Study of IMPULSE GENERATOR AND DETERMINATION OF IMPULSE BREAKDOWN VOLTAGE OF SPHERE GAP (CRITICAL FLASHOVER VOLTAGE)

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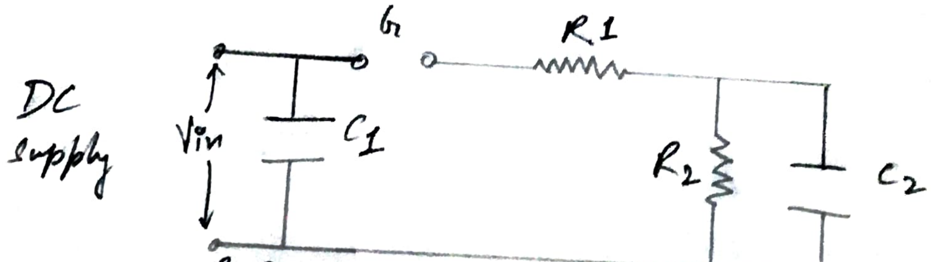
OBJECTIVE

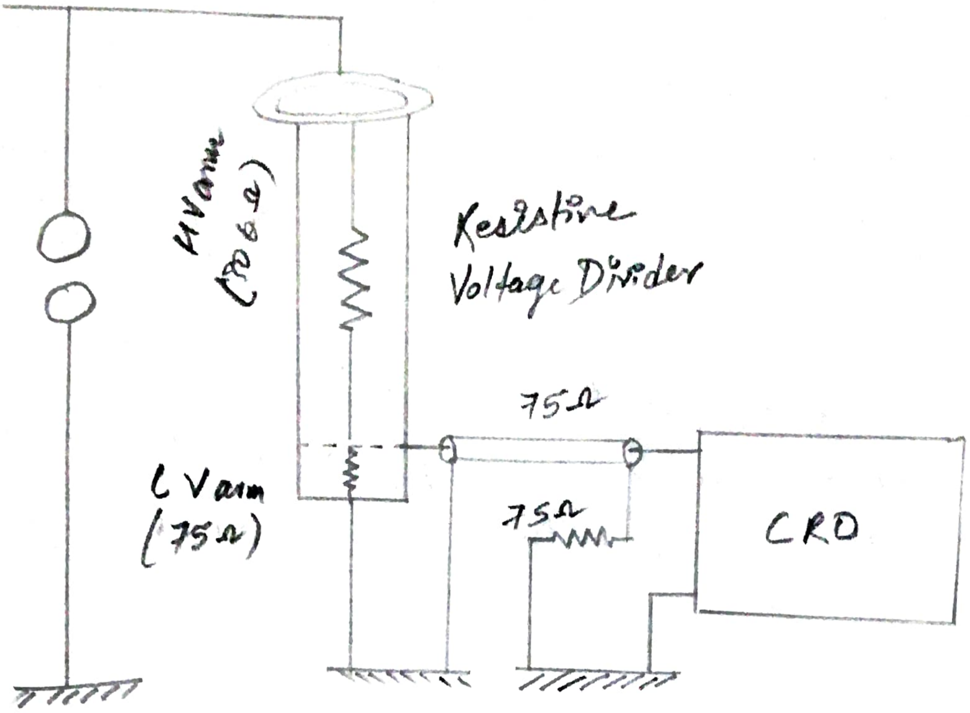
- Study of impulse voltage generator
- Generation of standard impulse voltage and
- Determination of impulse breakdown voltage of sphere gap.

