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Role of Dielectric Materials in Electrical Engineering

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Abstract- In India commercially industrial consumer consume more quantity of electrical energy which is inductive load has lagging power factor. Drawback is that more current and power required. Capacitor improves the power factor. Commercially manufactured capacitors typically used solid dielectric materials with high permittivity. The most obvious advantages to using such dielectric materials is that it prevents the conducting plates the charges are stored on from coming into direct electrical contact.

I. INTRODUCTION

Dielectric materials are those which are used in condensers to store electrical energy e.g. for power factor improvement in single phase motors, in tube lights etc. Dielectric materials are essentially insulating materials. The function of an insulating material is to obstruct the flow of electric current while the function of dielectric is to store electrical energy. Thus, insulating materials and dielectric materials differ in their function.

A. Electric Field Strength in a Dielectric

Thus electric field strength in a dielectric is defined as the potential drop per unit length measured in volts/m. Electric field strength is also called as electric force.

If a potential difference of V volts is maintained across the two metal plates say A₁ and A₂, held l meters apart, then

$$\text{Electric field strength} = E = \frac{V}{l} \text{ volts/m.}$$

B. Electric Flux in Dielectric

It is assumed that one line of electric flux comes out from a positive charge of one coulomb and enters a negative charge of one coulombs. Hence the flux emanating from any charge is equal to its strength in coulombs.

∴ Flux emanated (ψ) = charge Q and is measured in coulombs

C. Electric Flux Density in Dielectric

The electric flux density is defined as the charge per unit area of the dielectric. It is measured in coulombs/m²

$$\text{The electric flux density} = \frac{Q}{A} \text{ coulombs/m}^2$$

Where Q is the charge in coulombs and A is the area of dielectric in m²

D. Dielectric Constant or Permittivity

Consider two insulating conducting plates forming a capacitor having air in between them. Let the value of capacitance be C_a. If a piece of another dielectric, say glass, is introduced in the space between the two plates, it is observed that the value of the capacitance increases. Let it be KC_a. Therefore, it is seen that the charge storing capacity of the condenser increases by K times when air is replaced by another dielectric, i.e. glass in this case. Another dielectrics which can be used are wax, mica etc. The K is the measure of Permittivity. The ratio of capacity of a condenser with dielectric as medium to its capacity with air as a medium is called the "permittivity" or 'dielectric constant' of the dielectric medium. The dielectric constant of air is taken as 1. Permittivity of dielectrics other than air are more than one. Permittivity of a dielectric is analogous to permeability of a magnetic material. Permittivity is different dielectrics as shown in Table below. Just as permeability of a magnetic material is different for different magnetic materials in the same way permittivity is also different for different dielectric.

Table :1.Permittivity and dielectric Strength of some Dielectric Materials

Sr. No.	Material	Permittivity	Dielectric Strength(kV/mm)
1.	Air	1	3
2.	Bakelite	5.6	20 to 25
3.	Glass	3	5 to 12
4.	Mica	3 to 8	40 to 150
5.	Paper	2 to 2.5	4
6.	Porcelain	4 to 7	9 to 20
7.	Rubber	2 to 3.5	10 to 25
8.	Transformer oil	2	25 to 30



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Water is not used as a dielectric because it is very difficult to keep water in pure state.

II. POLARIZATION

A magnetic material gets magnetized when its magnetic dipoles get oriented in a particular direction under the influence of an externally applied magnetic field. This process is called magnetization. Similarly, polarization is a process of dielectric materials. Hence polarization of a dielectric material is analogous (similar) to magnetization of a dielectric material. If a slab of dielectric is placed in an electrostatic field it will undergo the process of polarization. Polarization can be defined as the definite orientation of electrostatic dipoles in a dielectric material due to an applied electric field.

When two conducting plates of a capacitor are taken and the capacitor is charged, a definite potential will developed between the two capacitor plates. Electric field thus formed between the two charged capacitor plates is shown in fig.2. If now a dielectric is introduced between the two plates it will be noticed that the intensity of the electric field and, therefore, the potential difference between the two plates gets reduced.

