EXTRA HIGH VOLTAGE AC TRANSMISSION

B.TECH IV YEAR-II SEMESTER

GEETHANJALI COLLEGE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF Electrical and Electronics Engineering

(Name of the Subject / Lab Course) : EHV AC

JNTU CODE – 558013 **Programme : UG**

Branch: EHV AC **Version No : 01**

Year: IV year **Updated on : 1/12/14**

Semester: II-Sem **No.of pages :60**

Classification status (<u>Unrestricted</u> / Restricted)

Distribution List :

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2) Sign :	**1) Name :**
3) Design :	**2) Sign :**
4) Date :	**3) Design :**
	4) Date :

Approved by : (HOD) 1) Name :Dr.S.Radhika

2) Sign :

3) Date :

2.SYLLABUS

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY, HYDERABAD

IV Year B.Tech EEE II-Semester	T	P	C
	4+1	*0	4

EHV AC TRANSMISSION (Elective-IV)

Unit -1: Preliminaries:
Necessity of EHV AC transmission - advantages and problems-power handling capacity and line losses. Mechanical considerations - resistance of conductors - properties of bundled conductors – bundle spacing and bundle radius- Examples.

Unit - II: Line and ground reactive parameters:
Line inductance and capacitances - sequence inductances and capacitances - modes of propagation - ground return - Examples

Unit - III: Voltage gradients of conductors:
Electrostatics - field of sphere gap - field of line changes and properties - charge - potential relations for multi-conductors - surface voltage gradient on conductors - distribution of voltage gradient on sub conductors of bundle - Examples.

Unit - IV: Corona effects -1:
Power loss and audible noise (AN) - corona loss formulae - charge voltage diagram - generation, characteristics - limits and measurements of AN - relation between 1-phase and 3-phase AN levels -Examples.

Unit-V: Corona effects-II:
Radio interference (RI) - corona pulses generation, properties, limits - frequency spectrum - modes of propagation - excitation function - measurement of RI, RIV and excitation functions - Examples.

Unit-VI: Electro static field:
Electrostatic field: calculation of electrostatic field of EHV/AC lines - effect on humans, animals and plants
- electrostatic induction in unenergised circuit of double-circuit line - electromagnetic interference-Examples.

Unit- VII: Traveling wave theory:
Traveling wave expression and solution- source of excitation- terminal conditions- open circuited and short-circuited end- reflection and refraction coefficients-Lumped

parameters of distributed lines generalized constants-No load voltage conditions and charging current.

Unit -VIII: Voltage control:

Power circle diagram and its use - voltage control using synchronous condensers - cascade connection of shunt and series compensation - sub synchronous resonance in series capacitor - compensated lines - static VAR compensating system.

TEXT BOOKS:

1. EHVAC Transmission Engineering by R. D. Begamudre, New Age International (p) Ltd.
2. HVAC and DC Transmission by S. Rao

Vision and Mission

Vision and Mission of the institute

Mission of the institute:

Our mission is to become a high quality premier educational institution, to create technocrats, by ensuring excellence, through enriched knowledge, creativity and self development.

Vision of the institute:

Geethanjali visualizes dissemination of knowledge and skills to students, who would eventually contribute to the well being of the people of the nation and global community.

DEPARTMENT OF EEE

Department of Electronics and Electronics Engineering is established in the year 2006 to meet the requirements of the Electrical and Electronic industries such as BHEL, BEL, Vijay electrical and society after the consultation with various stakeholders.

3. Vision of EEE

To provide excellent Electrical and electronics education by building strong teaching and research environment

4. Mission of EEE

1. To offer high quality graduate program in Electrical and Electronics education and to prepare students for professional career or higher studies.
2. The department promotes excellence in teaching, research, collaborative activities and positive contributions to society

5.Programme Educational Objectives(EEE)

PEO 1. Graduates will excel in professional career and/or higher education by acquiring knowledge in Mathematics, Science, Engineering principles and Computational skills.
PEO 2. Graduates will analyze real life problems, design Electrical systems appropriate to the requirement that are technically sound, economically feasible and socially acceptable.
PEO 3.Graduates will exhibit professionalism, ethical attitude, communication skills, team work in their profession, adapt to current trends by engaging in lifelong learning and participate in Research & Development.

5.Programme Outcomes (EEE)

PO 1. An ability to apply the knowledge of Mathematics, Science and Engineering in Electrical and Electronics Engineering.
PO 2. An ability to design and conduct experiments pertaining to Electrical and Electronics Engineering.
PO 3. An ability to function in multidisciplinary teams
PO 4. An ability to simulate and determine the parameters such as nominal voltage current, power and associated attributes.
PO 5. An ability to identify, formulate and solve problems in the areas of Electrical and Electronics Engineering.
PO 6. An ability to use appropriate network theorems to solve electrical engineering problems.
PO 7. An ability to communicate effectively.
PO 8. An ability to visualize the impact of electrical engineering solutions in global, economic and societal context.
PO 9. Recognition of the need and an ability to engage in life-long learning.
PO 10 An ability to understand contemporary issues related to alternate energy sources.
PO 11 An ability to use the techniques, skills and modern engineering tools necessary for Electrical Engineering Practice.
PO 12 An ability to simulate and determine the parameters like voltage profile and current ratings of transmission lines in Power Systems.
PO 13 An ability to understand and determine the performance of electrical machines namely speed, torque, efficiency etc.
PO 14 An ability to apply electrical engineering and management principles to Power Projects.

6.Course objectives and outcomes

Course objectives:

1. To Provide In-depth understanding of different aspects of Extra High Voltage AC transmission system design and Analysis.
2. To Calculate the Value of Line Inductance and Capacitance of EHV transmission Line
3. To understand the concept of Voltage gradients of conductors.
4. To develop the empirical formula to determine the Corona loss occurring in EHV AC transmission Line.
5. To determine the interference caused by Corona and to measure its magnitude.
6. To calculate the Electrostatic field and to understand its effects over humans, animal and plants.
7. To derive the expression and possible solution for travelling wave and its source of excitation.
8. To develop Power circle diagram and understand various Line Compensating systems

Course outcomes:

1. Students learn about the trends in EHV AC Transmission.
2. Student can calculate Line inductance and capacitances of bundled conductors.
3. Students can calculate voltage gradient of bundled conductors
4. Students will understand the effects of corona like Audible noise.
5. Students understand the effect of Radio Interference
6. Students can calculate electrostatic field of EHV AC lines
7. Students can analyze travelling waves
8. Students can analyze compensated devices for voltage control.

7. Importance of the course

Modern power transmission is utilizing voltages between 345 kV and 1150 kV, A.C. Distances of transmission and bulk powers handled have increased to such an extent that extra high voltages and ultra high voltages (EHV and UHV) are necessary. The problems encountered with such high voltage transmission lines exposed to nature are electrostatic fields near the lines, audible noise, radio interference, corona losses, carrier and TV interference, high voltage gradients, heavy bundled conductors, control of voltages at power frequency using shunt reactors of the switched type which inject harmonics into the system, switched capacitors, overvoltages caused by lightning and switching operations, long air gaps with weak insulating properties for switching surges, ground-return effects, and many more. This course covers all topics that are considered essential for understanding the operation and design of EHV ac overhead lines and underground cables. Theoretical analysis of all problems combined with practical application are dealt in this course.

8. Prerequisites

1. Power System II

9.Instructional Learning Outcomes

Unit -1: Preliminaries:

- Student shall be able to understand the Necessity of EHV AC transmission line.
- Student shall be able to identify advantages and problems in EHV AC transmission line
- Student shall be able to know how power handling capacity and line losses occur in EHV AC transmission line.
- Student shall be able to understand various Mechanical considerations.
- Student shall be able to calculate resistance of conductors
- Student shall be able to identify various properties of bundled conductors
- Student shall be able to understand bundle spacing and bundle radius with design examples.

Unit - II: Line and ground reactive parameters:

- Student shall be able to calculate Line inductance.
- Student shall be able to calculate Line capacitances.
- Student shall be able to understand what is sequence inductances
- Student shall be able to understand what is sequence capacitances
- Student shall be able to understand different modes of propagation and ground return.
- Student shall be able to solve various design examples.

Unit - III: Voltage gradients of conductors:

- Student shall be able to understand field of sphere gap as Electrostatics property.
- Student shall be able to understand field of line changes and their properties
- Student shall be able to understand charge and potential relations for multi-conductors
- Student shall be able to understand the concept of surface voltage gradient on conductors.
- Student shall be able to understand the distribution of voltage gradient on sub conductors of bundle with design examples.

