Kadi Sarva Vishvavidyalaya, Gandhinagar
Bachelor of Engineering (Electrical Engineering Syllabus)

B.E Semester: VIth (EE)
Subject Name & Subject Code: High Voltage Engineering (EE-604)

A. Course Objective:

- To present a problem oriented introductory knowledge of HVAC and HVDC.
- To understand the generation of HVAC and HVDC.
- To measurement of HVAC, HVDC and also Over voltages.
- To understand the Break down in Solid, Liquid and Gas.

B. Teaching / Examination Scheme

SUBJECT		Teaching Scheme				Total Credit	Examination Scheme					Total Marks
		L	T	P	Total		THEORY		IE	CIA	PR. / VIVO	
CODE	NAME	Hrs	Hrs	Hrs	Hrs		Hrs	Marks	Marks	Marks	Marks	
EE-604	High Voltage Engineering	4	0	2	6	5	3	70	30	20	30	150

SYLLABUS
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: charge simulation method (CSM)
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, mobility of gaseous ions and deionization by diffusion, relation between diffusion and mobility, 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, thebreakdown field strength, breakdown in non-uniform fields - effect of electron attachment on the breakdown criteria, partial

breakdown, corona discharges, polarity effect – influence of space charge - practical gaseous dielectrics: SF6, SF6 mixtures, vacuum, gas insulated substations.

Breakdown in liquid and solid dielectrics:

Liquid as insulators, breakdown in liquids - electronic breakdown, suspended solid particle mechanism, cavity breakdown, electro-convection and electro-hydrodynamic model of dielectric 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, solid dielectrics used in practice

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, impulse voltage generator circuits, Marx circuit, operation, design and construction of impulse generators, examples - impulse current generator - control systems

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, highvoltage capacitors for measuring circuits - voltage dividing systems and impulse voltage measurements, generalized voltage generation and measuring circuit, voltage dividers, interaction between voltage dividerand its lead, the divider’s low-voltage arm - digital recorders, errors inherent in digital recorders

Overvoltages, testing procedures:

The lightning mechanism, energy in lightning, nature of danger – simulated lightning surges for testing - switching surge test voltage characteristics - laboratory high-voltage testing procedures and statistical treatment of results, examples.

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.

INSTRUCTIONAL METHOD AND PEDAGOGY

(Continuous Internal Assessment (CIA) Scheme)

- At the start of course, the course delivery pattern, prerequisite of the subject will be discussed.
- Lecture may be conducted with the aid of multi-media projector, black board, OHP etc.
- Attendance is compulsory in lectures, practicals and Tutorial which carries 05 Marks.
- At regular intervals assignments is given. In all, a student should submit all assignments of 05 marks each.
- Classroom participation and involvement in solving the problems in Tutorial rooms carries 05 Marks.
- Viva Voce will be conducted at the end of the semester of 05 Marks.
- One internal exam of 30 marks is conducted as a part of mid semester evaluation.
- Experiments shall be performed in the laboratory related to course contents.
- The course includes a laboratory, where students have an opportunity to build an appreciation for the concept being taught in lectures.

C. Lesson Planning

SR No.	Lectures (Hours)	Weightage in % in Exam	Topic
1	02	4	**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: charge simulation method (CSM)
2	15	25	**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, mobility of gaseous ions and deionization by diffusion, relation between diffusion and mobility, 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 - effect of electron attachment on the breakdown criteria, partial breakdown, corona discharges, polarity effect – influence of space charge - practical gaseous dielectrics: SF6, SF6 mixtures, vacuum, gas insulated substations.

3	15	25	**Breakdown in liquid and solid dielectrics:** Liquid as insulators, breakdown in liquids - electronic breakdown, suspended solid particle mechanism, cavity breakdown, electro-convection and electro-hydrodynamic model of dielectric 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, solid dielectrics used in practice
4	08	13	**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, impulse voltage generator circuits, Marx circuit, operation, design and construction of impulse generators, examples - impulse current generator - control systems.
5	08	13	**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, highvoltage capacitors for measuring circuits - voltage dividing systems and impulse voltage measurements, generalized voltage generation and measuring circuit, voltage dividers, interaction between voltage dividerand its lead, the divider’s low-voltage arm - digital recorders, errors inherent in digital recorders.
6	08	13	**Overvoltages, testing procedures:** The lightning mechanism, energy in lightning, nature of danger – simulated lightning surges for testing - switching surge test voltage characteristics - laboratory high-voltage testing procedures and statistical treatment of results, examples.
7	04	7	**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.
TOTAL	60	100	

D. Instructional Method & Pedagogy

- At the start of course, the course delivery pattern , prerequisite of the subject will be discussed
- Lecture may be conducted with the aid of multi-media projector, black board, OHP etc. & equal weightage should be given to all topics while teaching and conduction of all examinations.
- Attendance is compulsory in lectures and laboratory, which may carries five marks in overall evaluation.
- One/Two internal exams may be conducted and total/average/best of the same may be converted to equivalent of 30 marks as a part of internal theory evaluation.
- Assignment based on course content will be given to the student for each unit/topic and will be evaluated at regular interval. It may carry an importance of ten marks in the overall internal evaluation.
- Surprise tests/Quizzes/Seminar/Tutorial may be conducted and having share of five marks in the overall internal evaluation.

Suggested 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. A report on visit to high voltage laboratory

Students Learning Outcomes

On successful completion of the course

- The student can be acquired the basic knowledge of high voltage generation.
- The student can be able to know the breakdown strength of Solid, Liquid and gas.
- The students will be able to effectively employ HVAC and HVDCto the exploration of new applications and techniques for their use.

Text Books:

1. Kuffel, E., Zaengl W.S., Kuffel J., "High Voltage Engineering : Fundamentals" Butterworth- Heinmann (A division of Reed Educatonal & Profession PublishingLimited), 2nd Edition, 2000.
2. Naidu M. S. and Kamaraju V., "High Voltage Engineering", fourth Edition, Tata McGraw- HillPublishing Company Limited, New Delhi, , 2009.

Reference Books:

1. Wadhwa C.L., "High Voltage Engineering", third edition, New Age publishers, New Delhi, 2010.
2. Ravindra Arora and Wolfgang Mosch, "High Voltage - Insulation Engineering", first edition, New Age International Publishers Limited, New Delhi, 2002
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