Schematic Diagram of Experimental Setup



R-C circuit for impulse voltage generation

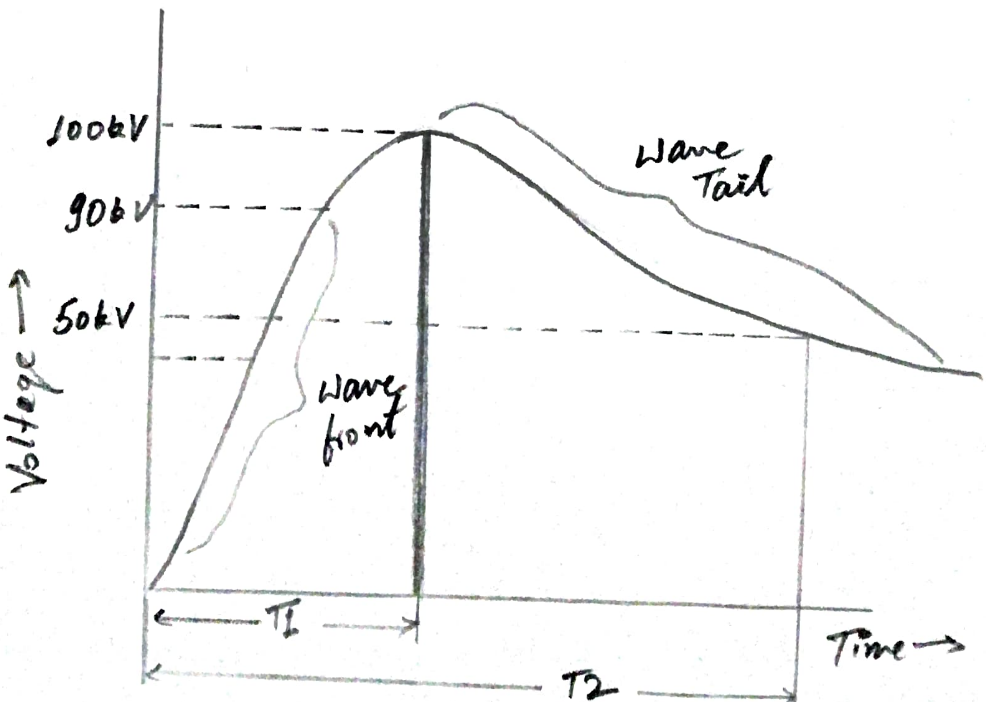
C_1 = Source Capacitor
C_2 = load Capacitor
R_1 = Damping resistor or front resistance
R_2 = discharge resistor or leg resistance



CRO acquires the impulse voltage of reduced magnitude, but with no distortion.

Measurement circuit for impulse voltage

Draw a standard 1.2/50 μs lightning impulse voltage (100 kV) on appropriate scale.



$T1 = 1.2\ \mu s$

$T2 = 50\ \mu s$

1.2/50 μs Standard lightning impulse voltage (100kV)

Compute Probability and draw "Probability vs Breakdown Voltage" curve for the records in Table 1

Voltage level / Stage kV	Pulse No.										Probability of Flash Over
	1	2	3	4	5	6	7	8	9	10	
35	W	W	W	W	W	W	W	W	W	W	0
37	W	W	W	W	F	W	W	W	W	W	0.1
37.5	W	F	W	W	W	W	F	W	F	W	0.3
37.7	W	F	W	F	F	F	F	W	F	F	0.7

F - Flash Over W - Withstand

Determine CFO voltage for 70 mm sphere gap at STP from the experimental measurement.

⇒ As we know that CFO for any system is defined as the crest value of a standard impulse (under specified conditions) for which the insulation exhibits 50% probability of withstand (50% failure).

So, the voltage corresponding to 50% is extracted from the graph & that is reckoned as the CFO voltage.