Unit - IV: Corona effects -1:

- Student shall be able to understand the concept of Power loss and audible noise (AN) due to corona.
- Student shall be able to derive corona loss formula
- Student shall be able to draw charge voltage diagram - generation, characteristics
- Student shall be able to determine the limits and measurements of AN
- Student shall be able to understand the relation between 1-phase and 3-phase AN levels.

Unit-V: Corona effects-II:

- Student shall be able to understand the concept of Radio interference (RI)
- Student shall be able to understand how corona pulses are generated.
- Student shall be able to understand the properties of corona pulses.
- Student shall be able to determine the limits of corona pulses
- Student shall be able to identify the frequency spectrum of corona pulses
- Student shall be able to distinguish various modes of propagation
- Student shall be able to determine excitation function
- Student shall be able to measure the value of RI, RIV and excitation functions.

Unit-VI: Electro static field:

- Student shall be able to understand the concept of Electrostatic field.
- Student shall be able to calculate the value of electrostatic field of EHV AC lines.
- Student shall be able to understand the effect of electrostatic field due to EHV AC lines on humans, animals and plants.
- Student shall be able to understand the effect of electrostatic induction in unenergised circuit of double-circuit line
- Student shall be able to understand the effect of electromagnetic interference.

Unit- VII: Traveling wave theory:

- Student shall be able to determine traveling wave expression and solution.
- Student shall be able to understand the source of excitation.
- Student shall be able to understand what are terminal conditions
- Student shall be able to determine design constants for Termination of lines with Open Circuited Line.
- Student shall be able to determine design constants for Termination of lines with short circuited end
- Student shall be able to determine reflection and refraction coefficients
- Student shall be able to determine Lumped parameters of distributed lines generalized constants
- Student shall be able to identify No load voltage conditions and charging current.

Unit -VIII: Voltage control:

- Student shall be able to understand the concept of Power circle diagram and its use.
- Student shall be able to control voltage using synchronous condensers.
- Student shall be able to identify cascade connection of shunt and series compensation.
- Student shall be able to find out Sub synchronous resonance in series capacitor.
- Student shall be able to understand the concept of compensated lines using static VAR compensating system.

COURSE MAPPING WITH PEOS AND POS

Mapping of Course with Programme Educational Objectives

S.No	Course component	code	course	Semester	PEO 1	PEO 2	PEO 3
1	Professional Core		EHV AC	II	√	√	√

Mapping of Course outcomes with Programme outcomes:

*When the course outcome weightage is < 40%, it will be given as moderately correlated (1)

*When the course outcome weightage is >40%, it will be given as strongly correlated (2)

PO'S	1	2	3	4	5	6	7	8	9	10	11	12	13	14
EHV AC														
CO1: Students learn about the trends in EHV AC Transmission	**1**	**1**	**2**	**2**	**2**	**2**	**1**	**2**	**2**	**1**	**2**	**2**	**1**	**2**
CO2: Student can calculate Line inductance and capacitances of bundled conductors	**1**	**1**	**2**	**2**	**2**	**2**	**1**	**2**	**2**	**1**	**2**	**2**	**1**	**2**
CO:3 . Students can calculate voltage gradient of bundled conductors	**1**	**1**	**2**	**2**	**2**	**2**	**1**	**2**	**2**	**1**	**2**	**2**	**1**	**2**
CO:4 Students will understand the effects of corona and audible noise	**1**	**1**	**2**	**2**	**2**	**2**	**1**	**2**	**2**	**1**	**2**	**2**	**1**	**2**
CO:5 Students understand the effect of Radio Interference	**1**	**1**	**2**	**2**	**2**	**2**	**1**	**2**	**2**	**1**	**2**	**2**	**1**	**2**

PO'S	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
EHV AC															
CO:6 Students can calculate electrostatic field of EHV AC lines	**1**	**1**	**2**	**2**	**2**	**2**	**1**	**2**	**2**	**1**	**2**	**2**	**1**	**2**	
CO:7 Students can analyze travelling waves	**1**	**1**	**2**	**2**	**2**	**2**	**1**	**2**	**2**	**1**	**2**	**2**	**1**	**2**	
CO:8 Students can analyze compensated devices for voltage control.	**1**	**1**	**2**	**2**	**2**	**2**	**1**	**2**	**2**	**1**	**2**	**2**	**1**	**2**	

11.Individual Time Table

Faculty Name: Mrs.AZRA ZAINEB						Acad Year 2014-15, WEF: 29-12-2014		
Time	09.30-10.20	10.20-11.10	11.10-12.00	12.00-12.50	12.50-13.30	13.30-14.20	14.20-15.10	15.10-16.00
Period	1	2	3	4	LUNCH	5	6	7
Monday								
Tuesday								
Wednesday								
Thursday								
Friday								
Saturday								
No								
1								
3								

12.CLASS TIME TABLE

Geethanjali College of Engineering & Technology

Department of Electrical & Electronics Engineering

Year/Sem/Sec: IV-B.Tech-II Semester(Version-1) **Room No: LH-14** **Acad Year: 2014-15,** **WEF: 29-12-2014**

CLASS TEACHER: N.V.BHARADWAJ

Time	09.30-10.20	10.20-11.10	11.10-12.00	12.00-12.50	12.50-13.30	13.30-14.20	14.20-15.10	15.10-16.00
Period	1	2	3	4	LUNCH	5	6	7

13.1 LECTURE SCHEDULE

SNO	Unit No	Topic Covered	No of Periods	Teaching Aids
1.	**UNIT-1**	Introduction to EHV AC transmission	1	BB
2.		Advantages and problems	1	BB
3.		Power handling capacity and line losses	1	BB
4.		Mechanical considerations-resistance of conductors	1	BB
5.		Properties of bundled conductors, bundle spacing and bundle radius	1	BB
6.		Examples , Problems solving	1	BB
7.		Tutorial	1	BB
8.	**UNIT-2**	Line inductance and capacitances	1	BB
9.		Sequence inductances and capacitances	1	BB
10.		Modes of propagation	1	BB
11.		Ground return -examples	1	BB
12.		Problems	1	BB
13.		Tutorial	1	BB
14.	**UNIT-3**	Electrostatics –field of sphere gap	1	BB
15.		Field of line changes and properties	1	BB
16.		Charge, potential relations for multiconductors	1	BB
17.		Surface voltage gradient on conductors	1	BB
18.		Distribution of voltage gradient on sub conductor of bundle-examples	1	BB
19.		Solving problems	1	BB
20.		Tutorial	1	BB
21.	**UNIT-4**	Power loss and audible noise	1	BB
22.		Corona loss formulae	1	BB
23.		Charge voltage diagram	1	BB
24.		Generation ,characteristics	1	BB
25.		Limits and measurements of AN	1	BB
26.		Relation between 1-phase and 3-phase AN levels-Examples	1	BB
27.		Solving problems	1	BB
28.		Tutorial	1	BB
29.	**UNIT-5**	Radio interference	1	BB
30.		Corona pulses generation	1	BB
31.		Properties,limits	1	BB
32.		Frequency spectrum	1	BB
33.		Modes of propagation	1	BB
34.		Excitation function	1	BB
35.		Measurement of RI, RIV and excitation functions-examples	1	BB

36.		Problems	1	BB
37.		Tutorial	1	BB
38.	**UNIT-6**	Calculation of Electrostatiac fieldof EHV AC lines	1	BB
39.		Effect on humans, animals and plants	1	BB
40.		Electrostatic induction in unenergised circuit of double circuit line	1	BB
41.		Electromagnetic interference-Examples	1	BB
42.		Problems solving	1	BB
43.		Tutorial	1	BB
44.	**UNIT-7**	Travelling wave expression and solution	1	BB
45.		Source of excitation	1	BB
46.		Terminal conditions	1	BB
47.		Open circuited and short circuited end	1	BB
48.		Reflection and refraction coefficients	1	BB
49.		Lumped parameters of distributed lines generalized constants	1	BB
50.		No load voltage conditions and charging current	1	BB
51.		Solving Problems	1	BB
52.		Tutorial	1	BB
53.	UNIT-8	Power circle diagram and its use	1	BB
54.		Voltage control using synchronous condensers	1	BB
55.		Cascade connection of shunt and series compensattion	1	BB
56.		Sub synchronous resonance in series capacitor	1	BB
57.		Compensated lines	1	BB
58.		Static VAR compensating system	1	BB
59.		Solving Problems	1	BB
60.		Tutorial	1	BB
				BB
		Total number of Classes required	60	BB

