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Cock-croft Walton voltage multiplier as a voltage source to three electrode setup of volume resistivity measurement

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ABSTRACT

The cock-croft Walton voltage multiplier is an electric circuit used to produce high dc voltage from low ac voltage. The CW model is manufactured by ladder network of capacitor and diode. As it is known that volume resistivity is the major specification to determine the performance of the insulation material, as the resistivity may be used to determine the dielectric breakdown, dissipation factor, moisture content etc. So far two electrode testing equipment was used for measuring the volume resistivity of material, neglecting the effect of surface current .As a result high amount of testing error may exist during testing of insulation material. To improve the testing precision three electrode testing equipment has been established for minimizing the effect of surface current. In this test system a sample is taken and electrodes are placed on the top and bottom of sample. In this work three electrode volume resistivity measurement system had been designed on the PSPICE simulation. This paper will present the effect of the ripple contents present in the supply voltage. The source voltage to volume resistivity measurement system can be applied by a pure dc voltage source or a Cock-croft Walton voltage multiplier. Here Cock-croft voltage multiplier circuit is also used as voltage source. The effect of the ripple present in the Cock-croft voltage multiplier circuit will be seen in the volume resistivity of the material. Cock-croft Walton is also designed on PSPICE

Keywords: Three electrode setup, cock-croft Walton voltage multiplier, volume current, resistivity.

1. INTRODUCTION

In recent years, it was recognized that due to high insulation properties electrical insulating materials are being used in high voltage application to provide insulation for various apparatus. Insulating material may be in form of solid, liquid or gas. These materials must acquire high insulation properties for different operating parameters. There are various test performed on these material to ensure that these material does not get damaged in case of high voltage testing. These tests are basically related to measurement of resistance or resistivity. for different operating condition. The main function of electrical insulation is to resist the electrical stress. In spite any dielectric material exposed under electric field will have dielectric polarization phenomenon. Basically dielectric phenomenon is to state the performance of insulation material under external electrical field. When external electric field is applied to insulating material there will be shift in positive and negative charges in material.

So far this two electrode method was being used for resistivity measurement, neglecting the effect of surface current. There will be high error in measurement of volume resistivity, in case of material with high resistivity. To neglect the effect of surface current a three electrode system was established, in which an extra electrode called as guard electrode was being used Thus in a simple way we can measure the volume resistivity of any insulating material by applying a known source voltage to material and then calculate the resistance, neglecting the effect of surface current. A three electrode system is displayed in below:

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1.1. Current in Dielectric

As stated above resistivity of insulating material is obtained by calculating resistance value, resistance is measured by value of consistent voltage V applied across dielectric specimen and steady state value of volume current I_V. As constant voltage is employed across dielectric specimen, result in flow of volume current, which decline continuously to a steady state value. In case of insulating material with large resistivity value ,the duration afterward volume current arrive at steady state value may take extreme time as hours, a week or even year. If insulating material has low resistivity then volume current reaches its steady state value within few minute. Meanwhile it was detected that decline of the volume current does not only depend on dielectric material but also on the space charge.

