Visual Preview

INTRODUCTION

CHAPTER

1

Introduction

In modern times, high voltages are used for a wide variety of applications covering the power systems, industry, and research laboratories. Such applications have become essential to sustain modern civilization. High voltages are applied in laboratories in nuclear research, in particle accelerators, and Van de Graaff generators. For transmission of large bulks of power over long distances, high voltages are indispensable. Also, voltages up to 100 kV are used in electrostatic precipitators, in automobile ignition coils, etc. X-ray equipment for medical and industrial applications also use high voltages. Modern high-voltage test laboratories employ voltages up to 6 MV or more. The diverse conditions under which a high-voltage apparatus is used necessitate careful design of its insulation and the electrostatic field profiles. The principal media of insulation used are gases, vacuum, solid, and liquid, or a combi-

Chapter Introduction provides a quick look into the concepts that will be discussed in the chapter.

WORKED EXAMPLES

WORKED EXAMPLES

Example 4.1 *A solid specimen of dielectric has a dielectric constant of 4.2, and tan δ = 0.001 at a frequency of 50 Hz. If it is subjected to an alternating field of 50 kV/cm, calculate the heat generated in the specimen due to the dielectric loss.*

Solution Dielectric heat loss at any electric stress E [Eq. (4.5)]

$$= \frac{E^2 f \varepsilon_r \tan\delta}{1.8 \times 10^{12}} \text{ W/cm}^3$$

For the specimen under study, the heat loss will be

$$= \frac{50 \times 50 \times 10^6 \times 50 \times 4.2 \times .001}{1.8 \times 10^{12}}$$

$$= 0.291 \text{ mW/cm}^3$$

Every chapter contains several worked out Examples which guide the student in understanding the concepts and working out the exercise problems.

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TABLES

Table 3.1 *Dielectric properties of some liquid dielectrics*

Property	*Transformer oil*	*Cable oil*	*Capacitor oil*	*PETEP oil*	*Silicone oils*
Breakdown strength at 20°C on 2.5 mm standard sphere gap	15 kV/mm	30 kV/mm	20 kV/mm	> 15 kV/mm	30–40 kV/mm
Relative permittivity (50 Hz)	2.2–2.3	2.3–2.6	2.1	2.7	2–73
Tan δ (50 Hz)	0.001	0.002	0.25×10^{-3}	0.1×10^{-3}	10^{-3}
(1 kHz)	0.0005	0.0001	0.10×10^{-3}	0.5×10^{-3}	10^{-4}
Resistivity (ohm-cm)	10^{12}–10^{13}	10^{12}–10^{13}	10^{13}–10^{14}	$> 10^{14}$	3×10^{14}
Specific gravity at 20°C	0.89	0.93	0.88–0.89	0.96–0.97	1.0–1.1
Viscosity at 20°C (CS)	30	30	30	80	10–1000
Acid value (mg/gm of KOH)	Nil	Nil	Nil	< 0.03	Nil
Refractive index	1.4820	1.4700	1.4740	1.4555	1.5000–1.6000
Saponification (mg of KOH/gm of oil)	0.01	0.01	0.01		< 0.01
Thermal expansion (20–100°C)	7×10^{-4}/°C	7×10^{-4}/°C	7×10^{-4}/°C	0.00075	5×10^{-4}/°C
Max. permissible water content (in ppm)	50	50	50	200	< 30 (negligible)

Wherever necessary, Tables provide accurate and extensive information on the topic discussed.

FIGURES

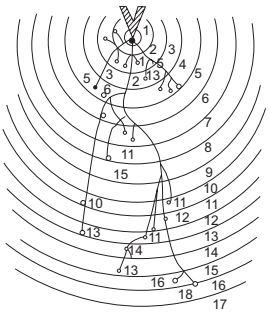

Fig. 4.2 *Breakdown channels in perspex between point-plane electrodes. Radius of point 0.01 in, thickness 0.19 in. Total number of impulses 190. Number of channels produced 16; (n) point indicates end of nth channel. Radii of circles increases in units of 10^{-2} in.*

Source: *R. Cooper, International Journal of Elec. Engg. Education, vol. 1, 241 (1963)*

Well-labelled illustrations give a clear understanding of the concepts.

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MCQs WITH ANS.

MULTIPLE-CHOICE QUESTIONS

1. A small high-voltage laboratory usually will have
   (a) ac, dc test sources with ratings less than 100 kV, 10 kVA./kW and impulse of voltage 400 kV, 5 kJ
   (b) ac, dc test sources of 500 kV, 100 kVA/kW, and impulse of 1 MV, 10 kJ
   (c) ac voltage sources of 300 kV, 10 kVA, and impulse voltage of 1 MV, 15 kJ
   (d) ac, dc sources only
2. Test sources required for testing power apparatus of 220 kV, 3-phase ac system are
   (a) 500 kV ac, 1 MV impulse (b) 800 kV impulse
   (c) 300 kV ac, 500 kV impulse (d) 250 kVA, 500 kV impulse.
3. The kVA rating of a testing transformer unit intended for test voltage and test object capacitance 'C' (pF)
   (a) $\omega C V^2$ (b) $\omega C V^2 \times 10^{-9}$
   (c) $\omega C^2 V^2 \times 10^9$ (d) $\omega C V^2 \times 10^{-6}$
4. The rating of an impulse voltage generator with generator capacitance C_g and voltage rating V with n stages is (kJ)
   (a) $0.5\, C_g V^2$ (b) $(n/2)(C_g V^2)$
   (c) $\frac{(C_g V^2)}{2n}$ (d) $\frac{(C_g V^2)}{2n^2}$

Multiple choice questions help the student gain a quick overview of the important topics in the chapter. Answers are also provided at the end.

QUESTIONS

REVIEW QUESTIONS

1. Explain with diagrams, different types of rectifier circuits for producing high dc voltages.
2. What are the special features of high-voltage rectifier valves? How is proper voltage division between the valves ensured, if a number of tubes are used in series?
3. Why is a Cockcroft–Walton circuit preferred for voltage multiplier circuits? Explain its working with a schematic diagram.

PROBLEMS

1. An impulse generator has 12 capacitors of 0.12 μF, and 200 kV rating. The wave-front and wave-tail resistances are 1.25 kΩ and 4 kΩ respectively. If the load capacitance including that of the test object is 1000 pF, find the wave-front and wave-tail times and the peak voltage of impulse wave produced.
2. An 8-stage impulse generator has 1.2 μF capacitors rated for 167 kV. What is its maximum discharge energy? If it has to produce a 1/50 μs waveform across a load capacitor of 15,000 pF, find the values if the wave front and wave tail resistances.
3. Calculate the peak current and waveshape of the output current of the following generator. Total capacitance of the generator is 53 μF. The charging voltage is 200 kV. The circuit inductance is 1.47 mH, and the dynamic resistance of the test object is 0.051 ohms.

Review questions and problems help students hone their problem-solving skills.

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Extensive list of References helps in selecting books for further study.

APPENDIX

Appendix

Important Formulae

Field enhancement factor

$$f = \frac{E_{\max}}{E_{\text{avg}}}$$

Townsend current growth equation

$$I = I_0 \exp(\alpha d)$$

Current growth in presence of secondary processes

$$I = \frac{I_0 \exp(\alpha d)}{1 - \gamma[\exp(\alpha d) - 1]}$$

Appendix at the end lists important Formulae and Symbols.