13.2 MICRO PLAN

SNO	Unit No	Date	Topic Covered	No of Periods	Teaching Aids
1.	**UNIT-1**		Introduction to EHV AC transmission	1	BB
2.			Advantages and problems	1	BB
3.			Power handling capacity and line losses	1	BB
4.			Mechanical considerations-resistance of conductors	1	BB
5.			Properties of bundled conductors, bundle spacing and bundle radius	1	BB
6.			Examples , Problems solving	1	BB
7.			Tutorial	1	BB
8.	**UNIT-2**		Line inductance and capacitances	1	BB
9.			Sequence inductances and capacitances	1	BB
10.			Modes of propagation	1	BB
11.			Ground return -examples	1	BB
12.			Problems	1	BB
13.			Tutorial	1	BB
14.	**UNIT-3**		Electrostatics –field of sphere gap	1	BB
15.			Field of line changes and properties	1	BB
16.			Charge, potential relations for multiconductors	1	BB
17.			Surface voltage gradient on conductors	1	BB
18.			Distribution of voltage gradient on sub conductor of bundle-examples	1	BB
19.			Solving problems	1	BB
20.			Tutorial	1	BB
21.	**UNIT-4**		Power loss and audible noise	1	BB
22.			Corona loss formulae	1	BB
23.			Charge voltage diagram	1	BB
24.			Generation ,characteristics	1	BB
25.			Limits and measurements of AN	1	BB
26.			Relation between 1-phase and 3-phase AN levels-Examples	1	BB
27.			Solving problems	1	BB
28.			Tutorial	1	BB
29.	**UNIT-5**		Radio interference	1	BB
30.			Corona pulses generation	1	BB
31.			Properties,limits	1	BB
32.			Frequency spectrum	1	BB
33.			Modes of propagation	1	BB
34.			Excitation function	1	BB
35.			Measurement of RI, RIV and excitation	1	BB

			functions-examples		
36.			Problems	1	BB
37.			Tutorial	1	BB
38.	**UNIT-6**		Calculation of Electrostatiac fieldof EHV AC lines	1	BB
39.			Effect on humans, animals and plants	1	BB
40.			Electrostatic induction in unenergised circuit of double circuit line	1	BB
41.			Electromagnetic interference-Examples	1	BB
42.			Problems solving	1	BB
43.			Tutorial	1	BB
44.	**UNIT-7**		Travelling wave expression and solution	1	BB
45.			Source of excitation	1	BB
46.			Terminal conditions	1	BB
47.			Open circuited and short circuited end	1	BB
48.			Reflection and refraction coefficients	1	BB
49.			Lumped parameters of distributed lines generalized constants	1	BB
50.			No load voltage conditions and charging current	1	BB
51.			Tutorial	1	BB
52.	UNIT-8		Power circle diagram and its use	1	BB
53.			Voltage control using synchronous condensers Cascade connection of shunt and series compensattion,	1	BB
54.			Sub synchronous resonance in series capacitor	1	BB
55.			Compensated lines, Static VAR compensating system	1	BB
56.			Tutorial	1	BB
57.			Solving Problems	1	BB
58.			University papers	1	BB
59.			University papers	1	BB
60.			University papers	1	BB
			Total number of Classes required	60	BB

14. Detailed Notes

15. Additional Topics

A comparative study between HVDC and EHV AC Transmission Systems

In the past few years, under power transmission systems we have observed that HVDC has increased its importance by proving itself a better mode of power delivery than various EHV AC systems. Here mild study upon various parameters that exists in both the systems and concluding with a comparative result obtained after the study at various distances. Basically we are focusing upon the cumulative loss that takes place in both the modes at various locations. The areas where we are going to focus the comparison are as follows

- Construction
- Electrical parameters
- Environmental impacts

In a general comparison of HVDC vs. EHVAC power transmission, the design of the transmission lines and the related investment costs are of great importance. The aim focus is on the differences in the design of line insulation and conductor configuration, and its influence on the mechanical loads. For the line insulation, air clearance requirements are more critical with EHVAC due to the nonlinear behavior of the switching overvoltage withstand. The corona effects are more pronounced at AC voltage; therefore, larger conductor bundles are needed at higher system voltages. The altitude effects are more important to HVDC lines, since the lightning overvoltage withstand is the most sensitive insulation parameter with regard to air density. The mechanical load on the tower is considerably lower with HVDC due to less number of subconductors required to fulfill the corona noise limits. The high transmission capacity of the HVDC lines, combined with lower requirements on conductor bundles and air clearances at the higher voltage levels, makes the HVDC lines very cost efficient compared to EHVAC lines over large distances. The cost advantage is even more pronounced at the highest voltage levels.

www.academia.edu/6697158/**HVDC_and_EHV_AC**

16.University Question papers of previous years

R09

Code No: 09A80206

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD

B. Tech IV Year II Semester Examinations, May - 2013

EHV AC Transmission

(Electrical and Electronics Engineering)

Time: 3 Hours **Max. Marks: 75**

Answer any Five Questions

All Questions Carry Equal Marks

\- - -

1.a) Discuss why EHV A.C lines are necessary to transmit large blocks of power over long distances?

b) Give the properties of bundled conductors

c) A power of 10,000 MW is required to be transmitted over a distance of 800 km. At voltage levels of 500 kV and 750 kV, determine the following (i) possible number of circuits required with equal magnitudes for sending and receiving-end voltages with 30^0 phase difference. (ii) the currents transmitted; and (iii) the total line losses. [15]

2.a) Derive the expression for Inductance of multi conductor line used in EHV A.C Transmission

b) A 3-phase, 750 kV horizontal line has minimum height of 14m, sag at midspan=14m.Phase spacing S=17 m. Conductors are 4x0.035m with bundle spacing of B=0.4572m. Calculate per kilometer: the Zero-, positive- and negative- sequence inductances and capacitances transposed line. For calculation take $H_{av} = H_{min} + sag/3$ [7+8]

3.a) Explain the field of line charges and their properties

b) For a 700kV line, calculate the maximum surface voltage gradients on the centre and outer phases in horizontal configuration at the maximum operating voltage of 750kV, r.m.s line to line. The other dimensions are: H=15m, S=13m, N=2, r = 0.0159m, B = 0.45m. [7+8]

4.a) Discuss different corona loss formulae used in EHV AC Lines

b) State the different factors that affect the Audible noise generated in EHV lines. [7+8]

5.a) Describe the mechanism of formation of pulse train from positive polarity conductor.

b) Explain the procedure of measuring Radio Influence Voltage (RIV) with the help of a Radio Noise meter. [7+8]

6.a) Write short note on electrostatic induction on unenergized circuit of a Double circuit line

b) Explain the electromagnetic interference induced by EHV lines. [7+8]

B.Tech IV Year I Semester Examinations, May/June-2012
EHV AC TRANSMISSION
(Electrical and Electronics Engineering)
Time: 3 hours Max. Marks: 80
Answer any five questions
All questions carry equal marks

1.a) Explain the effect of resistance of conductor in EHV AC transmission system.
b) A power of 1200 MW is required to be transmitted over a distance of 1000 km. At voltage levels of 400 KV, 750 KV, 1000 KV and 1200 KV, determine:
i) Possible number of circuits required with equal magnitudes for sending and receiving end voltages with 30_o phase difference.
ii) The current transmitted and
iii) Total line losses. [6+10]

2. Explain in detail capacitances and inductances of ground return and derive necessary expressions. [16]

3.a) Determine the field of sphere gap in EHV AC system.
b) A single conductor EHV line strung above ground is used for experimental purposes to investigate high voltage effects. The conductors are of expanded ACSR with diameter of 0.06 cm and the line height is 21 m above ground.
i) Find the charging current and MVAR of the single phase transformer for exciting 1Km length of the experimental line. Assume any, if necessary. [8+8]

4.a) Derive the expression for energy loss from the charge- voltage diagram with corona.
b) The following is the data for a 750 KV line. Calculate the corona loss per Km and the corona loss current.
Rate of rainfall ρ =5 mm/hr, $K=5.35\times10_{-10}$, P_{FW}=5 KW/km V=750 KV line to line, H=18 m, S=15 m phase spacing, N= 4 sub conductors each of r=0.017m with bundle spacing B=0.457 m. Use surface voltage gradient on center phase for calculation. [8+8]