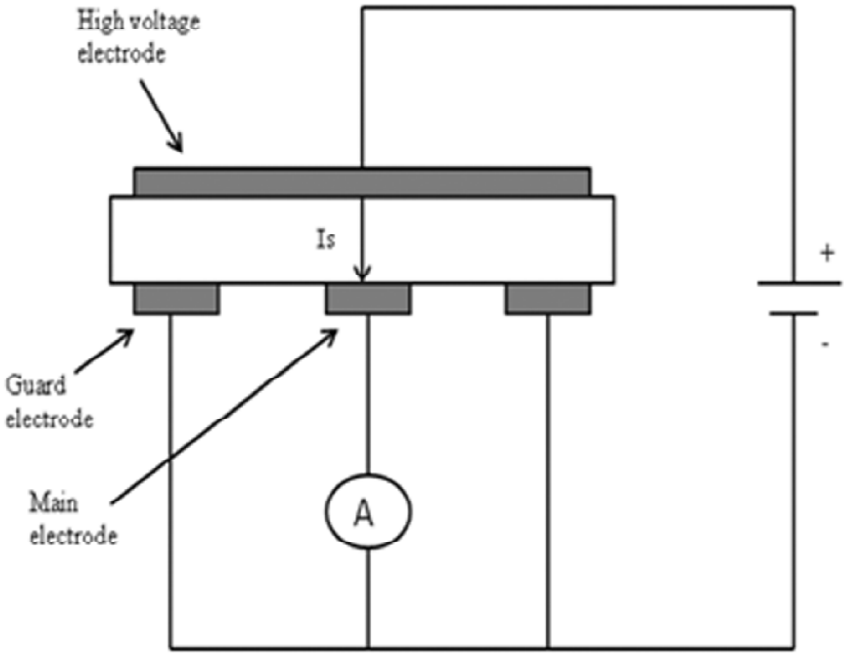


Figure 1: Three electrode testing system

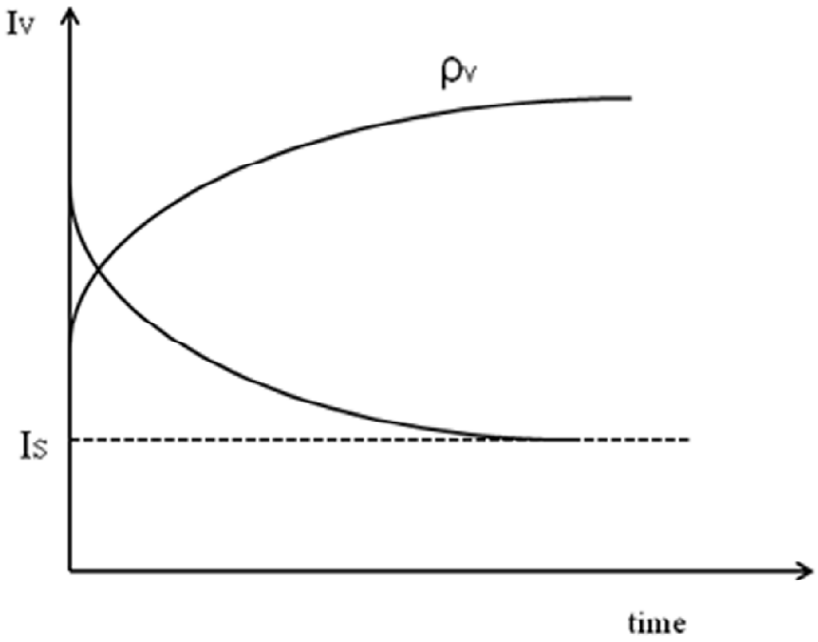


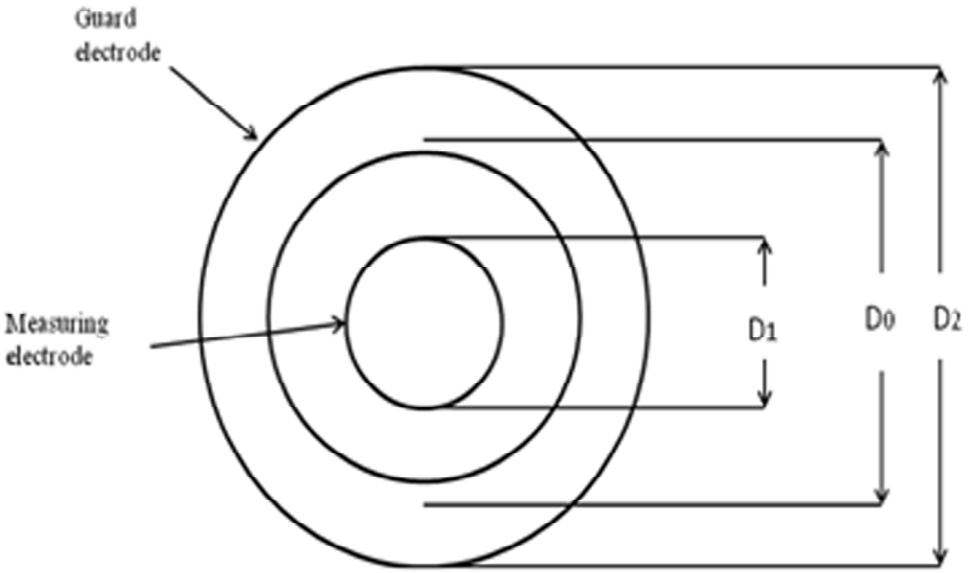
Figure 2: resistivity, volume current- time characteristics

2. MODELLING AND SIMULATION

As explained earlier that in this study designing of three electrodes measuring system and Cockcroft Walton voltage multiplier will be done.

