MUZAFFARPUR INSTITUTE OF TECHNOLOGY (MIT), MUZAFFARPUR

COURSE FILE

OF

High Voltage Engg.

Course Code **031x07**

Faculty Name: Mr. R.K.M

ASSISTANT PROFESSOR

DEPARTMENT OF ELECTRICAL ENGINEERIN

विज्ञान एवं प्रावैधिकी विभाग
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VISION STATEMENT OF ELECTRICAL ENGINEERING DEPARTMENT

To produce cutting edge Electrical Engineers, innovators, researchers, and entrepreneurs with high human values to serve society, industry, nation and the world.

MISSION STATEMENT OF ELECTRICAL ENGINEERING DEPARTMENT

M1. To create state-of-the-art facilities for under-graduate, post- graduate and R&D work.

M2. To cater the needs of society with recent technologies, innovative ideas and inculcate ethical responsibilities.

M3. To develop strong collaborative links with premier industries, institutions and the government agencies.

Program Educational Objectives (PEOs) of Electrical Engineering Department:

PEO 1. Students will be able to engage in life-long learning and research including supportive and responsible roles on multi-disciplinary tasks.

PEO 2. Students will acquire, use and develop skills as required for effective professional and societal practices and leadership quality.

PEO 3. Students will be able to create a new dimension of innovation and entrepreneurship.

Program Outcomes (POs) based on Program Educational Objectives (PEOs) of Electrical Engineering Department:

PO 1. Students will be able to apply knowledge of applied mathematics & science in electrical engineering problems.

PO 2. Students will be able to identify, formulate and solve society and industries related problems.

PO 3. Students will be able to apply knowledge to design a system, component or process to meet desired needs within realistic constraints.

PO 4. Students will be able to conduct laboratory experiments and to critically analyze and interpret experimental data.

PO 5. Students will be able to use the recent techniques, skills, and modern tools necessary for engineering practices.

PO 6. Students will be able to understand the impact of engineering problems, solutions in a global and societal context.

PO 7. Students will be able to demonstrate professional and ethical responsibilities.

PO 8. Students will be able to apply leadership quality to work with team in the area of electrical engineering towards the solution of multi-disciplinary tasks.

PO 9. Students will be able to communicate effectively through verbally, technical writing, reports and presentation.

PO 10. Students will be able to develop confidence for self-education and ability to engage in life-long learning.

Course objectives and course outcomes (CO)

Course objestives:

This course is designed to review the fundamentals and practices of insulating materials and their applications in electrical and electronics engineering, breakdown phenomenon in insulating material (solid, liquid, and gases), generation and measurement of high D.C., A.C. and impulse voltages and currents, overvoltage phenomenon in electrical power system and insulation coordination, high voltage testing techniques.

The course outcomes are:

CO-1 Design and development of high voltage equipments and utility establishment.

CO-2 Analyze and measure the magnitude of HVDC, HVAC (power frequency & high frequency) and impulse by different measurement schemes.

CO-3 Conduct high voltage test of materials and apparatus

CO-4 Evaluate the form of discharges in Gaseous, Liquid and Solid dielectrics.

Mapping of CO's with PO's

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	3	2	3	3	3	1	2	2	3	1	2	1
CO 2	3	2	3	3	3	-	2	-	2	-	2	-
CO 3	3	3	3	3	3	2	1	1	2	-	2	-
CO 4	3	2	3	3	3	1	1	-	1	-	1	-

Course syllabus and GATE syllabus

COURSE SYLLABUS

1. Generation of high voltages and current, AC voltage: cascade transformers-series response circuits DC voltages, voltage doubler cascade circuit electrostatic machines, impulse voltage: single stage and multistage circuits wave shaping tripping and control of impulse generators generation of switching surge voltage and impulse currents.

2. Measurement of high voltage and current: DC, AC and impulse voltages and currents – DSO – electrostatic and peak voltmeters - sphere, gaps-factors affecting measurements – potential divider (capacitance and resistive) - series impedance ammeters - Rogowski coils-Hall effect generators.