5. Explain the lateral profile of RI and modes of propagation in EHV lines. [16]

6.a) Obtain the electrostatic fields of double circuit 3-phase EHV AC line.
b) Describe the difference between primary shock current and secondary shock current. [10+6]

7. Discuss the line energization with tapped charge voltage of traveling waves in EHV AC lines. [16]

8.a) List the dangers resulting from series capacitor compensation on long lines and the remedies taken to control them.
b) A 420 kV line is 750 km long. Its inductance and capacitance per km are L=1.5 mH/km and C=10.5 nF/km. The voltage at the two ends are to be held 420 kV at no load. Neglect resistance. Calculate:
i) MVAR of shunt reactors to be provided at the two ends and at intermediate station midway with all four reactors having equal resistance.
ii) The A, B, C, D constants for the entire line with shunt reactors connected.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD
B.Tech (CCC) IV Year Supplementary Examinations July/August - 2010
EHV AC TRANSMISSION
(Electrical and Electronics Engineering)

Time: 3 Hours Max.Marks:100
Answer Any Five Questions
All Questions Carry Equal Marks

1. a) What is a bundled conductor? What are the advantages of bundled conductors?
b) Write short notes on positive, Negative and zero sequence impedances corresponding to E.H.V. lines. [20]

2. For a 400 KV line, calculate the maximum surface voltage gradients on the centre and outer phases in horizontal configuration at the max. operating voltage of 420 KV r.m.s (line to line). The other dimensions are: H=14 m, S=12 m N=2 r=0.016 m B=0.46 m. [20]

3. Explain the procedure of evaluation of voltage gradients for the phase single and double circuit lines. [20]

4. What are the causes of over voltages in EHV A.C. lines? How do you suppress them? Explain in detail. [20]

5. Explain the voltage control in EHV A.C. lines by using shunt and series compensation method. [20]

6. Explain about audio noise and radio interference due to Corona in EHV lines. [20]

7. Explain the procedure of design of EHVA.C. line based on steady state limits. [20]

8. Explain the design procedure of EHV cables on transient limits. [20]

17. QUESTION BANK

UNIT 1

1. a) Explain the effect of resistance of conductor in EHV AC transmission system.

   b) A power of 1200 MW is required to be transmitted over a distance of 1000 km. At voltage levels of 400 KV, 750 KV, 1000 KV and 1200 KV,
   Determine: i) possible number of circuits required with equal magnitudes for sending and receiving end voltages with 30^o phase difference. ii) The current transmitted and iii) Total line losses.
2. a) Discuss why EHV AC Lines are Necessary to transmit large blocks of power over long distances.

   b) Give the Properties of Bundled Conductors.
3. What are the Conductor configurations used for bundles in E.H.V. lines and also explain properties of Bundled conductors?
4. Write brief descriptions of (*a*) Aeolian vibration, and (*b*) Galloping (*c*) wake-induced oscillations. Describe the measures taken to minimize the damage due to them

UNIT 2

1. Derive the Expression for Inductance of a Multi conductor line used in EHV AC Transmission Line.
2. a)Explain in detail capacitances and inductances of ground return and derive necessary expressions.

   b) Why the Inductance and capacitance transformation required in Sequence Quantities in EHV-AC lines?
3. a)Discuss the convenience offered by using modes of propagation and possible uses of this technique in EHV-AC lines

   b) Inductance and Capacitance calculations for single and Multi-conductor line for calculation of Maxwell's potential coefficients
4. a) Among HVAC and DC Transmission which one is best transmission, also mention the advantages and disadvantages of it.
   b) The heights of conductors of a bipolar dc line are H = 18 m and the pole spacing P =12 m. Calculate and plot the field factors for this line for the two modes of propagation as the distance d from line centre is varied from 0 to 3.

UNIT 3

1. a) Explain the field of line charges and their properties.

   b) A 735-kV line has N = 4, r = 0.0176 m, B = 0.4572 m for the bundled conductor of each phase. The line height and phase spacing in horizontal configuration are H = 15,
   S =15 m. Calculate the maximum surface voltage gradients on the centre phase and outer phases using Mangoldt formula.

2 a) Determine the field of sphere gap in EHV AC system.

b) A single conductor EHV line strung above ground is used for experimental purposes to investigate high voltage effects. The conductors are of expanded ACSR with diameter of 0.06 cm and the line height is 21 m above ground. i) Find the charging current and MVAR of the single phase transformer for exciting 1Km length of the experimental line. Assume any, if necessary.

3 a) Describe the charge-potential relations of a transmission line with *n* conductors on a tower.

b) Derive an expression for Maximum Charge Condition on a 3-Phase Line.

4 If corona-inception gradient is measured in a h. v. testing laboratory at an elevation of 1000 metres and 25°C, give correction factors to be used when the equipment is used at (*a*) sea level at 35°C, and (*b*) 2000 m elevation at 15°C. Use conductor radius = *r* metre.

The following is the data for a 750 KV line. Calculate the corona loss per Km and the corona loss current. Rate of rainfall ρ =5 mm/hr, K=5.35×10-10, P_{FW}=5 KW/km V=750 KV line to line, H=18 m, S=15 m phase spacing, N= 4 sub conductors each of r=0.017m with bundle spacing B=0.457 m. Use surface voltage gradient on center phase for calculation.

UNIT 4

1. Derive expression $P_c = \frac{1}{2}KC(V_m^2 - V_0^2)$ for the energy loss from the charge-voltage diagram fig 5.3

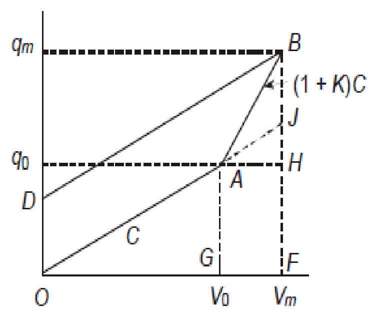

Fig. 5.3 Charge-Voltage diagram of corona.

2. a) Discuss different corona loss formula used in EHV AC transmission Line.

   b) State the different factors that affect the Audible noise generated in EHV AC Line.

3. a)Derive the relation between single phase and three phase audible noise level

   b)Explain the generation and characteristics of audible noise.

UNIT 5

1. Explain the lateral profile of RI and modes of propagation in EHV lines.
2. a) Describe the mechanism of formation of positive corona pulse train.
   b) Explain the procedure of measuring Radio Interference Voltage (RIV) by using an Radio Noise Meter.
3. Calculate and plot the field factor for the 3-modes of propagation for a line with H=15 m, S=12 m as the distance from the line center is varied from 0 to 3H.
4. A double exponential pulse has crest time t_p=50 nsec, and time to 50 % value on tail equal to t_t=100 n sec. Calculate α, β and K and also write the equation to pulse in terms of peak value i_p.

UNIT 6

1. a) Obtain electrostatic fields of single circuit 3-phase EHV line.
   b) Describe the difference between primary shock current and secondary shock current.
2. a) Explain the effect of high electrostatic field on human, animals and plants.
   b) The following are the details of a truck parked parallel to a line. Find its capacitance. Length a = 8 m, height of body v =3m, width b=3 m, t=1.5 m. Height of line conductor H=13 m, dia of conductor = 0.04 m, distance of parking L=6m.
3. Obtain electrostatic induction on unenergised circuit of double circuit EHVAC line

UNIT 7

1. Compute the RMS values of ground level E.S field of a 400 KV line at its maximum operating voltage of 420 KV (L-L) given the following details: Single circuit horizontal configuration H=13 m, S=12 m, conductor 2×3.18 cm diameter, B = 45.7 cm. Vary the horizontal distance along ground from the line centre from 0 to 3H.
2. a) Obtain the reflection and refraction of travelling waves.
   b) A transmission line is 300 Km long and open at the far end. The attenuation of surge is 0.9 over one length of travel at light velocity. It is energized by: i) A step of 1000KV and ii) A sine wave of 325 kV peak when the wave is passing through its peak. Calculate and plot the open end voltage up to 20 msec.
3. A 750 KV line has the distributed line constants r=0.025 ohm/Km, L=0.9 mH/Km and C=12.3 nF/Km at 50 Hz; Calculate the following if the line is 600 Km in length:
   a) A, B, C, D constants
   b) The charging current and MVAR at the receiving end voltage of 750 KV (L-L) on no-load.
   c) The coordinates of the center of the receiving end power circle diagram

d) The surge impedance loading.

