial Conditions:-

$V_b = V_c = 0$; $I_a = 0$

Same derivation as LLG on a Power System page NO 9-10.

$$V_{a1} = V_{a2} = V_{a0}$$

$$I_{a1} = \frac{V_{PF}}{Z_1 + \frac{Z_2 Z_0}{Z_0 + Z_2}}$$



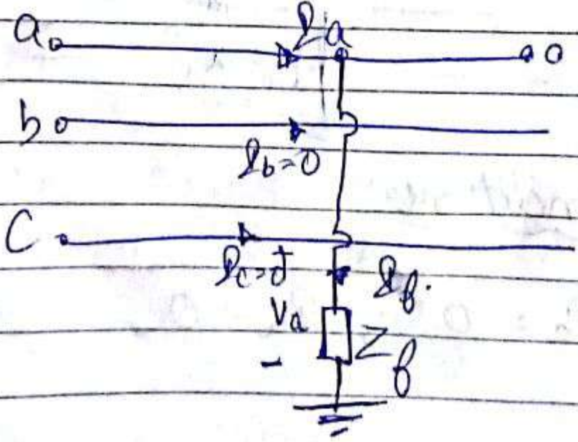
~~Va~~

Power System Fault with fault Impedance:

Single Line to ground fault:-

A single line to ground fault at point F in a power system through a fault impedance Z_f. The fault is on phase a.

$$I_b = 0; I_c = 0; \quad V_a = I_a Z_f.$$

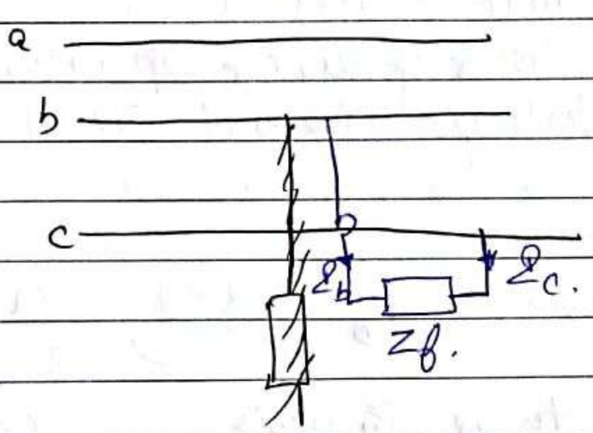


Terminal condition:-

$I_b = 0$; $I_c = 0$; $V_a = Z_f I_a$

[Same derivation as on page 12-14]
Dig all are same
except $E_a = V_{PF}$

Line to Line fault:-



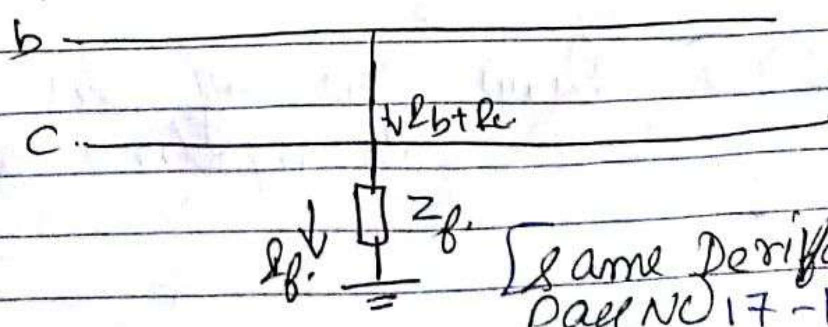
Terminal Conditions:- $I_a = 0$ $I_b = -I_c$.

$V_b - V_c = I_b Z_f \Rightarrow V_c = V_b - I_b Z_f$.

Same derivation as on page [14-16]

Replace E_a by V_{Th}.

Double Line to ground Fault:-



Terminal condition
$I_a = 0$
$V_b = (I_b + I_c) Z_f$
$V_c = (I_b + I_f) Z_f$.

[Same Derivation as page No 17-18]

Problems

① A Salient pole generator without dampers is rated 20MVA, 13.8KV and has a direct axis subtransient reactance of 0.25 per unit. The -ve, zero sequence reactances are 0.35 and 0.10 per unit respectively. The Neutral of the generator is solidly grounded. Determine the subtransient current in the generator and the line to line voltages for subtransient conditions when a single line to ground fault occurs at the generator terminals with generator operating unloaded at rated voltage. Neglect resistance?

Solutions :-

$$\underbrace{S_B = 20\,MVA \qquad V_B = 13.8\,KV}_{\text{This acts as the base also.}} \qquad \begin{aligned} X_d'' &= 0.25 \\ X_2 &= 0.35 \\ X_0 &= 0.10 \end{aligned}$$

To Find :- $I_d'' = ?$

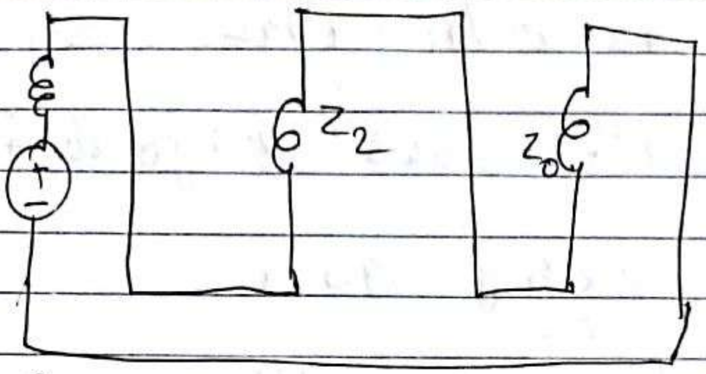
$V_a = ?$ $V_b = ?$ $V_c = ?$

Step1

$$I_b = \text{Base current} = \frac{S_B}{\sqrt{3}V_B} = \frac{20\times10^6}{\sqrt{3}\times13.8\times10^3}$$

$$\boxed{I_B = 836.7(A)}$$

Step2 :- Draw N/w Dig for SLG fault without fault impedance of a generator



$I_{a0} = I_{a1} = I_{a2}$.

Step3:- $I_{a1} = \dfrac{E_a}{Z_1+Z_2+Z_0} = \dfrac{1\angle 0^\circ}{j0.25+j0.35+j0.10}$ $\left\{ \begin{array}{l} \text{Assume} \\ E_a = 1\angle 0^\circ \end{array} \right.$

$= 1.43\angle -90^\circ = \underline{\underline{-j1.43}}$

Step4:-

$I_f = 3I_{a1} = 3 \times 1.43 = 4.29$ pu

$I_f(\text{in A}) = I_f(\text{pu}) \times I_B = 4.29 \times 836.7$

$= \underline{3.5894\,\text{kA}}$

Step5:-

$V_{a1} = E_a - I_{a1}Z_1 = 1.0 - (-j1.43)(j0.25)$

$= \underline{0.643\,\text{pu}}$

$V_{a2} = -I_{a2}Z_2 = -(-j1.43)(j0.35)$

$= \underline{\underline{-0.50\,\text{pu}}}$

$V_{a0} = -I_{a0}Z_0 = -(-j1.43)(j0.1) = -0.143\,\text{pu}$

Step6:-

$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix}.$$

$V_a = V_{a0} + V_{a1} + V_{a2} = 0.643 - 0.50 - 0.143 = 0$

$V_b = V_{a0} + a^2 V_{a1} + a V_{a2}$

$= -0{\cdot}143 + 0{\cdot}643(-0{\cdot}5 - j0{\cdot}866) \mp 0{\cdot}5(-0{\cdot}5 + j0{\cdot}866)$

$= -0{\cdot}215 - j0{\cdot}990$ pu

$V_c = V_{a0} + aV_{a1} + a^2 V_{a2}$

$= -0{\cdot}143 + 0{\cdot}643(-0{\cdot}5 + j0{\cdot}866) - 0{\cdot}5(-0{\cdot}5 - 0{\cdot}866j)$

$= -0{\cdot}215 + j0{\cdot}99$ pu

Step 7:- Line to Line Voltages are:-

$V_{ab} = V_a - V_b = 0{\cdot}215 + j0{\cdot}990$

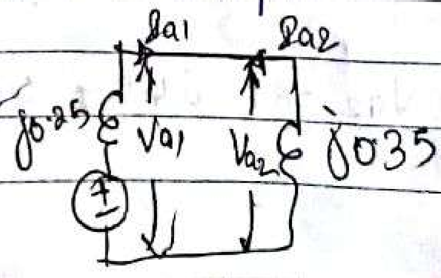
$V_{bc} = V_b - V_c = -j1{\cdot}980$

$V_{ca} = V_c - V_a = -0{\cdot}215 + j0{\cdot}99$

② ~~Step~~ Find the subtransient currents and line to line voltages at the fault under subtransient conditions when a line to line fault between Phase b and c occurs at the terminals of the generator in Problem 1. Assume that the generator is unloaded and operating at rated terminal voltage when the fault occurs.

Same till Step 1. $I_a = 0 \quad I_b = -I_c$

Step 2:-



$I_{a0} = 0 \; ; \; I_{a2} = -I_{a1}$

$V_b = V_c \; ; \; V_{bc} = 0$

$$I_{a1} = \frac{E_a}{Z_1+Z_2} = \frac{1}{j0.25+j0.35} = -j1.667$$

$$\boxed{I_{a2} = -I_1 = j1.667 \quad I_{a0} = 0}$$

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

$$I_a = I_{a0} + I_{a1} + I_{a2} = -j1.667 + j1.667 = 0$$

Step3:-

$$I_b = I_{a0} + a^2 I_{a1} + a I_{a2}$$

$$= -j1.6667(-0.5-j0.866) + j1.667(-0.5+j0.866)$$

$$= -2.886 \text{ pu}$$

$$I_c = I_{a0} + a I_{a1} + a^2 I_{a2} = -a I_{a2} - a^2 I_{a1}$$

$$= -I_b = 2.886 \text{ pu}$$

Step4:-

$I_0 = 0$; $I_b = -2.886 \times 837 = 2416\angle 180^\circ$ A

$I_c = 2.886 \times 837 = 2416\angle 0^\circ$ A.

$I_f = |I_b| = 2416$ A $= 2.416$ kA

~~Step5~~ $I_f = |I_b| = 2.416$ kA.

Step6: $V_{a0} = 0$; $V_{a1} = E_a - I_{a1} Z_1$; $V_{a2} = V_{a1}$

$$V_{a1} = V_{a2} = 1 - (-j1.6667)(j0.25)$$

$$= 0.583 \text{ pu}$$

Step6
$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix}.$$

$V_a = V_{a0} + V_{a1} + V_{a2} = 0·583 + 0·583$
$= 1·166 \angle 0°$ pu.

$V_b = V_{a0} + a^2 V_{a1} + a V_{a2}.$
$= 0·583(-0·5 - j0·866) + 0·58(-0·5 + j0·866)$
$= \underline{-0·583}$ pu

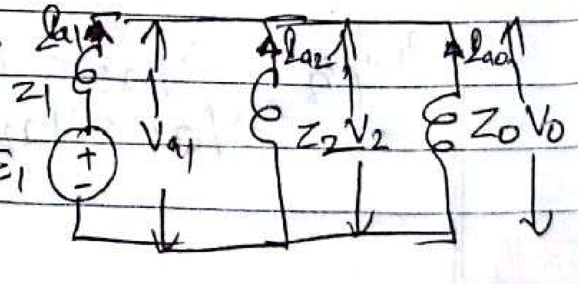
$V_c = V_b = \underline{-0·583}$ pu

Step7:-
$V_{ab} = V_a - V_b = 1·166 + 0·583 = 1·749$
$V_{bc} = V_b - V_c = -0·583 + 0·583 = 0$
$V_{ca} = V_c - V_a = -0·583 - 1·166 = -1·749$

③ Find the subtransient currents and the line to line voltages at the fault under subtransient conditions when a double line to ground fault involving phase b and c occurs at the terminals of the generator shown in Eg1. Assume that the generator is unloaded and operating at rated voltage when the fault occurs. Neglect resistance.

Till Step1 is same as problem1

Step2:- 'LLG fault:



$I_{a1} = -(I_{a2}+I_{a0})$

$V_{a0} = V_{a1} = V_{a2}$; $V_b = V_c = 0$.

Step 3:

$$I_{a1} = \frac{E_a}{Z_1+\frac{Z_2 Z_0}{Z_2+Z_0}} = \frac{1}{j0.25+\frac{(j0.35)\times j0.10}{j0.35+j0.10}}$$

$= -j3.05$ pu

$V_{a1} = V_{a0} = V_{a2} = E_1 - I_{a1} Z_1$

$= 1 - (-j3.05)(j0.25)$

$= 1 - 0.763 = 0.237$ pu.

$$I_{a2} = \frac{-V_{a2}}{Z_2} = \frac{-0.237}{j0.35} = j0.68 \text{ pu.}$$

$$I_{a0} = \frac{-V_{a0}}{Z_0} = \frac{-0.237}{j0.10} = j2.37 \text{ pu.}$$

Step 4:-

$I_a = I_{a0} + I_{a1} + I_{a2} = \cancel{0.237}$

$= j2.37 - j3.05 + j0.68 = 0$.

$I_b = I_{a0} + a^2 I_{a1} + a I_{a2}$

$= j2.37 - j3.05(-0.5 - j0.866) + (j0.68)(-0.5 + j0.866)$

$= -3.230 + j3.555$

$I_c = I_{a0} + a I_{a1} + a^2 I_{a2} = j2.37 + (-0.5 + j0.866)(-j3.05)$

$+ (-0.5 - j0.866)(j0.68)$

$= \cancel{3.231}\ 3.23 + j3.555$

Step5:-

$I_f = I_b + I_c = -3.230 + j3.555 + 3.230$
$+ 3.555j = j7.11$ pu

Step6:- $V_a = V_{a1} + V_{a2} + V_{a0} = 3V_{a1}$
$= 3 \times 0.237$
$= 0.711$ pu

$V_b = V_c = 0$
$V_{ab} = V_a - V_b = 0.711$ pu.
$V_{bc} = 0$
$V_{ca} = V_c - V_a = -0.711$ pu.

Step7:-

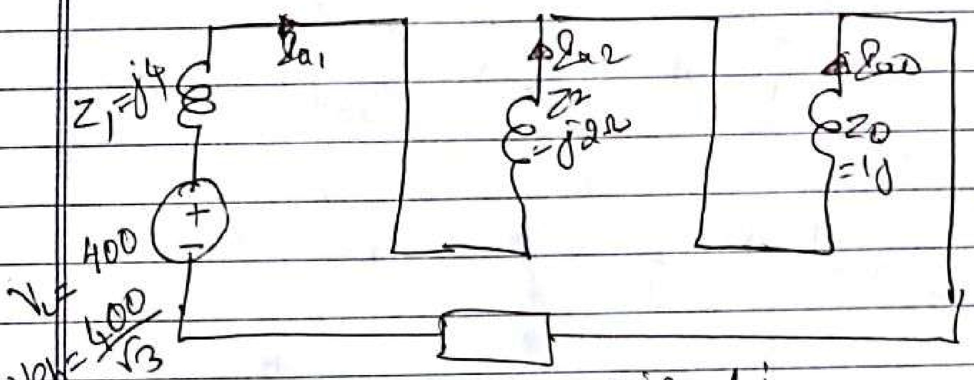
$I_a = 0$.
$I_b = 837 \times 4.8 \angle 132.3 = 4017 \angle 132.3$
$I_c = 837 \times 4.8 \angle 47.7 = 4017 \angle 47.7$

$I_f = 837 \times 7.11 \angle 90^\circ = 5951 \angle 90^\circ$ A.

Step8:- $V_{ab} = 0.711 \times 7.97 = 5.66 \angle 0^\circ$ KV
$V_{bc} = 0$
$V_{ca} = -0.711 \times 7.97 = 5.66 \angle 180^\circ$ KV

④ A 3ϕ phase generator with an open circuit Voltage of 400V is subjected to an LG fault through a fault impedance of $j2\Omega$. Determine the fault current if $Z_1 = j4\Omega$; $Z_2 = j2\Omega$ and $Z_0 = 1j\,\Omega$. Repeat the problem for LL & LLG fault.

i) LG fault :-



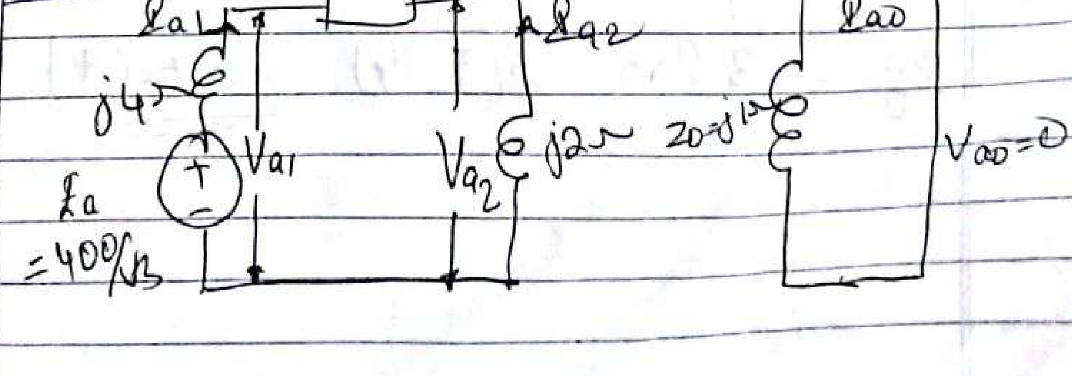
$3Z_f = 3j2 = \underline{6j}$

$$I_{a1} = I_{a2} = I_{a0} = \frac{E_0}{Z_\phi + Z_2 + Z_0 + 3Z_f}$$

$$= \frac{400/\sqrt{3}}{j4 + j2 + j1 + 6j} = -j\,17.765$$

$$I_f = 3\,I_{a0} = 3(17.765) = 53.295\,(A)$$

(ii) LL Fault :- $Z_f = j2\Omega$

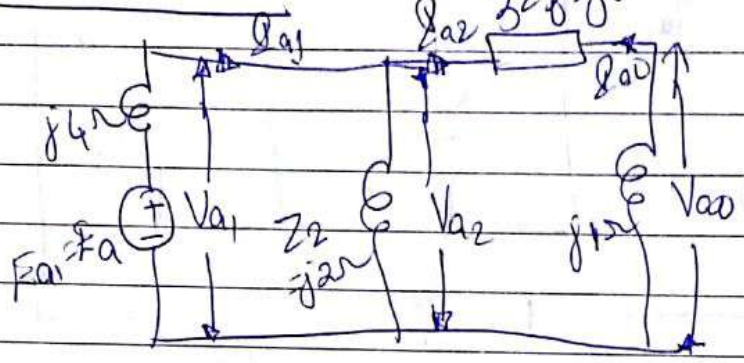


$$I_{a1} = \frac{E_a}{Z_1+Z_2+Z_f} = \frac{400/\sqrt{3}}{j4+j2+j2}$$

$$= -j28.87\,(A)$$

$$I_f = \sqrt{3}\,I_{a1} = \sqrt{3}*28.87 = \underline{\underline{50A}}$$

(iii) **LLG Fault:-**



$$I_{a1} = \frac{E_a}{Z_1 + \frac{Z_2(Z_0+3Z_f)}{Z_2+Z_0+3Z_f}} = \frac{400/\sqrt{3}}{j\left[4 + \frac{2(1+6)}{2+1+6}\right]}$$

$$= \underline{\underline{-j41.57\,(A)}}$$

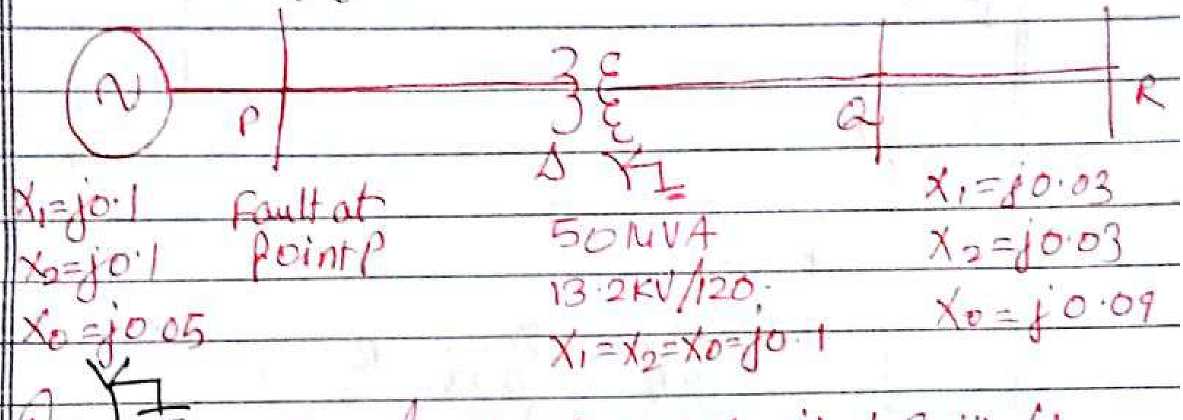
$$I_{a0} = -I_{a1}\left[\frac{Z_2}{Z_2+Z_0+3Z_f}\right]$$

$$= +j41.57\left[\frac{2}{2+1+6}\right]$$

$$= j9.24\,(A)$$

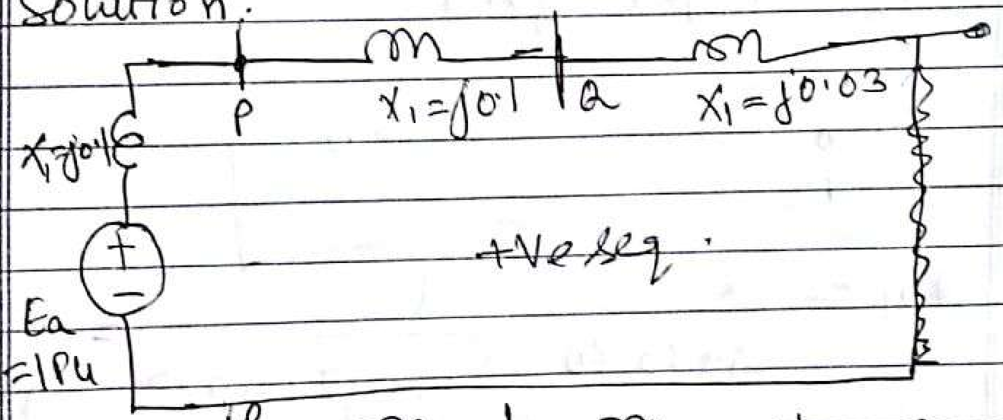
$$I_f = 3\,I_{a0} = 3(9.24) = \underline{\underline{27.72\,(A)}}$$

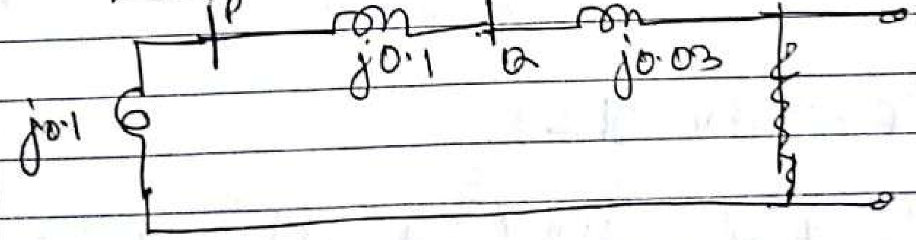
⑤ A 50HZ, 50MVA, 13.2KV Y grounded is connected to a line through a Δ-Y T/F as shown in figure.

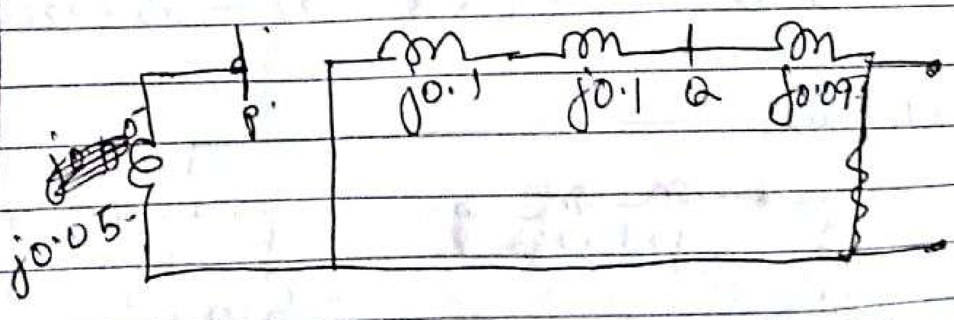


Determine the fault current i) LG (ii) LL (iii) LLG.

Solution.

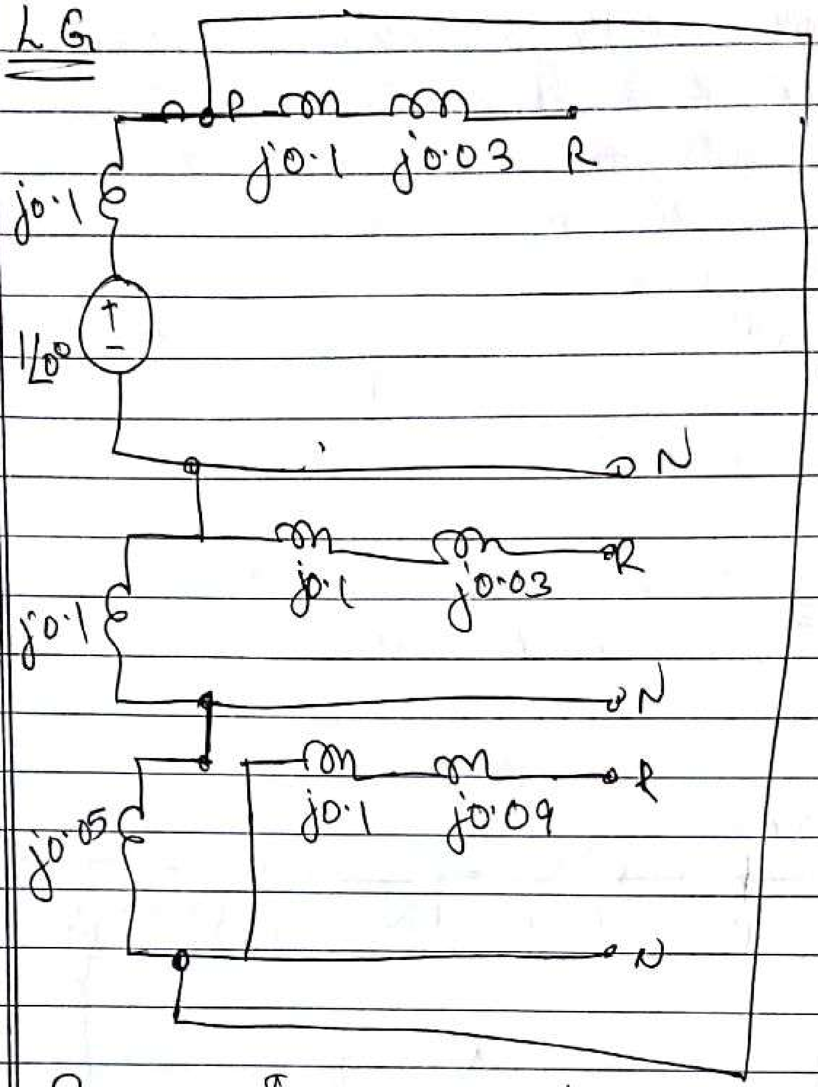






$Z_1 = j0.1$; $Z_2 = j0.1$; $Z_0 = j0.05$

(i) **LG**



$I_{base} = \frac{50\times10^6}{\sqrt{3}\,132\times10^3}$

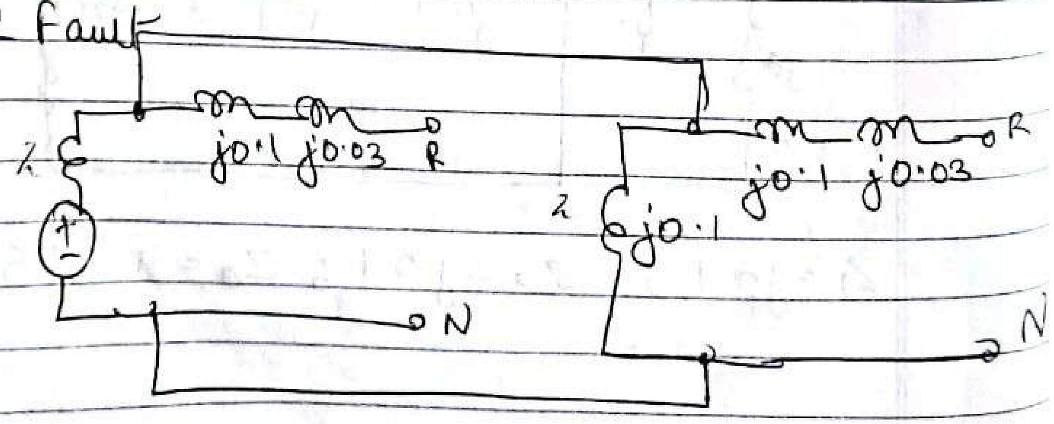
$= 2186.93 (A)$

$I_{a1} = \frac{E}{Z_1+Z_2+Z_0} = \frac{1}{j0.1+j0.1+j0.05} = \frac{1}{j0.96} = -j4$

$I_f = 3 I_{a1} = -j12$

$I_{f\,actual} = -j12 (2186.93) = 26235.6 (A)$

(ii) LL Fault



$Z_1 = j0.1$; $Z_2 = j0.1$

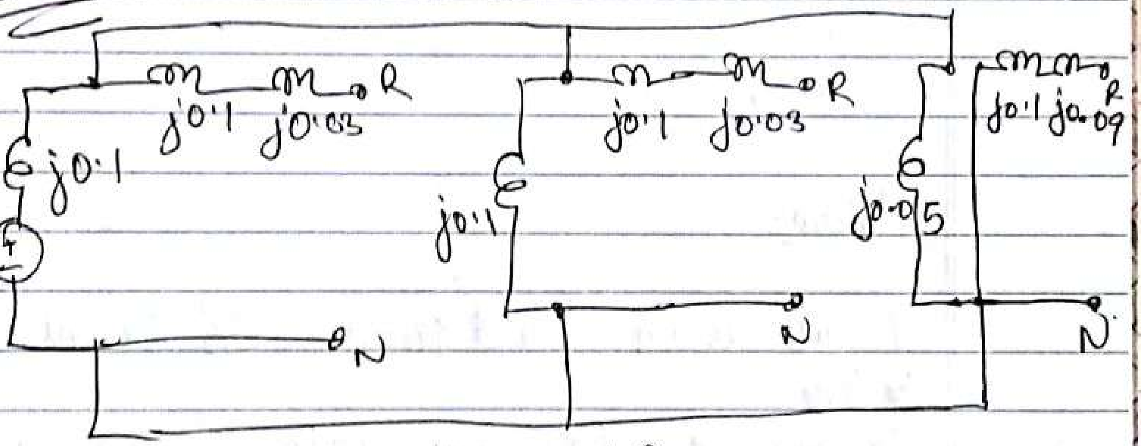
$I_{a1} = \dfrac{Ea}{Z_1 + Z_2} = \dfrac{1}{j0.2} = -j5$

$I_f = \sqrt{3}\, I_{a1} = \sqrt{3}\,(-j5) = -j8.6002$

$I_{f(A)} = I_{f(pu)} \times I_b = (-j\,8.6002)(2186.93)$

= j1[illegible]939.36

(ii) DLG



$I_{a1} = \dfrac{E_1}{Z_1 + \dfrac{Z_2 Z_0}{Z_0 + Z_2}} = \dfrac{1\angle 0}{j0.1 + \dfrac{j0.1 \times j0.05}{j0.15}} = -j7.5.$

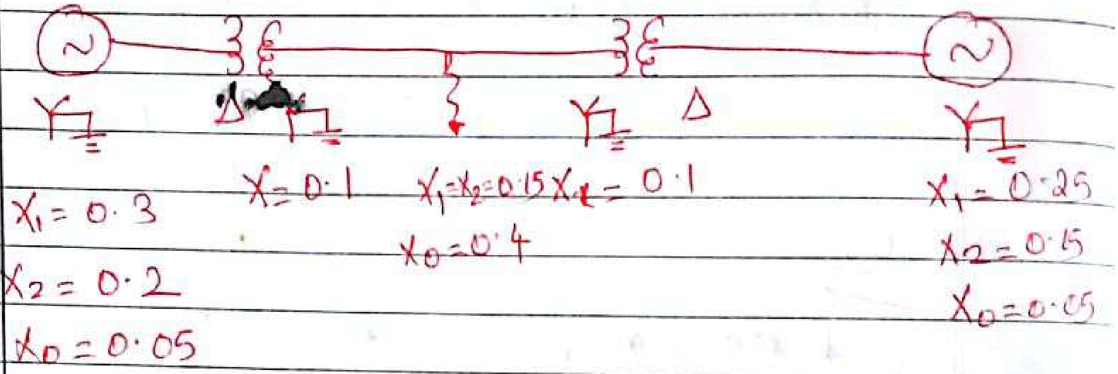
$I_{a0} = -I_{a1} \times \dfrac{Z_2}{Z_2 + Z_0} = (-j7.5) \times \dfrac{j0.1}{j0.1 + j0.05}$

$I_{a0} = -5$

$I_f = 3\, I_{a0} = -15.$

$I_{f(A)} = -15 \times 2186.93 = 32803.95\,(A)$

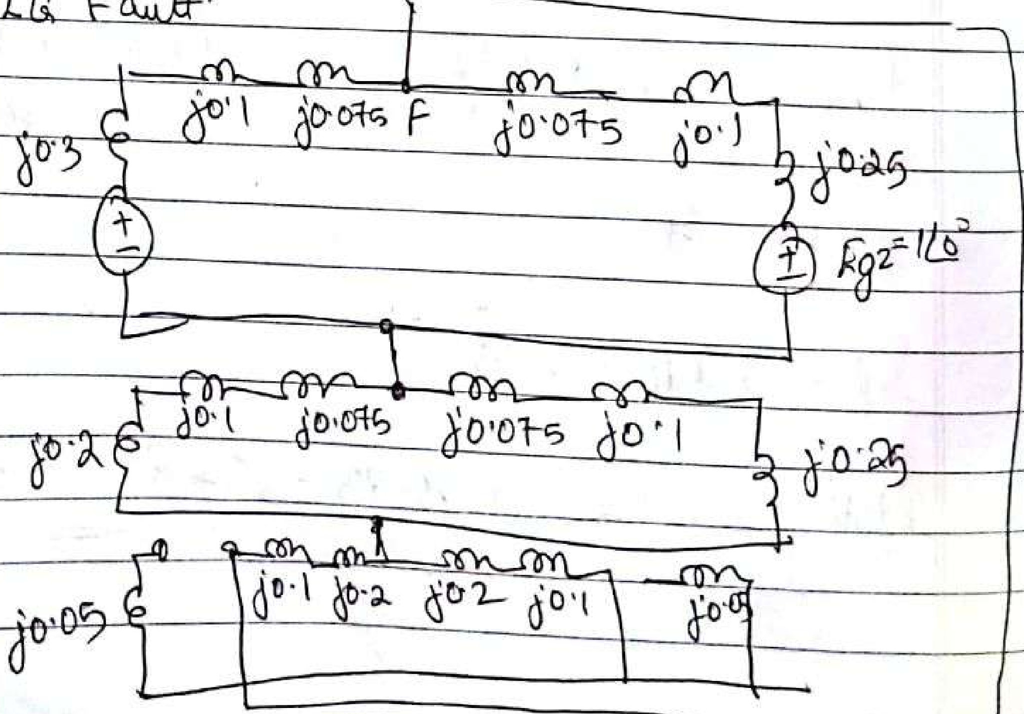
⑥ A Power System Shown in figure has a dead SC at the midpoint of the Tr. line. Find the Short circuit current for
(i) LG Fault (ii) LL fault (iii) LLG fault. Assume that the motor is operating at its rating Voltage. Neglect Prefault current. The reactances in pu are on the Same base



Solution:-

Fault is in Mid point of Transmission line.
So Divide Tr. line into 2 halves & draw +ve -ve & zero seq.

(i) LG Fault.



$Z_1 = (j0.3 + j0.1 + j0.075) \parallel (j0.075 + j0.1 + j0.25)$

$= j0.2243$

$Z_2 = (j0.2 + j0.1 + j0.075) \parallel (j0.25 + j0.075 + j0.1)$

$= j0.1741$

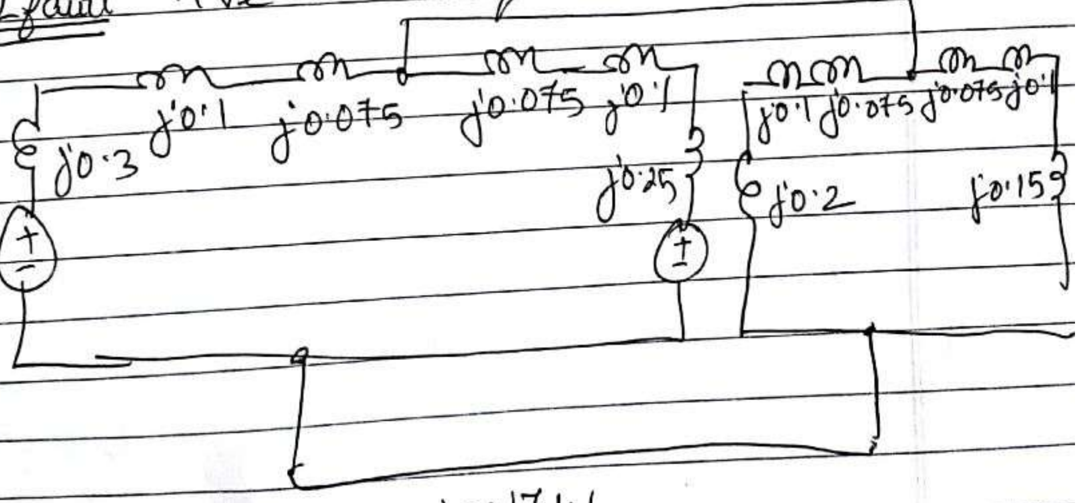
$Z_0 = j0.3 \parallel j0.3 = j0.15$

$$I_{a1} = \frac{E_a}{Z_1 + Z_2 + Z_0} = \frac{1\angle 0^\circ}{j0.2243 + j0.1741 + j0.15}$$

$= 1.8234\angle -90^\circ = -j1.8234$

$I_f = 3 I_{a1} = -j5.4702$

<u>LL fault</u> +Ve & -Ve seq connected in parallel



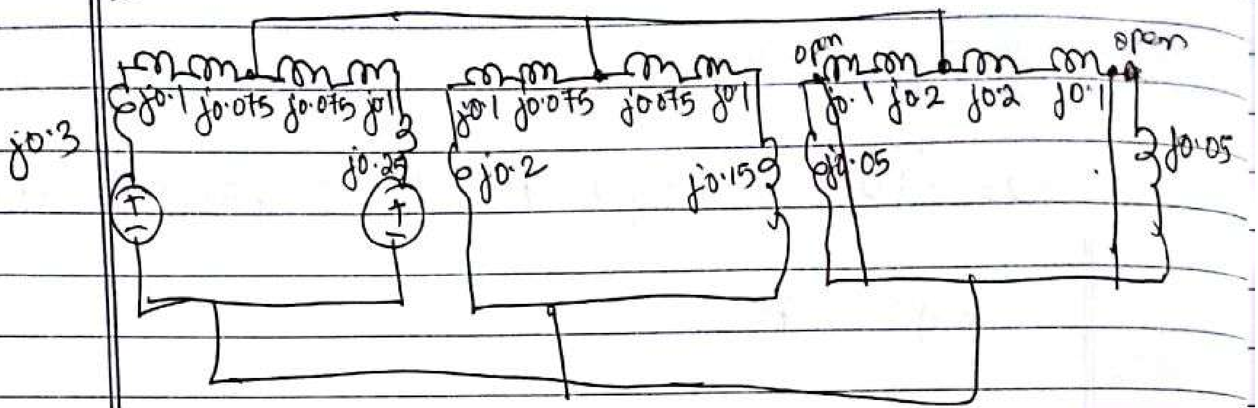
$Z_1 = j0.2243 \quad Z_2 = j0.1741$

$$I_{a1} = \frac{E}{Z_1 + Z_2} = \frac{1}{j0.2243 + j0.1741} = -j2.5$$

$I_b = I_{a0} + a^2 I_{a1} + a I_{a2} = 0 + 1\angle 240^\circ \times (-j2.5) + 1\angle 120^\circ \times (j2$

$= -j4.3475$

LLG $Z_1 = j0.2243$ $Z_2 = j0.1741$ $Z_0 = j0.15$



$$I_{a1} = \frac{E_a}{Z_1 + \frac{Z_0 Z_2}{Z_0 + Z_2}} = -j3.28$$

$$I_{a0} = -I_{a1}\frac{Z_2}{Z_0 + Z_2} = -1.7619.$$

$$I_f = 3 I_{a0} = -j5.285 //$$

Dynamics of a Synchronous Machine
Constants M and H of Rotating Machines-

~~Kin~~ Kinetic Energy of a rotor can be written as

$$K.E = \frac{1}{2} I \omega^2$$

where, I = Moment of Inertia in kgm^2
ω = Angular Speed in rad/sec.

The Angular momentum (or) Inertia Constant is defined as

$$M = I \omega$$

Therefore, $K.E = \frac{1}{2} M\omega$ (Joules)

Another Inertia constant (H)

$$H = \frac{\text{Stored Energy (in MJ)}}{\text{Machine rating (in MVA)}}$$

where G = Rating of M/c in MVA.

GH = Stored energy in (MJ)

$$GH = \frac{1}{\cancel{2}} M(\cancel{3} \cancel{2}\pi f).$$

$$GH = \cancel{18} M \pi f$$

$$M = \frac{GH}{\pi f} = \frac{GH}{180f} \quad \text{MJ sec/elec deg.}$$

For Many Interconnecting M/c:-

$$M_{eq} = M_1 + M_2 + \cdots + M_n.$$

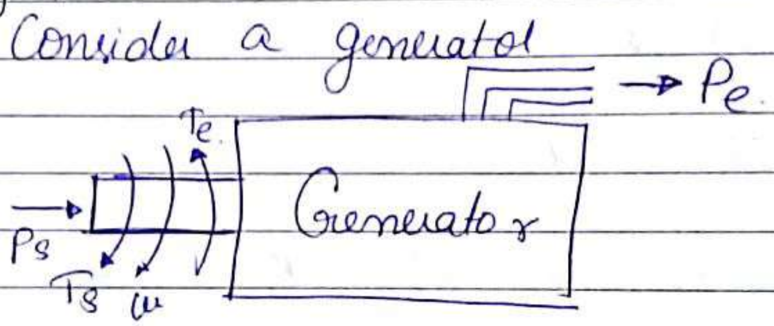
(or) $$H_{eq}\,G_{Base} = H_1 G_1 + H_2 G_2 + \cdots + H_n G_n$$

$$H_{eq} = \frac{H_1 G_1}{G_{Base}} + \frac{H_2 G_2}{G_{Base}} + \cdots + \frac{H_n G_n}{G_{Base}}$$

Rotor Dynamics & Swing Equation:-

~~Dyami~~

Consider a generatol



* It receives Mechanical power P_s at Torque T_s and rotor speed ω via Shaft from the prime mover.

* It delivers electrical Power T_e to the Power System Network via the bus bars

* The generator develops electromechanical Torque T_e in opposition to T_s.

* When both the torques are equal the rotor would be in a Stable running position at Synchronous speed.

* When there is a Torque difference, the resultant torque will accelerate the

Rotor of the generator.

* Assuming that winding and friction losses to be negligible, the accelerating torque on the rotor is given by

$T_a = T_s - T_e$

$\omega T_a = \omega T_s - \omega T_e$

$P_a = \omega T_a$ = Accelerating power
$P_s = \omega T_s$ = Mechanical power Input
$P_e = \omega T_e$ = Electrical power output

$\therefore P_a = P_s - P_e$.

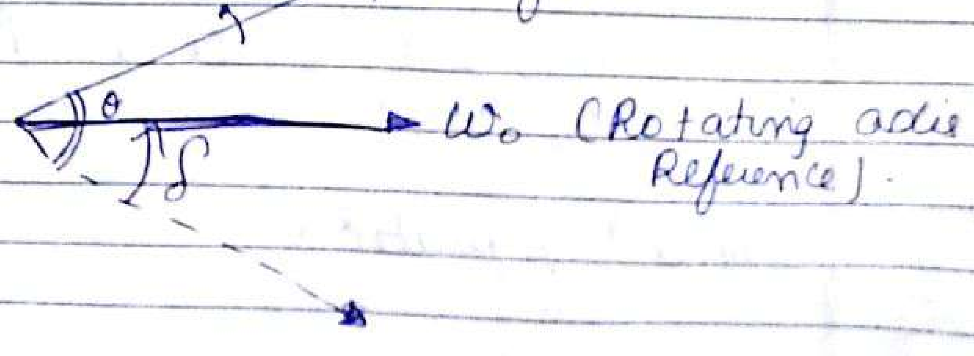
Under Steady State Conditions $P_s = P_e$.

So $P_a = 0$.

When the balance b/w P_s and T_e is disturbed the Machine dynamics is governed by

$$P_a = T_a \omega = I \alpha \omega = M \frac{d^2\theta}{dt^2}$$

$\alpha = \frac{d^2\theta}{dt^2}$ = Angular acceleration of the rotor.



Since the Angular Position of the rotor is continually varying with time, it is more convenient to measure the angular position and Velocity with respect to a synchronously rotating axis.

$$\delta = \theta - \omega_0 t$$

where,

ω_0 = Angular Velocity of the reference rotating axis

= rotor Angular displacement w.r.t the stator field

$$\frac{d\delta}{dt} = \frac{d\theta}{dt} - \omega_0$$

$$\frac{d^2\delta}{dt^2} = \frac{d^2\theta}{dt^2}$$

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

$$\frac{GH}{180f}\frac{d^2\delta}{dt^2} = P_a = P_s - P_e.$$

÷ by G (for ~~base~~ Pu Value Convertion)

$$\boxed{\frac{H}{180f}\frac{d^2\delta}{dt^2} = P_{a(pu)} = (P_s - P_e)_{pu}}$$

Swing Equation.

Swing Equation:-

It describes the relative motion of the rotor (Load angle (or) Torque angle (or) power angle δ) with respect to the Stator field as a function of time.

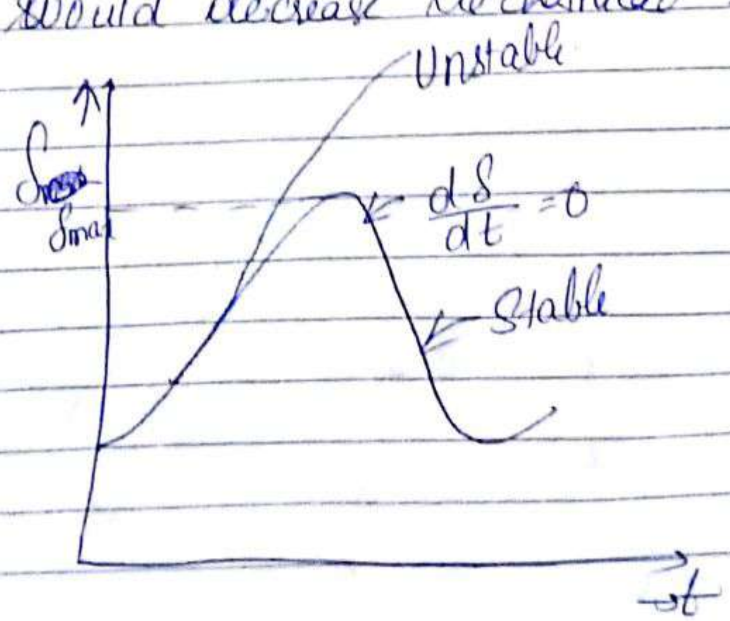
It is also the fundamental equation governing the rotor dynamics of the synchronous Machine.

Note :-

i) When Ps = Pe, No accelerating (or) decelerating Power. M/c would run as Syn Speed

ii) When Pe ↑es, Rotor Slows down, this Should be sensed by Speed governor & it would increase Mechanical I/p Power Ps to bring Rotor back to Syn. Speed

iii) When Pe ↓es, Rotor accelerates, this Should be sensed by speed governor & it would decrease Mechanical I/p power.

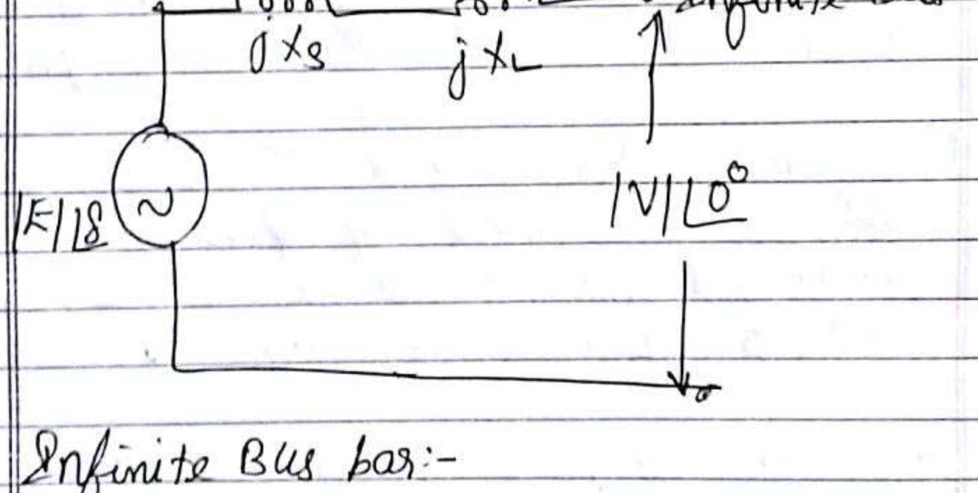


Swing curve:-

The plot between rotor angle δ as a function of time 't'.

Swing Curve is solved by Euler's method, Runge kutta method etc.

Power Angle equation of Non Salient pole Synchronous M/c



Infinite Bus bar:-

Let

$E\angle\delta$ = Generated Voltage in the M/C.

δ = Load angle (or) Torque angle (or) power angle

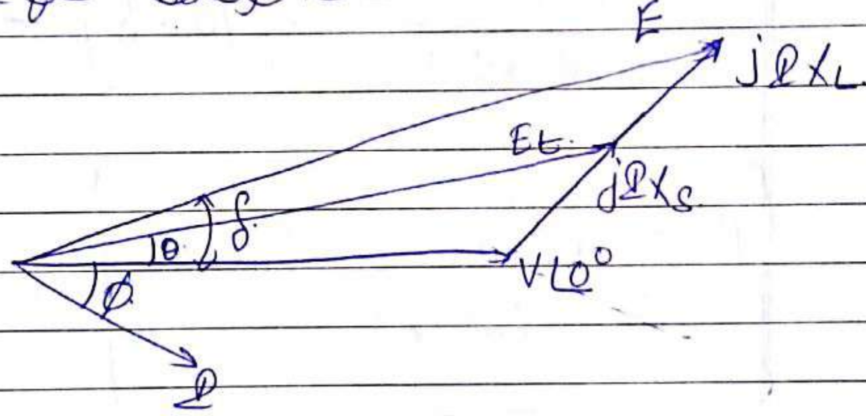
X_s = Synchronous reactance of the M/C.

X_L = Reactance of the Transmission line

$|V|\angle 0^\circ$ = Voltage at Infinite bus (taken as Ref).

I = Load current.

Phasor for lagging load:-



$|Et|\angle\theta$ = Terminal Voltage of the M/C.

$$\therefore E = V + jI(X_s + X_L).$$

$$\boxed{I = \frac{E-V}{j(X_s+X_L)}}$$

The net Power delivered by the M/c is given as

$$P = \text{Real}\left[V\, I^{*}\right].$$

$$= \text{Real}\left[V \left(\frac{E-V}{j(X_s+X_e)}\right)^{*}\right]$$

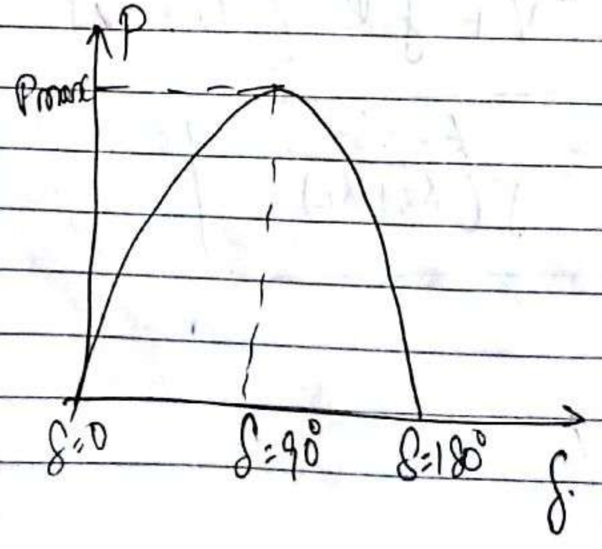
$$= \text{Real}\left[|V|\angle 0^\circ \left(\frac{|E|\angle\delta - |V|\angle 0^\circ}{(X_s+X_e)\angle 90^\circ}\right)^{*}\right]$$

$*$ → angles should be taken (−ve)

$$= \frac{|V||E|}{|X_s+X_e|}\cos\left[90^\circ-\delta\right] - \frac{|V|^2}{|X_s+X_e|}\cos 90^\circ$$

$$\boxed{P = \frac{|V||E|}{(X_s+X_e)}\sin\delta.} \Rightarrow \text{Power Angle Equation}$$

Power transfered depends upon the generated Voltage (E) and bus Voltage |V|, System reactance & torque angle δ.



At $\delta = 90^\circ$; $P_{Max} = \frac{|V|\,|E|}{(X_s+X_e)}$.

$\delta > 90^\circ \Rightarrow$ Power O/p of the M/c reduces successively & Finally M/c may Stall

Hence P_m at which maximum power transfer occurs is called as the Steady State Stability Limit (SSSL) of the M/c.

M/c operation is Stable in the region

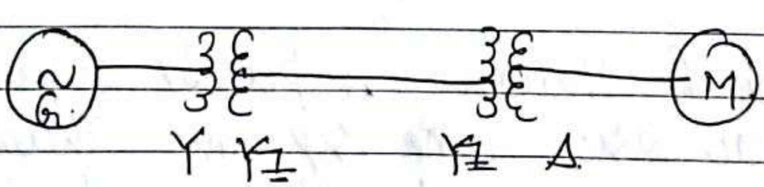
$$0^\circ < \delta \le 90^\circ$$

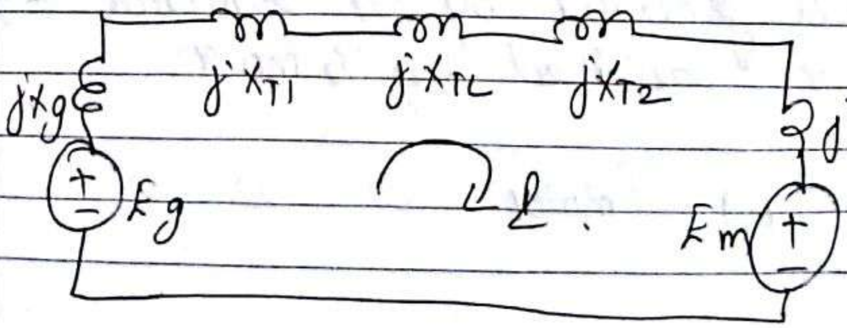
The slope of the curve $\frac{dP}{d\delta} > 0 \rightarrow$ Stability Criterion.

$\frac{dP}{d\delta}$ = Synchronizing Power Co-efficient (or) M/c Stiffness.

When $\frac{dP}{d\delta} = 0$ (or) $\frac{dP}{d\delta} < 0$ System is unstable.

Steady State Stability of a Two Machine System:-





Let $E_g \angle \delta^\circ$ = Internal emf of the generator.

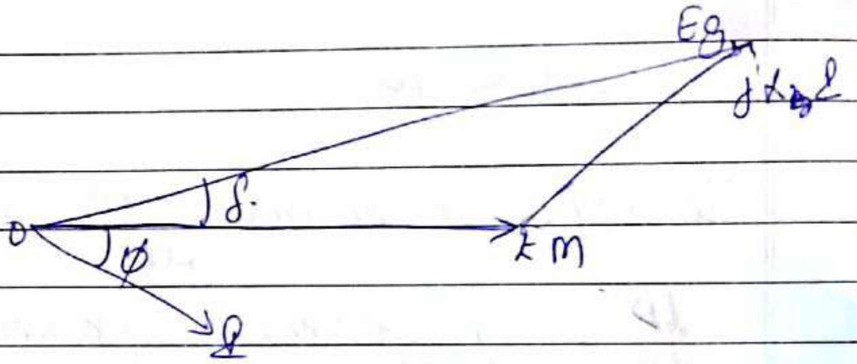
$E_m \angle 0^\circ$ = Back emf of the motor.

X_g = Reactance of Generator

X_{T_1}, X_{T_2} = Reactance of T/F 1 & 2

X_{TL} = Reactance of Tr. line

X_m = Reactance of Motor.



$$X = X_g + X_{T_1} + X_{TL} + X_{T_2} + X_m$$

$$E_g = E_m + jIX$$

$$\boxed{I = \frac{E_g - E_m}{jX}}$$

Since the Network is purely resistive, there are no losses in the system. Therefore the power generated by the generator equals the power received by the motor.

$$P_g = P_{motor}$$

Now, $P_g = Re[E_g I^*]$.

$$= Re\left[|E_g|\angle\delta * \left(\frac{|E_g|\angle\delta - |E_m|\angle 0^\circ}{|X|\angle 90^\circ}\right)^*\right]$$

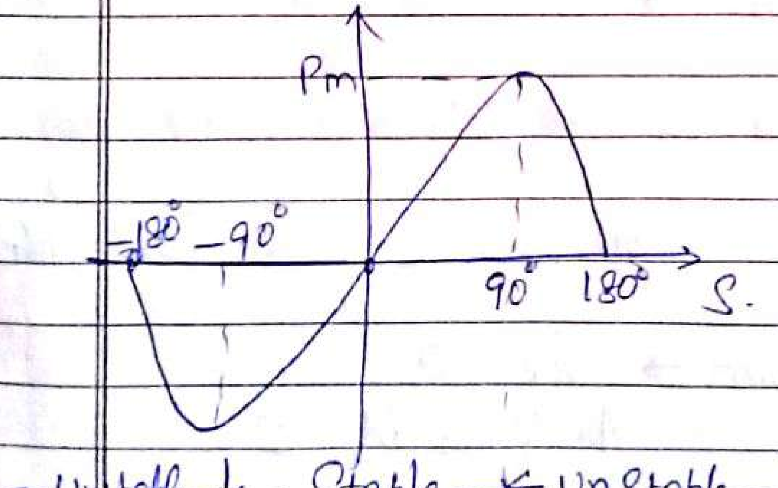
$$= Re\left[|E_g|\angle\delta * \left(\frac{|E_g|\angle -\delta - E_m\angle 0^\circ}{|X|\angle -90^\circ}\right)\right]$$

$$= \frac{|E_g|^2}{|X|}\cos 90^\circ - \frac{|E_g||E_m|}{|X|}\cos(90^\circ+\delta)$$

$$= -\frac{|E_g||E_m|}{|X|}(-\sin\delta)$$

$$\boxed{P_g = \frac{|E_g||E_m|}{|X|}\sin\delta -}$$

Power transfered depends upon the system Voltages, system reactance and angle between the rotor of two M/c.



$\delta = 90^\circ$

$P_m = \frac{|E_g||E_m|}{|X|}$

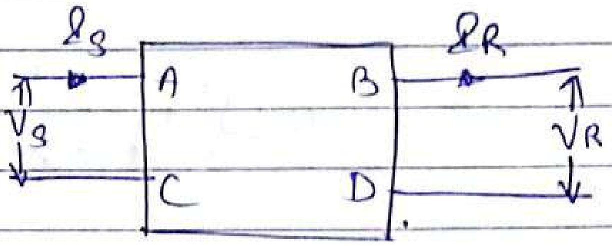
Stable Region

$-90^\circ < \delta < 90^\circ$

$\frac{dP}{d\delta}$ is +ve.

