HIGH VOLTAGE ENGINEERING

ENEE 413

Lecture : 3 **Year : IV**
Tutorial : 1 **Part : I**
Practical : 0

Course Objectives:
The objective of this course is to provide fundamental knowledge of high voltage electrical systems. Beginning with the concept of electrostatic fields, the course will progress towards conduction and breakdown in dielectric materials, generation and measurement and testing of high voltages. This course also provides students with basic knowledge on overvoltage and insulation coordination of high voltage systems.

1 High Voltage Power Systems (4 hours)

1.1 Evolution of power systems, Need for high voltage systems, Classification of high voltages
1.2 Overview of high-voltage equipment and insulation systems
1.3 High Voltage Power Cables
1.4 Emerging trends in Power

2 Electrostatic Fields (5 hours)

2.1 Electric field distribution and breakdown strength of dielectric materials
2.2 Electric field, Uniform and non-uniform electric fields
2.3 Electric field in typical geometric boundaries
2.4 Computational tools: Finite element method (FEM), Charge simulation method (CSM), Boundary element method (BEM)

3 Conduction and Breakdown in Dielectric Medium (8 hours)

3.1 Conduction and breakdown in gases
  3.1.1 Collision and other ionization processes, Townsend's current growth equation, primary and secondary ionization coefficients, Townsend's criterion for breakdown, Paschen's law
  3.1.2 Vacuum insulation
  3.1.3 Corona discharges
3.2 Conduction and breakdown in liquid dielectrics: Pure liquids and commercial liquids, Breakdown mechanisms
3.3 Breakdown in Solid Dielectrics: Breakdown mechanisms - intrinsic breakdown, electromechanical breakdown, thermal breakdown, chemical and electrochemical breakdown, treeing and tracking, surface and internal partial discharges

4 Generation and Measurement of High Voltages (6 hours)

4.1 Generation of High Voltages

4.1.1 Generation of high DC voltages: Rectifier circuits, Voltage double circuits, Voltage multiplier circuits

4.1.2 Generation of High AC Voltages: Cascade Transformers, Resonant Transformers

4.1.3 Generation of impulse voltages: Standard impulse wave shapes, Circuits for producing impulse waves, multistage impulse generators – Marx circuit, Generation of impulse currents

4.2 Measurement of High Voltages

4.2.1 Series resistance micrometers, potential dividers, Capacitance voltage transformers

4.2.2 Electrostatic voltmeter

4.2.3 Spark gaps, Peak voltmeter

4.2.4 Measurement of impulse voltage

5 Introduction to High Voltage Testing (6 hours)

5.1 Introduction, Types of tests, Standards

5.2 General Tests: Sustained low frequency tests, High voltage direct current tests, High frequency tests, Surge or impulse tests, Flashover tests

5.3 Testing of components like cables, line insulators, bushings, isolators, circuit breakers and surge arresters

5.4 Non-destructive tests: Dielectric loss and loss factor, Partial discharge measurements, Condition monitoring of HV equipment

5.5 Basic HV testing safety: General layout of high voltage laboratories, discharge, grounding of test objects, safe clearances, interlocking

6 Transmission Line Electric Field and Discharges (6 hours)

6.1 Surface voltage gradient on conductors

6.2 Corona discharges, Different types of corona, Corona loss, Audible Noise (AN) and Radio Interference (RI) due to corona

6.3 Electromagnetic induction in communication circuits, pipelines, railway tracks and fences, Effect on human health, animals and plant

7 Overvoltage and Insulation Coordination (10 hours)

7.1 Introduction

7.2 Temporary Over Voltage: Unsymmetrical faults, Ferranti Effect, Ferro-resonance, Load rejection, Interruption of current by circuit breaker; Effective grounding, Shunt compensations

7.3 Transient Overvoltage, Concept of Traveling waves

7.4 Switching overvoltage; switching surge ratio, Energizing and de-energizing a transmission line, Countermeasures to reduce switching over voltages

7.5 Lightning overvoltage: lightning phenomena, direct and indirect lightning strokes, Effect of ground wire, lightning arresters, tower top potential, tower footing resistance, Lightning arresters, Horn gap, grading rings

7.6 Insulation Coordination: Basic insulation level and basic switching level, volt-time curve, Insulation coordination among different equipment, Insulation coordination for different types of overvoltage, Surge protection

Tutorial **(15 hours)**

1. HVAC vs HVDC transmission line analysis for export of power from a hydropower project in Nepal
2. Formulating the nodal equations for a two-dimensional electrostatic region using Finite Element Method (FEM)
3. Field analysis of an EHVAC transmission line in Nepal
4. Visit to an HV lab/substation and study of basic test procedures and safety protocols
5. Insulator string design for a transmission line based on isokeraunic level and lightning surge current
6. Analysis of the insulation coordination practices of a 400 kV substation

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapter	Hours	Mark distribution*
1	4	4
2	5	6
3	8	10
4	6	8
5	6	8
6	6	9
7	10	15
Total	**45**	**60**

* There may be minor deviation in marks distribution.

References

1. Begamudre, R. D. (2011). Extra high voltage AC transmission engineering (latest ed.). New Age International.
2. Khalifa, M. (2000). High voltage engineering: Theory and practice (latest ed.). Marcel Dekker.

3. Kuffel, E., Zaengl, W. S., & Kuffel, J. (2000). High voltage engineering fundamentals (latest ed.). Newnes.
4. Naidu, M. S., & Kamaraju, V. (2020). High voltage engineering (latest ed.). McGraw Hill Education.
5. Wadhwa, C. L. (2010). High voltage engineering (3rd ed.). New Age International.