3. High voltage testing of materials and apparatus: Preventative and diagnostic tests-dielectric loss measurement-Schering bridge-inductively coupled ratio arm bridge-partial discharge and radio interference measurement-testing of circuit breakers and surge diverting.

4. Insulation materials and system: Insulation system in practice, dielectric losses, ageing and life expectancy.

5. Outdoor insulation: materials, ageing, diagnostic, polymeric materials (EPDM, SIR), semi conducting ceramic, glazes.

6. Breakdown in gas and gas mixtures-breakdown in uniform, in non-uniform field-Paschens law-Townsends criterion-streamer mechanism-corona discharge-breakdown in elector negative gases.

7. Breakdown in liquid dielectrics-suspended particle mechanism.

8. Breakdown in solid dielectrics-intrinsic, streamer, thermal breakdown

Student list

SL. NO.	ROLL NO.	AKU REG. NO.	NAME
1	15E56	15103107055	KRISHNA KUMAR
2	15E25	15103107126	SUJEET KUMAR
3	15E35	15103107127	HAPPY KUMAR
4	15E45	15103107128	MAYANK KASHYAP
5	15E01	15103107129	PRASOON BALA
6	15E02	15103107130	SUMI SINGH
7	15E03	15103107131	SURYA NARAYAN SINGH
8	15E07	15103107132	VIVEK KUMAR
9	15E09	15103107133	ANKITA KUMARI SINDURIYA
10	15E10	15103107134	NIRAJ KUMAR
11	15E11	15103107135	SANDEEP KUMAR SITESH
12	15E12	15103107136	NISHANT GUPTA
13	15E13	15103107137	PRAKASH KUMAR
14	15E14	15103107138	PRADEEP KUMAR
15	15E15	15103107139	RAVI RANJAN
16	15E16	15103107140	RAVI SHANKAR SAH
17	15E17	15103107141	ALOK KUMAR
18	15E18	15103107142	RAVI KANT SINGH
19	15E23	15103107143	NAYAN PRIYA
20	15E26	15103107144	ATUL SHAKTI
21	15E27	15103107145	RAHUL KUMAR
22	15E28	15103107146	ABHISHEK KISHORE
23	15E29	15103107147	RUHI KUMARI
24	15E30	15103107148	RAJEEV KUMAR CHOUDHARY
25	15E32	15103107149	KISHAN KUMAR
26	15E33	15103107150	MANISH KUMAR
27	15E34	15103107151	AMIT KUMAR
28	15E36	15103107152	RAVI RANJAN
29	15E37	15103107153	SHASHANK SUDHANSHU

30	15E38	15103107154	NEHA GUPTA
31	15E39	15103107155	SWETA JAMUAR
32	15E40	15103107156	SURUCHI KUMARI
33	15E42	15103107157	TAHA ALAM
34	15E44	15103107159	NIKET NIRAJ
35	15E47	15103107160	ASHUTOSH SHIVAM JHA
36	15E49	15103107161	MEDHA CHAUDHARY
37	15E41	15103107162	SOURAV SRIKANT
38	15E51	15103107163	PRIYANKA SUMAN
39	15E52	15103107164	PALLAVI KUMARI
40	15E54	15103107165	SHASHI RANJAN
41	15E57	15103107166	RAJLAXMI KUMARI
42	15E59	15103107168	AJIT KUMAR
43	15E61	15103107170	NAYAN KUMAR NAYAN
44	15E63	15103107171	RAJU KUMAR
45	15E64	15103107172	PREM NARAYAN CHAUDHARY
46	15E31	15103107173	SAURAV KUMAR
47	15E04	15103107174	BINDIA RANI
48	15E06	15103107176	MADHU KUMARI
49	15E08	15103107177	KAJAL RAJ
50	15E19	15103107178	OM PRAKASH CHAUDHARY
51	15E20	15103107179	AMAN KUMAR
52	15E24	15103107180	JYOTI KUMARI
53	15E21	15103107181	MD SARFARAJ AHMAD
54	15E46	15103107182	SATISH KUMAR
55	15E48	15103107183	PAVAN KUMAR
56	15E55	15103107184	DEO
57	15E62	15103107185	SUDEEP KUMAR
58	15E50	15103107186	NAGESHWAR SHARMA
59	15E22	15103107278	AZIM ANSARI
60	15E65	15104107203	PRIYANKA KUMARI
61	15E66	15106107258	DEEPAK KUMAR SINGH
62	16(LE)E10	16103107901	GAUTAM BHARTI
63	16(LE)E06	16103107902	SHEKHAR KUMAR
64	16(LE)E01	16103107903	SHAFAQUE NAZREEN