Note:-

SSSL of a two terminal Pair Network represented by ABCD Constants:



A Linear and bilateral two port N/W.
The input voltage per phase and input current of a Tr. line can be represented as.

$$V_S = AV_R + BI_R$$

$$I_S = CV_R + DI_R.$$

Where,

V_S = Sending end Voltage/phase = $|V_S| \angle \delta$.

I_S = Sending end current per Phase.

V_R = Receiving end Voltage per phase = $|V_R| \angle 0$

I_R = Receiving end current per Phase.

A, B, C, D – Generalised circuit Constants

On open circuit → $I_R = 0$

$$\therefore A = \frac{V_S}{V_R} = |A| \angle \alpha$$

$$C = \frac{I_S}{V_R} = |C| \angle \gamma$$

on Short circuit :-> $V_R = 0$

$$\rightarrow B = \frac{V_s}{I_R} = |B| \angle \beta$$

$$\rightarrow D = \frac{I_s}{I_R} = |D| \angle \Delta$$

The Power delivered by the System is

$$P = \text{Real}\left[V_R \, I_R^{*} \right]$$

$$= \text{Real}\left[V_R \left(\frac{V_s - A V_R}{B} \right)^{*} \right]$$

$$= \text{Real}\left[V_R \angle 0^\circ \left(\frac{|V_s| \angle \delta - |A| \angle \alpha \, |V_R| \angle 0^\circ}{|B| \angle \beta} \right) \right]$$

$$= \text{Real}\left[\frac{|V_R| \, |V_s|}{|B|} \angle 0^\circ - \delta + \beta - \frac{|V_R|^2 |A|}{|B|} \angle 0^\circ - \alpha + \beta \right]$$

$$\boxed{P = \frac{|V_R| \, |V_s|}{|B|} \cos(\beta - \delta) - \frac{|A| \, |V_R|^2}{|B|} \cos(\beta - \alpha)}$$

Maximum power :- $\delta = \beta$.

$$SSSL = \frac{|V_s| \, |V_R|}{|B|} - \frac{|A| \, |V_R|^2}{|B|} \cos(\beta - \alpha).$$

Methods of Improving Steady State Stability

For a Two M/c System, $SSSL = \frac{|E_g||E_m|}{|X|}$.

i) Increasing either of the Voltages $|E_g|$ or $|E$

- Can be done by Increasing the excitation ~~of~~ to the generator (or motor (or both.

ii) Reducing the reactance between the transmission and receiving points. This is more economical and viable

- Can be done using duplicate lines
  This is known as double circuit, the reactance is automatically reduced. In addition, the duplicate circuit also improve the reliability and flexibility of the System

- Can be done using Series Capacitors

  They are sometimes employed in lines. Automatically the line reactance is reduced. Moreover, the other advantage of using Series Capacitor is that voltage Regulation and powerfactor of the System is improved.

- Can be done using Bundled Conductors.
  This reduces the line reactance & hence improve the SSSL.

Problems:-

1) A 50HZ, four pole turbo generator rated 100MVA, 11KV has an Ineitia constant of 8.0 MJ/MVA ⓐ find the stored energy in the rotor at synchronous speed ⓑ If the Mechanical input is suddenly raised to 80MW for an electrical load of 50MW, find roto acceleration neglecting Mechanical and Electrical losses. ⓒ If the acceleration calculated in Part ⓑ is maintained for 10 cycles, find the Change in torque angle and rotor speed in revolutions per minute at the end of this period.

Solution:-

ⓐ $GH = 100 \times 8 = 800MJ$.

ⓑ $Pa = 80 - 50 = 30MW = M\frac{d^2\delta}{dt^2}$.

$M = \frac{GH}{180f} = \frac{800}{180 \times 50} = \frac{4}{45}$ MJ-s/elect deg.

$\frac{4}{45}\frac{d^2\delta}{dt^2} = 30$.

$\alpha = \frac{d^2\delta}{dt^2} = 337.5$ elec deg/s².

ⓒ 10 cycles = 0.2s.

change in $\delta = \frac{1}{2}(337.5) \times (0.2)^2 = 6.75$ elec deg.

$= 60 \times \frac{337.5}{2 \times 360^\circ} = 28.125$ rpm/sec

∴ Roto speed at the end of 10 cycles

$$= \frac{120 \times 50}{4} + 28.125 \times 0.2$$

$$= 1505.625 \text{ rpm}$$

② Two Power stations A and B are located close together. Station A has four identical generators each rated 100 MVA 9 MJ/MVA whereas Station B has three sets each rated 200 MVA, 4 MJ/MVA. Calculate the inertia constant of the equivalent machines of both stations on 150 MVA base.

$$H_{eq} = 4\left(\frac{H_1 G_1}{G_{Base}}\right) + 3\left(\frac{H_2 G_2}{G_{Base}}\right).$$

$G_1 = 100 \text{ MVA}$, $H_1 = 9 \text{ MJ/MVA}$.

$G_2 = 200 \text{ MVA}$, $H_2 = 4 \text{ MJ/MVA}$.

$G_{Base} = 150 \text{ MVA}$.

$$H_{eq} = 4\left(\frac{9 \times 100}{150}\right) + 3\left(\frac{4 \times 200}{150}\right).$$

$$= 40 \text{ MJ/MVA}$$

③ A turbo generator, 6 pole, 50 Hz of Capacity 80 MW working at 0·8 pf has an inertia of 10 MJ/MVA ⓐ Calculate the energy stored in the rotor at synchronous speed. ⓑ Find rotor acceleration if the mechanical input is suddenly raised to 75 MW for an electrical load of 60 MW. ⓒ Supposing the above acceleration is maintained for a duration of 6 cycles, calculate the change in torque angle and the rotor speed at the end of 6 cycles.

ⓐ Energy stored in rotor = GH

$$= \frac{80}{0.8} \times 10 = 1000 \text{ MJ}.$$

ⓑ Accelerating power, $P_a = (75-60) = 15$ MW

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

$$M = \frac{GH}{180f} = \frac{1000}{180 \times 50} = 0.111 \text{ MJ sec/Elec deg}$$

$$0.111 \frac{d^2\delta}{dt^2} = 15. \quad \text{(or)} \quad \alpha = \frac{d^2\delta}{dt^2} = \frac{15}{0.111} = 135 \text{ elec deg/sec}$$

ⓒ $\frac{d^2\delta}{dt^2} = \alpha$

$\int$ing twice we get $\delta = \frac{1}{2}\alpha t^2$.

6 cycles correspond to ⇒

50 cycles = 1 sec.

$$6 \text{ cycles} = \frac{6}{50} \text{ sec}$$

$$= 0.12 \text{ sec}.$$

Changing δ at end of 6 cycles = $\frac{1}{2} \times 135 \times (0.12)^2$

$\delta = \frac{1}{2}\alpha t^2$ = 0.972 elect deg

δ is converted to units of rpm/sec as follows

$$\delta = \frac{60 \times 135}{2 \times 360^\circ} = 11.25 \text{ rpm/sec}$$

Rotor speed at end of 6 cycles (0.12 sec)

$$= \frac{120 \times 50}{6} + 11.25 \times 0.12$$

$$= 1000 + 1.35$$

$$= 1001.35 \text{ rpm}$$

④ A 60Hz, 4 Pole turbogenerator rated 500MVA 22KV has an inertia constant of H = 7.5MJ/MVA. Find ⓐ K.E stored in the rotor at synchronous speed ⓑ The Angular acceleration if the electrical power developed is 400MW when the input minus rotational losses is 740 KHP.

ⓐ $KE = GH = 500 \times 7.5 = 3750$ MJ

ⓑ $\frac{GH}{180f} \frac{d^2\delta}{dt^2} = P_m - P_e$

$P_e = 400$ MW $\quad P_m = 740 \times 10^3$ HP $= 740 \times 10^3 \times 746$

$= 552.04 \times 10^6$ W

$= 552.04$ MW

$$\frac{d^2\delta}{dt^2} = \frac{(552.04 - 400) \times 180 \times 60}{500 \times 7.5}$$

$= 437.8$ Elect deg/sec²

⑤ A 50Hz, 4pole turbo alternator, rated 20MVA 11KV has an inertia Constant of H = 9KW/KVA Find the acceleration of the input less the rotational losses is 26,800 HP and the electrical power developed amount to 16 MW minus the losses.

K.E Stored in the rotor = GH = 20×9 = 180MJ.

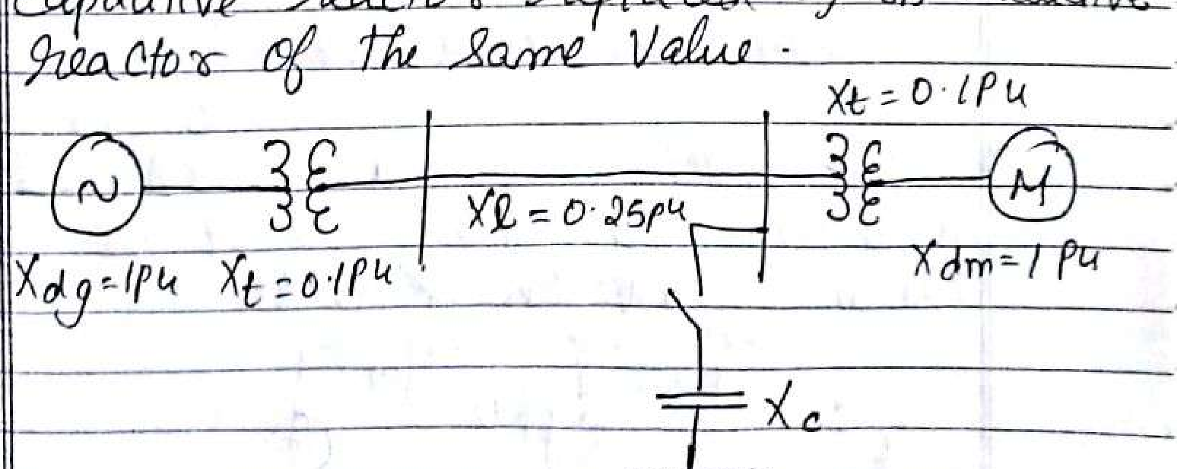
$$\frac{GH}{180f}\frac{d^2\delta}{dt^2} = P_m - P_a.$$

$P_m = 26800 = 26800 \times 746 = 19.99Mw$

$P_e = 16\,MW$.

$$\frac{180}{180\times50}\frac{d^2\delta}{dt^2} = 19.99 - 16 = 199.5$$ Elec deg/sec²

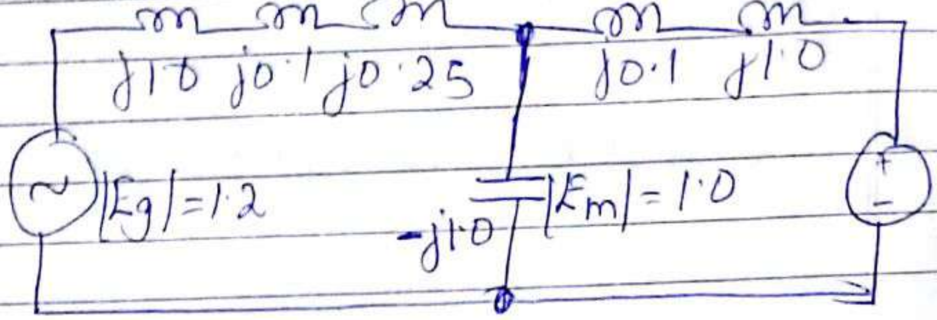
⑥ In the system shown in figure, a 3φ static capacitive reactor of reactance 1 Pu per phase is connected through a switch at motor bus bar. Calculate the limit of steady state power with and without reactor switch closed. Recalculate the power limit with capacitive reactor replaced by an inductive reactor of the same value.

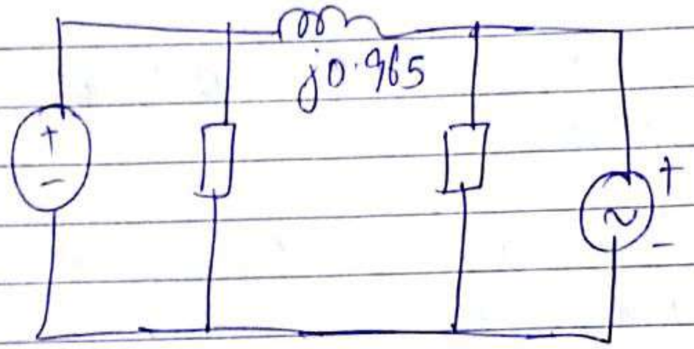


1) Steady State power limit without reactor.

$$= \frac{|E_g|\,|E_m|}{X_{(total)}} = \frac{1.2\times1}{1+0.1+0.25+0.1+1} = 0.49pu$$

2)



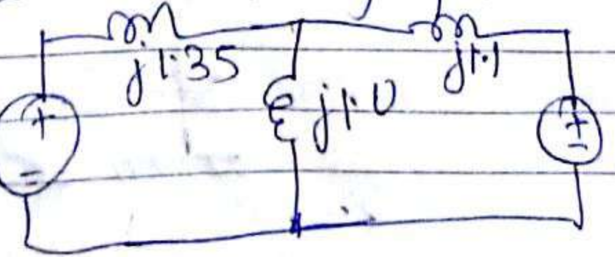


$$jX_{(transfer)} = \frac{j1.35\times j1.1 + j1.1\times(-j1.0) + (-j1.0)\times j1.35}{-j1.0}$$

$$= j0.965.$$

$$\text{Steady State Power limit} = \frac{1.2\times1}{0.965} = 1.244pu$$

③ With capacitive reactance replaced by inductive reactance, we get the equivalent circuit. Converting Y to Δ



$$jX\,(\text{Transfer}) = \frac{j1{\cdot}35 \times j1{\cdot}1 + j1{\cdot}1 \times j1{\cdot}0 + j1{\cdot}0 \times j1{\cdot}35}{j1{\cdot}0}$$

$$= j3{\cdot}935$$

$$\text{Steady State Power limit} = \frac{1{\cdot}2 \times 1}{3{\cdot}935} = 0{\cdot}304\,\text{pu}$$

⑦ The generator on problem ⑥ is delivering 1·0 pu power to the infinite bus $|V| = 1{\cdot}0$ pu with the generator terminal Voltage of $|V_t| = 1{\cdot}0$ pu. Calculate the generator emf behind transient reactance. Find the maximum power that can be transfered under the following conditions:
ⓐ System healthy ⓑ One line shorted (3ϕ) in the middle ⓒ One line open Plot. Plot all the three power angle curves.

$$V_t = |V_t| \angle \alpha = 1 \angle \alpha$$

$$\frac{|V_t||V|}{X} \sin\alpha = P_e$$

$$\frac{1 \times 1}{0{\cdot}25 + 0{\cdot}1} \sin\alpha = 1 \quad \boxed{\alpha = 20{\cdot}5^\circ}$$

Current into infinite bus,

$$I = \frac{|V_t| \angle \alpha - |V| \angle 0^\circ}{jX}$$

$$= \frac{1\angle 20.5 - 1\angle 0}{j0.35} = 1+j0.18$$

$$= 1.016 \angle 10.3^\circ$$ //.

$E' = 1\angle 0^\circ + j0.6 \times (1+j0.18)$.

$E' = 0.892 + j0.6 = 1.075 \angle 33.9$

ⓐ System Healthy,

$$P_{max} = \frac{|V||E'|}{X_{12}} = \frac{1 \times 1.075}{0.6} = 1.79pu$$

$P_e = 1.79 \sin\delta$.

ⓑ one line Shorted in the Middle.

$X_{12} = 1.55$ $\quad P_{max} = \frac{1 \times 1.0755}{1.55} = 0.694pu$

$P_e = 0.694 \sin\delta$.

ⓒ one line open -

$X_{12} = 0.25 + 0.1 + 0.5 = 0.85$

$$P_{max} = \frac{1 \times 1.075}{0.85} = 1.265$$

$$\boxed{P_e = 1.265 \sin\delta}$$

⑧ In the above system, the generator has an inertia constant of 4 MJ/MVA. Write the swing equation upon occurrence of the fault. What is the initial angular acceleration? If this acceleration can be assumed to remain constant for $\Delta t = 0.05$ sec. Find the rotor angle at the end of this time interval and the new acceleration.

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(Approved by AICTE, New Delhi, Accredited by NBA, & Affiliated to VTU, Belagavi-590 018)

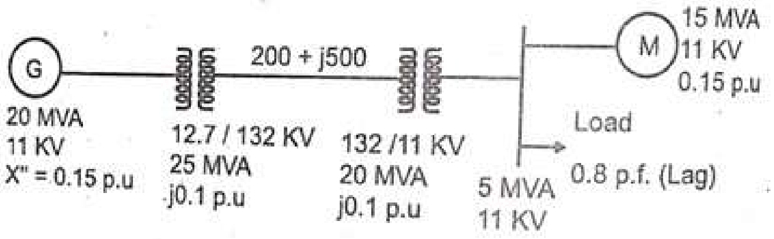
B.E. Electrical and Electronics Engineering
Outcome Based Education (OBE) and Choice Based Credit System (CBCS), VTU
Semester-IV
Internal Assessment Test- I
Date: 24-05-2021[AN]

Subject Code:	18EE62/17EE62/15EE62 – Set B	IA Marks:	30
Subject Title:	PowerSystemAnalysis–I	Exam Hrs:	90 minutes

Course Objectives: This course will enable the students to

- To introduce the per unit system and explain its advantages and computation.
- To explain analysis of 3-phase symmetrical faults on synchronous machine &simple power systems.
- To explain the concept of sequence impedance and its analysis in three phase unbalanced circuits
- To explain the analysis of synchronous machine and simple power systems for different unsymmetrical faults using symmetrical components
- To discuss the dynamics of synchronous machine and derive the power angle equation for a synchronous machine.
- Discuss stability and types of stability for a power system and the equal area criterion for the evaluation of stability of a simple system

Note: Answer FIVE full questions

S.No	**Questions**	**Marks**	**CO-PO**	**Bloom’s Taxonomy Level**
Q.1	A. Prove that the per unit impedance of a transformer is the same when referred to either primary or secondary side. Also, draw the circuit model of transformer.	6	CO – 1, PO -1, 2	L – 4
	OR			
	B. What is per unit quantity? Mention its advantages. How is the per unit impedance value in a given base are changed to per unit impedance value of new base.	6	CO – 1, PO -1, 2	L - 1
Q.2	A. A 100MVA,33KV,3-Φ generator has a subtransient reactance of 15%. The generator is connected to the motors through a transmission line and two transformers. The motors have rated inputs of 30 MVA, 20 MVA and 50 MVA at 30 KV with 20 % sub transient reactance. The 3-Φ transformers are rated at 110 MVA,32 KV/110 KV with leakage reactance of 8 %. The line has a reactance of 50Ω. Selecting the generator rating as the base quantities in generator circuit, determine the base quantities in other parts of the system&evaluate the corresponding puvalues.	6	CO – 1, PO -1, 2	L – 5
	OR			
	B. Draw the per unit reactance diagram choosing a base of 20MVA, 132KV in Transmission line. The ratings are given in the diagram shown below.  	6	CO – 1, PO -1, 2	L - 3

	Primary : Y connected, 6.6kV, 15MVA secondary: Y connected, 33kV, 10MVA tertiary : Δ connected, 2.2kV, 7.5MVA Leakage impedance measured from primary side as Zps=j0.232 Ω ,Zpt = j0.29 Ωand on the secondary side Zst’= j8.7 Ω.Obtain the star connected equivalent on a base of 15MVA, 6.6kV in the primary circuit. Neglect resistances.		PO -1, 2	
	OR			
	B.A 3-Φ, Δ-Y transformer with rating 100KVA,11kV/400V has its primary and secondary leakage reactance of 12 Ω/phase and 0.05 Ω/phase respectively. Calculate the p.u reactance of the transformer.	6	CO – 1, PO - 1,2	L - 5
Q.4	A. Explain the transients occurring on a transmission line due to a short circuit.Obtain the expression for maximum momentary current.	6	CO – 2, PO - 1,2,3,4, 5	L – 2
	OR			
	B. A 3-Φ,5MVA,6.6kV alternator with 8% reactance is connected to a feeder of series impedance (0.12+j0.48)Ω/phase/km. The transformer is rated at 3MVA, 6.6kV/33kV and has a series reactance of 5%. Determine the fault current supplied by the generator operating under no-load with a voltage of 6.9kV, when a 3-Φ symmetrical fault occurs at a point 15km along the feeder.	6	CO – 2, PO - 1,2,3,4, 5	L - 5
Q.5	A. With the help of oscillogram of short circuit current of a synchronous generator operating on no load, distinguish between subtransient, transient and steady state periods. Prove that Xd”<Xd’ <Xd	6	CO – 2, PO - 1,2,3,4, 5	L – 4
	OR			
	B. A synchronous generator and motor are rated for 25,000kVA, 13.2kV, both have subtransient reactance of 15%. The line connecting them has a reactance of 10% on the base of machine ratings. The motor is drawing 20,000kW at 0.8 p.f leading. The terminal voltage of the motor is 12.8kV. When a symmetrical three phase fault occurs at motor terminals, Estimate the subtransient current in generator, motor and at the fault point using Kirchoff’s laws.	6	CO – 2, PO - 1,2,3,4, 5	L - 6

Course Outcomes: After studying this course, students will be able to

CO1: Show understanding of per unit system, its advantages and computation.

CO2: Perform short circuit analysis on a synchronous machine and simple power system to select a circuit breaker for the system.

CO3: Evaluate symmetrical components of voltages and currents in un-balanced three phase circuits.

CO4: Explain the concept of sequence impedance and sequence networks of power system components and power system.

CO5: Analyze three phase synchronous machine and simple power systems for different unsymmetrical faults using symmetrical components.

CO6: Discuss the dynamics of synchronous machine, stability and types of stability.

PO CO	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
CO1	3	3	2	2	1	1	-	-	1	1	-	1
CO2	3	3	3	3	2	1	-	-	1	1	-	1

"1" – Slight (Low) Correlation, "2" – Moderate (Medium) Correlation,
"3" – Substantial (High) Correlation and "-" indicates there is no correlation.

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(Mrs. Sumitha T L)

(Dr. Bharath V S)

Dr. B. Devi 18EE62 - VI A

18EE62/17EE62/15EE62 - Power System Analysis-I

24/5/2021 [AN] - EEE - VI Semester - A.

(1a) S_B - Rated MVA.

V_{B1} - Rated Py Voltage V_{Base} Py

V_{B2} - V_{Base} Sy

Z_{eq1} → Imp. Ref to Py (Ω).

Z_{eq2} → Imp Ref to Sy (Ω).

(2 Mark)

$$Z_{eq1} = Z_{eq1}(\Omega)\frac{S_B}{V_{B1}^2} \quad -①$$

$$Z_{eq2} = Z_{eq2}(\Omega)\frac{S_B}{V_{B2}^2} \quad -②$$

(2 Marks)

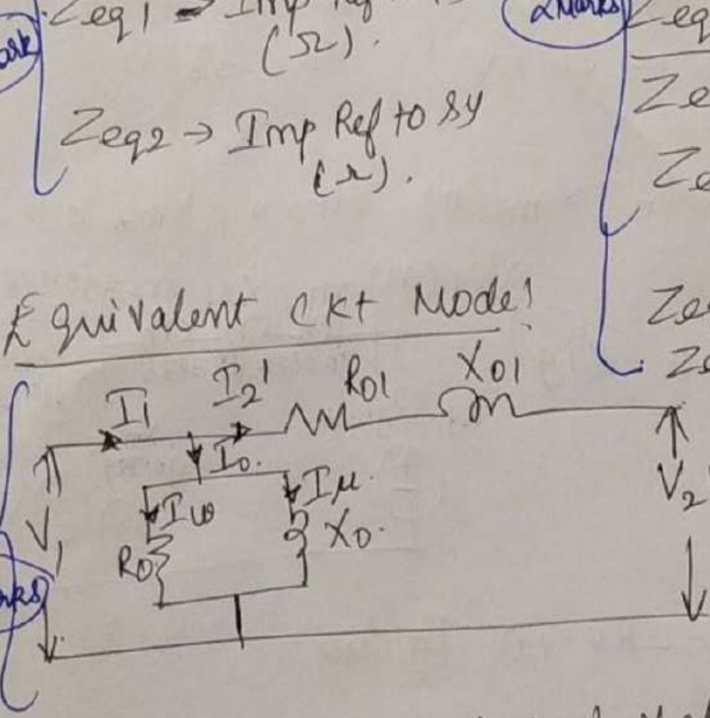
$$\frac{Z_{eq2}(\text{in }\Omega)}{Z_{eq1}(\text{in }\Omega)} = \frac{V_{B2}^2}{V_{B1}^2} \quad -③$$

$$Z_{eq2}(\text{in }\Omega) = Z_{eq1}(\text{in }\Omega) * \frac{V_{B2}^2}{V_{B1}^2} \quad -④$$

$$Z_{eq2}(pu) = Z_{eq1}(\text{in }\Omega) * \frac{V_{B2}^2}{V_{B1}^2} * \frac{S_B}{V_{B2}^2}$$

$$Z_{eq2}(pu) = Z_{eq1}(pu)$$

Equivalent Ckt Model



(2 Marks)

$$R_{01} = R_1 + R_2' = R_1 + R_2/K^2$$

$$X_{01} = X_1 + X_2' = X_1 + X_2/K^2$$

$$K = \frac{E_2}{E_1} = \frac{N_2}{N_1} = \frac{V_2}{V_1} = \frac{I_1}{I_2}$$

(1b) Perunit :- $PU = \frac{\text{Actual Value}}{\text{Base Value}}$ (1 Mark)

Eg ⇒ $I_A = 80A$

$I_B = 100A$

$I_{pu} = \frac{80}{100} = 0.8\,pu$

Adv :-

- $Z_{pu}(Py) = Z_{pu}$ Sy.
- Y-Y, Δ-Δ, Δ-Y are same
- Manufactures give in PU.
- Computation is easy.
- Line to Phase Phase to Line Conversion is easy

Adv ⇒ (2 Marks)

Conversion (3 Marks)

$$Z_{pu}(given) = \frac{Z_{actual}}{\frac{V_{Base}^2}{S_{Base}}}$$

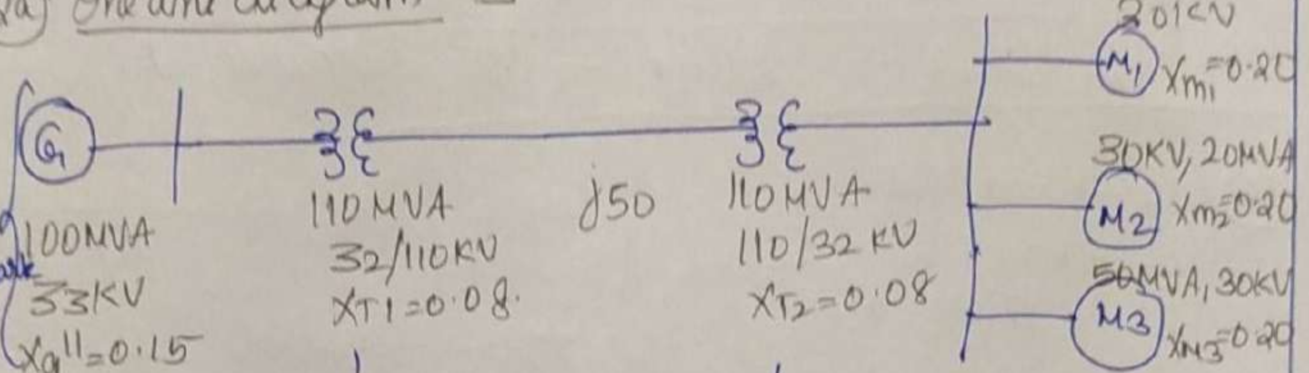
$$Z_{pu}(new) = \frac{Z_{actual}}{\frac{V_{Basenew}^2}{S_{Basenew}}}$$

$$Z_{pu}(n) = Z_{pug} * \frac{S_{Bn}}{S_{BO}} * \frac{V_{BO}^2}{V_{BN}^2}$$

Page ①

[Dr. B. Devi] Devi 24/5/21

(2a) One line diagram —



1 Mark

SB = 100MVA | SB = 100MVA | SB = 100MVA

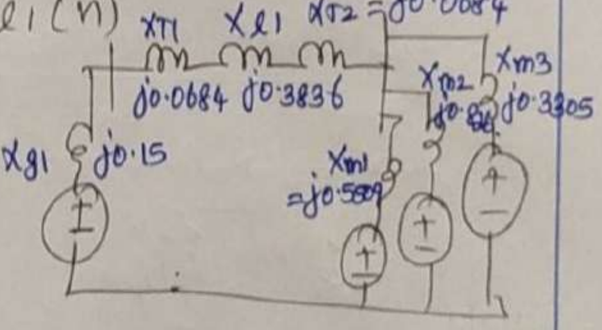
VB = 33KV | VB = 113.44 KV | VB = 33KV

1 Mark

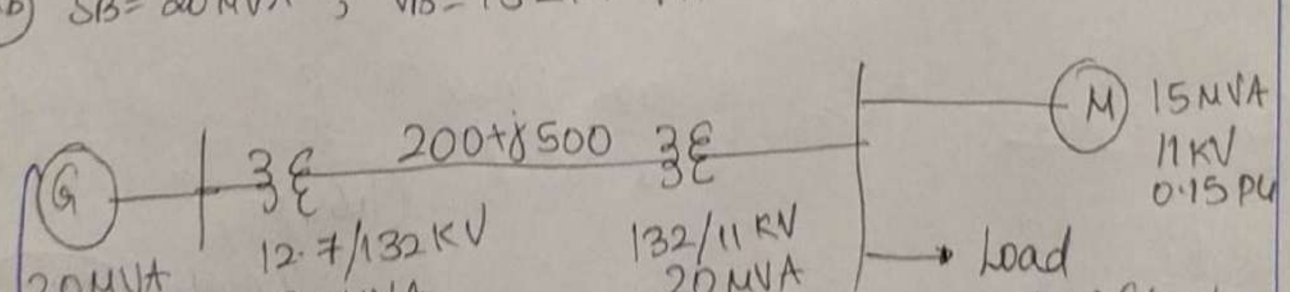
Calculation X_{g1n}, X_{T1n}, $X_{m1}(n)$, X_{m2n}, $X_{m3}(n)$, $X_{l1}(n)$

(2 Marks)

Dig (1 Mark) Reactance Dig



(2b) SB = 20MVA ; VB = 132KV in Tr. line



2 Marks

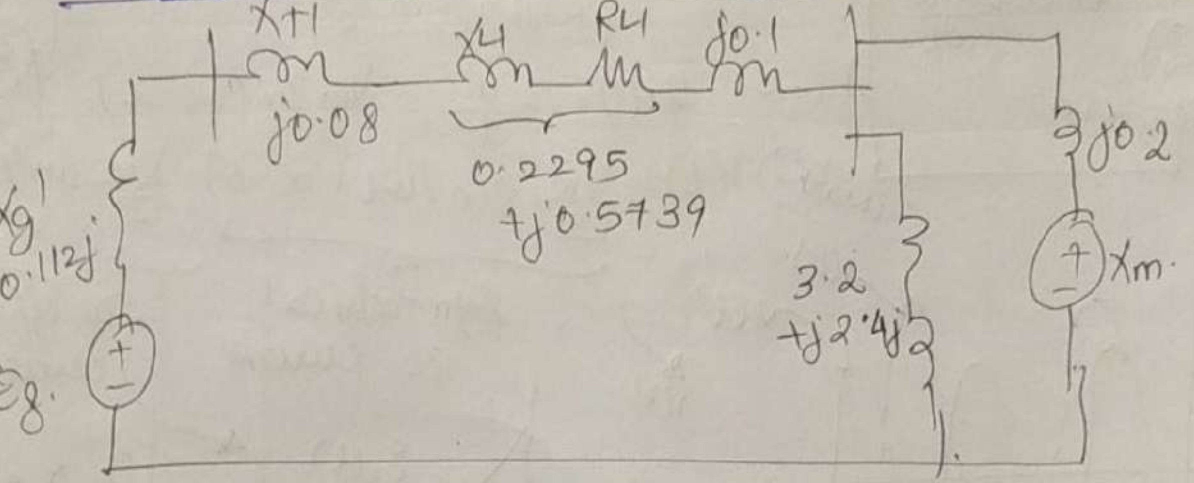
SB = 20MVA | SB = 20MVA | SB = 20MVA

VB = 127KV | VB = 132KV | VB = 1[illegible]KV

Page ②

Dr. B. Devi Devi.A 24/5/21

Calculation - 2 Marks + Reactance Dig (2 Marks)



(3a) Py side : $S_B = 15\,MVA$ $V_B = 6.6$

1 Marks Sy side : $S_B = 15\,MVA$ $V_B = 33\,KV$

Ty side : $S_B = 15\,MVA$ $V_B = 2.2\,KV$

$Z_{ps}(PU) = \frac{Z_{ps}(\Omega)}{V_B^2/S_B} = j0.08\,PU$

2 Marks

$Z_{pt}(PU) = \frac{j0.29}{\frac{6.6^2}{15}} = j0.1\,PU$

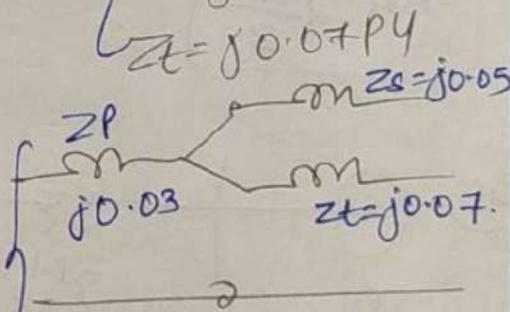
$Z_{st}(PU) = \frac{j8.7}{33^2/15} = j0.12\,PU$

$Z_P = \frac{1}{2}\{Z_{ps} + Z_{pt} - Z_{st}\}$

$= j0.03\,PU$

1 Marks $Z_S = j0.05\,PU$

$Z_t = j0.07\,PU$



2 Mark

(3b) $V_B = 11\,KV$ $S_B = 100\,KVA = \frac{100}{1000}\,MVA.$ } 2 Marks

$X_{01} = X_1 + X_2' = X_1 + \frac{X_2}{K^2} = 12 + \frac{0.05}{\left(\frac{400}{11000}\right)^2} = 49.737\,\Omega/Ph$

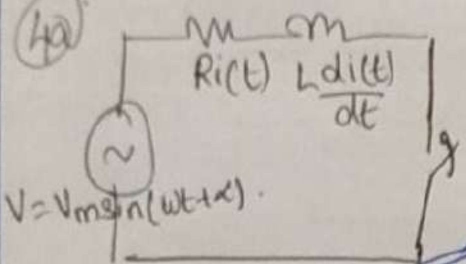
$X_{01}(in\,PU) = \frac{49.737}{\frac{11^2}{\frac{100}{1000}}} = 0.0411\,PU$ } 2 Marks

Illy X_{02} in PU. } 2 Marks

Page ③

Dr. B. Devi Devi 24/5/21

(4a)



(1Mark)

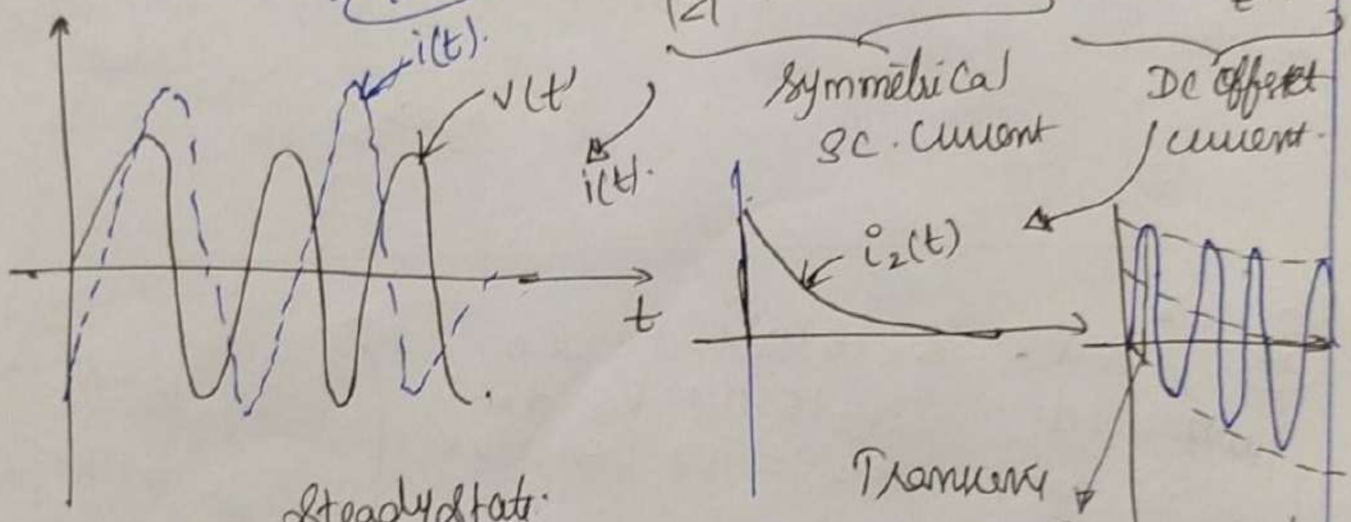
$Z = R + jωL$

$= \sqrt{R^2+ω^2L^2} \angle \tan^{-1}\frac{ωL}{R}$

$Ri(t) + L\frac{di}{dt} = V_m \sin(ωt+α)$.

(2Mark)

$$i(t) = \underbrace{\frac{V_m}{|Z|}\sin(ωt+α-θ)}_{\text{Symmetrical SC. current}} + \underbrace{\frac{V_m}{Z}\sin(θ-α)\, e^{-Rt}}_{\text{DC offset current}}$$



Steadystate

Transient

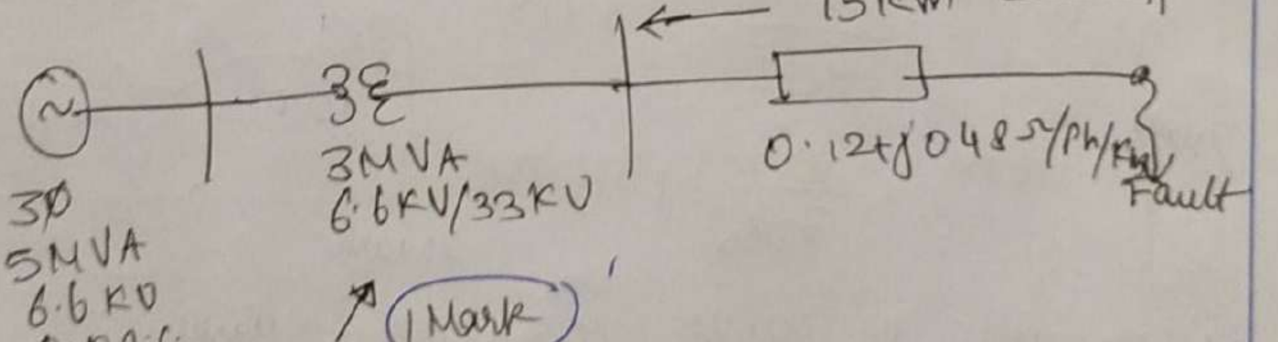
I_{mm}

Total SC

$\boxed{i_{MM} = 2\frac{V_m}{Z}}$

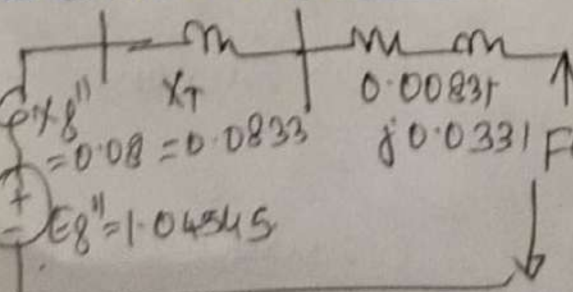
Waveform-(3)

(4B)



(1Mark)

Reactance Dig (2 Mark)



$I_f = 0.2226 - j5.313$

$I_{Base} = 87.4773$.

(2Mark)

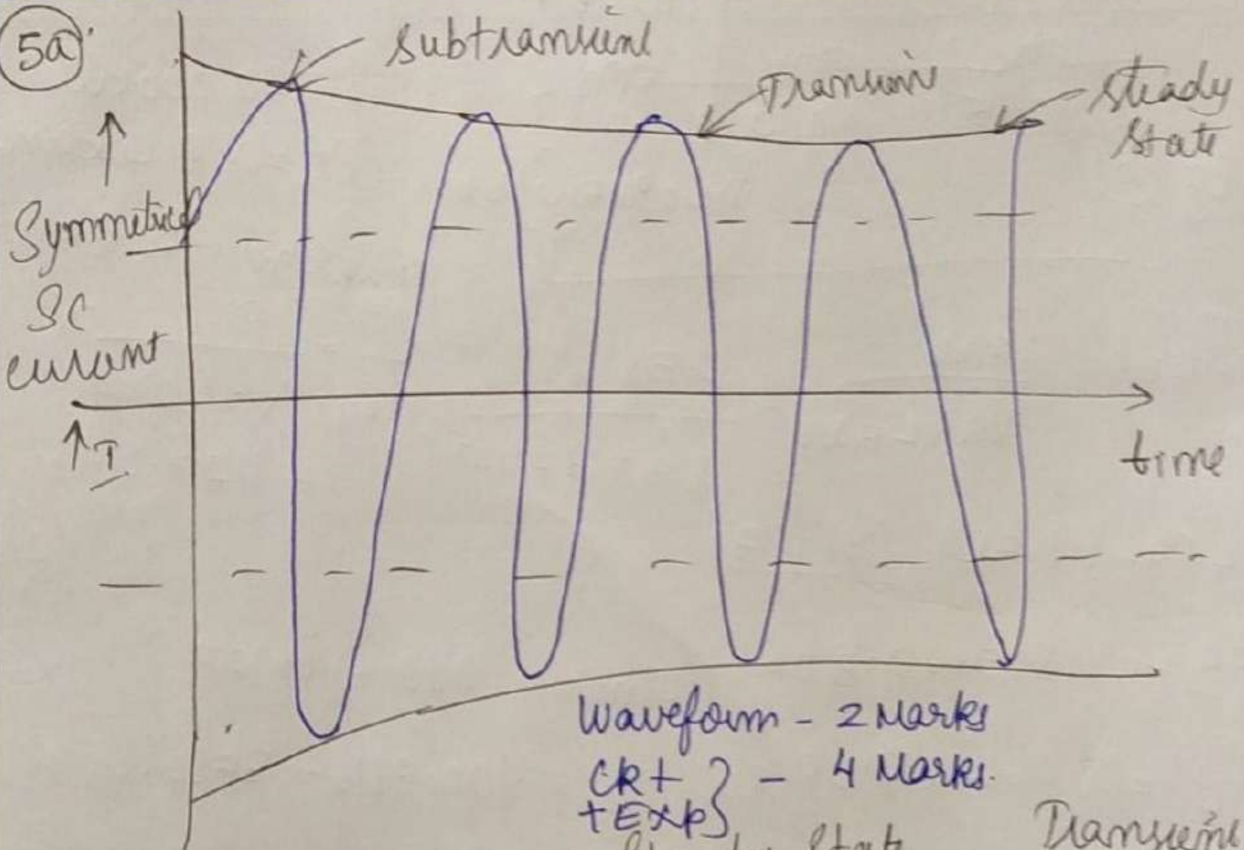
$I_{pu} = 0.2226 - j5.313$

$I_f(A) = 19.76 - j464.607$

(1Mark)

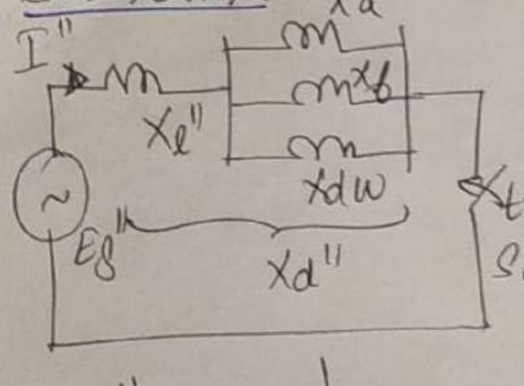
Dr. B. Devi 24/1/21

(5a)

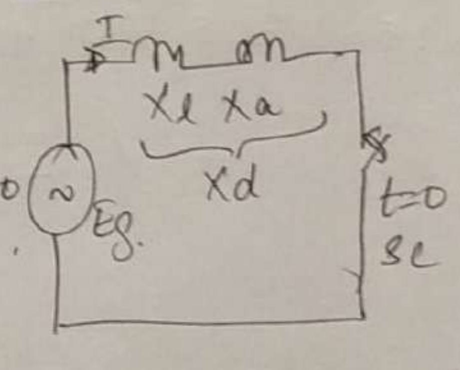


Waveform - 2 Marks
CKt + tExp } - 4 Marks

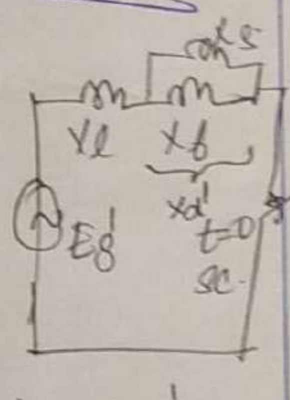
Subtransient



Steady State



Transient

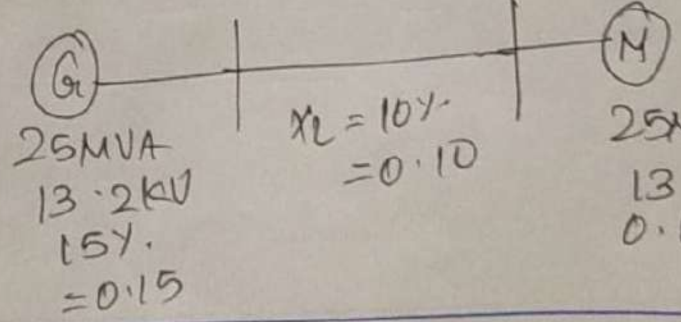


$$X_d'' = X_l + \frac{1}{\frac{1}{X_a} + \frac{1}{X_f} + \frac{1}{X_{dw}}}$$

$$X_d = X_l + X_a .$$

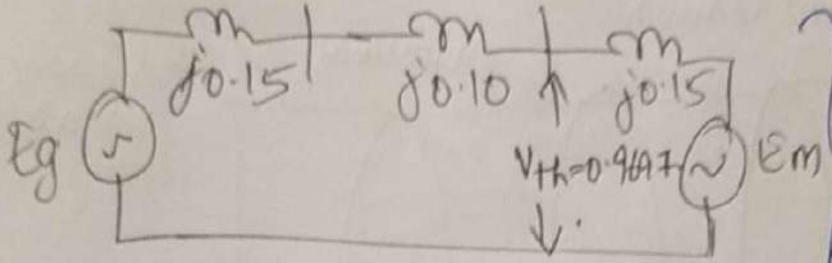
$$X_d' = X_l + \frac{1}{\frac{1}{X_a} + \frac{1}{X_f}}$$

(5b)



- 1 Mark

24/1/25



P=20,000kW

PF=0·8 leading

V_{Em} = 12-2 kV·

1 Mark

$I = \frac{P}{\sqrt{3} V \cos\phi}$

= 1127·6 A

2 Marks

$I_{base} = \frac{S_{Base}}{\sqrt{3} V_{L Base}} = \frac{25 \times 10^6}{\sqrt{3} \times 13 \cdot 2 \times 10^3} = 1093 \cdot 4 (A)$

$I_{L pu} = 1 \cdot 031 (A) \angle 36 \cdot 87$

$E_g = 0 \cdot 815 + j0 \cdot 806$ $E_m = 1 \cdot 062 - j0 \cdot 127$

$I_g'' = 0 \cdot 846 - j7 \cdot 08$ pu $I_g = 900 \cdot 9616 - 3564 \cdot 48 (A)$

$I_m = -925 \cdot 0164 - j774127$ (A)

$I_f = -24 \cdot 05 - 11305 \cdot 75$ (A)

- 2 Mark

— x —

Devi
24/5/21

Faculty

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Dr. B. Devi
Devi 24/5/21

Children’s Education Society
THE OXFORD COLLEGE OF ENGINEERING, BANGALORE -560 068
(Approved by AICTE, New Delhi, Accredited by NBA, & Affiliated to VTU, Belagavi-590 018)

B.E. Electrical & Electronics Engineering
Outcome Based Education (OBE) and Choice Based Credit System (CBCS), VTU
Semester-VI
Internal Assessment Test- II
Date: 28-06-2021 – AN [2:00PM – 3:30PM]

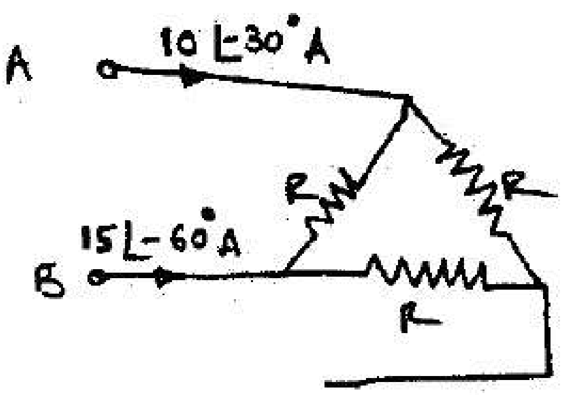
Subject Code:	18EE62 / 17EE62 / 15EE62	IA Marks:	30
Subject Title:	Power System Analysis – I	Exam Hrs:	90 minutes

Course Objectives: This course will enable the students to

- To introduce the per unit system and explain its advantages and computation.
- To explain analysis of three phase symmetrical faults on synchronous machine and simple power systems.
- To explain the concept of sequence impedance and its analysis in three phase unbalanced circuits
- To explain the analysis of synchronous machine and simple power systems for different unsymmetrical faults using symmetrical components
- To discuss the dynamics of synchronous machine and derive the power angle equation for a synchronous machine.
- Discuss stability and types of stability for a power system and the equal area criterion for the evaluation of stability of a simple system

Note: Answer FIVE full questions

QNo	**Questions**	**Marks**	**CO-PO**	**Bloom’s Taxonomy Level**
Q.1	A) What are sequence impedances and sequence network? Applying the above concept draw the single phase zero sequence networks for the transformers connected in different configuration.	6	CO – 3 PO - 1,2	L3
	OR			
	B) Derive an expression for the 3 phase complex power in terms of symmetrical components	6	CO – 3 PO - 1,3	L1
Q.2	A) Prove that a balanced set of 3 phase voltages will have only positive sequence components of voltage only	6	CO – 3 PO - 1,4	L4
	OR			
	B) Obtain the relationship between line and phase sequence components of voltages in star connection. Give the relevant phasor diagrams.	6	CO – 3 PO - 1,3,4	L2
Q.3	A) A delta connected balanced resistive load is connected across a balanced 3 phase supply as shown in figure. With currents in lines A & B specified. Find the symmetrical components of the currents.	6	CO – 3 PO - 1,2,4	L6

	 OR B) Draw the positive, negative and zero sequence network for the power system. Choose a base of 50MVA 220KV in the 50ohm transmission lines and marks all reactance's in pu. The ratings of the generator and transformers are: G1: 25MVA, 11KV, X"=20%, G2: 25MVA, 11KV, X"=20%, 3 phase transformers each: 20MVA, 11/220KV, X=15%. The negative sequence reactance of each synchronous machine is equal to the sub transient reactance. The zero sequence reactance of a each machine is 8% of positive sequence. Assume that the zero sequence reactances of lines are 250% of their positive sequence reactance's. Draw the Single Line diagram with each generator connected at the ends and two parallel transmission lines with two transformers on each line. Assume 50ohm as the line reactance for both the lines	6	CO – 3 PO - 1,2,3	L5
Q.4	A.) A double line to ground fault occurs at the terminals of a loaded generator. Derive an expression for the fault currents; draw the connecting of sequence networks. OR B.)A 30MVA, 11Kv generator has Z1 = Z2 = j0.21 pu and Z0= j0.05pu. If a line to line fault occurs on the terminals of the generator, find the line currents and line to neutral voltage under fault conditions	6 6	CO – 4 PO - 1,3 CO – 4 PO - 1,3,4	L1 L3
Q.5	A.) A three phase generator with line to line voltages of 400V is subjected to LLG fault. If Z1=j2 ohm, Z2=j0.5 ohm and Z0=j0.25 ohm. Determine the symmetrical components of currents and fault current. OR B) Draw the interconnected sequence networks for the following cases:	6 6	CO – 4 PO - 1,2,4 CO – 4 PO - 1,2,3	L4 L2

	i) L-G fault through fault impedance Zf ii) L – L fault through fault impedance Zf iii) LLG fault through fault impedance Zf			

Course Outcomes: After studying this course, students will able to

CO1: Show understanding of per unit system, its advantages and computation.

CO2: Perform short circuit analysis on a synchronous machine and simple power system to select a circuit breaker for the system.

CO3: Evaluate symmetrical components of voltages and currents in un-balanced three phase circuits.

CO4: Explain the concept of sequence impedance and sequence networks of power system components and power system.

CO5: Analyse three phase synchronous machine and simple power systems for different unsymmetrical faults using symmetrical components.

CO6: Discuss the dynamics of synchronous machine, stability and types of stability.

PO CO	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
CO3	3	3	3	3	2	1	1	1	1	1	1	1
CO4	3	3	3	3	2	1	1	1	1	1	1	1

"1" – Slight (Low) Correlation, "2" – Moderate (Medium) Correlation,
"3" – Substantial (High) Correlation and "-" indicates there is no correlation

HOD/EEE

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18EE62/17EE62/15EE62 - Power System Analysis-I

28/06/2021 [AN] Internal - 2

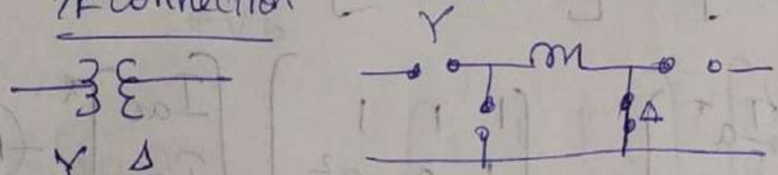
(1a) Sequence Impedances - Impedances offered by the circuit elements to +ve, -ve & zero sequence currents

Sequence N/w - The Power system represented using Sequence Impedances.

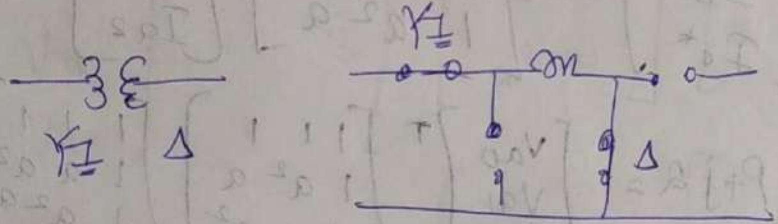
(1 Mark)

T/F connection

i)

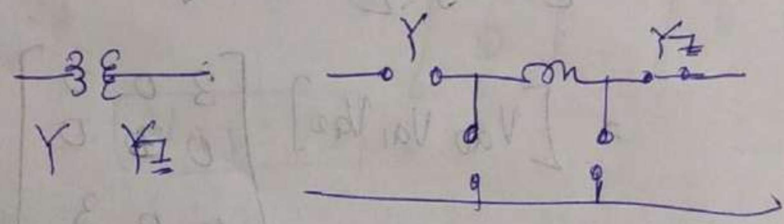


ii)

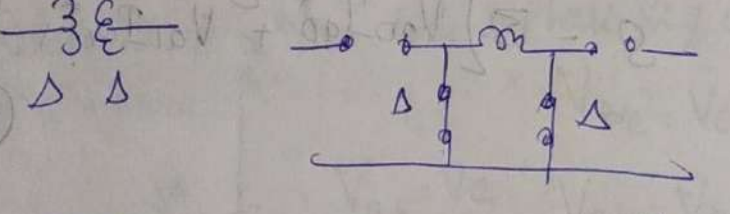


(5 Marks)

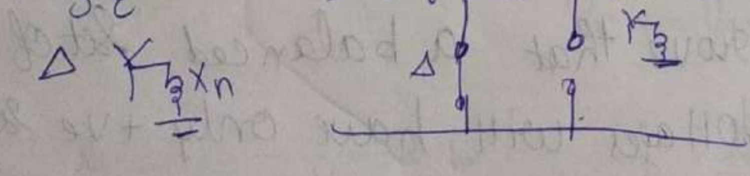
iii)



iv)



(v)



Expression for complex power in symmetrical components

1B) $S = P+jQ = V_a I_a^* + V_b I_b^* + V_c I_c^*$

$$S = P+jQ = \begin{bmatrix} V_a & V_b & V_c \end{bmatrix} \begin{bmatrix} I_a^* \\ I_b^* \\ I_c^* \end{bmatrix}$$ (1 Mark)

$$\begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix}^T * \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} = \begin{bmatrix} V_a & V_b & V_c \end{bmatrix}$$ — (1 Mark)

$$\begin{bmatrix} I_a^* \\ I_b^* \\ I_c^* \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \begin{bmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{bmatrix}^*$$ — (1 Mark)

$$S = P+jQ = \begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix}^T \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \begin{bmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{bmatrix}^*$$

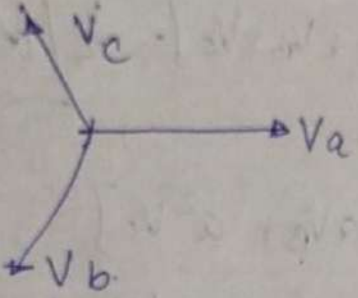
$$= \begin{bmatrix} V_{a0} & V_{a1} & V_{a2} \end{bmatrix} \begin{bmatrix} 3 & 0 & 0 \\ 0 & 3 & 0 \\ 0 & 0 & 3 \end{bmatrix} \begin{bmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{bmatrix}$$

$$S = 3\left[V_{a0} I_{a0}^* + V_{a1} I_{a1}^* + V_{a2} I_{a2}^*\right]$$ (3 Mark)

2A) Prove that a balanced set of 3ϕ Voltages will have only +ve seq components of voltages.

