Department of Electrical & Electronics Engineering

Course File

POWER SYATEMS-II
(Course Code: EE405PC)

II B.Tech II Semester

2023-24

S.Yasoda Krishna
Asst.Professor

Anurag Engineering College
(An Autonomous Institution)
Ananthagiri, Kodad, Telangana 508 206, India.

Department of Electrical & Electronics Engineering

POWER SYSTEMS-II

Check List

Department of Electrical & Electronics Engineering

Int. Marks:40 Ext. Marks:60 Total Marks:100

(EE405PC) POWER SYSTEMS-II

II Year B.Tech. EEE -II Sem

L	T	P	C
3	0	0	3

UNIT-I:

PERFORMANCE OF LINES: Representation of lines, short transmission lines, medium length lines, nominal T and PI- representations, long transmission lines. The equivalent circuit representation of a long Line, A, B, C, D constants, Ferranti Effect.

Corona: Introduction, disruptive critical voltage, corona loss, Factors affecting corona loss and methods of reducing corona loss, Disadvantages of corona, interference between power and Communication lines.

UNIT-II:

VOLTAGE CONTROL & POWER FACTOR IMPROVEMENT: Introduction – methods of voltage control, shunt and series capacitors / Inductors, tap changing transformers, synchronous phase modifiers, power factor improvement methods.

COMPENSATION IN POWER SYSTEMS: Introduction - Concepts of Load compensation – Load ability characteristics of overhead lines – Uncompensated transmission line – Symmetrical line – Radial line with asynchronous load – Compensation of lines

UNIT-III:

PER UNIT REPRESENTATION OF POWER SYSTEMS: The one-line diagram, impedance and reactance diagrams, per unit quantities, changing the base of per unit quantities, advantages of per unit system.

TRAVELLING WAVES ON TRANSMISSION LINES: Production of travelling waves, open circuited line, short-circuited line, line terminated through a resistance, line connected to a cable, reflection and refraction at T-junction line terminated through a capacitance, capacitor connection at a T-junction, Attenuation of travelling waves.

UNIT-IV:

OVERVOLTAGE PROTECTION AND INSULATION COORDINATION: Over voltage due to arcing ground and Peterson coil, lightning, horn gaps, surge diverters, rod gaps, expulsion type lightning arrester, valve type lightning arrester, ground wires, ground rods, counter poise, surge absorbers, insulation coordination, volt-time curves.

UNIT-V:

SYMMETRICAL COMPONENTS AND FAULT CALCULATIONS: Significance of positive, negative and zero sequence components, Average 3-phase power in terms of symmetrical components, sequence impedances and sequence networks, fault calculations, sequence network equations, single line to ground fault, line to line fault, double line to ground fault, three phase fault, faults on power systems, faults with fault impedance, reactors and their location, short circuit capacity of a bus.

TEXT BOOKS:

1. A Text Book on Power System Engineering- M.L.Soni, P.V.Gupta, U.S.Bhatnagar, A.Chakrabarthy, Dhanpat Rai & Co Pvt. Ltd, 2nd Revised Edition, 2010.
2. Electrical power systems - C.L.Wadhwa, New Age International (P) Limited Publishers, 6th Edition, 2010.

REFERENCE BOOKS:

1. Power system Analysis- John J Grainger William D Stevenson,Tata McGraw-Hill Companies, illustrated edition,1994.
2. Power System Analysis - Hadi Saadat – Tata McGraw-Hill Education, 3rd Edition, 2010.
3. Modern Power System Analysis- I.J.Nagaraj and D.P.Kothari, Tata McGraw Hill, 4th Edition.
4. A course in Power systems-J.B.Gupta, S.K.Kataria& Sons, 11th Edition, 2014.

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Timetable

II B.Tech. II Semester – PS-II

Day/Hour	9.30-10.20	10.20-11.10	11.20-12.10	12.10-01.00	01.40-02.25	02.25-03.10	03.15-04.00
Monday			PS-II				
Tuesday	PS-II						
Wednesday		PS-II					
Thursday			PS-II				
Friday							PS-II
Saturday						PS-II	

Department of Electrical & Electronics Engineering

Vision of the Institute
To be a premier Institute in the country and region for the study of Engineering, Technology and Management by maintaining high academic standards which promotes the analytical thinking and independent judgment among the prime stakeholders, enabling them to function responsibly in the globalized society.

Mission of the Institute
To be a world-class Institute, achieving excellence in teaching, research and consultancy in cutting-edge Technologies and be in the service of society in promoting continued education in Engineering, Technology and Management.

Quality Policy
To ensure high standards in imparting professional education by providing world-class infrastructure, top-quality-faculty and decent work culture to sculpt the students into Socially Responsible Professionals through creative team-work, innovation and research

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

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

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Program Educational Objectives (B.Tech. – EEE)
Graduates will be able to

PEO 1: Have a successful technical or professional career, including supportive and leadership roles on multidisciplinary teams.
PEO 2: Acquire, use and develop skills as required for effective professional practices.
PEO 3: Able to attain holistic education that is an essential prerequisite for being a responsible member of society.

Program Outcomes (B.Tech. – EEE)
At the end of the Program, a graduate will have the ability to

PO 1: Apply knowledge of mathematics, science, and engineering.
PO 2: Design and conduct experiments, as well as to analyze and interpret data.
PO 3: Design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
PO 4: Function on multi-disciplinary teams.
PO 5: Identify, formulates, and solves engineering problems.
PO 6: Understanding of professional and ethical responsibility.
PO 7: Communicate effectively.
PO 8: Broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.
PO 9: Recognition of the need for, and an ability to engage in life-long learning.
PO 10: Knowledge of contemporary issues.
PO 11: Utilize experimental, statistical and computational methods and tools necessary for engineering practice.
PO 12: Demonstrate an ability to design electrical and electronic circuits, power electronics, power systems; electrical machines analyze and interpret data and also an ability to design digital and analog systems and programming them.

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COURSE OBJECTIVES

On completion of this Subject/Course the student shall be able to:

S.No	Objectives
1	To study the performance of transmission lines.
2	To understand the concept of voltage control, compensation methods
3	To understand the concept of per unit representation of power systems and knowledge about the power system transients.
4	To know the methods of overvoltage protection, Insulation coordination.
5	To know the methods of Symmetrical components and fault calculation analysis.

COURSE OUTCOMES

The expected outcomes of the Course/Subject are:

S.No	Outcomes
1.	Analyze transmission line performance.
2.	Apply load compensation techniques to control reactive power.
3.	Understand the application of per unit quantities in power systems and analyze of travelling waves.
4.	Design over voltage protection, insulation coordination
5.	Determine the fault currents for symmetrical and unbalanced faults.

Signature of faculty

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

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GUIDELINES TO STUDY THE COURSE / SUBJECT

Course Design and Delivery System (CDD):

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

The faculty be able to –

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

Signature of HOD   Signature of faculty

Date: Date:

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COURSE SCHEDULE

The Schedule for the whole Course / Subject is:

S. No.	Description	Duration (Date)		Total No. of Periods
		From	To	
1.	**UNIT-I:** PERFORMANCE OF LINES: Representation of lines, short transmission lines, medium length lines, nominal T and PI- representations, long transmission lines. The equivalent circuit representation of a long Line, A, B, C, D constants, Ferranti Effect. Corona: Introduction, disruptive critical voltage, corona loss, Factors affecting corona loss and methods of reducing corona loss, Disadvantages of corona, interference between power and Communication lines.	05.02.2024	23.02.2024	16
2.	**UNIT-II:** VOLTAGE CONTROL & POWER FACTOR IMPROVEMENT: Introduction – methods of voltage control, shunt and series capacitors / Inductors, tap changing transformers, synchronous phase modifiers, power factor improvement methods. COMPENSATION IN POWER SYSTEMS: Introduction **-** Concepts of Load compensation – Load ability characteristics of overhead lines – Uncompensated transmission line – Symmetrical line – Radial line with asynchronous load – Compensation of lines	24.02.2024	19.03.3024	19
3.	**UNIT-III:** PER UNIT REPRESENTATION OF POWER SYSTEMS: The one-line diagram, impedance and reactance diagrams, per unit quantities, changing the base of per unit quantities, advantages of per unit system. TRAVELLING WAVES ON TRANSMISSION LINES: Production of travelling waves, open circuited line, short-circuited line, line terminated through a resistance, line connected to a cable, reflection and refraction at T-junction line terminated through a capacitance, capacitor connection at a T-junction, Attenuation of travelling waves.	20.03.2024	22.04.2024	18
4.	**UNIT-IV:** OVERVOLTAGE PROTECTION AND INSULATION COORDINATION: Over voltage due to arcing ground and Peterson coil, lightning, horn gaps, surge diverters, rod gaps, expulsion type lightning arrester, valve type lightning arrester, ground wires, ground rods, counter poise, surge absorbers, insulation coordination, volt-time curves.	23.04.2024	04.05.2024	15
5.	**UNIT-V:** SYMMETRICAL COMPONENTS AND FAULT CALCULATIONS: Significance of positive, negative and zero sequence components, Average 3-phase power in terms of symmetrical components, sequence impedances and sequence networks, fault calculations, sequence network equations, single line to ground fault, line to line fault, double line to ground fault, three phase fault, faults on power systems, faults with fault impedance, reactors and their location, short circuit capacity of a bus.	06.05.2024	12.06.2024	13

Total No. of Instructional periods available for the course: 81 Hours

Department of Electrical & Electronics Engineering

SCHEDULE OF INSTRUCTIONS - COURSE PLAN

Unit No.	Lesson No.	Date	No. of Periods	Topics / Sub-Topics	Objectives & Outcomes Nos.	References (Textbook, Journal)
1.	1	05.02.2024	1	Representation of lines	1 1	Electrical power systems - C.L.Wadhwa
	2	06.02.2024	1	short transmission lines	1 1	Electrical power systems - C.L.Wadhwa
	3	07.02.2024	1	medium length lines	1 1	Electrical power systems - C.L.Wadhwa
	4	08.02.2024	1	nominal T representations	1 1	Electrical power systems - C.L.Wadhwa
	5	09.02.2024	1	nominal PI- representations	1 1	Electrical power systems - C.L.Wadhwa
	6	12.02.2024	1	long transmission lines	1 1	Electrical power systems - C.L.Wadhwa
	7	13.02.2024	1	The equivalent circuit representation of a long Line, A, B, C, D constants	1 1	Electrical power systems - C.L.Wadhwa
	8	14.02.2024	1	Ferranti Effect	1 1	Electrical power systems - C.L.Wadhwa
	9	15.02.2024	1	Corona: Introduction	1 1	Electrical power systems - C.L.Wadhwa
	10	16.02.2024	1	disruptive critical voltage, corona loss	1 1	Electrical power systems - C.L.Wadhwa
	11	17.02.2024	1	Factors affecting corona loss and methods of reducing corona loss	1 1	Electrical power systems - C.L.Wadhwa
	12	19.02.2024	1	Disadvantages of corona	1 1	Electrical power systems - C.L.Wadhwa
	13	20.02.2024	1	interference between power and Communication lines.	1 1	Electrical power systems - C.L.Wadhwa
	14	21.02.2024	1	Numerical Problems	1 1	Electrical power systems - C.L.Wadhwa

	15	22.02.2024	1	Numerical Problems	1 1	Electrical power systems - C.L.Wadhwa
	16	23.02.2024	1	Numerical Problems	1 1	Electrical power systems - C.L.Wadhwa
2.	1	24.02.2024	1	VOLTAGE CONTROL Introdution	2 2	Electrical power systems - C.L.Wadhwa
	2	26.02.2024	1	methods of voltage control	2 2	Electrical power systems - C.L.Wadhwa
	3	27.02.2024	1	shunt and series capacitors / Inductors	2 2	Electrical power systems - C.L.Wadhwa
	4	28.02.2024	1	tap changing transformers	2 2	Electrical power systems - C.L.Wadhwa
	5	29.02.2024	1	synchronous phase modifiers	2 2	Electrical power systems - C.L.Wadhwa
	6	01.03.2024	1	power factor improvement methods	2 2	Electrical power systems - C.L.Wadhwa
	7	02.03.2024	1	Numerical Problems	2 2	Electrical power systems - C.L.Wadhwa
	8	04.03.2024	1	COMPENSATION IN POWER SYSTEMS: Introduction	2 2	Electrical power systems - C.L.Wadhwa
	9	05.03.2024	1	Numerical Problems	2 2	Electrical power systems - C.L.Wadhwa
	10	06.03.2024	1	Concepts of Load compensation	2 2	Electrical power systems - C.L.Wadhwa
	11	07.03.2024	1	Numerical Problems	2 2	Electrical power systems - C.L.Wadhwa
	12	11.03.2024	1	Load ability characteristics of overhead lines	2 2	Electrical power systems - C.L.Wadhwa
	13	12.03.2024	1	Uncompensated transmission line	2 2	Electrical power systems - C.L.Wadhwa
	14	13.03.2024	1	Symmetrical line	2 2	Electrical power systems - C.L.Wadhwa