65	16(LE)E07	16103107904	MD MOIN
66	16(LE)E03	16103107905	PRIYANKA KUMARI
67	16(LE)E02	16103107906	PAVAN KUMAR
68	16(LE)E04	16103107908	ROHAN RAJ
69	16(LE)E09	16103107909	PINTU KUMAR

Course handout

Lecture Number	Topics	Web Links for video lectures	Text Book / Reference Book / Other reading material	Page numbers of Text Book(s)
	Generation of high voltage & Currents		TB1	142
1-2	Introduction to HV, Classifications, generation of high voltage & current			142-162
3-4	Cascade transformers-series response circuits DC			162-168
5-6	Voltage doubler cascade circuit electrostatic machine			144-146
7-8	Impulse voltage: single stage and multistage circuits	https://www.sciencedirect.com/science/article/pii/S0016003213900442		171-175
9-10	Generation of switching surge voltage and impulse currents, Wave shaping tripping and control of impulse			314-326
	Measurement of high voltage & current		TB1	205
11	Measurement of high voltage and current			205-206
12-13	DC, AC and impulse voltages and currents - DSO – electrostatic & peak voltmeter			207-212
14-15	Sphere, gaps-factors affecting measurements			227-234
16-17	Potential divider (capacitance and resistive)-series impedance ammeters			238-250
	High voltage testing of materials and apparatus		TB1, RB1	
18	Preventative and diagnostic tests-dielectric loss		TB1	357-358
19-20	measurement-Schering bridge-inductively coupled ratio arm bridge-partial discharge and radio interference			364-370
21-22	Measurement-testing of circuit breakers and surge diverting.			402-406,416-420
	Insulation materials and system		TB1, RB1	
23-24	Insulation system in practice, dielectric losses, ageing and life expectancy		TB1	125-140
	Outdoor insulation		RB1	
25-28	Breakdown in gas and gas mixtures, polymetric		https://www.sciencedirect.com/sc	

	materials, semiconducting ceremicgazes		ience/article/pii/S0016003213900442	
	Breakdown in gas and gas mixtures		TB1, TB2, RB3	
29-32	Breakdown in uniform, in non-uniform field-Paschens law, Townsends criterion-streamer mechanism, Corona discharge-breakdown in elector negative gases		TB1	27-49
	Breakdown in liquid dielectrics		TB1	
33-34	Suspended particle mechanism		TB1	69-78
	Breakdown in solid dielectrics		TB1, RB3	
35-36	intrinsic, streamer, thermal breakdown		TB1	87-102

