SARVAJANIK UNIVERSITY
Sarvajanik College of Engineering and Technology
Bachelor of Technology

B.Tech. Semester VI

Subject Name: High Voltage Engineering **Subject Code: BTEL14621**

Type of course: Professional Elective Course
Prerequisite: Basic Electrical Engineering, Engineering Electromagnetic
Rationale: Electrical power system is becoming complex technology to satisfy the energy demands in the modern days. The operation and control of these technologies and equipments should be synchronizing each other to maintain the overall efficiency of the system. Under such circumstances, the conceptual understanding related to various insulation properties, insulation co-ordination, testing of the HV equipments is must for every electrical engineer. This subject deals with HV generation techniques, measuring techniques and devices, over voltages including lightning and non-destructive testing as well.

Teaching and Examination Scheme:

TEACHING SCHEME				Theory Marks			Practical Marks		Total
L	T	P	C	TEE	CA1	CA2	TEP	CA3	150
3	0	2	4	60	25	15	30	20	

CA1: Continuous Assessment (assignments/projects/open book tests/closed book tests **CA2:** Sincerity in attending classes/class tests/ timely submissions of assignments/self-learning attitude/solving advanced problems **TEE:** Term End Examination **TEP:** Term End Practical Exam (Performance and viva on practical skills learned in course) **CA3:** Regular submission of Lab work/Quality of work submitted/Active participation in lab sessions/viva on practical skills learned in course

Content:

Sr. No.	Topics	Teaching Hrs.	Module Weightage
1.	**Electrostatic fields and field stress control:** Electrical field distribution and breakdown strength of insulating materials - fields in homogeneous, isotropic materials - fields in multi-dielectric, isotropic materials.	**02**	**4%**
2.	**Electrical breakdown in gases:** Gases as insulating media - ionization and decay processes, Townsend first ionization coefficient, photo ionization, ionization by interaction of metastable with atoms, thermal ionization, deionization by recombination, deionization by attachment–negative ion formation, examples - cathode	**07**	**16%**

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	processes – secondary effects, photoelectric emission, electron emission by positive ion and excited atom impact, thermionic emission, field emission, Townsend second ionization coefficient, secondary electron emission by photon impact, examples - transition from non-self-sustained discharges to breakdown, the Townsend mechanism, examples - the streamer or 'kanal' mechanism of spark, examples - the sparking voltage–Paschen's law, penning effect.		
3.	**Breakdown in liquid and solid dielectrics:** Liquid as insulators, breakdown in liquids - electronic breakdown, suspended solid particle mechanism, cavity breakdown, examples - static electrification in power transformers, transformer oil filtration, transformer oil test, alternative liquid insulations like vegetable oils, esters and silicon oils - breakdown in solids, intrinsic breakdown, streamer breakdown, electromechanical breakdown, edge breakdown and treeing, thermal breakdown, erosion breakdown, tracking - breakdown of solid dielectrics in practice, partial discharges in solid insulation.	**07**	**16%**
4.	**Generation of high voltages:** Generation of high direct voltages, half and full wave rectifier circuits, voltage multiplier circuits, Van de Graff generators, electrostatic generators, examples - generation of alternating voltages, testing transformers, cascaded transformers, resonant transformers, examples - impulse voltages, Standard lightning and switching surge and associated parameters and their corrections, design and construction of impulse voltage generator circuits, Marx circuit, operation, examples - impulse current generator.	**07**	**16%**
5.	**Measurement of high voltages:** High direct voltage measurement, peak voltage measurements by spark gaps, sphere gaps, reference measuring systems, uniform field gaps, rod gaps, factors affecting sphere gap measurements, examples - electrostatic voltmeters - ammeter in series with high ohmic resistors and high ohmic resistor voltage dividers - generating voltmeters and field sensors - the measurement of peak voltages, the Chubb–Fortescue method, high- voltage capacitors for measuring circuits - voltage dividing systems and impulse voltage measurements. Numerical	**06**	**16%**
6.	**Over voltages, and insulation coordination:** The lightning mechanism, energy in lightning, nature of danger -	**03**	**8%**

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	examples - insulation coordination, insulation level, statistical approach to insulation coordination, correlation between insulation and protection levels.		
7.	**Non-destructive test techniques:** **Insulation:** Measurement of d.c. resistivity - dielectric loss and capacitance measurements, the Schering bridge, current comparator bridges, Tan Delta measurement, Partial-discharge (PD) measurements - the basic PD test circuit, Dissolved gas analysis - Key gas method, Duval's triangle. **Machine winding:** Frequency Response Analysis Method (FRA)- Introduction, Sweep Frequency Response Analysis (SFRA), procedure, methods of interpretation of signature.	**08**	**14%**
8.	**High voltage testing:** Layout of High Voltage Laboratory, Testing of insulators and bushings, testing of isolators and circuit breakers Testing of cables, testing of transformers - testing of surge diverters	**05**	**10%**