	15	14.03.2024	1	Numerical Problems	2 2	Electrical power systems - C.L.Wadhwa
	16	15.03.2024	1	Numerical Problems	2 2	Electrical power systems - C.L.Wadhwa
	17	16.03.2024	1	Radial line with asynchronous load	2 2	Electrical power systems - C.L.Wadhwa
	18	18.03.2024	1	Numerical Problems	2 2	Electrical power systems - C.L.Wadhwa
	19	19.03.2024	1	Compensation of lines	2 2	Electrical power systems - C.L.Wadhwa
3.	1	20.03.2024	1	Per uint representation	3 3	Electrical power systems - C.L.Wadhwa
	2	21.03.2024	1	The one-line diagram	3 3	Electrical power systems - C.L.Wadhwa
	3	22.03.2024	1	impedance and reactance diagrams	3 3	Electrical power systems - C.L.Wadhwa
	4	23.03.2024	1	per unit quantities	3 3	Electrical power systems - C.L.Wadhwa
	5	26.03.2024	1	Numerical Problems	3 3	Electrical power systems - C.L.Wadhwa
	6	27.03.2024	1	Numerical Problems	3 3	Electrical power systems - C.L.Wadhwa
	7	28.03.2024	1	changing the base of per unit quantities	3 3	Electrical power systems - C.L.Wadhwa
	8	30.03.2024	1	advantages of per unit system.	3 3	Electrical power systems - C.L.Wadhwa
	9	04.04.2024	1	Production of travelling waves	3 3	Electrical power systems - C.L.Wadhwa
	10	06.04.2024	1	open circuited line	3 3	Electrical power systems - C.L.Wadhwa
	11	08.04.2024	1	short-circuited line	3 3	Electrical power systems - C.L.Wadhwa

Department of Electrical & Electronics Engineering

	12	10.04.2024	1	line terminated through a resistance	3 3	Electrical power systems - C.L.Wadhwa
	13	15.04.2024	1	line connected to a cable	3 3	Electrical power systems - C.L.Wadhwa
	14	16.04.2024	1	Numerical Problems	3 3	Electrical power systems - C.L.Wadhwa
	15	18.04.2024	1	reflection and refraction at T-junction line terminated through a capacitance	3 3	Electrical power systems - C.L.Wadhwa
	16	19.04.2024	1	capacitor connection at a T-junction	3 3	Electrical power systems - C.L.Wadhwa
	17	20.04.2024	1	Numerical Problems	3 3	Electrical power systems - C.L.Wadhwa
	18	22.04.2024	1	Attenuation of travelling waves	3 3	Electrical power systems - C.L.Wadhwa
4	1	23.04.2024	1	Over voltage due to arcing ground and Peterson coil	4 4	Electrical power systems - C.L.Wadhwa
	2	24.04.2024	1	lightning	4 4	Electrical power systems - C.L.Wadhwa
	3	25.04.2024	1	horn gaps, surge diverters, rod gaps	4 4	Electrical power systems - C.L.Wadhwa
	4	26.04.2024	1	expulsion type lightning arrester	4 4	Electrical power systems - C.L.Wadhwa
	5	27.04.2024	1	valve type lightning arrester	4 4	Electrical power systems - C.L.Wadhwa
	6	29.04.2024	1	ground wires, ground rods	4 4	Electrical power systems - C.L.Wadhwa
	7	30.04.2024	1	counter poise, surge absorbers	4 4	Electrical power systems - C.L.Wadhwa
	8	01.05.2024	1	insulation coordination	4 4	Electrical power systems - C.L.Wadhwa
	9	02.05.2024	1	volt-time curves	4 4	Electrical power systems - C.L.Wadhwa

Department of Electrical & Electronics Engineering

	10	03.05.2024	1	Numerical Problems	4 4	Electrical power systems - C.L.Wadhwa
	11	04.05.2024	1	Numerical Problems	4 4	Electrical power systems - C.L.Wadhwa
5	1	06.05.2024	1	Significance of positive, negative and zero sequence components	5 5	Electrical power systems - C.L.Wadhwa
	2	07.05.2024	1	Average 3-phase power in terms of symmetrical components	5 5	Electrical power systems - C.L.Wadhwa
	3	08.05.2024	1	sequence impedances and sequence networks	5 5	Electrical power systems - C.L.Wadhwa
	4	09.05.2024	1	fault calculations, sequence network equations	5 5	Electrical power systems - C.L.Wadhwa
	5	10.05.2024	1	single line to ground fault,	5 5	Electrical power systems - C.L.Wadhwa
	6	03.06.2024	1	Numerical Problems	5 5	Electrical power systems - C.L.Wadhwa
	7	04.06.2024	1	line to line fault	5 5	Electrical power systems - C.L.Wadhwa
	8	05.06.2024	1	double line to ground fault,	5 5	Electrical power systems - C.L.Wadhwa
	9	06.06.2024	1	three phase fault	5 5	Electrical power systems - C.L.Wadhwa
	10	07.06.2024	1	Numerical Problems	5 5	Electrical power systems - C.L.Wadhwa
	11	10.06.2024	1	faults with fault impedance	5 5	Electrical power systems - C.L.Wadhwa
	12	11.06.2024	1	reactors and their location	5 5	Electrical power systems - C.L.Wadhwa
	13	12.06.2024	1	short circuit capacity of a bus	5 5	Electrical power systems - C.L.Wadhwa

Signature of HOD Signature of faculty

Date: Date:

Department of Electrical & Electronics Engineering

Note:
1. Ensure that all topics specified in the course are mentioned.
2. Additional topics covered, if any, may also be specified in bold.
3. Mention the corresponding course objective and outcome numbers against each topic.

LESSON PLAN (U-I)

Lesson No: 01,02,03,04,05 Duration of Lesson: 50min

Instructional / Lesson Objectives:

- To study the performance of transmission lines.
- To understand the concept of voltage control, compensation methods
- To understand the concept of per unit representation of power systems and knowledge about the power system transients.
- To know the methods of overvoltage protection, Insulation coordination
- To know the methods of Symmetrical components and fault calculation analysis.

Teaching AIDS : PPTs, Digital Board
Time Management of Class :

5 mins for taking attendance
40 min for the lecture delivery
5 min for doubts session

Signature of faculty

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Date	Day	Week No	Classes per week	Topics to be covered
5/Feb/24	MON	1	5	Representation of lines
6/Feb/24	TUE			short transmission lines
7/Feb/24	WED			medium length lines
8/Feb/24	THU			nominal T representations
9/Feb/24	FRI			nominal PI- representations
10/Feb/24	SAT			**Second Saturday**
11/Feb/24	SUN	SUNDAY		
12/Feb/24	MON	2	6	long transmission lines
13/Feb/24	TUE			The equivalent circuit representation of a long Line, A, B, C, D constants
14/Feb/24	WED			Ferranti Effect
15/Feb/24	THU			Corona: Introduction
16/Feb/24	FRI			disruptive critical voltage, corona loss
17/Feb/24	SAT			Factors affecting corona loss and methods of reducing corona loss
18/Feb/24	SUN	SUNDAY		
19/Feb/24	MON	3	6	Disadvantages of corona
20/Feb/24	TUE			interference between power and Communication lines.
21/Feb/24	WED			Numerical Problems
22/Feb/24	THU			Numerical Problems
23/Feb/24	FRI			Numerical Problems
24/Feb/24	SAT			VOLTAGE CONTROL Introdution
25/Feb/24	SUN	SUNDAY		
26/Feb/24	MON	4	6	methods of voltage control
27/Feb/24	TUE			shunt and series capacitors / Inductors
28/Feb/24	WED			tap changing transformers
29/Feb/24	THU			synchronous phase modifiers
1/Mar/24	FRI			power factor improvement methods
2/Mar/24	SAT			Numerical Problems
3/Mar/24	SUN	SUNDAY		
4/Mar/24	MON	5	4	COMPENSATION IN POWER SYSTEMS: Introduction
5/Mar/24	TUE			Numerical Problems
6/Mar/24	WED			Concepts of Load compensation
7/Mar/24	THU			Numerical Problems

8/Mar/24	FRI			**Maha Shivaratri**
9/Mar/24	SAT			**Second Saturday**
10/Mar/24	SUN			**SUNDAY**
11/Mar/24	MON	**6**	**6**	Load ability characteristics of overhead lines
12/Mar/24	TUE			Uncompensated transmission line
13/Mar/24	WED			Symmetrical line
14/Mar/24	THU			Numerical Problems
15/Mar/24	FRI			Numerical Problems
16/Mar/24	SAT			Radial line with asynchronous load
17/Mar/24	SUN			**SUNDAY**
18/Mar/24	MON	**7**	**6**	Numerical Problems
19/Mar/24	TUE			Compensation of lines
20/Mar/24	WED			Per uint representation
21/Mar/24	THU			The one-line diagram
22/Mar/24	FRI			impedance and reactance diagrams
23/Mar/24	SAT			per unit quantities
24/Mar/24	SUN			**SUNDAY**
25/Mar/24	MON	**8**	**4**	**Holi**
26/Mar/24	TUE			Numerical Problems
27/Mar/24	WED			Numerical Problems
28/Mar/24	THU			changing the base of per unit quantities
29/Mar/24	FRI			**Good Friday**
30/Mar/24	SAT			advantages of per unit system.
31/Mar/24	SUN			**SUNDAY**
1/Apr/24	MON	**9**	**2**	**I Mid Examinations**
2/Apr/24	TUE			**I Mid Examinations**
3/Apr/24	WED			**I Mid Examinations**
4/Apr/24	THU			Production of travelling waves
5/Apr/24	FRI			**Babu Jagjivan Ram Jayanthi**
6/Apr/24	SAT			open circuited line
7/Apr/24	SUN			**SUNDAY**
8/Apr/24	MON	**10**	**2**	short-circuited line
9/Apr/24	TUE			**Ugadi**
10/Apr/24	WED			line terminated through a resistance
11/Apr/24	THU			**Ramzan**
12/Apr/24	FRI			**Ramzan**
13/Apr/24	SAT			**Second Saturday**
14/Apr/24	SUN			**SUNDAY**

15/Apr/24	MON	11	5	line connected to a cable
16/Apr/24	TUE			Numerical Problems
17/Apr/24	WED			**Ram Navami**
18/Apr/24	THU			reflection and refraction at T-junction line terminated through a capacitance
19/Apr/24	FRI			capacitor connection at a T-junction
20/Apr/24	SAT			Numerical Problems
21/Apr/24	SUN	**SUNDAY**		
22/Apr/24	MON	12	6	Attenuation of travelling waves
23/Apr/24	TUE			Over voltage due to arcing ground and Peterson coil
24/Apr/24	WED			lightning
25/Apr/24	THU			horn gaps, surge diverters, rod gaps
26/Apr/24	FRI			expulsion type lightning arrester
27/Apr/24	SAT			valve type lightning arrester
28/Apr/24	SUN	**SUNDAY**		
29/Apr/24	MON	13	6	ground wires, ground rods
30/Apr/24	TUE			counter poise, surge absorbers
1/May/24	WED			insulation coordination
2/May/24	THU			volt-time curves
3/May/24	FRI			Numerical Problems
4/May/24	SAT			Numerical Problems
5/May/24	SUN	**SUNDAY**		
6/May/24	MON	14	5	Significance of positive, negative and zero sequence components
7/May/24	TUE			Average 3-phase power in terms of symmetrical components
8/May/24	WED			sequence impedances and sequence networks
9/May/24	THU			fault calculations, sequence network equations
10/May/24	FRI			single line to ground fault,
11/May/24	SAT			**Second Saturday**
12/May/24	SUN	**SUNDAY**		
13/May/24	to 02-06-2024			**Summer vacation**
3/Jun/24	MON	15		Numerical Problems
4/Jun/24	TUE			line to line fault
5/Jun/24	WED			double line to ground fault,
6/Jun/24	THU		2	three phase fault
7/Jun/24	FRI			Numerical Problems
8/Jun/24	SAT			**Second Saturday**
9/Jun/24	SUN	**SUNDAY**		
10/Jun/24	MON	18	3	faults with fault impedance

11/Jun/24	TUE			reactors and their location
12/Jun/24	WED			short circuit capacity of a bus
18-06-2024 to 20-06-2024				**II Mid Examinations**

Department of Electrical & Electronics Engineering

ASSIGNMENT – 1

Question No.	Question	Objective No.	Outcome No.
1	Deduce an expression for voltage regulation of a short transmission line, giving the phasor diagram	1	1
2	What is Corona effect in transmission lines and factors effecting corona loss & methods of reducing corona loss?	1	1
3	Describe the principle of on-load tap changing transformer? List out its merits and demerits	2	2
4	Explain the importance of voltage control in power system.	2	2
5	Explain the p.u. system of analyzing power system problems. Discuss the advantages of this method over the absolute method of analysis.	3	3

Signature of HOD

Date:

Signature of faculty

Date:

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ASSIGNMENT – 2

Question No.	Question	Objective No.	Outcome No.
1	The Direct axis reactance of a synchronous generator is given as 0.4 pu based on the generators name plate rating of 10 KV,75MVA. The base for calculation is 11KV,100MVA. What is the pu value of Generator on the new base?	3	3
2	Briefly discuss about various cases of over voltages in power system Network.	4	4
3	Explain the various methods of transmission line protection against over voltages due to lightning strokes.	4	4
4	Describe the significance of positive, negative and zero sequence components.	5	5
5	Derive an expression for the fault current for a double line to ground fault as an unloaded generator and draw its equivalent circuit.	5	5

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TUTORIAL SHEET – 1

This tutorial corresponds to Unit No. 1 (Objective Nos.: 1, Outcome Nos.: 1)

Q1. Voltage Regulation of Short transmission lInes___
a) 1 b) 0 c) 0.5 d) 0.95

Q2. In short transmission lines, the effects of .... are neglected
a) L b) C c) R d)None of the above

Q3. The length of a short transmission line is upto about ....
a) 80-160 b) above 160 c) below80 d) None of the above

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TUTORIAL SHEET – 2

This tutorial corresponds to Unit No. 2 (Objective Nos.: 2, Outcome Nos.: 2)

Q1. The voltage control equipment is used at .... in the power system
a) one point b) Null c) More than one point d) coupled circuit

Q2. The excitation control method is suitable only for .... lines
a) Short b) Long c) Medium d) None

Q3. The principal cause of voltage variation is the change of .... on the system.
a) source b) Load c) mid point d) None

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TUTORIAL SHEET – 3

This tutorial corresponds to Unit No. 3 (Objective Nos.: 3, Outcome Nos.: 3)

Q1 Per unit system____

a) Actual Value/Base Value   b) Base Value/Actual Value   c) Actual*Base Values   d) None

Q2 What is the main purpose of reactance diagram?
a) Load flow analysis   b) Falt analysis
c) Calculation of ratings of Alternators   d) Calculation of ratings of Transformers

Q3. Lightening arrester should be located
a) Near the circuit breaker   b) Away from the circuit breaker
c) Near the transformer   d) Away from the transformer

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TUTORIAL SHEET – 4

This tutorial corresponds to Unit No. 4 (Objective Nos.: 3, Outcome Nos.: 3)

Q1. The voltage rating of long transmission line is _________
a) 20 KV to 100 KV b) Upto 20 KV
c) Above 100 KV d) 60 KV to 80 KV

Q2. What is the value of characteristics impedance for loss free transmission line?
a) √(L/C) b) √(R/C) c) √(LC) d) √(C/L)

Q3. The power factor of the arc in a circuit breaker is
a) Zero leading. b) Zero lagging
c) Unity d) Any value from zero to unity

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Date: Date:

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TUTORIAL SHEET – 5

This tutorial corresponds to Unit No. 5 (Objective Nos.: 5, Outcome Nos.: 5)

Q1. The value of expression $1 + \alpha + \alpha 2$
a) 0 b) 1 c) -1 d) 2

Q2 Zero sequence component in 3 phase voltage of delta is

a) Line voltage b) Zero c) $\sqrt{3}$ line voltage d) Line voltage/3

Q3. The positive sequence component of voltage at the point of fault is zero when it is a
a) 3-phase fault b) L-L fault c) L-L-G fault d) L-G fault

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EVALUATION STRATEGY

Target (s)

a. Percentage of Pass : 95%

Assessment Method (s) (Maximum Marks for evaluation are defined in the Academic Regulations)

a. Daily Attendance
b. Assignments
c. Online Quiz (or) Seminars
d. Continuous Internal Assessment
e. Semester / End Examination

List out any new topic(s) or any innovation you would like to introduce in teaching the subjects in this semester

Case Study of any one existing application

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Date:

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Date:

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COURSE COMPLETION STATUS

Actual Date of Completion & Remarks if any

Units	Remarks	Objective No. Achieved	Outcome No. Achieved
Unit 1	completed on 23.02.2024	1	1
Unit 2	completed on 19.03.2024	2	2
Unit 3	completed on 22.04.2024	3	3
Unit 4	completed on 04.05.2024	4	4
Unit 5	completed on 12.06.2024	5	5

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Mappings

1. Course Objectives-Course Outcomes Relationship Matrix

(Indicate the relationships by mark "X")

Course-Outcomes / Course-Objectives	1	2	3	4	5
1	H			M	
2		H			
3				H	
4				H	
5					H

2. Course Outcomes-Program Outcomes (POs) & PSOs Relationship Matrix

(Indicate the relationships by mark "X")

P-Outcomes / C-Outcomes	a	b	c	d	e	f	g	h	i	j	k	l	PSO 1	PSO 2
1	H	H	L		M		H	H	H			M	H	
2	H		L		M			L		M	H	M	H	H
3	H	H	L		M		H	L		H		M		M
4	H	L	H		H		L	L		H		M	M	
5	H	H	L		H		H	M		H		M		

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Rubric for Evaluation

Performance Criteria	Unsatisfactory	Developing	Satisfactory	Exemplary
	1	**2**	**3**	**4**
Research & Gather Information	Does not collect any information that relates to the topic	Collects very little information some relates to the topic	Collects some basic Information most relates to the topic	Collects a great deal of Information all relates to the topic
Fulfill team role's duty	Does not perform any duties of assigned team role.	Performs very little duties.	Performs nearly all duties.	Performs all duties of assigned team role.
Share Equally	Always relies on others to do the work.	Rarely does the assigned work - often needs reminding.	Usually does the assigned work - rarely needs reminding.	Always does the assigned work without having to be reminded
Listen to other team mates	Is always talking—never allows anyone else to speak.	Usually doing most of the talking-- rarely allows others to speak.	Listens, but sometimes talks too much.	Listens and speaks a fair amount.

Department of Electrical & Electronics Engineering

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An Autonomous Institution
(Approved by AICTE, New Delhi & Affiliated to JNTUH)
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www.anurag.ac.in +91 8553122270

II B.TECH IV SEMESTER I MID EXAMINATIONS - APRIL 2024

Branch : B.Tech. (EEE) **Max. Marks: 30**
Date : 03 - Apr - 2024 **Time: 120 Minutes**
Subject : Power System-II,EE405PC

PART - A

ANSWER ALL QUESTIONS **10 X 1 M = 10 M**

Q.No	Question		CO	BTL
1.	The length of a short transmission line is upto about .... (A). 80-160 (B). above 160 (C). below80 (D). None	( )	CO1	L1
2.	The rigorous solution of transmission lines takes into account the .... nature of line constants. (A). Distributed (B). Lumped (C). Bilateral (D). None	( )	CO1	L1
3.	In short transmission lines, the effects of .... are neglected (A). L (B). R (C). C (D). None	( )	CO1	L1
4.	The length of a medium transmission line is upto about .... (A). 80-160 (B). above 160 (C). below20 (D). None	( )	CO1	L1
5.	A synchronous condenser is generally installed at the .... end of a transmission line. (A). receiving (B). sending (C). mid point (D). None	( )	CO2	L1
6.	The voltage control equipment is used at .... in the power system (A). one point (B). (C). More than one point (D). coupled circuit	( )	CO2	L1
7.	Induction regulators are used for voltage control in .... system. (A). Secondary Distribution (B). Transmission (C). Primary Distribution (D). None	( )	CO2	L1
8.	The excitation control method is suitable only for .... lines (A). Short (B). Long (C). Medium (D). None	( )	CO2	L1
9.	A single phase motor is connected to 400V, 50Hz supply. The motor draws a current of 31.7A at a power factor 0.7 lag. The additional reactive power (in VAR) to be supplied by the capacitor bank will be ____________ (A). 4756 (B). 4873 (C). 4299 (D). 9055.3	( )	CO3	L2
10.	What is the main purpose of reactance diagram? (A). Load flow analysis (B). Falt analysis (C). Calculation of ratings of Alternators (D). Calculation of ratings of Transformers	( )	CO3	L1

Department of Electrical & Electronics Engineering

PART - B

ANSWER ANY FOUR **4 X 5 M = 20 M**

Q.No	Question	CO	BTL
11.	Deduce an expression for voltage regulation of a short transmission line, giving the phasor diagram	CO1	L3
12.	What is Ferranti effect in transmission lines? Explain.	CO1	L2
13.	Describe the principle of on-load tap changing transformer? List out its merits and demerits	CO2	L3
14.	What is the need of compensation in power system? Explain about Load ability characteristics of overhead lines.	CO2	L2
15.	Explain the p.u. system of analysing power system problems. Discuss the advantages of this method over the absolute method of analysis.	CO3	L3
16.	Two generators rated at 10 MVA, 13.2 kV and 15 MVA, 13.2 kV are connected in parallel to a busbar. They feed supply to two motors of inputs 8 MVA and 12 MVA respectively. The operating voltage of motors is 12.5 kV. Assuming base quantities as 50 MVA and 13.8 Kv, draw the reactance diagram. The percent reactance for generators is 15% and that for motors is 20%.	CO3	L3

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II B.TECH IV SEMESTER II MID EXAMINATIONS - JUNE 2024

Branch : B.Tech. (EEE) **Max. Marks : 30M**
Date : 20-Jun-2024 **Session : Morning** **Time : 120 Min**
Subject : Power System-II,EE405PC

PART - A

ANSWER ALL THE QUESTIONS **10 X 1M = 10M**

Q.No	Question		CO	BTL
1.	The coefficient of reflection for current for an open ended line is (A). 1 (B). 0.5 (C). – 1.0 (D). Zero	( )	CO3	L1
2.	Lightening arrester should be located (A). Near the circuit breaker (B). Away from the circuit breaker (C). Near the transformer (D). Away from the transformer	( )	CO3	L2
3.	What is the value of characteristics impedance for loss free transmission line? (A). (L/C) (B). (R/C) (C). (LC) (D). (C/L)	( )	CO4	L2
4.	Range of surge impedance for an overhead transmission line is ______ (A). 12 – 144 (B). 40 – 60 (C). 400 – 600 (D). 300 – 900	( )	CO4	L1
5.	Which of thermal protection switch is provided in power line system to protect against? (A). Over voltage (B). Short circuit (C). Temperature rise (D). Overload	( )	CO4	L1
6.	Which of the following circuit breaker is generally used in applications in railways? (A). Bulk oil circuit breakers (B). Minimum oil circuit breakers (C). Air break circuit breakers (D). None of these	( )	CO4	L1
7.	In case of an unbalanced star connected load supplied from an unbalanced 3 phase, 3 wire system, load current will consist of (A). Positive sequence components (B). Negative sequence components (C). Zero sequence components (D). Only (a) and (b)	( )	CO5	L1
8.	The positive sequence component of voltage at the point of fault is zero when it is a (A). 3-phase fault (B). L-L fault (C). L-L-G fault (D). L-G fault	( )	CO5	L1
9.	The charging currents due to shunt admittance can be neglected for ______ transmission line? (A). short (B). long (C). medium (D). all of the mentioned	( )	CO5	L2
10.	Positive sequence current of a transmission line is (A). Always zero (B). One third of negative sequence current (C). Equal to negative sequence current (D). Three times the negative sequence current	( )	CO5	L1

Department of Electrical & Electronics Engineering

PART - B

ANSWER ANY FOUR **4 X 5M = 20M**

Q.No	Question	CO	BTL
11.	An overhead line with surge impedance 400 ohms bifurcates into two lines of surge impedance 400 ohms and 40 ohms respectively. If a surge of 20 kV is incident on the overhead line, determine the magnitudes of voltage and current which enter the bifurcated lines.	CO3	L4
12.	Explain the generation of traveling waves on a transmission line.	CO3	L3
13.	What are the causes of over-voltages in the power system network?	CO4	L3
14.	Distinguish between surge diverters and rod gaps.	CO4	L3
15.	Derive an expression for the fault current for a double line to ground fault as an unloaded generator and draw its equivalent circuit.	CO5	L4
16.	What are symmetrical components? Explain.	CO5	L3

Department of Electrical & Electronics Engineering

Continuous Internal Assessment (R-22)

Programme: **BTech** Year: **II** Course: **Theory** **A.Y: 2023-24**

Course: Power Systems-II Section: A Faculty Name: S.Yasoda Krishna

S. No	Roll No	MID-I (35M)	MID-II (35M)	Avg. of MID I & II	Viva-Voce/Poster Presentation (5M)	Total Marks (40)
1	22C11A0201	33	19	26	5	31
2	22C11A0202	28	28	28	5	33
3	22C11A0203	30	22	26	5	31
4	22C11A0204	28	26	27	5	32
5	22C11A0205	28	26	27	5	32
6	22C11A0206	33	27	30	5	35
7	22C11A0207	31	30	31	5	36
8	22C11A0208	33	30	32	5	37
9	23C15A0201	32	31	32	5	37
10	23C15A0202	31	33	32	5	37
11	23C15A0203	33	33	33	5	38
12	23C15A0204	33	33	33	5	38
13	23C15A0205	32	30	31	5	36
14	23C15A0206	33	33	33	5	38
15	23C15A0207	34	32	33	5	38
16	23C15A0208	33	32	33	5	38
17	23C15A0209	33	33	33	5	38
18	23C15A0210	29	33	31	5	36
19	23C15A0211	31	30	31	5	36

20	23C15A0212	33	32	33	5	38
21	23C15A0213	34	31	33	5	38

No. of Absentees: **00**

Total Strength: **21**

Signature of Faculty

: **Signature of HoD**

Course material

UNIT-I

PERFORMANCE OF SHORT, MEDIUM AND LONG TRANSMISSION LINES

CLASSIFICATION OF LINES - INTRODUCTION

The important considerations in the design and operation of a transmission line are the determination of voltage drop, line losses and efficiency of transmission. These values are greatly influenced by the line constants *R*, *L* and *C* of the transmission line. For instance the voltage drop in the line depends upon the values of above three line constants. Similarly, the resistance of transmission line conductors is the most important cause of power loss in the line and determines the transmission efficiency. In this chapter, we shall develop formulas by which we can calculate voltage regulation, line losses and efficiency of transmission lines. These formulas are important for two principal reasons. Firstly, they provide an opportunity to understand the effects of the parameters of the line on bus voltages and the flow of power. Secondly, they help in developing an overall understanding of what is occurring on electric power system.