(2B) $$\begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}$$ — (1 Mark)

$V_a = V_a \quad V_b = a^2 V_a \quad V_c = a V_a$ — (1 Mark)



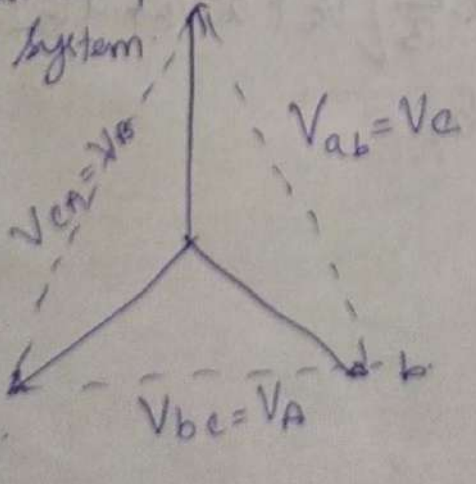
→ (1 Mark)

$$\begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \begin{bmatrix} V_a \\ a^2 V_a \\ a V_a \end{bmatrix}$$

$$= \frac{1}{3} \begin{bmatrix} 0 \\ 3V_a \\ 0 \end{bmatrix} = \begin{bmatrix} 0 \\ V_a \\ 0 \end{bmatrix}$$

$\therefore \boxed{V_{a1} = V_a}$, — (3 Marks)

2B) Relationship b/w Line & Phase seq components in Y system



$V_{bc} = V_c - V_b = V_A$

$V_{ab} = V_b - V_a = V_c$

$V_{cA} = V_a - V_c = V_B$

— (1 Mark)

$$\begin{bmatrix} V_{A0} \\ V_{A1} \\ V_{A2} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}\begin{bmatrix} V_A \\ V_B \\ V_C \end{bmatrix} \Bigg\}$$ 1 Mark

$$V_{A0} = \frac{1}{3}\left[V_A + V_B + V_C\right] = \frac{1}{3}\left[(V_c - V_b) + (V_a - V_c) + (V_b - V_a)\right]$$

$$\boxed{V_{A0} = 0}$$

$$V_{A1} = \frac{1}{3}\left[V_A + aV_B + a^2 V_C\right]$$

$$= \frac{1}{3}\left[(V_c - V_b + a(V_a - V_c) + a^2(V_b - V_a)\right]$$

$$= \frac{1}{3}\left[(aV_a + a^2V_b + V_c) - (a^2V_a + V_b + aV_c)\right]$$

$$= \frac{1}{3}\left[(a - a^2)\ (V_a + aV_b + a^2V_c)\right]$$

$$a - a^2 = j\sqrt{3}$$

$$V_{A1} = j\sqrt{3}\,V_{a1}$$

↳ 2 Mark

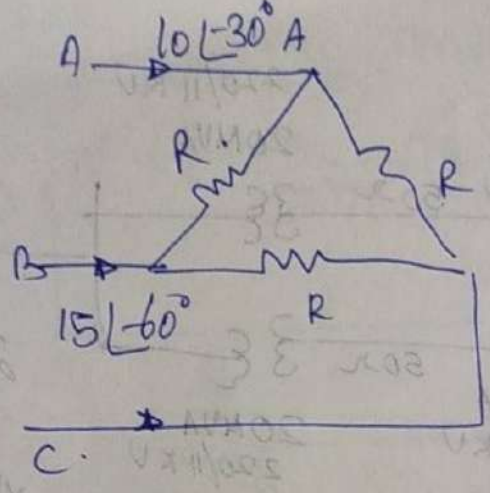
$$V_{A2} = \frac{1}{3}\left[V_{A1} + a^2V_B + aV_C\right]$$

$$= \frac{1}{3}\left[(V_c - V_b) + a^2(V_a - V_c) + a(V_b - V_a)\right]$$

$$= -j\sqrt{3} \times \frac{1}{3}\left[V_a + a^2V_b + aV_c\right]$$ → 2 Mark

$$= -j\sqrt{3}\,V_{a2}$$

3a



$$I_A + I_B + I_C = 0$$

$$I_C = -(I_A + I_B) = -\left[(10\angle -30^\circ) + 15\angle -60^\circ\right]$$

$$= -\left[(8.66 - j5) + (7.5 - j12.99)\right]$$

2 Marks

$$= -16.16 + j17.99 =$$

$$I_0 = \frac{1}{3}\left[I_A + I_B + I_C\right] = \frac{1}{3}\left[\overset{8.66-j5}{\cancel{10\angle 30}} + 7.5 - 12.99 - 16.16 + j17.99\right]$$

$$= \underline{\underline{0}}$$

$$I_1 = \frac{1}{3}\left[I_A + aI_B + a^2 I_C\right] = \frac{1}{3}\left[\cancel{8.66-j5}\right.$$

$$= \frac{1}{3}\left\{8.66 - j5 + (-0.5 + j0.866)(7.5 - j12.99) + (-0.5 - j0.866)(-16.16 + j17.99)\right]$$

2 Marks

$$= 13.2469 + j4.34485 = 13.941\angle 18.1589$$

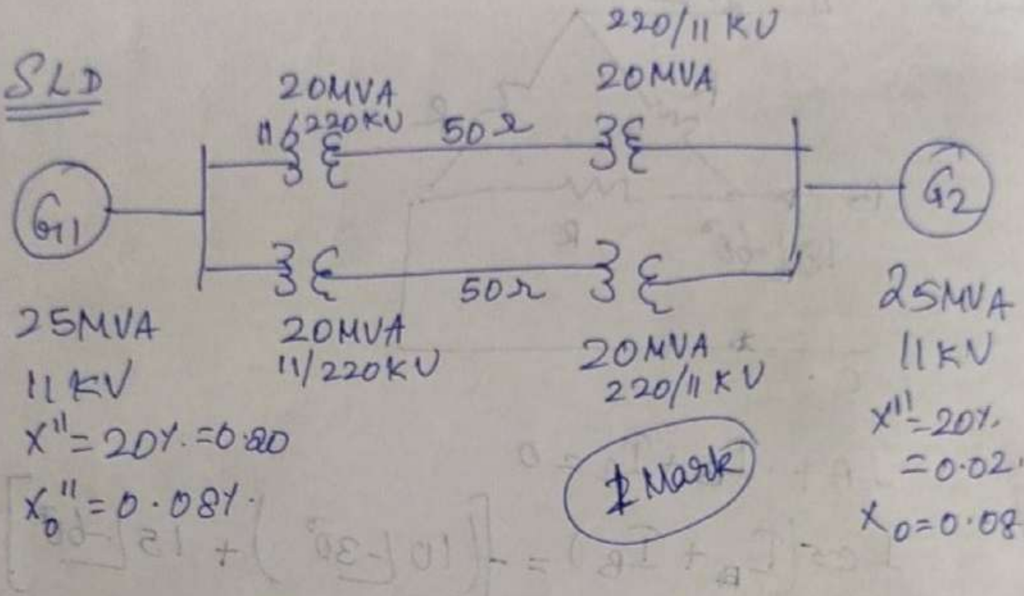
$$I_2 = \frac{1}{3}\left[I_A + a^2 I_b + aI_c\right] =$$

2 Marks

$$= \frac{1}{3}\left[8.66 - j5 + (-0.5 - j0.866)(7.5 - j12.99) + (-0.5 + j0.866)(-16.16 + j17.99)\right]$$

$$= -4.57691 - j9.29753 = 10.3630\angle -116.2$$

3b) SLD



1 Mark

Base KV ⇒ S_B = 50MVA, V_B = 220KV in 50Ω line

S_B = 50MVA	S_B = 50MVA	S_B = 50MVA
V_B = 11KV	V_B = 220KV	V_B = 11KV
$x_{g(1)\,New}$ = 0.4 pu		

1 Mark

G1, G2

$X_1 = X_2 = j0.4$

$X_0 = j0.16$

T1/T2/T3/T4

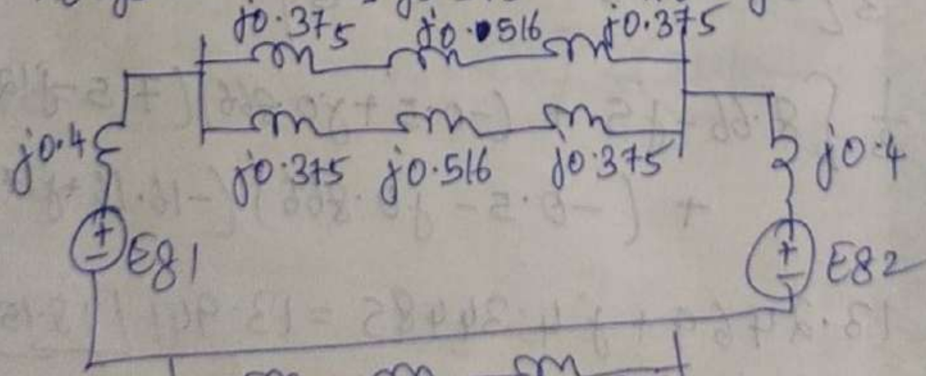
$X_0 = X_1 = X_2$
$= j0.375$

X_L :-

$X_1 = X_2 = j0.516$pu

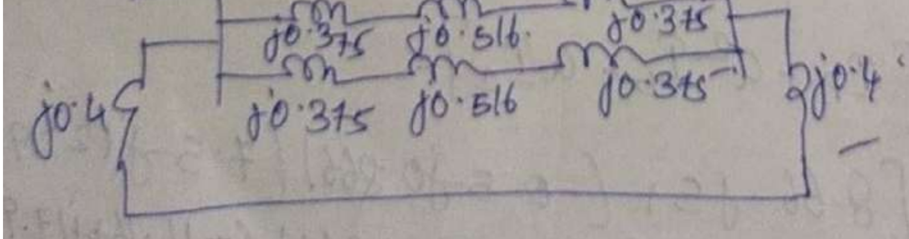
$X_0 = j0.129$Pu

2 Mark



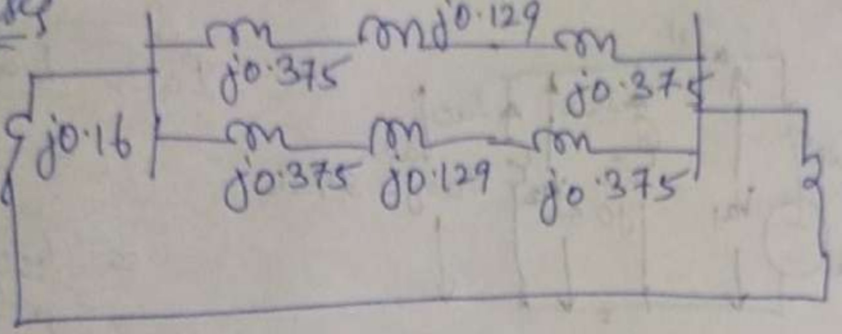
2 Marks

+Ve seq

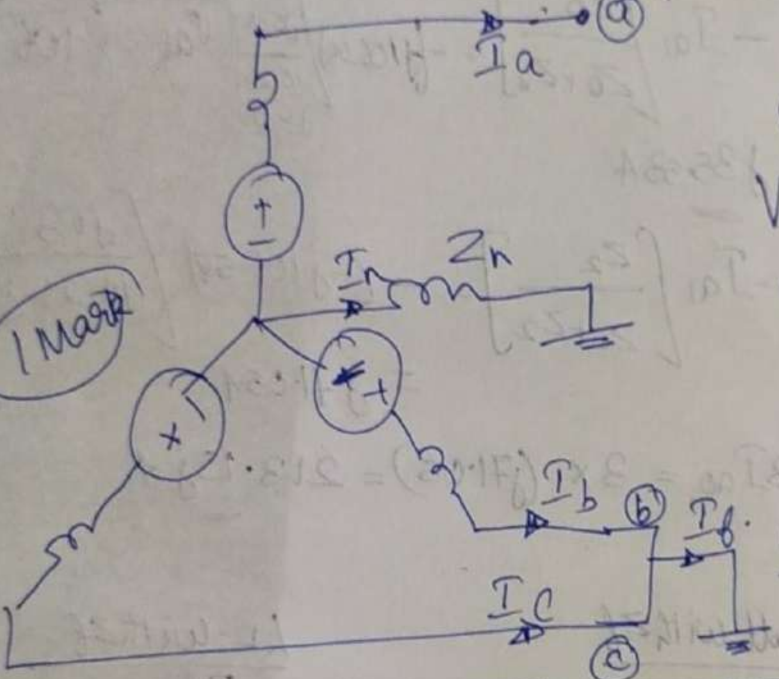


-Ve seq

Zero seq



④a



1 Mark

1 Mark

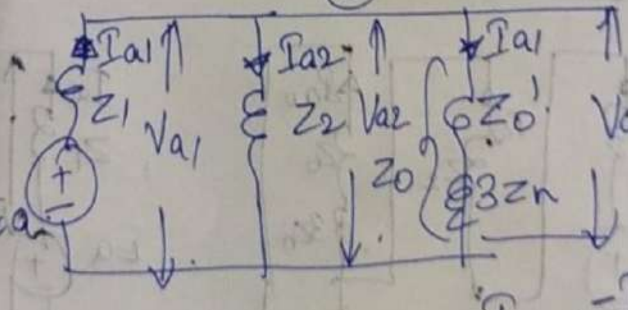
$V_{a0} = V_a/3$

$V_{a1} = \frac{V_a}{3}$

$V_{a2} = \frac{V_a}{3}$

$I_{a0} + I_{a1} + I_{a2} = 0$

2 Marks →



$I_{a0} = -I_{a1} \frac{Z_2}{Z_0+Z_2}$

$I_f = I_b + I_c = 3 I_{a0}$

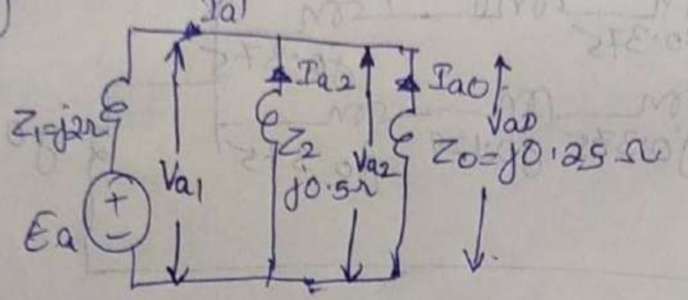
$= -3 I_{a1} \left(\frac{Z_2}{Z_0+Z_2} \right)$ — 2 Marks

④b $I_{a1} = \frac{E_a}{Z_1+Z_2} = -j2.38A$

$I_f = I_b = -I_c = -j\sqrt{3} I_{a1} = -4.124 A$

$V_{a1} = V_{a2} = E_a Z_2 / (Z_1 + Z_2) = 0.5V$

(5A)



$$I_{a1} = \frac{E_a}{Z_1 + \frac{Z_0 Z_2}{Z_0 + Z_2}}$$

$$= \frac{400/\sqrt{3}}{j\left[2 + \frac{0.5 \times 0.25}{0.5 + 0.25}\right]}$$

$$I_{a2} = -I_{a1}\left[\frac{Z_0}{Z_0 + Z_2}\right] = -(-j106.58)\left[\frac{j0.25}{j0.25 + j0.5}\right] \quad \boxed{I_{a1} = -j\,106.58}$$

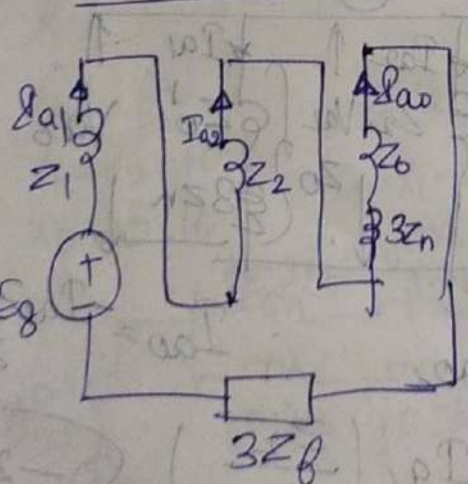
$$= j35.53A$$

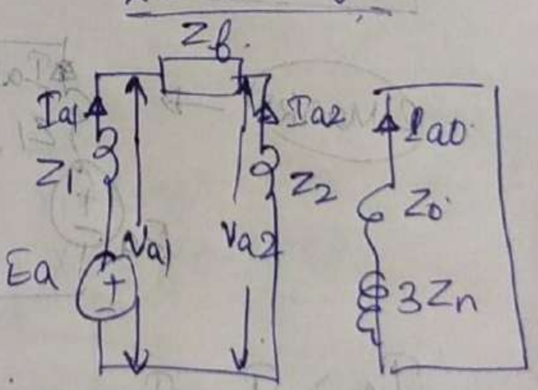
$$I_{a0} = -I_{a1}\left[\frac{Z_2}{Z_0 + Z_2}\right] = -(-j106.58)\left[\frac{j0.5}{j0.25 + j0.5}\right]$$

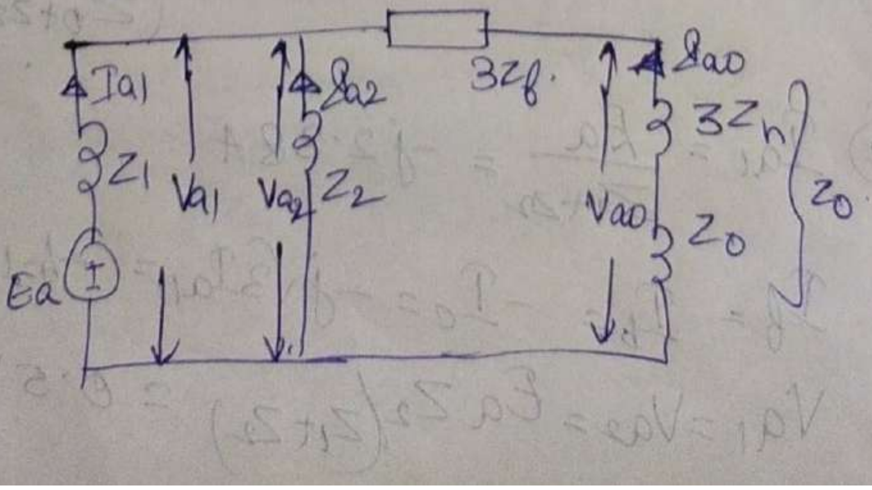
$$= j71.05A$$

$$I_f = 3I_{a0} = 3 \times (j71.05) = 213.15j\,A$$

(5B) LG fault with Z_f LL - With Z_f







Children’s Education Society
THE OXFORD COLLEGE OF ENGINEERING, BANGALORE -560 068
(Approved by AICTE, New Delhi, Accredited by NBA, & Affiliated to VTU, Belagavi-590 018)

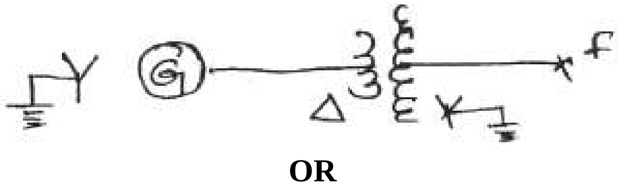
B.E. Electrical & Electronics Engineering
Outcome Based Education (OBE) and Choice Based Credit System (CBCS), VTU
Semester-VI
Internal Assessment Test- III
Date: 29-07-2021 – AN [2:00PM – 3:30PM]

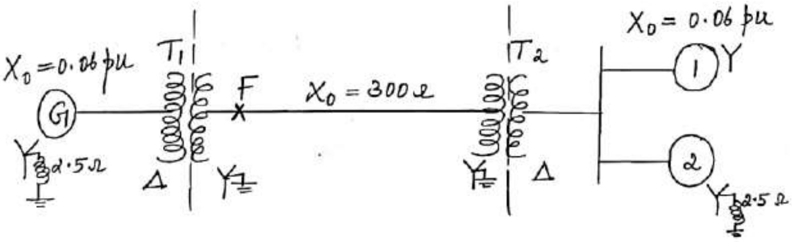
Subject Code:	18EE62/17EE62/15EE62	IA Marks:	30
Subject Title:	Power System Analysis – I	Exam Hrs:	90 minutes

Course Objectives: This course will enable the students to

- To introduce the per unit system and explain its advantages and computation.
- To explain analysis of three phase symmetrical faults on synchronous machine and simple power systems.
- To explain the concept of sequence impedance and its analysis in three phase unbalanced circuits
- To explain the analysis of synchronous machine and simple power systems for different unsymmetrical faults using symmetrical components
- To discuss the dynamics of synchronous machine and derive the power angle equation for a synchronous machine.
- Discuss stability and types of stability for a power system and the equal area criterion for the evaluation of stability of a simple system

Note: Answer FIVE full questions

Q. No	Questions	Marks	CO-PO	Bloom’s Taxonomy Level
Q.1	**A.** Derive expression for fault current if LG fault occurs through fault impedance Zf in a power system. Show the connection of sequence networks to represent the fault.	6	CO – 5 PO -1,2	L3
	OR			
	B. Derive expression for fault current if LL fault occurs through fault impedance Zf in a power system. Show the connection of sequence networks to represent the fault.	6	CO – 5 PO -1,2	L2
Q.2	**A.** The following data may be assumed for the network shown in figure: Generator:50MVA, 11KV, X1 = 80%. X2 = 50%, X0 = 20% Trasformer: 40MVA, 11/110KV, X1 = X2 = X0 = 6% If a LLG fault occurs at ‘F” find the current flowing in the conductor at ‘F’ 	6	CO – 5 PO -1,2	L4
	OR			
	B. A 25MVA, 11Kv, 3 Phase generator has a sub transient reactance of 20%. The generator suppliers 2 motor over transmission lines with transformer at both ends as shown in Figure. The motors have rated input of 15MVA and 7.5MVA both 10Kv with 25% sub transient reactance. The 3 phase transformers are rated 30MVA, 10.8/ 121Kv, Δ/Y, with leakage reactance of 10% each. The series reactance of the line is 100Ω.	6	CO – 5 PO -1,2	L2

	Calculate the fault current when a LG fault occurs at F. The motors are loaded to draw 15MVA and 7.5MVA at 10Kv and 0.8pf leading. Assume that negative sequence reactance is equal to positive sequence reactance. The zero sequence reactance is marked in the figure.  			
Q.3	**A.** For two conductor open faults, derive the expressions for currents and show the connections of sequence network to represent the fault. **OR** **B.** Derive an expression for the SSSL of a two terminal network represented by ABCD constants. List the methods to improve SSSL.	6 6	CO – 5 PO -1,2 CO – 6 PO -1,2	L6 L5
Q.4	**A.** With relevant diagrams, Derive the Power angle equation of a Salient pole synchronous machine. **OR** **B.** What is transient stability? Write the classification of transient stability. Discuss the methods to improve transient stability.	6 6	CO – 6 PO -1,2 CO – 6 PO -1,2	L1 L3
Q.5	**A.** A 50 Hz, 4-pole turbo generator rated 20 MVA, 11 KV has an inertia constant of 9 KW/KVA. Find (a) Kinetic energy stored in the rotor at synchronous speed (b) Angular acceleration if the electrical power developed is 16 MW when the input minus rotational losses is 26,800 HP. **OR** **B.** A salient pole alternator has Xd = 0.7 pu and Xq = 0.4 pu. If the machine is operating at normal voltage and full load at a power factor of 0.8 lag, to what value will the terminal voltage rise if the load is disconnected. Neglect armature resistance.	6 6	CO –6 PO -1,2 CO –6 PO -1,2	L4 L2

Course Outcomes: After studying this course, students will be able to

CO1: Show understanding of per unit system, its advantages and computation.

CO2: Perform short circuit analysis on a synchronous machine and simple power system to select a circuit breaker for the system.

CO3: Evaluate symmetrical components of voltages and currents in un-balanced three phase circuits.

CO4: Explain the concept of sequence impedance and sequence networks of power system components and power system.

CO5: Analyse three phase synchronous machine and simple power systems for different unsymmetrical faults using symmetrical components.

CO6: Discuss the dynamics of synchronous machine, stability and types of stability.

PO CO	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
CO5	3	3	2	2	1	1	-	-	1	1	-	1
CO6	3	3	2	2	1	1	-	-	1	1	-	1

“1” – Slight (Low) Correlation, “2” – Moderate (Medium) Correlation,
“3” – Substantial (High) Correlation and “-” indicates there is no correlation

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B.E. Electrical and Electronics Engineering
Outcome Based Education (OBE) and Choice Based Credit System (CBCS), VTU
Semester-VI
Internal Assessment Test- III – **SCHEME OF EVALUATION**
Date: 29-07-2021[AN]

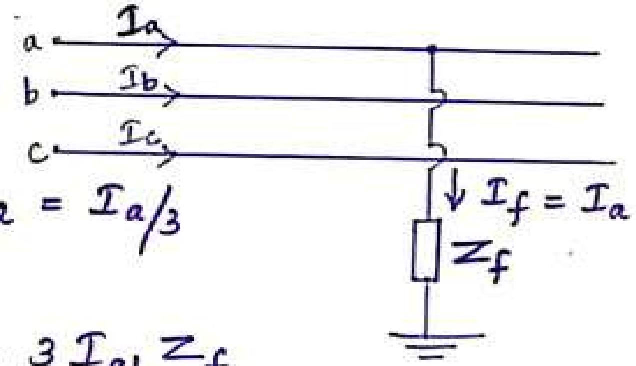
Subject Code:	18EE62/17EE62/15EE62	IA Marks:	30
Subject Title:	PowerSystemAnalysis–I	Exam Hrs:	90 min

Q.No	**Answers**	**Marks**

Q.1 **A.**

$I_b = 0 \; ; \; I_c = 0$

$V_a = I_a Z_f$



$I_{a0} = I_{a1} = I_{a2} = I_a/3$

$I_a = 3 I_{a1}$

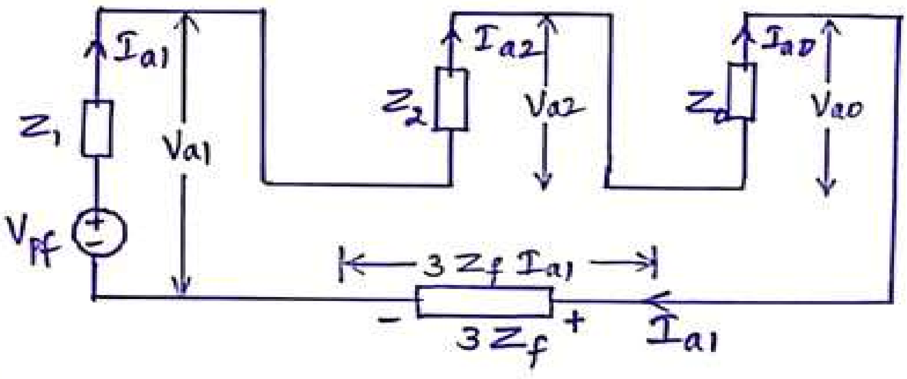
2

$V_{a0} + V_{a1} + V_{a2} = 3 I_{a1} Z_f$

$$I_{a1} = \frac{V_{pf}}{Z_1 + Z_2 + Z_0 + 3Z_f}$$

$I_f = I_a = 3 I_{a1}$

2



2

OR

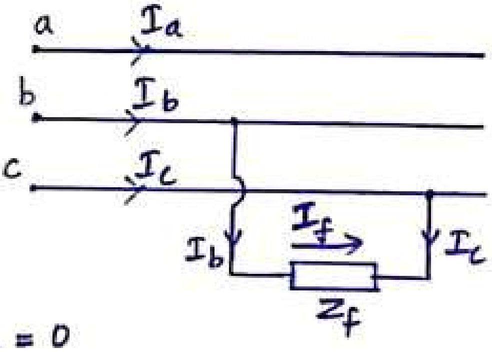
B.

$I_a = 0$

$I_b = - I_c$

$V_b - V_c = I_b Z_f$

$V_b = V_c + I_b Z_f$



2

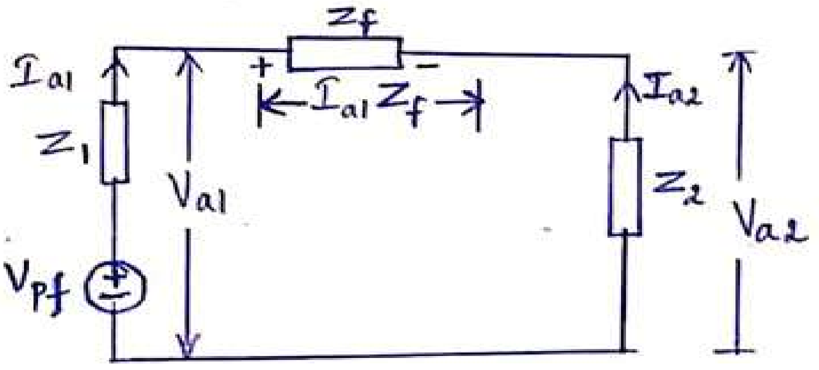
$I_{a1} = - I_{a2} \; ; \; I_{a0} = 0$

$V_{a1} - V_{a2} = I_{a1} Z_f$; $V_{a0} = 0$

$$I_{a1} = \frac{V_{pf}}{Z_1 + Z_2 + Z_f}$$

$I_f = I_b = -j\sqrt{3}\, I_{a1}$; $|I_f| = \sqrt{3}\, I_{a1}$

2



2

Q.2 **A.**

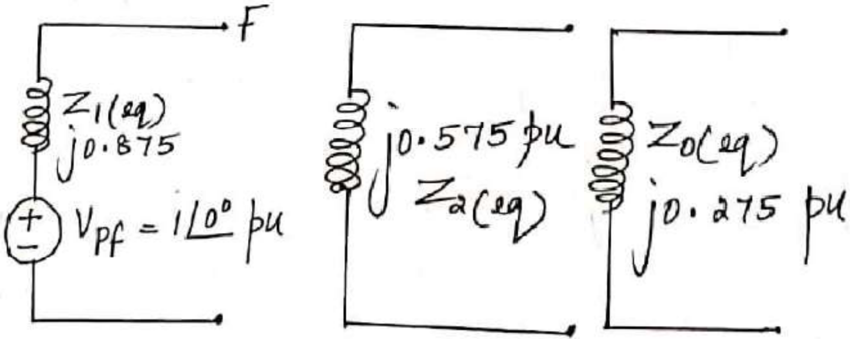
Reactances of Generator:

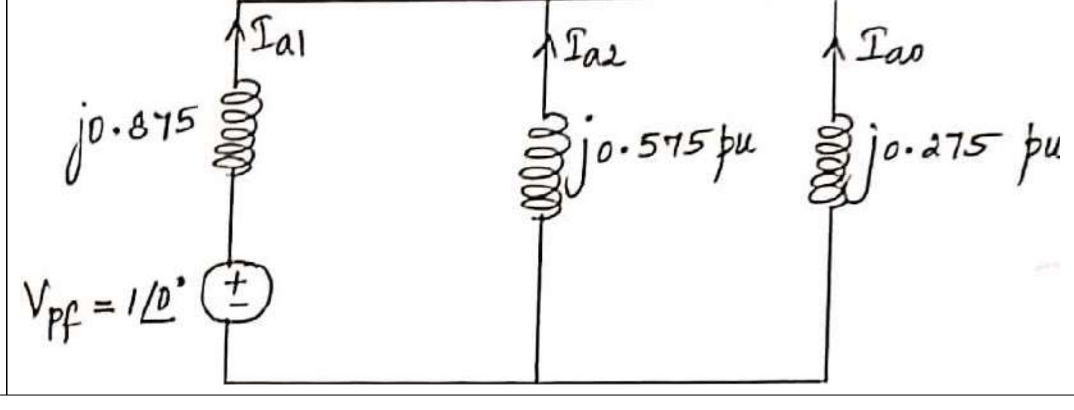
$X_1 = j0.8$ pu ; $X_2 = j0.5$ pu ; $X_0 = j0.2$ pu

Reactances of Transformer:

$X_1 = X_2 = X_0 = j0.06 * \frac{50}{40} * \left(\frac{11}{11}\right)^2 = j0.075$ pu

1





2

$$I_{a1} = \frac{V_{pf}}{Z_1 + \frac{Z_2 Z_0}{Z_2 + Z_0}} = 0.942\,\angle{-90^\circ}\ pu$$

1

$$I_{a0} = -\,I_{a1}\,\frac{Z_2}{Z_0 + Z_2} = 0.637\,\angle{90^\circ}\ pu$$

1

$$|I_f| = 3\,|I_{a0}| = 1.912\ pu$$

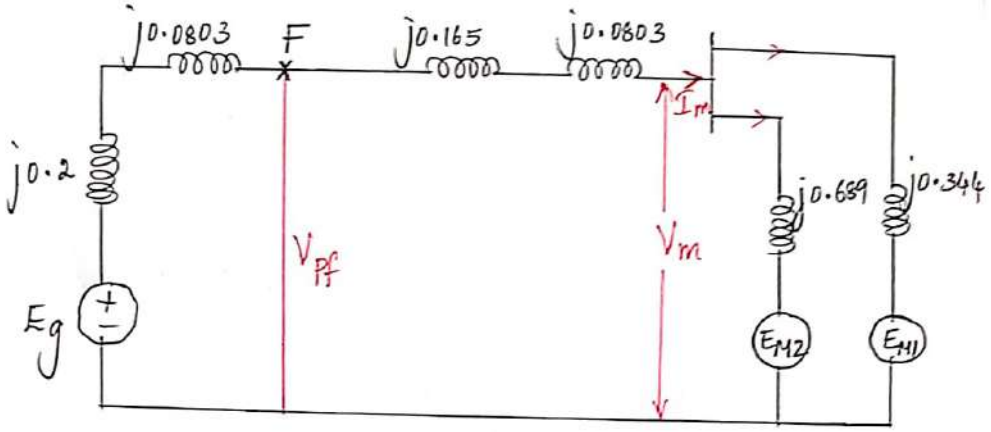
$$I_B = \frac{1000 * MVA_B}{\sqrt{3} * kV_B} = 262.4\ A$$

$$I_f\ (in\ A) = 1.912 * 262.44 = 501.78\ A$$

1

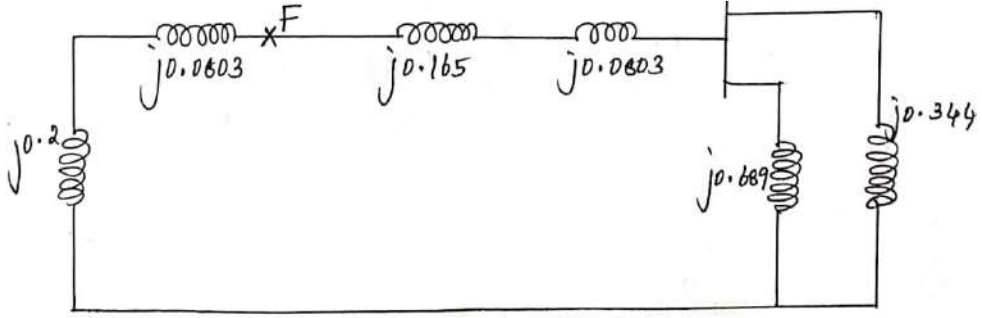
OR

B.Positive sequence network:



1

Negative sequence network:



1

$$I_m\ (actual) = \frac{P_m}{\sqrt{3}\ V\ \cos\phi} = 1623.85\ A$$

$$I_m\ (pu) = \frac{1623.85}{1312.2} = 1.238\ pu$$

$$I_m = |I_m|\ \angle{+\cos^{-1}(0.8)} = 1.238\,\angle{+36.87^\circ}\ pu$$

$$V_m(pu) = \frac{V_{actual}}{V_{Base}} = \frac{10\ kV}{11\ kV} = 0.909\,\angle{0^\circ}\ pu$$

1

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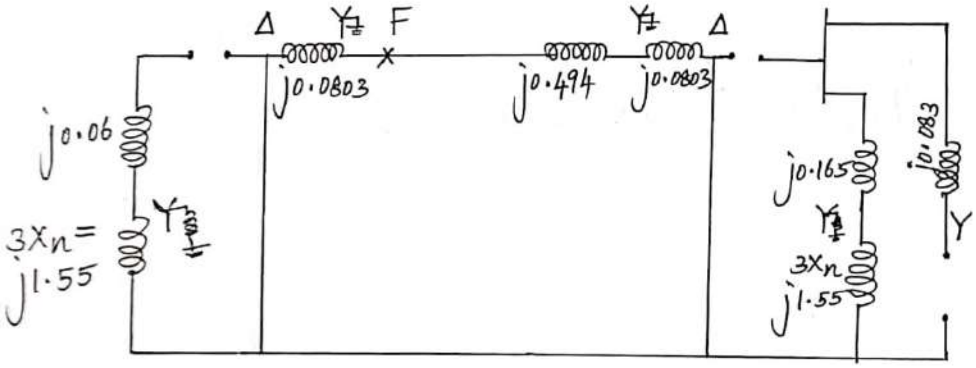
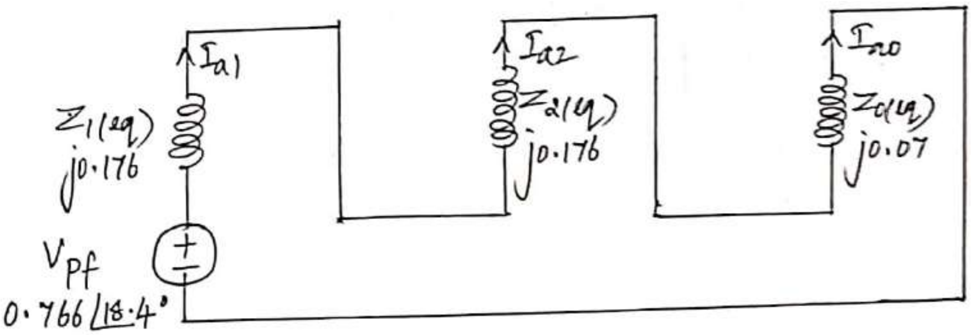
Zero sequence network:



Interconnected network:



$$I_{a1} = \frac{V_{pf}}{Z_1 + Z_2 + Z_0} = 1.815\angle{-71.6^\circ} \text{ pu}$$

Fault current, $|I_f| = 3\,|I_{a1}| = 3*1.815 = 5.445$ pu

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Q.3

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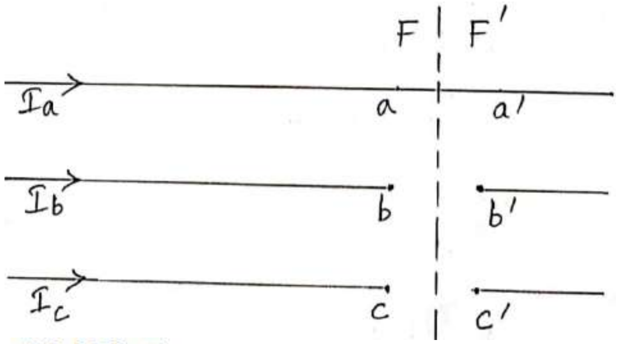
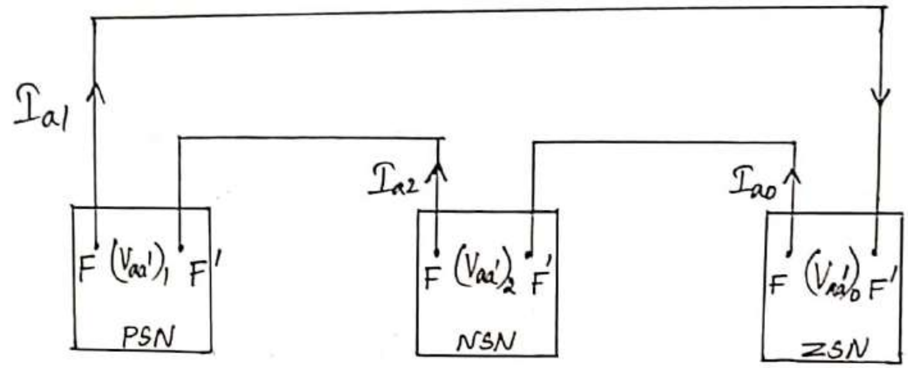
A. Terminal conditions: Ib = 0 ; Ic = 0 ; Vaa' = 0



$I_{a1}=I_{a2}=I_{a0}=(1/3).I_a$

$(V_{aa'})_0+(V_{aa'})_1+(V_{aa'})_2=0$



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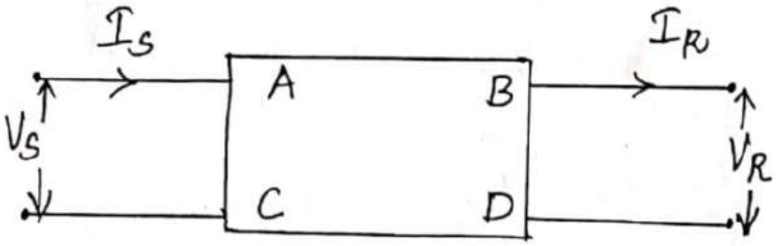
OR

B.



$$V_S = A V_R + B I_R \longrightarrow (1)$$

$$I_S = C V_R + D I_R \longrightarrow (2)$$

1

$$P = Re\left[V_R I_R^* \right]$$

$$I_R = \frac{V_S - A V_R}{B}$$

$$= \frac{|V_S| \angle \delta^\circ - |A| \angle \alpha^\circ \cdot |V_R| \angle 0^\circ}{|B| \angle \beta^\circ}$$

$$I_R^* = \frac{|V_S|}{|B|} \angle \beta - \delta - \frac{|A||V_R|}{|B|} \angle \beta - \alpha$$

1

$$\boxed{P = \frac{|V_R||V_S|}{|B|} \cos(\beta - \delta) - \frac{|A||V_R|^2}{|B|} \cos(\beta - \alpha)}$$

1

$$P_m = SSSL = \frac{|V_R||V_S|}{|B|} - \frac{|A||V_R|^2}{|B|} \cos(\beta - \alpha)$$

1

For a two-machine system, we have

SSSL = |Eg|.|Em| / |X|

SSSL can be increased by

(i)Increasing either of the voltages |Eg| or |Em|.

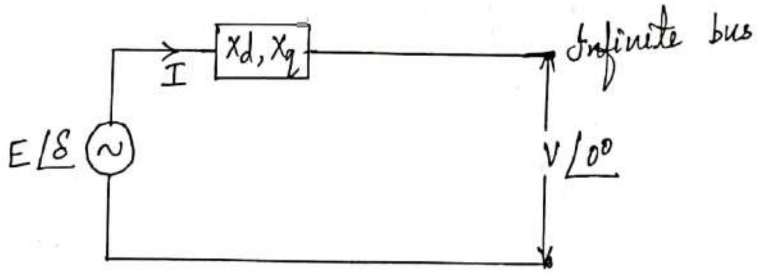
(ii) Reducing the reactance |X| between transmission and receiving side.

(iii) Series capacitors - better voltageRegulation, power factor and to raise the SSSL by decreasing the line reactance.

(iv) The use of **bundled conductors** is another method of reducing the line reactance and hence improving the SSSL.

2

Q.4 **A.**



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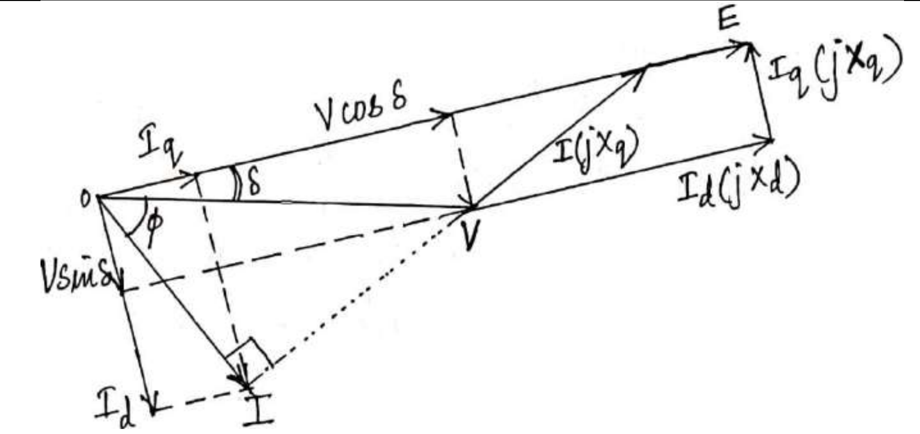
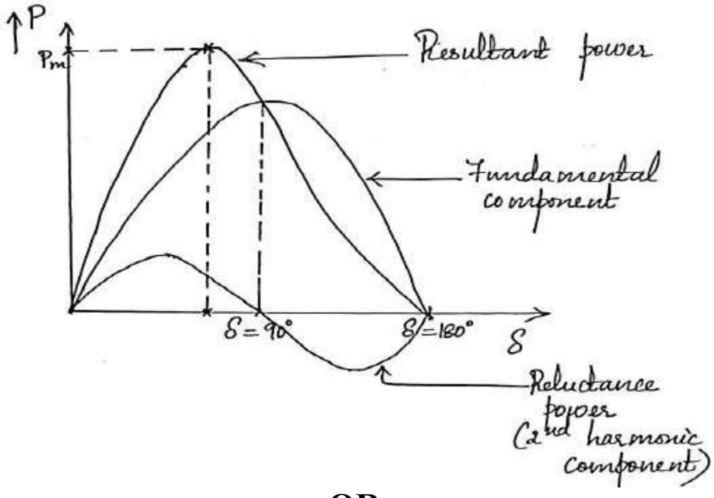


1

P = |V| cos δ. |Iq| + |V| sinδ. |Id|
|Iq . Xq| = |V| . sinδor |Iq| = |V| . sinδ /Xq
|Id . Xd| = |E – V cosδ|or |Id| = (|E| - |V| . Cosδ) /Xd

$$P = |V| \cos\delta \frac{(|V| \sin\delta)}{X_q} + |V| \sin\delta \frac{(|E| - |V| \cos\delta)}{X_d}$$

$$= \frac{|V||E|}{X_d} \sin\delta + \frac{|V|^2 (X_d - X_q)}{2 X_q X_d} \sin 2\delta$$ 2



2

OR

B. Transient Stability – It is defined as the ability of the power system to return to its normal conditions after a large disturbance. The large disturbance occurs in the system due to the sudden removal of the load, line switching operations; fault occurs in the system, sudden outage of a line, etc. 2

*** Large signal rotor angle stability**
*** Large signal voltage stability** 1

The methods to improve transient stability are:

Pm =| Eg| .|Em|) / X

(1) Increase of system voltages.
(2) Reduction of transfer reactance. 3
(3) Use of high speed circuit breakers and auto-reclosingbreakers.

Q.5

A.

$KE = GH = 20 * 9 = 180\ MJ$ **1**

$\frac{GH}{180f}\frac{d^2\delta}{dt^2} = P_m - P_e$ **1**

$\frac{180}{180*50} * \frac{d^2\delta}{dt^2} = 19.993 - 16$ **2**

Angular acceleration,

$\alpha = \frac{d^2\delta}{dt^2} = 199.65\ elec.deg/sec^2$ **2**

OR

B.

$I = |I|\angle\phi = \frac{P}{V\cos\phi}\angle{-\cos^{-1}(\phi)}$ $[lagging\ pf]$

$= \frac{1}{1*0.8}\angle{-\cos^{-1}(0.8)} = 1.25\angle{-36.87^\circ}\ pu$ **1**

$E' = V + I(jX_q)$

$= (1.3 + j0.4)\ pu = 1.36\angle{17.1^\circ}\ pu = |E'|\angle\delta^\circ$ **2**

$I_d = I\sin(\delta + \phi)$

$= 1.25\angle{-36.87^\circ} * \sin(17.1^\circ + 36.87^\circ)$

$= 0.8087 - j0.6065 = 1.01\angle{-36.87^\circ}$ **2**

$|I_d| = 1.01\ pu$

$|E| = |E'| + I_d X_d - I_d X_q$

$= 1.36 + 1.01(0.7 - 0.4) = 1.663\ pu$ **1**

Professor & Head EEE
The Oxford College of Engg
Bommanahalli, Hosur Road
Bangalore-560 068

Sixth Semester B.E. Degree Examination, June/July 2018
Power System Analysis – I

Time: 3 hrs. Max. Marks: 80

Note: *Answer FIVE full questions, choosing one full question from each module.*

Module-1

1 a. With suitable example explain one line diagram and discuss the elements represented. **(06 Marks)**

b. Draw the per unit reactions diagram for the power system shown in Fig. Q1 (b). Selecting the generator rating as the base. Also find the generator terminal voltage.

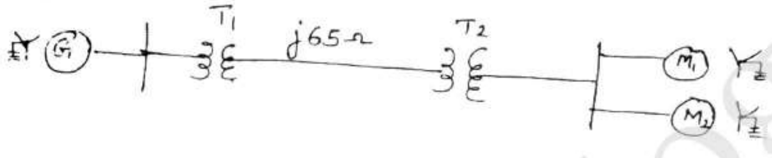


Fig. Q1 (b)

The ratings of the various components are,

G = 13.8 kV, 25 MVA, X″ = j0.15 pu ;

T_1 = 13.2/69 kV, 25 MVA, X = j0.11 pu; T_2 = 69/13.2 kV, 25 MVA, X = j0.11 pu;

M_1 = 13 kV, 15 MVA, X″ = j0.15 pu ; M_2 = 13 kV, 10 MVA, X″ = j0.15 pu

Determine the generator terminal voltage when both the motors operate at 12 kV 75% full load and unity power factor. **(10 Marks)**

OR

2 a. With help of typical electrical power system, explain impedance and reactance diagram and mention the assumptions made in that. **(06 Marks)**

b. The schematic diagram of a radial transmission system is shown in Fig. Q2 (b). The ratings and reactance of the various components are show there in. A load of 60 MW at 0.9 p.f lagging is tapped from 66 kV sub station which is to be maintained at 60 kV. Calculate the terminal voltages of the machine. Represent the transmission line and transformer by series reactance only. **(10 Marks)**

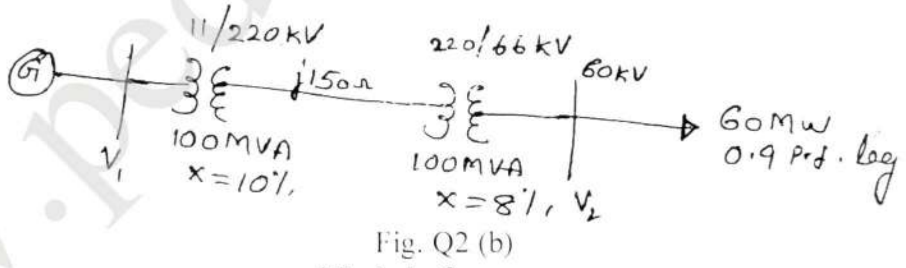


Fig. Q2 (b)

Module-2

3 a. What is the significance of transient and subtransient reactances in short circuit studies. Distinguish between transient and subtransient reactances of a synchronous machine. **(06 Marks)**

b. For the radial network shown in Fig. Q3 (b) a 3 phase fault occurs at point F. Determine the fault current. choose the generator ratings as base values:

Generator G_1: 10 MVA, 11 kV, X″ = 15% ; Generator G_2: 10 MVA, 11 kV, X″ = 12.5%

Transformer T_1 : 10 MVA, 11/33 kV, X = 10%; Transformer T_2 : 5 MVA, 33/6.6 kV, X= 8%

Overhead line impedance $z = +j\ \Omega$; Feeder impedance $z = (0.135 + j0.08)\ \Omega$/km

(10 Marks)

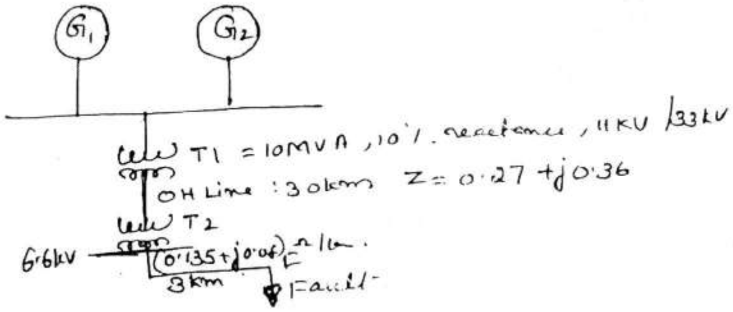


Fig. Q3 (b)

OR

4 a. What is doubling effect in a transmission line? Substantiate with equations. **(06 Marks)**

b. Generator G_1 and G_2 are identical and rated 11 kV, 20 MVA and have a transient reactance of 0.25 pu at own MVA base. The transformer T_1 and T_2 are also identical and are rated 11/66 kV, 5 MVA and have a reactance of 0.06 p.u. to their own MVA base. The tie line is 50 km long each conductor has a reactance of 0.848 Ω/km. The three phase fault is assumed at F, 20 km from generator G_1, as shown in Fig. Q4 (b). Find the short circuit current. **(10 Marks)**

Fig. Q4 (b)

Module-3

5 a. What are symmetrical components and explain how they are useful in solving the power system problems. **(04 Marks)**

b. Prove that : (i) $\left(1+\alpha+\alpha^2\right)=0$ (ii) $\left(\alpha-\alpha^2\right)=j\sqrt{3}$ (iii) $\left(\alpha^2-\alpha\right)=-j\sqrt{3}$ **(04 Marks)**

c. A balanced delta connected load is connected to a 3 phase symmetrical supply. The line currents are each 10 A in magnitude. If fuse in one of the lines blows out. Determine the sequence components of line currents. **(08 Marks)**

OR

6 a. Explain the concept of phase shift in star delta transformer bank. **(06 Marks)**

b. Draw the positive, negative and zero sequence networks for the power system shown in Fig Q6 (b).

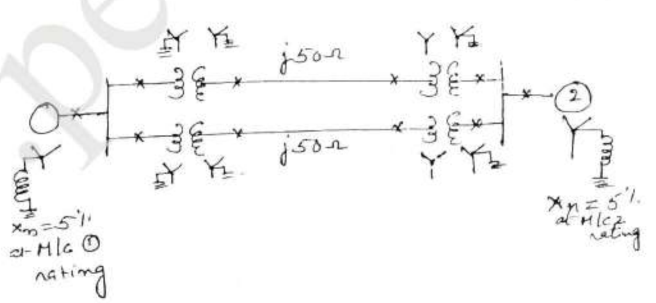


Fig. Q6 (b)

Choose a base of 50 MVA, 220 kV in the 50 Ω transmission lines and mark all reactances in p.u. The ratings of the generators and transformers are:

Generator 1 : 25 MVA, 11 kV, X″ = 20% ; Generator 2 : 25 MVA, 11 kV, X″ = 20%

Three phase transformer (each) : 20 MVA, $^{11\text{Y}}\!/_{220\text{Y}}$ kV, X = 15%

The negative sequences reactance of each syn machine is equal to the sub transient reactance. The zero sequence of each machine is 8%. Assume that the zero sequence of lines of lines are 250% of their positive sequence reactance. **(10 Marks)**

Module-4

7 a. Derive an expression for fault current when single line to ground fault occurs through a fault impedance Z_f in a power system. Draw the sequence network to represent the fault. **(10 Marks)**

b. For one conductor open fault in a power system, derive an expression for fault current. **(06 Marks)**

OR

8 a. What are the boundary/terminal condition in relation to the unsymmetrical faults. Mention the boundary conditions for LG, LL, LLL and LLG fault. **(06 Marks)**

b. A syn motor is receiving 10 MW of power at 0.8 pf lag at 6 kV. A LG fault takes place at the middle point of the transmission line as shown in Fig. Q8 (b), find the fault current. The ratings of the generator motor and transformer are as under.

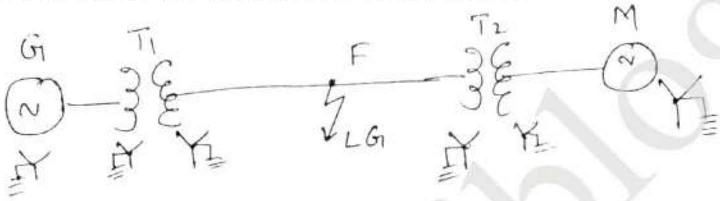


Fig. Q8 (b)

Generator: 20 MVA, 11 kV, $X_1 = 0.2$ pu, $X_2 = 0.1$ pu, $X_0 = 0.1$ pu

T_1 : 18 MVA, $^{11.5}/_{34.5}$ kV , X = 0.1 pu

T_2 : 15 MVA, $^{6.9}/_{34.5}$ kV , X = 0.1 pu

M : 15 MVA, 6.9 kV, $X_1 = 0.2$ pu, $X_2 = X_0 = 0.1$ pu

Transmission line : $X_1 = X_2 = 5\ \Omega$, $X_0 = 10\ \Omega$ **(10 Marks)**

Module-5

9 a. Briefly explain (i) Steady state stability (ii) Transient stability. **(06 Marks)**

b. A loss free alternator supplies 50 MW to an infinite bus, the SSSL being 100 MW. Determine if the alternator will remains stable if the input to the prime moves of the alternator is abruptly increased by 40 MW. **(10 Marks)**

OR

10 a. State and explain equal area criteria. What are the assumptions made in applying EAC? Discuss. **(06 Marks)**

b. The transfer reactances between a generator and an infinite bus bar operating at 200 kV under various conditions on inter connection are:

Prefault : 150 Ω per phase.

During fault : 400 Ω per phase

Past fault : 200 Ω per phase

If the fault is cleared when the rotor has advanced 60° electrical from the prefault position, determine the maximum load that could be transferred without loss of stability. **(10 Marks)**

CBCS SCHEME

USN ☐☐☐☐☐☐☐☐☐☐ **15EE62**

Sixth Semester B.E. Degree Examination, Dec.2018/Jan.2019
Power System Analysis – I

Time: 3 hrs. Max. Marks: 80

Note: Answer any FIVE full questions, choosing ONE full question from each module.

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages. 2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

Module-1

1 a. Show that the per unit impedance of a transformer is the same when referred to either primary or secondary side. **(04 Marks)**

b. Draw the circuit model of synchronous generator, transmission lines and transformer. **(04 Marks)**

c. The OLD of an unloaded power system is as shown in Fig.Q1(c). Reactance of Tr. Line are shown in figure. Draw the per unit impedance diagram. Choose a base of 50 MVA, 13.8 KV in G, circuit. The ratings are as under.

$G_1 \rightarrow 20$ MVA, 13.8 KV, $X'' = 0.2$Pu. $T_1 \rightarrow 25$MVA, 220/13.8 KV, X = 10%
$G_2 \rightarrow 30$ MVA, 18 KV, $X'' = 0.2$Pu. $T_2 \rightarrow 3$, 1ϕTr% each 10 MVA, 127/18 KV, X = 10%
$G_3 \rightarrow 30$ MVA, 20 KV, $X'' = 0.2$Pu. $T_3 \rightarrow 35$MVA, 220/22 KV, X = 10%. **(08 Marks)**

Fig.Q1(c)

OR

2 a. What is per unit quantity? Mention its advantage. **(04 Marks)**

b. How is the per unit impedance value in a given base are changed to per unit impedance value on new base. **(04 Marks)**

c. Draw the impedance diagram for the power system shown in Fig. Q2(c). The ratings of the components are as under.

