Que 1:-

First Midterm Examination

High voltage Engineering

Ans:(a) Townsend Breakdown Mechanism:-

From Townsend's procedure for current growth, when voltage b/w the anode and cathode is increased. The current at the anode is given by

$$I = \frac{I_0 e^{\alpha d}}{1-\gamma\left[e^{(\alpha d)}-1\right]} \quad \text{—— (1)}$$

As the distance b/w the electrodes d is increased the denominator of the eq^n (1) tends to zero and at some critical distance $d = d_s$ the current becomes infinite if

$$1-\gamma\left[e^{(\alpha d)}-1\right] = 0 \quad \text{—— (2)}$$

for values of $d < d_s$ I is approximately equal to I_0 And if the external source for the supply of I_0 is removed, I becomes zero. If $d = d_s$ $I \rightarrow \infty$ and the current will be limited only by the resistance of power supply and the external circuit. This condition is called Townsend's breakdown mechanism and can be written as.

$$\gamma\left[e^{(\alpha d)}-1\right] = 1 \quad \text{——}$$

Normally $e^{(\alpha d)}$ is very Large and hence the above equation reduces to

$$\gamma\left[e^{(\alpha d)}\right] = 1 \quad \text{—— (3)}$$

$$e^{(\alpha d)} = 1$$

The above condition $e^{(\alpha d)} = 1$ defines the condition for begining of spark and is known as the Townsend criterion for spark formation or Townsend breakdown criterion.

using the above equation the following three Conditions are possible.

(i) $\gamma[e^{(\alpha d)}] = 1$

This Condition defines the thresold sparking Condition. This includes the repetition of avalanche process by production of Secondary electrons

(ii) $\gamma[e^{(\alpha d)}] > 1$

Here ionization produced by Successive avalanche is Cumulative The spark discharge grows more rapidly the more $\gamma[e^{(\alpha d)}]$ exceeds unity

(iii) $\gamma[e^{(\alpha d)}] < 1$

Here the current I is not self-Sustained i.e. on removal of the source the current I_0 ceases to flow

Ans(b) Electromechanical Breakdown:-

when a dielectric material is subjected to an electric field, charge of opposite nature are induced on the two opposite surfaces of the material and hence a force of attraction is developed and the speciman is subjected to electrostatic Compressive forces and when these forces exceed the mechanical withstand strength of the material the material collapses. If the initial thickness of the material is d_0 and is Compresses to a thickness d under the applied voltage V then the Compressive stress developed due to electric field is

$$f = \frac{1}{2}\varepsilon_0\varepsilon_r\frac{V^2}{d^2} \quad \text{——} (1)$$

where ε_r is the relative permittivity of the specimen. If Y is the Young's Modulus the mechanical compressive strength is

$$Y \ln \frac{d_0}{d} \quad \text{—— (2)}$$

Equating the eq^n (1) & (2) under equilibrium condition, we have

$$\frac{1}{2} \varepsilon_0 \varepsilon_r \frac{V^2}{d^2} = Y \ln \frac{d_0}{d}$$

$$V^2 = d^2 \cdot \frac{2Y}{\varepsilon_0 \varepsilon_r} \ln \frac{d_0}{d} = K d^2 \ln \frac{d_0}{d} \quad \text{—— (3)}$$

Differentiating the eq^n (3) with respect to d we have

$$2V \frac{dV}{dd} = K\left[2d \ln \frac{d_0}{d} - d^2 \cdot \frac{d}{d_0} \frac{d_0}{d^2}\right] = 0 \quad \text{—— (4)}$$

On solving the above eq^n, we have

or $$2d \ln \frac{d_0}{d} = d$$

or $$\ln \frac{d_0}{d} = \frac{1}{2}$$

or $$\frac{d}{d_0} = 0.6 \quad \text{—— (5)}$$

For any real value of voltage V the reduction in thickness of the specimen can not be more than 40%. If the ratio V/d at this value of V is less than the intrinsic strength of the specimen, a further increase in V shall make the thickness unstable and the specimen collapses. The highest apparent strength is then obtained by substituting $d = 0.6 d_0$ in the above expressions

$$\frac{V}{d} = \sqrt{\frac{2Y}{\varepsilon_0 \varepsilon_r} \ln 1.67}$$

or $$\frac{V}{d_0} = E_a = 0.6\left[\frac{\gamma}{\varepsilon_0 \varepsilon_r}\right]^{1/2} \quad \text{--- (6)}$$

The above equation is approximate only as γ depends upon the mechanical stress. The possibility of instability occuring for lower avg field is ignored. The effect of stress concentration at irregularities is not taken into account

Ans 2(a) : Genration of high DC voltage :-

The areas of electrical engineering and applied physics Mainly requires genration of high DC Voltages. Impulse genrator charging units also require high DC voltage of about 100 to 200 kV. for the genration of DC Voltage of upto 100 kV. Electronic valve rectifiers are used normally and the output currents are about 100mA. The AC Supply to the rectifier tubes may be of power frequency or may be of Radio frequency from an oscillator. Since a high electrostatic field of serval kV/cm exists b/w the anode and Cathode. The Rectifier Value require Special Construction for Cathode and filaments.