4. Derive the general equations for voltage and current at any distance on the line in the operation form and illustrate with different conditions.
5. Explain the travelling wave concept with standing waves and natural frequencies

UNIT 8

1. A 420 kV line is 750 km long. Its inductance and capacitance per km are L=1.5 mH/km and C=10.5 nF/km. The voltages at the two ends are to be held 420 kV at no load. Neglect resistance. Calculate:
   i) MVAR of shunt reactors to be provided at the two ends and at intermediate station midway with all four reactors having equal resistance.
   ii) The A, B, C, D constants for the entire line with shunt reactors connected.
2. a) A single-circuit 3-phase, 50 Hz, 400 kV line has a series reactance per phase of 0.327 ohm/km. Neglect line resistance. The line is 400 km long and the receiving- end load is 600 MW at 0.9 p.f. lag. The positive-sequence line capacitance is 7.27nF/km. In the absence of any compensating equipment connected to ends of line, calculate the sending-end voltage. Work with and without considering line capacitance. The base quantities for calculation are 400 kV, 1000 MVA.
3. a) What is the reason for the existence of SSSR in the steady state and transient conditions in series capacitor compensated lines?
   b) Explain the voltage control using synchronous condensers.
4. Explain in detail sub synchronous resonance problem and counter measures.

18. Assignment Questions

UNIT-I

1a) Explain the effect of resistance of conductor in EHV AC transmission system.

b) A power of 1200 MW is required to be transmitted over a distance of 1000 km. At voltage levels of 400 KV, 750 KV, 1000 KV and 1200 KV,
Determine: i) possible number of circuits required with equal magnitudes for sending and receiving end voltages with 30^o phase difference. ii) The current transmitted and iii) Total line losses.

2 a) Discuss why EHV AC Lines are Necessary to transmit large blocks of power over long distances.

b) Give the Properties of Bundled Conductors.

3 Write brief descriptions of (*a*) Aeolian vibration, and (*b*) Galloping (*c*) wake-induced oscillations. Describe the measures taken to minimize the damage due to them.

4 A 750 kV line has the details given below. Calculate the temperature rise of the conductor under given conditions. Conductor–4 × 0.03 m ACSR (area = 954,000 cir mils). Power carried 2000 MW. r_a = 2.7 × 10–8 ohm-m at 20°C, a = 0.0045 ohm/°C, ambient t_a = 45°C, e = 0.5, p = 1, v = 1.2 m/s, solar irradiation 1 kW/m^2, s_a = 0.8.

UNIT-II

1. Derive the Expression for Inductance of a Multi conductor line used in EHV AC Transmission Line.
2. Explain in detail capacitances and inductances of ground return and derive necessary expressions.
3. a) What are the Conductor configurations used for bundles in E.H.V. lines and also explain properties of Bundled conductors?

   b) Why the Inductance and capacitance transformation required in Sequence Quantities in EHV-AC lines?
4. a)Discuss the convenience offered by using modes of propagation and possible uses of this technique in EHV-AC lines

   b) Inductance and Capacitance calculations for single and Multi-conductor line for calculation of Maxwell's potential coefficients
5. A 3-phase 750 kV horizontal line has minimum height of 12 m, sag at mid span = 12 m. Phase spacing S = 15 m. Conductors are 4 × 0.035 m with bundle spacing of B = 0.4572 m. Calculate per kilometer:

   (*a*) The matrix of Maxwell's Potential coefficients for an un-transposed configuration.
   (*b*) The inductance and capacitance matrices for un-transposed and transposed configurations.
   (*c*) The zero-, positive- and negative-sequence inductances and capacitances for transposed line.
   (*d*) The ground-return resistance and inductance matrices at 750 Hz taking ρ_s = 100 ohm-metre.
   For calculation take $H_{av} = H_{min}$ + Sag/3.

UNIT-III

1. a) Explain the field of line charges and their properties.
   b) A 735-kV line has N = 4, r = 0.0176 m, B = 0.4572 m for the bundled conductor of each phase. The line height and phase spacing in horizontal configuration are H = 15, S =15 m. Calculate the maximum surface voltage gradients on the centre phase and outer phases using Mangoldt formula.
2. a) Describe the charge-potential relations of a transmission line with n conductors on a tower.
   b) Derive an expression for Maximum Charge Condition on a 3-Phase Line.
3. a) Determine the field of sphere gap in EHV AC system.
   b) A single conductor EHV line strung above ground is used for experimental purposes to investigate high voltage effects. The conductors are of expanded ACSR with diameter of 0.06 cm and the line height is 21 m above ground. i) Find the charging current and MVAR of the single phase transformer for exciting 1Km length of the experimental line. Assume any, if necessary.
4. If corona-inception gradient is measured in a h. v. testing laboratory at an elevation of 1000 metres and 25°C, give correction factors to be used when the equipment is used at (a) sea level at 35°C, and (b) 2000 m elevation at 15°C. Use conductor radius = r metre.
5. Determine Surface voltage Gradient on conductors under
   i) Maximum Surface Voltage Gradients for $N \geq 3$.
   ii) Mangoldt (Markt-Mengele) Formulae

UNIT-IV

3. Derive the expression $P_c = \frac{1}{2}KC(V_m^2 - V_0^2)$
   for the energy loss from the charge-voltage diagram. Fig 5.3

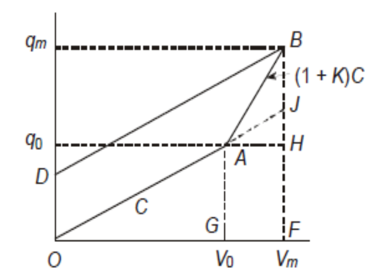

Fig. 5.3 Charge-Voltage diagram of corona.

4. a) Discuss different coronal loss formula used in EHV AC transmission Line.
   b) State the different factors that affect the Audible noise generated in EHV AC Line.
5. a) Among HVAC and DC Transmission which one is best transmission, also mention the advantages and disadvantages of it.
   b) The heights of conductors of a bipolar dc line are H = 18 m and the pole spacing P =12 m. Calculate and plot the field factors for this line for the two modes of propagation as the distance d from line centre is varied from 0 to 3 H.
6. The following is the data for a 750 KV line. Calculate the corona loss per Km and the corona loss current. Rate of rainfall ρ =5 mm/hr, K=5.35×10-10, P_{FW}=5 KW/km V=750 KV line to line, H=18 m, S=15 m phase spacing, N= 4 sub conductors each of r=0.017m with bundle spacing B=0.457 m. Use surface voltage gradient on center phase for calculation.
7. a) Explain the generation and characteristics of audible noise.
   b) The AN level of one phase of a 3-phase transmission line at a point is 70 dB. Calculate:
   i) The *Sound Pressure Level* (SPL) in Pascal.
   ii) If a second source of noise contributes 65 dB at the same location, calculate the combined AN level due to the two sources.

UNIT-V

1. Explain the lateral profile of RI and modes of propagation in EHV lines.
2. a) Describe the mechanism of formation of positive corona pulse train.
   b) Explain the procedure of Measuring Radio Voltage (RIV) interference by using Radio Noise Meter.
3. Calculate and plot the field factor for the 3-modes of propagation for a line with H=15 m, S=12 m as the distance from the line center is varied from 0 to 3H.
4. A double exponential pulse has crest time t_p=50 nsec, and time to 50 % value on tail equal to t_t=100 n sec. Calculate α, β and K and also write the equation to pulse in terms of peak value i_p.
5. a) Explain the properties of pulse trains and filter response on EHV lines.
   b) Discuss the procedure for obtaining excitation function from CIGRE formula.

UNIT-VI

5 a) Explain the effect of high electrostatic field on human, animals and plants.
b) The following are the details of a truck parked parallel to a line. Find its capacitance. Length a = 8 m, height of body v =3m, width b=3 m, t=1.5 m. Height of line conductor H=13 m, dia of conductor = 0.04 m, distance of parking L=6m.

6 a) Obtain electrostatic fields of single circuit 3-phase EHV line.
b) Describe the difference between primary shock current and secondary shock current.

7 Compute the RMS values of ground level E.S field of a 400 KV line at its maximum operating voltage of 420 KV (L-L) given the following details: Single circuit horizontal configuration H=13 m, S=12 m, conductor 2×3.18 cm diameter, B = 45.7 cm. Vary the horizontal distance along ground from the line centre from 0 to 3H.