$G_1 \rightarrow 25$ MVA, 11 KV, x = 15% $G_2 \rightarrow 30$ MVA, 12.5 KV, x = 20%
$M_1 \rightarrow 15$ MVA, 11 KV, x = 12% $M_2 \rightarrow 25$ MVA, 11.5 KV, x = 15%
$T_1 \rightarrow 30$ MVA, 13/132 KV, x = 25% $T_2 \rightarrow 35$ MVA, 132/11 KV, x = 20%

Choose a base of 132 KV on (100 + j150)Ω Tr. Line at 30 MVA base. **(08 Marks)**

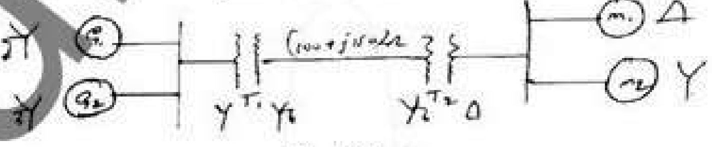


Fig.Q2(c)

Module-2

3 a. With the help of oscillogram of short circuit current of a synchronous generator operating on no load distinguish between subtransient, transient and steady state reactances. Also show that $X_d'' < X_d' < X_d$ with equivalent circuit diagram. **(08 Marks)**

b. A generator is connected to a synchronous motor through transformer. Reduced to a common base, the per unit subtransient reactance of generator and motor are 0.15 and 0.35 respectively. The leakage reactance of the transformer 0.1 pu. A 3ϕ short circuit fault occurs at terminals of the motor when terminal voltage of generator is 0.9 Pu, and output current of the generator is 1pu at 0.8 pf leading. Find the sub transient current in the fault, generator and motor. **(08 Marks)**

OR

4 a. Explain clearly how circuit breakers are rated. **(04 Marks)**

b. For the radial network shown in Fig.Q4(b), a 3ϕ fault occurs at 'F'. Determine the fault current. Choose a base of 100 MVA and base KV of 33 KV in overhead transmission line. **(12 Marks)**

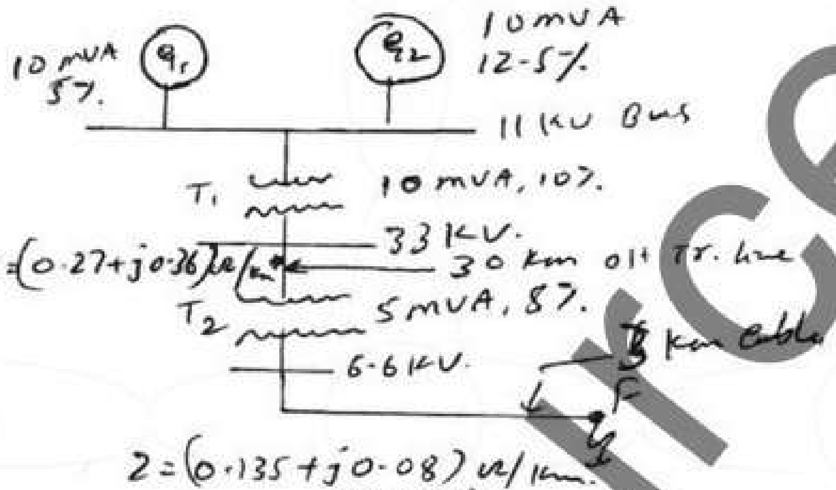


Fig.Q4(b)

Module-3

5 a. Derive an expression for the 3ϕ, complex power in terms of symmetrical components. **(08 Marks)**

b. Draw the zero sequence network for different combination of 3ϕ transformer bank. **(04 Marks)**

c. A balanced Δ connected load is connected to a 3ϕ symmetrical supply. The line currents are each 10A in magnitude. If fuse in one of the line is blown out. Determine the sequence component of the line current. **(04 Marks)**

OR

6 a. Derive an expression for symmetrical components of voltage in terms of phase voltage. **(06 Marks)**

b. Draw the positive, negative and zero sequence network for the power system shown in Fig.Q6(b). Choose a base of 50MVA, 220KV in the 50Ω transmission line and mark all reactance in per unit. The ratings are as under :
$G_1 \to$ 25 MVA, 12 KV, $X'' = 20\%$, $G_2 \to$ 25MVA, 11KV, $X'' = 20\%$ T_1 to $T_4 \to$ 20MVA, 11/220 KV, X = 15%.
The negative sequence reactance of each synchronous machine is equal to the subtransient reactance. The zero sequence reactance of each machine is 8%. Assume that the zero sequence reactance of line are 250% of their positive sequence reactance. **(10 Marks)**

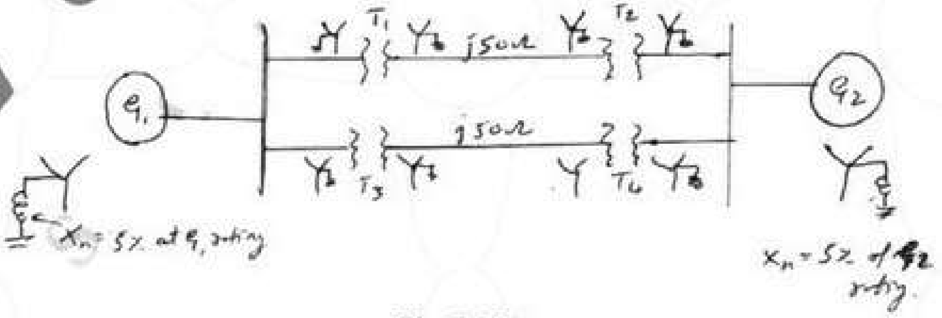


Fig.Q6(b)

Module-4

7 a. A double line to ground fault occurs at the terminals of an unloaded generator. Derive an expression for fault current, Draw the connection of sequence network. **(06 Marks)**

b. A 25MVA, 11KV, 3ϕ generator has a subtransient reactance of 20%. The generator suppliers 2 motor over transmission lines with transformer at both ends as shown in Fig.Q7(b). The motors have rated input of 15 MVA and 7.5MVA, both 10 KV, with 25% subtransient reactance. The 3ϕ transformer are both rated 30MVA, 10.8/121KV, ΔY, with leakage reactance of 10% each. The series reactance of the line is 100Ω. Calculate the fault current when a LG fault occurs at F. The motors are loaded to draw 15 MVA and 7.5MVA at 10KV and 0.8pf leading. Assume that negative sequence reactance is equal to positive sequence reactance. The zero sequence reactance are marked in the Fig.Q7(b). **(10 Marks)**

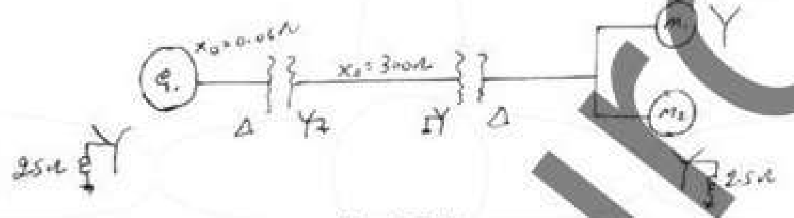


Fig.Q7(b)

OR

8 a. Derive an expression for fault current if LL fault occurs through a fault impedance Z_f in a power system. Show the connection of sequence network to represent the fault. **(06 Marks)**

b. A 3ϕ, 50MVA, 11KV, star connected neutral solidly grounded generator operating on no load at rated voltage give the following fault currents for the fault specified.
3ϕ fault → 2000A, LL fault-1800A, LG fault 2200A. Determine the 3 sequence reactance in ohm and per unit. **(10 Marks)**

Module-5

9 a. Derive swing equation for a synchronous reactance. **(08 Marks)**

b. A 3ϕ power system consists of a synchronous generator connected to a infinite bus bar through a loss less double circuit transmission line. A fault occurs on the transmission line. The maximum power transfer for the system when unfaulted is 5Pu and immediately prior to the instant of the fault the power transfer is 2.5pu. The power angle curves during fault and post fault conditions have peak values of 2pu and 4pu respectively. Determine the critical clearing angle. **(08 Marks)**

OR

10 a. Derive the power angle equation as applied to salient pole synchronous machine. **(07 Marks)**

b. Explain the terms :
- i) steady state stability
- ii) transient stability
- iii) dynamic stability as applied to power system **(03 Marks)**

c. A 50Hz, 4P, turbo generator rated 100MVA, 11KV, has an inertia constant of 8 MJ/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 50MW, find rotor acceleration not neglecting mechanical and electrical losses.
- iii) If the acceleration calculated in part (ii) is maintained for 10 cycles, find the change in torque angle and rotor speed in revolution per minute at the end of this period. **(06 Marks)**

* * * * *

CBCS SCHEME

USN ☐☐☐☐☐☐☐☐☐☐ **15EE62**

Sixth Semester B.E. Degree Examination, June/July 2019
Power System Analysis – I

Time: 3 hrs. Max. Marks: 80

Note: Answer any FIVE full questions, choosing ONE full question from each module.

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

Module-1

1 a. Show that per unit impedance of two winding transformer will remain same referred to primary as well as secondary. **(06 Marks)**

b. A 300 MVA, 20 KV, 3-phase generator has subtransient reactance of 20%. The generator supplies two synchronous motors through a 64 KVA transmission line having transformers at both ends as shown in Fig.Q1(b). T_1 is a 3-phase transformer and T_2 is composed of 3-single phase transformers of rating 100 MVA each, 127/13.2 KV, 10% reactance. series reactance of transmission line is 0.5 ohm/km. Draw the reactance diagram with all reactances marked in per unit. Select generator rating on base values.

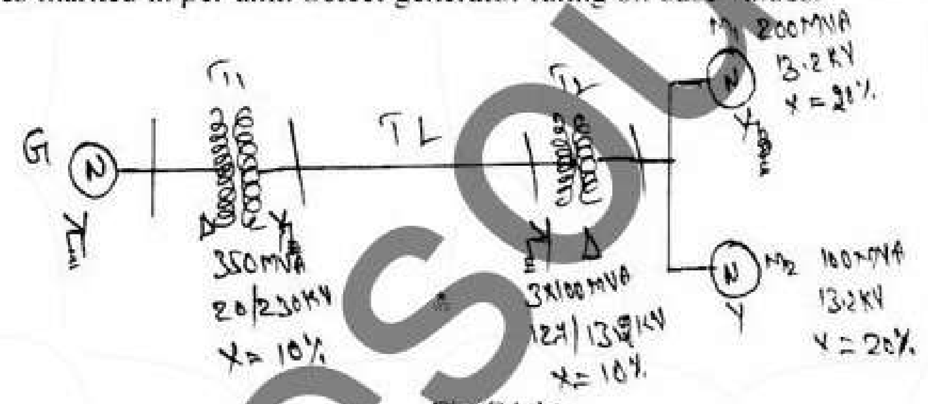


Fig.Q1(b) **(10 Marks)**

OR

2 a. Define per unit quantity. Mention the advantages of per unit system. **(04 Marks)**

b. The one line diagram of an unloaded generator is shown in Fig.Q2(b). Draw the PU reactance diagram. Choose a base of 50 MVA, 13.8 KV in the circuit of generator G_1. The ratings are as follows:

G_1 : 20 MVA, 13.8 KV, $X'' = 20\%$ T_1 : 25 MVA, 13.8/220 KV, $X = 10\%$
G_2 : 30 MVA, 18 KV, $X'' = 20\%$ T_2 : 30 MVA, 220/18 KV, $X = 10\%$
G_3 : 30 MVA, 20 KV, $X'' = 20\%$ T_3 : 35 MVA, 220/22 KV, $X = 10\%$

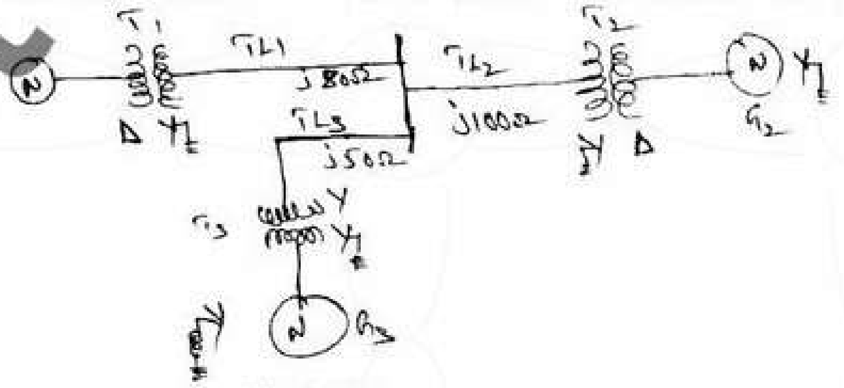


Fig.Q2(b) **(12 Marks)**

Module-2

3 a. With the help of waveform at the time of three phase symmetrical fault, on synchronous generator define steady state, transient and subtransient reactances. **(08 Marks)**

b. A generator is connected to a synchronous motor through transformer. Reduced to a common base, the per unit subtransient reactances of generator and motor are 0.15 and 0.35 PU respectively. The leakage reactance of the transformer is 0.1 PU. A 3-phase star circuit fault occurs at terminals of the motor when terminal voltage of generator is 0.9 P.U and output current of generator is 1 P.U at 0.8 pf leading. Find the subtransient current in the fault, generator and motor.

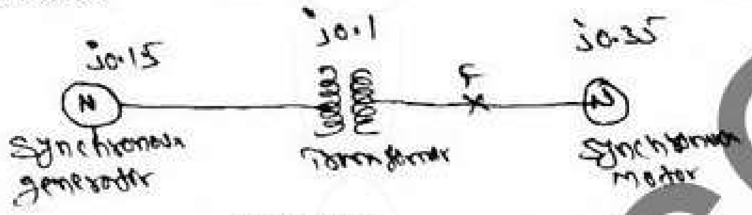


Fig.Q3(b) **(08 Marks)**

OR

4 a. Explain clearly, how circuit breaker are rated? **(06 Marks)**

b. A synchronous generator and motor are rated 30 MVA, 13.2 KV, both have subtransient reactance of 20%. The line connecting them has a reactance of 20%, on the base of machine rating. The motor is drawing 20 MW at 0.8 pf (lead). The terminal voltage of motor is 12.8 KV, when a symmetrical fault occurs at motor terminals, find subtransient current in generator, motor and at the point of fault? **(10 Marks)**

Module-3

5 a. Obtain the relationship between line and phase sequence components of voltages in star connection. Give the relevant phasor diagrams. **(08 Marks)**

b. Draw the positive, negative and zero sequence network for the power system shown in Fig.Q5(b). Choose a base of 50 MVA, 220 KV in the 50Ω transmission lines and marks all reactances in PU. The ratings of the generator and transformers are:

G_1: 25 MVA, 11 KV, X″ = 20%, G_2: 25 MVA, 11 KV, X″ = 20%

3ϕ transformers (each) : 20 MVA, 11/220 KV, X = 15%

The negative sequence reactance of each synchronous machine is equal to the sub-transient reactance. The zero sequence reactance of a each machine is 8%. Assume that the zero sequence reactances of lines are 250% of their positive sequence reactances.

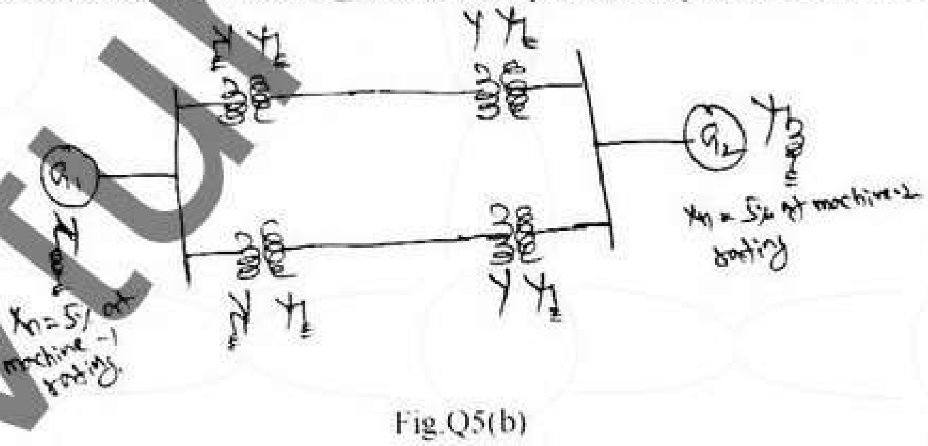


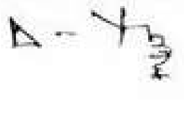
Fig.Q5(b) **(08 Marks)**

OR

6 a. Draw the zero sequence impedance networks of a transformer for the following connections:

i) 

ii) 

iii) 

(06 Marks)

b. The positive, negative and zero sequence components of line currents are $20\angle 10^\circ$, $6\angle 60^\circ$ and $3\angle 30^\circ$ A respectively. Determine the line currents. **(04 Marks)**

c. In a 3ϕ, 4 wire system, the sequence voltages and currents are:

$V_{a1} = 0.9\angle 10^\circ$ PU ; $V_{a2} = 0.25\angle 110^\circ$ PU ; $V_{a0} = 0.12\angle 300^\circ$ PU ;

$I_{a1} = 0.75\angle 25^\circ$ PU ; $I_{a2} = 0.15\angle 170^\circ$ PU ; $I_{a0} = 0.1\angle 330^\circ$ PU

Find the complex power in PU. If the neutral gets disconnected, find the new power. **(06 Marks)**

Module-4

7 a. An unloaded fully excited three phone aftemafor is subjected to an L-G fault at its terminals. Find the fault current. Using symmetrical components by showing the interconnection of all sequence networks. **(08 Marks)**

b. Draw the sequence networks for the system shown in Fig.Q7(b). Determine the fault current if a line to line occurs at F. The PU reactances all referred to the same base are as follows. Both the generators are generating 1.0 PU.

Component	X_0	X_1	X_2
G_1	0.05	0.30	0.20
G_2	0.03	0.25	0.15
Line-1	0.70	0.30	0.30
Line-2	0.70	0.30	0.30
T_1	0.12	0.12	0.12
T_2	0.10	0.10	0.10

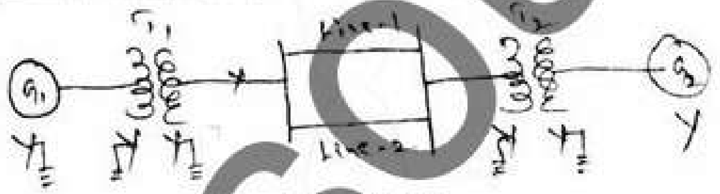


Fig.Q7(b) **(08 Marks)**

OR

8 a. Derive expression for fault current if Line-Line-Ground (LLG) fault occurs through fault impedance Z_f in power system. Show the connection of sequence networks to represent the fault. **(08 Marks)**

b. A three phase generator with an open circuit voltage of 400 V is subjected to an LG fault through a fault impedance of j2Ω. Determine the fault current is Z_1 = j4Ω, Z_2 = j2Ω and Z_0 = j1Ω. Repeat the problem for LL fault. **(08 Marks)**

Module-5

9 a. Explain 'equal area criteria' concept when a power system is subjected, to sudden loss of one of the 'parallel lines'. **(08 Marks)**

b. Define stability pertaining to a power system and classify the different types of stability. **(04 Marks)**

c. A 2 pole, 50 Hz, 11 KV turbo alternator has a rating of 100 MW, 0.85 p.f. lagging. The rotor has moment of inertia of 10000 kg-m². Calculate H and M. **(04 Marks)**

OR

10 a. Derive the power angle equation of a salient pole synchronous machine connected to an infinite bus. Draw the power angle curve. **(08 Marks)**

b. Derive an expression for the swing equation. **(08 Marks)**

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CBCS SCHEME

USN ☐☐☐☐☐☐☐☐☐☐ **15EE62**

Sixth Semester B.E. Degree Examination, Dec.2019/Jan.2020

Power System Analysis – I

Time: 3 hrs. Max. Marks: 80

Note: Answer any FIVE full questions, choosing ONE full question from each module.

Module-1

1 a. Define per unit quantity. Mention the advantages of per unit system. **(04 Marks)**

b. Show that the per unit impedance of a transformer remains same whether it is referred to HV or LV winding. **(04 Marks)**

c. A 100MVA, 33KV 3ϕ generator has a subtransient 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 30MVA, 20MVA and 50MVA at 30KV with 20% subtransient reactance each. The three phase transformers are rated at 100MVA 32KV-Δ/110 KV-Y with 8% leakage reactance. The line has a reactance of 50Ω. By selecting the generator ratings as base in the generator circuit, determine the loose values in all other parts of the system, Hence evaluate the corresponding per unit values and draw the equivalent per unit reactance diagram. (Ref.Fig.Q.1(c)) **(08 Marks)**

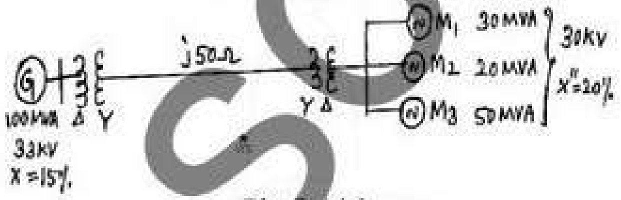


Fig.Q.1(c)

OR

2 a. Draw single line diagram of a power system indicating the various components of it. Obtain the impedance diagram and reactance diagram. Explain each component and the assumptions made to draw the reactance diagram. **(08 Marks)**

b. A 300MVA, 20KV 3 phase generator has a reactance of 20%. The generator supplies two motors M_1 and M_2 over a transmission line of 64KM as shown in one line diagram in Fig.Q.2(b).

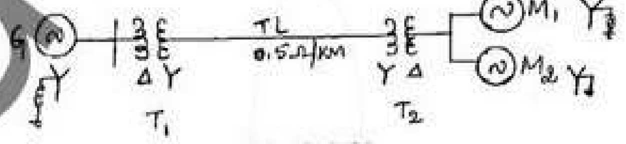


Fig.Q.2(b)

Ratings:

T_1 : 350MVA 230 KV-Y/20KV-Δ, X = 10%

T_2 : Composed of three single phase transformers each rated $\underset{Y}{127}/\underset{\Delta}{13.2}$ KV, 100MVA with reactance of 10%

M_1 : 200MVA, 13.2 KV X'' = j0.2pu

M_2 : 100MVA, 13.2 KV X'' = j0.2pu

Select the generator ratings as base and draw the reactance diagram with all reactances marked in pu. **(08 Marks)**

Module-2

3 a. Explain the transients occurring on a transmission line on the occurrence of a short circuit. Obtain the expression for maximum momentary current. **(06 Marks)**

b. A 25MVA, 11KV generator with $X''_d = 20\%$ is connected through a transformer, line and a transformer to a bus that supplies three identical motors as shown in Fig.Q.3(b). Each motor has X''_d = 25% and $X'_d = 30\%$ on a base of 5MVA, 6.6KV. The three phase rating of the step-up transformer is 25MVA, 11/66 KV with a leakage reactance of 10% and that of step-down transformer is 25MVA, 66/6.6KV with X = 10%. The bus voltage of the motors is 6.6KV when a three-phase fault occurs at point F. Calculate:

i) The subtransient current in the fault
ii) The subtransient current in the breaker B
iii) The momentary current in breaker B and
iv) The current to be interrupted by breaker B in five cycles.

X of transmission line is 15% on a base of 25MVA, 66KV. Assume that the system is on no load when the fault occurs.

Fig.Q.3(b) **(10 Marks)**

OR

4 a. With the help of oscillogram of short circuit current, of a synchronous generator, operating on no load, distinguish between subtransient, transient and steady state periods. Prove that $X''_d < X'_d < X_d$. **(08 Marks)**

b. A 25MVA, 13.2KV synchronous generator is connected to a synchronous motor of same rating. Both have a transient reactance of 15%. The line connecting them has a reactance of 10% on the machine base. The motor is drawing a power of 18MW at 0.8 pf lead, at 12.9KV, when a short circuit occurs at its terminals, find the subtransient currents in the motor, generator and at fault points. **(08 Marks)**

Module-3

5 a. What are symmetrical components? Obtain the expression for symmetrical components interms of unbalanced phasor of voltages and currents. **(06 Marks)**

b. What are sequence impedances and sequence networks? Explain the sequence impedances of a synchronous generator. **(06 Marks)**

c. In a 3 phase system supplying power to a Y load, the line currents when the neutral of the supply is not connected to the neutral of the load are $I_a = 20\angle 0^\circ$ A and $I_b = 20\angle -100^\circ$ A. When the neutrals are connected, the current through the neutral wire is found to be $12\angle -30^\circ$ A. Determine the line currents under this situation. **(04 Marks)**

OR

6 a. Determine the relation between the symmetrical components of voltages on either side of a star-delta transformer. **(08 Marks)**

b. Explain the effect of neutral in 3 phase system with 3 wire and four wire. **(04 Marks)**

c. A 250MVA, 11KV, 3 phase generator is connected to a large system through a transformer and a line as shown in Fig.Q.6(c).

Fig.Q.6(c)

The parameters on 250MVA base are as follows:
Generator: $X_1 = X_2 = 0.15$pu $X_0 = 0.1$pu
Transformer: $X_1 = X_2 = X_0 = 0.12$pu
Line: $X_1 = X_2 = 0.25$pu $X_0 = 0.75$pu
Equivalent system: $X_1 = X_2 = X_0 = 0.15$pu. Draw the sequence network diagrams for the system and indicate all per unit values. **(04 Marks)**

Module-4

7 a. Define faults. Classify the unsymmetrical faults with its frequency of occurrence. **(04 Marks)**

b. Derive expression for fault currents if double line to ground fault occurs through fault impedance Z_f on a power system. **(08 Marks)**

c. A three phase generator with an open circuit voltage of 400V is subjected to an LG fault through a fault impedance of j2Ω. Determine the fault current if $z_1 = j4\Omega$, $z_2 = j2\Omega$ and $z_0 = j1\Omega$. Repeat the problem for LL fault. **(04 Marks)**

OR

8 A synchronous motor is receiving 10MW of power at 0.8pf lag at 6KV. An LG fault takes place at the mid point of the transmission line as shown in Fig.Q.8. Find the fault current. The ratings of the generator, motor and transformer are as follows.
Generator: 20MVA, 11KV, $X_1 = 0.2$pu, $X_2 = 0.1$pu, $X_0 = 0.1$pu
Transformer T_1: 18MVA, 11.5Y-34.5KV, X = 0.1pu
Transmission line: $X_1 = X_2 = 5\Omega$ $X_0 = 10\Omega$
Transformer T_2: 15MVA 6.9Y – 34.5Y KV X = 0.1pu
Motor: 15MVA, 6.9KV, $X_1 = 0.2$pu, $X_2 = X_0 = 0.1$pu.

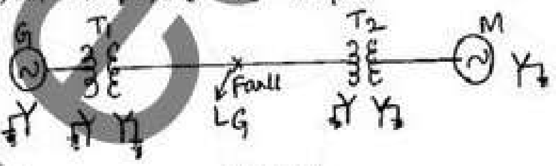


Fig.Q.8

Draw all the sequence network. **(16 Marks)**

Module-5

9 a. Derive the power angle equation of a non-salient pole synchronous machine. **(08 Marks)**

b. Find the steady state stability limit of a system consisting of a generator of equivalent reactance 0.5pu connected to an infinite bus through a series reactance of 1pu. The terminal voltage of the generator is held at 1.2pu and voltage of the infinite bus is 1.0pu. **(04 Marks)**

c. Define: i) Steady state stability and ii) Transient state stability. **(04 Marks)**

OR

10 a. Write short notes on: i) Equal area criterion ii) Swing curve **(08 Marks)**

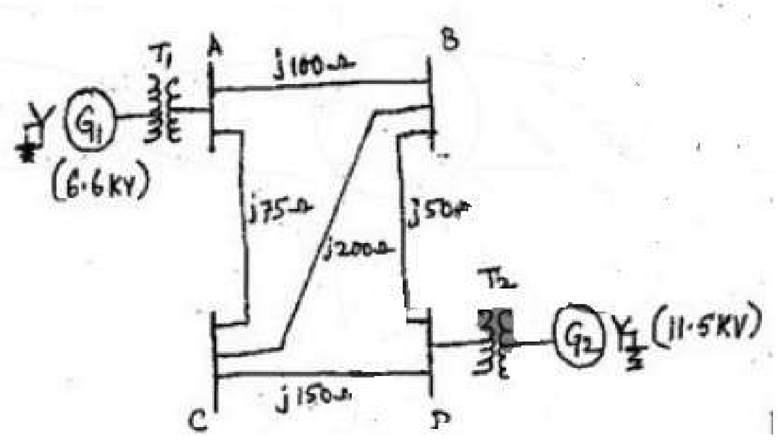
b. A loss free alternator supplies 50MW to an infinite bus, the steady state stability limit being 100MW. Determine if the alternator will remain stable if the input to the prime mover of the alternator is abruptly increased by 40MW. **(08 Marks)**

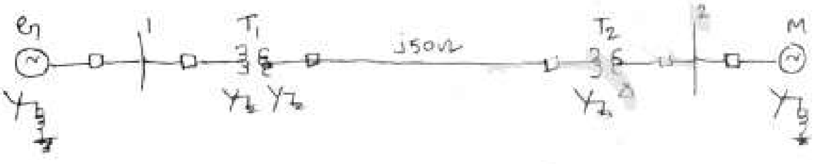
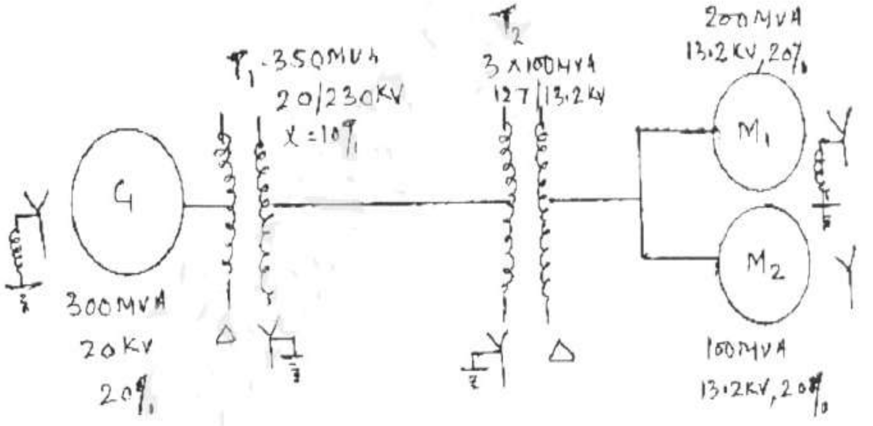
* * * * *

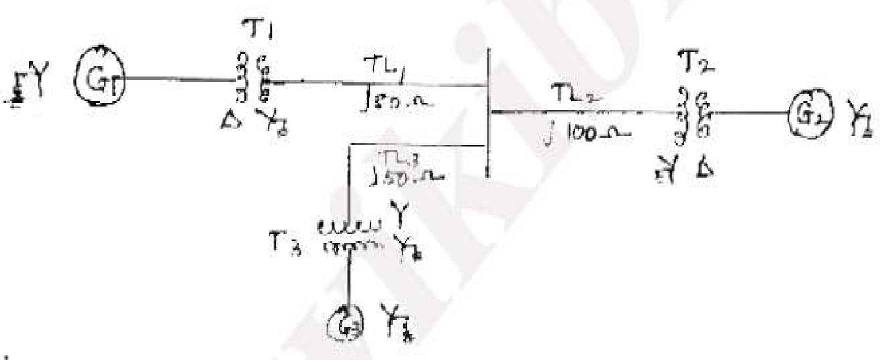
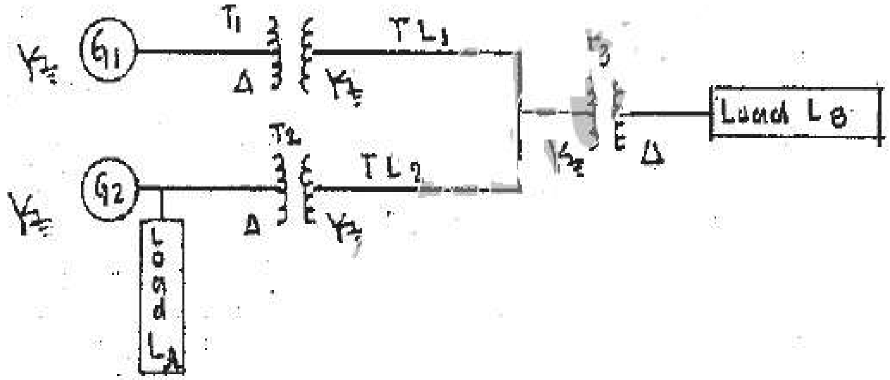
POWER SYSTEM ANALYSIS – I (Core Subject)Subject Code: 18EE62

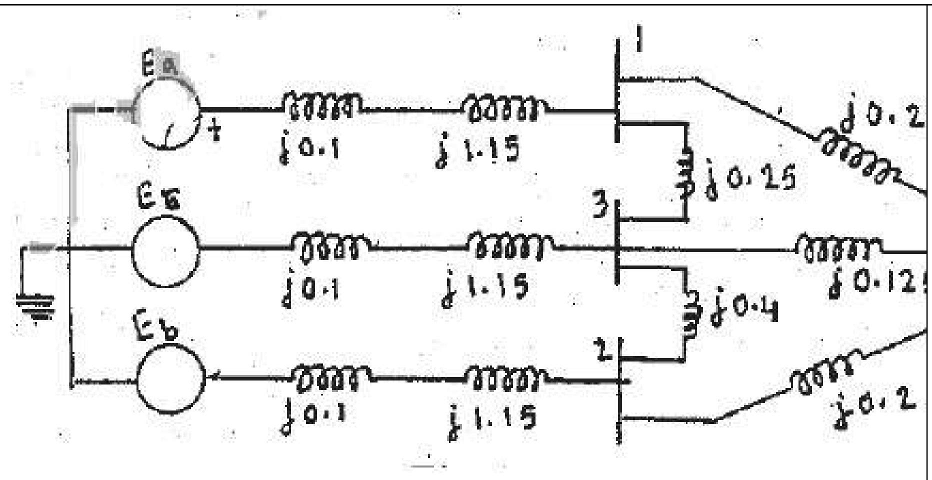
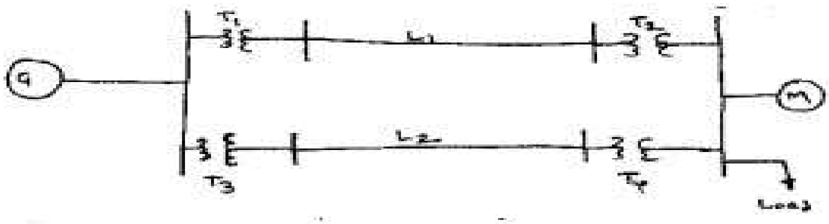
MODULE-1

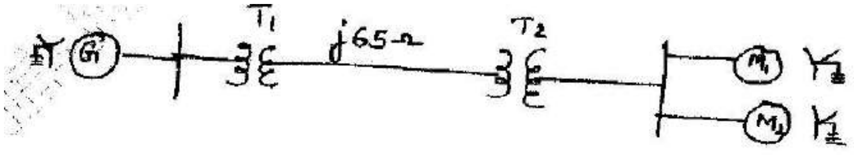
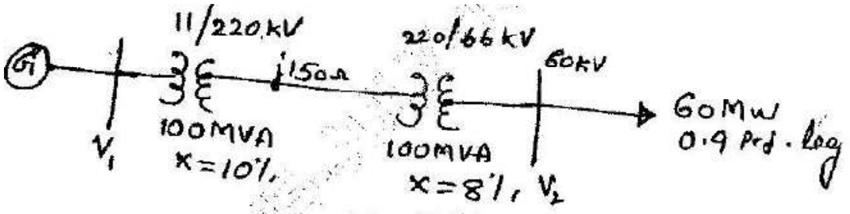
Representation of Power System Components: Introduction, Single-phase Representation of Balanced Three Phase Networks, One-Line Diagram and Impedance orReactance Diagram, Per Unit (PU) System,Steady State Model of Synchronous Machine, Power Transformer, Transmission of electrical Power, Representation of Loads.

1.	What is meant by one line diagram of a power system? With typical example explain its significance	8	June / July 2017
2.	Draw the per unit reactance diagram for the power system shown in figure below on 20MVA, 6.6KV base in the generator1 circuit. The rating of the various components: Gen1: 10MVA, 6.6KV, X”=0.1Pu, Gen2: 20MVA, 11.5KV, X”=0.1Pu, Transformer1: 10MVA, 3 phase, 6.6/115KV, X=0.15pu, Transformer2: 3, 1 phase units each rated 10MVA, 7.5/75KV, X=0.10pu 	12	June / July 2017
3.	What is per unit quantity? Mention the advantages of per unit quantities	6	Dec 2016
4.	What is single line diagram? Explain how to obtain impedance and reactance diagrams from single line diagram of a power system	6	Dec 2016 /Jan 2017
5.	Draw a per unit reactance diagram for the power system shown in figure below. Use a base of 100MVA, 220KV in 50 ohm line. The ratings of the generator, motor and transformer are Generator: 40MVA, 25KV, X”=20%, Motor: 50MVA, 11KV, X”=30%, Star - star Transformer: 40MVA, 33 star/220 star KV, X=15%, Y –delta Transformer: 30MVA, 11 Delta / 220 Y KV, X=15%	8	Dec 2016 / Jan 2017

			
6.	Show the per unit impedance of two winding transformer will remain same referred to primary as well as secondary	6	June / July 2016 June / July 2015
7.	A 300MVA, 20KV, 3 phase generator has sub transient reactance of 20%. The generator supplies two synchronous motors through a 64Km transmission line having transformers at both ends as shown in figure. T1 is a 3 phase transformer and T2 is composed of 3 single phase transformers of 100MVA each, 127/13.2KV, and 10% reactance. Series reactance of transmission line is 0.5 ohm/ Km. Draw the reactance diagram with all reactances marked in per unit. Select generator rating as base values 	10	June / July 2016 Dec 2013 / Jan 2014 Dec 2015/ Jan2016
8.	What are the advantages of per unit system?	4	Dec 2015 / Jan 2016
9.	Draw the per phase basis modelling of synchronous machines, transformers, transmission line and load.	4	Dec 2015 / Jan 2016 June/July 2013
10	The one line diagram of an unloaded generator is shown in figure. Draw the PV reactance diagram. Choose a base of 50MVA, 13.8KV in the circuit of generator G1. The ratings are as follows: G1: 20MVA, 13.8KV,	10	June / July 2015

	X”=20%, T1: 25MVA, 13.8/220KV, X=10%, G2: 30MVA, 18KV, X”=20%, T2: 30MVA, 220/18KV, X=10%, G3: 30MVA, 20KV, X”=20%, T3:35MVA, 220/22KV, X=10%  		
11	Draw the impedance diagram for the power system shown in figure and mark on it the per unit impedance calculated on a base of 50MVA, 13KV in the circuit of generator1. The ratings are as follows: G1: 25MVA, 13KV, Xd”=0.15pu, T1: 30MVA, 220 Y/13.84KV, X=10%, G2: 35MVA, 22KV, Xd”=0.12, T2: 40MVA, 220/20KV, X=12%, T3: Bank of 1 Phase transformers each rated 10MVA, 127/18KV, X = 8%, Load La=3+j1 ohm, Load Lb=4+j2 ohm, Transmission line TL1=j60 ohms, Transmission line TL2 = j90 Ohms.  	12	June / July 2014
12	Write in matrix form, the node equations necessary to solve for the voltages of numbered buses as shown in figure below. All the impedances are marked in per unit.	8	June / July 2014

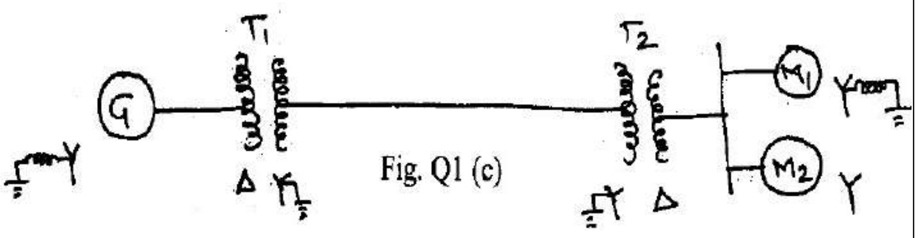
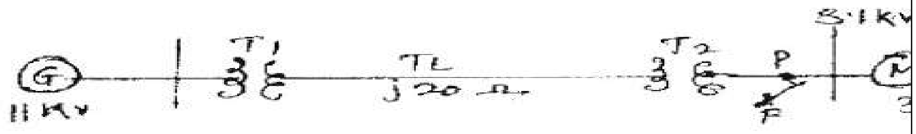
			
13	Explain the procedure of drawing reactance diagram. List the assumptions made	4	Dec 2013 / Jan 2014
14	Derive an equation for per unit impedance if a change of base occurs	3	June / July 2013
15	Draw the per unit impedance diagram of power system shown in figure below Ratings: Generator G: 22KV, 90MVA, Xg”=18%, Transformer T1: 22/220KV, 50MVA,X=10%, Line L1: j48.4ohm, Transformer T2: 11/220KV, 40MVA, X=6%, Transformer T3: 22/110KV, 40MVA, X=6.4%, Line 2: j65.13ohm, Transformer T3: 11/110KV, 40MVA, X= 8%; Motor M: 10.45KV, 66.5MVA, X= 18.5%: load: 57MVA, 0.6Lag, 10.15KV. Take base KV=22 and base MVA = 100 in the generator circuit. 	13	June / July 2013
16	With suitable example explain one line diagram and discuss the elements represented.	06	June / July 2018

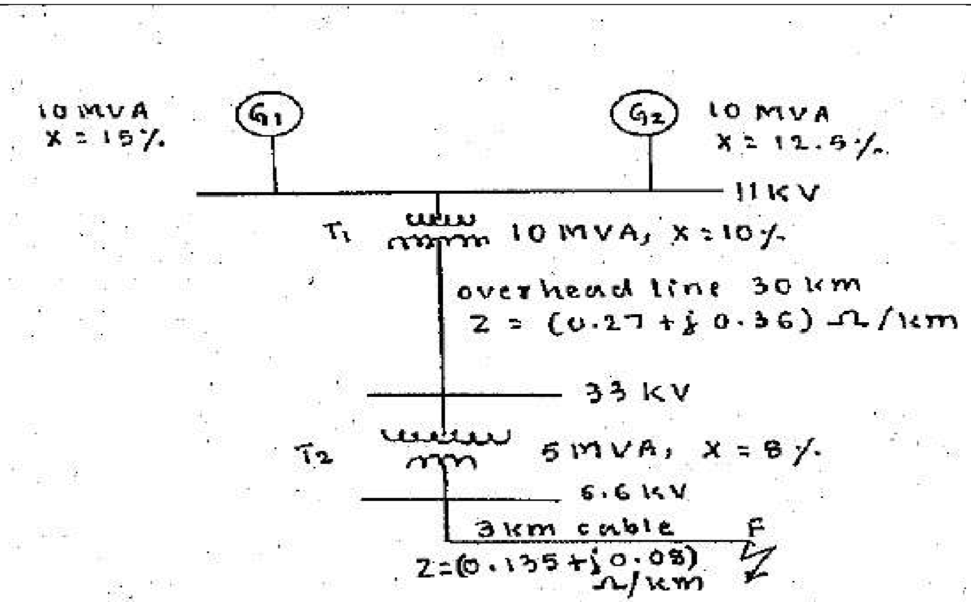
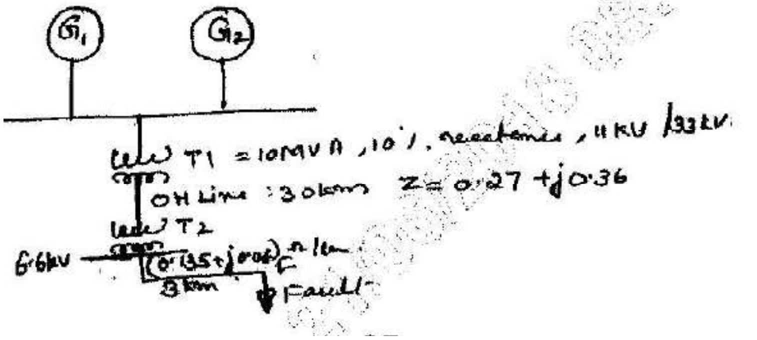
17	Draw the per unit reactions diagrams for the power system shown in fig 1(b).selecting the generator rating as the base. Also find the generator terminal voltage  Fig. Q1 (b) The ratings of the various components are , G=13.8Kv,25MVA,X”=j0.15pu; T1=13.2/69Kv,25MVA,X=j0.11 pu;T2=69/13.2 Kv,25MVA,X=j0.15 pu Determine the generator terminal voltage when both motors operate at 12KV,75% full load and unity power factor.	10	June / July 2018
18	With the help of typical electrical power system ,explain impedance and reactance diagrams and mention the assumptions made in that.	6	June / July 2018
19	The schematic diagram of a radial transmission system is shown in fig 2(b).The ratings and reactance of the various components are show there in A load of 60MW at 0.9 p.f lagging is tapped from 66Kv substation which is to be maintained at 60Kv.Calculate the terminal voltages of the machine.Represent the transmission line and transformer by series reactance only.  Fig. Q2 (b)	10	June / July 2018

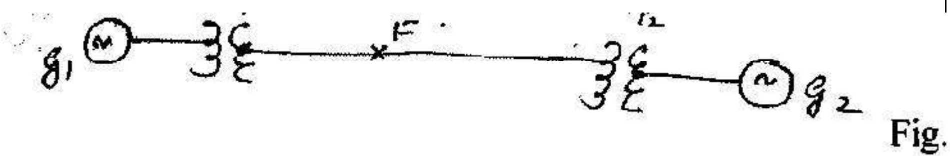
MODULE – 2

Symmetrical Fault Analysis: Introduction, Transient on a Transmission Line, Short Circuit of a Synchronous Machine(On No Load), Short Circuit of a Loaded Synchronous Machine, Selection of Circuit Breakers.

1.	What are symmetrical components and their significance and obtain the equations for their average power and reactive power in terms of symmetrical components	8	June / July 2017
2.	The voltage at the terminals of a three phase balanced load consisting of three (10+j8) ohms connected in star are Vab=100∠0V, Vbc=90∠240, Vca=94∠120 . Find the power consumed in load using symmetrical components.	12	June / July 2017
3.	Discuss the different types of faults in power system.	4	Dec 2016
4.	Explain clearly, how circuit breakers are rated?	8	Dec 2016
5.	A generator is connected to a synchronous motor through transformer. Reduced to a common base, the per unit sub transient reactances of generator and motor are 0.15 and 0.35 pu respectively. The leakage reactance of the transformer is 0.1pu. A 3 phase short circuit fault occurs at terminals of the motor when terminal voltage of generator is 0.9pu and output current of generator is 1 pu at 0.8pf leading. Find the sub transient current in the fault, generator and motor	8	Dec 2016/ Jan 2017
6.	A sudden three phase short circuit takes place at the terminals of an unloaded three phase alternator. Discuss briefly on different reactances that are met with assuming that the damper windings are provided at the pole faces of the alternator	8	June / July 2016
7.	A synchronous generator and motor are rated 30MVA, 13.2KV and both have sub transient reactances of 20%. The line connecting them has a reactance of 10% on the base of the machine ratings. The motor is drawing 20MW at 0.8Power factor leading and a terminal voltage of 12.8KV when a symmetrical three phase fault occurs at the motor terminals. Find the sub transient current in the generator, motor and the fault by using internal voltages of the machines.	12	June / July 2016 Dec 2013 / Jan 2014
8.	With the help of waveform at the time of three phase symmetrical fault on 3 phase synchronous generator, define synchronous reactances. (Steady state, transient and sub transient condition)	6	Dec 2015 / Jan 2016 June / July

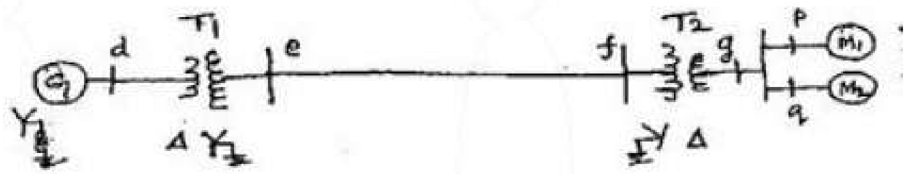
			2013
9.	A synchronous generator and synchronous motor each rated 25MVA, 11KV having 15% sub transient reactance are connected through transformers and line as shown in figure. The transformers are rated 25KVA, 11/66KV and 66/11KV with leakage reactance of 10% each. The line has a reactance of 10% on base of 25MVA, 66KV. The motor is drawing 15MW at 0.8Power factor leading and terminal voltage of 106KV when a symmetrical three phase fault occurs at the motor terminals. Find sub transient current in the generator motor and fault. Choose base of 25MVA, 11KV in the generator circuit.  Fig. Q1 (c)	14	Dec 2015 / Jan 2016 June / July 2013
10.	With the oscillogram of the short circuit current of a synchronous machine, define sub transient reactance, transient and steady state reactances.	10	June / July 2015
11	For the system shown in figure. The ratings of the various components are G: 25MVA, 12.4KV, Xd”=10%, M: 20MVA, 3.8KV, Xd”=15%, T1: 25MVA, 11/33KV, X=8%, T2: 25MVA, 33/3.3KV, X=10%, Tline: 20 ohm reactance. The system is loaded such that the motor is drawing 15MW at 0.9pf leading, the motor terminal voltage being 3.1KV. Find the sub transient fault current at motor side. Choose 25MVA as base power, 11KV in the generator circuit.  	10	June / July 2015
12	Explain in detail the transients on a transmission line	8	June / July 2014
13	For the radial network shown in figure, a 3 phase fault occurs at F. Determine the fault current and line voltage at 11KV bus under fault condition. Select a base of 100MVA, 11KV on generator side	12	June / July 201

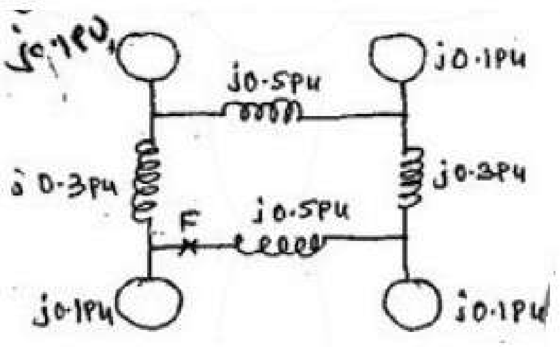
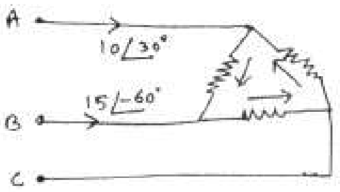
			4
14	In a synchronous machine Xd”<Xd’ <Xd why?	10	Dec 2013 / Jan 2014
15	What is the signifance of transient and sub transient reactances in short circuit studies. Distinguish between transient and sub transient reactance’s of a synchronous machine.	06	June / July 2018
16	**For the radial network shown in Fig. Q3 (b) a 3 phase fault occurs at point F. Determine fault current, choose the generator ratings as base values:** **Generator G_1: 10 MVA, 11 kV, $X''=15\%$; Generator G_2: 10 MVA, 11 kV, $X''=12.5\%$** **Transformer T_1 : 10 MVA, 11/33 kV, X = 10%; Transformer T_2 : 5 MVA, 33/6.6 kV, X=** **Overhead line impedance $z=+j\ \Omega$; Feeder impedance $z=(0.135+j0.08)\ \Omega/\text{km}$**  Fig. Q3 (b)	10	June / July 2018
17	What is the doubling effect in a transmission line?substantiate with equations.	6	June / July 201

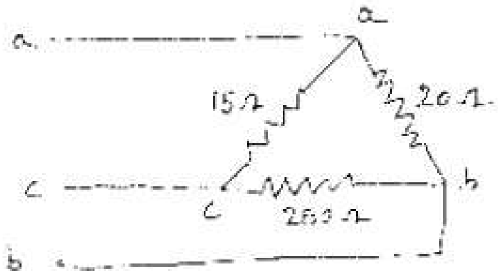
			8
18	Generator G_1 and G_2 are identical and rated 11 kV, 20 MVA and have a transient r of 0.25 pu at own MVA base. The transformer T_1 and T_2 are also identical and 11/66 kV, 5 MVA and have a reactance of 0.06 p.u. to their own MVA base. The ti 50 km long each conductor has a reactance of 0.848 Ω/km. The three phase fault is at F, 20 km from generator G_1, as shown in Fig. Q4 (b). Find the short circuit current  Fig.	10	June / July 2018

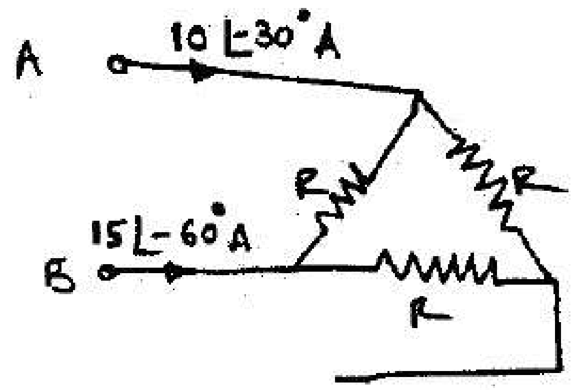
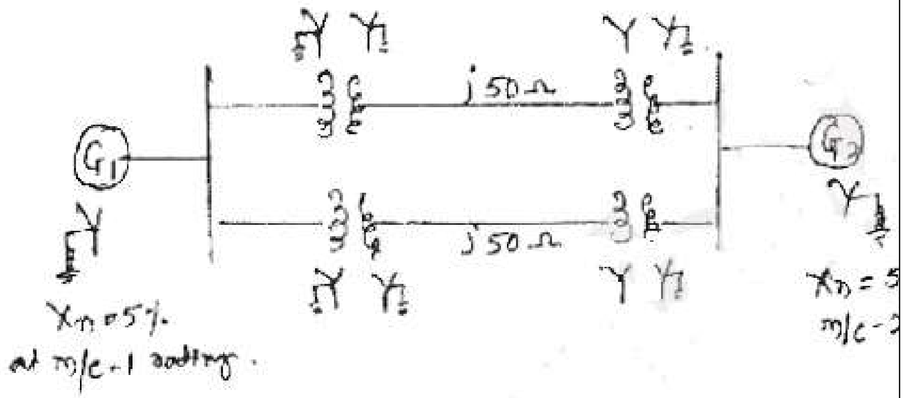
MODULE – 3.

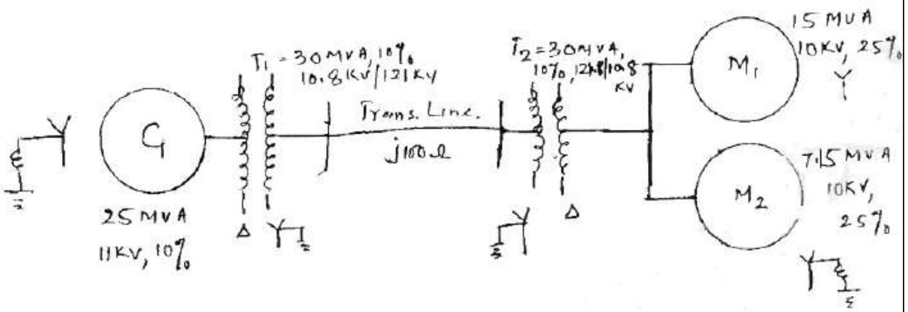
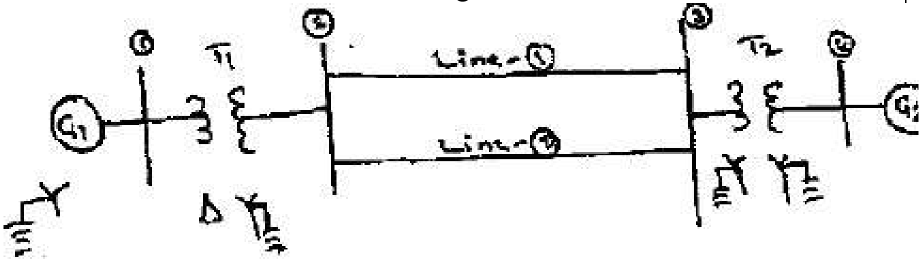
<u>Symmetrical Components:</u>Introduction, SymmetricalComponentTransformation, Phase Shift in Star-Delta Transformers, Sequence Impedances of Transmission Lines, Sequence Impedances and Sequence NetworkofPower System, Sequence Impedances and Networks ofSynchronous Machine, Sequence Impedances of Transmission Lines, Sequence Impedances and Networksof Transformers, Construction of Sequence Networks ofa Power System, Measurement of sequence Impedance of Synchronous Generator.

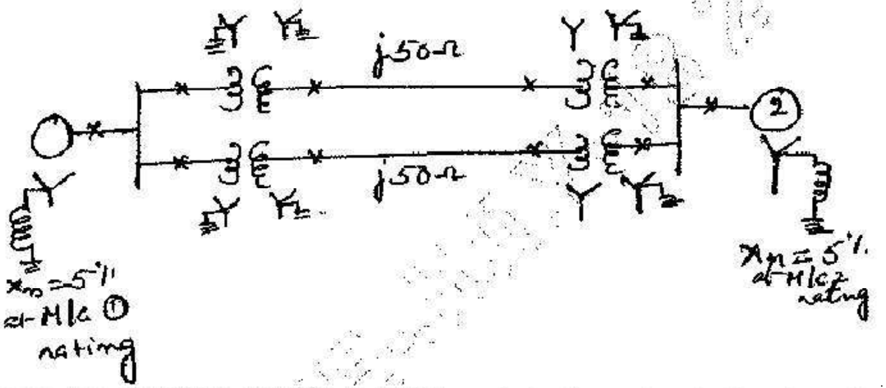
1.	What are sequence impedances and sequence network? Draw the single phase zero sequence networks for the transformers connected in different configuration.	8	June / July 2017
2.	A 25MVA, 11KV, 3 Phase generator has a sub transient reactance of 20%. The generator supplies two motors over a transmission line with transformers at both sides as shown in the one line diagram of figure. The motors have rated inputs of 15MVA and 7.5MVA both at 10KV with 25% sub transient reactance. The three phase transformers are rated 30MVA, 10.8/ 121KV, connection delta – star with leakage reactance of 10% each. The series reactance of the line is 100 ohms. Draw the positive, negative and zero sequence network of the system with all reactances marked in pu. Assume that the negative sequence reactance of each machine is equal to the sub transient reactance. Select the generator rating as the base in the generator circuit. Assume the zero sequence reactance for the generator and motors are 0.6pu each. Current limiting reactors of 2.5 ohms each are connected in the neutrals of the generator and motors. The zero sequence reactance of the transmission line is 300 ohms. 	12	June / July 2017
3.	Determine the fault MVA, if a 3 phase fault takes place at F in the diagram shown in figure. The pu values of reactances are given with 100MVA as	20	June/ July

	base.  		2017
4.	What are symmetrical components? How they are useful in solution of power system?	4	Dec2016/ Jan 2017
5.	Derive an expression for the 3 phase complex power in terms of symmetrical components	8	Dec 2016 / Jan 2017 June / July 2015
6.	A delta connected balanced resistive load is connected across a balanced 3 phase supply as shown in figure. With currents in lines A & B specified. Find the symmetrical components of the currents.  	8	Dec 2016 / Jan 2017
7.	With the help of relevant vector diagrams for voltages and currents establish the phase shift of symmetrical components in Y – Delta transformer	12	Dec 2016 / Jan 2017
8.	What are sequence impedances and sequence network? Draw the zero sequence networks for different combination of 3 phase transformer bank	8	Dec 2016 / Jan 2017, June / July 2015
9	The phase voltage of a three phase system are Va=100∠0, Vb=33∠100, Vc=38∠176.5 all in volts. Compute the symmetrical components	6	June / July 2016

	of voltages.		
10	Obtain the relationship between line and phase sequence components of voltages in star connection. Give the relevant phasor diagrams.	8	June / July 2016
11	Obtain an expression for power in terms of sequence components of line to neutral voltages and line currents	6	June / July 2016 June / July 2015
12	A delta connected balanced resistive load is connected across a balanced 3 phase supply of 400V as shown in figure. Find the symmetrical components of the currents. 	8	June / July 2016
13	Show that in symmetrical systems, currents of a given sequence produce voltage drops of the same sequence.	6	June / July 2016
14	Explain measurement of negative sequence impedance of synchronous generator	6	June / July 2016
15	Derive phase currents of unbalanced system in terms of sequence currents.	5	Dec 2015/ Jan 2016 June / July 2013
16	Develop an expression for three phase power in terms of symmetrical components	5	Dec 2015/ Jan 2016 June / July 2013
17	A delta connected balanced resistive load is connected across an unbalance three phase supply as shown in figure. With currents in lines A and B specified, find the symmetrical components of line currents.	10	Dec 2015/ Jan 2016 June / July 2014

			
18	Express symmetrical components in terms of unbalanced phasors	06	June / July 2015
19	In a 3 phase, 3 wire system the line currents are Ia=100∠0 and Ib=100 ∠-100 A. Determine the sequence components of a line currents.	6	June / July 2015
20	Draw the zero sequence impedance network of a transformer for the following connection: 1) Y (with gnd) – Y 2) Y – Delta 3) Delta – Y 4) Delta – Delta 5) Y(with gnd) – Y (with gnd) 6) Y (with gnd) - Delta	8	June / July 2015 June / July 2014
21	Draw the positive, negative and zero sequence network for the power system shown in figure. Choose a base of 50MVA 220KV in the 50ohm transmission lines and marks all reactances in pu. The ratings of the generator and transformers are: G1: 25MVA, 11KV, X”=20%, G2: 25MVA, 11KV, X”=20%, 3 phase transformers each: 20MVA, 11/220KV, X=15%. The negative sequence reactance of each synchronous machine is equal to the sub transient reactance. The zero sequence reactance of a each machine is 8%. Assume that the zero sequence reactances of lines are 250% of their positive sequence reactances. 	8	June / July 2015 June / July 2014
22	Prove that a balanced set of 3 phase voltages will have only positive sequence components of voltage only	6	June / July 2014

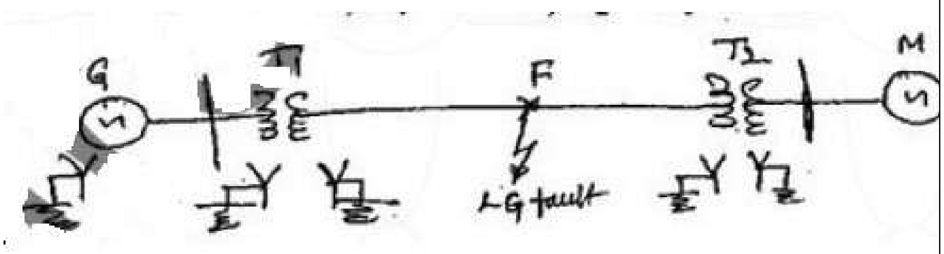
23	Show that power is invariant using symmetrical components	10	Dec 2013 / Jan 2014
24	The current flowing to a delta connected load through a line is 10A. With the current in line a as reference and assuming that line c is open. Find symmetrical components of line current	10	Dec 2013 / Jan 2014
25	Explain the phase shift of symmetrical components in Y – delta Transformer	8	Dec 2013 / Jan 2014
26	Determine the positive, negative and zero sequence networks for the system shown in figure. Assume zero sequence reactance for the generator and synchronous motors as 0.06pu. Current limiting reactors of 2.5 ohm are connected in the neutral of generator and motor no 2 . The zero sequence reactance of the transmission line is j300 ohm 	12	Dec 2013 / Jan 2014
27	Find the symmetrical components for three phase currents Ia = 10 $\angle$0 A, Ib =10$\angle$-90 A Ic= 15$\angle$135 A	6	June / July 2013
28	Figure shows a power system network. Draw positive, negative and zero sequence network. The system data is as under. Gen1: 100MVA, 11KV, X1=0.25pu, X2=0.25pu,X0= 0.05pu Gen2: 100MVA, 11KV, X1=0.2pu, X2=0.2pu,X0= 0.05pu T/F1: 100MVA, 11/220KV, X1=0.06pu, X2=0.06pu,X0= 0.06pu T/F2: 100MVA, 11/220KV, X1=0.07pu, X2=0.07pu,X0= 0.07pu Line1: 100MVA, 220KV, X1=0.1pu, X2=0.1pu,X0= 0.3pu Line2: 100MVA, 220KV, X1=0.1pu, X2=0.1pu,X0= 0.3pu Take a base of 11KV and 100MVA in generator 1 circuit. 	15	June / July 2013

29	What are symmetrical components and explain how they are useful in solving the power system problems.	4	June / July 2018
30	Prove that : (i) $\left(1+\alpha+\alpha^2\right)=0$ (ii) $\left(\alpha-\alpha^2\right)=j\sqrt{3}$ (iii) $\left(\alpha^2-\alpha\right)=-j\sqrt{3}$.	4	June / July 2018
31	A balanced delta connected load is connected to a 3 phase symmetrical supply. The line currents are each 10 A in magnitude. If fuse in one of the lines blows out. Determine the sequence components of line currents.	8	June / July 2018
32	Explain the concept of phase shift in star delta transformer bank.	6	June / July 2018
33	Draw the positive, negative and zero sequence networks for the power system shown in Fig  Choose a base of 50 MVA, 220 kV in the 50 Ω transmission lines and mark all reactances in p.u. The ratings of the generators and transformers are: Generator 1 : 25 MVA, 11 kV, X″ = 20% ; Generator 2 : 25 MVA, 11 kV, X″ = 20% Three phase transformer (each) : 20 MVA, $^{11\text{Y}}/_{220\text{Y}}$ kV, X = 15% The negative sequences reactance of each syn machine is equal to the sub transient reactance. The zero sequence of each machine is 8%. Assume that the zero sequence of lines of lines are 250% of their positive sequence reactance.	10	June / July 2018

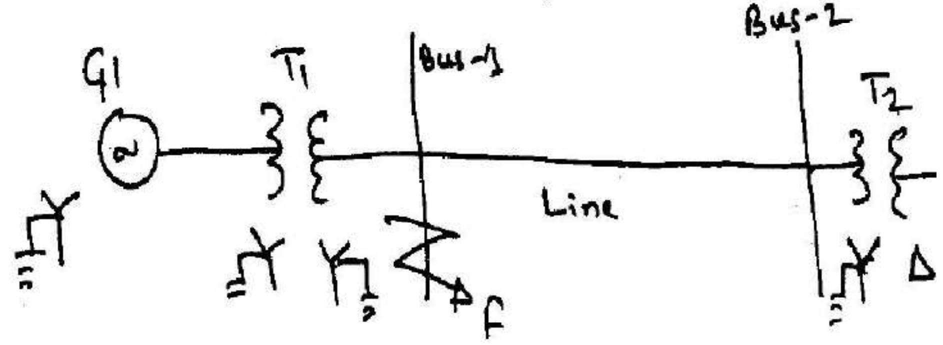
MODULE – 4

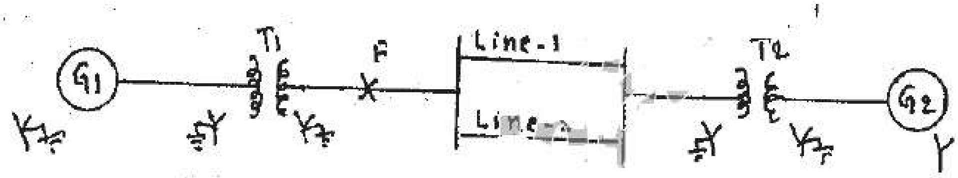
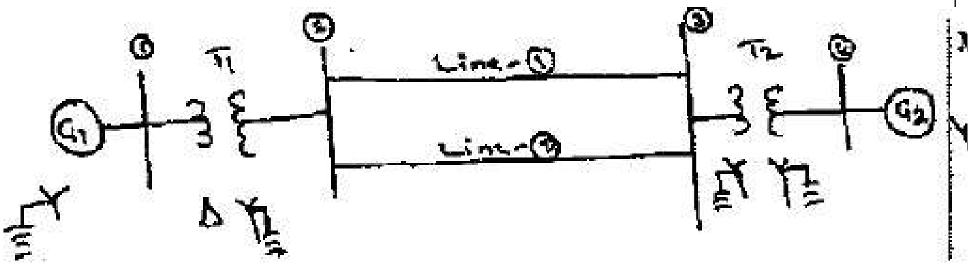
Unsymmetrical Fault Analysis: Introduction, Symmetrical Component Analysis ofUnsymmetricalFaults, Single Line-To-Ground (LG) Fault, Line-To-Line (LL) Fault, Double LineTo-Ground (LLG) Fault, Open Conductor Faults.

