GUJARAT TECHNOLOGICAL UNIVERSITY

Bachelor of Engineering

Subject Code: 3170917

HIGH VOLTAGE ENGINEERING

B.E. 7th SEMESTER

Type of course: Professional Core Course (Electrical)

Prerequisite: Not applicable

Rationale: Electrical power transmission is trending towards higher and higher voltages. Under such scenario, the conceptual understanding related to insulation, testing the HV devices is must for every electrical engineer. The subject deals with HV test generating devices, measurement devices, over voltages including lightning and non-destructive testing as well.

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)	
3	0	2	4	70	30	30	20	150

Content:

Sr. No.	Content	Total Hrs
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
2.	Numerical analysis of electrical fields in high voltage equipment: numerical methods - Charge simulation method (CSM), Finite Difference Method (FDM), Finite Element Method (FEM), The boundary-element method, Comparative summary, Formulation of the finite-element equations in two and three dimensions - Forming the functional equation, The energy functional illustrated, Numerical representation.	04
3.	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 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.	05
4.	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,	07

	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.	
5.	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
6.	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. Numericals	06
7.	Over voltages, and insulation coordination: The lightning mechanism, energy in lightning, nature of danger - examples - insulation coordination, insulation level, statistical approach to insulation coordination, correlation between insulation and protection levels.	04
8.	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.	05
9.	High voltage testing: Testing of insulators and bushings, testing of isolators and circuit breakers Testing of cables, testing of transformers - testing of surge diverters	05

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:AnalyzeandE:EvaluateC:Createa ndabove Levels (Revised Bloom'sTaxonomy)

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.,ZaenglW.S.,KuffelJ.,"HighVoltageEngineering: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), NewDelhi-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.
8. A. Haddad, D. Warne, "Advances in High Voltage Engineering", IET Power and Energy, Series 40, 2007.
9. Sivaji Chakravorti, Debangshu Dey, BiswenduChatterjee,"Recent Trends in the Condition Monitoring of Transformers",Springer, 2013.
10. Alston L L, High Voltage Technology, Oxford University Press, 2008.

Course Outcome:

After learning the course, the students should be able to

1. Apply numerical methods for engineering problem. (Applying)
2. Recall breakdown mechanism for dielectric materials in solid, liquid and gaseous state. (Remembering)
3. Classify insulation test techniques. (Understanding)
4. Examine methods for generation of test high voltage and as well for its measurement. (Analyzing).
5. Conclude about correctness of design and manufacturing of high voltage insulations after performing tests.(Evaluate)

List of Experiments:

1. Testing of transformer oil according toIS:6792

2. Testing of solid insulation with tapeelectrodes
3. Generation of High D.C. Voltages and measurement through spheregaps
4. Generation of High A. C. voltages and measurement through spheregaps
5. Generation of High A. C. voltages through cascadedtransformers
6. Impulse voltage generation through Marxgenerator
7. Impulse voltage generation thoughsimulation
8. Trace the field through electrolytictank
9. Generation and visualization of corona in coronacage
10. Capacitance and loss factormeasurement
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 andcapacitor
2. Design of CW type voltage multiplier with variousstages
3. Design of teslacoil
4. Design of Generatingvoltmeter

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

Major Equipment:

1. Multi stage Impulse voltagegenerator
2. Multi stage Impulse currentgenerator
3. High voltage AC and DC generating source (Min 100kV)
4. Partial Discharge Measurement setup
5. Coronasetup
6. Electrostaticgenerator
7. Cascadetransformer
8. ResonantTransformer
9. Two to three sets of sphere gap assembly of variousdiameters
10. Faradaycage
11. Oil testkit
12. Solid insulation testkit
13. Scheringbridge
14. DC resistivity measurement testkit
15. Surface resistance measurement testkit
16. Paschen's law testkit

List of Open Source Software/learning website:

Open source software:

1. Finite Element Method Magnetics FEMM
2. LTSpice for circuitsimulation,
3. KiCAD for CADapplication

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-voltagetesttechniques,Part1:Generaldefinitionsandtestrequirements”,IEC60060-1,1989.
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. IndianStandardspecificationsforHighVoltagetesttechniques”,BureauofIndianStandard,IS 2071, New Delhi,1991.
7. "IEEE Standard for High Voltage Switchgear (Above 1000 V) Test Techniques - Partial Discharge Measurements" - IEEE Std. C37.301 - 2009.
8. "IEEE guide for the application and interpretation of Frequency Response Analysis for Oil-Immersed Transformers" - IEEE Std. C57.149 - 2012.
9. "Mechanical Condition Assessment of Transformer Windings Using Frequency Response Analysis (FRA)" - CIGRE report by working group A2.26, April 2008.
10. "Power Transformers - Part 18: Measurement of frequency response" - IEC60076-18, 2012.
11. "Mineral oil-filled electrical equipment in service - Guidance on the interpretation of dissolved and free gases analysis" -IEC 60599 - 2015.
12. "IEEE Guide for the Interpretation of Gases Generated in Mineral Oil-Immersed Transformers" - C57.104-2019.