Lecture plan

Sl. No.		Topic Name	Periods
1	**Generation of high voltage & Currents**		
	1.1	Introduction to HV, Classifications	**1**
	1.2	Generation of high voltage & Currents	**2**
	1.3	Cascade transformers-series response circuits DC	**1**
	1.4	Voltage doubler cascade circuit electrostatic machine	**2**
	1.5	Impulse voltage: single stage and multistage circuits	**2**
	1.6	Generation of switching surge voltage and impulse currents	**1**
	1.7	Wave shaping tripping and control of impulse	**1**
2	**Measurement of high voltage & current**		
	2.1	Measurement of high voltage and currant	**1**
	2.2	DC, AC and impulse voltages and currents – DSO – electrostatic & peak voltmeter	**2**
	2.3	Sphere, gaps-factors affecting measurements	**2**
	2.4	Potential divider (capacitance and resistive) - series impedance ammeters	**2**
3	**High voltage testing of materials and apparatus**		
	3.1	Preventative and diagnostic tests-dielectric loss	**1**
	3.2	measurement-Schering bridge-inductively coupled ratio arm bridge-partial discharge and radio interference	**2**
	3.3	Measurement-testing of circuit breakers and surge diverting.	**2**
	3.4	Potential divider (capacitance and resistive) - series impedance ammeters	**2**
4	**Insulation materials and system**		
	4.1	Insulation system in practice, dielectric losses, ageing and life expectancy.	**2**
5	**Outdoor insulation**		
	5.1	Breakdown in gas and gas mixtures	**2**
	5.2	polymeric materials (EPDM,SIR),	**1**
	5.3	semi conducting, ceramic, glazes.	**1**
6	**Breakdown in gas and gas mixtures**		
	6.1	Breakdown in uniform, in non-uniform field-Paschens law	**2**
	6.2	Townsends criterion-streamer mechanism	**1**
	6.3	Corona discharge-breakdown in elector negative gases	**1**
7	**Breakdown in liquid dielectrics**		
	7.1	suspended particle mechanism	**2**
8	**Breakdown in solid dielectrics**		

	8.1	Intrinsic, streamer, thermal breakdown.	**3**
		TOTAL	**39**

Assignment sheets

Assignment I

Q.1- An impulse generator has 12 capacitors of 0.12 micro farad and 200 KV rating. The wave front and wave tail resistances are 1.25 K Ohm and 4 K Ohm respectively. If the load capacitance including that of the test object is 10000pico farad, find the wave tail times and peak voltage of impulse voltage produced.

Q.2- A voltage doubler circuit has C1=C2=0.01micro farad and is supplied from a voltage source of V= 100Sin314t KV. If the DC output current is to be 4 mA, calculate the output voltage and ripple.

Q.3- Explain the method of controlled tripping of impulse generators. Why is controlled tripping necessary?

Q.4- What is the trigatron gap? Explain its function and operation.

Assignment II

Q.1- Discuss the different methods of measuring high DC voltages. What are the limitations in each method?

Q.2- A bifilar strip shunt has a resistance of 100mili ohm and inductance of 0.1micro henry with a parallel capacitance of 5pf across its terminal. What will be its step response? Determine the rise time of the shunt.

Q.3- What is capacitance voltage transformer? Explain with a phasor diagram how a tuned capacitive voltage transformer can be used for voltage measurement in power system.

Q.4- Compare the use of uniform field electrode spark gap and sphere gap for measuring peak values of voltages.

Assignment III

Q.1- What are the different power frequency tests done on insulators? Mention the procedure for testing?

Q.2- What is the significance of impulse tests? Briefly explain the impulse testing of insulators.

Q.3- Explain the partial discharge tests on high voltage cables. How is a fault in the insulation located in this test?

Q.4- What is an operating duty cycle test on a surge arrestor? Why is it more significant than other tests?

Assignment IV

Q.1- Give the temperature classification for solid insulating materials. Why is this classification not done for liquids and gases?

Q.2- How the transformer insulation divided? Briefly indicate the insulation arrangement indicating insulating materials chosen?

Q.3- Give the application of gases and gas mixtures as insulating medium in high voltage switchgear and high voltage power cables.

Q.4- How is the insulation arrangement done for different parts of switchgear?

Assignment V

Q.1- Explain the phenomenon of electrical conduction in liquids. How does it differ from pure liquid dielectrics?

Q.2- What are the commercial liquid dielectrics and how are they different from pure liquid dielectrics?

Q.3- Explain the various theories that explain breakdown in commercial liquid dielectrics?

Q.4- What is "stressed oil volume theory", how does it explain breakdown in large volumes of commercial liquid dielectrics?

Tutorial sheets

Tutorial 1

Q.1- Calculate the peak current and wave shape of a output current of the following generator. Total capacitance of the generator is 53micro farad. The charging voltage is 200KV. The circuit inductance is 1.47mili henry and the dynamic resistance of the test object is 0.051 ohms.