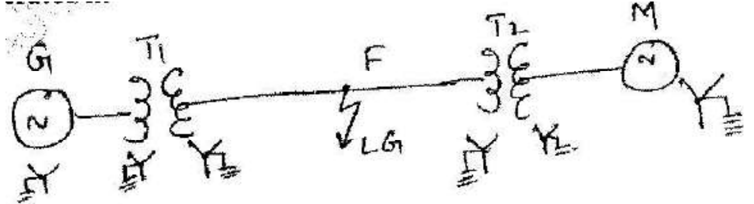
1	What are the different types of unsymmetrical faults and explain in brief their frequency of occurrence?	8	June / July 2017
2	A double line to ground fault occurs at the terminals of a loaded generator.	1	Jun

	Derive an expression for the fault currents; draw the connecting of sequence networks.	2	e / July 2017
3	For one conductor open faults, derive expressions for currents and show the connections of sequence network to represent the fault	8	June / July 2017
4	A synchronous motor is receiving 10MW of power at 0.8pf lag at 6KV. An LG fault takes place at the middle point of the transmission line as shown in figure. Find the fault current. The rating of the generator, motor and transformer are as under Gen: 20MVA, 11KV, X1=0.2pu, X2=0.1pu, X0=0.1pu T1: 18MVA, 11.5Y/34.5Y KV, X=0.1pu Transmission Line: X1=X2=5 ohm, X0=10ohm T2: 15MVA, 6.9Y/34.5Y KV, X=0.1pu Motor: 15MVA, 6.9KV, Xt=0.2pu, X2=X0=0.1pu  	12	June / July 2017 June / July 2016
5	Mention the different types of faults occurring in electrical power system and their probability of occurrence	4	Dec 2016 / Jan 2017
6	A double line to ground fault occurs at the terminals of an unloaded generator. Derive an expression for the fault currents. Also draw connection of sequence networks.	10	Dec 2016 / Jan 2017 June / July 2016

7	Discuss briefly about the open conductor faults in power system	6	Dec 2016 / Jan 2017 Dec 2015 / Jan 2016
8	A single line to ground fault occurs at mid-point F of transmission line in power system shown in figure. Determine the fault current in pu and in amperes from generator if the system were on no load and at a voltage of 100KV at the fault point. The ratings are Gen: 11.5KV, 500MVA, X1=0.3pu, X2=0.2pu, X0=0.1pu T1: 11/110KV, 45MVA, X=0.1pu T2: Consists of 3 single phase units each rated 20MVA, 66/6.6KV, X=10% Motor: 6KV, 55MVA, X1=0.4pu, X2=0.3pu, X0=0.2pu Line: X1=X2=48.5 ohm, X0=90 ohm Choose a base of 60MVA, 110KV in transmission line. 	20	Dec 2016 / Jan 2017
9	A 400V, star connected neutral grounded three phase generator is subjected to various types of faults, the fault currents for various types of faults are: i) three phase, 120 ampere ii) line to line, 150 amp iii) line to ground, 250 amp. If the resistances are neglected, determine the three sequence impedances and fault current for a double line to ground fault.	10	June / July 2016
10	Derive the equation for the fault current when single line to ground fault occurs on an unloaded generator.	8	Dec 2015 / Jan 2016
11	A salient pole generator without dampers is rated 20MVA, 13.8KV and has direct axis sub transient reactance of 0.25pu. The negatively, 0.35 and 0.10 pu. The neutral of the generator is solidly grounded. Determine the sub transient current in the generator for sub transient conditions when a double link to ground fault occurs at the terminals of the generator. Assume that the generator is un loaded and operating at rated voltage when fault occurs neglect resistance.	12	Dec 2015 / Jan 2016
12	A two bus system is shown below the generators G1 and G2 are identical Neglecting pre fault current and losses, calculate the fault current for LG fault at bus – 1. All pu reactances are based on common base values. Reactances of	12	Dec 2015 /

	components on common base G1, G2: X1=0.17pu, X2=0.14pu, X0=0.05pu T1, T2: X1=0.11 pu, X2=0.11pu, X0=0.11pu Line: X1=0.22 pu, X2=0.22pu, X0=0.60pu 		Jan 2016
13	A three phase generator with an open circuit voltage of 400V is subjected to an SLG fault through a fault impedance of j2 ohm. Determine the fault current, if Z1=j4 ohm, Z2=j2 ohm and Z0=1 ohm. Repeat the problem for LL Fault.	8	June / July 2015
14	Derive expression for fault current if LLG fault occurs through fault impedance Zf in power system. Show the connection of sequence networks to represent the fault	10	June / July 2015
15	Derive expression for fault currents for i) one conductor open fault ii) two conductor open fault and draw the sequence network diagrams	10	June / July 2015
16	Draw the interconnected sequence networks for the following cases: i) L-G fault through fault impedance Zf ii) L – L fault through fault impedance Zf iii) LLG fault through fault impedance Zf Clearly indicating positive, negative and zero sequence impedance, symmetrical components of voltages and currents. Also write the expressions for fault current in the above three cases.	12	June / July 2014
17	A three phase generator with line to line voltages of 400V is subjected to LLG fault. If Z1=j2 ohm, Z2=j0.5 ohm and Z0=j0.25 ohm. Determine the symmetrical components of currents and fault current.	8	June / July 2014
18	Draw the sequence networks for the system shown in fig. Determine the fault current if a line to line fault occurs at point F. The pu reactances all referred to the same base are as follows. Both the generators are generating 1.0pu G1: X1=0.05pu, X2=0.30pu, X0=0.20pu	10	June / July

	G2: X1=0.03pu, X2=0.25pu, X0=0.15pu T1: X1=0.12 pu, X2=0.12pu, X0=0.12pu T2: X1=0.10 pu, X2=0.10pu, X0=0.10pu Line1: X1=0.70 pu, X2=0.30pu, X0=0.30pu Line2: X1=0.70 pu, X2=0.30pu, X0=0.30pu 		2014
19	Determine the fault current at the faulted bus for a line to line fault which occurs between phases b and c at bus 4 as shown in figure Gen1, Gen2: 100MVA, 20KV, X1==X2=15%,X0= 4%, Xn=6% T/F1, T/F2: 100MVA, 20/345KV, Xlekage=9% Line1, Line 2: 100MVA, 345KV, X1= X2=10%pu,X0= 40% Line2: 100MVA, 220KV, X1=0.1pu, X2=0.1pu,X0= 0.3pu Take a base of 345KV and 100MVA in transmission line. 	14	June / July 2013
20	A 50Hz generator is delivering 50% of the power that it is capable of delivering through a transmission line to an infinite bus. A fault occurs that increases the reactance between the generator and the infinite bus to 500% of the value before three faults when the fault is isolated, the maximum power that can be delivered is 75% of the original maximum value. Determine the critical clearing angle for the condition described.	12	June / July 2013
21	Derived an expression for fault current when single line to ground fault occurs throught a fault impedence Z_f in a power system .Drew the seqence network to represent the fault.	10	June / July 2018
22	For one conductor open fault in a power system , drive an expression for fault current	6	June / July 2018

23	What are the boudary /terminal condition in relation to the unsymmetrical fault. Mention the boundary condition for LG, LL, LLL and LLG fault.	6	June / July 2018
24	A syn moto is reciving 10 MW of power at 0.8pf lag at 6 kV.A LG fault takes place at the middle point of the transmission line as shown in the fig , Find the fault current the rating of the generator motor and transformer are as under .  Generator: 20 MVA, 11 kV, $X_1 = 0.2$ pu, $X_2 = 0.1$ pu, $X_0 = 0.1$ pu T_1 : 18 MVA, $^{11.5}/_{34.5}$kV , X = 0.1 pu T_2 : 15 MVA, $^{6.9}/_{34.5}$kV , X = 0.1 pu M : 15 MVA, 6.9 kV, $X_1 = 0.2$pu, $X_2 = X_0 = 0.1$ pu Transmission line : $X_1 = X_2 = 5\ \Omega$, $X_0 = 10\ \Omega$	10	June / July 2018

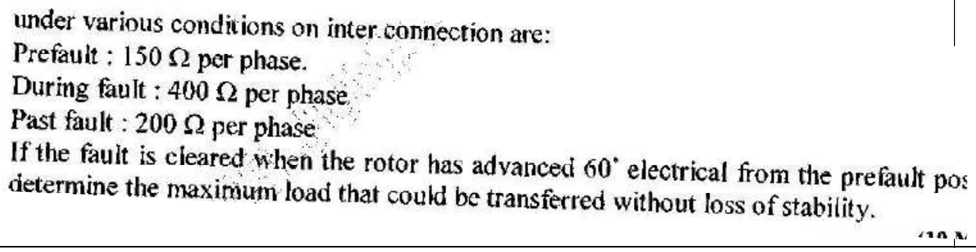
MODULE – 5

Power System Stability: Introduction, Dynamics of a Synchronous Machine, Power Angle Equation Salient and Non – Salient pole Synchronous Machines, Simple Systems, Steady State Stability, Transient Stability,Equal Area Criterion,Factors Affecting Transient Stability.

1	Define Stability as applied to power system studies and distinguish between i) Steady state stability and ii) Transient stability	8	June / July 2017
2	The transfer reactance between a generator an infinite bus bar operating at 200KV under various conditions on interconnection are Pre fault: 150 ohm / phase, During fault: 400 ohm/ Phase, Past fault: 200 ohm/ Phase. If the fault is cleared when the rotor has advanced 60 degree electrical from the prefault position, determine the maximum load that could be transferred without loss of stability	12	June / July 2017
3	Explain clearly the methods of improving transient stability.	8	June / July 2017
4	Explain the effect of unbalanced voltage on the performance of an induction motor. Find the expression for power developed and torque developed under such operating conditions	12	June / July 2017

5	Differentiate between steady state and transient state stability of a power system. Can these stability limits have multiple values?	6	Dec 2016 / Jan 2017
6	Derive swing equation with usual notation	8	Dec 2016 / Jan 2017 June / July 2016
7	Explain the equal area criterion for investigating the stability of power system	6	Dec 2016 / Jan 2017 June / July 2016
8	An ac generator is delivering 50% of maximum power to an infinite bus. Due to a sudden short circuit, the reactance between generator and infinite bus increases to 500% of the value before fault. The maximum power that can be delivered after clearance of the fault is 75% of the original value. Calculate the critical clearing angle to maintain the stability of the system	8	Dec 2016 / Jan 2017
9	Explain the analysis of 3 Phase induction motor with one line open	6	Dec 2016 / Jan 2017 June / July 2016
10	Explain the analysis of 3 phase induction motor with unbalanced voltage	6	Dec 2016 / Jan 201

			7
11	Define the following: i) steady state stability ii) Transient stability iii) Steady state stability limit iv) Transient stability limit.	8	June / July 2016
12	A 400V, 6 pole, 50Hz, 3 Phase induction motor with Rs=Rr=0.5 ohm and Xs=Xr=2 ohm runs at a slip at 0.06. When lines are gets open? Determine the power output and torque developed	10	June / July 2016
13	Derive expression for critical clearing angle	8	Dec 2015 / Jan 2016
14	A 50Hz four pole turbo generator rated 100MVA, 11KV has an inertia constant of 2 MJ/MVA. I) Find the stored energy in the rotor at synchronous speed ii) If mechanical input is suddenly raised to 80MW for an electrical load of 50MW, find rotor acceleration neglecting mechanical and electrical losses	6	Dec 2015 / Jan 2016
15	Write short notes on a) Operation of 3 phase induction motor with one line open b) Steady state and transient stability c) Line to line fault on unloaded generator d) Concept of equal area criterion	20	Dec 2015 / Jan 2016
16	A 2 pole, 50Hz, 11KV turbo alternator has a rating of 100MW, 0.85 PF lagging. The rotor has a moment of inertia of 10000 Kg – m^2. Calculate H and M.	6	June / July 2015
17	Write short notes on: a) Swing equation b) Steady state and transient stability c) Equal area criterion for transient stability d) Analysis of 3 phase IM with one line open	20	June / July 2015
18	At turbo generator, 6 pole, 50Hz of capacity 80MW working at 0.8pf has an inertia of 10MJ/MVA i) Calculate the energy stored in the rotor at synchronous speed ii) Find rotor acceleration if the mechanical input is suddenly raised to 75MW for an electrical load of 60MW iii) Supposing the above acceleration is maintained for a duration of 6 cycles, calculate the change in torque angle and rotor speed at the end of 6 cycles	10	June / July 2014
19	A load free alternator supplies 50MW to an infinite bus the steady state stability being 100MW, determine if the alternator will remain stable if the	8	June /

	input to alternator is abruptly increased by 40MW		July 2014
20	A 50 Hz generator is delivering 50% of the power that it is capable of delivering through a transmission line to an infinite bus. A fault occurs that increase the reactance between the generators and the infinite bus to 500% of the value before fault. When the fault is isolated the maximum power that can be delivered is 75% of the original maximum value. Determine the critical angle for the condition described.	12	Dec 2013 / Jan 2014
21	Breifly explain (i) steady state stability (ii) transient stability	6	June / July 2018
22	A loss free alternator supplies 50 MW to an infinite bus , the SSSL being 100 MW . determine if the alternator will remaines stable if the input the prime mover of the alternator is abruptly incrased by 40 MW .	10	June / July 2018
23	State and explain equal area criteria .what are the assumptions made in applying EAC ? Discuss.	6	June / July 2018
24	The transfer reactance between a generator and an infinite bus bar operation at 200 kV  under various conditions on inter connection are: Prefault : 150 Ω per phase. During fault : 400 Ω per phase Past fault : 200 Ω per phase If the fault is cleared when the rotor has advanced 60° electrical from the prefault pos determine the maximum load that could be transferred without loss of stability.	10	June / July 2018

THE OXFORD COLLEGE OF ENGINEERING
DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING
POWER SYSTEM ANALYSIS - PSA - 17EE62 - VI B SECTION -Final Marks

S.No	USN	Name of the Student	IA1	IA2	IA3	TOTAL
1	1OX17EE036	MEGHA M	32	36	35	**36**
2	1OX17EE039	MUDIMALLA	31	36	35	**36**
3	1OX17EE040	NAGARAJ H S	35	37	37	**37**
4	1OX17EE041	P R CHARAN	27	34	20	**30**
5	1OX17EE043	PAVAN PRIYA	24	33	22	**30**
6	1OX17EE044	POOJA UMESH	32	39	37	**37**
7	1OX17EE045	PRABATH S	35	36	30	**35**
8	1OX17EE048	PREETHI P	40	38	30	**37**
9	1OX17EE049	RACHAREDDY	28	36	25	**32**
10	1OX17EE051	RAKSHITH R C	24	34	31	**32**
11	1OX17EE052	RUTHIK GOWDA	33	36	30	**35**
12	1OX17EE053	RUZAINA	34	37	25	**34**
13	1OX17EE054	SAGAR	29	36	25	**33**
14	1OX17EE055	SAGAR D	38	37	35	**38**
15	1OX17EE056	SATHISH S	30	36	25	**33**
16	1OX17EE057	SHAKIB KHAN	23	36	30	**32**
17	1OX17EE058	SHASHANK K	25	36	29	**33**
18	1OX17EE059	SHAZIYA M B	29	36	29	**34**
19	1OX17EE060	SHEETAL A NAIK	25	38	20	**31**
20	1OX17EE061	SHRUTHI A	40	34	40	**39**
21	1OX17EE062	SNEHA S KADANI	40	39	39	**40**
22	1OX17EE063	SNEHAL	16	29	25	**28**
23	1OX17EE064	SOURAV SHARMA	36	36	36	**37**
24	1OX17EE067	SUPRIYA S	30	36	35	**35**
25	1OX17EE068	SUSHMITHA K	36	36	37	**37**
26	1OX17EE069	THANUJA K H	36	36	39	**38**
27	1OX17EE071	VIDYA	38	36	37	**38**
28	1OX17EE072	VILAS	30	36	18	**31**
29	1OX17EE073	YASHAS Y S	18	35	15	**27**
30	1OX18EE404	PREM B	25	27	ab	**23**
31	1OX18EE402	MANOHARA	25	32	22	**30**
32	1OX16EE021	KEERTHI KUMAR	19	29	15	**26**

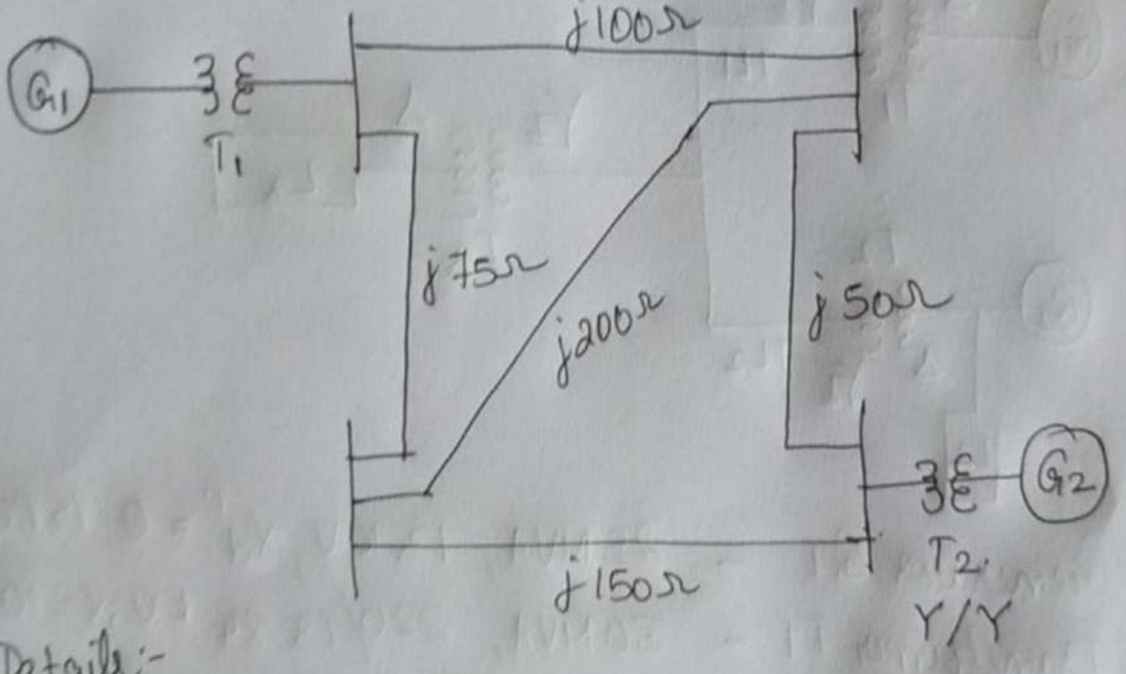
18EE62/17EE62/15EE62 - Tutorial1

Module 1

Submission Date :

08/05/2021

Problem 1



Details :-

G1 : 10MVA, 6.6KV, $X'' = 0.1$ Pu

T1 : 10MVA, 3ϕ, 115KV/6.6 KV, $X = 0.15$ Pu

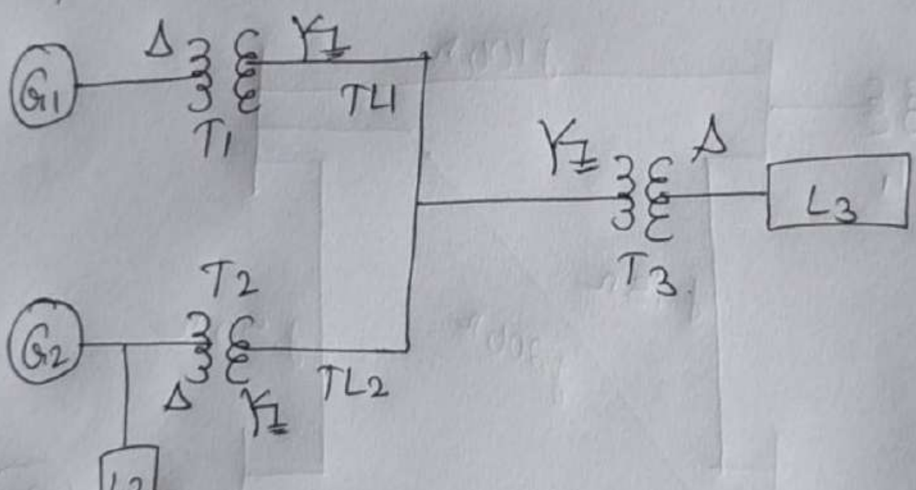
T2 : 3, 1ϕT/F, 10 MVA, 7.5/75 KV ; $X = 0.10$ Pu

G2 : 20MVA, 11.5 KV $X'' = 0.1$ Pu

Convert all to a Common base and Draw the Reactance Diagram for the Same.

Problem-2

Draw the Impedance Diagram for the power System Shown in Fig below and mark on it the Per unit Impedances Calculated on the base of 50 MVA, 13 KV in the circuit of Generator G1.



Generator G1 - 25 MVA, 13 KV, $X_d'' = 0.15$ PU

Transformer T1 - 30 MVA, 220/13.84 KV; X = 10%

Transmission line TL1 - j60 Ω

Transformer T3 - Bank of 1ϕ T/F each Rated 10 MVA, 127/18 KV, X = 8%

Load L3 - (4 + j2) Ω

Transmission line TL2 - j90 Ω

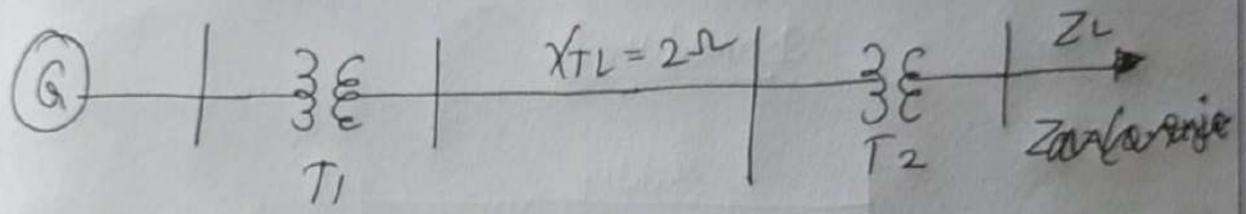
Transformer T3 - 40 MVA, 220/20 KV, X = 12%

Generator G2 - 35 MVA, 22 KV, $X_d'' = 0.12$ PU

Load L2 - (3 + j1) Ω

Problem - 3

Draw the reactance Diagram for the system shown below:



G: 240 V, 30KVA, $X_g'' = 0 \cdot 1$ Pu.

T1 : 30 KVA, 240/480V $X_{eq} = 0 \cdot 1$ Pu.

T_2 : 20KVA, 460/115 V, $X_{eq} = 0 \cdot 1$ PU

ZL: $(0 \cdot 9 + j0 \cdot 2)\ \Omega$

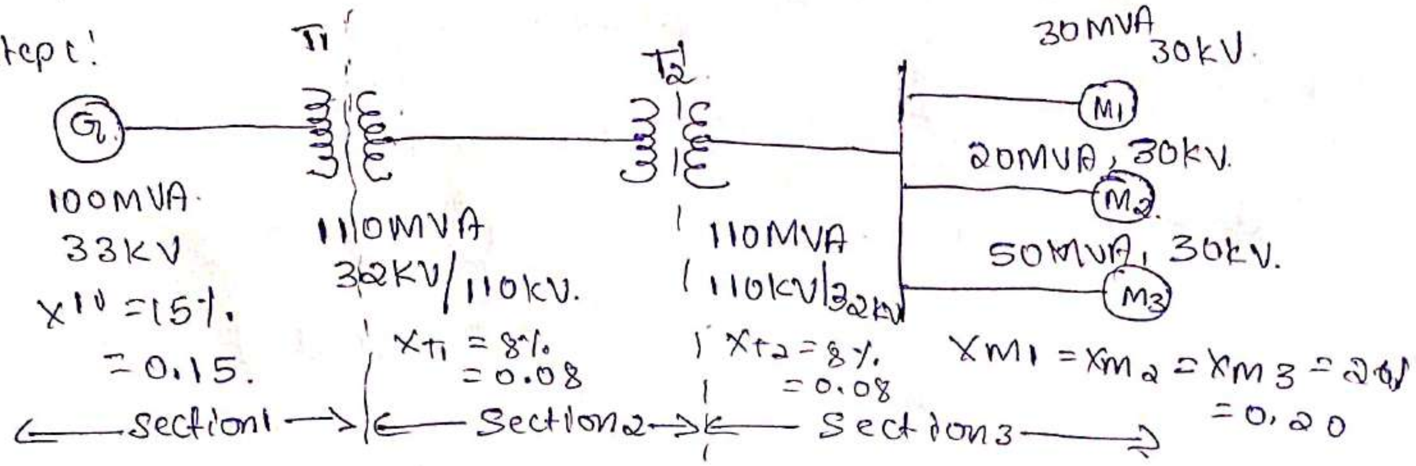
[Reactance Diagram in Series & Parallel]

Power System Analysis
IA - 1

Gagana.S.M
10X18EE016
5 A

2) a)

Step 1:



Step 2:

Section 1.	Section 2	Section 3
$SB_{new} = 100MVA$.	$SB_{new} = 100MVA$.	$Sb_{new} = 100MVA$
$VB_{new} = 33KV$.	$VB_{new} = ?$	$VB_{new} = ?$

~~VB new in Section2~~.

Section 2

T1 32/110kV, Section 1
Primary/Secondary $VB_{new} = 33kV$.

To find V_{Bnew} in Sec 2. $= V_{Bnew}$ in Sec 1 * $\frac{\text{Secondary V/g}}{\text{Primary V/g}}$

$$V_{bnew} \text{ in Sec 2} = 33 * \frac{110}{32} = 113.4375kV.$$

$SB_{new} = 100MVA$

$VB_{new} = 113.4375kV$.

Sections 3. $T_2 \rightarrow 110/32$ kV.
Py/Sy.

Section 2 (Py).
$V_{bnew} = 113.4375kV$

$\therefore V_{Bnew}$ in Section 3 = V_{Bnew} in Sec2 * $\frac{\text{Sy voltage}}{\text{Py voltage}}$.

$$= 113.4375 * \frac{32}{110} = 33kV$$

$S_{Bnew} = 100MVA$, $V_{Bnew} = 33kV$.

Step 3!- Generator I, $G_1 = 100MVA$, $33kV$, $X_g'' = 0.15$ (old)

$S_{Bnew} = 100MVA$. $V_{Bnew} = 33kV$.

$$X_{g1}(new) = X_{g1}(old) * \frac{S_{Bnew}}{S_{Bold}} * \left[\frac{V_{Bold}}{V_{Bnew}}\right]^2$$

$$= 0.15 * \frac{100}{100} * \left[\frac{33}{33}\right]^2$$

$$= 0.15pu.$$

Transformer1 $T_1 = 110MVA$, $32kV/110kV$ $X_{T1} = 0.08$ (old)

$S_{Bnew} = 100MVA$; $V_{Bnew} = 33kV$.

$$X_{T1}(new) = 0.08 * \frac{100}{110} * \left[\frac{32}{33}\right]^2$$

$$= 0.0684pu.$$

$X_{L1} = j50\Omega$ (old). Section2 → $S_{Bnew} = 100MVA$

$V_{Bnew} = 113.4375kV$.

$$X_{L1}(new) = \frac{X_{L1}\,actual}{X_{L1}\,Base(new)} = \frac{X_{L1}\,Actual}{\frac{V_{Basenew}^2}{S_{Bnew}}} = \frac{j50}{\frac{(113.44)^2}{100}}$$

$X_{L1}\,new = 0.3885pu$.

Transformer2:- $T_2 = 110MVA$, $110kV / 32kV$ $X_{T2} = 0.08$ old

$S_{Bnew} = 100MVA$, $V_{Bnew} = 113.44kV$.

$$X_{T2}(new) = 0.08 \times \frac{100}{110} \times \left(\frac{110}{113.44}\right)^2$$

$$= 0.06833\,pu.$$

<u>motor</u> $S_{Bnew} = 100\,MVA.$

$V_{Bnew} = 33\,kV.$

$M_1 = 30MVA,\ 30kV,\ X_{m1}'' = 20\% = 0.20.$ (old)

$$X_{m1}(new) = 0.20 * \frac{100}{30} + \left[\frac{30}{33}\right]^2.$$

$$= 0.55096\,pu.$$

$M_2 = 20MVA,\ 30kV = X_{M2}'' = 0.20$ (old)

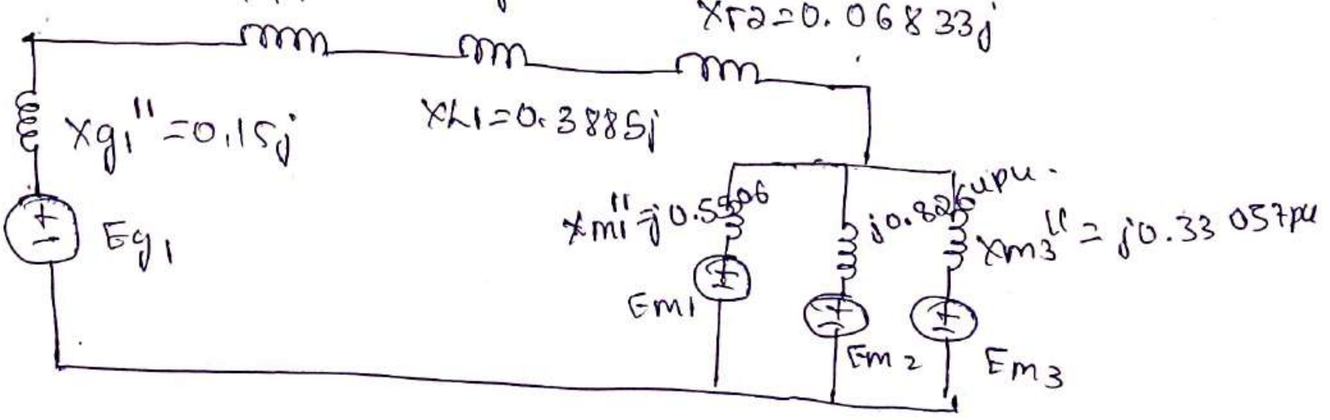
$$X_{m2}(new) = 0.20 * \frac{100}{20} * \left[\frac{30}{33}\right]^2.$$

$$= 0.8264\,pu$$

$M_3 = 50MVA,\ 30kV,\ X_{m3}'' = 0.20$ (old)

$$X_{m3}(new) = 0.20 * \frac{100}{50} * \left[\frac{30}{33}\right]^2$$

$$= 0.33057\,pu$$



1> b> per unit value of any Quantity is defined as the ratio of Actual value of the quantity to the Base or reference value of the quantity.

Eg :- If I_b Ibase = 100A

Icurrent Actual = 80A

$$I_{pu} = \frac{80}{100} = 0.8 pu.$$

Advantages of per unit system

i> the perunit impedence referred to Either side of a single phase transformer is the same.

ii> the per unit impedence referred to Either side of 3φ transformer is the same regardless of the 3φ connections whether they are Y-Y, Δ-Δ, Δ-Y

iii> the manufacturers usually provide the Impedence value in per unit.

iv> The computational Effort in power system is very much reduced with the use of per unit quantities

v> Line to phase or phase to line conversions are reduced.

Changing the base of ~~pow~~ perunit quantities

If the values given are already in pu values refereed by their own ratings. then to convert them to the selected base values

$$Z_{pu\,given} = \frac{Z_{actual}}{Z_{Base}} = \frac{Z_{actual}}{\frac{V^2_{Base\,given}}{S_{base\,given}}} \longrightarrow ①$$

$$Z_{Base} = \frac{V_{Base}}{I_{Base}} = \frac{V_{Base}}{\frac{S_{Base}}{V_{Base}}} = \frac{V_{Base}^2}{S_{Base}}.$$

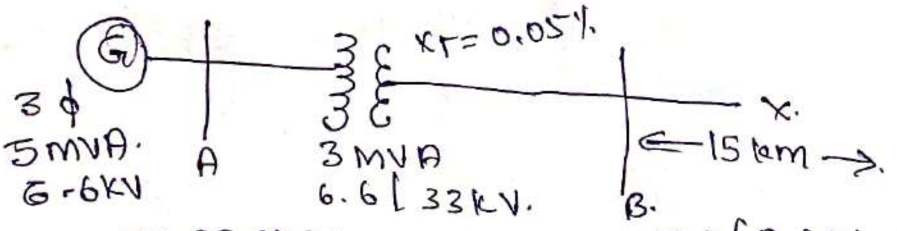
|||ly $$Z_{punew} = \frac{Z_{actual}}{Z_{Basenew}} = \frac{Z_{actual}}{\frac{(V_{Basenew})^2}{S_{Basenew}}} \rightarrow ②$$

$\div \frac{②}{①}$

$$\frac{Z_{pu(new)}}{Z_{pugiven}} = \frac{\frac{Z_{actual}}{(V_{Basenew})^2} \times S_{Basenew}}{\frac{Z_{actual}}{V_{Basegiven}^2} * S_{Basegiven}}$$

$$\boxed{Z_{punew} = Z_{pugiven} * \frac{S_{Basenew}}{S_{Basegiven}} * \frac{V_{Base}^2{}_{given}}{V_{Base}^2{}_{new}}}$$

4b>



$x_g = 0.08$ pu.

$z = (0.12 + j0.48)\ \Omega/ph/km$

Step 1 :-

Section 1

$S_B = 5$ MVA.

$V_B = 6.6$ kV.

Section 2

$S_B = 5$ MVA

$V_B = 33$ kV.

$X_{gnew} = j\,0.08$ pu

$$X_{Tnew} = 0.05 \times \frac{5}{3} \times \left(\frac{6.6}{6.6}\right)^2 = 0.0833 \text{ pu}$$

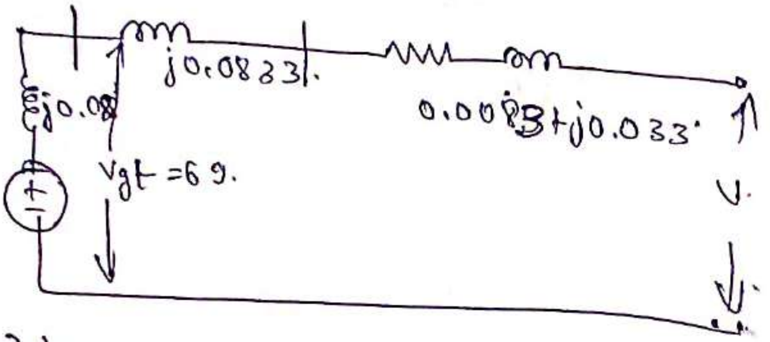
$$Z_{enpu} = \frac{Z_{in\Omega}}{Z_{base}} = \frac{Z_{in\Omega}}{\frac{V_B^2}{S_B}}$$

zin Ω = z (Ω/ph/km) * 15 m(km)

= [0.12 + j0.48] * 15

$$Z_{in}\ pu = \frac{(0.12 + j0.48) * 15}{\frac{33^2}{5}}$$

$$\boxed{= 0.0083 + j0.033\ pu}$$



Step 2:-

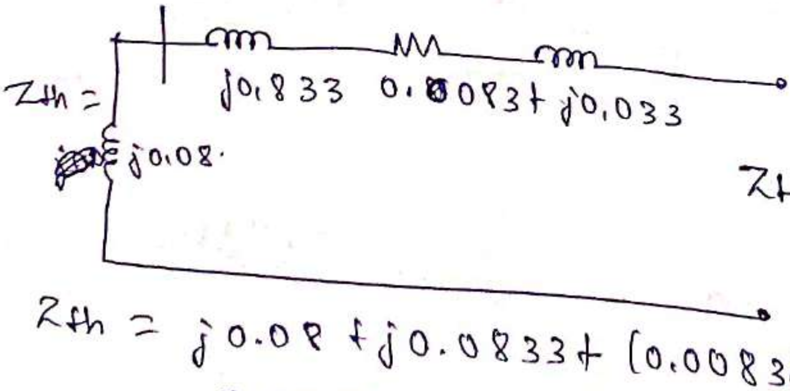
Vg and Vpf

$$Vg(pu) = \frac{6.9}{6.6} = 1.0455pu$$

Since no load.

Vg(pu) = Vt = 1.0455pu

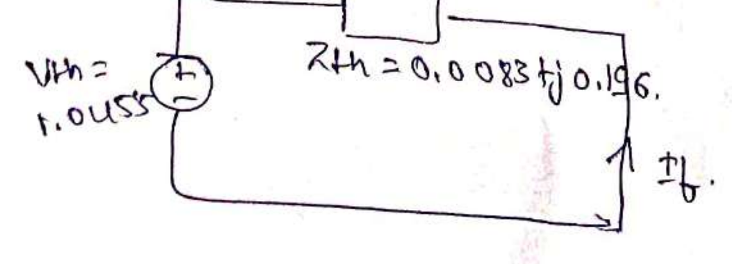
Step 3:- Vth = Vt = 1.045pu.



Zth = j0.08 + j0.0833 + (0.0083 + j0.033)

= 0.0083 + j0.196.

Step4:-



$$I_f = \frac{V_{th}}{Z_{th}} = \frac{1.0455}{(0.0083 + j0.196)}$$

$$= 0.2268 - j5.3245$$

$$I_f \text{ (in A)} = (0.2268 - j5.3245) * I_{base}$$

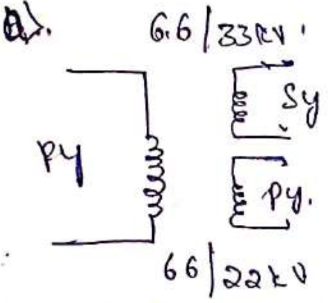
$$= 5.329 \angle -87.56$$

$$I_{base} = \frac{S_B}{\sqrt{3}\, V_B} = \frac{5 \times 106}{\sqrt{3} \times 33 \times 10^3}$$

$$I_f \text{ in A} = [5.329] * 87.477$$

$$= 466.25 A.$$

Q3) a).



Py - Sbase = 15MVA Vbase = 6.6kV.

Sy - Sbase = 15MVA Vbase = 33kV.

Ty - Sbase = 15MVA Vbase = 22kV.

$$(Z_{ps})_{pu} \text{ in primary} = \frac{Z_{ps}(\Omega)}{\frac{V_b^2}{S_b}} = \frac{0.23\,\Omega}{\frac{6.6^2}{15}} = j0.08 \text{pu}$$

$$(Z_{pt})_{pu} \text{ (in primary)} = \frac{Z_{pt}(\Omega)}{\frac{V_b^2}{S_b}} = \frac{j0.29}{\frac{6.6^2}{15}} = j0.1 \text{pu.}$$

$$Z_{st}(\text{pu}) \text{ (Secondary)} = \frac{Z_{st}(\Omega)}{V_b^2/S_b} = \frac{j8.7}{33^2/15} = j0.12 \text{pu.}$$

$$Z_p = 1/2\, [Z_{ps} + Z_{pt} - Z_{st}].$$

$$= 1/2\, [j0.08 + j0.1 + 0.12].$$

$$Z_p = j0.03 \text{pu.}$$

$Zs = \frac{1}{2}[Zst + Zps - Zpt]$

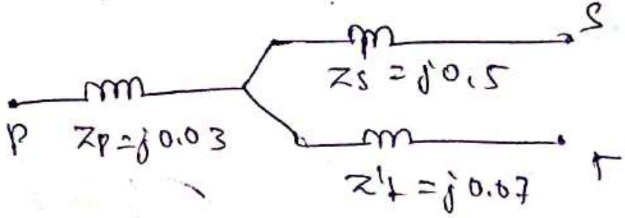
$= 1/2 [j0.08 + j0.12 - j0.1]$.

$Zs = j0.05pu$

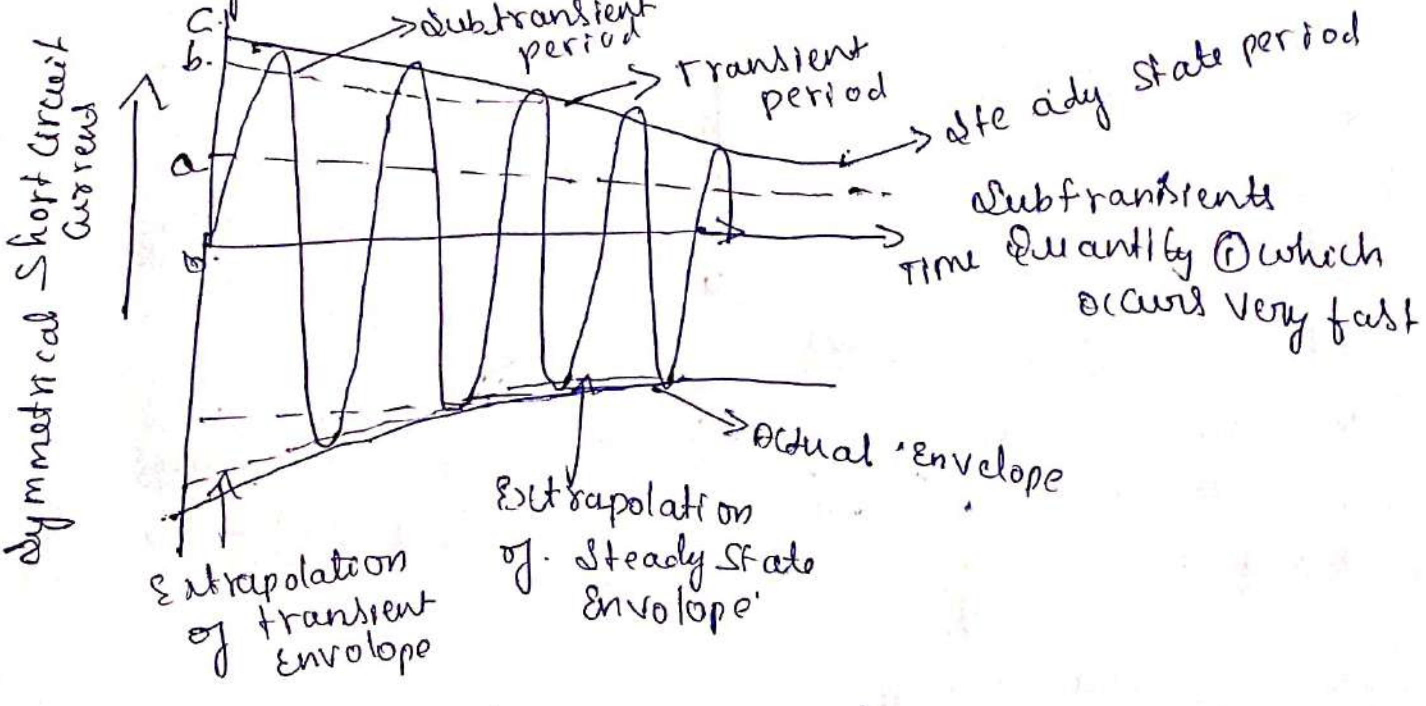
$Zt = 1/2[Zsf + Zpt - Zps]$

$= 1/2 [j0.12 + j0.1 - j0.08)$

$= j0.07pu$



5)a) Consider a 3φ alternator running on no-load If a 3-φ fault occure at the terminals of the alternator, then heavy Short circuit current flows on armature Circuit.

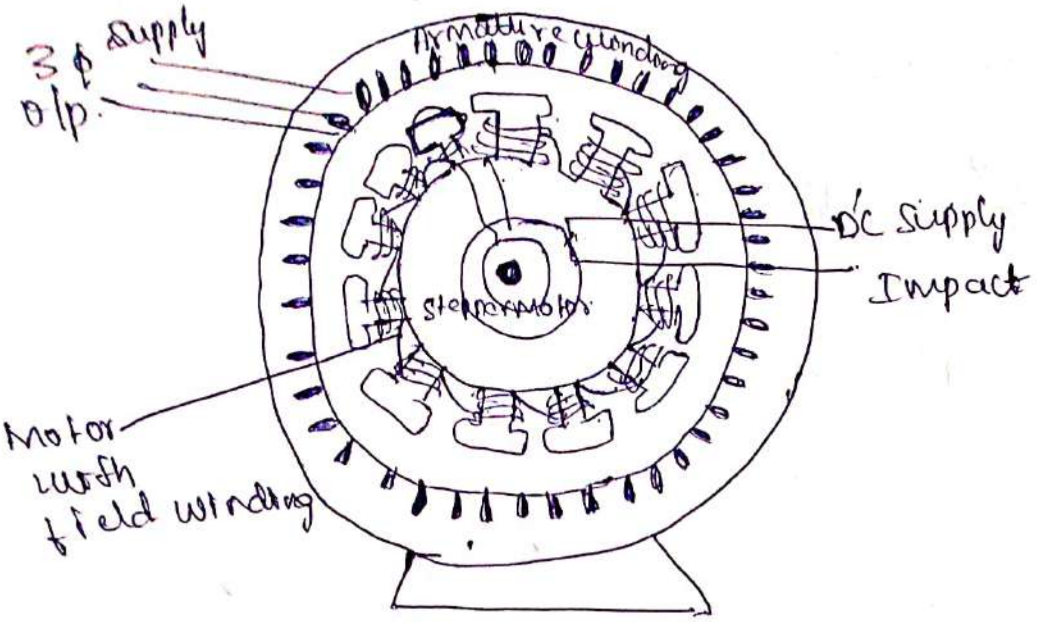


Transient → Lasting for a short time

Steady → firm & fixed

* DC winding in rotor induces main flux & it is rotating

* So the rotating flux cut the stator conductors & induced current.

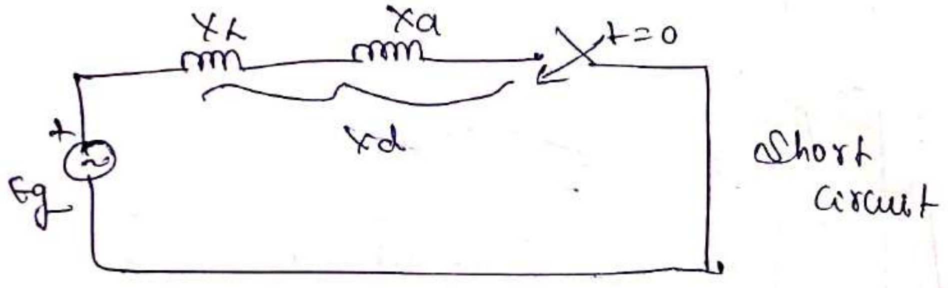


i) <u>Steady State region</u>:

under Steady State the total Reactance is given by sum X_1 and X_a & it is given by $X_d = X_L + X_a$ → Direct Axis reactance.

X_L → opposition to main flux.

X_a → Inductive reactance called as X_a



Immediate after the fault.

Sub transient → DC offset current is produced in stator will Induced a flux in the rotating rotor as well as damper winding present in motor

ii) <u>Sub transient region</u>:-

* the Increase in field current and damper winding current will set up flux in the direction to arrangement the main flux.
* the combined Effect of all 5 is to reduce the total reactance Hence the short circuit current is very high in this State.

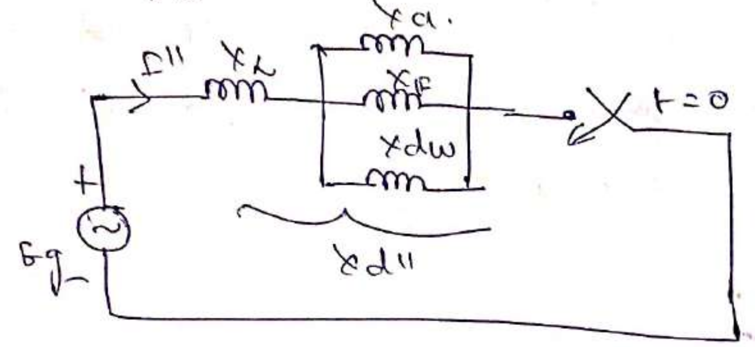
$Xd'' = X_L + \frac{1}{\frac{1}{Xa} + \frac{1}{Xf} + \frac{1}{Xdw}}$ d. Sub-transient.

reactance by Xd'',

X_L -> Leakage reactance

Xa -> armature reaction reactance.

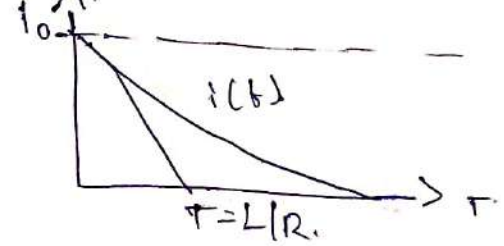
* $I = E/Z$

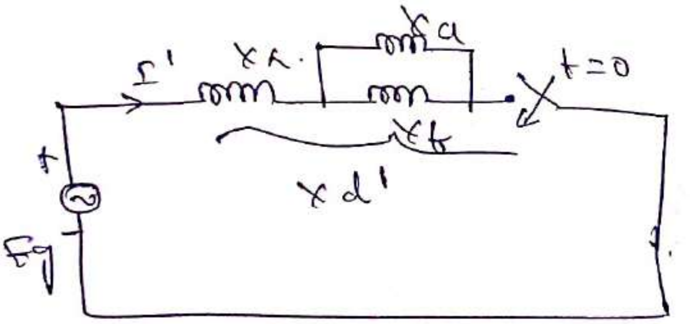


Short circuit.

iii) Transient region.

$Xd' = X_L + \frac{1}{\frac{1}{Xa} + \frac{1}{Xf}}$.





Short circuit.

$\therefore Xd'' < Xd' < Xd$.

If is found that the sub transient reactance (Xd'') of the machine is smallest of steady state Reactance (Xd)

|I| -> RMS value of Steady State Current

|I'| -> RMS value of transient Current Excluded DC comp.

|I''| -> RMS value of Sub transient current Exclude DC Comp

from waveform we get | $I_{rms} = \frac{I_{peak}}{\sqrt{2}}$

* $\therefore X_d'' = \frac{|E_g|}{|I''|} = \frac{|E_g|}{oc/\sqrt{2}}$.

$$X_d' = \frac{|E_g|}{|I'|} = \frac{|E_g|}{ob/\sqrt{2}}$$

$$X_d = \frac{|E_g|}{|I|} = \frac{|E_g|}{oa/\sqrt{2}}.$$

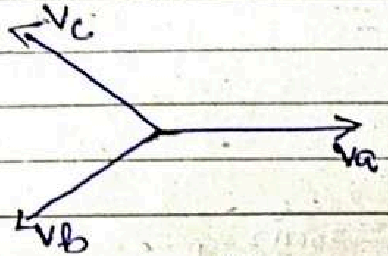
* the momentary current rating of the circuit breakers used for generators & synchronous motors are determining using sub transient reactance (X_d'').

Power System Analysis
Dilber Bashir Kumar
10X18EE014. IA-2

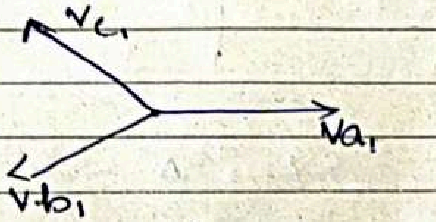
1A. Dr. C Fortosque proved that an unbalanced system of 'n' related vectors can be resolved into n system of balanced vectors called as symmetrical components of the original vector. The 'n' vectors of each set of components are equal in length & phase angles between them of the set are equal.

The symmetrical components can be classified as:

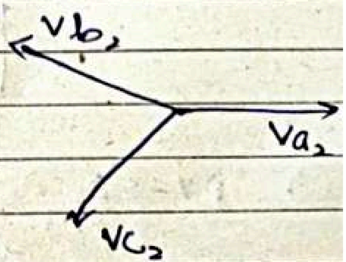
1) Positive sequence component: Represented as 1
2) Negative sequence component: Represented as 2
3) Zero sequence component: Represented as 0



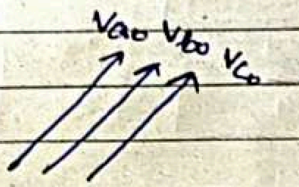
(original)



(+ve sequence)



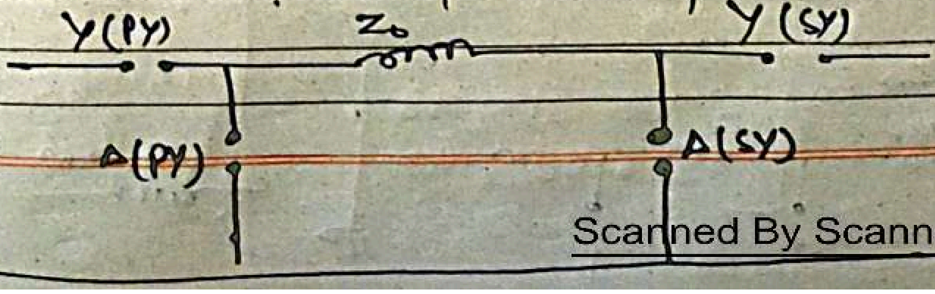
(-ve sequence)



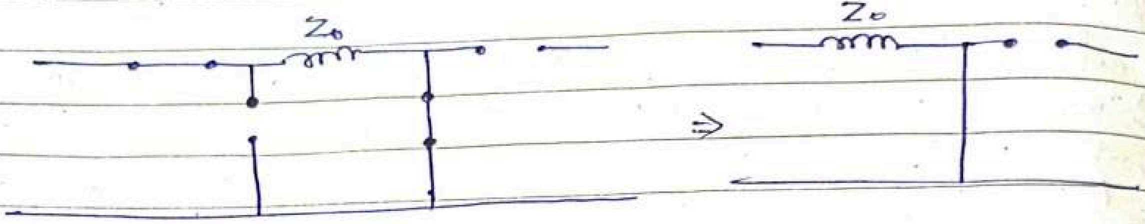
Zero sequence

A network consisting of only the sequence components is called as sequence network.