CLASSIFICATION OF OVERHEAD TRANSMISSION LINES

A transmission line has *three constants *R*, *L* and *C* distributed uniformly along the whole length of the line. The resistance and inductance form the series impedance. The capacitance existing between conductors for 1-phase line or from a conductor to neutral for a 3- phase line forms a shunt path throughout the length of the line. Therefore, capacitance effects introduce complications in transmission line calculations. Depending upon the manner in which capacitance is taken into account, the overhead transmission lines are classified as :

(i) Short transmission lines. When the length of an overhead transmission line is up to about 50 km and the line voltage is comparatively low (< 20 kV), it is usually considered as a short transmission line. Due to smaller length and lower voltage, the capacitance effects are small and hence can be neglected. Therefore, while studying the performance of a short transmission line, only resistance and inductance of the line are taken into account.

(ii) Medium transmission lines. When the length of an overhead transmission line is about 50-150 km and the line voltage is moderately high (>20 kV < 100 kV), it is considered as a medium transmission line. Due to sufficient length and voltage of the line, the capacitance effects are taken into account. For purposes of calculations, the distributed capacitance of the line is divided and lumped in the form of condensers shunted across the line at one or more points.

(iii) Long transmission lines. When the length of an overhead transmission line is more than 150 km and line voltage is very high (> 100 kV), it is considered as a long transmission line. For the treatment of such a line, the line constants are considered uniformly distributed over the whole length of the line and rigorous methods are employed for solution.

(iv) **Voltage regulation.** When a transmission line is carrying current, there is a voltage drop in the line due to resistance and inductance of the line. The result is that receiving end voltage (V_R) of the line is generally less than the sending end voltage (V_S). This voltage drop ($V_s - V_R$) in the line is expressed as a percentage of receiving end voltage V and is called voltage regulation. The difference in voltage at the receiving end of a transmission line **between conditions of no load and full load is called **voltage regulation** and is expressed as a percentage of the receiving end voltage.

(v) **Transmission efficiency.** The power obtained at the receiving end of a transmission line is generally less than the sending end power due to losses in the line resistance.

The ratio of receiving end power to the sending end power of a transmission line is known as the **transmission efficiency** of the line

PERFORMANCE OF SINGLE PHASE SHORT TRANSMISSION LINES

As stated earlier, the effects of line capacitance are neglected for a short transmission line. Therefore, while studying the performance of such a line, only resistance and inductance of the line are taken into account. The equivalent circuit of a single phase short transmission line is shown in Fig.

Here, the total line resistance and inductance are shown as concentrated or lumped instead of being distributed. The circuit is a simple a.c. series circuit.

Let

I = load current

R = loop resistance i.e., resistance of both conductors X_L= loop reactance

V_R = receiving end voltage

cos ϕ_R = receiving end power factor (lagging)

V_S= sending end voltage

cos ϕ_S= sending end power factor

$$(OC)^2 = (OD)^2 + (DC)^2$$

or

$$V_S^2 = (OE + ED)^2 + (DB + BC)^2$$
$$= (V_R \cos \phi_R + IR)^2 + (V_R \sin \phi_R + IX_L)^2$$

$$\therefore \quad V_S = \sqrt{(V_R \cos \phi_R + IR)^2 + (V_R \sin \phi_R + IX_L)^2}$$

(*i*) %age Voltage regulation $= \dfrac{V_S - V_R}{V_R} \times 100$

(*ii*) Sending end *p.f.*, $\cos \phi_S = \dfrac{OD}{OC} = \dfrac{V_R \cos \phi_R + IR}{V_S}$

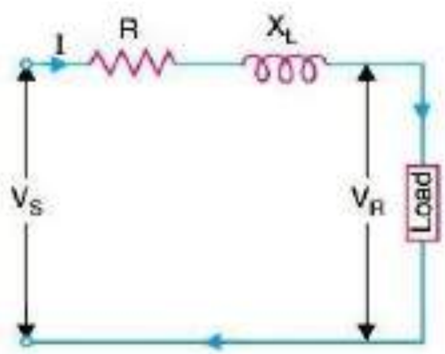
(*iii*) Power delivered $= V_R I_R \cos \phi_R$

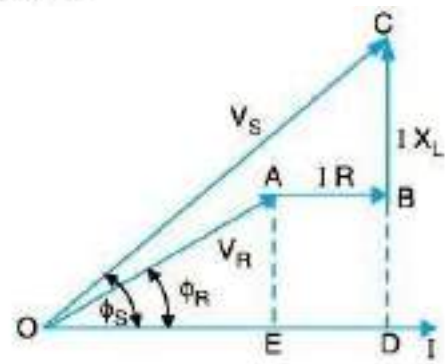
Line losses $= I^2 R$

Power sent out $= V_R I_R \cos \phi_R + I^2 R$

%age Transmission efficiency $= \dfrac{\text{Power delivered}}{\text{Power sent out}} \times 100$

$$= \frac{V_R I_R \cos \phi_R}{V_R I_R \cos \phi_R + I^2 R} \times 100$$





ABCD PARAMETERS

A major section of power system engineering deals in the transmission of electrical power from one particular place (eg. Generating station) to another like substations or distribution units with maximum efficiency. So its of substantial importance for power system engineers to be thorough with its mathematical modeling. Thus the entire transmission system can be simplified to a **two port network** for the sake of easier calculations.

The circuit of a 2 port network is shown in the diagram below. As the name suggests, a 2 port network consists of an input port PQ and an output port RS. Each port has 2 terminals to

Connect itself to the external circuit. Thus it is essentially a 2 port or a 4 terminal circuit, having

Supply end voltage = VS and Supply end current = IS given to the input port P Q.

And there is the Receiving end Voltage = VR and Receiving end current =

IR Given to the output port R S. As shown in the diagram below.

Now the **ABCD parameters** or the transmission line parameters provide the link between the supply and receiving end voltages and currents, considering the circuit elements to be linear in nature.

Thus the relation between the sending and receiving end specifications are given using

ABCD parameters by the equations below.

VS = A VR + B IR ————————-(1)

IS = C VR + D IR ————————-(2)

Now in order to determine the ABCD parameters of transmission line let us impose the required circuit conditions in different cases.

ParameterSpecifn Unit A =

VS / VR Voltage ratio Unit

less B = VS / IR Short

circuit resistance

Ω

C = IS / VR Open circuit conductance mho

D = IS / IR Current ratio Unit less

Now from equivalent circuit, it is found that,

Vs = Vr + IrZ and Is = Ir Comparing these equations with equation 1 and 2 we get,

A = 1, B = Z, C = 0 and D = 1. As we know that the constant A, B, C and D are related for passive network as

Here, A = 1, B = Z, C = 0 and D = 1

AD − BC = 1.

⇒ 1.1 − Z.0 = 1

So the values calculated are correct for short transmission line. From above equation (1),

Vs = AVr + BIr

When Ir = 0 that means receiving end terminals is open circuited and then from the equation 1, we get receiving end voltage at no load

$$V_r' = \frac{V_s}{A}$$

and as per definition of voltage regulation,

$$\%\ \text{voltage regulation} = \frac{V_s / A - V_r}{V_r} X100\ \%$$

MEDIUM TRANSMISSION LINES

In short transmission line calculations, the effects of the line capacitance are neglected because such lines have smaller lengths and transmit power at relatively low voltages (< 20 kV). However, as the length and voltage of the line increase, the capacitance gradually becomes of greater importance.

Since medium transmission lines have sufficient length (50-150 km) and usually operate at voltages greater than 20 kV, the effects of capacitance cannot be neglected. Therefore, in order to obtain reasonable accuracy in medium transmission line calculations, the line capacitance must be taken into consideration.

The capacitance is uniformly distributed over the entire length of the line. However, in order to make the calculations simple, the line capacitance is assumed to be lumped or concentrated in the form of capacitors shunted across the line at one or more points. Such a treatment of localising the

line capacitance gives reasonably accurate results. The most commonly used methods (known as localised capacitance methods) for the solution of medium transmissions lines are:

(i) End condenser method

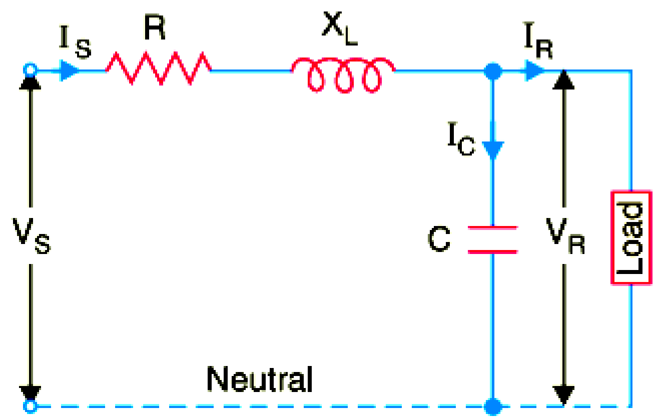
(ii) Nominal T method

(iii) Nominal π method.

Although the above methods are used for obtaining the performance calculations of medium lines, they can also be used for short lines if their line capacitance is given in a particular problem.

i)End Condenser Method

In this method, the capacitance of the line is lumped or concentrated at the receiving or load end as shown in Fig. This method of localising the line capacitance at the load end overestimates the effects of capacitance. In Fig, one phase of the 3-phase transmission line is shown as it is more convenient to work in phase instead of line-to-line values.



Let

I_R= load current per

phase R = resistance per
phase
X_L= inductive reactance per
phase C = capacitance per
phase
cos φ_R= receiving end power factor (
lagging) V_S= sending end voltage per phase

The *phasor diagram for the circuit is shown in Fig Taking the receiving end voltage VR as the reference phasor,

we have, $\vec{V_R} = V_R + j\,0$

Load current, $\vec{I_R} = I_R(\cos\phi_R - j\sin\phi_R)$

Capacitive current, $\vec{I_C} = j\,\vec{V_R}\,\omega C = j\,2\pi f C\,\vec{V_R}$

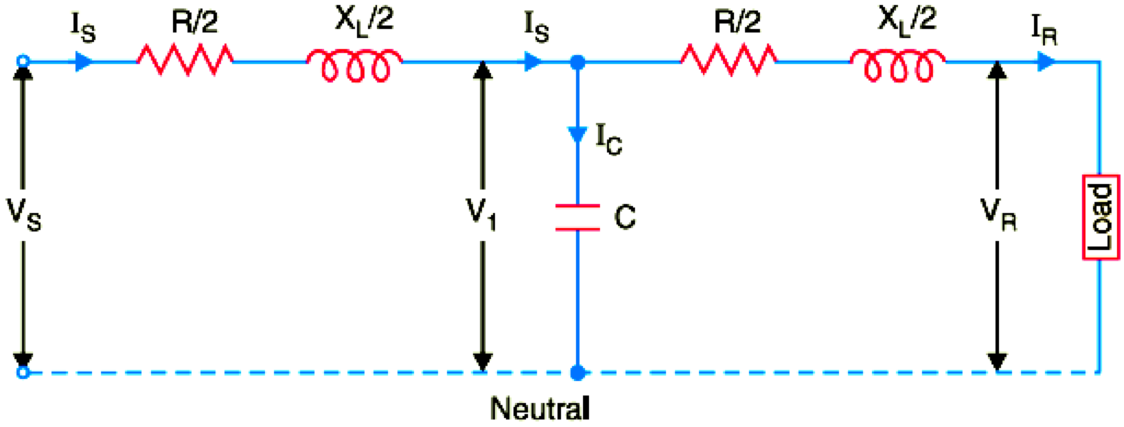
The sending end current I_s is the phasor sum of load current I_R and capacitive current I_C i.e.

$$\begin{aligned}
\vec{I_S} &= \vec{I_R} + \vec{I_C} \\
&= I_R(\cos\phi_R - j\sin\phi_R) + j\,2\pi f C\,V_R \\
&= I_R\cos\phi_R + j(-I_R\sin\phi_R + 2\pi f C V_R) \\
&= \vec{I_S}\,\vec{Z} = \vec{I_S}\,(R + jX_L) \\
\vec{V_S} &= \vec{V_R} + \vec{I_S}\,\vec{Z} = \vec{V_R} + \vec{I_S}\,(R + jX_L)
\end{aligned}$$

$$\%\text{ Voltage transmission efficiency} = \frac{\text{Power delivered / phase}}{\text{Power delivered / phase + losses / phase}} \times 100 = \frac{V_R I_R \cos\phi_R}{V_R I_R \cos\phi_R + I_S^2 R} \times 100$$

i)Nominal T Method

In this method, the whole line capacitance is assumed to be concentrated at the middle point of the line and half the line resistance and reactance are lumped on its either side as shown in Fig. Therefore, in this arrangement, full charging current flows over half the line. In Fig. one phase of 3- phase transmission line is shown as it is advantageous to work in phase instead of line-to-line values.



