Chapter-0
High Voltage Engineering: Introduction

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Learning Goals

- Description of fundamental terminology in the subject of high voltage engineering.
- Classification of electric fields and the techniques of field estimation.
- Performance of gaseous, liquid and solid dielectrics under different field conditions is described.
- Generation and measurement techniques for high test voltages will be discussed.
- Vacuum as insulation and the lightning phenomenon are included.

Course Outline

- Electric fields and their numerical estimation;
- breakdown mechanism, arcs, intrinsic and practical strength of dielectrics;
- breakdown characteristics of gases, liquids and solids;
- avalanche, streamer, and leader processes;
- ageing of solids, liquids and gases;
- gas insulated systems,
- effects of corona;
- generation and measurement techniques of high test voltages.
- Introduction to national and international standards.
- Few real-world examples and numerical's related to course will be carried out.

Course Outline

- Electric Field Strength (4 lectures)
- Gaseous Dielectrics (9 lectures)
- Properties of Liquid and Solid Dielectrics (6 lectures)
- Breakdown in Liquid and Solid Dielectrics (4 lectures)
- Generation of High Test Voltages (6 lectures)
- Measurement of High Test Voltages (4 lectures)
- Non-destructive High Voltage Testing and Quality Control (4 lectures)
- Insulation Coordination and Over Voltages in Power Systems (2 lectures)
- Introduction National and International standards such as IEC-60060-1, 60-2, etc. (1 lecture)
- Recent trends and developments (2 lectures)
- Numerical's (3 lectures)

Course Details

- Credit: **3 credit course with 40-42 lectures**
- Prerequisites: EE 303 Power Systems
- Students intended for: **B.Tech./MTech /Ph.D.**

Textbook ad Reference Material

- Ravindra Arora and Bharat Singh Rajpurohit, "Fundamentals of High-Voltage Engineering" Wiley India, 2019.
- High Voltage and Electrical Insulation Engineering, By R. Arora, W. Mosch, IEEE Press, August 2011.
- High Voltage Insulation Engineering: Behaviour of Dielectrics ; Their Properties and Applications by R. Arora, W. Mosch, New Age International, 1995
- NPTEL Web Course on High Voltage Engineering by Ravindra Arora, www.nptel.ac.in

Basic Terminology

Electric Charge:

- The presence of an uncancelled excess of either positive subatomic particles (protons), or negative subatomic particles (electrons) in a substance.
- Free subatomic particles of a polarity, positive or negative.
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- The behaviour of electric charge can be explained with the following typical characteristics:
- Ionisation is a process by which charges build up.
- Accumulation of charge (q) builds up potential (Φ).
- Concentration of like polarity charge (in dielectrics) is known as " space charge".
- When the positive and the negative charges are uniformly distributed in a dielectric, the volume charge density "ρv", is equal to zero.
- On the contrary, when there is a concentration of any one polarity charge, ρv is not equal to zero.
- The electric charge is at rest in dielectrics, however, it is restless in conductors.
- The electric charge always acquires the least resistance path to flow.
- Flow of charge is electric current.
- The electric charge finds its ultimate peace only inside the earth, the mother earth.

Basic Terminology

Electric discharge:

- To get rid of a charge of electricity
- Withdrawing or transference of an electric charge.
- Release or neutralise the electric charge.
- A flow of electricity through the air or other gas.
- A sudden movement of charge.
- The electric discharge process can be typically described by the following:
- Ionisation is the process by which electric charges – hence potential builds up; while discharge involves movement of charge – hence loss of potential.
- Ionisation builds up potential on a body while discharge tends to lose it.
- Electric discharge leads to equalisation of the difference of electric potential built by the charge between any two bodies/electrodes.

Basic Terminology

Electric Field:

- A quantitative description of the attraction or repulsion of one electric charge by another at any one point.
- The ratio of the force exerted on a positive test charge, placed at that point, to the magnitude of the charge.
- The source of electric field intensity is electric charge.

Magnetic Field:

- The portion of space near a magnetic body or a current carrying body in which the forces from the body or current can be detected.
- A region around a magnet within which the force of magnetism acts.
- Any space or region in which magnetic forces are present, as the space or region in or around a piece of magnetised steel, or in or around an electrical current.