Q.2- What are the requirements of an oscillograph for impulse and high frequency measurement in high voltage test circuits?

Q.3- Explain the importance of RIV measurement for EHV power apparatus.

Tutorial 2

Q.1- What are the electronegative gases? Why is the breakdown strength higher in these gases compared to that in other gases?

Q.2- Explain the difference between photoionization and photo-electric emission.

Q.3- Derive the criterion for breakdown in electronegative gases.

Tutorial 3

Q.1- Describe the current growth phenomenon in a gas subjected to uniform electric fields.

Q.2- Define Townsend's first and second ionization coefficient. How is the condition for breakdown obtained in a Townsend gases discharge?

Sessional question papers

Mid-Term Exam 2017-18 Semester: 8th

Duration: 2 Hrs **Max. Marks: 40**

Subject Name: High Voltage Engineering **Subject Code:**031X36

Part-I

A. All questions are compulsory (2X5=10 marks)

1. Which among the following is the Average Electrical field magnitude of electric field:

(a) At midpoint between conductors

(b) Ratio of potential difference to the distance between the conductors.

c) At surface of the lower potential

2. Write the name of five gaseous dielectrics with their breakdown strength.

3.Write the name of five solid dielectrics with their breakdown strength.

4.Write the ratings of various voltage levels used in India.

5. What is the application of impulse overvoltage?

Part-II

B. Attempt the following questions (3x10=30 marks)

1. (a) Define Townsend's first and second ionization coefficients. How is the condition for breakdown obtained in a Townsend discharge? (10)

(or)

(b) What is Vacuum? Discuss the various mechanisms of Vacuum breakdown. (10)

2. (a) Explain the phenomenon of electrical conduction in liquids. How does it differ from that in gas? (10)

(or)

(b) What is 'stressed oil volume theory', how does it explain breakdown in large volume of commercial liquid dielectrics. (10)

3. (a) What do you understand by intrinsic strength of a solid dielectric? How does breakdown occur due to electron in a solid dielectric (10)

(or)

(b) What are the various methods of generating high voltage AC at power frequency explain any one in detail. (10)

University question papers

Code : 031836

B.Tech. 8th Semester Exam., 2017

High Voltage Engineering

Time : 3 hours *Full Marks : 70*

Instructions :

(i) The marks are indicated in the right-hand margin.

*(ii) There are **Nine** questions in this paper.*

*(iii) Attempt **Five** questions in all.*

(iv) Questions No. 1 is compulsory.

1. Choose the correct option (any seven) 2×7=14

(a) Dielectric strength in case of mica can be expected to be more than

(i) 500 kV/mm (ii) 1500 kV/mm

(iii) 2500 kV/mm (iv) 3500 kV/mm

(b) All of the following dielectric materials are preferred for high frequency applications EXCEPT.

(i) Polyethylene (ii) Butyl rubber

(iii) Teflon (iv) Polystyrene

(c) Which of the following technique/method is used for the measurements of ac high frequency voltages?

(i) Peak voltmeter

(ii) Series resistance micro ammeter

(iii) Resistance potential divider

(iv) Any of the above

(d) Failure during switching impulse tests are can be determined by
(i) Visible in oscillograms (ii) Loud noise produced
(iii) External flashovers (iv) All of these

(e) In routine tests, the cable is tested by applying an ac voltage of
(i) 2 times the rated value (ii) 2.5 times the rated value
(iii) 3 times the rated value (iv) 3.5 times the rated value

(f) Insulation is necessary for the protection of equipment. Insulation is not necessary between (i) Coils and earth (ii) Coils of different phases (iii) Turns in a coil (iv) None of these

(g) The thermal breakdown stresses are
(i) Lower under ac conditions than under dc condition
(ii) Greater under ac condition than dc condition
(iii) Equal in both condition
(iv) None of these

(h) Which is having higher breakdown strength ?
(i) Solid dielectrics
(ii) Liquid dielectrics
(iii) Gases dielectrics
(iv) Equal in all

(i) Corona results in

(i) improvement in power factor
(ii) increased capacitive reactance of transmission lines
(iii) radio interference
(iv) better regulation