Let

I_R = load current per phase; R = resistance per phase

X_L = inductive reactance per phase;

C = capacitance per phase

cos φ_R = receiving end power factor (lagging) ;

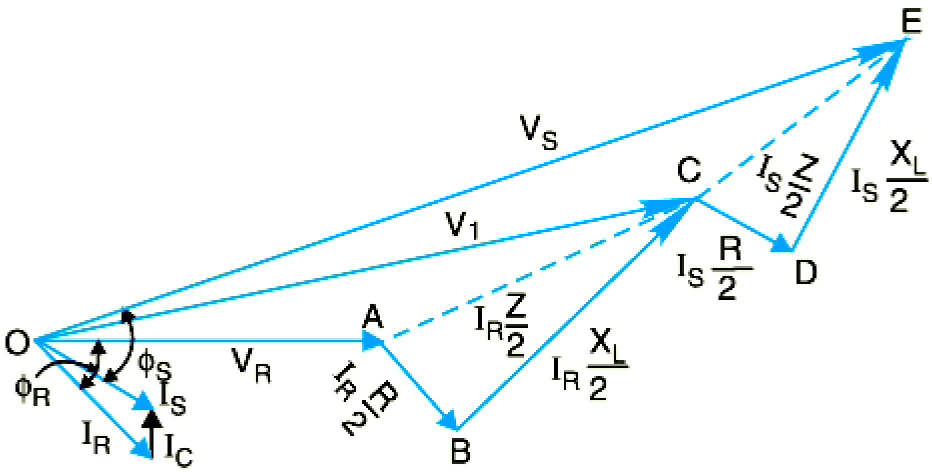
V_S= sending end voltage/phase

V_1 = voltage across capacitor C

The *phasor diagram for the circuit is shown in Fig. Taking the receiving end voltage V_R as the reference phasor, we have,

Receiving end voltage, $\vec{V_R} = V_R + j\,0$

Load current, $\vec{I_R} = I_R(\cos\phi_R - j\sin\phi_R)$



Voltage across C, $\vec{V_1} = \vec{V_R} + \vec{I_R}\,\vec{Z}/2$

$$= V_R + I_R(\cos\phi_R - j\sin\phi_R)\left(\frac{R}{2} + j\frac{X_L}{2}\right)$$

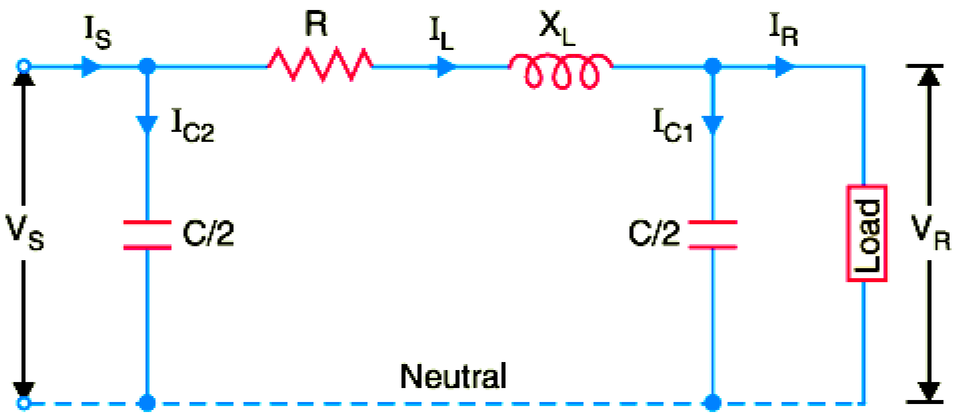
Capacitive current, $\vec{I_C} = j\omega C\vec{V_1} = j2\pi f C\,\vec{V_1}$

Sending end current, $\vec{I_S} = \vec{I_R} + \vec{I_C}$

Sending end voltage, $\vec{V_S} = \vec{V_1} + \vec{I_S}\,\frac{\vec{Z}}{2} = \vec{V_1} + \vec{I_S}\left(\frac{R}{2} + j\frac{X_L}{2}\right)$

ii)Nominal π Method

In this method, capacitance of each conductor (i.e., line to neutral) is divided into two halves; one half being lumped at the sending end and the other half at the receiving end as shown in Fig. It is obvious that capacitance at the sending end has no effect on the line drop. However, its charging current must be added to line current in order to obtain the total sending end current.



Let

I_R = load current per phase R = resistance per phase

X_L = inductive reactance per phase C = capacitance per phase

cos φ_R = receiving end power factor (lagging) V_S= sending end voltage per phase

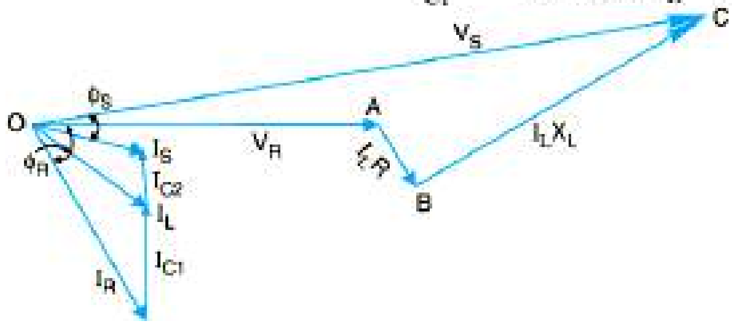
The *phasor diagram for the circuit is shown in Fig. Taking the receiving end voltage as the reference phasor, we have,

$$\vec{V_R} = V_R + j\,0$$

Load current, $\vec{I_R} = I_R(\cos\phi_R - j\sin\phi_R)$

Charging current at load end is

$$\vec{I_{C1}} = j\,\omega\,(C/2)\,\vec{V_R} = j\,\pi\,f\,C\,\vec{V_R}$$



Line current, $\vec{I_L} = \vec{I_R} + \vec{I_{C1}}$

Sending end voltage, $\vec{V_S} = \vec{V_R} + \vec{I_L}\,\vec{Z} = \vec{V_R} + \vec{I_L}\,(R + jX_L)$

Charging current at the sending end is

$$\vec{I_{C2}} = j\,\omega\,(C/2)\,\vec{V_S} = j\,\pi\,f\,C\,\vec{V_S}$$

∴ Sending end current, $\vec{I_S} = \vec{I_L} + \vec{I_{C2}}$

LONG TRANSMISSION LINES

It is well known that line constants of the transmission line are uniformly distributed over the entire length of the line. However, reasonable accuracy can be obtained in line calculations for short and medium lines by considering these constants as lumped. If such an assumption of lumped constants is applied to long transmission lines (having length excess of about 150 km), it is found that serious errors are introduced in the performance calculations. Therefore, in order to obtain fair degree of accuracy in the performance calculations of long lines, the line constants are considered as uniformly distributed throughout the length of the line. Rigorous mathematical treatment is required for the solution of such lines. Fig shows the equivalent circuit of a 3-phase long transmission line on a phase-neutral basis. The whole line length is divided into n sections, each section having line constants 1 /n th of those for the whole line. The following points may by noted :

(i) The line constants are uniformly distributed over the entire length of line as is actually the case.

(ii) The resistance and inductive reactance are the series elements.

(ii) The leakage susceptance (B) and leakage conductance (G) are shunt elements.

(iii) The leakage susceptance is due to the fact that capacitance exists between line and neutral. The leakage conductance takes into account the energy losses occurring through leakage over the

$$= \sqrt{G^2 + B^2} \, .$$

insulators or due to corona effect between conductors. Admittance

(iv) The leakage current through shunt admittance is maximum at the sending end of the line and decreases continuously as the receiving end of the circuit is approached at which point its value is zero.

(v) I = current leaving the element dx Then for the small element dx,

(vi) z dx = series impedance y dx = shunt admittance

(vii) Obviously, dV = I z dx

$$\frac{dV}{dx} = I z$$

(viii)

(ix) Now, the current entering the element is I + dI whereas the current leaving the element is I. The difference in the currents flows through shunt admittance of the element i.e.,

(x) dI = Current through shunt admittance of element = Vy dx

ANALYSIS OF LONG TRANSMISSION LINE (RIGOROUS METHOD)

Fig. shows one phase and neutral connection of a 3-phase line with impedance and shunt admittance of the line uniformly distributed.

Consider a small element in the line of length dx situated at a distance x from the receiving end.

Let

z = series impedance of the line per unit length y

= shunt admittance of the line per unit length

V = voltage at the end of element towards receiving end

V + dV = voltage at the end of element towards sending end I

or $$\frac{dI}{dx} = Vy \quad ...(ii)$$

Differentiating eq. (*i*) w.r.t. *x*, we get.

$$\frac{d^2V}{dx^2} = z\frac{dI}{dx} = z(Vy) \quad \left[\because \frac{dI}{dx} = V\,y \text{ from exp. } (ii)\right]$$

or $$\frac{d^2V}{dx^2} = yzV \quad ...(iii)$$

The solution of this differential equation is

$$V = k_1 \cosh\left(x\sqrt{yz}\right) + k_2 \sinh\left(x\sqrt{yz}\right) \quad ...(iv)$$

or $$\frac{dI}{dx} = Vy \quad ...(ii)$$

Differentiating eq. (*i*) w.r.t. *x*, we get.

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or $$\frac{d^2V}{dx^2} = yzV \quad ...(iii)$$

The solution of this differential equation is

$$V = k_1 \cosh\left(x\sqrt{yz}\right) + k_2 \sinh\left(x\sqrt{yz}\right) \quad ...(iv)$$

At $x = 0, \quad V = V_R$ and $I = I_R$

Putting these values in eq. (*iv*), we have,

$$V_R = k_1 \cosh 0 + k_2 \sinh 0 = k_1 + 0$$

$$\therefore \quad V_R = k_1$$

Similarly, putting $x = 0, \quad V = V_R$ and $I = I_R$ in eq. (*v*), we have,

$$I_R = \sqrt{\frac{y}{z}}\left[k_1 \sinh 0 + k_2 \cosh 0\right] = \sqrt{\frac{y}{z}}\left[0 + k_2\right]$$

$$\therefore \quad k_2 = \sqrt{\frac{z}{y}}\, I_R$$

Substituting the values of k_1 and k_2 in eqs. (*iv*) and (*v*), we get,

$$V = V_R \cosh(x\sqrt{yz}) + \sqrt{\frac{z}{y}}\, I_R \sinh(x\sqrt{yz})$$

and

$$I = \sqrt{\frac{y}{z}}\, V_R \sinh(x\sqrt{yz}) + I_R \cosh(x\sqrt{yz})$$

The sending end voltage (V_S) and sending end current (I_S) are obtained by putting $x = l$ in the above equations *i.e.*,

$$V_S = V_R \cosh(l\sqrt{y\,z}) + \sqrt{\frac{z}{y}} I_R \sinh(l\sqrt{y\,z})$$

$$I_S = \sqrt{\frac{y}{z}} V_R \sinh(l\sqrt{y\,z}) + I_R \cosh(l\sqrt{y\,z})$$

Now, $$l\sqrt{y\,z} = \sqrt{l\,y \cdot l\,z} = \sqrt{Y\,Z}$$

and $$\sqrt{\frac{y}{z}} = \sqrt{\frac{y\,l}{z\,l}} = \sqrt{\frac{Y}{Z}}$$

where Y = total shunt admittance of the line

Z = total series impedance of the line

Therefore, expressions for V_S and I_S become :

$$\mathbf{V}_S = \mathbf{V}_R \cosh\sqrt{\mathbf{YZ}} + \mathbf{I}_R \sqrt{\frac{\mathbf{Z}}{\mathbf{Y}}} \sinh\sqrt{\mathbf{YZ}}$$

$$\mathbf{I}_S = \mathbf{V}_R \sqrt{\frac{\mathbf{Y}}{\mathbf{Z}}} \sinh\sqrt{\mathbf{YZ}} + \mathbf{I}_R \cosh\sqrt{\mathbf{YZ}}$$

It is helpful to expand hyperbolic sine and cosine in terms of their power series.

$$\cosh\sqrt{Y\,Z} = \left(1 + \frac{Z\,Y}{2} + \frac{Z^2Y^2}{24} + \ldots\ldots\right)$$

$$\sinh\sqrt{Y\,Z} = \left(\sqrt{Y\,Z} + \frac{(Y\,Z)^{3/2}}{6} + \ldots\ldots\right)$$

Department of Electrical & Electronics Engineering

UNIT-II

Importance of Voltage Control: -

When the load on the supply system changes, the voltage at the consumer's terminals also changes. The variations of voltage at the consumer's terminals are undesirable and must be kept within pre-scribed limits for the following reasons: -

(i) In case of lighting load, the lamp characteristics are very sensitive to changes of voltage. For instance, if the supply voltage to an incandescent lamp decreases by 6% of rated value, then illuminating power may decrease by 20%. On the other hand, if the supply voltage is 6% above the rated value, the life of the lamp may be reduced by 50% due to rapid deterioration of the filament.