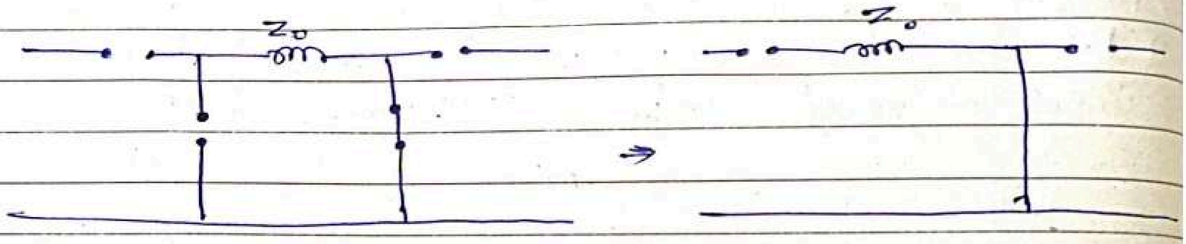
Symmetrical network for transformers



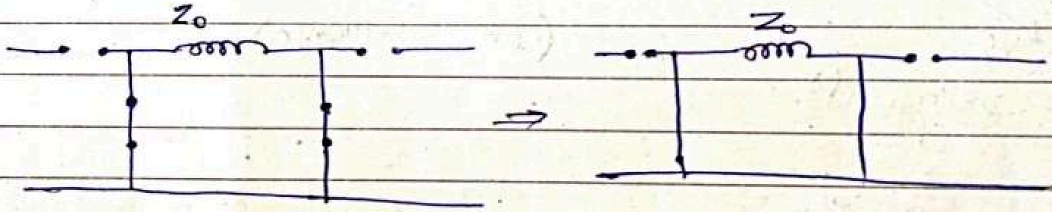
① PY → Y⏚ SY → Δ



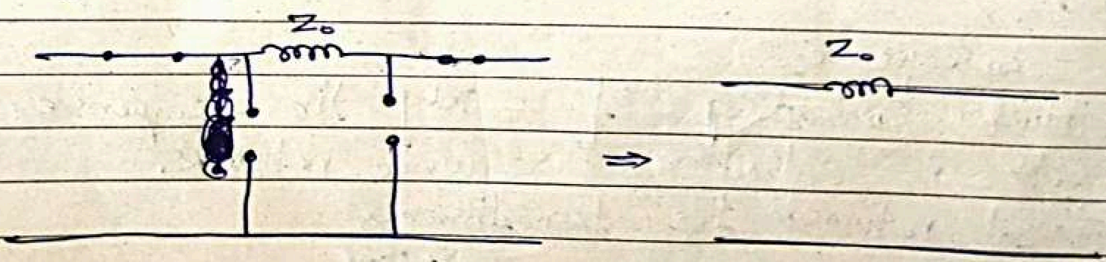
② PY → Y SY → Δ



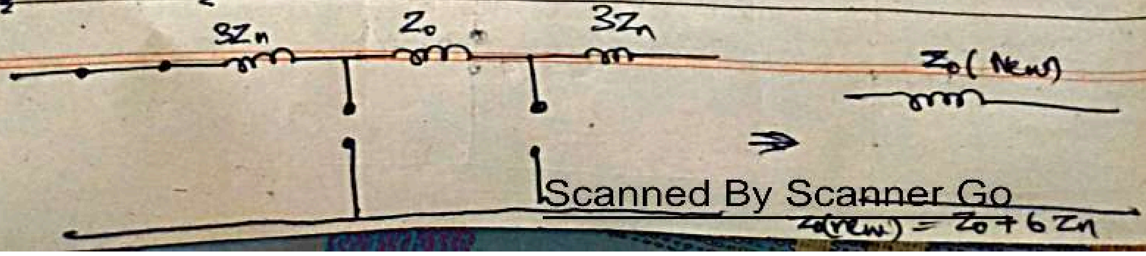
③ PY → Δ SY → Δ



④ Y⏚ – Y⏚

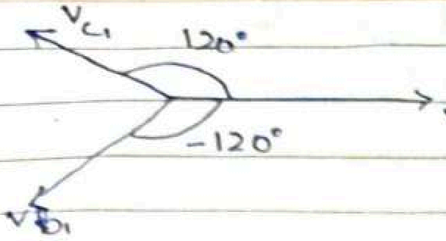


⑤ Y⏚ Zn – Y⏚ Zn



$Z_0(new) = Z_0 + 6Z_n$

2a.



→ (+ve Seq).

$V_{b_1} = V_{a_1} \angle -120 = V_{a_1} \angle 240 = a^2 V_{a_1}$

$V_{c_1} = V_{a_1} \angle 120 = a V_{a_1}$

$$\begin{bmatrix} V_0 \\ V_1 \\ V_2 \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}$$

$$= \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \begin{bmatrix} V_a \\ a^2 V_a \\ a V_a \end{bmatrix}$$

$$= \frac{1}{3} \begin{bmatrix} V_a + a^2 V_a + a V_a \\ V_a + a^3 V_a + a^3 V_a \\ V_a + a^4 V_a + a^2 V_a \end{bmatrix}$$

$a^3 = 1 \qquad a^4 = a$

$$= \frac{1}{3} V_a \left[1 + \underbrace{\cancel{a^2 + a}}_{0} \right]$$

$V_{a_0} = 0$

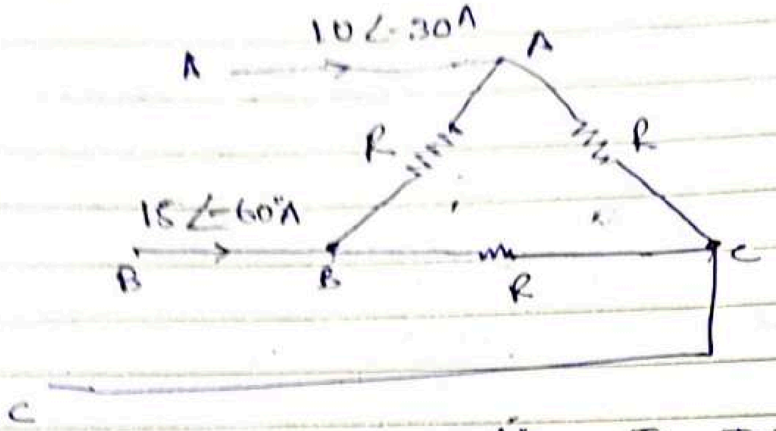
$V_{a_1} = \frac{1}{3} [V_a]$

$V_{a_2} = \frac{V_{a_0}}{3} \left[1 + \underbrace{\cancel{a + a^2}}_{0} \right]$

$V_{a_2} = 0$

∴ Three phase balanced voltage have only +ve sequence component.

3. A.



In Δ Connection $I_A + I_B' + I_C' = 0$

$$I_C = -(I_A + I_B)$$

$$I_C = -(10\angle -30 + 15\angle -60^\circ)$$

$$I_C = 24.183\angle 131.93\ A$$

$$\begin{bmatrix} I_{A0} \\ I_{A1} \\ I_{A2} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}\begin{bmatrix} I_A \\ I_B \\ I_C \end{bmatrix}$$

$$= \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1\angle 120 & 1\angle 240 \\ 1 & 1\angle 240 & 1\angle 120 \end{bmatrix}\begin{bmatrix} 10\angle -30 \\ 15\angle -60 \\ 24.183\angle 131.93 \end{bmatrix}$$

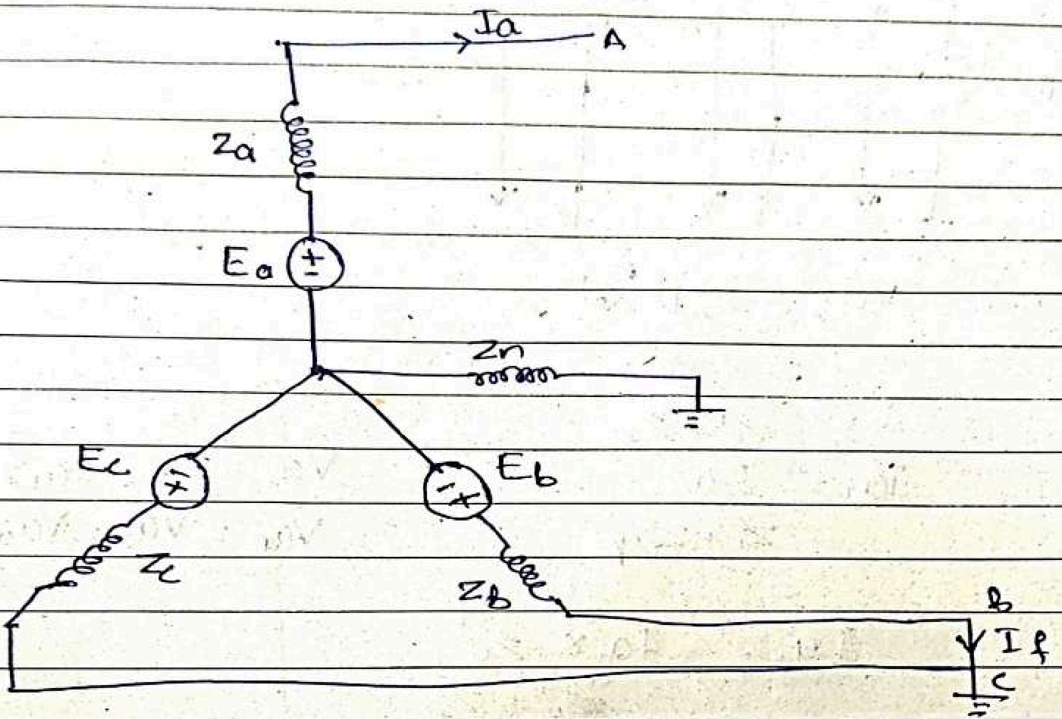
$$= \frac{1}{3}\begin{bmatrix} 0 \\ 41.885\angle 18.066 \\ 310.82\angle -116.311 \end{bmatrix} = \begin{bmatrix} 0 \\ 13.96\angle 18066 \\ 10.40\angle -116.311 \end{bmatrix}$$

$I_{a_0} = 0$ A

$$I_{a1} = \frac{I_{A1}}{j\sqrt{3}} = \frac{13.96\angle 18.066}{j\sqrt{3}} = 8.059\angle -71.93 \text{ A}$$

$$I_{a2} = \frac{I_{A2}}{-j\sqrt{3}} = \frac{10.40\angle -116.311}{-j\sqrt{3}} = 6.004\angle -26.311 \text{ A}$$

4a. Double line to ground fault



Terminal conditions

$I_a = 0$

$V_b = V_c = 0$

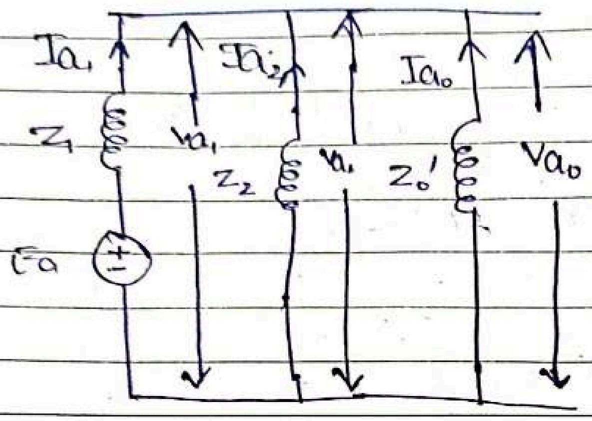
$$\begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}$$

$$= \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}\begin{bmatrix} V_a \\ 0 \\ 0 \end{bmatrix} = \frac{1}{3}\begin{bmatrix} V_a + 0 + 0 \\ V_a + 0 + 0 \\ V_a + 0 + 0 \end{bmatrix}$$

$\therefore V_{a0} = V_{a1} = V_{a2} = \frac{V_a}{3} \Rightarrow$ Parallel circuit

$I_a = I_{a0} + I_{a1} + I_{a2}$

$0 = I_{a0} + I_{a1} + I_{a2} \Rightarrow I_{a0} = -(I_{a1} + I_{a2})$



$Z_{eq} = Z_2 \| Z_0'$

$= \frac{Z_2 Z_0'}{Z_0' + Z_2}$

$I_{a1} = \frac{E_a}{Z_1 + Z_{eq}}$

$V_{a1} = E_a - I_{a1} Z_1$

$V_{a1} = V_{a2} = V_{a0}$

$I_{a2} = -I_{a1} \times \frac{Z_0'}{Z_0' + Z_2}$

$I_{a0} = -I_{a2} \times \frac{Z_2}{Z_0' + Z_2}$

$I_f = I_b + I_c$

$= (I_{b0} + I_{b1} + I_{b2}) + (I_{c0} + I_{c1} + I_{c2})$

$= I_{a0} + a^2 I_{a1} + a I_{a2}) + (I_{a0} + a I_{a1} + a^2 I_{a2})$

$= 2I_{a0} + I_{a1} (\underbrace{a^2 + a}_{-1}) + I_{a2} (\underbrace{a + a^2}_{-1})$

$= 2I_{a0} - I_{a1}$ I_{a2}

$= 2I_{a_0} - (I_{a_1} + I_{a_2})$

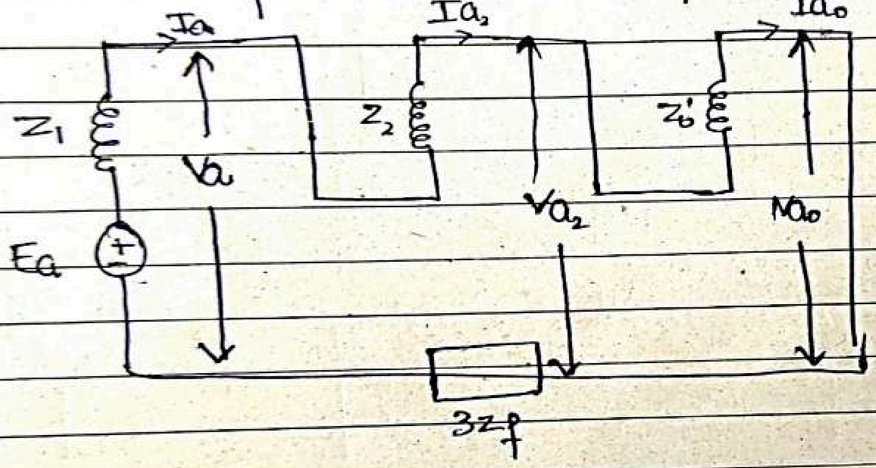
$= 2I_{a_0} + I_{a_0}$

$= 3I_{a_0}$

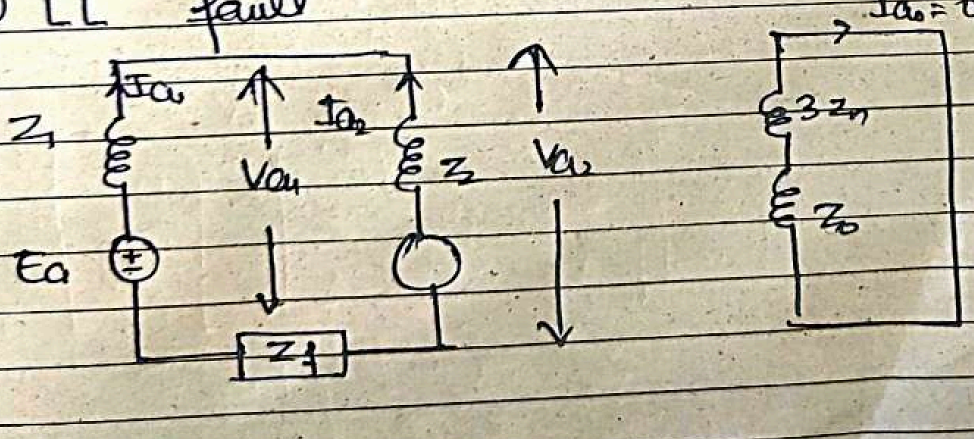
$$I_f = 3\left[-I_{a_1}\left[\frac{Z_2}{Z_0' + Z_2}\right]\right]$$

$$I_f = -3I_{a_1}\left[\frac{Z_2}{Z_2 + Z_0'}\right]$$

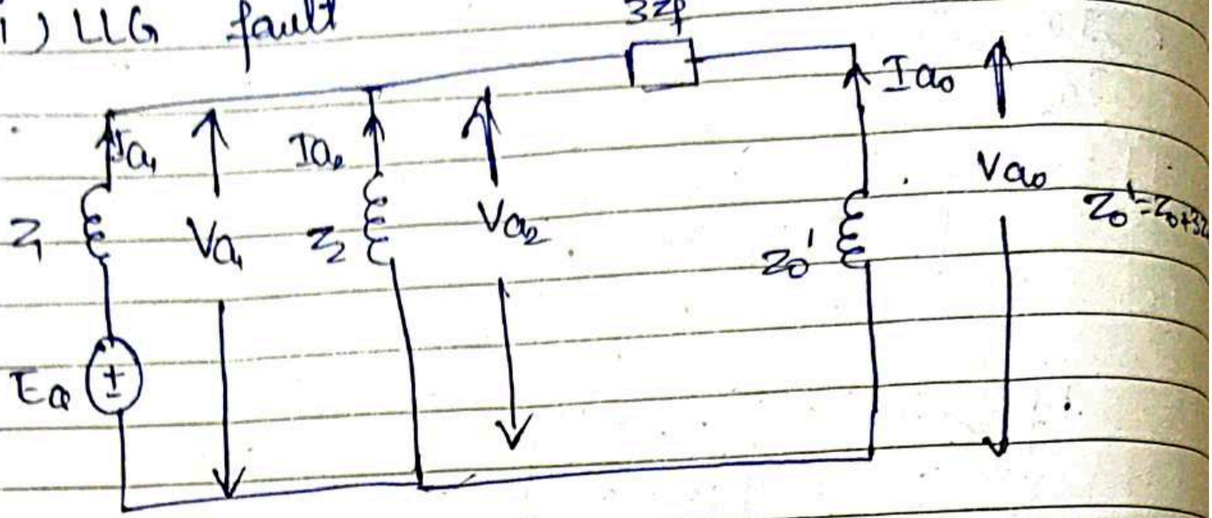
5b. (i) LG fault through Zf $\quad Z_0' = Z_0 + 3Z_n$



(ii) LL fault



(iii) LLG fault



Kusuma. G. Naik
10X18EE028.
6A.
28/06/21

Power System Analysis.

IA = 2

1. B. expression for 3 phase ~~voltao~~ complex powa in terms of Symmetrical components.

The total complex power flowing through three phase circuit diagram.

$$S = P + jQ.$$

$$= V_a I_a^* + V_b I_b^* + V_c I_c^*.$$

where S = total complex power
P = Active Power
Q reactive power.

$$S = P + jQ = \begin{bmatrix} V_a & V_b & V_c \end{bmatrix} \begin{bmatrix} I_a^* \\ I_b^* \\ I_c^* \end{bmatrix}$$

$$\begin{bmatrix} V_a & V_b \cdot & V_c \end{bmatrix} = \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}^T = \left\{ \begin{bmatrix} 1 & 1 & 1 \\ 1 & a2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} V_a \\ V_{a1} \\ V_{a2} \end{bmatrix} \right\}^T.$$

$$= \begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix}^T \begin{bmatrix} 1 & 1 & 1 \\ 1 & a2 & a \\ 1 & a & a^2 \end{bmatrix}.$$

Since $\{[A]\,[B]\}^T = [B]^T [A]^T$

and

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

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

$a^* = a^2 \, (a^2) = a$

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

$$S = P + jQ = \begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix}^T \begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \begin{bmatrix} \cancel{I_{a0}^*} \\ \cancel{I_{a1}^*} \\ \cancel{I_{a2}^*} \end{bmatrix} \begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \begin{bmatrix} I_{a0}^* \\ I_{a1}^* \\ I_{a2}^* \end{bmatrix}$$

$$S = P + jQ$$

$$= \begin{bmatrix} V_{a0} & V_{a1} & V_{a2} \end{bmatrix} \begin{bmatrix} 1+1+1 & 1+a+a^2 & 1+a^2+a \\ 1+a^2+a & 1+a^3+a^3 & 1+a^4+a^2 \\ 1+a+a^2 & 1+a^2+a^4 & 1+a^3+a^3 \end{bmatrix} \begin{bmatrix} I_{a0}^{+} \\ I_{a1}^{+} \\ I_{a2} \end{bmatrix}$$

$$= \begin{bmatrix} V_{a0} & V_{a1} & V_{a2} \end{bmatrix} \begin{bmatrix} 3 & 0 & 0 \\ 0 & 3 & 0 \\ 0 & 0 & 3 \end{bmatrix} \begin{bmatrix} I_{a0}^* \\ I_{a1}^* \\ I_{a2}^* \end{bmatrix}$$

$1+a^4+a^2 = 1+a+a^2=0.$

$1+a^3+a^3 = 1+1+1=3$

$$S = \begin{bmatrix} V_{a0} & V_{a1} & V_{a2} \end{bmatrix} \begin{bmatrix} 3 & 0 & 0 \\ 0 & 3 & 0 \\ 0 & 0 & 3 \end{bmatrix} \begin{bmatrix} I_{a0}^{*} \\ I_{a1}^{*} \\ I_{a2}^{*} \end{bmatrix}$$

$$S = 3\left[V_{a0} I_{a0}^{*} + V_{a1} I_{a1}^{*} + V_{a2} I_{a2}^{*} \right]$$

$$S_{in\,pu} = \frac{S}{S_B} = \frac{S}{3 V_B I_B}$$

$$= \frac{3\left[V_{a0} I_{a0}^{*} + V_{a1} I_{a1}^{*} + V_{a2} I_{a2} \right]}{3 \quad V_B I_B}.$$

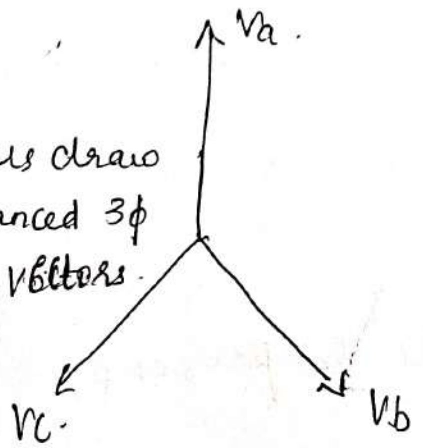
$$S_{in\,pu} = V_{a0\,pu} I_{a0\,pu}^{*} + V_{a1\,pu} I_{a1\,pu}^{*} + V_{a2\,pu} I_{a2\,pu}^{*}$$

$\boxed{S_{in\,pu} = S_{in\,3\phi}}$ Hence proved.

② A. prove that a balanced set of 3 phase voltages will have only positive sequence component of voltage only.

Sol:-

Let us draw the balanced 3φ voltage vectors.



Va is ref

$V_b = V_a\left[1\angle{-120^\circ}\right)$

$= 1\angle 240^\circ.$

$V_b = a^2 V_a.$

$V_c = V_a\left(1\angle 120^\circ\right)$

$V_c = V_a\, a.$

$$\begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a2 \\ 1 & a2 & a \end{bmatrix}\begin{bmatrix} V_q \\ V_b \\ V_c \end{bmatrix}.$$

$$\begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}\begin{bmatrix} V_q \\ a^2V_q \\ aV_a \end{bmatrix}$$

$$= \frac{1}{3}\begin{bmatrix} V_a + a^2V_a + aV_a \\ V_a + a^3V_a + a^3V_a \\ V_a + a^4V_a + a^2V_a \end{bmatrix}$$

$$= \frac{1}{3}\begin{bmatrix} (1+a^2+a)V_a \\ V_a(1+a^3+a^3) \\ V_a(1+a^4+a^2) \end{bmatrix}$$

$$= \frac{1}{3}\begin{bmatrix} 0 * V_a \\ (1+1+1)V_q \\ V_a(1+a+a^2) \end{bmatrix} \qquad \therefore \; 1+a^2+a=0$$

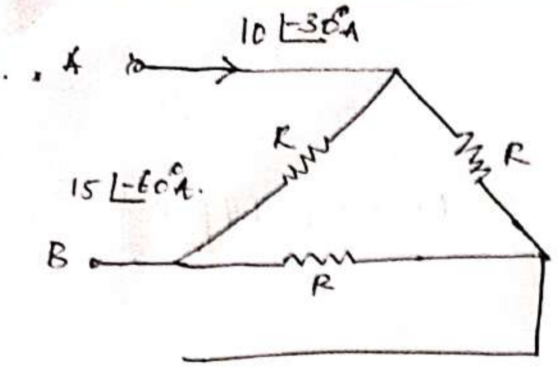
$$a^3=1$$

$$a^4=a.$$

$$= \frac{1}{3}\begin{bmatrix} 0 \\ 3V_q \\ V_a \end{bmatrix}$$

$$\boxed{V_{a1} = V_a}$$ only +ve Sequence is present.

③



$$I_A = 10\angle{-30^\circ}$$

$$I_B = 15\angle{-60^\circ}$$

$$I_C = -(I_A + I_B)$$

$$= -\left[10\angle{-30^\circ} + 15\angle{-60^\circ}\right].$$

~~$= -16.16 +$~~

$$\boxed{I_C = -16.16 + 17.99j} = 24.1828\angle 131.9325\ A.$$

$$I_{A1} = \frac{1}{3}\left[I_A + aI_B + a^2 I_C\right]$$

$$= \frac{1}{3}\left[10\angle{-30^\circ} + 1\angle 120\,(15\angle{-60^\circ}) + 1\angle 240\,(-16.16+17.99j)\right]$$

$$I_{A1} = 13.273 + 4.33i = 13.9614\angle 18.0677.$$

$$I_{A2} = \frac{1}{3}\left[I_a + a^2 I_B + aI_C\right]$$

$$= \frac{1}{3}\left[10\angle{-30^\circ} + 1\angle 240\,(15\angle{-60}) + 1\angle 120\,(-16.16+17.99j)\right]$$

$$I_{A2} = -4.6132 - 9.330i$$

$$= 10.4083\angle{-116.30}$$

$I_{A3} = \frac{1}{3}\left[I_a + I_b + I_c\right]$

$= \frac{1}{3}\left[10\angle 30^\circ + 15\angle -60^\circ + (-16.66 + 17.99j)\right]$

$= \frac{1}{3}$

$\doteq 0$ //

$I_{a1} = \frac{I_{A1}}{j\sqrt{3}} = \frac{13.273 + 4.33i}{j\sqrt{3}}$

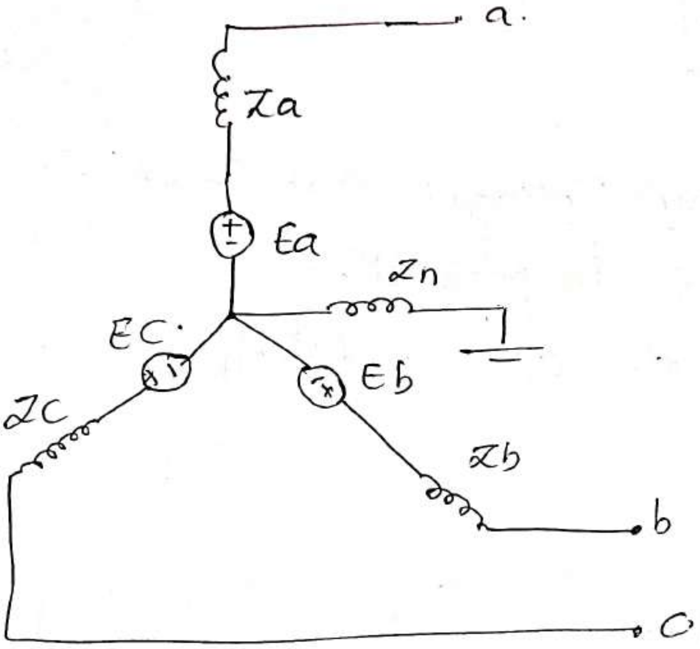
$I_{a1} = 2.499 - 7.6632i = 8.060\angle -71.93$ A

$I_{a2} = \frac{I_{A2}}{-j\sqrt{3}} = \frac{-4.6132 - 9.330i}{-j\sqrt{3}}$

$I_{a2} = 5.3867 - 2.6634i$

$= 6.0092\angle -26.30$ A.

4. A double line to ground fault occurs at the terminal of a loaded generator. Derive an expression for the draw the connecting of Sequence networks.



Initial conditions.

$V_a = 0$; $V_c = 0$; $I_a = 0$.

Symmetrical component relations.

$$\begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a2 \\ 1 & a2 & a \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}$$

$$\begin{bmatrix} V_{a0} \\ V_{c1} \\ V_{a2} \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a2 \\ 1 & a2 & a \end{bmatrix} \begin{bmatrix} V_a \\ V\cancel{b}0 \\ V\cancel{c}0 \end{bmatrix}$$

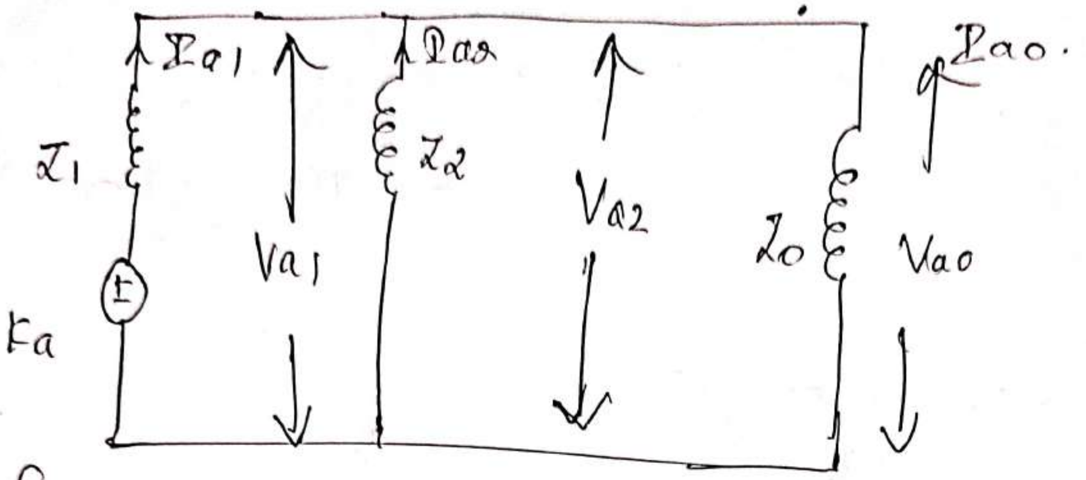
$V_{a0} = \frac{1}{3} V_a$; $V_{a1} = \frac{1}{3} V_a$; $V_{a2} = \frac{1}{3} V_a$

$$\boxed{V_{a0} = V_{a1} = V_{a2} = \frac{1}{3} V_a}$$

$$\boxed{I_a = I_{a1} + I_{a2} + I_{a0} = 0}$$

~~so~~ ckt All three phase Voltages are same so all three N/w's will be in parallel.

Since all the currents are addition they are shorted.



Sequence quantities :-

$$V_{a1} = V_{a2} = V_{a0} = E_a - I_{a1} Z_1$$

$$I_{a1} = \frac{E_a}{Z_1 + \left[\frac{Z_2 Z_0}{Z_2 + Z_0}\right]}$$ by reducing the N/w we will get.

$$I_{a2} = -I_{a1}\left[\frac{Z_0}{Z_2+Z_0}\right]$$
$$I_{a0} = -I_{a1}\left[\frac{Z_2}{Z_2+Z_0}\right]$$
By 'I' division rule.

Fault current :-

$$I_f = I_b + I_c$$

$$= (I_{a0} + a^2 I_{a1} + a I_{a2}) + (I_{a0} + a I_{a1} + a^2 I_{a2})$$

$$= 2I_{a0} + (a+a^2) I_{a1} + (a+a^2) I_{a2}$$

$$= 2I_{a0} - I_{a1} - I_{a2} \quad (\because (a+a^2) = -1)$$

$I_f = 2I_{a0} - (I_{a1}+I_{a2})$

$= 2I_{a0} - (-I_{a0})$ $\{ \because I_{a1} + I_{a2} + I_{a0} = C$

$I_{a1} + I_{a2} = -I_{a0}$

$$\boxed{I_f = 3I_{a0}}$$

$$I_f = 3\left[-I_{a1}\left(\frac{Z_2}{Z_2+Z_0}\right)\right\}$$

$$\boxed{I_f = -3I_{a1}\left[\frac{Z_2}{Z_0+Z_2}\right)}$$

Incase :- If Neutral Grounding is Absent

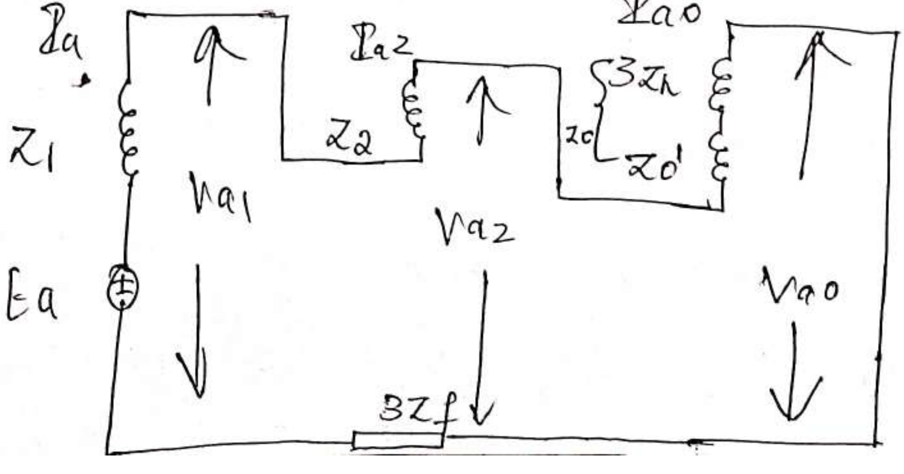
$Z_n = \infty$

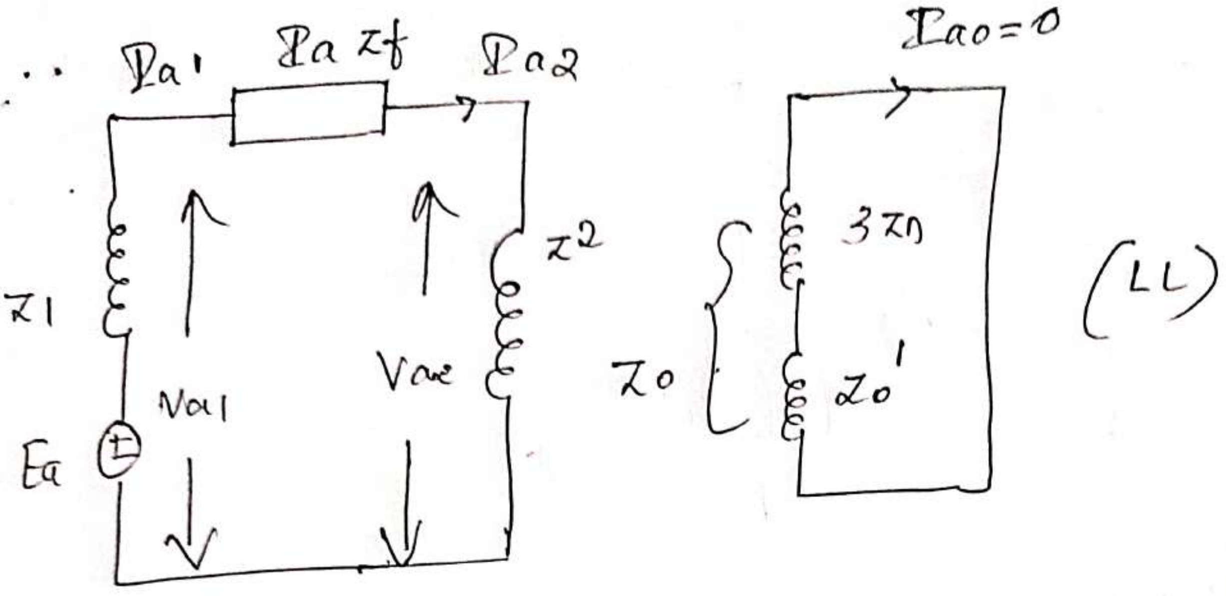
$Z_0 = Z_{g0} + 3Z_n = Z_{g0} + \infty = \infty$

Hence $I_f = -3I_{a1}\left[\frac{Z_2}{Z_2+\infty}\right] = 0$

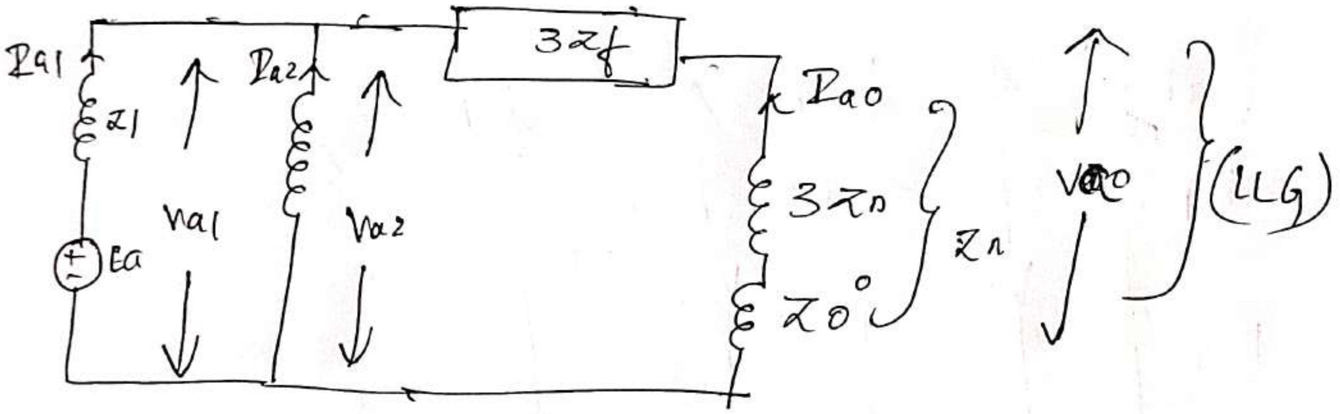
5] B.

(i) L - G





Ia1
Ia Zf
Ia2
Ia0=0
Z1
Z2
Va1
Va2
Ea
Z0
3Zn
Z0'
(LL)



Ia1
Z1
Ia2
Va1
Va2
Ea
3Zf
Ia0
3Zn
Z0
Zn
Va0
(LLG)

Name:- Karthik.G

USN:- 1OX18EE023

EEE VI 'A'

PSA

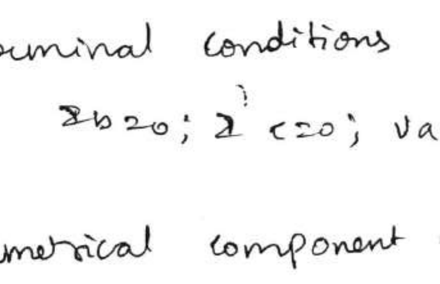
Internal III

1)

a) expression for fault current

A single line to ground fault at Point F in a power system through a fault impedance zf. the fault on phase a

$I_b = 0 ; I_c = 0 ; V_a = I_a Z_f$



Terminal conditions

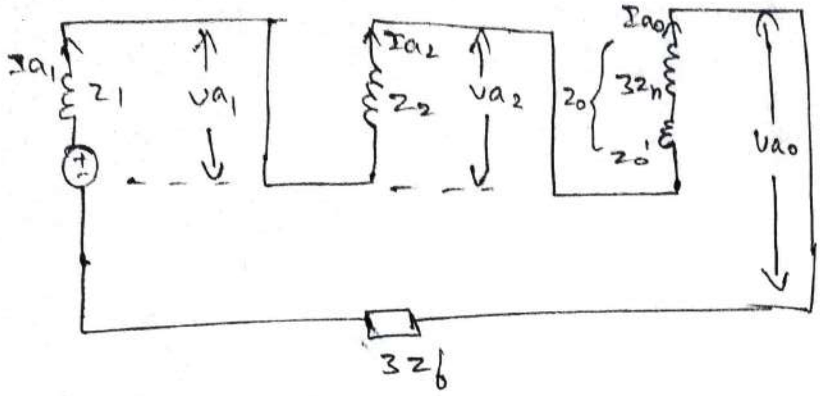
$I_b = 0 ; I_c = 0 ; V_a = Z_f I_a$

Symmetrical component Relations

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

$$I_{a_0} = \frac{1}{3} I_a = I_{a_1} = I_{a_2}$$

$$V_{a0} + V_{a1} + V_{a2} = I_a Z_f = 3 I_{a1} Z_f$$



$$I_{a0} = I_{a1} = I_{a2} = \frac{E_a}{Z_1 + Z_2 + Z_0 + 3Z_f}$$

$$V_{a1} = E_a - I_{a1} Z_1 = E_a \left[\frac{Z_2 + Z_0 + 3Z_f}{Z_1 + Z_2 + Z_0 + 3Z_f} \right]$$

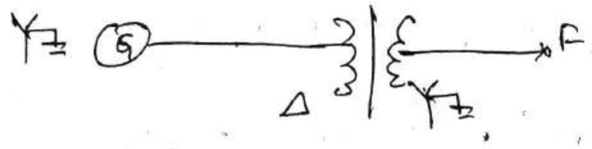
$$V_{a2} = -I_{a2} Z_2 = \frac{-E_a Z_2}{Z_1 + Z_2 + Z_0 + 3Z_f}$$

$$V_{a0} = -I_{a0} Z_0 = \frac{-E_a Z_0}{Z_1 + Z_2 + Z_0 + 3Z_F}$$

fault current.

$$I_f = I_a = 3 I_{a1} = 3 \left(\frac{E_a}{Z_1 + Z_2 + Z_0 + 3Z_f} \right)$$

2) a)



→

Section 1 : choose generator rating as common base

MVA$_B$ = 50; kV$_B$ = 11 kV

section 2 : MVA$_B$ = 50 MVA

kV$_B$ = $11 \times \frac{110}{11}$ = 110 kV

Reactance of generator

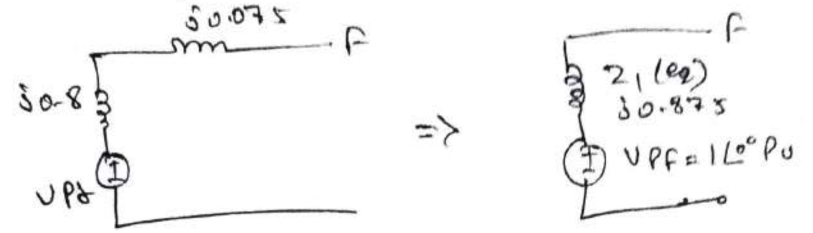
$x_1 = j0.8$ Pu ; $x_2 = j0.5$ Pu ; $x_0 = j0.2$ Pu

Reactance of Transformer

$x_1 = x_2 = x_0 = j\,0.06 \times \frac{50}{40} \times \left(\frac{11}{11}\right)^2$

$= j0.075$ Pu

Positive sequence network · Thevenins equi n/w



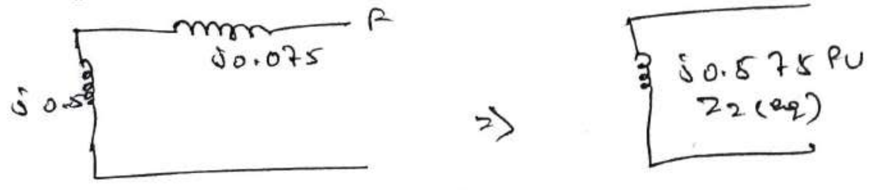
Vpf = 1∠0° Pu

$Z_{1(eq)} = j0.8 + j0.075$

$= j0.875$ Pu

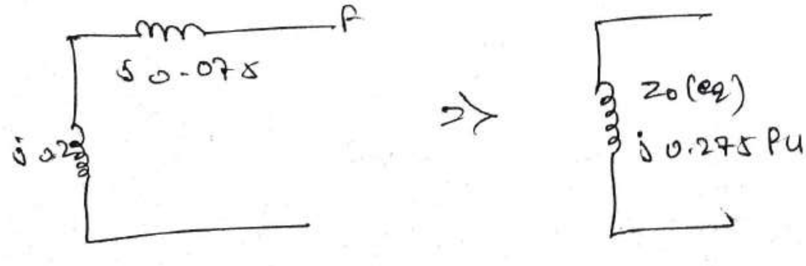
Negative sequence n/w

Thevenin eq NSN:



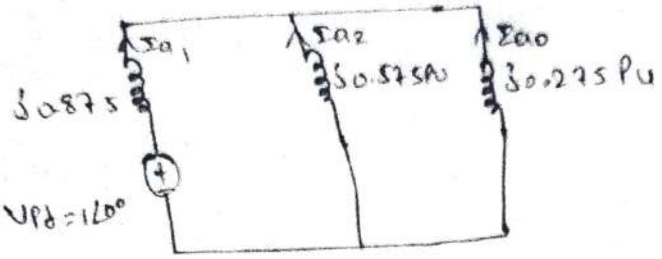
Zero sequence n/w

Thevenins eq ZSN:-



LLg fault

- Thevenin's equivalent PSN, NSN, ZSN in parallel



$$I_{a1} = \frac{V_{pf}}{Z_1 + \frac{Z_2 Z_0}{Z_2 + Z_0}}$$

$$= \frac{1\angle 0°}{j0.875 + \frac{j0.575 \times j0.275}{j0.575 + j0.275}}$$

$$= 0.942\angle -90° \text{ Pu}$$

$$I_{a0} = -I_{a1}\frac{Z_2}{Z_0 + Z_2}$$

$$= -(0.942\angle -90°)\frac{j0.575}{j0.575 + j0.275}$$

$$= 0.637\angle 90° \text{ Pu}$$

Fault current at Point F is $|I_f| = 3\,|I_{a0}|$.

$= 3 * 0.637$

$= 1.912$ Pu

Bare current, $I_B = \frac{1000 \times MVA_B}{\sqrt{3} \times KV_B}$

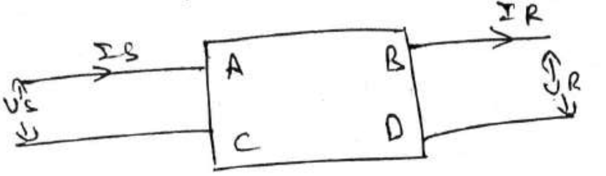
$= \frac{1000 \times 50}{\sqrt{3} * 110} = 262.4$ A

I_f (in A) $= 1.912 * 262.4$.

$= \underline{\underline{501.78 \text{ A}}}$

3) b)

→ In any linear network with two input and two output terminals, the input voltage and input current can be expressed interms of output voltage and output current. A transmission line can be represented as linear, bilateral, two terminal n/w.



The sending end voltage and sending end current of T/L line express as

$V_S = AV_R + BI_R$ → ①

$I_S = CV_R + DI_R$ ← ②

V_S ⇒ sending end v/g / phase ; $V_S = |V_S| \angle \delta°$

V_R → receiving end voltage / phase

I_S → sending end current / phase

I_R → receiving end current / phase

A, B, C, D → generalised circuit constants

on open circuit, $I_R = 0$

$$A = \frac{V_S}{V_R} = |A| \angle \alpha°$$

$$C = \frac{I_S}{V_R} = |C| \angle \vartheta°$$

on short circuit, $V_R = 0$

$$B = \frac{V_S}{I_R} = |B| \angle \beta°$$

$$D = \frac{I_S}{I_R} = |D| \angle \Delta°$$

Power delivered by the system is

$$P = Re\{V_R I_R^*] \rightarrow ③$$

from ①,

$$I_R = \frac{V_S - AV_R}{B}$$

$$= \frac{|V_S|\angle\delta^\circ - |A|\angle\alpha^\circ\,|V_R|\angle 0^\circ}{|B|\angle\beta^\circ}$$

$$= \frac{|V_S|}{|B|}\angle\delta-\beta - \frac{|A|\,|V_R|}{|B|}\angle\alpha-\beta$$

$$I_R^* = \frac{|V_S|}{|B|}\angle\beta-\delta - \frac{|A|\,|V_R|}{|B|}\angle\beta-\alpha \rightarrow ④$$

$$③ \Rightarrow P = Re\left\{|V_R|\angle 0^\circ * \left(\frac{|V_S|}{|B|}\angle\beta-\delta - \frac{|A|\,|V_R|}{|B|}\angle\beta-\alpha\right)\right]$$

$$= Re\left[\frac{|V_R||V_S|}{|B|}\angle\beta-\delta - \frac{|A|\,|V_R|^2}{|B|}\angle\beta-\alpha\right]$$

$$P = \frac{|V_R||V_S|}{|B|}\cos(\beta-\delta) - \frac{|A||V_R|^2}{|B|}\cos(\beta-\alpha)$$

* Max Power that can be transfered occurs at $\delta = \beta$ Hence SSSL of system is

$$P_m = SSSL = \frac{|V_R||V_S|}{|B|} - \frac{|A|\,|V_R|^2}{|B|}\cos(\beta-\alpha)$$

* Methods of Improving SSL

for a two m/c system, $SSSL = \frac{|E_g|\,|E_M|}{X}$

i) Increase either of voltages $|E_g|$ or $|E_w)$ can done by ↑ the excitation to the generator (or) motor or both

ii) Can be done using duplicate lines

This is known as double circuit the reactance is automatically reduced In addition the duplicate circuit also improve The reliability and flexibility

iii) can be done using series capacitors

They are sometimes employed in lines automatically the line reactance is reduced more over other advantage of using services capacitor is V/g regulation & PF of system is improved

iv) can be done using Bundled conductors

This reduce the line reactance & hence improve the SSSC

5)
a)

a) $KE = GH = 20 \times 9$

$= 180 \ MJ$

b) $\frac{GH}{180 \delta} \frac{d^2 \delta}{dt^2} = P_m - P_e$

$P_m = 26800 * 746$

$= 19.993 \ MU$

$P_e = 16 \ MW$

$\frac{180}{180 \times 50} * \frac{d^2 \delta}{dt^2} = 19.993 - 16$

[illegible]

∴ Rotor acceleration

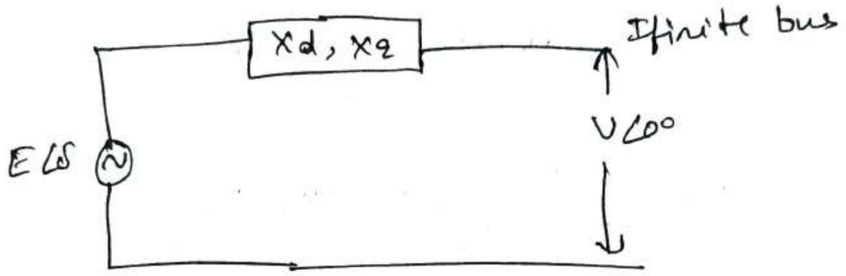
$\alpha = \frac{d^2 \delta}{dt^2}$

$= 199.65$ elec. deg/sec²

4) a) Power angle equation - Salient pole synchronous machine

* A salient Pole machine has a number of projecting Poles. Hence, the air gap is non-uniform along the rotar periphery. It least along the axis of the main poles and air-gap is maximum along axis of inter-polar region. hence flux linkages will also be non-uniform.

-> axis reactance (xd) & quadrature axis reactance (xq) for flow of armature current.



E∠δ° -> emf generated by the synchronous m/c

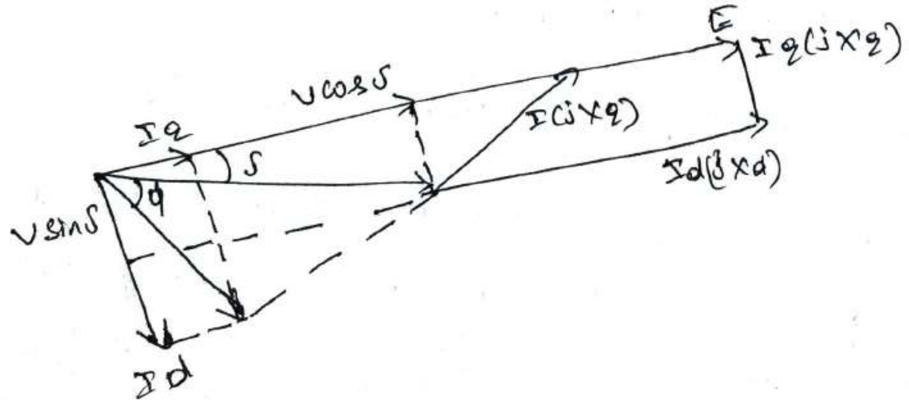
v∠0° -> Bus bus v/g

xd -> direct axis synchronous reactance

xq -> quadrature-axis synchronous reactance

I -> current delivered at lagging Pf of cos φ

Phasar diagram. by neglecting its armature resistance



$$P = |V| \cos\delta * |I_q| + |V| \sin\delta * |I_d| \rightarrow ①$$

also, $|I_q \cdot X_q| = |V| \sin\delta$

$$|I_q| = \frac{|V| \sin\delta}{X_q} \rightarrow ②$$

$$|I_d \cdot X_d| = |E - V\cos\delta|$$

$$|I_d| = \frac{|E| - |V|\cos\delta}{X_d} \rightarrow ③$$

Sub 2 & 3 in eqn ①

$$P = |V| \cos\delta \frac{(|V| \sin\delta)}{X_q} + |V| \sin\delta \frac{(|E| - |V|\cos\delta)}{X_d}$$

$$= |V|^2 \frac{\sin 2\delta}{2X_q} + \frac{|V||E| \sin\delta}{X_d} - \frac{|V^2| \sin 2\delta}{2X_d}$$

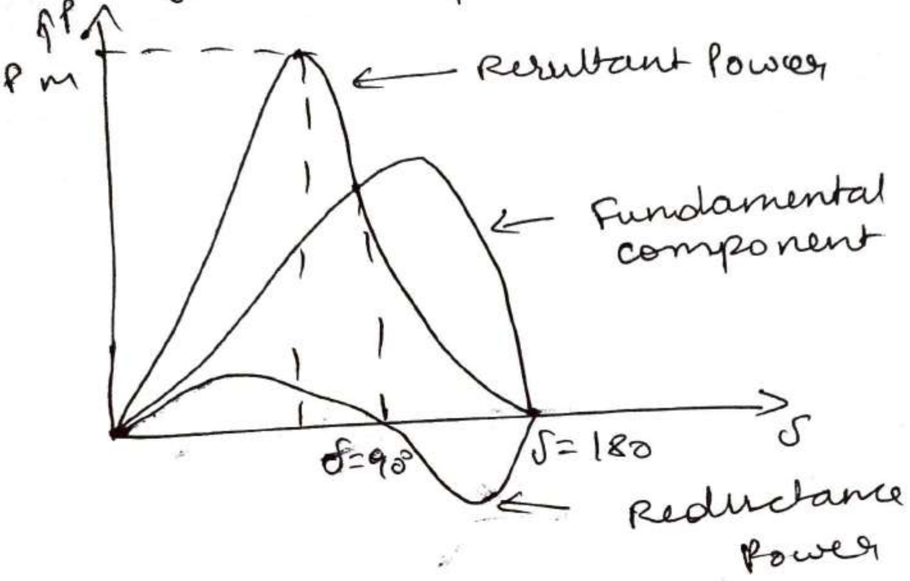
$$= |V|^2 \frac{\sin 2\delta}{2} \left\{ \frac{1}{X_q} - \frac{1}{X_d} \right] + |V||E| \frac{\sin\delta}{X_d}$$

$$= \frac{|V||E|}{X_d} \sin\delta + \frac{|V|^2 \sin 2\delta}{2} \left[\frac{X_d - X_q}{X_q X_d} \right]$$

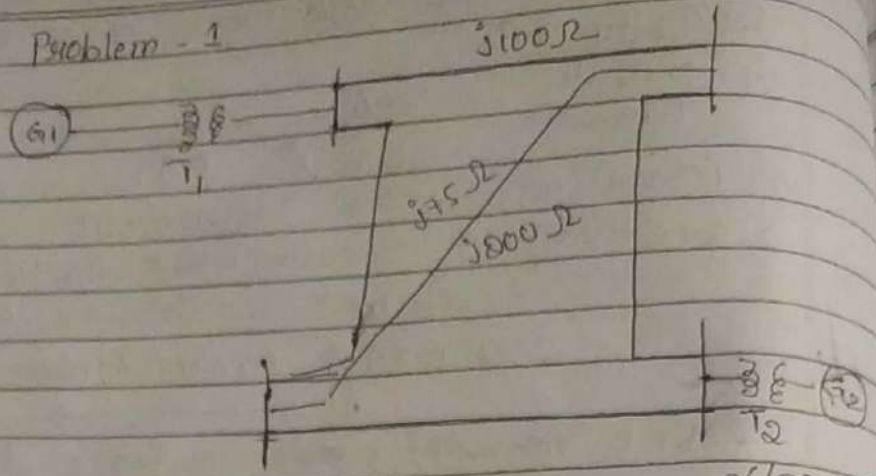
$$= \frac{|V||E|}{X_d} \sin\delta + \frac{|V|^2 (X_d - X_q)}{2 X_q X_d} \sin 2\delta \rightarrow ④$$

- Fundamental components is same as power of non salient Pole machine $X_s = X_d$
- Second harmonic component is quite small (10-20%) compared to fundamental component and known as reluctance power
- maximum power out put (sssl) occurs $\delta < 90°$
- This value of δ (around 70°) at which the power flow is maximum can be computed by equating the synchronizing power coefficient to zero, $\frac{dP}{d\delta} = 0$

* Power angle cure of salient-Pole machine is



Problem - 1



Details

G1 : 10MVA, 6.6KV, $x'' = 0.1$ PU

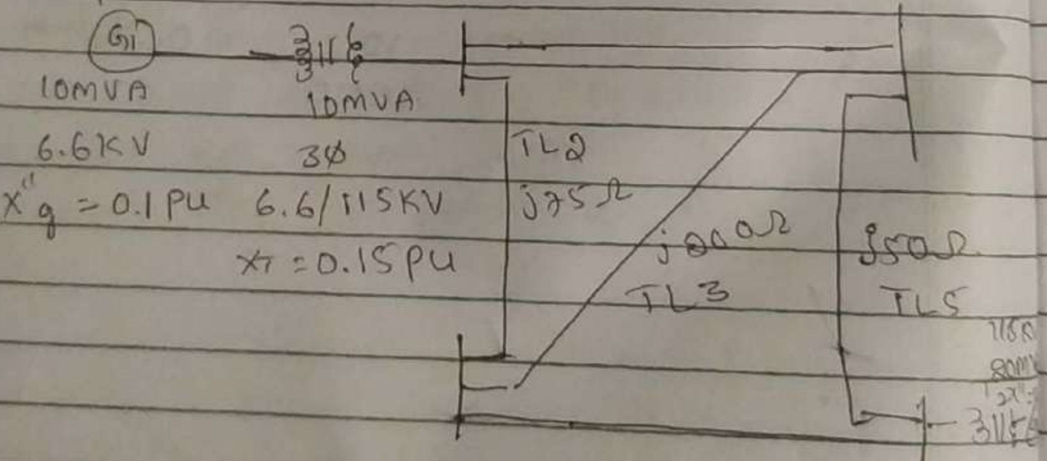
T1 : 10 MVA, 3∅, 115KV / 6.6KV, $X = 0.15$ PU

T2 : 3, 1∅TF, 10MVA, 7.5/75KΩ, $x = 0.10$ PU

G2 : 20MVA, 11.5KV $x'' = 0.1$ PU

Convert all to a common bale and Draw the reactance diagram for the same

Step 1



30 MVA

30/3 KVA

$XT_2 = 0.10$ PU

$T_2 \rightarrow 3$ NOS of 1∅ TF

∴ MVA = 10 × 3 = 30MVA

$T_2 \rightarrow$ Y/Y

$7.5 \times \sqrt{3} / 75 \times \sqrt{3}$

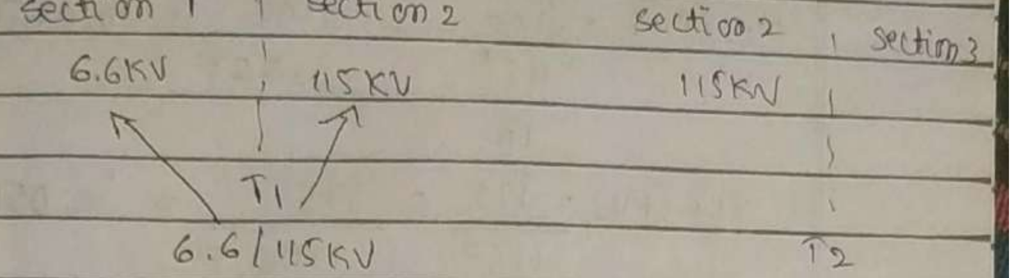
12.99/ 130KV

$x = 0.10$ pu

section 1 : G1 , T1 (PY) $S_B = 10$ MVA $V_B = 6.6$ KV

section 2 : T2 (SY) , TL1, TL2 , TL3 , TL4 , TL5 , T2 (PY)

$SB = 10$ MVA $VB = 115$ KV



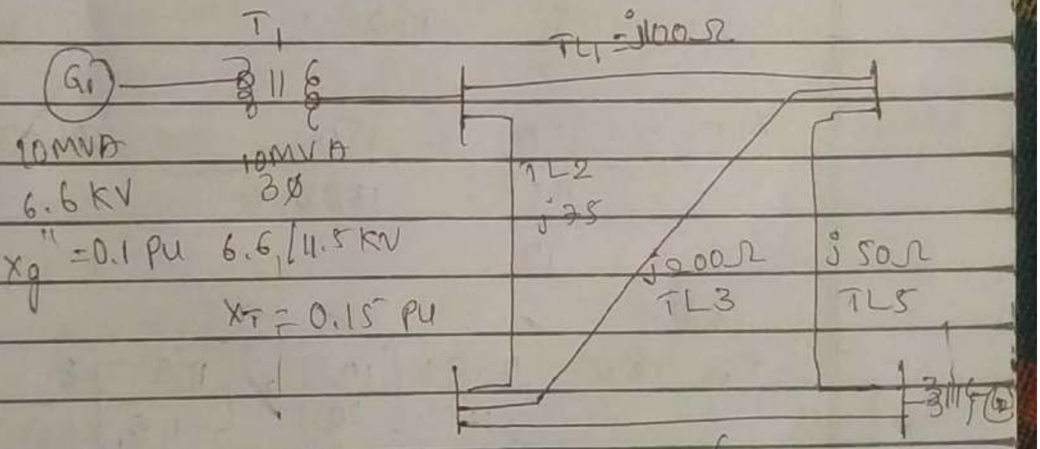
130 / 13KV

130 - 13

$115 - \frac{115 \times 13}{130}$

$= 11.5$ KV

step 1



step 2 : $x_{gn} = x_g(\text{old}) \times \frac{SB\text{new}}{SB\text{old}} \times \left(\frac{VB\text{old}}{VB\text{ new}}\right)^2$

$x_{g_2 n} = 0.10 \times \frac{10}{10} + \left(\frac{6.6}{6.6}\right)^2 = 0.10$ pu

$x_{T_1}(n) = 0.15 + \frac{10}{10} + \left(\frac{6.6}{6.6}\right)^2 - 0.15$ pu

TF$_2$

$x_{T_2} = 0.10 + \left[\frac{10}{30}\right] + \left[\frac{130}{115}\right]^2 = 0.04259$ pu

$$X_{L1} \,(pu) = \frac{X_{L1} \text{ actual (in ohms)}}{X_L \text{ base (in } \Omega)} = \frac{X_{L1}(\Omega)}{\frac{V_B^2}{S_B}}$$

All Tx lines lie in section 2 => $S_B = 1$
$V_B = 11$

$$X_{L1}(Pu) = \frac{j100}{\frac{115^2}{10}} = \frac{j100}{13225} = j0.0756 \text{ PU}$$

$$X_{L2}(Pu) = \frac{j75}{\frac{115^2}{10}} = \frac{j75}{1322.5} = j0.0567 \text{ PU}$$

$$X_{L3} = \frac{j200}{\frac{115^2}{10}} = \frac{j200}{1322.5} = j0.15122 \text{ pu}$$

$$X_{L4} = \frac{j150}{\frac{115^2}{10}} = \frac{j150}{1322.5} = j0.1134 \text{ Pu}$$

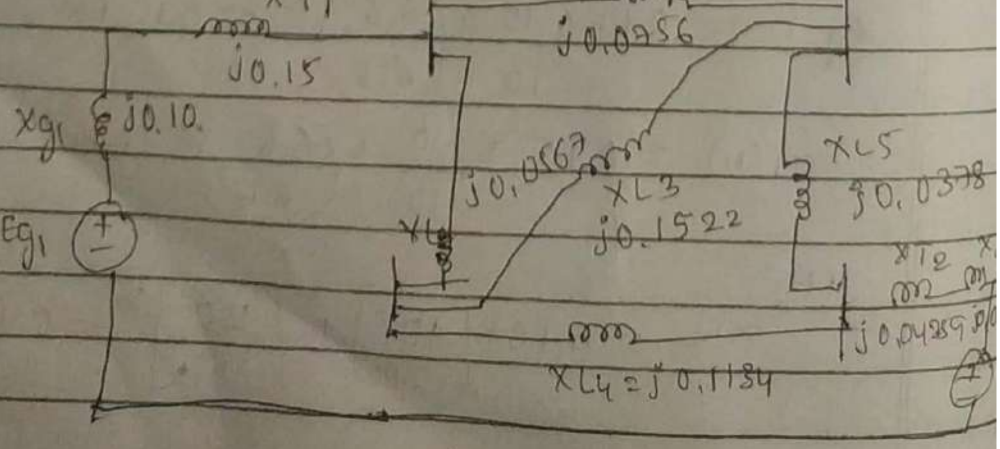
$$X_{L5} = \frac{j50}{\frac{115^2}{10}} = \frac{j50}{1322.5} = j0.03781$$

Section 3

$$X_{G2} \text{ new} = 0.10 + \left[\frac{10}{20}\right] + \left[\frac{11.5}{115}\right]^2$$

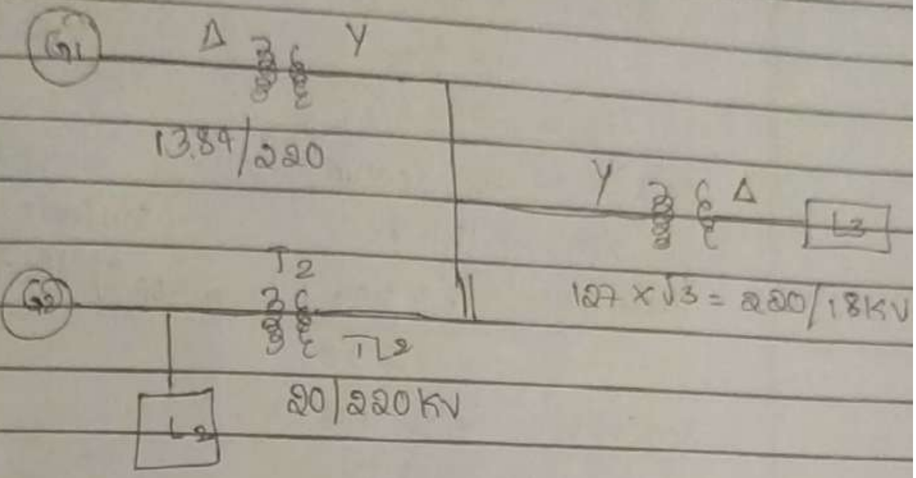
$$= j0.05 \text{ pu}$$

Reactance Diagram



Problem - 2

Draw the impedance diagram for the power system shown in fig below and mark on it The PQ unit Impedances calculated on DC base of 50MVA, 13KV in the circuit of Generator G1.