2.1. Modelling of Three Electrode Test System

As it is shown in fig. (1) The voltage is applied across the high voltage electrode and the measuring electrode (guarded electrode) across which electrometer is connected is guarded by guard (ring electrode) electrode. The measuring electrode is placed under the insulation of guard electrode. The top view of three electrode testing system is:



As shown in above fig the measuring electrode is shielded with guard electrode .There will be a distance between guard electrode and measuring electrode and this distance is filled with air. Air gap is also taken in studies because there will be effect of this air gap into measuring of current across the system. The formula given for the measurement of capacitance is:

$$\text{Capacitance} = (K*R)/9*10^{9} \text{ farad}$$

Where K is dielectric constant =1.01; and R is radius

From the above formula the capacitances are

- Capacitance of guard electrode = 3.64PF
- Capacitance of main electrode = 1.402 PF
- Capacitance across air gap =. 056 PF

It was cleared that these capacitance are not distributed on a single point they are distributed all over the electrode. So after the calculation the total capacitance of electrode and air gap the distributed circuit of the three electrode model was designed and these total capacitances are distributed in the circuit.

Now this model is simulated in PSPICE A/D LITE. The distributed capacitances are shown in above figure. In this model the specimen under insulation of guard electrode, air gap, main electrodes are shown. As it was discussed above the capacitance is distributed all over the circuit and also there will be resistance in the circuit. As it is known that there is always some resistance present in the material. These resistances are distributed in form of parallel and series circuit. Here rc are the internal resistance of the capacitance.