(ii) In case of power load consisting of induction motors, the voltage variations may cause erratic operation. If the supply voltage is above the normal, the motor may operate with a saturated magnetic circuit, with consequent large magnetizing current, heating and low power factor. On the other hand, if the voltage is too low, it will reduce the starting torque of the motor considerably.

(iii) Too wide variations of voltage cause excessive heating of distribution transformers. This may reduce their ratings to a considerable extent.

Location of Voltage Control Equipment: -

In a modern power system, there are several elements between the generating station and the consumers. The voltage control equipment is used at more than one point in the system for two reasons. Firstly, the power network is very extensive and there is a considerable voltage drop in transmission and distribution systems. Secondly, the various circuits of the power system have dissimilar load characteristics. For these reasons, it is necessary to provide individual means of voltage control for each circuit or group of circuits.

In practice, voltage control equipment is used at:

(i) generating stations
(ii) transformer stations
(iii) the feeders if the drop exceeds the permissible limits

Methods of Voltage Control

There are several methods of voltage control. In each method, the system voltage is changed in accordance with the load to obtain a fairly constant voltage at the consumer's end of the system.

The following are the methods of voltage control in an *a.c. power system:

(i) By excitation control
(ii) By using tap changing transformers
(iii) Auto-transformer tap changing
(iv) Booster transformers

(v) Induction regulators

(vi) By synchronous condenser

Excitation Control: -

When the load on the supply system changes, the terminal voltage of the alternator also varies due to the changed voltage drop in the synchronous reactance of the armature. The voltage of the alternator can be kept constant by changing the *field current of the alternator in accordance with the load. This is known as excitation control method. The excitation of alternator can be controlled by the use of automatic or hand operated regulator acting in the field circuit of the alternator. The first method is preferred in modern practice.

There are two main types of automatic voltage regulators viz.

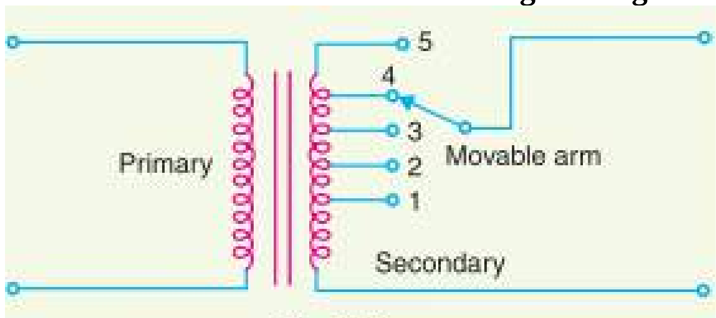
(i) Tirril Regulator (ii) Brown-Boveri Regulator

These regulators are based on the "overshooting the mark †principle" to enable them to respond quickly to the rapid fluctuations of load. When the load on the alternator increases, the regulator produces an increase in excitation more than is ultimately necessary. Before the voltage has the time to increase to the value corresponding to the increased excitation, the regulator reduces the excitation to the proper value.

Tap-Changing Transformers: -

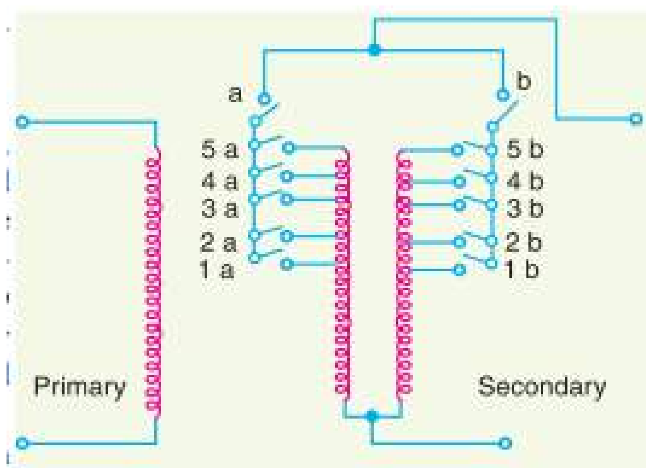
The excitation control method is satisfactory only for relatively short lines. However, it is *not suitable for long lines as the voltage at the alternator terminals will have to be varied too much in order that the voltage at the far end of the line may be constant. Under such situations, the problem of voltage control can be solved by employing other methods. One important method is to use tapchanging transformer and is commonly employed where main transformer is necessary. In this method, a number of tappings are provided on the secondary of the transformer. The voltage drop in the line is supplied by changing the secondary e.m.f. of the transformer through the adjustment of its number of turns

(i) **Off load tap-changing transformer.** Fig. shows the arrangement where a number of tappings have been provided on the secondary. As the position of the tap is varied, the effective number of secondary turns is varied and hence the output voltage of the secondary can be changed. Thus referring to Fig. 15.4, when the movable arm makes contact with stud 1, the secondary voltage is minimum and when with stud 5, it is maximum. During the period of light load, the voltage across the primary is not much below the alternator voltage and the movable arm is placed on stud 1. When the load increases, the voltage across the primary drops, but the secondary voltage can be kept at the previous value by placing the movable arm on to a higher stud. Whenever a tapping is to be changed in this type of transformer, the load is kept off and hence the name off load tap-changing transformer.



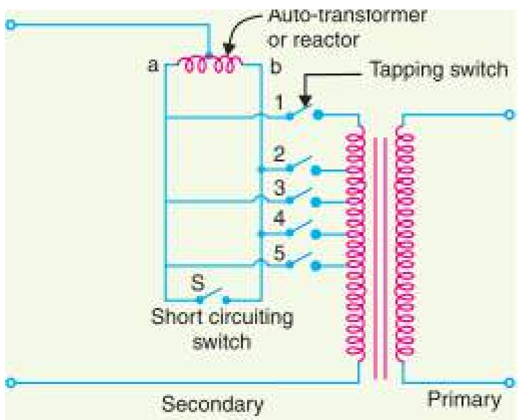
(ii) On-load tap-changing transformer. In supply system, tap-changing has normally to be performed on load so that there is no interruption to supply. Fig. shows diagrammatically one type of on-load tap-changing transformer. The secondary consists of two equal parallel windings which have similar tappings 1a ...... 5a and 1b .... 5b. In the normal working conditions, switches a, b and tappings with the same number remain closed and each secondary winding carries one-half of the total current. Referring to Fig. 15.5, the secondary voltage will be maximum when switches a, b and 5a, 5b are closed. However, the secondary voltage will be minimum when switches a, b and 1a, 1b are closed. Suppose that the transformer is working with tapping position at 4a, 4b and it is desired to alter its position to 5a, 5b. For this purpose, one of the switches a and b, say a, is opened. This takes the secondary winding controlled by switch a out of the circuit. Now, the secondary winding controlled by switch b carries the total current which is twice its rated capacity. Then the tapping on the disconnected winding is changed to 5a and switch a is closed. After this, switch b is opened to disconnect its winding, tapping position on this winding is changed to 5b and then switch b is closed. In this way, tapping position is changed without interrupting the supply.

This method has the following disadvantages : (i) During switching, the impedance of transformer is increased and there will be a voltage surge. (ii) There are twice as many tappings as the voltage steps.



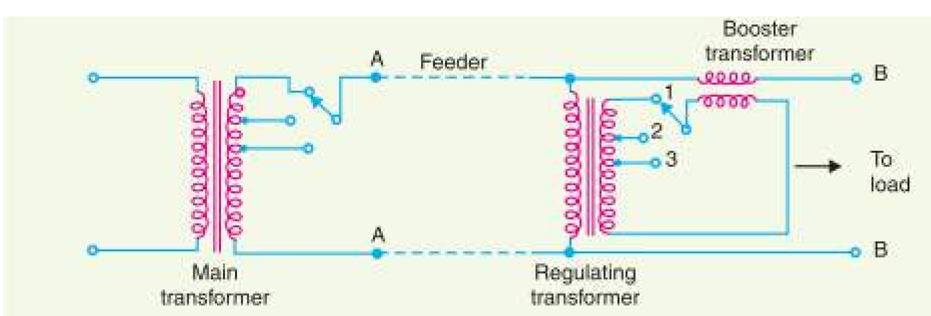
Auto-Transformer Tap-changing

Fig shows diagrammatically auto-transformer tap changing. Here, a mid-tapped auto-transformer or reactor is used. One of the lines is connected to its mid-tapping. One end, say a of this transformer is connected to a series of switches across the odd tappings and the other end b is connected to switches across even tappings. A short-circuiting switch S is connected across the auto-transformer and remains in the closed position under normal operation. In the normal operation, there is *no inductive voltage drop across the auto-transformer. Referring to Fig. 15.6, it is clear that with switch 5 closed, minimum secondary turns are in the circuit and hence the output voltage will be the lowest. On the other hand, the output voltage will be maximum when switch 1 is closed. Suppose now it is desired to alter the tapping point from position 5 to position 4 in order to raise the output voltage. For this purpose, short-circuiting switch S is opened, switch 4 is closed, then switch 5 is opened and finally short-circuiting switch is closed. In this way, tapping can be changed without interrupting the supply. It is worthwhile to describe the electrical phenomenon occurring during the tap changing. When the short-circuiting switch is opened, the load current flows through one-half of the reactor coil so that there is a voltage drop across the reactor. When switch 4 is closed, the turns between points 4 and 5 are connected through the whole reactor winding. A circulating current flows through this local circuit but it is limited to a low value due to high reactance of the reactor.



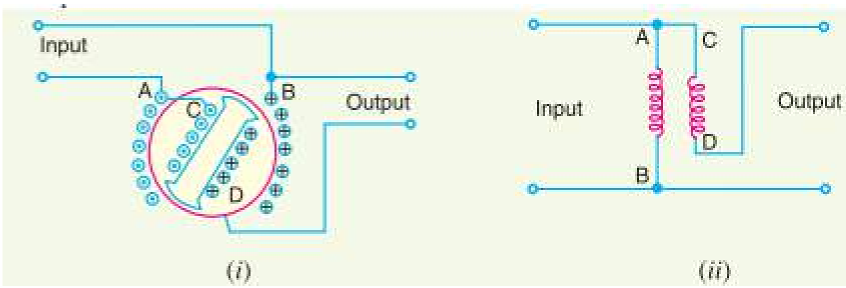
Booster Transformer:-

Sometimes it is desired to control the voltage of a transmission line at a point far away from the main transformer. This can be conveniently achieved by the use of a booster transformer as shown in Fig. 15.7. The secondary of the booster transformer is connected in series with the line whose voltage is to be controlled. The primary of this transformer is supplied from a regulating transformer *fitted with on-load tap-changing gear. The booster transformer is connected in such a way that its secondary injects a voltage in phase with the line voltage.



Induction Regulators

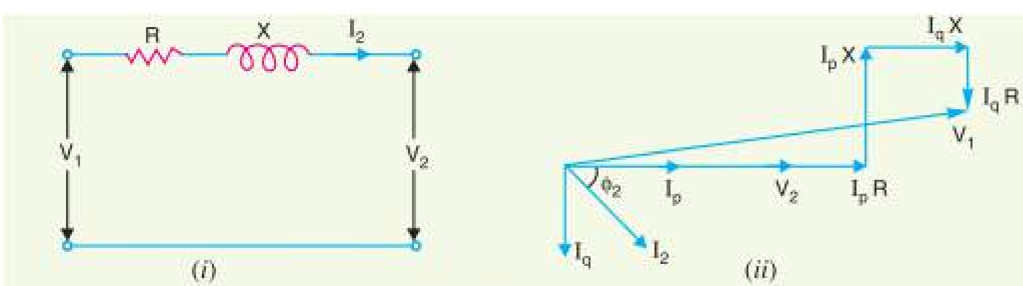
An induction regulator is essentially a constant voltage transformer, one winding of which can be moved w.r.t. the other, thereby obtaining a variable secondary voltage. The primary winding is connected across the supply while the secondary winding is connected in series with the line whose voltage is to be controlled. When the position of one winding is changed w.r.t. the other, the secondary voltage injected into the line also changes. There are two types of induction regulators viz. single phase and 3-phase.