Ans (b) :-

Mixed potential Divider:- R-C elements in series or in parallel are used in mixed potential dividers. One method is to connect Capacitance in parallel with each R_1 element. This Successfully employed for voltage dividers of

Rating 2MW and above. A better connection is to make an R-C series element connection. The equivalent ckt is shown in figure 2.21 (a) & (b)

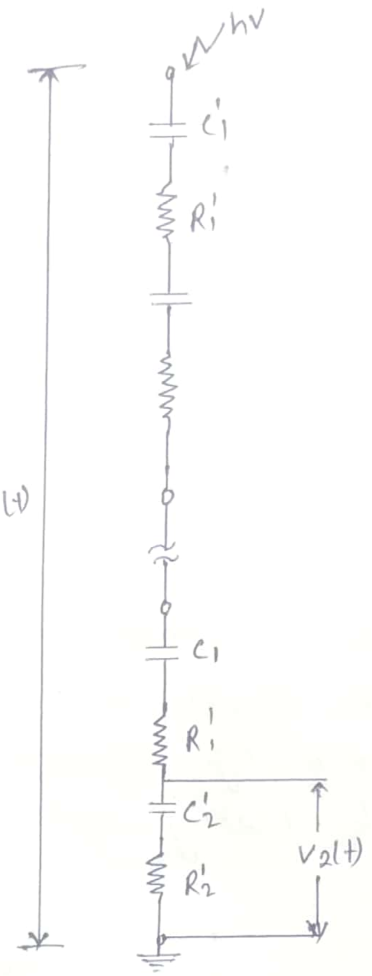


Fig: (a) equivalent ckt of mixed potential Divider

$$R_1' = \frac{R_1}{n}$$

$$C_1' = nC_1\left[1 - \frac{C_g}{6C_1}\right]$$

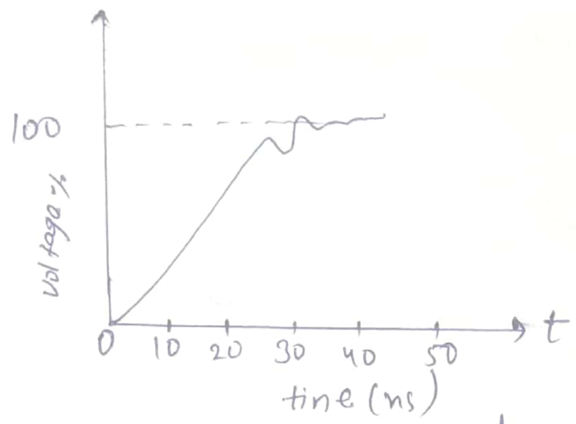
where

C_g = ground capacitance

C_1 = Total series capacitance

R_1 = Total Resistance

$C_1 R_1 = R_2 C_2$



(b) Step Response determined with low voltage step pulse.

Fig:- Equivalent ckt of a series R-C voltage divider and its step Response.

Such dividers are made upto 5MW with Response times less than 30 nanoseconds (ns). The low voltage arm R_2 is given "L peaking" by connecting a variable inductance L in series with R_2. The step Response of the divider and the schematic connection of low voltage arm shown in fig. However for a correctly designed voltage divider L peaking will not be necessary.

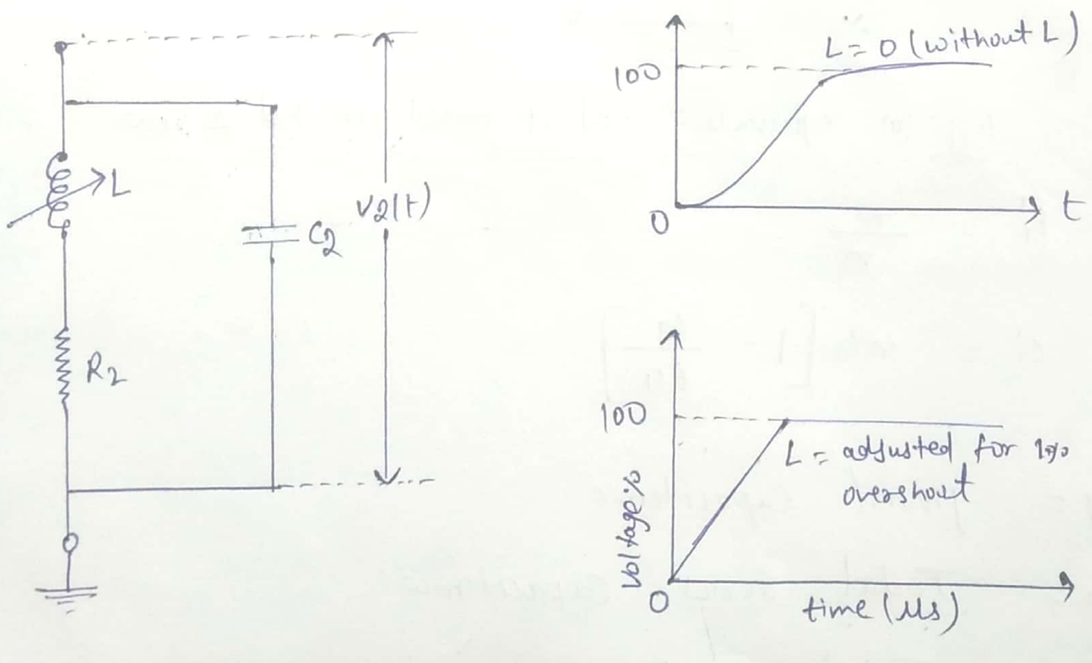


Fig:- L peaking in low voltage arm and step Response of divider with L peaking.