GUJARAT TECHNOLOGICAL UNIVERSITY

ELECTRICAL ENGINEERING (09)
HIGH VOLTAGE ENGINEERING
SUBJECT CODE: 2160904
B.E. 6th SEMESTER

Type of course: Engineering Science (Electrical)

Prerequisite: NA

Rationale:NA.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks						Total Marks
L	T	P	C	Theory Marks			Practical Marks			
				ESE (E)	PA (M)		ESE (V)		PA (I)	
					PA	ALA	ESE	OEP		
3	0	2	5	70	20	10	20	10	20	150

Content:

Sr. No.	Content	Total Hrs	% 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 - numerical method: Finite Element Method (FEM), charge simulation method (CSM)	04	08
2.	Electrical breakdown in gases Gases as insulating media - ionization and decay processes, Townsend first ionization coefficient, photoionization, ionization by interaction of metastable with atoms, thermal ionization, deionization by recombination, deionization by attachment–negative ion formation, examples - cathode 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, the breakdown field strength, breakdown in non-uniform fields-partial breakdown, corona discharges,	05	12
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 -	07	16

	breakdown of solid dielectrics in practice, partial discharges in solid insulation, solid dielectrics used in practice		
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, impulse voltage generator circuits, Marx circuit, operation, design and construction of impulse generators, examples - impulse current generator - control systems	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, digital recorders, errors inherent in digital recorders	06	16
6.	Over voltages, testing procedures and insulation coordination : The lightning mechanism, energy in lightning, nature of danger - laboratory high-voltage testing procedures and statistical treatment of results, examples - insulation coordination, insulation level, statistical approach to insulation coordination, correlation between insulation and protection levels - modern power systems protection devices, M O A – metal oxide arresters	04	10
7.	Non-destructive insulation test techniques : Measurement of d.c. resistivity - dielectric loss and capacitance measurements, the Schering bridge, current comparator bridges, Tan Delta measurement, null detectors - partial-discharge (PD) measurements, the basic PD test circuit, PD currents, PD measuring systems within the PD test circuit, measuring systems for apparent charge, sources and reduction of disturbances, other PD quantities, calibration of PD detectors in a complete test circuit, digital PD instruments	05	12
8	High voltage testing: Testing of insulators and bushings, testing of isolators and circuit breakers Testing of cables, testing of transformers - testing of surge diverters - radio interference measurements - design, planning and layout of high voltage laboratory	04	10

Note:

1. 10%-20% weightage should be given to the Examples and Short/Multiple choice questions.
2. The institutes which does not have proper High Voltage Laboratory are advised to visit nearby High Voltage laboratory

Suggested Specification table with Marks (Theory):

Distribution of Theory 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 and 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 Books:

1. Kuffel, E., Zaengl W.S., Kuffel J., "High Voltage Engineering: Fundamentals" Butterworth-Heinmann (A division of Reed Educational & Profession Publishing Limited), 2nd Edition, 2000.
2. Naidu M. S. and Kamaraju V., "High Voltage Engineering", fourth Edition, Tata McGraw- Hill Publishing Company Limited, New Delhi, 2009.
3. Rakosh Das Begamudre, "High Voltage Engineering, Problems and Solutions", New Age International Publishers, New Delhi, 2010.
4. Dieter Kind, Kurt Feser, "High Voltage Test Techniques", Reed educational and professional publishing ltd. (Indian edition), New Delhi-2001
5. M. Khalifa, "High Voltage Engineering-Theory and Practice", Marcel Dekker, Inc. New York and Basel,1990.
6. Hugh M. Ryan, "High Voltage Engineering and Testing", 2nd edition, The Institution of Electrical Engineers, London, United Kingdom, 2001.
7. Wadhwa C.L., "High Voltage Engineering", third edition, New Age publishers, New Delhi, 2010.

Course Outcome:

After learning the course the students should be able to

1. Understand the basic generation and measurement of High voltage and High current for testing purposes
2. Comprehend Breakdown phenomenon in air, solid and liquid insulation
3. Test high voltage electrical Equipment with various testing devices.

List of Experiments:

1. Testing of transformer oil according to IS:6792
2. Testing of solid insulation with tape electrodes
3. Generation High D.C. Voltages and measurement through sphere gaps
4. Generation High A. C. voltages and measurement through sphere gaps
5. Generation of High A. C. voltages through cascaded transformers
6. Impulse voltage generation through Marx generator
7. Impulse voltage generation though simulation
8. Trace the field through electrolytic tank
9. Generation and visualization of corona in corona cage
10. Capacitance and loss factor measurement
11. A report on visit to high voltage laboratory

Note: At least eight practicals shall be performed depending on availability of the equipment

Design based Problems (DP)/Open Ended Problem:

1. Design of impulse generator with various combination of wave shaping resistor and capacitor
2. Design of CW type voltage multiplier with various stages
3. Design of tesla coil
4. Design of Generating voltmeter

These problems may be done on paper by hand and/or using some simulation software.

Major Equipment:

1. Multi stage Impulse voltage generator
2. Multi stage Impulse current generator
3. High voltage AC and DC generating source (Min 100 kV)
4. Partial Discharge Measurement set up
5. Corona setup
6. Electrostatic generator
7. Cascade transformer
8. Resonant Transformer
9. Two to three sets of sphere gap assembly of various diameters
10. Faraday cage
11. Oil test kit
12. Solid insulation test kit\
13. Schering bridge
14. DC resistivity measurement test kit
15. Surface resistance measurement test kit
16. Paschen's law test kit

List of Open Source Software/learning website:

Open source software:

1. Finite Element Method Magnetics FEMM
2. LTSpice for circuit simulation,
3. KiCAD for CAD application

Web-based tools for design:

1. http://www.fairchildsemi.com/support/design-tools/power-supply-webdesigner/
2. http://www.ti.com/lsds/ti/analog/webench/overview.page

Circuit Lab:

1. https://www.circuitlab.com/editor/

Open source Math Tools:

1. http://maxima.sourceforge.net/
2. http://www.sagemath.org/
3. http://www.scilab.org/
4. http://www.gnu.org/software/octave/

Online Experiment Portal

1. http://vlab-ee1.iitkgp.ernet.in

Learning website

1. http://www.electrical-engineering-portal.com/
2. http://nptel.iitm.ac.in/courses.php

Standards

1. "IEEE Standard Techniques for High-Voltage Testing", 6th edition, IEEE Std. 4-1978.
2. "High-voltage test techniques, Part 1: General definitions and test requirements", IEC 60060-1, 1989.
3. "High Voltage Test Techniques, Part 2: Measuring Systems", IEC Publication 60060-2, 1994.
4. "High Voltage Test Techniques, Part 3: Measuring Devices", IEC Publication 60060-3, 1976.
5. "High Voltage Test Techniques, Part 4: Application Guide for Measuring Devices", 1st ed., IEC Publication 60060-4, 1977.
6. Indian Standard specifications for High Voltage test techniques", Bureau of Indian Standard, IS 2071, New Delhi, 1991.

ACTIVE LEARNING ASSIGNMENTS: Preparation of power-point slides, which include videos, animations, pictures, graphics for better understanding theory and practical work – The faculty will allocate chapters/ parts of chapters to groups of students so that the entire syllabus to be covered. The power-point slides should be put up on the web-site of the College/ Institute, along with the names of the students of the group, the name of the faculty, Department and College on the first slide. The best three works should submit to GTU.