So, the required CFO voltage obtained from graph is

= 37.65 kV

Probability vs breakdown Voltage for Table 1. Pratyush Jaiswal
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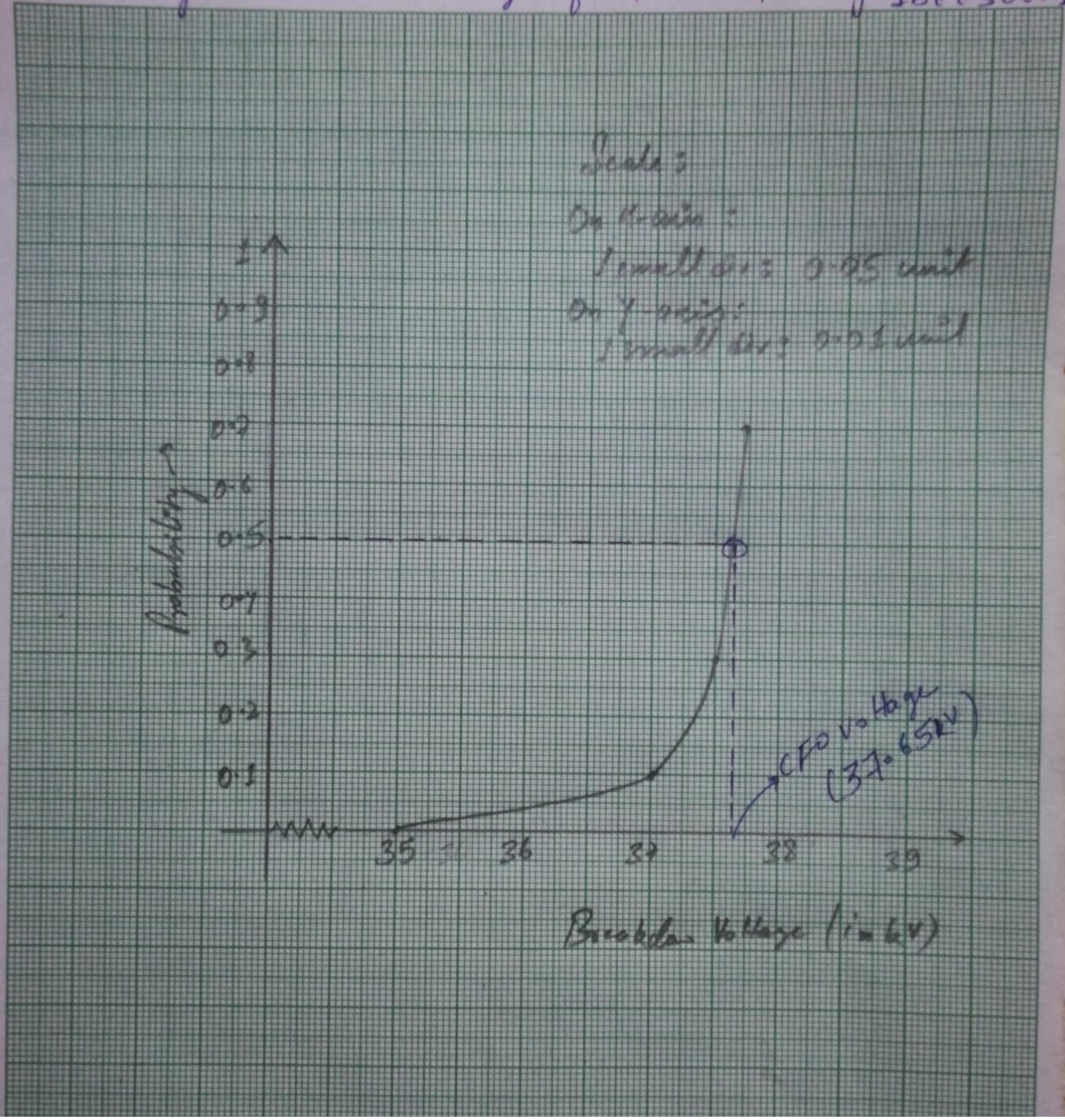
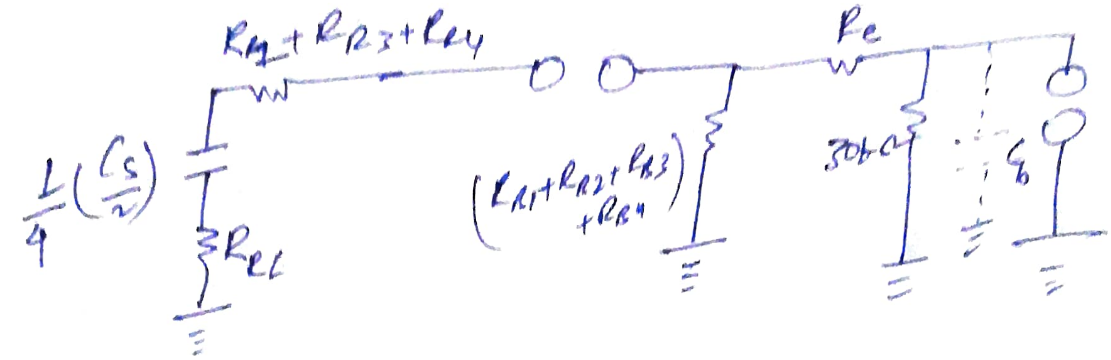
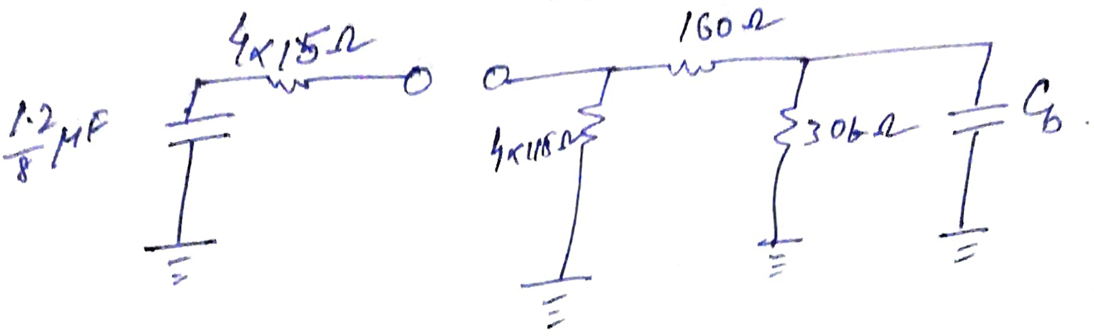
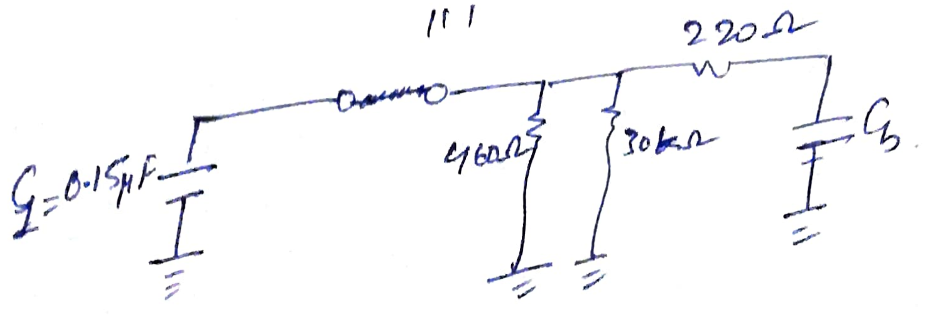