8 Obtain electrostatic induction on unenergised circuit of double circuit EHVAC line.

9 A 1150 KV, Δ line has conductors at heights 26m and 44 m with 24m spacing between the lowest conductors. Each phase is equipped with 8×46mm diameter conductor on circle of 1.2m diameter. At 1200 KV, calculate the electrostatic field at ground level at distances from the line center d =0, 13, 26 m.

UNIT-VII

1. Derive the general equations for voltage and current at any distance on the line in the operation form and illustrate with different conditions.
2. a) Obtain the reflection and refraction of travelling waves. b) A transmission line is 300 Km long and open at the far end. The attenuation of surge is 0.9 over one length of travel at light velocity. It is energized by:
   i) A step of 1000KV and
   ii) A sine wave of 325 kV peak when the wave is passing through its peak.
   Calculate and plot the open end voltage up to 20 msec.
3. Explain the travelling wave concept with standing waves and natural frequencies.

4. An over head line with Z_o = 400 ohms continues into a cable with Z_c = 100 ohms. A surge with a creast value of 750 kV is connected towards the junction from the overhead line. Calculate the voltage in cable.

UNIT-VIII

10 A 750 KV line has the distributed line constants r=0.025 ohm/Km, L=0.9 mH/Km and C=12.3 nF/Km at 50 Hz; Calculate the following if the line is 600 Km in length:

a) A, B, C, D constants

b) The charging current and MVAR at the receiving end voltage of 750 KV (L-L) on no-load.

c) The coordinates of the center of the receiving end power circle diagram

d) The surge impedance loading.

11 Explain in detail sub synchronous resonance problem and counter measures.

12 a) What is the reason for the existence of SSSR in the steady state and transient conditions in series capacitor compensated lines?

b) Explain the voltage control using synchronous condensers.

13 A 420 kV line is 750 km long. Its inductance and capacitance per km are L=1.5 mH/km and C=10.5 nF/km. The voltages at the two ends are to be held 420 kV at no load. Neglect resistance.

Calculate: i) MVAR of shunt reactors to be provided at the two ends and at intermediate station midway with all four reactors having equal resistance.

ii) The A, B, C, D constants for the entire line with shunt reactors connected.

14 List the dangers resulting from series capacitor compensation on long lines and the remedies taken to control them.

19.Unit Wise Quiz Questions and long questions

1. By which of the following systems electric power may be transmitted ?
(a) Overhead system
(b) Underground system
(c) Both (a) and (b)
(d) None of the above
Ans: c

2 are the conductors, which connect the consumer's terminals to the distribution
(a) Distributors
(b) Service mains
(c) Feeders
(d) None of the above
Ans: b

3. The underground system cannot be operated above
(a) 440 V
(b) 11 kV
(c) 33 kV
(d) 66 kV
Ans: d

4. Overhead system can be designed for operation up to
(a) 11 kV
(b) 33 kV
(c) 66 kV
(d) 400 kV
Ans: c

7. Which of the following materials is not used for transmission and distribution of electrical power ?
(a) Copper
(b) Aluminium
(c) Steel
(d) Tungsten
Ans: d

(d) all of the above
Ans: d

10. The corona is considerably affected by which of the following ?
(a) Size of the conductor
(b) Shape of the conductor
(c) Surface condition of the conductor
(d) All of the above
Ans: d

11. Which of the following are the constants of the transmission lines ?
(a) Resistance
(b) Inductance
(c) Capacitance
(d) All of the above
Ans: d

12. The phenomenon qf rise in voltage at the receiving end of the open-circuited or lightly loaded line is called the
(a) Seeback effect
(b) Ferranti effect
(c) Raman effect
(d) none of the above
Ans: b

13. The square root of the ratio of line impedance and shunt admittance is called the
(a) surge impedance of the line
(b) conductance of the line
(c) regulation of the line
(d) none of the above
Ans: a

14. Which of the following is the demerit of a 'constant voltage transmission system' ?
(a) Increase of short-circuit current of the system
(b) Availability of steady voltage at all loads at the line terminals
(c) Possibility of better protection for the line due to possible use of higher terminal reactants
(d) Improvement of power factor at times of moderate and heavy loads
(e) Possibility of carrying increased power for a given conductor size in case of long-distance heavy power transmission
Ans: a

15. Low voltage cables are meant for use up to
(a)l.lkV
(b)3.3kV
(c)6.6kV
(d)llkV
Ans: e

16. Which of the following D.C. distribution system is the simplest and lowest in first cost ?
(a) Radial system
(b) Ring system
(c) Inter-connected system
(d) None of the above
Ans: a

17. A booster is a
(a) series wound generator
(b) shunt wound generator
(c) synchronous generator
(d) none of the above
Ans: a

26. Which of the following faults is most likely to occur in cables ?
(a) Cross or short-circuit fault
(b) Open circuit fault
(c) Breakdown of cable insulation
(d) All of the above
Ans:

28. The voltage of the single phase supply to residential consumers is
(a) 110 V
(b) 210 V
(c) 230 V
(d) 400 V
Ans: c

29. Most of the high voltage transmission lines in India are
(a) underground
(b) overhead
(c) either of the above
(d) none of the above
Ans: b

30. The distributors for residential areas are
(a) single phase
(b) three-phase three wire
(c) three-phase four wire
(d) none of the above
Ans: c

31. The conductors of the overhead lines are
(a) solid

(b) stranded
(c) both solid and stranded
(d) none of the above
Ans:

32. High voltage transmission lines use
(a) suspension insulators
(b) pin insulators
(c) both (a) and (b)
(d) none of the above
Ans: a

34. Distribution lines in India generally use
(a) wooden poles
(b) R.C.C. poles
(c) steel towers
(d) none of the above
Ans: b

35. The material commonly used for insulation in high voltage cables is
(a) lead
(b) paper
(c) rubber
(d) none of the above
Ans: b

1 The loads on distributors systems are generally
(a) balanced
(b) unbalanced
(c) either of the above
(d) none of the above
Ans: b

2. The power factor of industrial loads is generally
(a) unity
(b) lagging
(c) leading
(d) zero
Ans: b

3. Overhead lines generally use

(a) copper conductors
(b) all aluminium conductors
(c) A.C.S.R. conductors
(d) none of these
Ans: c

4. In transmission lines the cross-arms are made of
(a) copper
(b) wood
(c) R.C.C.
(d) steel
Ans: d

5. The material generally used for armour of high voltage cables is
(a) aluminium
(b) steel
(c) brass
(d) copper
Ans: b

6. Transmission line insulators are made of
(a) glass
(b) porcelain
(c) iron
(d) P.V.C.
Ans:

7. The material commonly used for sheaths of underground cables is
(a) lead
(b) rubber
(c) copper
(d) iron
Ans: a

8. The minimum clearance between the ground and a 220 kV line is about
(a) 4.3 m
(b) 5.5 m
(c) 7.0 m
(d) 10.5 m
Ans: c

9. The spacing between phase conductors of a 220 kV line is approximately equal to
(a) 2 m
(b) 3.5 m
(c) 6 m
(d) 8.5 m

Ans: c

10. Large industrial consumers are supplied electrical energy at
(a) 400 V
(b) 11 kV
(c) 66 kV
(d) 400 kV
Ans: c

46. In a D.C. 3-wire distribution system, balancer fields are cross-connected in order to
(a) boost the generated voltage
(b) balance loads on both sides of the neutral
(c) make both machine^ run as unloaded motors
(d) equalize voltages on the positive and negative outers
Ans:

47. In a D.C. 3-wire distributor using balancers and having unequal loads on the two sides
(a) both balancers run as generators
(b) both balancers run as motors
(c) balancer connected to lightly- loaded side runs as a motor
(d) balancer connected to heavily- loaded side runs as a motor
Ans:

48. Transmitted power remaining the same, if supply voltage of a D.C. 2-wire feeder is increased 100 percent, saving in copper is
(a) 25 percent
(b) 50 percent
(c) 75 percent
(d) 100 percent
Ans: b

49. A uniformly-loaded D.C. distributor is fed at both ends with equal voltages. As compared to a similar distributor fed at one end only, the drop at the middle point is
(a) one-fourth
(b) one-third
(c) one-half
(d) twice
(e) none of the above
Ans: a