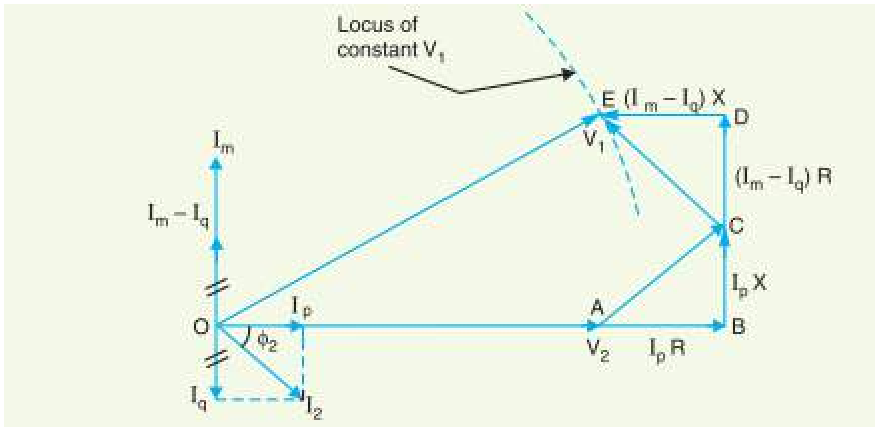
Voltage Control by Synchronous Condenser

The voltage at the receiving end of a transmission line can be controlled by installing specially designed synchronous motors called *synchronous condensers at the receiving end of the line. The synchronous condenser supplies wattless leading kVA to the line depending upon the excitation of the motor. This wattless leading kVA partly or fully cancels the wattless lagging kVA of the line, thus controlling the voltage drop in the line. In this way, voltage at the receiving end of a transmission line can be kept constant as the load on the system changes. For simplicity, consider a short transmission line where the effects of capacitance are neglected. Therefore, the line has only resistance and inductance. Let V1 and V2 be the per phase sending end and receiving end voltages respectively. Let I 2 be the load current at a lagging power factor of cos φ2 .

(i) Without synchronous condenser. Fig shows the transmission line with resistance R and inductive reactance X per phase. The load current I 2 can be resolved into two rectangular components viz I p in phase with V2 and I q at right angles to V2 [See Fig. 15.12 (ii)]. Each component will produce resistive and reactive drops ; the resistive drops being in phase with and the reactive drops in quadrature leading with the corresponding currents. The vector addition of these voltage drops to V2 gives the sending end voltage V1 .



(ii) With synchronous condenser. Now suppose that a synchronous condenser taking a leading current **Im is connected at the receiving end of the line. The vector diagram of the circuit becomes as shown in Fig. . Note that since Im and I q are in direct opposition and that Im must be greater than I q , the four drops due to these two currents simplify to :



$(I_m - I_q)\,R$ in phase with I_m

and $(I_m - I_q)\,X$ in quadrature leading with I_m

From the vector diagram, the relation between V_1 and V_2 is given by ;

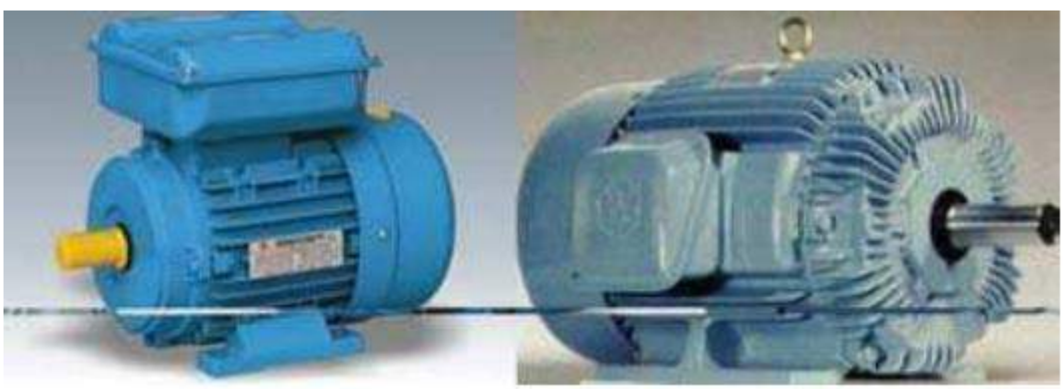
$$OE^2 = (OA + AB - DE)^2 + (BC + CD)^2$$

or

$$V_1^2 = [V_2 + I_p R - (I_m - I_q) X]^2 + [I_p X + (I_m - I_q) R]^2$$

From this equation, the value of I_m can be calculated to obtain any desired ratio of V_1/V_2 for a given load current and power factor.

$$\text{kVAR capacity of condenser} = \frac{3\,V_2\,I_m}{1000}$$



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Problem:-A load of 10,000 kW at a power factor of 0·8 lagging is supplied by a 3-phase line whose voltage has to be maintained at 33kV at each end. If the line resistance and reactance per phase are 5 Ω and 10 Ω respectively, calculate the capacity of the synchronous condenser to be installed for the purpose. Comment on the result.

$$\text{Load current, } I_2 = \frac{10{,}000 \times 10^3}{\sqrt{3} \times 33 \times 10^3 \times 0\cdot8} = 218 \text{ A}$$

$$I_p = I_2 \cos\phi_2 = 218 \times 0\cdot8 = 174\cdot4 \text{ A}$$

$$I_q = I_2 \sin\phi_2 = 218 \times 0\cdot6 = 130\cdot8 \text{ A}$$

$$R = 5\,\Omega\,;\, X = 10\,\Omega$$

$$\text{Sending-end voltage/phase, } V_1 = \text{Receiving end voltage/phase } (V_2)$$

$$= \frac{33 \times 10^3}{\sqrt{3}} = 19{,}053 \text{ V}$$

Let I_m be the current taken by the synchronous condenser. Referring to Fig. 15.13,

$$(19{,}053)^2 = [19{,}053 + 174\cdot4 \times 5 - 10\,(I_m - 130\cdot8)]^2 + [174\cdot4 \times 10 + (I_m - 130\cdot8)5]^2$$

Solving this equation, we get, $I_m = 231$ A

$$\text{Capacity of synchronous condenser} = \frac{3V_2\, I_m}{1000} \text{ kVAR} = \frac{3 \times 19{,}053 \times 231}{1000} \text{ kVAR}$$

$$= \mathbf{13{,}203 \text{ kVAR}}$$

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UNIT-III

Per Unit System

- Introduction
- Change of base quantities
- Calculation of base quantities for T/F
- Advantages of Per Unit Computations

Introduction:-

❖The various components of a power system like Alternators, Transformers, Induction Motors etc., have their voltage, power, current and impedance ratings in KV, KVA, KA and KΩ respectively

❖It will be convenient for analysis of power system networks if the voltage, power, current and impedance ratings of components of power system are expressed with reference to a common value called base value

❖For analysis purpose, a base value is chosen for voltage, power, current and impedance

Hence, All the Voltage, Power, Current and Impedance ratings of the components are expressed as a percentage or per unit of the base value

❖Per unit value of any quantity is defined as the ratio of actual value to the chosen base value in the same unit.

$$i.e\ Perunit\ value = \frac{Actual\ value\ in\ any\ unit}{Base\ value\ in\ the\ same\ unit}$$

❖ Per unit Impedance

$$Z_{pu} = \frac{Z}{Z_b} = Z \times \frac{(MVA)_b}{(kV)_b^2} = Z \times \frac{(KVA)_b}{(kV)_b^2} \cdot \frac{1}{1000} \quad \ldots (1)$$

Where,

Actual Impedance = Z in ohms

Base Impedance = Zb in ohms

Base Mega Volt Amps = (MVA)b

Line to line base Kilo Volts = (kV)b

This Formula is applicable for both Single & Three-Phase Systems

Normally, the impedances are specified on the rating of the equipment.

Hence, there is a need to change the p.u values from the base of the equipment rating (old value) to that of the chosen system base (new value)

❖When MVA base is changed from (MVA)b,old to (MVA)b,new and KV base is changed from (KV)b,old to (KV)b,new the per unit impedance from the above equation

$$Z(p.u)_{new} = Z(p.u)_{old} \times \frac{(MVA)_{b,new}}{(MVA)_{b,old}} \times \frac{(kV)^2_{b,old}}{(kV)^2_{b,new}}$$

❖Similarly we can also write

$$X(p.u)_{new} = X(p.u)_{old} \times \frac{(MVA)_{b,new}}{(MVA)_{b,old}} \times \frac{(kV)^2_{b,old}}{(kV)^2_{b,new}}$$

The various sections of power system works at different voltage levels and the voltage conversion is achieved by means of Transformers

❖For a Transformer, primary side of Base KV of power system should be converted to secondary side of Base KV as per the Transformation Ration of the Transformer.

❖ Base KV on L.T side of T/F = Base KV on H.T side of T/F $\times \frac{L.T \text{ voltage rating}}{H.T \text{ voltage rating}}$

Advantages of Per Unit Computations:-

Manufacturers usually specify the Impedance of a device or machine in per unit on the name pates

❖ The various components of power system and their interconnections are usually represented by single line diagram

❖ In a single line diagram, the components are represented by standard symbols and their interconnections are shown by single line with the representations in per unit quantities

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UNIT-IV

OVER VOLTAGES IN ELECTRICAL POWER SYSTEMS

- Causes of over voltage
- Lightning phenomenon
- Charge formation of Lightning
- Rate of Charging of thunder cloud
- Mechanism of lightning strokes
- Characteristics of Lightning strokes

LIGHTING:-

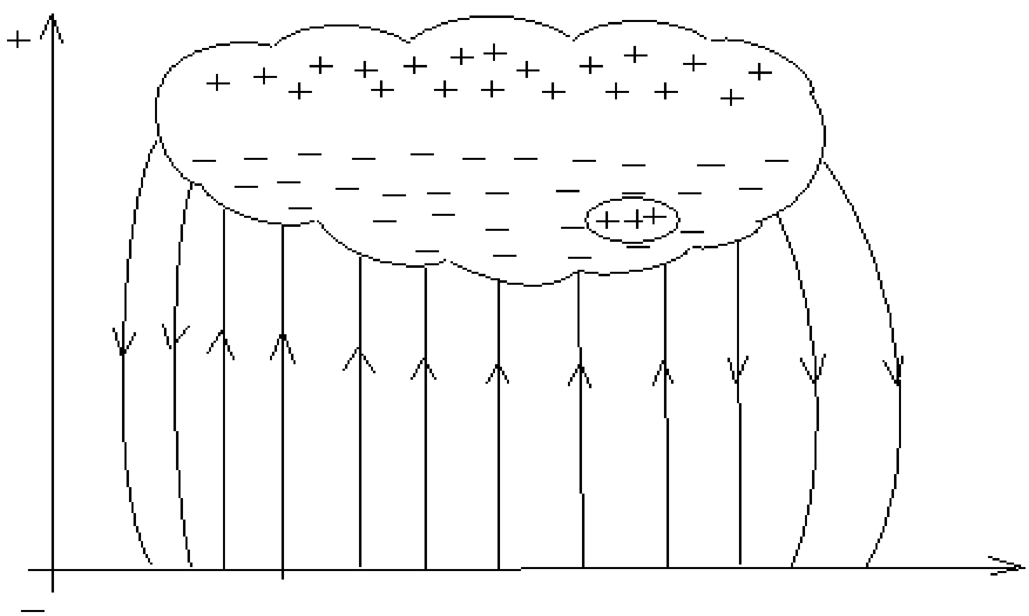
- Factors contributing to good line design
- Protection afforded by ground wires.
- Tower footing resistance
- Interaction between lightning and power system
- Mathematical model of Lightning

Causes of Lightning:-

- Lightning phenomenon
  - peak discharge in which charge accumulated in the cloud into neighbouring cloud or to the ground
- Electrode separation – cloud to cloud or cloud to ground is about 10 km or more