It happens due to the polarization of the dielectric material under the influence of the electric field. Polarization effect depends upon the dielectric constant of the dielectric material. A better dielectric material, possessing higher dielectric constant will show more effect of polarization. As the voltage drop between the two charged plates of the capacitor reduces due to the introduction of a dielectric material, the charge storing capacity of the capacitor is increased. When connected across a battery more charging current will flow through the capacitor till the battery voltage and the voltage drop across the charged capacitor become equal. The capacitor plates being of conducting material have many electrons in them and, therefore, saturation stage does not reach in them during charging .The molecules of a dielectric are either polar or non polar. A non polar molecule is one in which the ‘center of gravity’ of the positive nuclei and electrons almost coincide with each other. When placed within an electric field, the electrons are attracted by the positive charge of one electrode and repelled by the negative charges of the other electrode. On account of this , the electrons undergo some displacement towards the positively charged electrode. This displacement of electrons within the atoms is called electronic polarization. Electronic polarization converts each atom into a dipole become the centre of electron orbits and the positively charged nucleus are displaced with respect to one another by a small distance. Due to this phenomenon the dipoles are induced. Gaseous dielectrics exhibit a very little electronic polarization . due to their very low density .That is the reasons why all gaseous dielectric constant (i.e. permittivity) almost one i.e. very near to unit.

III. ELECTRICAL DIPOLE MOMENT

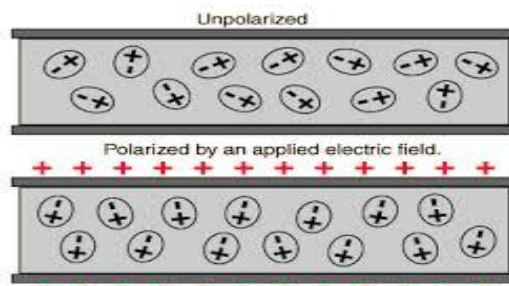
A polarized particle will have an elementary electric dipole moment which can be expressed mathematically as

$$M=q \times l$$

Where, q =elementary charge of the particle

l =distance between the centre of electron orbit and the positively charged nucleus

The sum of the dipole moments per unit volume of the dielectric material is equal to the polarization of the dielectric. The degree of polarization in the case of electronic polarization mostly depends upon the density or specific gravity of the dielectric material.





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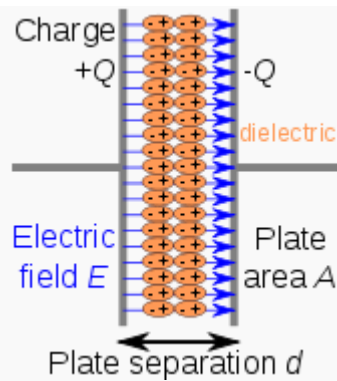
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In most of the dielectric the molecules of the dielectric have an electric dipole moment even if an external electrical field is absent. Such molecules have the centers of their positive and negative charges displaced with respect to one another and hence constitute a dipole. These dipoles are oriented in an irregular way in the absence of electric field but under the influence of an electric field these dipoles orient or align themselves in lines in the direction of the applied electric field. The stronger the electric field, the greater will be the number of dipoles pointing or orienting in the direction of the electric field. The total effect of an external electric field on the dielectric is independent of the polar or non polar molecules of the dielectric material. Due to the polarization and in the presence of an electric field the dipole line up and point in the direction of the applied electric field. On account of this, the negative charges will appear on the surface of the dielectric facing the positive plate of the capacitor and positive charges will appear on the surface of the dielectric facing the negative plate of the capacitor. In this way electric field induced within the dielectric due to polarization will be in the opposite direction to that of the applied field. Thus the resultant field becomes weak and the potential difference developing across the plates will be reduced. There when the plates of a capacitor are connected across a battery, more charge will be stored in the capacitor i.e. the charge storing capacity of the capacitor is increased.

IV. APPLICATIONS

1] Capacitors:-



Charge separation in a parallel-plate capacitor causes an internal electric field. A dielectric (orange) reduces the field and increases the capacitance.