50. As compared to a 2-wire D.C. distributor, a 3-wire distributor with same maximum voltage to earth uses only
(a) 31.25 percent of copper
(b) 33.3 percent of copper
(c) 66.7 percent of copper
(d) 125 percent of copper

Ans: a

51. Which of the following is usually not the generating voltage ?
(a) 6.6 kV
(b) 8.8 kV
(c) 11 kV
(d) 13.2 kV
Ans: b

52. For an overhead line, the surge impedance is taken as
(a) 20-30 ohms
(b) 70—80 ohms
(c) 100—200 ohms
(d) 500—1000 ohms
(e) none of the above
Ans: c

53. The presence of ozone due to corona is harmful because it
(a) reduces power factor
(b) corrodes the material
(c) gives odour
(d) transfer energy to the ground
(e) none of the above
Ans: b

54. A feeder, in a transmission system, feeds power to
(a) distributors
(b) generating stations
(c) service mains
(d) all of the above
Ans: a

55. The power transmitted will be maximum when
(a) corona losses are minimum
(b) reactance is high
(c) sending end voltage is more
(d) receiving end voltage is more
Ans: c

56. A 3-phase 4 wire system is commonly used on
(a) primary transmission
(b) secondary transmission
(c) primary distribution
(d) secondary distribution
Ans: d

57. Which of the following materials is used for overhead transmission lines ?
(a) Steel cored aluminium
(b) Galvanised steel
(c) Cadmium copper
(d) Any of the above
Ans: d

58. Which of the following is not a constituent for making porcelain insulators ?
(a) Quartz
(b) Kaolin
(c) Felspar
(d) Silica
Ans: d

59. There is a greater possibility of occurence of corona during
(a) dry weather
(b) winter
(c) summer heat
(d) humid weather
(e) none of the above
Ans: d

60. Which of the following relays is used on long transmission lines ?
(a) Impedance relay
(b) Mho's relay
(c) Reactance relay
(d) None of the above
Ans: b

61. The steel used in steel cored conductors is usually
(a) alloy steel
(b) stainless steel
(c) mild steel
(d) high speed steel
(e) all of the above
Ans: c

62. Which of the following distribution systems is more reliable ?
(a) Radial system
(b) Tree system
(c) Ring main system
(d) All are equally reliable
Ans: c

63. Which of the following characteristics should the line supports for transmission lines possess ?

(a) Low cost
(b) High mechanical strength
(c) Longer life
(d) All of the above
Ans: d

64. Transmission voltage of ll kV is normally used for distances upto
(a) 20—25 km
(b) 40—50 km
(c) 60—70 km
(d) 80—100 km
Ans: a

65. Which of the following regulations is considered best?
(a) 50%
(b) 20%
(c) 10%
(d) 2%
Ans: d

66. Skin effect is proportional to
(a) (conductor diameter)
(b) (conductor diameter)
(c) (conductor diameter)
(d) (conductor diameter)
(e) none of the above
Ans: c

67. A conductor, due to sag between two supports, takes the form of
(a) semi-circle
(b) triangle
(c) ellipse
(d) catenary
Ans: d

68. In AC.S.R. conductors, the insulation between aluminium and steel conductors is
(a) insulin
(b) bitumen
(c) varnish
(d) no insulation is required
Ans: d

69. Which of the following bus-bar schemes has the lowest cost ?
(a) Ring bus-bar scheme
(b) Single bus-bar scheme
(c) Breaker and a half scheme

(d) Main and transfer scheme
Ans: b

70. Owing to skin effect
(a) current flows through the half cross-section of the conductor
(b) portion of the conductor near the surface carries more current and core of the conductor carries less current
(c) portion of the conductor near the surface carries less current and core of the conductor carries more cur¬rent
(d) any of the above
(e) none of the above
Ans: b

71. By which of the following methods string efficiency can be improved ?
(a) Using a guard ring
(b) Grading the insulator
(c) Using long cross arm
(d) Any of the above
(e) None of the above
Ans: d

72. In aluminium conductors, steel core is provided to
(a) compensate for skin effect
(b) neutralise proximity effect
(c) reduce line inductance
(d) increase the tensile strength
Ans: d

73. By which of the following a bus-bar is rated ?
(a) Current only
(b) Current and voltage
(c) Current, voltage and frequency
(d) Current, voltage, frequency and short time current
Ans: d

74. A circuit is disconnected by isolators when
(a) line is energized
(b) there is no current in the line
(c) line is on full load
(d) circuit breaker is not open
Ans: b

75. For which of the following equipment current rating is not necessary ?
(a) Circuit breakers
(b) Isolators
(c) Load break switch

(d) Circuit breakers and load break switches
Ans: b

76. In a substation the following equipment is not installed
(a) exciters
(b) series capacitors
(c) shunt reactors
(d) voltatre transformers
Ans: a

77. jCorona usually occurs when the electrostatic stress in air around the conductor exceeds
(a) 6.6 kV (r.m.s. value)/cm
(b) 11 kV (r.m.s. value)/cm
(c) 22 kV (maximum value)/cm
(d) 30 kV (maximum value)/cm
Ans: d

78. The voltage drop, for constant voltage transmission is compensated by installing
(a) inductors
(b) capacitors
(c) synchronous motors
(d) all of above
(e) none of the above
Ans: c

79. The use of strain type insulators is made where the conductors are
(a) dead ended
(b) at intermediate anchor towers
(c) any of the above
(d) none of the above
Ans: c

80. The current drawn by the line due to corona losses is
(a) non-sinusoidal
(b) sinusoidal
(c) triangular
(d) square
Ans: a

81. Pin type insulators are generally not used for voltages beyond
(a) 1 kV
(b) 11 kV
(c) 22 kV
(d) 33 kV
Ans: d

82. Aluminium has a specific gravity of
(a) 1.5
(b) 2.7
(c) 4.2
(d) 7.8
Ans: b

83. For transmission of power over a distance of 200 km, the transmission voltage should be
(a) 132 kV
(b) 66 kV
(c) 33 kV
(d) 11 kV
Ans: a

84. For aluminium, as compared to copper, all the following factors have higher values except
(a) specific volume
(6) electrical conductivity
(c) co-efficient of linear expansion
(d) resistance per unit length for same cross-section
Ans: b

85. Which of the following equipment, for regulating the voltage in distribution feeder, will be most economical ?
(a) Static condenser
(b) Synchronous condenser
(c) Tap changing transformer
(d) Booster transformer
Ans: d

86. In a tap changing transformer, the tappings are provided on
(a) primary winding
(b) secondary winding
(c) high voltage winding
(d) any of the above
Ans: b

87. Constant voltage transmission entails the following disadvantage
(a) large conductor area is required for same power transmission
(b) short-circuit current of the system is increased
(c) either of the above
(d) none of the above
Ans: b

88. On which of the following factors skin effect depends ?
(a) Frequency of the current

(b) Size of the conductor
(c) Resistivity of the conductor material
(d) All of the above
Ans: d

89. The effect of corona can be detected by
(a) presence of ozone detected by odour
(b) hissing sound
(c) faint luminous glow of bluish colour
(d) all of the above
Ans: d

90. For transmission of power over a distance of 500 km, the transmission voltage should be in the range
(a) 150 to 220 kV
(b) 100 to 120 kV
(c) 60 to 100 kV
(d) 20 to 50 kV
Ans: a

91. In the analysis of which of the following lines shunt capacitance is neglected ?
(a) Short transmission lines
(b) Medium transmission lines
(c) Long transmission lines
(d) Medium as well as long transmission lines
Ans: a

92. When the interconnector between two stations has large reactance
(a) the transfer of power will take place with voltage fluctuation and noise
(b) the transfer of power will take place with least loss
(c) the stations will fall out of step be¬cause of large angular displacement between the stations
(d) none of the above
Ans: c

93. The frequency of voltage generated, in case of generators, can be increased by
(a) using reactors
(b) increasing the load
(c) adjusting the governor
(d) reducing the terminal voltage
(e) none of the above
Ans: c

94. When an alternator connected to the bus-bar is shut down the bus-bar voltage will
(a) fall
(b) rise
(c) remain unchanged

(d) none of the above
Ans: c

95. The angular displacement between two interconnected stations is mainly due to
(a) armature reactance of both alternators
(b) reactance of the interconnector
(c) synchronous reactance of both the alternators
(d) all of the above
Ans: a