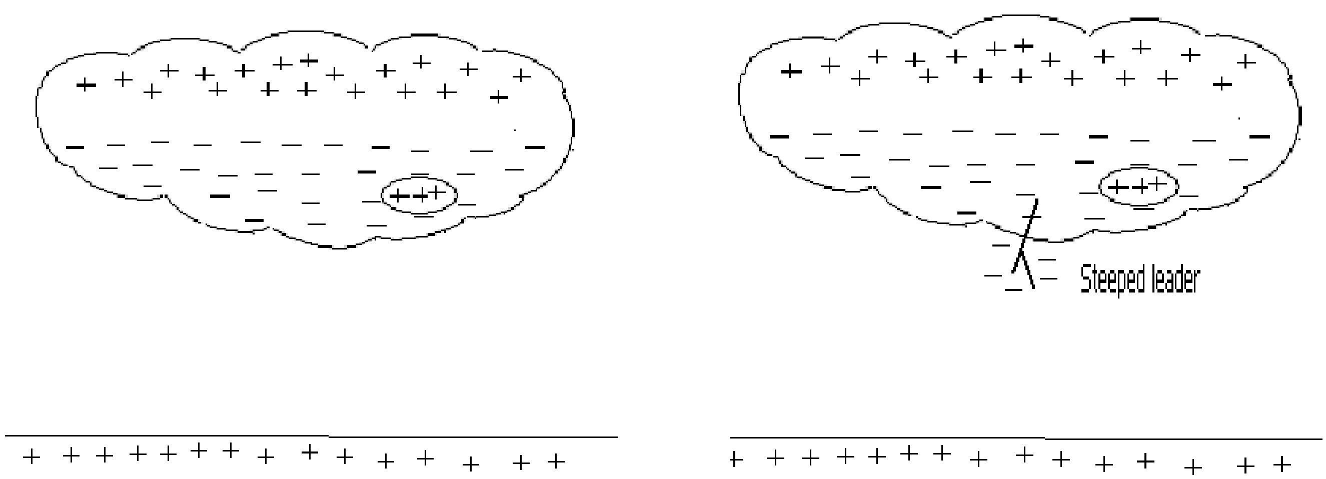
CHARGE FORMATION OF CLOUD:-

- Positive and negative charges become separated by heavy air current with ice crystals in the upper part and rain in the lower region.
- Charge separation depends on height of cloud (200 – 10,000m).
- Charge centers at a distance about 300 – 2km
- Charge inside the cloud – 1 to 100 C
- Cloud potential – 10^7 to 10^8 V
- Gradient within a cloud – 100 V/cm
- Gradient at initial discharge point –
  - 10kV/cm
- Energy at discharge – 250 kWhr



MECHANISM OF LIGHTNING FLASH:-

- Pilot streamer and Stepped leader
- Ground streamer and return stroke
- Subsequent strokes



CHARACTERISTICS OF LIGHTNING STROKES:-

- Current-time characteristics
- Time to peak or Rate of rise
- Probability distribution of current and time
- Wave shapes of lightning voltage and current

SURGE VOLTAGE:-

- Maximum surge voltage in transmission line – 5MV
- Most of the surge voltage is less than 1000 kV on line.
- Front time – 2 to 10 μs
- Tail time – 20 to 100 μs
- Rate of rise of voltage – 1MV/ μs

OVER VOLTAGE DUE TO SWITCHING SURGES:-

- In switching, the over voltage thus generated last for longer durations and therefore are severe and more dangerous to the system.
- The switching over voltages depends on the normal voltage of the system and hence increase with increased system voltage.
- Making and breaking of electric circuits with switchgear may results in abnormal over voltages in power systems having large inductances and capacitances.
- over voltages may go as high as 6 times the normal power frequency voltage.
- In circuit breaking operation switching surges with a high rate of rise of voltage may cause repeated restriking of the arc between the contacts of a circuit breaker, thereby causing destruction of the circuit breaker contacts.
- Switching surges may include high natural frequencies of the system, a damped normal frequency voltage component, or restriking and recovery voltage of the system with successive reflected waves from terminations.

CHARACTERISTICS OF SWITCHING SURGES:-

- De-energizing of transmission lines, cables, shunt capacitor, banks, etc.
- Disconnection of unloaded transformers, reactors, etc.
- Energization or reclosing of lines and reactive loads.
- Sudden switching off of loads.
- Short circuit and fault clearances.
- Resonance phenomenon like ferro- resonance, arcing grounds, etc.

CONTROL OF OVERVOLTAGES DUE TO SWITCHING:-

- Energization of transmission lines in one or more steps by inserting resistances and withdrawing them afterwards.
- Phase controlled closing of circuit breakers.
- Drainage of trapped charges before reclosing
- Use of shunt reactors.
- Limiting switching surges by suitable surge diverters.

PROTECTION AGAINST OVERVOLTAGS:-

- Minimizing the lightning over voltages are done by suitable line designs,
- Providing guard and ground wires,
- Using surge diverters.

- Shielding the overhead lines by using ground wires above the phase wires,
- Using ground rods and counter-poise wires,
- Including protective devices like explosion gaps, protector tubes on the lines, and surge diverters at the line terminations and substations

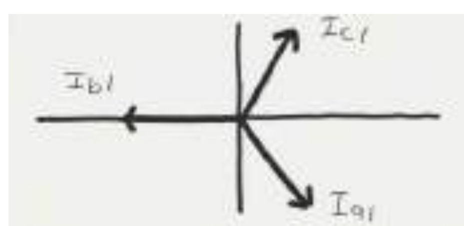
UNIT-V

Analysis of Unsymmetric Systems:-

- Except for the balanced three-phase fault, faults result in an unbalanced system.
- The most common types of faults are single line- ground (SLG) and line-line (LL). Other types are double line-ground (DLG), open conductor, and balanced three phase.
- System is only unbalanced at point of fault!
- The easiest method to analyze unbalanced system operation due to faults is through the use of symmetrical components

Symmetric Components:-

- The key idea of symmetrical component analysis is to decompose the system into three sequence networks. The networks are then coupled only at the point of the unbalance (i.e., the fault)
- The three sequence networks are known as the
- positive sequence (this is the one we've been using)
- negative sequence
- zero sequence
- The positive sequence sets have three phase currents/voltages with equal magnitude, with phase b lagging phase a by 120°, and phase c lagging phase b by 120°.
- We've been studying positive sequence sets
- Positive sequence sets have zero neutral current



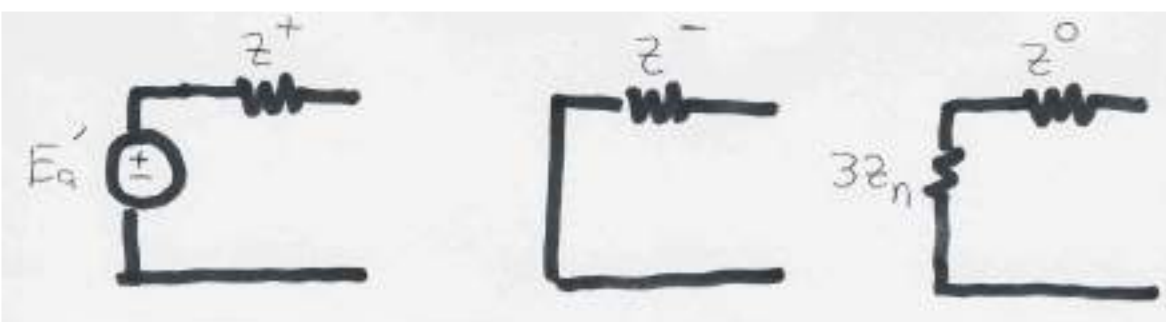
- The negative sequence sets have three phase currents/voltages with equal magnitude, with phase b leading phase a by 120°, and phase c leading phase b by 120°.
- Negative sequence sets are similar to positive sequence, except the phase order is reversed.
- Zero sequence sets have three values with equal magnitude and angle.
- Zero sequence sets have neutral current.

Sequence Set Representation:-

- Any arbitrary set of three phasors, say Ia, Ib, Ic can be represented as a sum of the three sequence sets

Sequence diagrams for generators:-

- Key point: generators only produce positive sequence voltages; therefore only the positive sequence has a voltage source.

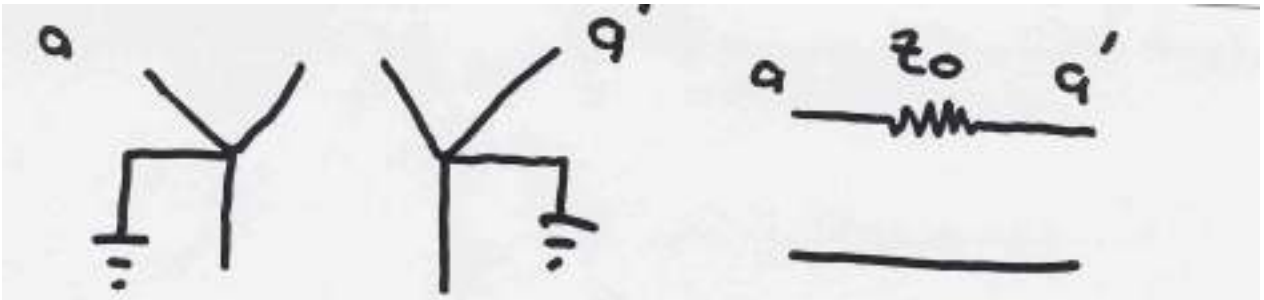


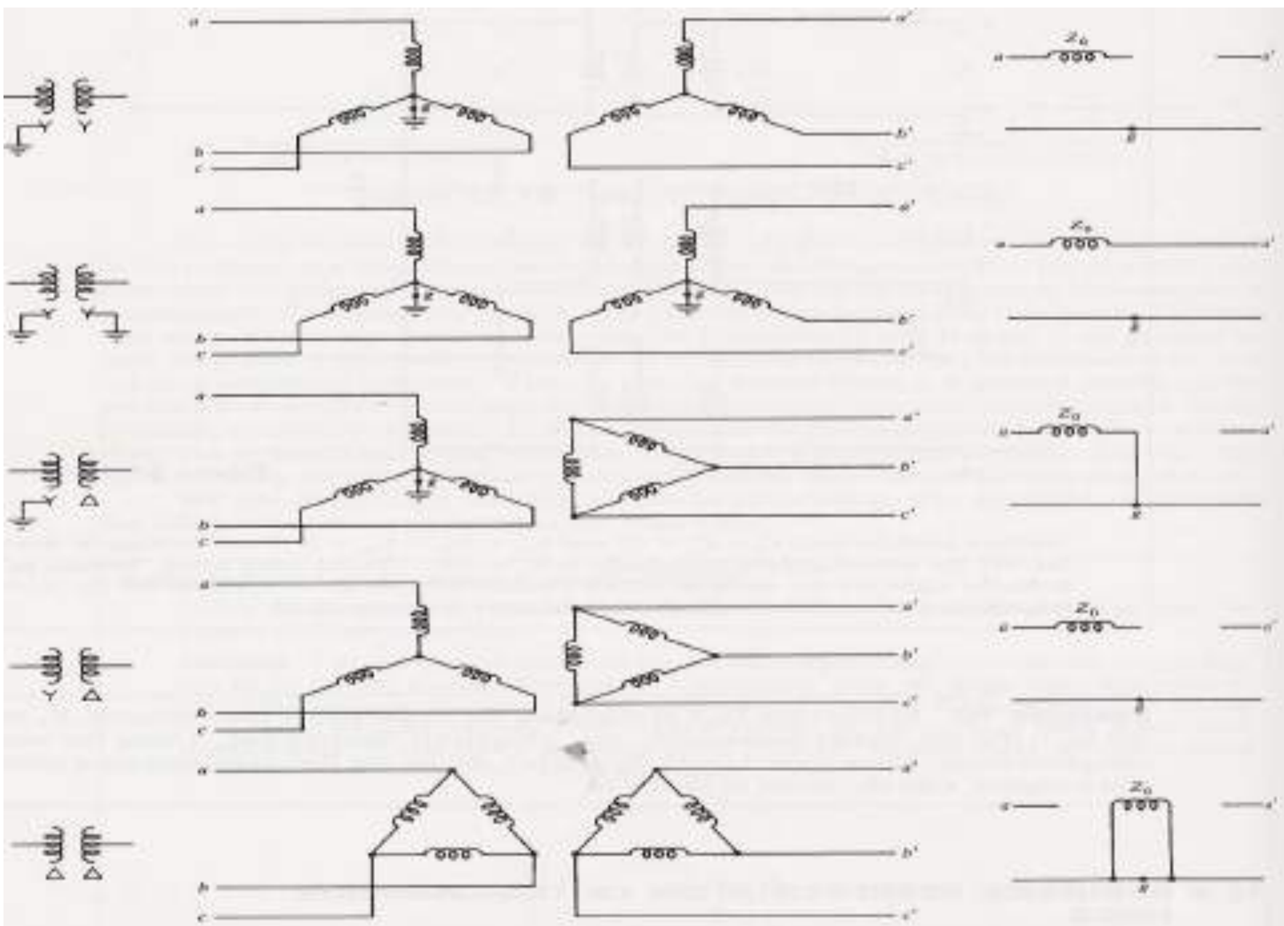
During a fault Z+ Z^1+ Xd”. The zero sequence impedance is usually substantially smaller. The value of Zn depends on whether the generator is grounded

Sequence diagrams for Transformers:-

- The positive and negative sequence diagrams for transformers are similar to those for transmission lines.

- The zero sequence network depends upon both how the transformer is grounded and its type of connection. The easiest to understand is a double grounded wye-wye.





Unbalanced Fault Analysis:-

- The first step in the analysis of unbalanced faults is to assemble the three sequence networks. For example, for the earlier single generator, single motor example let's develop the sequence networks.