Generation G_1 - 25 MVA, 13KV, $X_d'' = 0.15$ pu

Transformer T_1 = 30MVA, 220/13.84 KV; $X = 10\%$,

Transmission Line TL1 = j60Ω

Transformer T_3 - Bank of 1φ T/F each Rated 10MVA, 127/18 KV, $X = 8\%$.

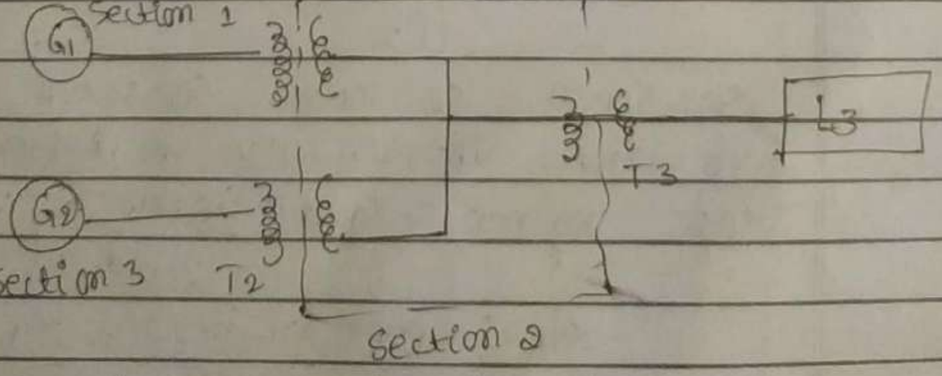
Load L_3 - $(4+j2)\ \Omega$

Transmission Line TL2 - j90Ω

Transformer T_2 - 40MVA, 220/20KV, $X = 12\%$.

Generator G_2 - 35MVA, 22KV, $X_d'' = 0.12$ pu

Load L_2 - $(3+j1)\ \Omega$



Section 1 : $S_B = 50$MVA, $V_B = 13$KV

Section 2 : $S_B = 50$MVA

Section 1	section 2
T1	

13.84/220KV

$13.84 \rightarrow 220$

$13 \rightarrow \frac{13 \times 220}{13.84}$

$V_B = 206.64$

Section 4 : $S_B = 50MVA$

$220 \rightarrow 18KV$

$206.64 \rightarrow \frac{18 + 206.64}{220} = 16.906$ pu

Section 3

$S_B = 50MVA$

Section 2 | Section 3

T2

220/20

$220 \rightarrow 20KV$

$206.64 \rightarrow \frac{206.64 + 2}{220}$

$\Rightarrow 18.785$

section 2 | section 3

$\sqrt{3}+127/\frac{18}{13}$

Section 4 : $S_B = 50MVA$

$220 \rightarrow 18KV$

$206.64 \rightarrow \frac{18 + 206.64}{220} = 16.906$ pu

Section 4: SB = 50MVA

$220 \rightarrow 18KV$

$206.64 \rightarrow \frac{18 + 206.64}{220} = 16.906$ pu

Section2 | section 4

T3

$\sqrt{3}+(27/18$

220/18

Section 1	section 2	Section 3	Section 4
G1, T1 (pu)	T1 Sy T3 (pu)	G1 T2 (pu)	T3 Sy, L3
	T2 (Sy)	L2	
	TL1		
	TL2		
SB = 50mVA	SB = 50MVA	SB = 50MVA	SB = 50MVA
VB = 13KV	VB = 206.64KV	VB = 18.785KV	VB = 16.906KV

Step 2 : $X_{g\,new} = X_{g\,old} * \frac{S_{B\,new}}{S_{B\,old}} * \left(\frac{V_{B\,old}}{V_{B\,new}}\right)^2$

X_{TL} in pu $= \frac{X_{TL} \text{ in } \Omega}{X\ Base} = \frac{X_{TL} \text{ in } \Omega}{\frac{V_B^2}{S_B}}$

$$X_{g1}n = 0.15 + \left[\frac{50}{25}\right] + \left[\frac{13}{13}\right]^2 = j0.3\,pu$$

$$X_{T1}(n)\,pu = 0.10 + \left[\frac{50}{30}\right] + \left[\frac{13.84}{13}\right]^2 = j0.1889$$

Step 3

$$X_{L1} = \frac{j60}{\frac{206.64^2}{50}} = j0.07025\,pu$$

$$X_{L2} = \frac{j90}{\frac{206.64^2}{50}} = j0.1054\,pu$$

Step 4: section 3

$$G_2(n) = 0.12 + \left[\frac{50}{35}\right] + \left[\frac{22}{18.785}\right]^2 = 0.2351$$

$$T_2(n) = 0.12 + \left[\frac{50}{40}\right] + \left[\frac{20}{18.785}\right]^2 = 0.17003$$

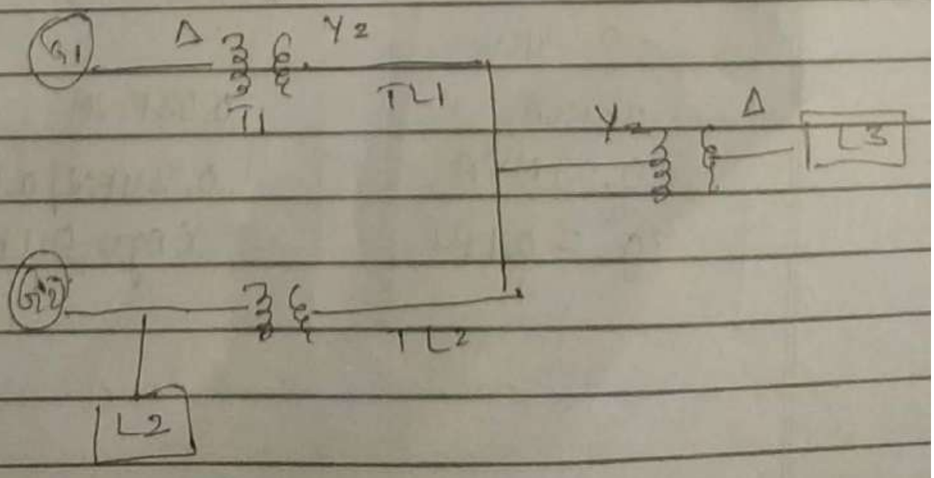
$$L_2 = \frac{3+j1}{\frac{18,785^2}{50}} = 0,425078 + j\,0,14169$$

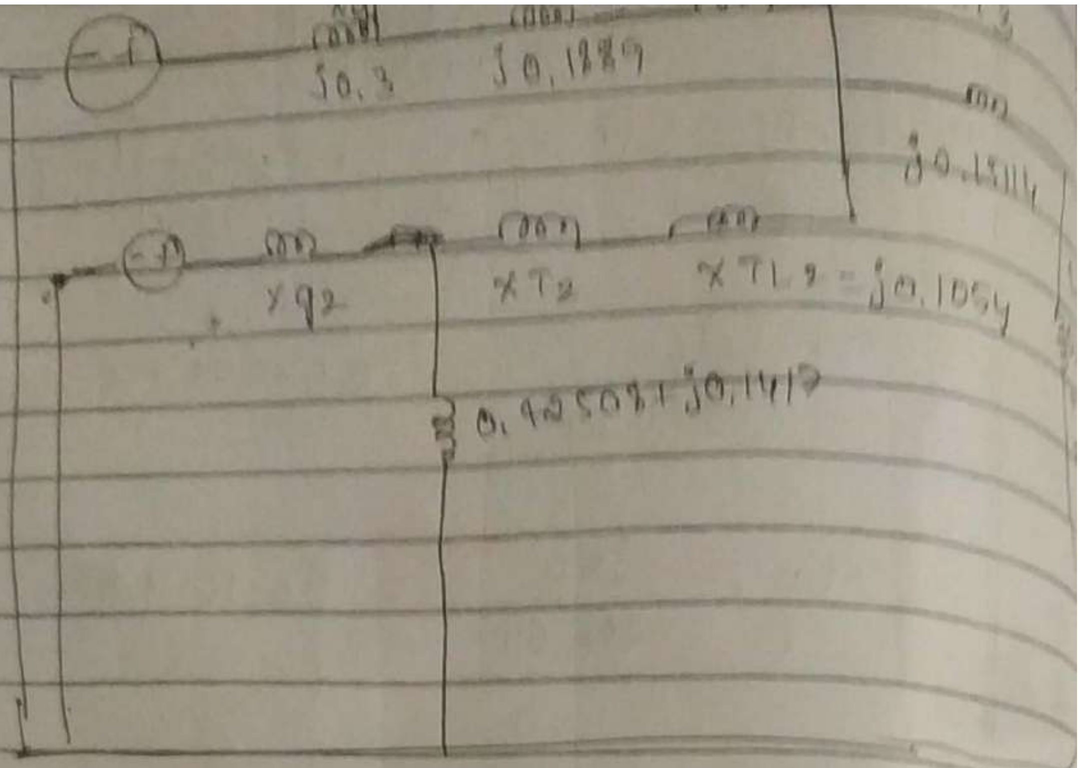
18,785² ⊕ ~~99250~~

section 4

$$X_{T3}\ new\ (sy) = 0.08 + \left[\frac{50}{30}\right] + \left[\frac{18}{16.806}\right]^2$$

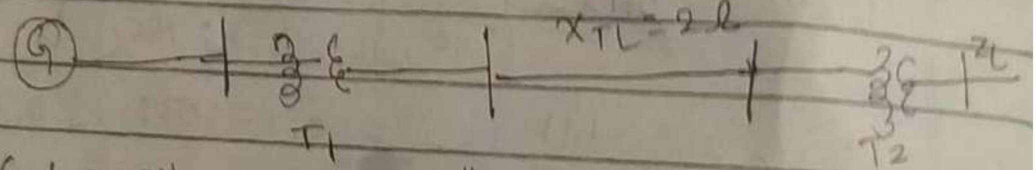
$$X_{L3} = \frac{4+j2}{\frac{16.906^2}{50}} = 0,6997 + j\,0,3487$$





problem - 3

Draw the reactance diagram for the system shown below



G : 240V, 30KVA, X_g'' = 0.1 PU

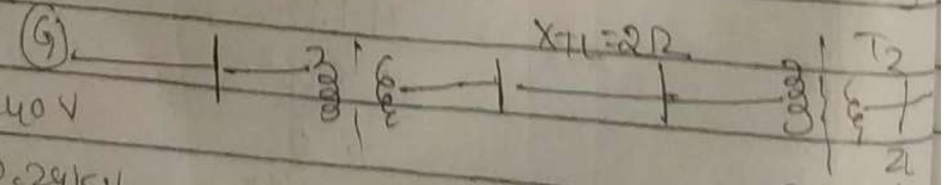
T_1 : 30KVA, 240 / 420V X_{eq} = 0.1 PU

T_2 : 20KVA, 460/115KV . X_{eq} = 0.1 PU

Z_L = (0.9 + j0.2) Ω

[Reactance diagram in series & parallel]

Step1



240 V
= 0.24KV

30KVA
= 0.03 MVA

X_g'' = 0.1 pu

0.03MVA
0.24KV / 0.48KV
Xeg = 0.1 pu

= 0.9 + j0.2
(Ω)

0.02MVA
0.46KV/
0.115

Xeq = 0.1PU

section 1
G_1 T_1,(Py)
SB = 0.03MVA
VB = 0.24kV

section 2
SB = 0.3MVA
VB = 0.48kV

section 3
SB = 0.03MVA
VB = 0.12kV

T_2
0.46/0.115kV
0.46 → 0.115
0.48 → 0.12kV

step 2 :

$$X_{gn} = X_{g(0)} \times \frac{SB\ new}{SB\ old} \times \left(\frac{VB_{OLD}}{V_{B\ new}}\right)^2$$

$$X \text{ in pu} = \frac{X \text{ in } \Omega}{\frac{V_B^2}{SB}}$$

step 2 :

$$X_{gn} = 0.1 \times \frac{0.03}{0.03} \times \left(\frac{0.24}{0.24}\right)^2 = 0.1j \text{ pu}$$

$$X_{TL} = \frac{2}{\frac{0.48^2}{0.03}} = j0.26041 \text{ pu}$$

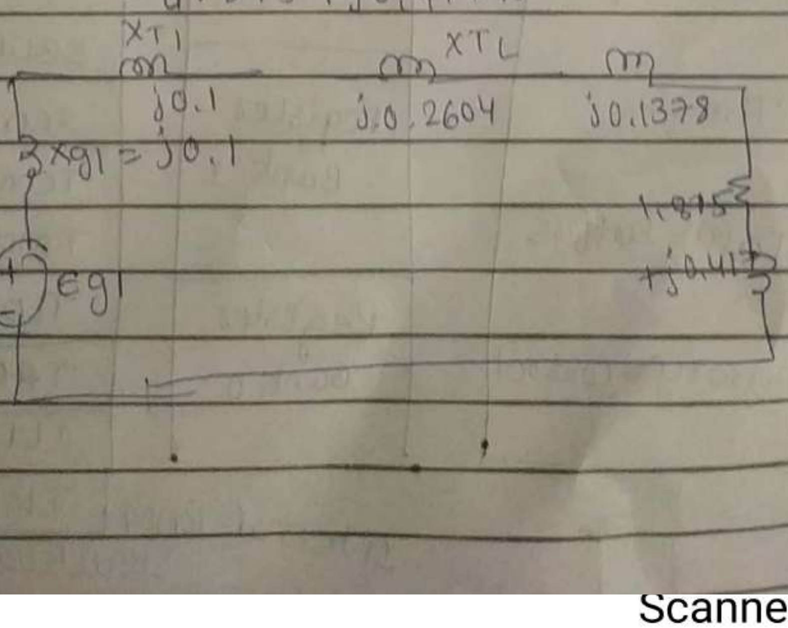
$$X_T = n = 0.1 \times \left[\frac{0.03}{0.02}\right] \times \left[\frac{0.46}{0.48}\right]^2 = 0.1378j$$

Z_L = series

$$Z_L = \frac{0.9 + j0.2}{\frac{0.12^2}{0.03}}$$

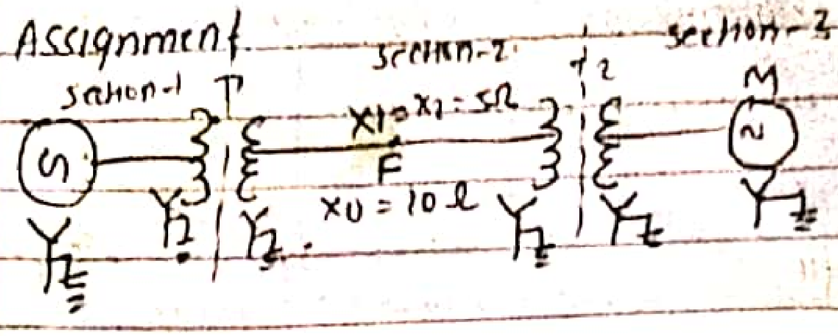
$$= 0.875 + j0.417A$$

Parallel
R = 1.875 pu
X_L = 0.417 pu



Assignment.

①



Section-1 :- G , $T_1(PY)$

Section-2 :- $T_1(SY)$, F , $T_2(PY)$

Section-3 :- $T_2(SY)$, M

- G = 20MVA , 11KV , $X_1 = 0.2PU$, $X_2 = 0.1PU$, $X_0 = 0.1PU$
- T_1 = 18MVA , 11.5/34.5kV , X = 0.1PU
- T_2 = 15MVA , 34.5/6.9kV , X = 0.1PU
- M = 15MVA , 6.9kV , $X_1 = 0.2PU$, $X_2 = X_0 = 0.1PU$

→ Since base is not given we assume base as generator.

Sec-1 = Sb = 20MVA , Vb = 11KV

Sec-2 :- Sb = 20MVA , Vb = 33kV

Sec-3 :- Sb = 20MVA , Vb = 6.6kV

- X_g :- $X_1 = \frac{0.2 \times 20 \times 11 \times 11}{20 \times 11 \times 11} = 0.2j$

$X_2 = \frac{0.1 \times 20 \times 11 \times 11}{20 \times 11 \times 11} = 0.1j$

$X_0 = 0.1j$

- $X_{T_1} = X = \frac{0.1 \times 20 \times 11.5 \times 11.5}{18 \times 11 \times 11} = \frac{264.5}{2178} = 0.121j$

- $X_{T_2} = \frac{0.1 \times 20 \times 34.5 \times 34.5}{15 \times 33 \times 33} = \frac{2380.5}{16335} = 0.145j$

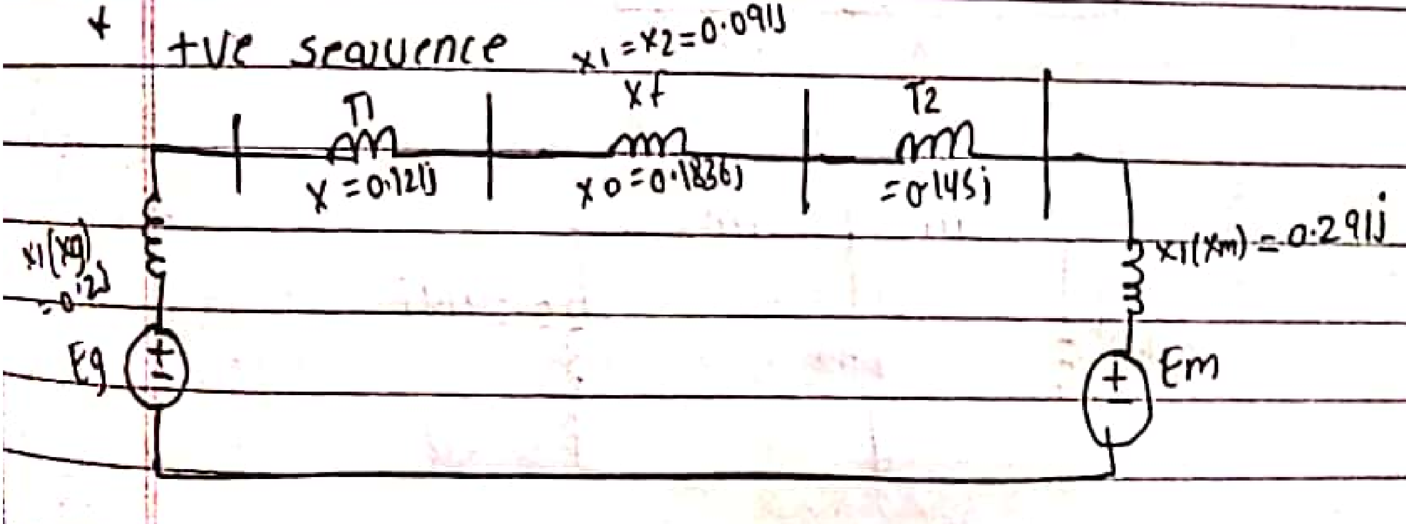
- $X_m = X_1 = \frac{0.2 \times 20 \times 6.9 \times 6.9}{15 \times 6.6 \times 6.6} = \frac{190.44}{653.4} = 0.291j$

- $X_2 = X_0 = \frac{0.1 \times 20 \times 6.9 \times 6.9}{15 \times 6.6 \times 6.6} = \frac{95.22}{653.4} = 0.1457j$

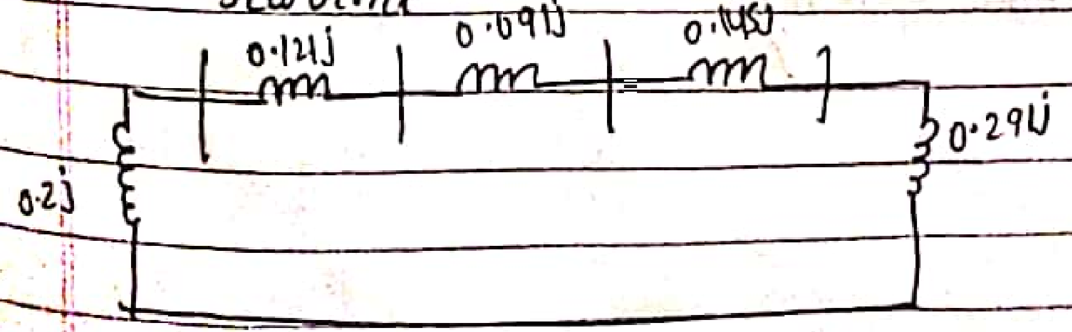
- $X_F = X_1 = X_2 = \frac{5j}{\frac{(33)^2}{20}} = \frac{5j}{54.45} = 0.091j$

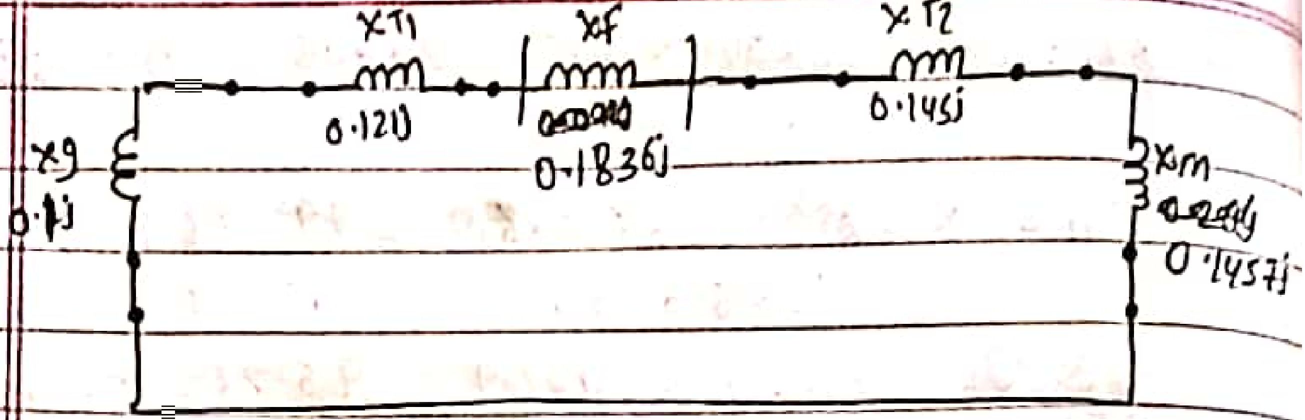
$X_0 = \frac{10j}{54.45} = 0.1836j$

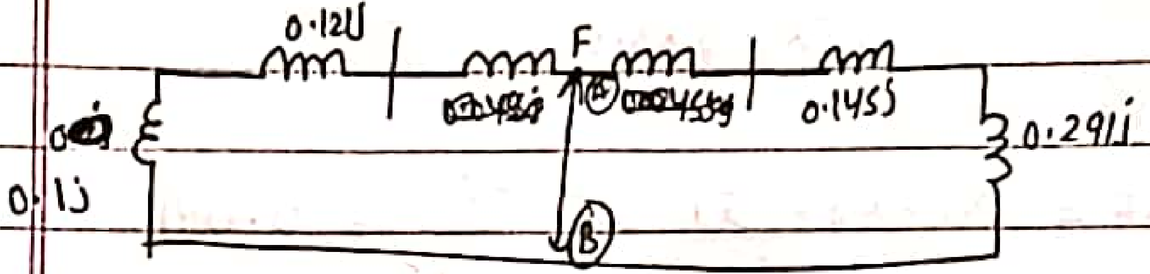
* +ve sequence

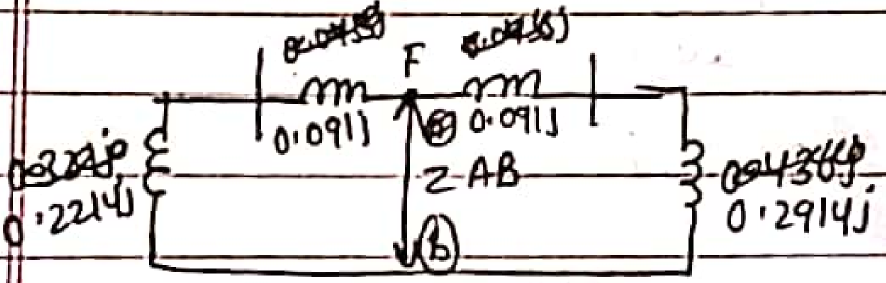


* -ve sequence

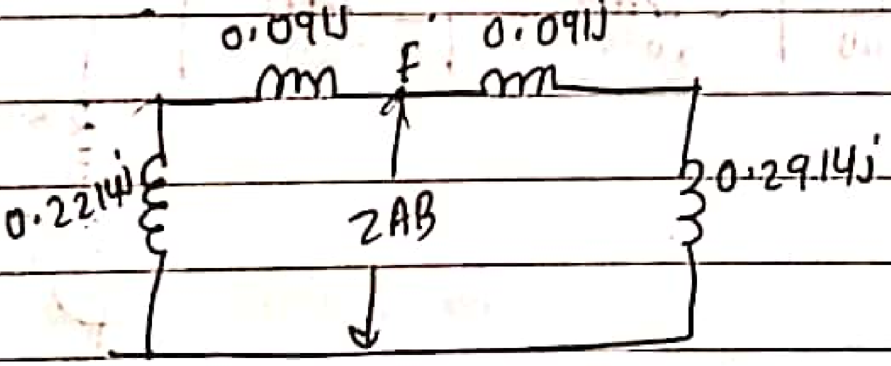






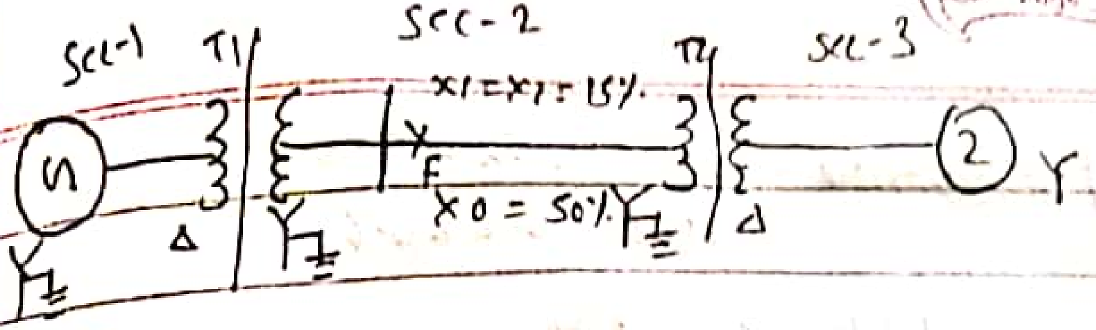


0.3124
0.3824



$ZAB = 0.1724j$ //

②



Section-1 = G, T1(PY)

Section-2 = T1(SY), F, T2(PY)

Section-3 = T2(SY), 2

- G :- 1250KVA, 600V, X1=X2=10%, X0=4%
  = 1.25MVA, 0.6KV, X1=X2=0.10, X0 = 0.04
- T1 :- 1250KVA, 600/4160V, X=5%
  = 1.25MVA, 0.6/4.16KV, X=0.05
- T2 :- 1250KVA, 4160/600V, X=5%
  = 1.25MVA, 4.16/0.6KV, X=0.05
- 2 :- 1250KVA, 600V, X1=X2=10%, X0=4%
  = 1.25MVA, 0.6KV, X1=X2=0.10, X0 = 0.04%

Section-1 :- Sb = ~~0.12~~ 1.25 MVA, Vb = 0.6KV

Section-2 :- Sb = ~~0.12~~ 1.25 MVA, Vb = ~~0.6~~ 4.16 KV

Section-3 :- Sb = ~~0.12~~ 1.25 MVA, Vb = 0.6KV

- $X_g = X_1 = X_2 = \frac{0.1\times1.25\times0.6\times0.6}{1.25\times0.6\times0.6} = 0.1j$

- $X_0 = \frac{0.4\times1.25\times0.6\times0.6}{1.25\times0.6\times0.6} = 0.4j$

- $X_{T1} = X_1 = X_2 = X_0 = \frac{0.05\times1.25\times0.6\times0.6}{1.25\times0.6\times0.6} = 0.05j$

- $X_L = X_1 = X_2 = \frac{0.15j}{\frac{(\text{[illegible]})^2}{1.\text{[illegible]}}} = \text{[illegible]}$

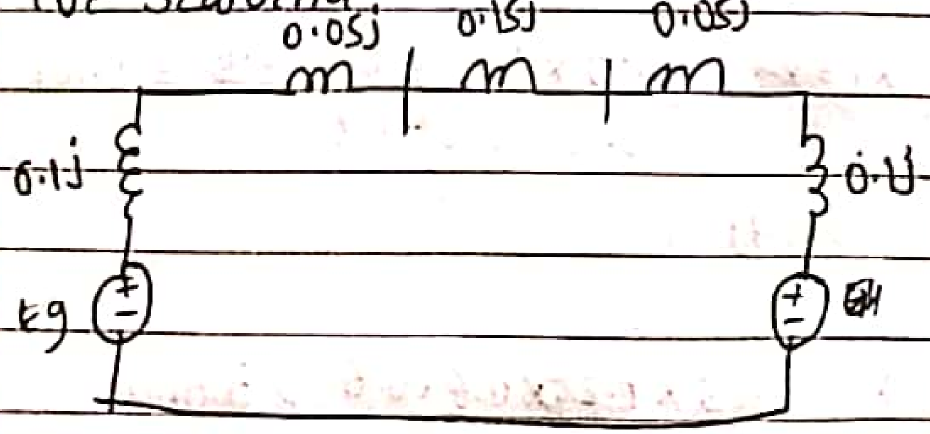
  $X_0 = \frac{0.5j}{\text{[illegible]}} = \text{[illegible]}$

- $X_{T2} = \frac{0.05\times1.25\times4.16\times4.16}{1.25\times4.16\times4.16} = 0.05j$

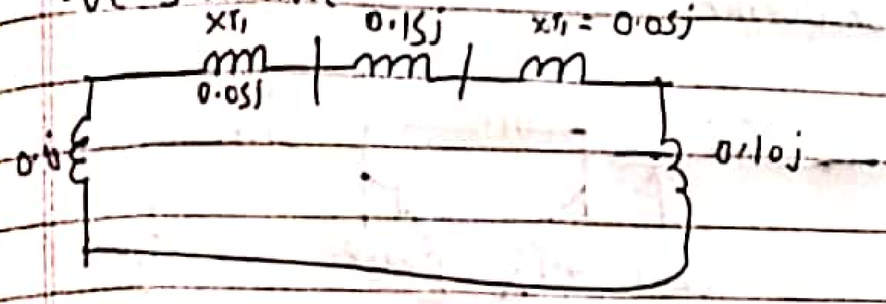
- $X_m = X_1 = X_2 = \frac{0.10\times1.25\times0.6\times0.6}{1.25\times0.6\times0.6} = 0.10j$

  $X_0 = \frac{0.04\times1.25\times0.6\times0.6}{1.25\times0.6\times0.6} = 0.04j$

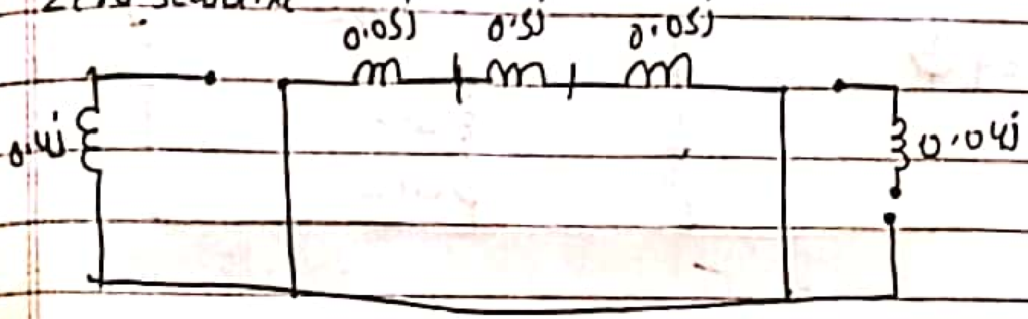
* +ve seauence



* -ve sequence

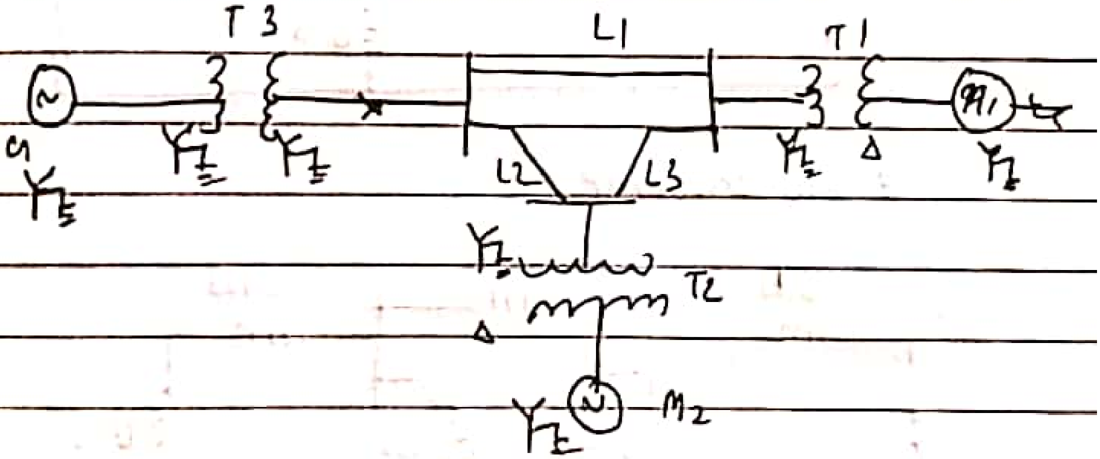


* zero sequence



$Z_{AB} = 0.12j\ pU$ //

③



G :- $X_1 = 0.3$, $X_2 = 0.2$, $X_0 = 0.1$

T_1 & T_2 :- $X_1 = X_2 = X_0 = 0.12$

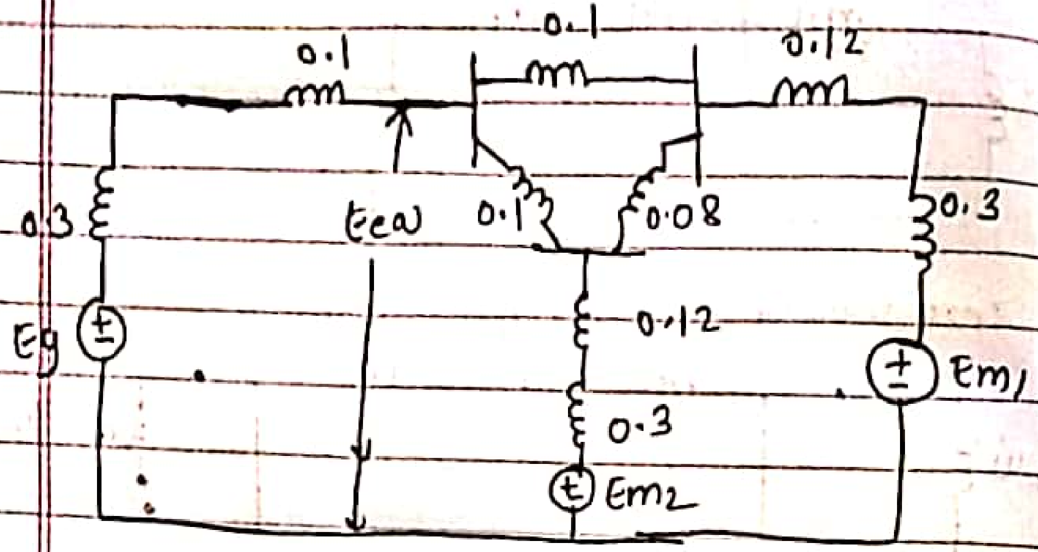
T_3 :- $X_1 = X_2 = X_0 = 0.1$

L_1 & L_2 :- $X_1 = X_2 = 0.1$, $X_0 = 0.2$

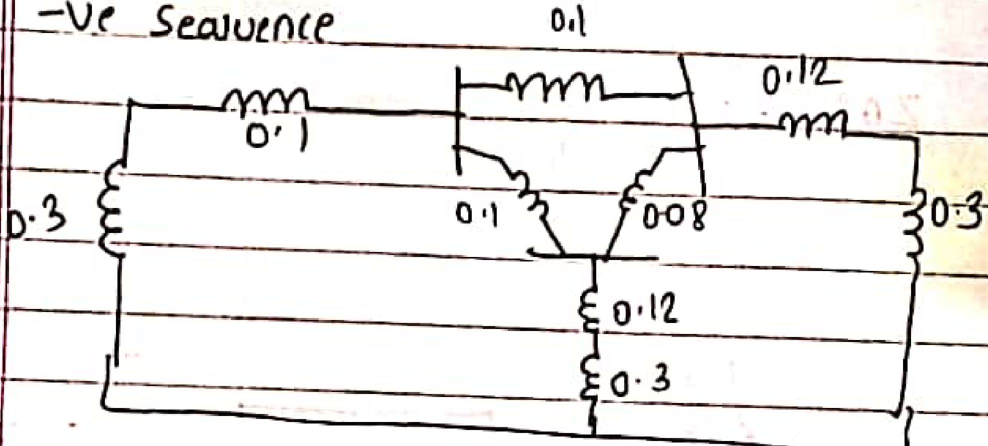
L_3 :- $X_1 = X_2 = 0.08$, $X_0 = 0.25$

M_1 & M_2 :- $X_1 = 0.3$, $X_2 = 0.2$, $X_0 = 0.1$

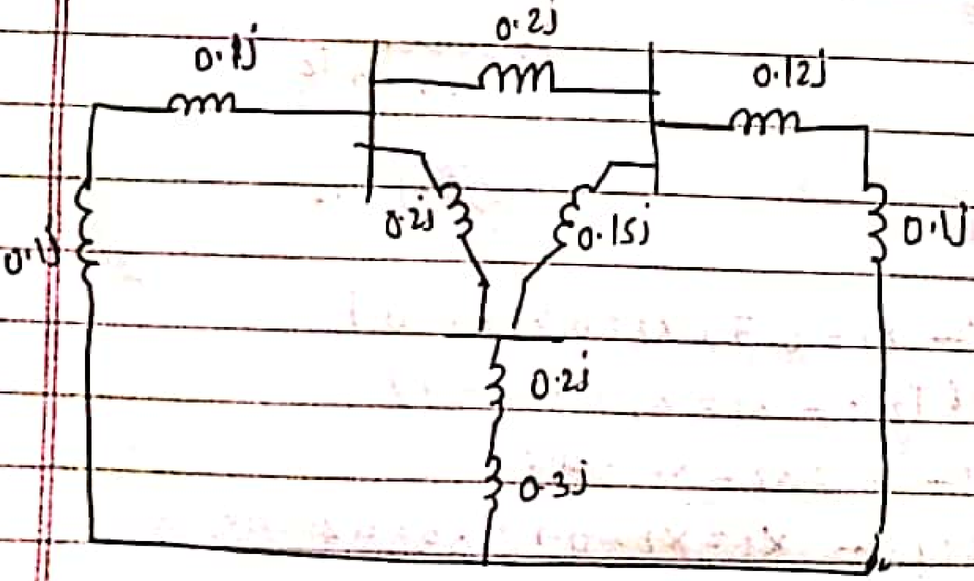
- +ve seaquence

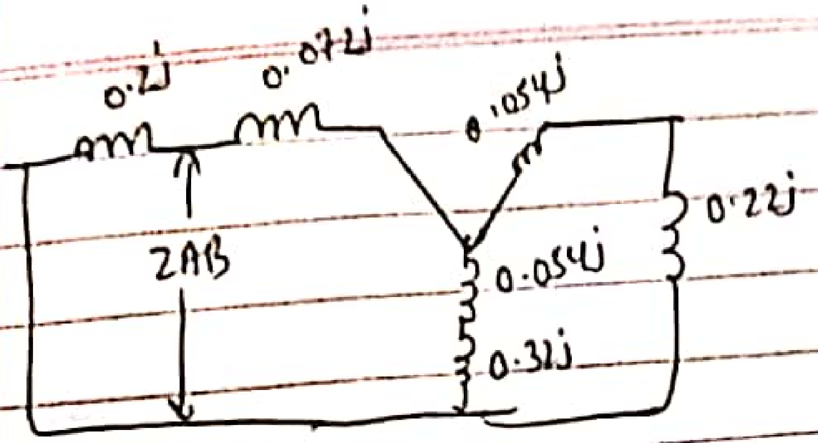


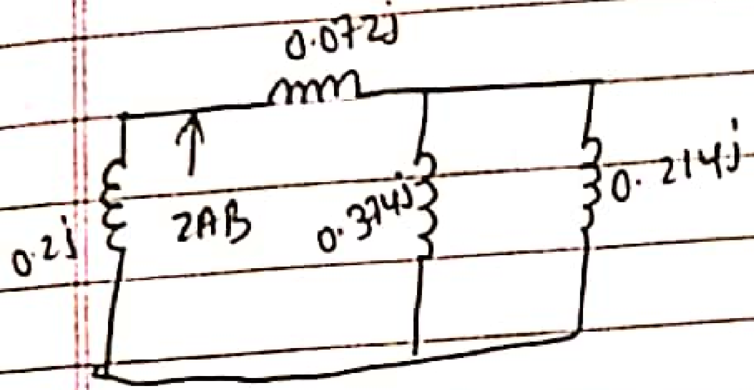
- -ve Seaquence

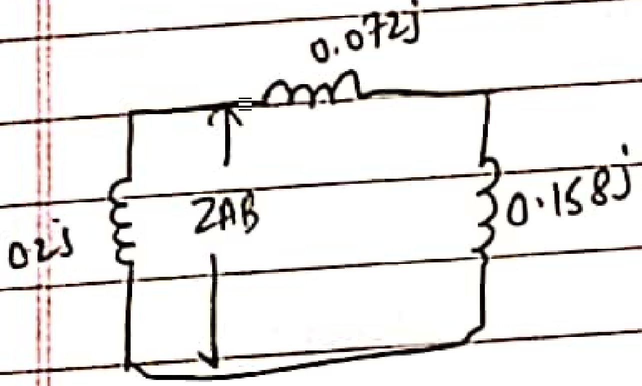


- Zero seaquence









0.072+0.158 = 0.23

0.1022j

$$ZAB = 0.2 \,||\, 0.23 = \frac{0.2 \times 0.23}{0.2+0.23} = \frac{0.0\overset{4}{6}}{0.45} = \text{[illegible]} \;//$$

question paper   Manik belure

10X18EE031

PSA

Assignment -1   June/July 2018.

1a, 1b, 2a, 2b

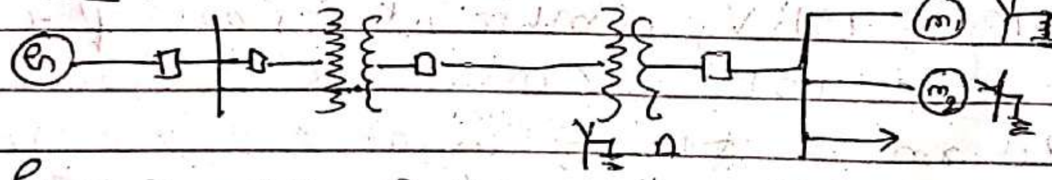
Dec 2018 / Jan19

1a, 1b, 1c, 2(a, b, c)

a) 1) With suitable example explain one line diagram & discuss the elements represent

⇒ one line diagram (or) single line diagram do not show all the 3 phases. It consists of one of the 3 lines & a neutral return. Also the diagram represents the components of the system by standard symboles rather than by their equivalent circuit

Eg:-



G = 300mVA, 20KV, $X'' = 1.2\Omega$

T_1 = 350mVA, 230V-Y / 20KV-Δ, $X = 15.2\Omega/ph$

T_2 = 300mVA, 230V-Y/13.2KV-Δ, $X = 16\Omega/ph$

T_L — l = 64km ; $X_{T_1} = 0.5\Omega/km$

M_1 = 200mVA, 13.2KV, $X'' = 1.6\Omega$

M_2 = 100MVA, 13.2KV, $X' = 1.6\Omega$

Static Load.

Ⓖ → G = generator

M_1 → motor 1

M_2 → motor 2

—▷ → static load

T_1 = Transformer -1

T_2 = ' ' — 2

Δ → delta

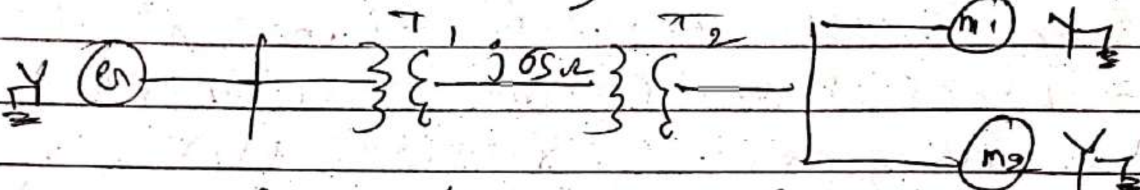
Y⏚ → star with ground

TL → Transmission Line

X → Reactance

Y⏚ → star with load to ground

(1b) Draw the per unit Reactance diagram for the system shown. Selecting the generator rating as the base. Also find the generator terminal voltage.



The rating of the various components

G = 13.8 KV, 25 MVA, X'' = j0.15 pu

T1 = 13.2/69 KV, 25MVA, X = j0.11 pu

T2 = 69/13.2 KV, 25MVA, X = j0.11 pu

M1 = 13KV, 15MVA, X'' = j0.15 pu

M2 = 13KV, 10 MVA, X'' = j0.15 pu

Determine the generator terminal voltage when both the motors operate at 12 KV, 75% full load & UPF

⇒

Base value = 25 MVA, 13.8 KV

Section 1	Section-2	Section-3
SB = 25MVA	SB = 25MVA	SB = 25MVA
VB = 13.8KV	13.2 → 69	69 → 13.2KV
	$13.8 \to \frac{13.8 \times 69}{16.2}$	$72 \to \frac{13.2 \times 72}{69}$
	VB = 72.136KV	

VB = 13.8KV

$X_{g}(n) = 0.15j \times \frac{25}{25} \times \frac{13.8^2}{13.8^2} = 0.15j\ pu$

$X_{T_1}(n) = 0.11j \times \frac{25}{25} \times \frac{13.2^2}{13.8^2} = 0.10j\ pu$

$X_{T_1}(n) = 0.11j \times \frac{25}{25} \times \frac{69^2}{72.836^2} = 0.1006j\ pu$

$X_{m_1}(n) = 0.15j \times \frac{25}{25} \times \left(\frac{13}{13.8}\right)^2 = 0.2218j\ pu$

$X_{m_2}(n) = 0.15j \times \frac{25}{10} \times \left(\frac{13}{13.8}\right)^2 = 0.3327j$

$X_{L_1}(pu) = \frac{05j}{\frac{72.136^2}{25}} = 0.313j$

$\Rightarrow I_L = I_{L1} + I_{L2}$

$S_1 = 15\ mVA$

75% of $S_1 = 11.25\ mVA$

$= \left(15 \times \frac{75}{100}\right)$

$I_1 = \frac{S_1}{\sqrt{3} V_1} = \frac{11.25 \times 10^6}{\sqrt{3} \times 12 \times 10^3}$

$= 541.26A$

$S_2 = 10\ mVA$

75% of $S_2 = 75\ mVA$

$\left(10 \times \frac{75}{100}\right)$

$I_2 = \frac{7.5 \times 10^6}{\sqrt{3} \times 12 \times 10^3}$

$= 360.84A$

$I_{actual} = 541.26 + 360.84 = 902.10A$

$I_{Base} = \frac{25 \times 10^6}{\sqrt{2} \times 13.8 \times 10^3} = 1045.92$

$I_{pu} = \frac{I_{actual}}{I_{Base}} = 0.86\ pu$

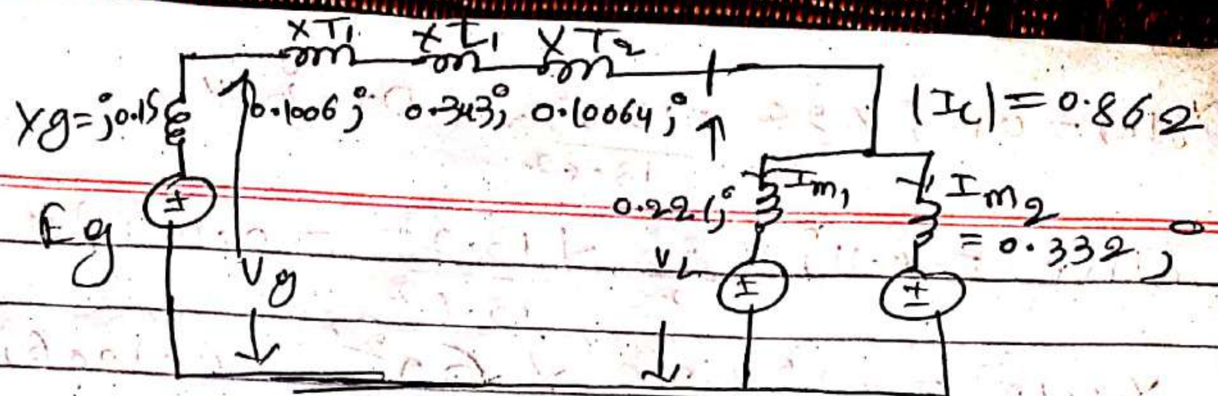
$V_L(pu) = \frac{12}{13.8} = 0.87\ pu$

$V_g = V_t + I_L(jT_1 + jL_1 + jT_2)$

$V_g = 0.87 + 0.8624(0.1006j + 0.313j + 0.10064j)$

$= 0.87 + 0.44j$

$= 0.97667\angle 27.03\ pu$



$V_g(pu) = V_{g\,pu} \times$ Base of generation $= 0.97 \times 13.8 = 13.4$ KV.

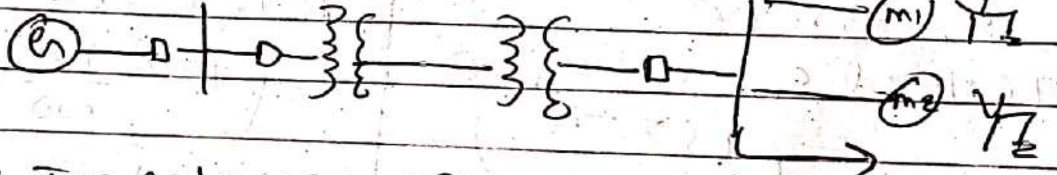
$E_{g\,in}(pu) = V_g + I_L(jX_g) = (0.87 + 0.44j) + 0.8624(0.15j)$

$= 1.0397 \angle 33.20$

$E_{g\,in}(pu) = 1.0394 \times 13.5 = 14.35$ Kv

② a) with help of typical electrical power system, explain impedance & reactance diagram & mention the assumption made in that.

=>



· Impedance Diagram.

The impedance diagram is obtained by replacing each component of the power system by its single phase equivalent circuit.

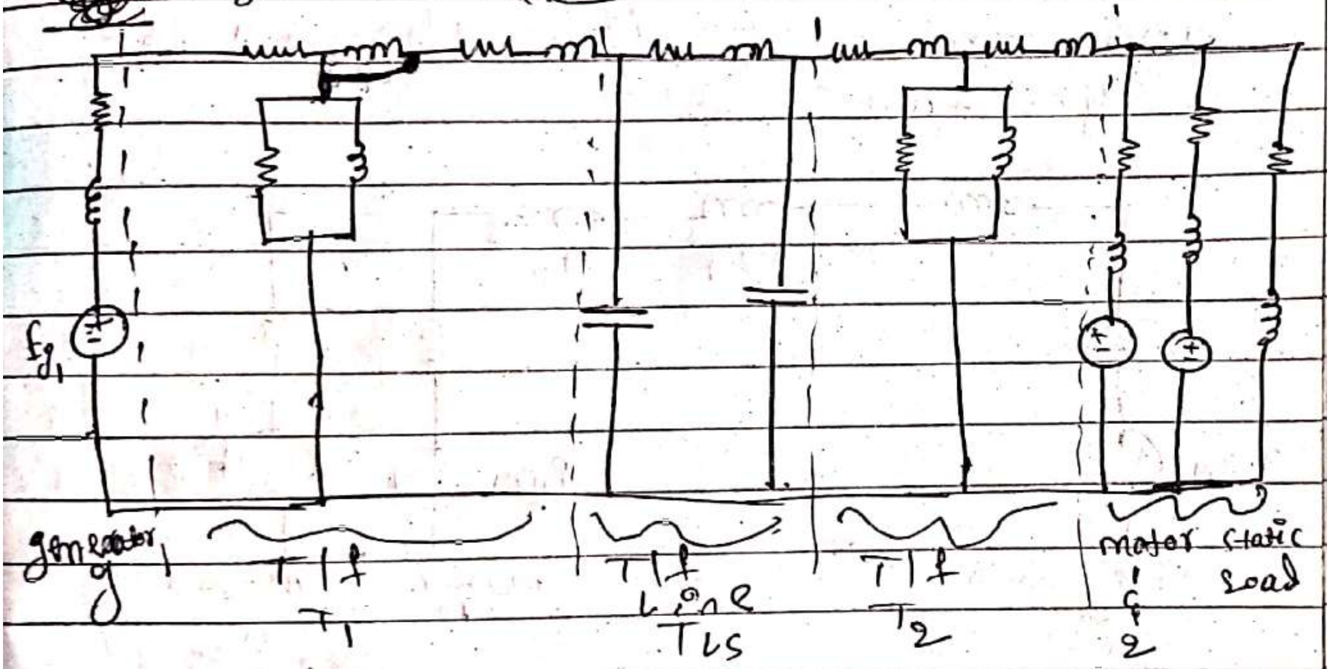
use:- To calculate the performance of a system under load conditions (or) upon the occurance of a fault.

Assumption made:-

① Resistance & reactance used for grounding the neutral of the generator is not shown Assumption made is : During balanced state no current flows through the neutral

Eg:- for the above 1 line Diagram the Impedance diagram is given below.