Draw single stage equivalent circuit for 4-stage Marx generator in Fig 14 and obtain equivalent parameters.

:- Equivalent Circuit is :-







$R_1 = 220\,\Omega$

$R_2 = (460 \,||\, 30k)\,\Omega$

$\simeq 460\,\Omega$

So, $\frac{1}{\alpha} = R_2 C_1 = 460 \times 0.15 \times 10^{-6}\,s = 69\,\mu s$

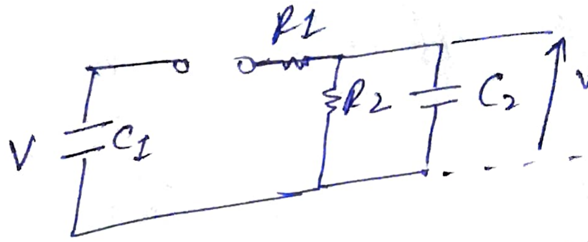
$\simeq \alpha$ (theoretical $= 68.1\,\mu s$)

$\frac{1}{\beta} = 0.405\,\mu s$; $C_2 = \frac{0.405}{220}\,\mu F$

$= 1.84\,nF$

Also obtain the approximated expression for double exponential impulse voltage across load capacitor.

→



For the configuration shown, the output voltage across $C_2 = V_0(t) = \frac{1}{C_2}\int^{t} i_2 \, dt$

i_2 is the current through C_2.

Performing laplace Transformation,

$$\frac{1}{C_2 s} I_2(s) = V_0(s)$$

Taking the current through C_1 as I_1 and its transformed values as $I_1(s)$,

$$I_2(s) = \left(\frac{R_2}{R_2 + \frac{1}{C_2 s}}\right) I_1(s)$$

$$I_1(s) = \left(\frac{V}{s}\right) \cdot \frac{1}{\frac{1}{C_1 s} + R_1 + \left(\frac{\frac{R_2}{C_2 s}}{R_2 + \frac{1}{C_2 s}}\right)}$$

the impedance of the parallel combination of R_2 & C_2.

