Unit – III

MAGNETIC AND DIELECTRIC PROPERTIES OF MATERIALS

DIELECTRIC PROPERTIES OF MATERIALS

3.8 Dielectric loss

When an AC field is applied to a dielectric material, some amount of electrical energy is absorbed by the dielectric material and remaining amount of energy is losses in the form of heat. This loss of energy is known as dielectric loss.

Dielectric loss can occur in both direct and alternating voltages. It is less in direct voltage than that of alternating voltages.

Loss in ideal dielectric

If an alternating voltage is applied across the ideal dielectric, the charging current (I) leads the voltage by an angle of 90° as shown in figure.

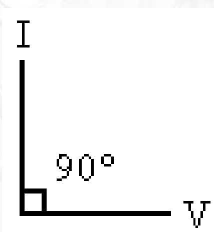


Fig 3.8.1.Variation of current with voltage

We know that,

$$\text{Power loss } P_L = VI \cos\theta$$

$$\theta = 90°$$

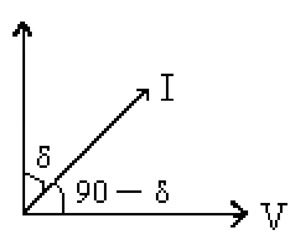
$$P_L = VI \cos 90°$$

$$P_L = 0 \quad [\cos 90° = 0]$$

This means that no electrical energy is lost during charging.

Loss in commercial dielectric

In a practical dielectric, the current leads the voltage by (90 – δ). This shows that there is some loss in electrical energy as shown in figure.



δ – Dielectric loss angle

This loss angle is a measure of the power dissipated in each cycle. The power loss for a dielectric having a capacitance and a voltage V applied to it at a frequency F is given by

$$\text{Power loss} \quad P_L = VI \cos\theta$$

$$\text{Since} \qquad \theta = 90 - \delta$$

$$P_L = VI \cos(90 - \delta)$$

$$P_L = VI \sin\delta \ldots\ldots\ldots\ldots (1)$$

We know that

$$V = IR$$

$$I = \frac{V}{R} \ldots\ldots (2)$$

Substitute equation (2) in (1) we get,

$$\text{Power loss} P_L = V.\frac{V}{R}\sin\delta$$

$$P_L = \frac{V^2}{R}\sin\delta \text{-------- } (3)$$

We know that

$$\text{Frequency} f = \frac{1}{2\pi RC}$$

Therefore

$$R = \frac{1}{2\pi fC} \text{------- } (4)$$

Substituting equation (4) in (3)

$$\text{Power loss } P_L = 2\,\pi\, f\, C\, V^2 \sin\delta$$

If δ is very small, then $\sin\delta = \tan\delta$

Therefore

$$\text{Power loss } P_L = 2\,\pi\, f\, C\, V^2 \tan\delta$$

Hence tan δ is called the power factor of dielectric. If f, C, and Vare constants then

$$P_L \propto \tan\delta \text{ ---------- } (5)$$

The power loss depends only on the power factor of the dielectric as long as the applied voltage, frequency and capacitance are kept constant. Naturally, power loss varies with frequency.

3.9 Dielectric breakdown

When a dielectric is placed in an electric field and when the field exceeds the critical field, the dielectric loses its insulation property and becomes conduction. This phenomenon is known as dielectric breakdown.

Dielectric strength

The electrical field strength at which dielectric breakdown occurs is known as dielectric strength. It is the breakdown voltage per unit thickness of the material

$$\textbf{The dielectric strength} = \frac{\textbf{Dielectric voltage}}{\textbf{Thickness of dielectric}}$$

There are different mechanisms by which the dielectric breakdown takes place. Some of the types of breakdown are

1. Intrinsic (or) avalanche breakdown
2. Thermal breakdown
3. Chemical and electrochemical breakdown
4. Discharge breakdown
5. Defect breakdown

3.9.1 Intrinsic (or) avalanche breakdown

When a dielectric is subjected to electric field then the electrons in the valance band acquire sufficient energy, go to conduction band by crossing the energy gap, and hence become conducting electrons. Therefore, large current flows and is called Intrinsic (or) Zener breakdown

Avalanche breakdown

These conduction electrons on further application of field collide with the valence electrons, which are involved in the covalent bonds and remove more electrons hence transferring them as conduction electrons. This process continues as a chain reaction. Therefore, very large current flows through the dielectric and hence called avalanche breakdown

Characteristics

1. It can occur even at lower temperatures
2. It requires relatively large electric fields
3. This kind of breakdowns occurs in thin samples
4. It does not depends on the electrodes and shape of the material.

5. It occurs within a short span of time (milliseconds)

3.9.2 Thermal Breakdown

When a dielectric is subjected to an electrical field, heat is generated. The generated heat is dissipated by the dielectric. In some cases, the heat generated will be very high compared to the heat dissipated. Under such conditions, the temperature inside the dielectric increases which results in local melting. Once melting starts, that particular region becomes highly conduction. So enormous current flows through the material and dielectric breakdown occurs

Characteristics

1. It can occur even at higher temperatures
2. It requires moderate electric fields
3. It depends on the size and shape of the dielectric material
4. Since the dielectric loss is proportional to frequency, the breakdown occurs at relatively lower field strength
5. It occurs in the order of milli seconds

3.9.3 Chemical and electrochemical breakdown

This type of breakdown is almost similar to the thermal breakdown. If the temperature increases, mobility of the ions will increase. When mobility increases, leakage current also increases and hence the electro chemical reaction may be induced to take place.

Therefore when mobility of ions is increased, insulation resistance decreases and hence dielectrics become conducting. This type of break down is known as Chemical and electrochemical breakdown

Characteristics

1. It can occurs only at lower temperatures
2. It occurs even in the absence of electric field
3. It depends on the concentration of ions and magnitude of leakage curr4ent

3.9.4 Discharge breakdown

In some dielectric gas bubbles are present. When these dielectrics are subjected to electric field, the gas present in the material will easily ionize and hence produce large ionization current and is known as Discharge breakdown

Characteristics

1. It occurs at low voltages

2. It occurs due to the presence of gas bubbles
3. It depends upon the frequency of the applied voltage

3.9.5 Defect breakdown

Some dielectrics have defects such as cracks, pores, blow holes etc. These vacant position may have moisture or impurities which leads too breakdown known as defect breakdown

3.9.6 Remedies for breakdown mechanisms

To avoid breakdown the dielectrics should have the following properties

(i) It should possess high dielectric strength

(ii) It should have high resistivity

(iii) Dielectric loss should be low

(iv) Thermal expansion should be low

(v) It should have sufficient mechanical strength

(vi) It should be fire proof

(vii) It must have less density

(viii) It should be resistive to oils, liquids and gases

(ix) There should not be any defects

(x) It must be in pure form