~~for the above l~~



Reactance Diagram

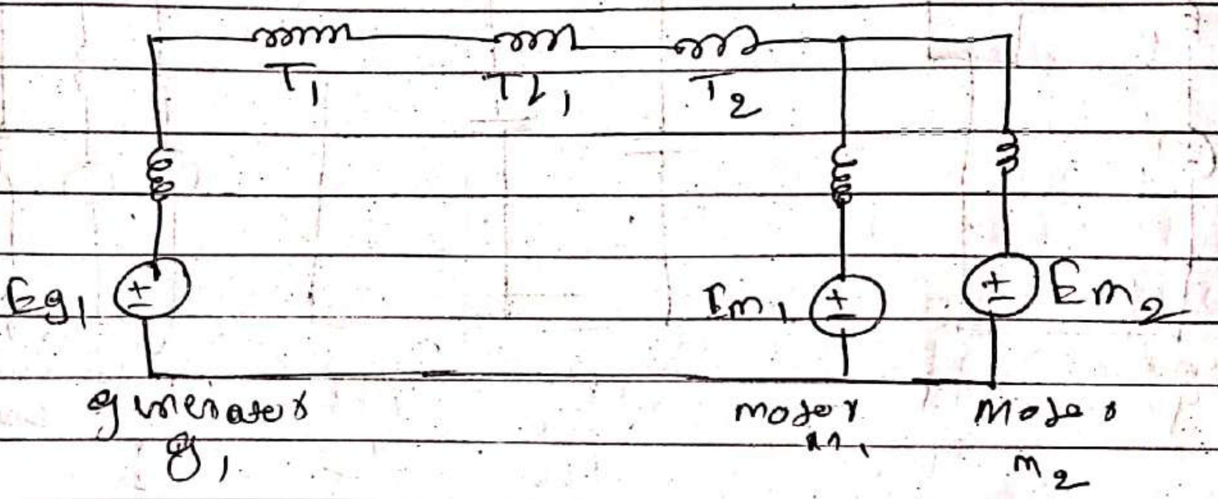
Assumption made:-

(i) while doing fault calculations, resistance value can be omitted, since the impedance is not so different from the inductive reactance as the resistance is small.

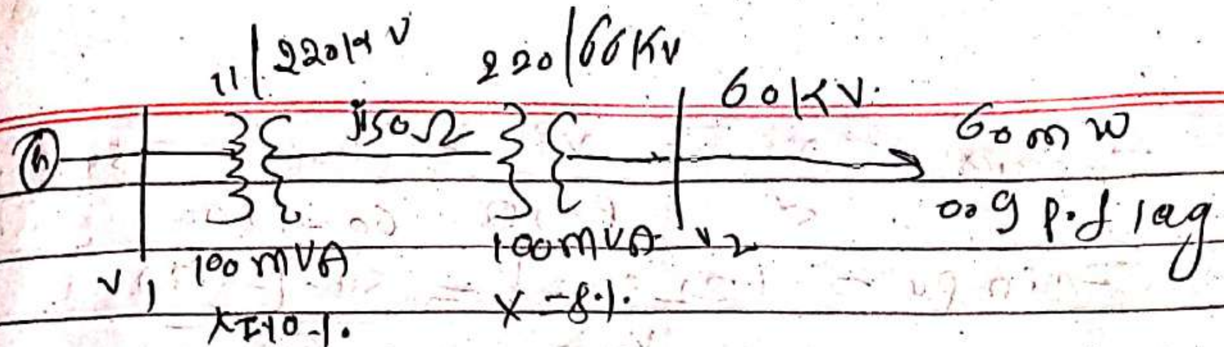
(ii) Loads which do not involve rotating machinery have little effect on the total line current during a fault & hence they are omitted

iii) magnetizing components of t/f are also neglected as magnetizing current as less compared to full load current.

iv) The capacitance of the transmission line is also neglected as only less current will flow through the capacitance.



2b) The schematic diagram of a radical transmission system is shown in fig. The rating & reactance of the various components are shown in. A load of 60mw at 0.9 p.f lagging is tapped from 66kV substation which is to be maintained at 60kV. calculate the terminal voltage of the machine. Represent the t/f line & t/f by series reactance only.



⇒ generator SB = 100 MVA, VB = 22 KV

Step 1 :- Section 1 : G, T1 (PY), SB = 100 MVA
VB = 11 KV

Section 2 :- T1 (sec), T2 (PY) SB = 100 MVA
VB = 220 KV

Section 3 :- T2 (sec), load SB = 100 MVA
VB = 66 KV

Section 1 :- $X_{T_1}(new) = 0.1 * \frac{100}{100} \times \frac{11^2}{11^2} = 0.1j$ pu

Section 2 :- $X_{T_2}(n) = 0.08j \times \frac{100}{100} \times \frac{220^2}{220^2}$

$= 0.08j$ pu

$X_{TL}(n) = \frac{j50}{\frac{220^2}{100}} = 0.3j$ pu

$P = S\sin\phi$

$V_r = 60$ KV ; $P = 60$ MW, $\cos\phi = 0.9$ $\quad Q = S\sin\phi$

$P = S\cos\phi$

$S = \frac{P}{\cos\phi} = \frac{60}{0.9} = 66.6$ MVA

$\cos\phi = 0.9$ $\quad \sin\phi = \sin(25.84) = 0.4358$

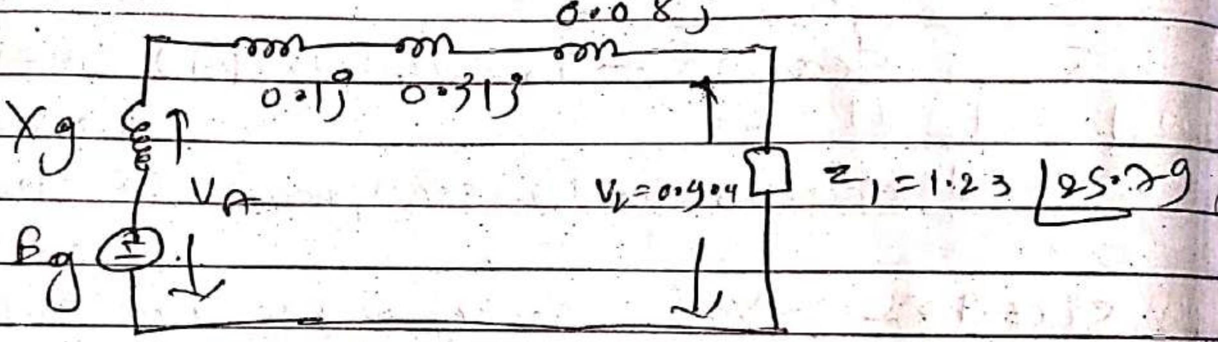
$Q = S * S\sin\phi = 66.67 * 0.435 = 29.$

$P - jQ = 60 - j29 = 66.66 \angle -25.843$

$$Z_{l\,\text{series}} = \frac{V^2}{S^*} = \frac{V^2}{P - jQ} = \frac{66^2}{60 - j29} = 54\angle 25.79\Omega$$

$$Z_l \text{ in pu} = \frac{|Z_L \text{ in } \Omega|}{\frac{V_B^2}{S_B}} = \frac{54 \cdot \angle 25.79}{\frac{66^2}{100}}$$

$$= 1.28 \angle 25.79$$



$$V_L(pu) = 0.9090 + jI_L(0.1 + 0.31 + 0.08j)$$

$$I_L(pu) = \frac{0.9090}{1.23\angle 25.79} = 0.733\angle -25.79$$

$$V_t(pu) = 0.909 + 0.73j(0.1j + 0.31j + 0.08j)$$

$$= 0.909 - 0.3577j$$

$$= 0.9768 \angle 21.48 \text{ pu}$$

$$V_t(V) = 0.97 \times 11 = \underline{10.67 \text{ KV}}$$

2018 2019
Dec | Jan

Part - 1

① (a) Show that the per unit impedance of a transformer is the same when referred to either primary or 2° side

⇒ Let S_B = Rated MVA of the Transformer

V_{B_1} = Base voltage in the primary side

V_{B_2} = Base Voltage in the 2° side

Z_{eq1} = Impedance referred to 1° side

Z_{eq2} = " " 2° side

$$Z_{eq1}\,pu = Z_{eq1}\text{ in }\Omega * \frac{S_B}{V_{B_1}^2} \rightarrow ①$$

$$\& \quad Z_{eq2}\,pu = Z_{eq2}\text{ in }\Omega * \frac{S_B}{V_B^2} \rightarrow ②$$

By T/f Ratio

$$Z_{eq2}(\text{in }\Omega) = Z_{eq1}(\text{in }\Omega) * \frac{V_B^2}{V_{B_1}^2} \rightarrow ③$$

Sub ③ in ②

$$Z_{eq2}(pu) = \left\{ Z_{eq1}(\text{in }\Omega) * \frac{V_B^2}{V_{B_1}^2} * \frac{S_B}{V_{B_2}^2} \right\}$$

$$= Z_{eq1}(\text{in }\Omega) * \frac{S_B}{V_{B_1}^2}$$

$$= eq ①$$

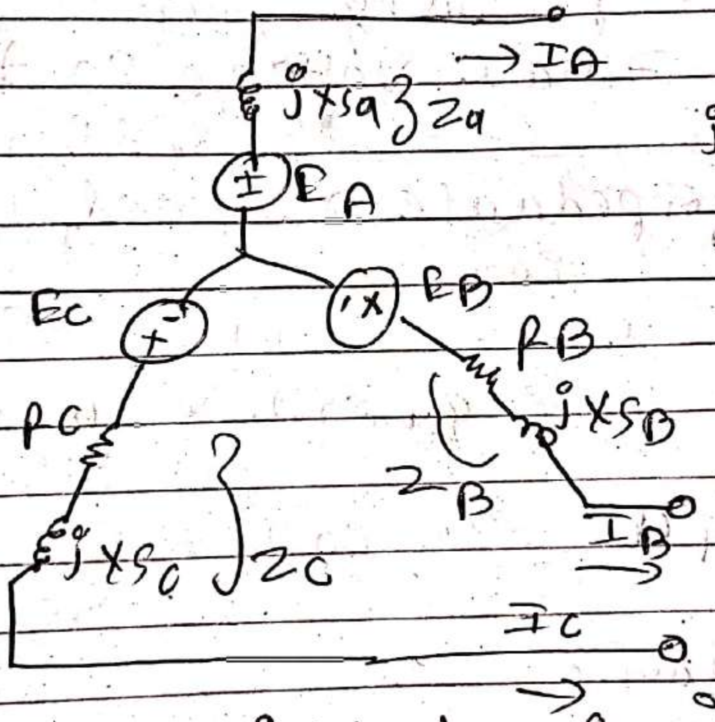
Hence proved

$$\boxed{Z_{eq2}(pu) = Z_{eq1}(pu}$$

(1b) Draw the Circuit model of synchronous generator · transmission lines & transformer

=)

Synchronous generator



Ra = RB = Rc = Ra

jXsa = jXsb = jXsc

= jXsa

Za = ZB = Zc = Za

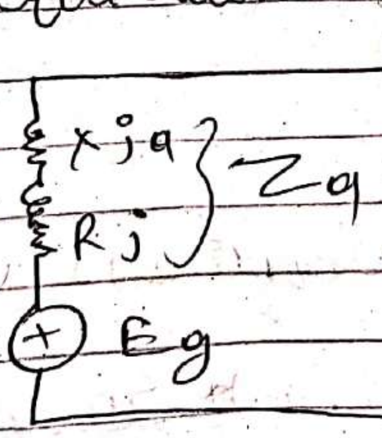
Ea = Eb = Ec

= Ea

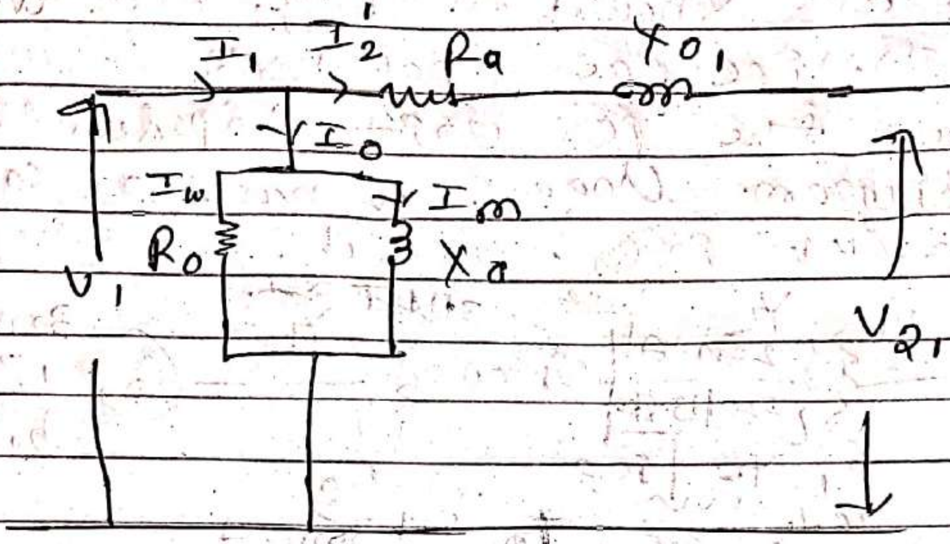
IA = IB = Ic

= IA

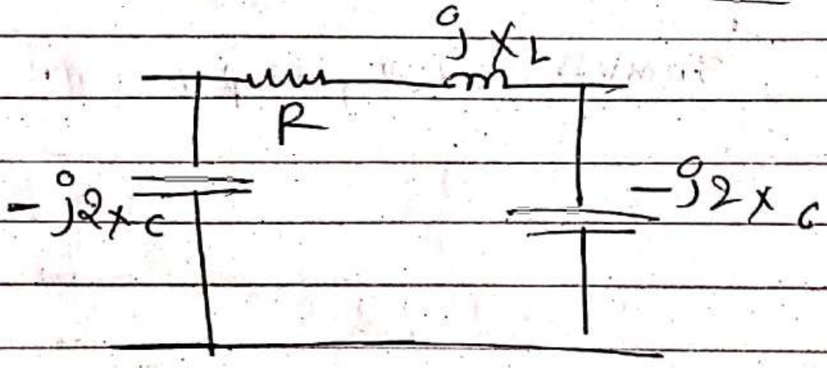
1 φ equivalent circuit



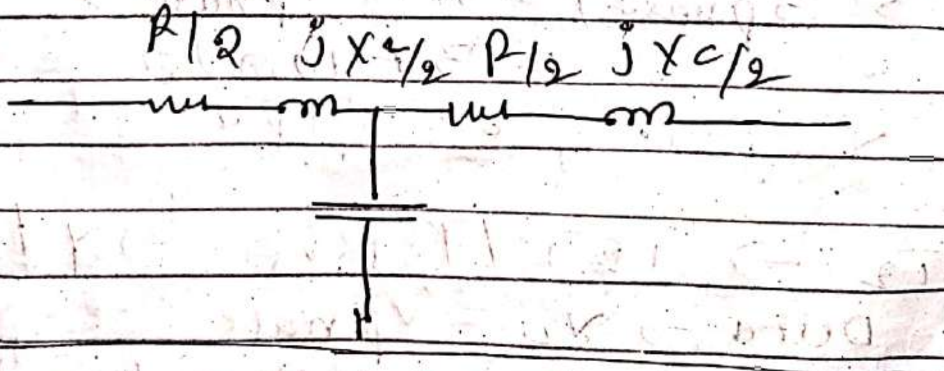
* Transformer



* Transmission Line

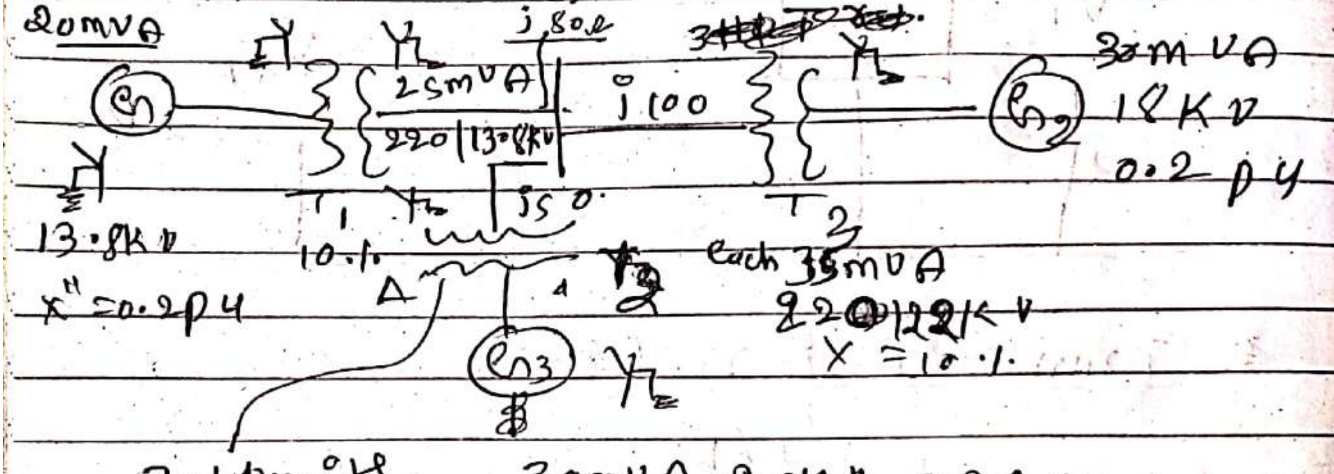


π - type



T - Type

(1c) The OLD of an unloaded power system is as shown in fig. Reactance of Tr. line are shown in figure. Draw the per unit impedance diagram. Choose a base of 50MVA 13.8KV in G_1 circuit.



3-1φ units 30MVA, 20KV, 0.2pu
each rated
10MVA
(127/18KVA
10%

⇒ T_2 = 1 phase unit - 3 unit

S(3 phase) = 3 * S(1 phase)

= 3 * 10MVA = 30MVA

X = 10%, or 0.1 pu

T_2 → 127/18KVA → Y/D

Delta → $V_L = V_{phase}$

Y → $V_L = V_{phase}(\sqrt{3})$

for T_2 = 3 - 1φ unit

so that

$$\frac{127 * \sqrt{3}}{18}$$

* T_2 = 30 MVA, 220 KV / 18 KV, = 0.10 pu

Section 1 :- G_1, T_1(Py)
Section 2 :- T_1(sy), T_3(py), T_2(py),
L_1, L_2, L_3
Section 3 :- G_2, T_2(sy)
Section 4 :- G_3, T_3(sy)

S_1 : Sbnew = 50MVA   Vb(n) = 13.8 KV
S_2 : Sb(n) = 50 MVA   Vb(n) = 220KV
S_3 :- Sb(n) = 50MVA   Vb(n) = 18KV
S_4 : Sb(n) = 50 MVA   Vb(n) = 22KV

$$X_{g1}(new) = X_{g1}(old) * \frac{S_B(n)}{S_B(g)} * \frac{V_B(g)^2}{V_B(n)^2}$$
$$= 0.2 * \frac{50}{20} * \frac{13.8^2}{13.8^2}$$
$$= \underline{0.5pu}$$

Transform px.

$$X_{T1}(n) = 0.2 * \frac{50}{25} * \frac{13.8^2}{13.8^2}$$

$$X_{L1}(n) = \frac{j80\Omega}{\frac{220^2}{50}} = j0.0826 pu$$

$$X_{L2}(n) = \frac{j100\Omega}{\frac{220^2}{50}} = j0.103 pu$$

$XL_3(\Omega) = \frac{j50\Omega}{\frac{220^2}{50}} = j0.0516\,pu$

$XT_2(\Omega) = 0.10 * \frac{50}{30} * \frac{220^2}{220^2} \cdot (pu)$

$= 0.166 \angle 0^\circ\ pu \quad (0.166\,pu)$

$XT_3(\Omega) = 0.18 * \frac{50}{35} * \frac{220^2}{220^2}$

$= \underline{0.142\,pu}$

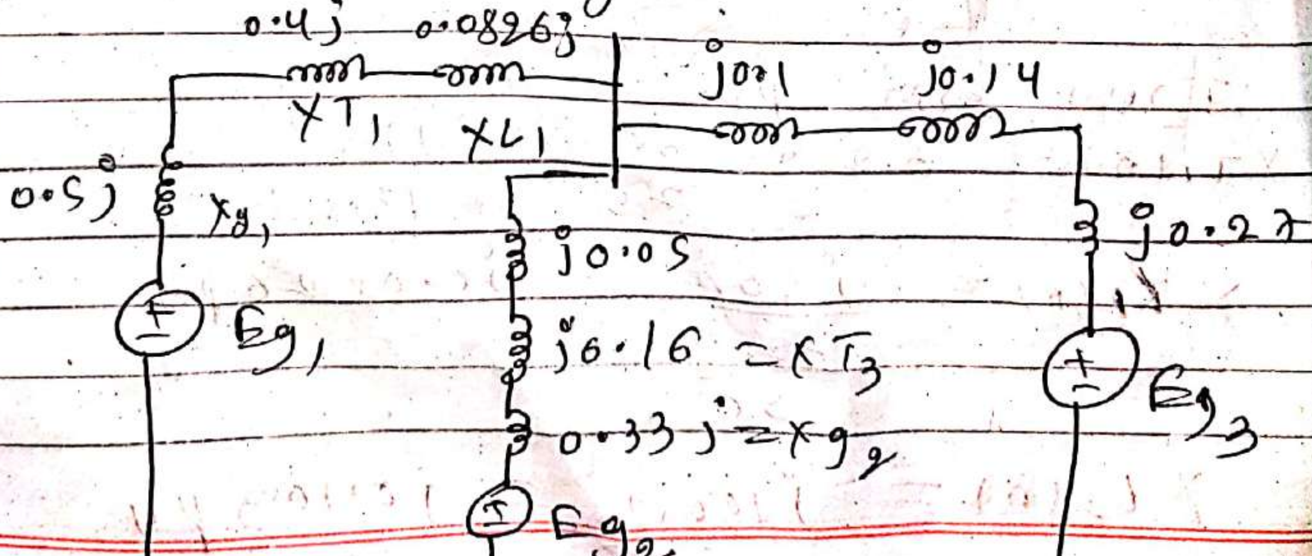
$Xg_2(\Omega) = 0.2 * \frac{50}{30} * \frac{18^2}{18^2}$

$= \underline{0.333\,pu}$

$Xg_3(\Omega) = 0.2 * \frac{50}{30} * \frac{20^2}{22^2}$

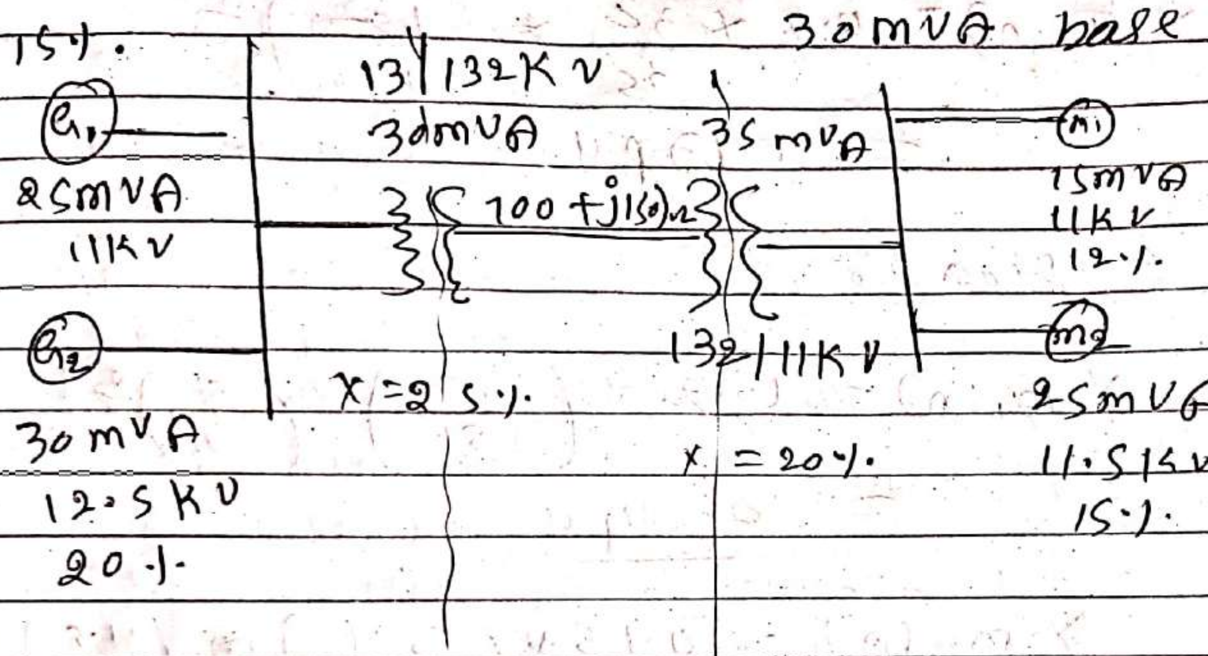
$= \underline{0.275\,pu}$

Reactance Diagram



part-2

(2c) Draw the impedance diagram for the power system. Choose a base 132KV on (100 − j150) Ω Tr. line at 30MVA base



Section 2 :-	Section 1	Section 3
$S_B = 30MVA$.	$S_B = 30MVA$.	$S_B = 30MVA$.
$V_B = 132KV$	$V_B = 13KV$	$V_B = 11KV$.

Section 1 :-

$$X_{g_1(n)} = 0.15 * \frac{30}{20} * \left(\frac{11}{13}\right)^2 = 0.12pu$$

$$X_{g_2(n)} = 0.2 \times \frac{30}{30} * \left(\frac{12.5}{13}\right)^2 = 0.18pu$$

$$X_{T_1(n)} = 0.25 * \left(\frac{30}{30}\right) * \left(\frac{13}{13}\right)^2$$

$$= 0.25pu$$

Section-2:-

$$X_L(\Omega) = \frac{100+150j}{\frac{(132)^2}{30}} = 0.17+0.25j\,pu$$

$$X_{T_2}(\Omega) = 0.2 \times \frac{30}{35} \times \left(\frac{132}{132}\right)^2$$

$$= 0.17pu$$

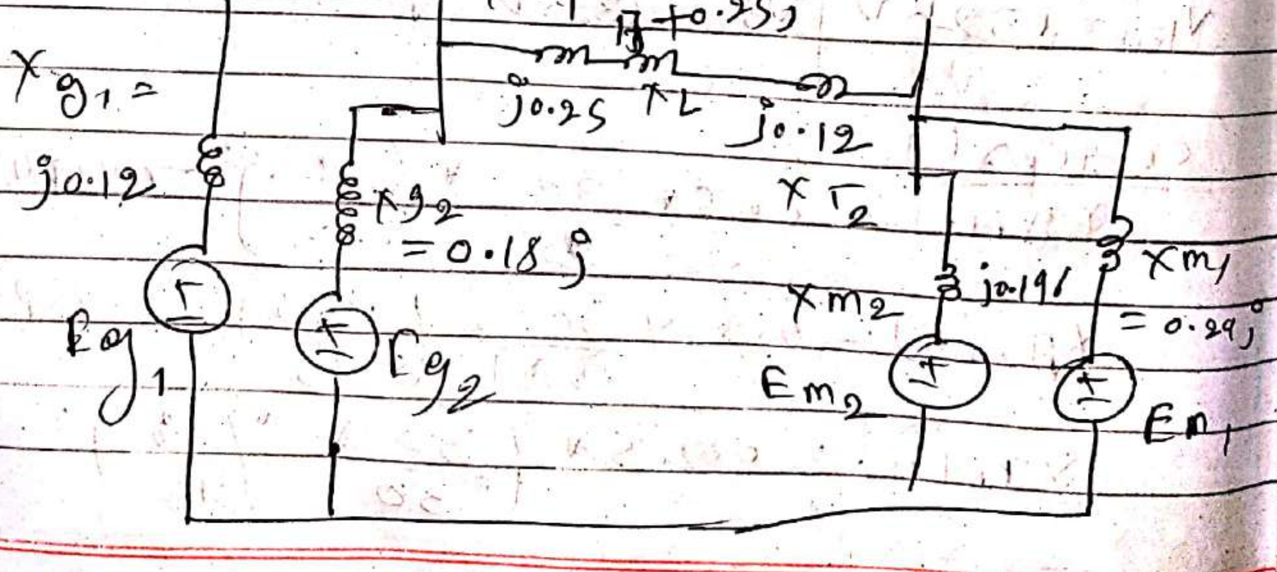
Section 3:-

$$X_{m_1}(\Omega) = 0.12 \times \left(\frac{30}{15}\right) \times \left(\frac{11}{11}\right)^2$$

$$= 0.24pu$$

$$X_{m_2}(\Omega) = 0.15 \times \left(\frac{30}{25}\right) \times \left(\frac{11.5}{11}\right)^2$$

$$= 0.196pu$$



(2a) ~~per~~ what is per unit quantity?
mention its advantages

4 ⇒ per unit value of any quantity is defined as

$$p.u = \frac{\text{Actual value of the quantity}}{\text{Base or reference value of the quantity}}$$

Eg :- If $I_{Base} = 100A$

I current $= I_{actual}$
$= 80A$

$$I_{pu} = \frac{80}{100} = 0.8 pu$$

Advantages :-

2 1) The per unit impedance referred to either side of a single phase transformer is the same

2) The per unit impedance referred to either side of the 3ϕ T/f is the same regardless of the 3ϕ t/f connections wheather they are Y-Y, Δ-Δ, Δ-Y

1,° 3) The manufactures usually provide the impedance value in per unit

1 4) Line to phase or phase to line conversions are reduced

5) The computational effort in power system is very much reduced with use of per unit quantities

Eg :- Calculation manually is simple as per unit value are < or close to 1.

(2b) How is the per unit impedance value in a given base are changed to per unit impedance values on new base

=>

If already the values are in pu but with different Base - Then we can change to common base

$$* \; Z_{pu(g)} = \frac{Z_{actual}}{Z_{Base}} = \frac{Z_{actual}}{\frac{V^2_{Base(g)}}{S_{B(g)}}} \rightarrow ①$$

$$\left\{ Z_{Base} = \frac{V_{Base}}{I_{Base}} = \frac{V_{Base}}{\frac{S_{Base}}{V_{Base}}} \right.$$

$$= \frac{V^2_{Base}}{S_{Base}}.$$

III'y $Z_{pu}(n) = \frac{Z_{actual}}{Z_{Base}(n)}$

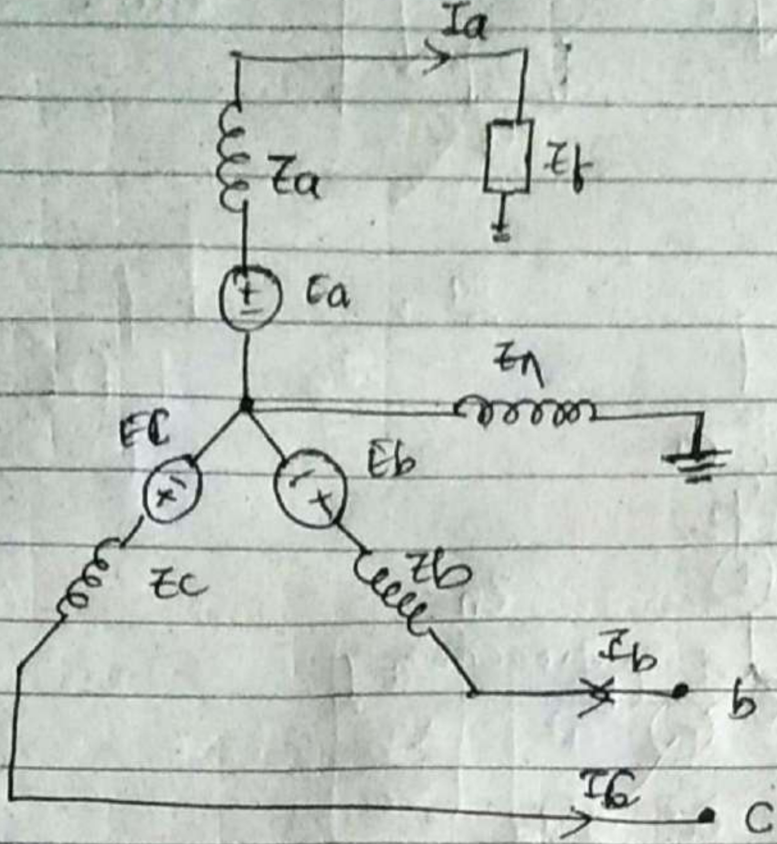
$= \frac{Z_{actual}}{\frac{V^2_B(n)}{S_B(n)}} \rightarrow ②$

$\div ② / ①$

$$\frac{Z_{pu}(n)}{Z_{pu}(g)} = \frac{\frac{Z_{actual} * S_B(n)}{V_B^2(n)}}{\frac{Z_{actual} * S_B(g)}{V_B^2(g)}}$$

$$\boxed{Z_{pu}(n) = Z_{pu}(g) * \frac{S_B(n)}{S_B(g)} * \frac{V_B^2(g)}{V^2_{B(n)}}}$$

single line to ground Fault with EF (Generator)
Z_F



Terminal conditions

$V_a = I_a Z_f$

$I_b = 0$

$I_c = 0$

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

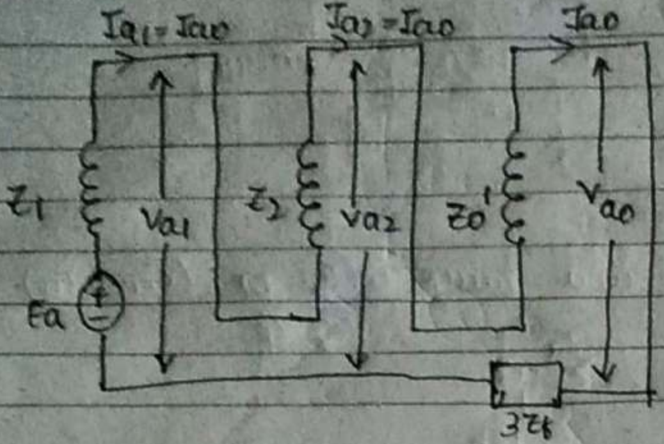
$I_{a0} = \frac{1}{3} I_a = I_{a1} = I_{a2}$ (series ckT)

$\Rightarrow I_a = 3 I_{a0}$

$V_a = V_{a0} + V_{a1} + V_{a2}$

$I_a Z_f = V_{a0} + V_{a1} + V_{a2}$

$V_{a0} + V_{a1} + V_{a2} = 3 I_{a0} Z_f$



$Z_0' = Z_0 + 3Z_n$

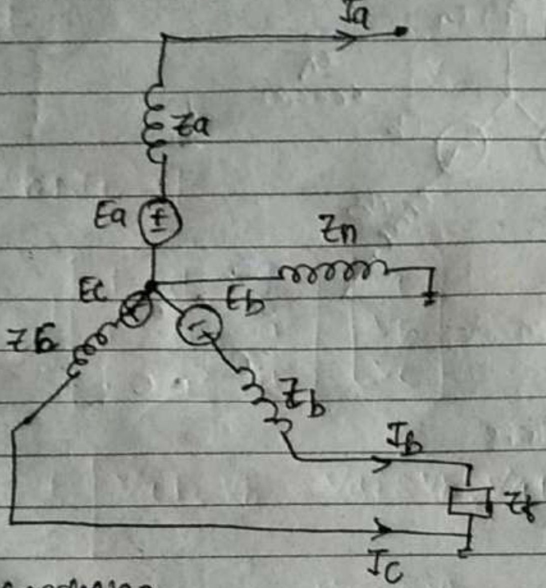
$I_{a0} = \frac{E_a}{Z_1 + Z_2 + Z_0' + 3Z_f}$

$V_{a1} = E_a - I_{a1} Z_1$

$V_{a2} = -I_{a2} Z_2$

$V_{a0} = -I_{a0}(Z_0' + 3Z_f)$

Line to line



Terminal condition

$I_a = 0$ $I_b = -I_c$

~~$V_b - V_a = $~~ $V_b = V_c + I_b Z_f$

$V_b - V_c = I_b Z_f$

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

$$= \frac{1}{3}\left[[I_b - I_b], [aI_b - a^2 I_b], [a^2 I_b - aI_b]\right]$$

$$= \frac{1}{3}\left[0, I_b[a-a^2], I_b[a^2-a]\right]$$

$I_{a0} = 0$

$I_{a1} = jI_b/\sqrt{3}$ $\quad I_{a2} = -jI_b/\sqrt{3}$ $\quad \Rightarrow I_{a1} = -I_{a2}$

[illegible] · $V_b = V_c + I_b Z_f$

$V_b - V_c = I_b Z_f$

$[V_{b0} + V_{b1} + V_{b2}] - [V_{c0} + V_{c1} + V_{c2}] = [I_{b0} + I_{b1} + I_{b2}] Z_f$

$[\cancel{V_{a0}} + a^2 V_{a1} + aV_{a2}] - [\cancel{V_{a0}} + aV_{a1} + a^2 V_{a2}] = [\overset{}{\underset{0}{\cancel{I_{a0}}}} + a^2 I_{a1} + a I_{a2}] Z_f$

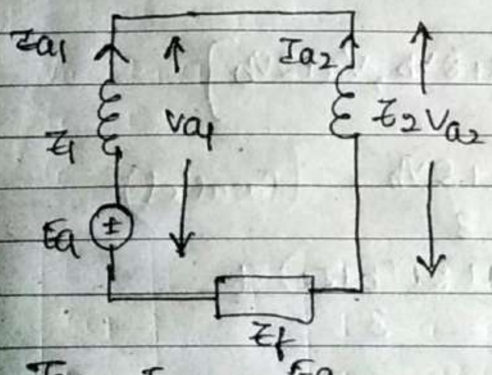
$V_{a1}[a^2 - a] + V_{a2}[a - a^2] = [a^2 I_{a1} + aI_{a2}] Z_f$

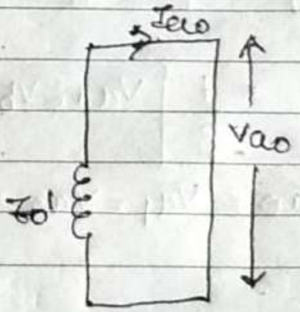
$V_{a1}[a^2 - a] + V_{a2}[a - a^2] = a^2 I_{a1} - aI_{a1}$

$I_{a1}[a^2 - a]$

$V_{a1}\cancel{[a^2 - a]} - V_{a2}\cancel{[a^2 - a]} = I_{a1}\cancel{[a^2 - a]} Z_f$

$V_{a1} - V_{a2} = I_{a1} Z_f$





$I_{a1} = -I_{a2} = \dfrac{E_a}{Z_1 + Z_2 + Z_f}$

$I_f = I_b$

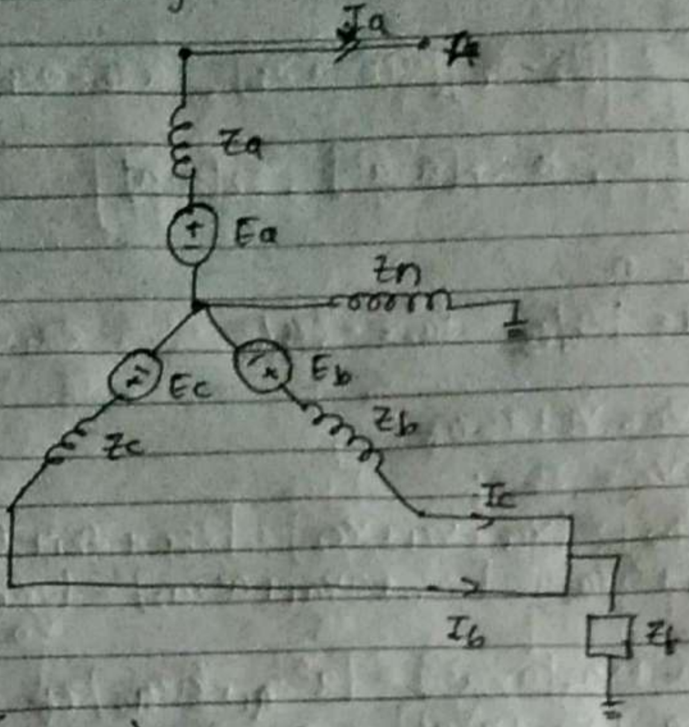
$= I_{b0} + I_{b1} + I_{b2}$

$= \underset{0}{\cancel{I_{a0}}} + a^2 I_{a1} + a I_{a2}$

$= I_{a1}[a^2 - a]$

$I_f = (a^2 - a) I_{a1}$

Doulble lene to ground



$I_a = 0$

$V_b = V_c = (I_b + I_c) Z_f$

$$\begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & a & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}$$

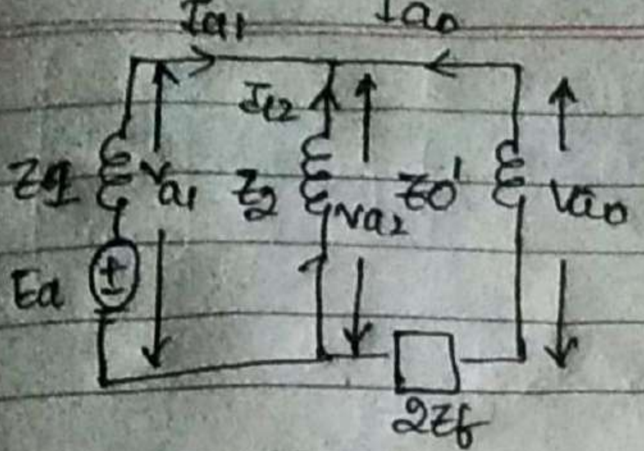
$$= \frac{1}{3} \begin{bmatrix} V_a + 2V_b , & V_a + 2V_b , & V_a + 2V_b \end{bmatrix}$$

$V_{a0} = V_{a1} = V_{a2} = \dfrac{V_a + 2V_b}{3}$ (Parallel)

$= \dfrac{V_a + 2(I_b + I_c) Z_f}{3}$

$I_a = 0$

$0 = I_{a0} + I_{a1} + I_{a2}$



$$Z_{eq} = Z_2 \parallel (2Z_f + Z_0')$$

$$Z_{eq} = 2Z\,2Z_f\,Z_0$$

$$Z_{eq} = \frac{Z_2(2Z_f + Z_0')}{Z_2 + 2Z_f + Z_0'}$$

$$I_{a_1} = \frac{E_a}{Z_1 + Z_{eq}}$$

$$I_{a_2} = \frac{-I_{a_1} \times (Z_0' + 2Z_f)}{Z_0' + 2Z_f + Z_2}$$

$$I_{a_0} = \frac{-I_{a_1} \times Z_2}{Z_0' + 2Z_f + Z_2}$$

$$\begin{aligned}
I_f &= I_b + I_c \\
&= I_{b0} + I_{b1} + I_{b2} + I_{c0} + I_{c1} + I_{c2} \\
&= 2I_{a0} + I_{a_1}(a^2 + a) + I_{a_2}(a + a^2) \\
&= 2I_{a0} - I_{a_1} - I_{a2} \\
&= 2I_{a_0} - (I_{a_1} + I_{a2}) \\
&= 3I_{a0}
\end{aligned}$$

$$I_f = 3\left[\frac{-I_{a_1} Z_2}{Z_0' + 2Z_f + Z_2}\right]$$

INSTITUTION

Vision

To be a Respected and Most Sought after Engineering Educational Institution Engaged in Equipping Individuals Capable of Building Learning Organizations in the New Millennium.

Mission

To Develop Competent Students with Good Value Systems to Face Challenges of the Continuously Changing World.

DEPARTMENT

Vision

To establish the department as a renowned center of excellence in the area of scientific education, research with industrial guidance, and exploration of the latest advances in the rapidly changing field of computer science.

Mission

To produce technocrats with creative technical knowledge and intellectual skills to sustain and excel in the highly demanding world with confidence.

Program Educational Objectives (PEO)

1. To create graduates equipped with life-long learning skills and have a successful professional career in IT industry.
2. To prepare graduates to pursue higher education and get inclined towards research & development in computer science engineering.
3. To provide adequate training and opportunities, with exposure to emerging cutting edge technologies and to work in teams on multidisciplinary projects with effective communication skills and leadership qualities.

Program Specific Outcomes (PSO)

1. To design efficient algorithms and develop effective code for real-time computations.
2. To apply software engineering principles in developing optimal software solutions.

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Website:www.theoxford.edu Email : engprincipal@theoxford.edu
(Approved by AICTE, New Delhi, Accredited by NBA, New Delhi & Affiliated to VTU, Belgaum)

Academic Semester: Sep 2020 to Jan 2021

Subject: 17CS742 Sub Code: Cloud Computing and Its Applications

Course Objectives

This course will enable students to:

- Explain the fundamentals of cloud computing
- Illustrate the cloud application programming and aneka platform
- Contrast different cloud platforms used in industry

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Academic Semester: Sep 2020 to Jan 2021

Subject: Cloud Computing and Its Applications Sub Code: 17CS742

Course Outcomes (COs)

C404.1: To learn about the concept of cloud computing benefits, reference models and Virtualization.

C404.2: To understand the concepts of types of clouds and benefits of clouds and Aneka Container.

C404.3: Illustrate architecture and programming in cloud.

C404.4: Describe the platforms for development of cloud applications and List the application of cloud.

C404.5: Write comprehensive case studies for analysing and contrasting different cloud Solutions.

CO-PO Mapping

PO CO	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
C404.1	3	3	3	3	3	2	3	3	1	2	2	3
C404.2	3	3	3	3	3	2	3	3	1	2	2	3
C404.3	3	3	3	3	3	2	3	3	1	1	2	3
C404.4	3	3	3	3	3	2	3	3	1	1	2	3
C404.5	3	3	3	3	3	2	3	3	1	2	2	3

CO-PSO Mapping

CO	PSO1	PSO2
C404.1	2	2
C404.2	2	2
C404.3	2	2
C404.4	2	2
C404.5	2	2

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THE OXFORD COLLEGE OF ENGINEERING

Department of Computer Science and Engineering

ACADEMIC YEAR 2020– 2021: ODD SEMESTER [AUG'20 – DEC'20] **W.E.F: 17/08/2020**

COURSE: B.E
SEM: VII CSE "A" & "B" **CLASS TEACHER: Ms. Shobha T& Ms. Florance T**

DAY/ TIME	9.00 to 9.55	9.55 to 10.50	SHORT BREAK	11.00 to 11.55	11.55 to 12.50	LUNCH BREAK	1.30 to 2.25	2.25 to 3.20	3.20 to 4.15
MON	WEB(ST)	ACA(FL)		ML(RSK)	CC(KV)		ML LAB B2 (RSK+ Dr. SK) WEB LAB B1(SBT + ST)		
TUE	ACA(FL)	ML(RSK)		WEB(ST)	SEMINAR (ST)		PROJECT PHASE-I(SHK/RSK)		
WED	SAN(SP)	ML LAB WEB LAB		ML LAB B2(RSK+ AR) WEB LAB B1(GT+ST)			ACA(FL)	ML(RSK)	PROJECT PHASE-I(SHK)
THU	WEB(ST))	SAN(SP)		CC(KV)	ACA(FL)		WEB(ST)	CC(KV)	SAN(SP)
FRI	SAN(SP)	WEB(ST)		CC(KV)	ACA(FL)		SEMINAR (ST)		
SAT	ML(RSK)	CC(KV)		SAN(SP)	ML(RSK)				

SUB CODE	SUBJECT	FACULTY
17CS71	Web Technology	Ms. Sushma T (ST)
17CS72	Advanced Computer Architecture	Ms. Florance (FL)
17CS73	Machine Learning	Mr. Senthil Kumar(RSK)
17CS742	Cloud Computing &Its application	Ms. Krishnaveni (KV)
17CS754	Storage Area Networks	Ms. Seema Patil (SP)
17CSL76	Machine Learning Lab	Mr. Senthil Kumar / Dr. Saravana Kumar (RSK+ Dr. SK)
17CSL77	Web Technology & Mini Project	Ms. Shobha T / Ms. Sushma T (SBT + ST)
17CSP78	Project Work Phase–I + Project work Seminar	Ms. Sowmya HK (SHK) / Mr. Senthil Kumar(RSK)

11/08/2020

TIMETABLE INCHARGE

Naveen
11/08/2020

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The Oxford College of Engineering
Bangalore-560 068.

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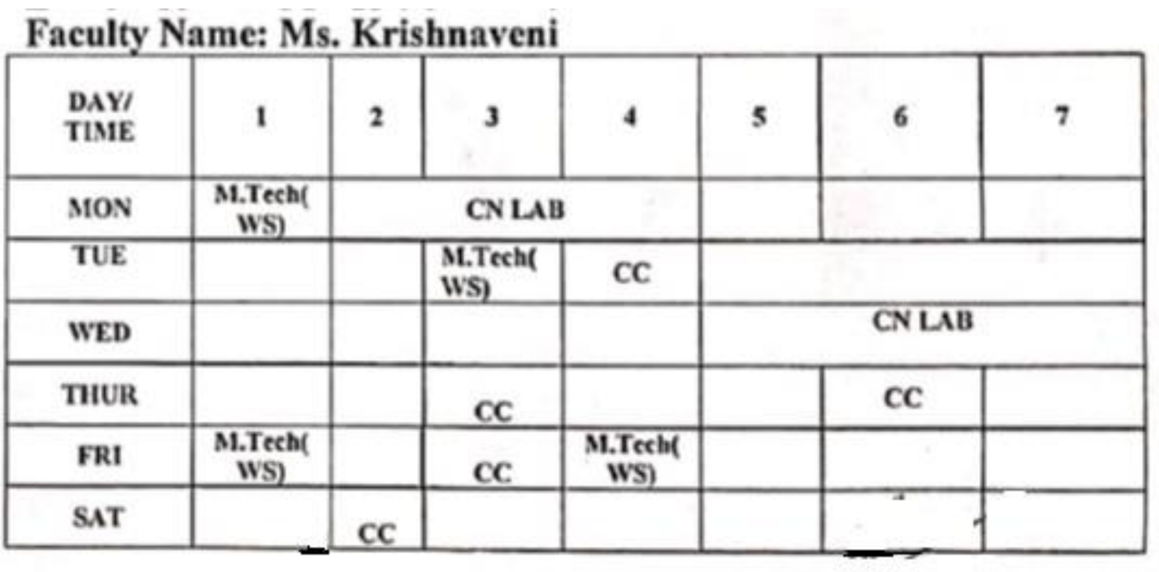
ACADEMIC YEAR 2020-2021: ODD SEMESTER [Sep 2020-Jan 2021]

Individual Time Table



Faculty Name: Ms. Krishnaveni

DAY/ TIME	1	2	3	4	5	6	7
MON	M.Tech(WS)	CN LAB					
TUE			M.Tech(WS)	CC			
WED					CN LAB		
THUR			CC			CC	
FRI	M.Tech(WS)		CC	M.Tech(WS)			
SAT		CC					

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To access the VTU Scheme and Syllabus of CBCS 17Scheme, kindly follow this below link.

17 Scheme VTU Scheme and Syllabus

https://drive.google.com/file/d/1RHbBVKjrMi1W88IMo4e0CKn6Af_SA9uS/view?usp=sharing

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To access the VTU Regulations of CBCS 17Scheme, kindly follow this below link.

17 Scheme VTU Regulations

https://drive.google.com/file/d/1SM_RE0Vezs0N-Cxj_CfvPX5wSu3gdpQo/view?usp=sharing

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Lesson Plan

Subject code: 15/17CS742 **Date:**17-8-2020

Subject Title : Cloud Computing and its Applications

Course / Branch: B.Tech./Computer Science and Engineering

Semester /Academic Year : VII Sem,Aug 2020-Dec 2020

Objective of Course: Understand the concepts of cloud computing, virtualization and classify services of cloud computing.

- Illustrate architecture and programming in cloud.
- Define the platforms for development of cloud applications and List the application of cloud. **Prerequisite:** Extend knowledge in Cloud Applications.

Module	Topic No	Date	Topic
I	1	18/8/2020	Introduction ,Cloud Computing at a Glance, The Vision of Cloud Computing
	2	21/8/2020	Defining a Cloud, A Closer Look, Cloud Computing Reference Model
	3	25/8/2020	Characteristics and Benefits, Challenges Ahead
	4	28/8/2020	Historical Developments, Distributed Systems, Virtualization, Web 2.0, Service-Oriented Computing, Utility Oriented Computing
	5	29/8/2020	Building Cloud Computing Environments, Application Development, Infrastructure and System Development, Computing Platforms and Technologies, Amazon Web Services (AWS)
	6	29/8/2020	Google App Engine, Microsoft Azure, Hadoop, Force.com and Salesforce.com, Manjra soft Aneka
	7	1/9/2020	Virtualization, Introduction, Characteristics of Virtualized, Environments Taxonomy of Virtualization Techniques
	8	4/9/2020	Execution Virtualization, Other Types of Virtualization, Virtualization and Cloud Computing
	9	5/9/2020	Pros and Cons of Virtualization
	10	5/9/2020	Technology Examples Xen: Paravirtualization, VMware: Full Virtualization, Microsoft Hyper-V
II	11	8/9/2020	Cloud Computing Architecture, Introduction
	12	11/9/2020	Cloud Reference Model, Architecture, Infrastructure / Hardware as a Service, Platform as a Service, Software as a Service

	13	12/9/2020	Types of Clouds, Public Clouds, Private Clouds, Hybrid Clouds, Community Clouds
	14	12/9/2020	Economics of the Cloud, Open Challenges, Cloud Definition
	15	15/9/2020	Cloud Interoperability and Standards Scalability and Fault Tolerance Security
	16	18/9/2020	Trust, and Privacy Organizational Aspects
	17	19/9/2020	Aneka: Cloud Application Platform, Framework Overview
	18	19/9/2020	Anatomy of the Aneka Container, From the Ground Up: Platform Abstraction Layer, Fabric Services, foundation Services, Application Services
	19	22/9/2020	Building Aneka Clouds, Infrastructure Organization, Logical Organization, Private Cloud Deployment Mode
	20	25/9/2020	Public Cloud Deployment Mode, Hybrid Cloud Deployment Mode, Cloud Programming and Management, Aneka SDK, Management Tools
III	21	26/9/2020	Thread Programming, Introducing Parallelism for Single Machine Computation, Programming Applications with Threads, What is a Thread?
	22	26/9/2020	Thread APIs, Techniques for Parallel Computation with Threads, Multithreading with Aneka, Introducing the Thread Programming Mode
	23	29/9/2020	Aneka Thread vs. Common Threads, Programming Applications with Aneka Threads, Aneka Threads Application Model
	24	3/10/2020	Domain Decomposition: Matrix Multiplication, Functional Decomposition: Sine, Cosine, and Tangent.
	25	6/10/2020	High-Throughput Computing: Task Programming, Task Computing, Characterizing a Task, Computing Categories
	26	13/10/2020	Frameworks for Task, Computing, Task-based Application Models
	27	16/10/2020	Embarrassingly Parallel Applications, Parameter Sweep Applications, MPI Applications
	28	17/10/2020	Workflow Applications with Task Dependencies, Aneka Task-Based Programming, Task Programming Model
	29	17/10/2020	Developing Applications with the Task Model,
	30	20/10/2020	Developing Parameter Sweep Application, Managing Workflows.
IV	31	23/10/2020	Map-Reduce Programming, What is Data-Intensive Computing?,
	32	24/10/2020	Characterizing Data-Intensive Computations
	33	24/10/2020	Challenges Ahead, Historical Perspective
	34	27/10/2020	Technologies for Data-Intensive Computing,
	35	3/11/2020	Storage Systems
	36	6/11/2020	Programming Platforms
	37	7/11/2020	Aneka MapReduce Programming
	38	7/11/2020	Introducing the MapReduce Programming Model
	39	13/11/2020	MapReduce Programming Model
	40	17/11/2020	Example Application

V	41	20/11/2020	Cloud Platforms in Industry
	42	21/11/2020	Amazon Web Services, Compute Services, Storage Services
	43	21/11/2020	Communication Services, Additional Services, Google App Engine
	44	24/11/2020	Architecture and Core Concepts, Application Life-Cycle, Cost Model
	45	27/11/2020	Observations, Microsoft Azure, Azure Core Concepts
	46	28/11/2020	SQL Azure, Windows Azure Platform Appliance.
	47	28/11/2020	Cloud Applications Scientific Applications
	48	1/12/2020	Healthcare: ECG Analysis in the Cloud, Biology: Protein Structure Prediction
	49	4/12/2020	Biology: Gene Expression Data Analysis for Cancer Diagnosis
	50	5/12/2020	Geoscience: Satellite Image Processing
	51	5/12/2020	Business and Consumer Applications, CRM and ERP
	52	8/12/2020	Productivity, Social Networking
	53	15/12/2020	Media Applications, Multiplayer Online Gaming.

	Assignment Topics	Submission due on
1.	Cloud Computing Reference Model, Characteristics and Benefits of cloud computing, Virtualization,Aneka Frame work.	26/09/2020
2.	Thread Programming, Parallelism for Single Machine Computation, High-Throughput Computing: Task Programming, Task Computing	24/10/2020
3.	Aneka MapReduce Programming, MapReduce Programming Model, Cloud Platforms in Industry	28/11/2020

Textbooks:

1. Rajkumar Buyya, Christian Vecchiola, and Thamarai Selvi Mastering Cloud. Computing McGraw Hill Education
2. **Reference Books:** 1. Dan C. Marinescu, Cloud Computing Theory and Practice, Morgan Kaufmann, Elsevier 2013.

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CBCS SCHEME

USN ☐☐☐☐☐☐☐☐☐☐ 17CS742

Seventh Semester B.E. Degree Examination, Jan./Feb. 2021
Cloud Computing and Its Applications

Time: 3 hrs. Max. Marks: 100

Note: Answer any FIVE full questions, choosing ONE full question from each module.

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

Module-1

1 a. Define cloud computing. With a neat diagram, explain major deployment models for cloud computing. (08 Marks)
b. Explain cloud computing reference model with a neat diagram. (08 Marks)
c. Discuss major milestones which have lead to cloud computing. (04 Marks)

OR

2 a. Describe the characteristics of virtualized environments with the required diagrams. (08 Marks)
b. With a neat diagram, explain Xen architecture and guest OS management. (06 Marks)
c. Explain live migration and server consolidation with a neat diagram. (06 Marks)

Module-2

3 a. Explain cloud computing architecture with a neat diagram. (08 Marks)
b. Discuss how SaaS provides access to application through the internet as a web based service. (04 Marks)
c. Describe the various open challenges in clod computing. (08 Marks)

OR

4 a. Discuss the anatomy of Aneka container in detail. (12 Marks)
b. Explain Aneka hybrid cloud deployment mode with a neat diagram. (08 Marks)

Module-3

5 a. What is a thread? Discuss different thread APIs. (06 Marks)
b. With a neat diagram compare thread life cycle in system threading and Aneka threading. (08 Marks)
c. Explain Aneka thread application model with a listing for application creation and configuration. (06 Marks)

OR

6 a. Explain MPI reference scenario and MPI program structure with the required diagrams. (08 Marks)
b. Explain task programming model with a neat diagram. (06 Marks)
c. Discuss how workflows are managed in Aneka with required diagram. (06 Marks)

Module-4

7 a. What is data intensive computing? Explain Amazon dynamo architecture with a neat diagram. (10 Marks)
b. Explain map reduce computation workflow with a neat diagram. (10 Marks)

OR

8 a. Discuss the variations and extensions of map reduce. (06 Marks)
b. Describe Aneka map reduce infrastructure with a neat diagram. (08 Marks)
c. Discuss distributed life system support for execution of map reduce job with a neat diagram. (06 Marks)

Module-5

9 a. Discuss the storage services provided by AWS. (12 Marks)
b. Explain SQL Azure architecture with a neat diagram. (08 Marks)

OR

10 a. Describe how cloud computing can be applied to remote ECG monitoring with a required diagram. (10 Marks)
b. Explain CRM and ERP implementations with three examples and the required diagrams. (10 Marks)

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(Approved by AICTE, New Delhi, Accredited by NBA, New Delhi & Affiliated to VTU, Belgaum)

Academic Semester: Sep 2020 to Jan 2021

Subject: Cloud Computing and Its Applications Sub Code: 17CS742

DIRECT ATTAINMENT

CO Attainment

CO	IA Attainment %	IA Attainment	Ext Attainment	Final Co Attainment
C404.1	100	3	2	2.4
C404.2	100	3	2	2.4
C404.3	98.90	3	2	2.4
C404.4	100	3	2	2.4
C404.5	100	3	2	2.4

PO Attainment

CO/PO	CO Attainment	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
C404.1	2.4	3	3	3	3	3	2	3	3	1	2	2	3
C404.2	2.4	3	3	3	3	3	2	3	3	1	2	2	3
C404.3	2.4	3	3	3	3	3	2	3	3	1	1	2	3
C404.4	2.4	3	3	3	3	3	2	3	3	1	1	2	3
C404.5	2.4	3	3	3	3	3	2	3	3	1	2	2	3
PO Attainment		2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4

PSO Attainment

CO/PO	CO Attainment	PSO1	PSO2
C404.1	2.4	2	2
C404.2	2.4	2	2
C404.3	2.4	2	2
C404.4	2.4	2	2
C404.5	2.4	2	2
PSO Attainment		2.4	2.4

Krishnan
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