Substitution of $I_1(s)$ gives

$$V_0(s) = \frac{1}{C_2 s} \times \frac{R_2}{\left(R_2 + \frac{1}{C_2 s}\right)} \times \frac{1}{\frac{1}{C_1 s} + R_1 + \left(\frac{\frac{R_2}{C_2 s}}{R_2 + \frac{1}{C_2 s}}\right)}$$

$$\Rightarrow V_0(s) = \frac{V}{R_1 C_2}\left[\frac{1}{s^2 + \left(\frac{1}{C_1 R_1} + \frac{1}{C_2 R_2} + \frac{1}{C_2 R_1}\right)s + \frac{1}{C_1 C_2 R_1 R_2}}\right]$$

Hence the roots of the equation.

$$s^2 + \left(\frac{1}{C_1 R_1} + \frac{1}{C_2 R_2} + \frac{1}{C_2 R_1}\right) s + \frac{1}{C_1 C_2 R_1 R_2}$$

Are found from the relations,

$$\alpha + \beta = \left[\frac{1}{C_1 R_1} + \frac{1}{C_2 R_2} + \frac{1}{C_2 R_1}\right]$$

$$\alpha \beta = \frac{1}{R_1 R_2 C_1 C_2}$$

Taking inverse transform of $V_0(s)$ gives,

$$V_0(t) = \frac{V}{R_1 C_2 (\alpha - \beta)}\left[\exp(-\alpha t) - \exp(-\beta t)\right]$$

Usually $\frac{1}{C_1 R_1}$ & $\frac{1}{C_2 R_2}$ will be much smaller than $\frac{1}{C_2 R_1}$. Hence the roots may be approximated as $\alpha \approx \frac{1}{R_1 C_2}$ & $\beta \approx \frac{1}{R_2 C_1}$.

ANSWER THE FOLLOWING QUESTIONS? Pratyush Jaiswal 18EE30021

1. Why is the impulse breakdown of a sphere gap isstatistical?

→ Impulse breakdown of a sphere gap happens if the electron on sphere have enough energy. For standard 1.2/50 μs impulse voltage, the time duration of voltage peak is of the order of 0.01 μs, which is very less to energize an electron completely. So depending upon availability of initiated electrons. Since presence of initiated electrons is statistical in nature, occurrence of impulse breakdown is statistical.

2. How is the wave shape of impulse voltage is controlled?

→ Wave shape is done by proper selection of T_1 (front time) T_2 (tail time). The resistors R_{R1}, R_{R2}, R_{e3} & R_{R4} come in series with capacitors while rising of voltage (impulse voltage). They decide the front time. We choose less value of resistance so that the front time is less, so that rising will be quick. Similarly R_{e1}, R_{e2}, R_{e3} & R_{e4} contribute to the falling part of impulse voltage. We use relatively high resistance so that tail part has smooth fall of voltage. This way wave shape is controlled. Waveform adjustments are necessary, so experience gained from results of tests on similar units or eventual pre-calculation can give guidance for selecting components for the wave shaping circuit.

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3. Why is the capacitive storage, not the inductive storage for impulse voltage generator.

→ Impulse generators are of two types - Impulse Voltage generator and Impulse Current generators. High Impulsive voltages are used to ~~tt~~ test the strength of electric power equipment against lighting and switching surges. High impulse currents are needed not only for tests on lighting arrestors and fuses but also for several applications such as lasers, thermonuclear fusion & plasma devices. The experiment done is to find electric strength against lighting surges, so we need Impulse Voltage generator. Capacitors stores energy in the form of Electric potential while Inductor in Current. So, capacitor storage is used to produce Impulse Voltages, while Inductive storage is used to produce Impulse Currents.

4. Describe, briefly, how the operator can vary the peak of the impulse voltage.

→ As the wave front resistance is increased the magnitude of the peak value of the wave is decreased. ~~On~~ On the other hand as the wave tail resistance is increased the magnitude of the peak value of the wave is increased also. From the general features R_1 will ~~control~~ primarily damp the circuit and control the front time while R_2 will discharge the capacitors & therefore essentially control the wave tail.

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5. Describe the concept of 50% flashover voltage and indicate how it can be determined for a test sample, such as an insulator.

→ 50% flashover voltage is the voltage which has a probability of 50% flashover when applied to the test object. This is normally applied in impulse tests in which loss of insulation strength is temporary. The most common method is the Regression method. In this method, one starts with a voltage V, that is sufficiently low, so that no breakdown occurs. 10 pulses are applied & the number of breakdowns, if any are noted. Next the voltage is increased by 10% and 10 pulses are applied & then number of breakdowns noted. This is continued until breakdown occurs for all the applied pulses. At each voltage level, the probability of breakdown is calculated as

No of breakdowns/No. of pulses applied.

A graph of Probability of breakdown vs the applied voltage is ~~applied~~ plotted. The voltage corresponding to 50% is extracted from the graph. This value is reckoned as the critical (50%) flash over voltage for the given insulator.