Basic Terminology

DIELECTRIC AND ELECTRICAL INSULATION

- **Electric:**
- Electricus produced from amber (a resin) by friction.
- Amber's substance that develops electricity under friction.
- Pertaining to, consisting of, or containing electric charge or electric current.
- Charged with or capable of developing electricity.

- **Dielectric:**
- Archaic: a non-conductor of electricity used to excite or accumulate electricity
- Dia + electric: non-conductor of direct electric current.
- Insulating (medium or substance), non-conductive, non-conductor, through which electricity is transmitted (without conduction).
- A non-conducting or insulating material; a material which admits electrostatic and magnetic lines of force but resists passage of electric current.

Basic Terminology

ELECTRICAL BREAKDOWN

- High voltage may lead to electrical breakdown of insulating materials, resulting in electrical discharge, the short circuit current. Hence, the failure of electrical insulation properties of insulating materials is known as “breakdown”. The electrical breakdown of dielectrics can be distinguished between “Global” and “Local” breakdowns, as described below

Global Breakdown

- The complete rupture or failure of the electrical insulation between two electrodes is described as “breakdown”. It is generally termed as “electrical breakdown”, or simply “breakdown”.

Basic Terminology

Local Breakdown

- The phenomenon of failure of insulating properties confined locally to a part of the total insulation system provided between two electrodes is known as “local breakdown”.
- Since it takes place partially, not globally, it is described as “Partial Breakdown” (PB) in an electrical insulation. The healthy part of the dielectric continues to provide electrical insulation between the two electrodes in spite of failure of insulating properties in some limited part.
- The terminology, used very widely so far, for describing this phenomenon, has been “Partial Discharge” (PD) in the literature. Since the word discharge has several meanings, it is more appropriate to describe this phenomenon as PB.
- This phenomenon can occur in any dielectric under adverse conditions. Like breakdown, the PB phenomenon is injurious for the dielectrics. Hence, it is most undesirable and should be prevented as far as possible.

Basic Terminology

Corona:

- The gaseous envelope of the sun or star.
- A small circle of light seen around the sun or moon.
- Origin Latin; crown, cornice, garland.
- Halo of white light seen around the black disc of moon in total eclipse of sun.
- The brush discharge of electricity.
- A circle of light made by the apparent convergence of the streamers of the aurora borealis
- A faint glow adjacent to the surface of an electrical conductor at high voltage.
- A crown or garland, especially that bestowed upon the ancient Romans as a reward for distinguished services.
- White or coloured circle of light seen around a luminous body, the sun or moon.
- The thin, hot outer atmosphere of the sun that is shaped by solar magnetic fields.

- The stable PB phenomenon in gaseous dielectrics/mediums is known as *corona*.

Basic Terminology

Streamer:

- A long, narrow strip of material used as a decoration or flag.
- A Pennon, ribbon attached at one end and floating or waving at the other column of light shooting up in aurora.
- Any long narrow wavy strip resembling or suggesting a banner floating in the wind.
- A long extension of the solar corona visible only during a total solar eclipse.
- Aurora Borealis.
- Anything which streams stream of light shooting upward from the horizon, as in some forms of the aurora borealis.

- The PB phenomenon in gaseous dielectrics at hemispherical rods, spherical or similar electrodes appear like a streamer or a shower of discharge, are known as streamer corona.

Basic Terminology

Aurora:

- Luminous atmospheric phenomenon (electrical) radiating from earth's northern or southern magnetic pole; colour of sky at dawn, sunrise.
- Roman Goddess of dawn (morning).
- A luminous phenomenon that consists of streamers or arches of light appearing in the upper atmosphere of a planet' s polar regions and is caused by the emission of light from atoms excited by electrons accelerated along the planets magnetic field lines.
- The sporadic radiant emission of light from the upper atmosphere over middle and high latitudes.

Pic Source : NY Times

Thank You
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References

- Ravindra Arora and Bharat Singh Rajpurohit, "Fundamentals of High-Voltage Engineering" Wiley India, 2019.
- High Voltage and Electrical Insulation Engineering, By R. Arora, W. Mosch, IEEE Press, August 2011.
- High Voltage Insulation Engineering: Behaviour of Dielectrics ; Their Properties and Applications by R. Arora, W. Mosch, New Age International, 1995