Commercially manufactured capacitors typically use a solid dielectric material with high permittivity as the intervening medium between the stored positive and negative charges. This material is often referred to in technical contexts as the capacitor dielectric. The most obvious advantage to using such a dielectric material is that it prevents the conducting plates the charges are stored on from coming into direct electrical contact. More significantly, however, a high permittivity allows a greater stored charge at a given voltage. This can be seen by treating the case of a linear dielectric with permittivity ϵ and thickness d between two conducting plates with uniform charge density σ_ϵ . In this case the charge density is given by

$$\sigma_\epsilon = \epsilon \frac{V}{d}$$

and the capacitance per unit area by

$$c = \frac{\sigma_\epsilon}{V} = \frac{\epsilon}{d}$$

From this, it can easily be seen that a larger ϵ leads to greater charge stored and thus greater capacitance. Dielectric materials used for capacitors are also chosen such that they are resistant to ionization. This allows the capacitor to operate at higher voltages before the insulating dielectric ionizes and begins to allow undesirable current.



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2] Dielectric resonator:-

A dielectric resonator oscillator (DRO) is an electronic component that exhibits *resonance* for a narrow range of frequencies, generally in the microwave band. It consists of a "puck" of ceramic that has a large dielectric constant and a low dissipation factor. Such resonators are often used to provide a frequency reference in an oscillator circuit. An unshielded dielectric resonator can be used as a Dielectric Resonator Antenna (DRA).

3] Some practical dielectrics

Dielectric materials can be solids, liquids, or gases. In addition, a high vacuum can also be a useful, nearly lossless dielectric even though its relative dielectric constant is only unity. Solid dielectrics are perhaps the most commonly used dielectrics in electrical engineering, and many solids are very good insulators. Some examples include porcelain, glass, and most plastics. Air, nitrogen and sulfur hexafluoride are the three most commonly used gaseous dielectrics.

[A] Industrial coatings such as parylene provide a dielectric barrier between the substrate and its environment.

[B] Mineral oil is used extensively inside electrical transformers as a fluid dielectric and to assist in cooling. Dielectric fluids with higher dielectric constants, such as electrical grade castor oil, are often used in high voltage capacitors to help prevent corona discharge and increase capacitance.

[C] Because dielectrics resist the flow of electricity, the surface of a dielectric may retain stranded excess electrical charges. This may occur accidentally when the dielectric is rubbed (the triboelectric effect). This can be useful, as in a Van de Graaff generator or electrophorus, or it can be potentially destructive as in the case of electrostatic discharge.

[D] Specially processed dielectrics, called electrets (which should not be confused with ferroelectrics), may retain excess internal charge or "frozen in" polarization. Electrets have a semi permanent external electric field, and are the electrostatic equivalent to magnets. Electrets have numerous practical applications in the home and industry.

[E] Some dielectrics can generate a potential difference when subjected to mechanical stress, or change physical shape if an external voltage is applied across the material. This property is called piezoelectricity. Piezoelectric materials are another class of very useful dielectrics.

[F] Some ionic crystals and polymer dielectrics exhibit a spontaneous dipole moment, which can be reversed by an externally applied electric field. This behavior is called the ferroelectric effect. These materials are analogous to the way ferromagnetic materials behave within an externally applied magnetic field. Ferroelectric materials often have very high dielectric constants, making them quite useful for capacitors.

REFERENCES

- [1] C.S.Indulkar and S.Thiruvengadam, "Electrical Engineering Materials", S. Chand and Company New Delhi, 110055.
- [2] D.M.Tagare, "Electrical power Capacitors, Design and Manufacture", Tata McGraw—Hill Publishing Company Ltd. New Delhi.
- [3] S.P.Seth and P.V.Gupta,"A Course in Electrical Engineering Materials Physics ,Properties and Application", Dhanpat Rai Publication.
- [4] P.L.Kapur, "Electrical Engineering Materials", m/s Khanna Publication, New Delhi.

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