Suggested Specification table with Marks (Theory/Practical):

% Distribution of Marks					
R Level	**U Level**	**A Level**	**N Level**	**E Level**	**C Level**
20%	**20%**	**20%**	**20%**	**20%**	**0%**

Legends: R: Remembrance, **U:** Understanding; **A:** Application, **N:** Analyze, **E:** Evaluate **C:** Create and above Levels **(Revised Bloom's Taxonomy)**

Note: This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may vary slightly from above table.

Reference Text Books:

Sr. No.	Title of book /article	Author(s)	Publisher and details like ISBN	Year of publication	Publication Edition
1	High Voltage Engineering: Fundamentals	Kuffel,E., Zaengl W.S., Kuffel J	Butterworth-Heinemann	2000	Second
2	High Voltage Engineering	M. S. Naidu, V. Kamaraju	Tata McGraw-Hill Publishing Company Limited, New	2020	Sixth

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			Delhi		
3	High Voltage Engineering, Problems and Solutions	Rakosh Das Begamudre,	New Age International Publishers, New Delhi	2010	
4	High Voltage Test Techniques	Dieter Kind, Kurt Feser,	Reed educational and professional publishing ltd. (Indian edition),	2001	
5	High Voltage Engineering-Theory and Practice	M. Khalifa	Marcel Dekker, Inc. New York and Basel	1990	
6	High Voltage Engineering and Testing	Hugh M. Ryan	The Institution of Electrical Engineers, London, United Kingdom	2001	Second
7	High Voltage Engineering	Wadhwa C.L.	New Age publishers, New Delhi	2010	Third
8	Advances in High Voltage Engineering	A. Haddad, D. Warne	IET Power and Energy, Series 40	2007	
9	Recent Trends in the Condition Monitoring of Transformers	Sivaji Chakravorti, Debangshu Dey, Biswendu Chatterjee	Springer	2013	
10	High Voltage Technology.	Alston L L	Oxford University Press	2008	

LIST OF PRACTICALS: (Minimum **10 Practical** to be performed.)

[1] Testing of transformer oil according to IS: 6792.

[2] To study Horn Gap Apparatus.

[3] To perform the breakdown test of different solid dielectric material.

[4] To plot equipotential field lines to calculate the capacitance and energy for a given (a) parallel plate and (b) co-axial cable capacitor model electrode configuration.

[5] High Voltage AC generation through cascade connection of transformer.

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[6] High Voltage DC generation through cascade connection of transformer.

[7] To perform (i) High voltage DC Measurement through Resistor Divider (ii) High Voltage Measurement through Capacitor Divider .

[8] To determine the breakdown characteristics of air as a dielectric medium, under different types of electrode configurations, such as: (i) Gap between two uniform spherical electrodes. (ii) Gap between two uniform pointed non uniform electrodes

[9] To study Corona formation at HVAC transmission line.

[10] Lightning Impulse voltage generation through single stage circuit using MATLAB simulink model.

[11] High voltage DC generation through half wave and full wave rectifier circuit using MATLAB simulink model.

[12] High voltage DC generation through voltage doubler circuit using MATLAB simulink model.

Course Outcome:

Sr. No.	CO Statement After learning this subject, students will be able to	Marks % weightage
CO-1	Ability to demonstrate phenomenon of electrical breakdown in gas, liquid and solid medium.	32
CO-2	Ability to carry out generation and measurement of high voltage AC, DC and Impulse.	32
CO-3	Ability to carry out high voltage non-destructive testing techniques.	18
CO-4	Ability to conduct high voltage testing and analysis of power system apparatus such as cables, insulators, transformers, and generators.	14
CO-5	Ability to design, plan and develop layout of High-voltage laboratory.	4

Mapping with POs:

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
CO-1	-	-	1	3	2	3	2	-	-	3	2	3	2	3	-
CO-2	3	3	2	3	3	-	3	1	3	2	-	3	3	3	3
CO-3	3	3	3	2	3	3	3	2	2	2	1	3	3	3	1
CO-4	2	3	3	3	3	1	2	3	3	3	3	3	3	2	3
CO-5	3	3	2	2	3	3	3	3	3	3	3	3	3	2	3
Rationale*	11	12	11	13	14	10	13	09	11	13	09	15	14	13	10

Major Equipment: N/A

List of Open Source/learning website:

- https://nptel.ac.in/courses/108/104/108104048/
- https://www.pfiffner-group.com/about-pfiffner-group/haefely

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