96. Electro-mechanical voltage regulators are generally used in
(a) reactors
(b) generators
(c) transformers
(d) all of the above
Ans: b

97. Series capacitors on transmission lines are of little use when the load VAR requirement is
(a) large
(b) small
(b) fluctuating
(d) any of the above
Ans: b

98. The voltage regulation in magnetic amplifier type voltage regulator is effected by
(a) electromagnetic induction
(b) varying the resistance
(c) varying the reactance
(d) variable transformer
Ans: c

99. When a conductor carries more current on the surface as compared to core, it is due to
(a) permeability variation
(b) corona
(c) skin effect
(d) unsymmetrical fault
(e) none of the above
Ans: c

100. The following system is not generally used
(a) 1-phase 3 wire
(b) 1-phase 4 wire
(c) 3-phase 3 wire
(d) 3-phase 4 wire
Ans: a

101. The skin effect of a conductor will reduce as the
(a) resistivity of conductor material increases
(b) permeability of conductor material increases
(c) diameter increases
(d) frequency increases
Ans: a

102. When a live conductor of public electric supply breaks down and touches the earth which of the following will happen ?
(a) Current will flow to earth
(b) Supply voltage will drop
(c) Supply voltage will increase
(d) No current will flow in the conductor
(e) None of the above
Ans: a

1. What for series and shunt compensation provided in EHV transmission lines?
Answer: Series capacitance is provided in EHV lines to artificially reduce the series reactance of the line so as to improve stability, voltage regulation and transmission efficiency
Shunt compensation is provided to artificially reduce the line susceptance so as to improve the voltage regulation under light load condition

2. What is the material used for overhead transmission lines?
Answer: ACSR conductors are employed.

3. What are the problems associated with EHV transmission?
Answer: The problems associated with EHV transmission are corona loss and radio interference, requirement of heavy supporting structures and insulation requirments

4. Why does surge impedance loading (SIL) increase with increase in voltage level?
Answer: SIL varies as the square of the operating voltage, so SIL inceases with increase in voltage level

5. What are the factors that limit the maximum power transfer capability in a transmission line?
Answer: Some of the factors which limits the maximum power transfer are:

1. Electrical phase shift
2. Voltage drop
3. Thermal effects in the line

6. Explain some of the methods to improve the strength of transmission system?
Answer:

- Introducing or adding of new transmission lines in to the system to avoid the overloading of the existing lines
- Application of devices such as series capacitors in the right location of power system which helps in increase in the power transfer capability
- Up gradation of the existing transmission system
- Adoption of multi-voltage levels an multi-circuits in the existing ac transmission system

7. Why phase shift is kept low for transmission of power for large distances?

Answer:

$$\text{Power delivered } P = \frac{E1 \times E2}{X} \sin \delta$$

Generally δ is kept low (around 30^o) because any disturbance can affect the stability of the system if δ value is high.

20. Tutorial Problems

Unit 1

1)A power of 1200 MW is required to be transmitted over a distance of 1000 km. At voltage levels of 400 KV, 750 KV, 1000 KV and 1200 KV, determine:
i) Possible number of circuits required with equal magnitudes for sending and receiving end voltages with 30o phase difference.
ii) The current transmitted and
iii) Total line losses.

2)A power of 2000MW is to be transmitted from a super thermal power station in Central India over 800km to Delhi. Use 400kV and 750kV alternatives. Suggest the number of circuits required with 50% series capacitor compensation, and calculate the total power and loss per km.

Unit 2

1. The configurations of some e.h.v lines for 400kV to 1200kV are given. Calculate r_{eq} for each.
   (a) 400kV : N=2, d=2r=3.18cm, B=45cm
   (b) 750kV : N=4, d=3.46 , B=45cm
   (c) 1000kV : N=6, d=4.6cm, B=12d
   (d) 1200kV : N=2, d=2r=3.18cm, B=45cm

2. A single conductor EHV line strung above ground is used for experimental purposes to investigate high voltage effects. The conductors are of expanded ACSR with diameter of 0.06 cm and the line height is 21 m above ground.
i) Find the charging current and MVAR of the single phase transformer for exciting 1Km length of the experimental line. Assume any, if necessary

Unit 3

1. A point charge Q=10-6 Coulomb (1 micro C) is kept on the surface of a conducting sphere of radius r=1cm, which can be considered as a point charge located at the centre of the sphere. Calculate the field strength and potential at a distance of 0.5cm from the surface of the sphere. Also find the capacitance of the sphere. ϵ_r =1.

2. The field strength on the surface of a sphere of 1cm radius is equal to the corona inception gradient in air of 30kV/cm. Find the charge on the sphere.

Unit 4

1. A single conductor 2.5inch in diameter of a 525kV line(line-to-line voltage) is strung 13m above ground. Calculate (a) the corona inception voltage and (b) the effective radius of conductor at an overvoltage of 2.5p.u. Consider a stranding factor m=1.25 for roughness. (c)Calculate the capacitance of conductor of ground with and without corona. (d)If a second conductor is strung 10m away at the same height, calculate the coupling factors in the two cases. Take δ=1.

2. 1. The following is the data for a 750 KV line. Calculate the corona loss per Km and the corona loss current. Rate of rainfall ρ =5 mm/hr, K=5.35×10-10, PFW=5 KW/km V=750 KV line toline, H=18 m, S=15 m phase spacing, N= 4 sub conductors each of r=0.017m with bundle spacing B=0.457 m. Use surfacevoltage gradient on center phase.

Unit 5

1. A double –exponential pulse has a crest time of t_p=50ns and time To 50% value on tail equal to t_t=150ns. Calculate α , β and K and write the equation to the pulse in terms of the peak value i_p.

Unit 6

1. The following details of a truck parked parallel to a line are given. Find its capacitance. Length a=8cm, height of body v=3m, width b=3m, t=1.5m. Height of line conductor H=13m, dia of conductor =0.0406m, distance of parking L=6m.
2. Compute the r.m.s values of ground level electrostatic field of a 400kV line at its maximum operating voltage of 420kV(line to line) given the following details. Single circuit horizontal distance along ground from the line centre from 0 to 3H.

Unit 7

1. For α=0.96 and 0.8, find the resulting attenuation factor when r/l=g/c, assuming line length L to be equal in both cases. Also the maximum values of the surge in the two cases in p.u.
2. A 300km line is to be represented by a model consisting of 12π sections for the above 400kV line. Find the values of resistances to be connected in shunt for each section.

Unit 8

1. For a 400kV line, l=1mH/km and c=11.1nF/km and E_s=400kV from the source, line – line rms calculate the charging MVAR for line lengths varying from 100km to 1000km. Neglect resistance.
2. The following details are given for a 750kV 3-phase line: Resistance r=0.014 ohm/km, inductance l=0.866mH/km, reactance x=0.272ohm/km at 50Hz, c=12.82nF/km giving a susceptance of y=4.0275x10-^{6}mho/km , velocity v_o=3x10^8 m/s=3x10^5 km/s line length=500km. Calculate items (a) and (b) below and work parts (c) and (d). Give proper units for all quantities.
   (a) Z=L(r+jwl), Y=jwcL, Z_{00}=sqrt(l/c)
   (b) The generalized constants A,B,C and D in both polar and rectangular forms.
   (c) For Er=750kV and |Es|=0.98Er, determine the coordinates of the centre of the receiving end power circle diagram and the radius.
   (d) Find the power angle δ for transmitting a load of 2000MW at 750kV at the receiving end at unity power factor.

21. Known Gaps if any

Known gaps:No gaps

Action taken:------

22. Discussion topics if any (group wise topics)

1. EHV AC Transmission necessity and advantages
2. Corona effects in EHV AC Transmission
3. Radio Interference on EHV AC Transmission
4. Electrostatic effect on EHV AC Transmission
5. Voltage Control using FACT s

23.References, Journals, websites and E-links

TEXT BOOKS:

1.EHVAC Transmission Engineering by R.D.Begamudre, New Age International (p) Ltd.

2. HVAC and DC Transmission by S. Rao

REFERENCE BOOKS:

1. EHV AC/DC transmission by Shobhit Gupta/ Deepak Gupta.
2. EHVAC Transmission Engineering by R.D.Begamudre, New Academic Science.

Websites

1. www.academia.edu/6697158/HVDC_and_**EHV_AC**
2. www.ijsret.org
3. *ieeexplore.ieee.org*

24. Quality Measurment Sheets

a. Course end Survey

b. Teaching Evaluation