(j) Switching surge is
(i) high voltage dc
(ii) high voltage ac
(iii) short duration transient voltage
(iv) hyperbolically dying voltage

2. A Rogowski coil is to be designed to measure impulse currents of 10 kA having a rate of change of current of 10^{11} A/s. The current is read by a VTVM as a potential drop across the integrating circuit connected to the secondary. Estimate the values of mutual inductance, resistance and capacitance to be connected, if the meter reading is to be 10 V for full sacle deflection. 14

3. With neat sketch explain the working principle of a Cockcroft - Walton voltage multiplier circuit. 14

4. An impulse generator has eight stages with each condenser rated for 0.16 μF and 125 kV. The load capacitor available is 1000 pF. Find the series resistance and the damping resistance needed to produce 1.2/50 μs impulse wave. What is the maximum output voltage of the generator, if the charging voltage is 120 kV? 14

5. Discuss the different high voltage tests conducted on bushings. 14

6. A Schering bridge was used to measure the capacitance and loss angle of a h.v. bushing. At balance, the observations were: the value of the standard condenser = 100 pF, R_3 = 3180 Ω, C_3=0.00125 μF and R_4 = 636 Ω. What are the values of capacitance and tan δ of the bushing. 14

7. Define the following terms: 14
   (a) Disruptive Discharge Voltage
   (b) Withstand Voltage
   (c) Fifty per cent Flashover Voltage
   (d) Hundred Per cent Flashover Voltage
   (e) Creepage Distance
   (f) a.c Test Voltages
   (g) Impulse Voltage

8. Design a peak reading voltmeter along with a suitable micro-ammeter such that it will be able to read voltages, up to 100 kV (peak). The capacitance potential divider available is of the ratio 1000:1. 14

9. (a) State and explain Paschen's law. 4
   (b) Explain the Chubb-Fortescue method for HVAC measurement. 10

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Question bank

Q.1- Explain the method of controlled tripping of impulse generators. Why is controlled tripping necessary?

Q.2- What is the trigatron gap? Explain its function and operation.

Q.3- What is capacitance voltage transformer? Explain with a phasor diagram how a tuned capacitive voltage transformer can be used for voltage measurement in power system.

Q.4- Compare the use of uniform field electrode spark gap and sphere gap for measuring peak values of voltages.

Q.5- Explain the partial discharge tests on high voltage cables. How is a fault in the insulation located in this test?

Q.6- What is an operating duty cycle test on a surge arrestor? Why is it more significant than other tests?

Q.7- Give the application of gases and gas mixtures as insulating medium in high voltage switchgear and high voltage power cables.

Q.8- How is the insulation arrangement done for different parts of switchgear?

Q.9- Explain the various theories that explain breakdown in commercial liquid dielectrics?

Q.10- What is "stressed oil volume theory", how does it explain breakdown in large volumes of commercial liquid dielectrics?

Q.11- What do you understand by intrinsic strength of a solid dielectric? How does breakdown occur due to electron in a solid dielectric

Q.12- What are the various methods of generating high voltage AC at power frequency explain any one in detail.

Reference materials

- **Textbooks**

  TB1: 'High Voltage Engineering' by M.S. Naidu, V Kamraju, Third Edition, Tata Mcgraw Hill

  TB2: 'High Voltage Engineering' by C.L.Wadhea, Third Edition, New Age International Publisher

- **Reference Books**

  RB1: 'High Voltage Engineering Fundamentals' by E. Kuffel, W.S. Zaengl, J Kuffel, Second Edition, Newnes

Other readings and relevant websites

S.No.	**Link of Journals, Magazines, websites and Research Papers**
1	http://digital-library.theiet.org/content/journals/hve
2	http://ieeexplore.ieee.org/xpl/aboutJournal.jsp?punumber=7494695
3	https://www.sciencedirect.com/science/article/pii/S0016003213900442
4	https://www.iospress.nl/book/high-voltage-engineering/
5	https://journals.indexcopernicus.com/search/details?id=34045