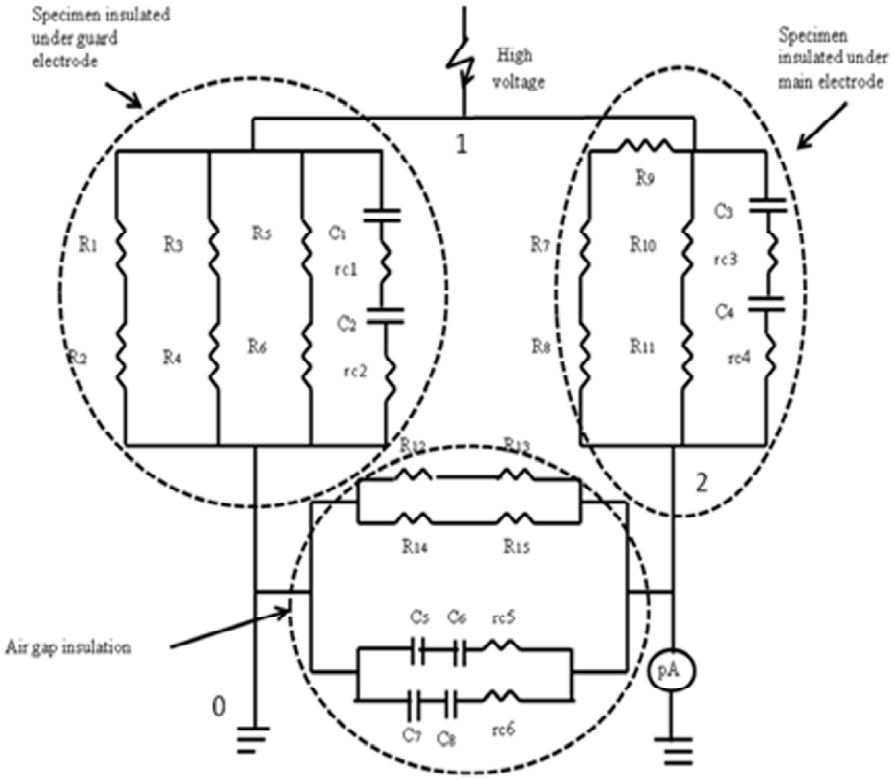


Figure 3: Designed model of three electrode testing system

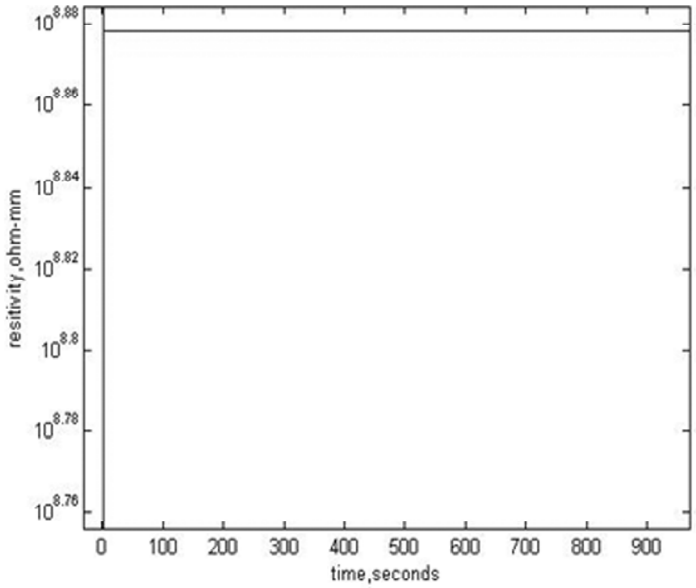


Figure 4: time- resistivity characteristics for a DC source

The time- resistivity characteristics in case of pure DC as voltage source are plotted in MATLAB software are illustrated below:

2.2. Modelling of Cock-croft Walton Voltage Multiplier

The cock-croft Walton voltage multiplier is an electric circuit used to produce high dc voltage from ac voltage. In this work a five stage Cockcroft Walton model was designed on PSPICE A/D LITE. As here we had connected five capacitances between ground and output terminal so this model is called a five stage CW circuit.

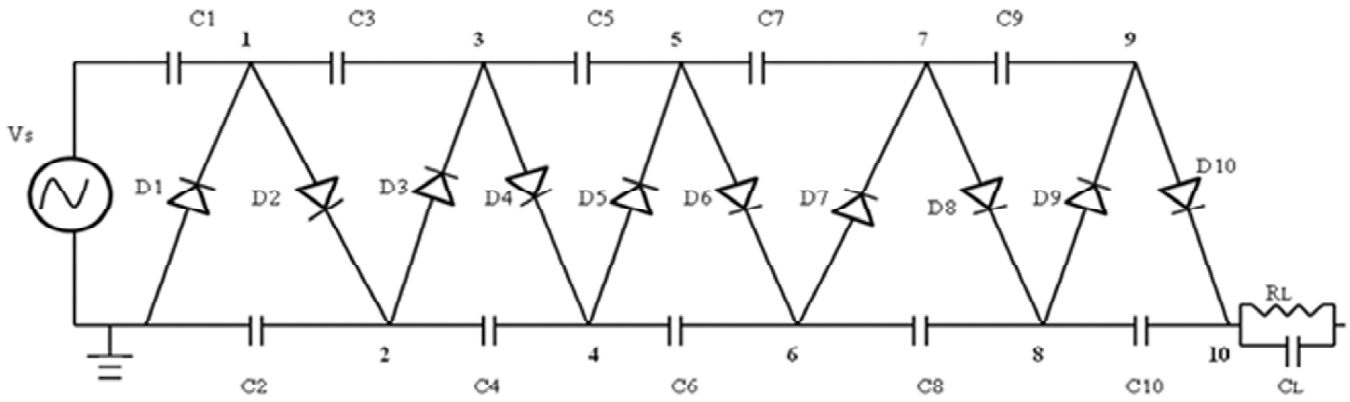


Figure 5: CW voltage multiplier

The output voltage is twice the peak input voltage multiplied by the number of stage N. Then output of the circuit is

VO = 2NVs

Vi = Applied voltage

Vs = Peak input voltage

Here Vi = 7kv so Vs = 9.898kv and N = 5 therefore

VO = 98.98kv

This cock croft voltage multiplier will be simulated on PSPICE. The output of Cockcroft model is displayed below:

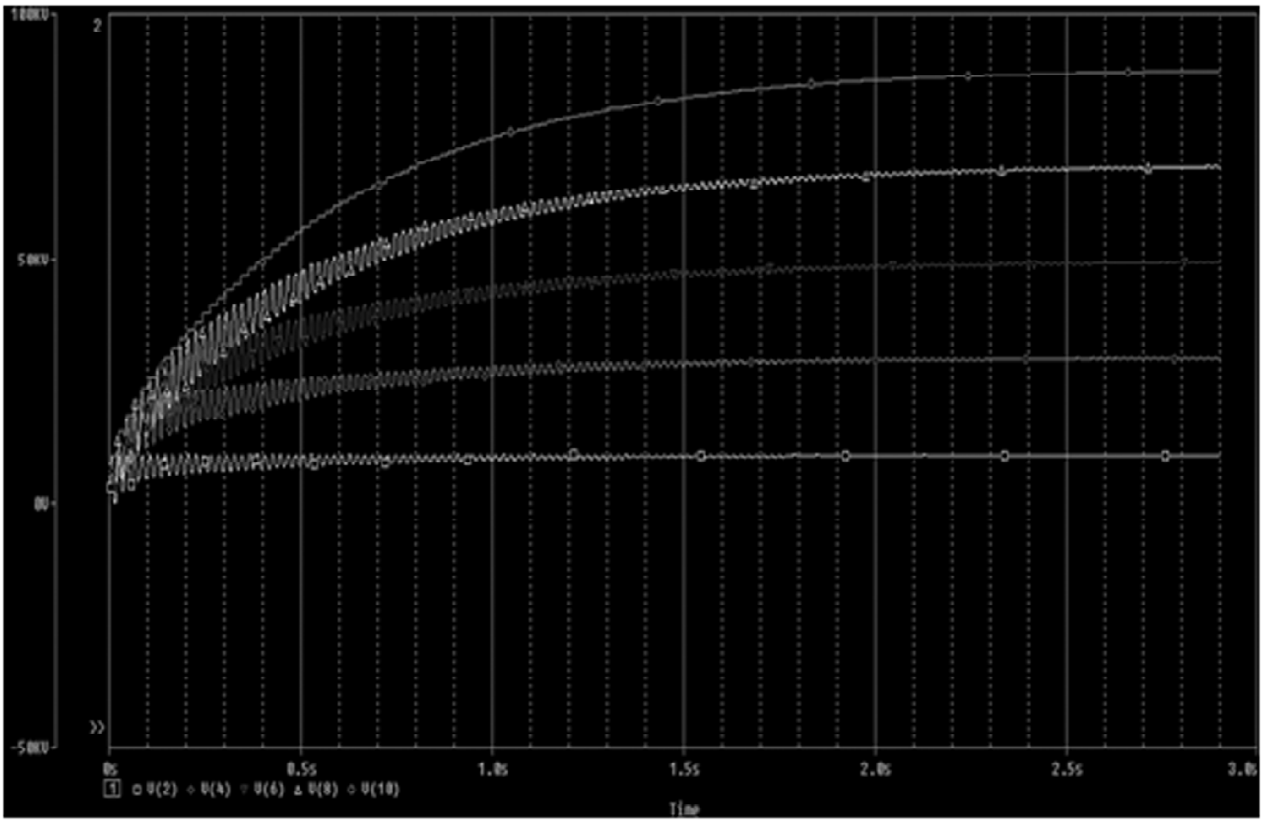


Figure 6: output of CW model

3. RESULTS AND DISCUSSION

When this output of Cockcroft model is used for powering the three electrodes setup the time –resistivity characteristics are presented below:

It is seen that from fig. (4) And (6) that the resistivity measurement is greatly affected by applied source voltage. Ripple in the output of the Cockcroft mode give high inaccuracy in measurement of resistivity. From earlier studies it was explained that the resistivity of sample increase with time .But there is a large effect of the voltage source applied to the three electrode system. From above figure it is shown resistivity of the material gradually raises up but also there are effects of ripple present in the time resistivity characteristic of material and thus it is cleared from this figure that there will be inaccuracy in resistivity measurement. It is also seen that there will be rising in the voltage level but the voltage level had not reached its output value of 99 kv because with larger number stages there is voltage drop across each of diode during charging period .

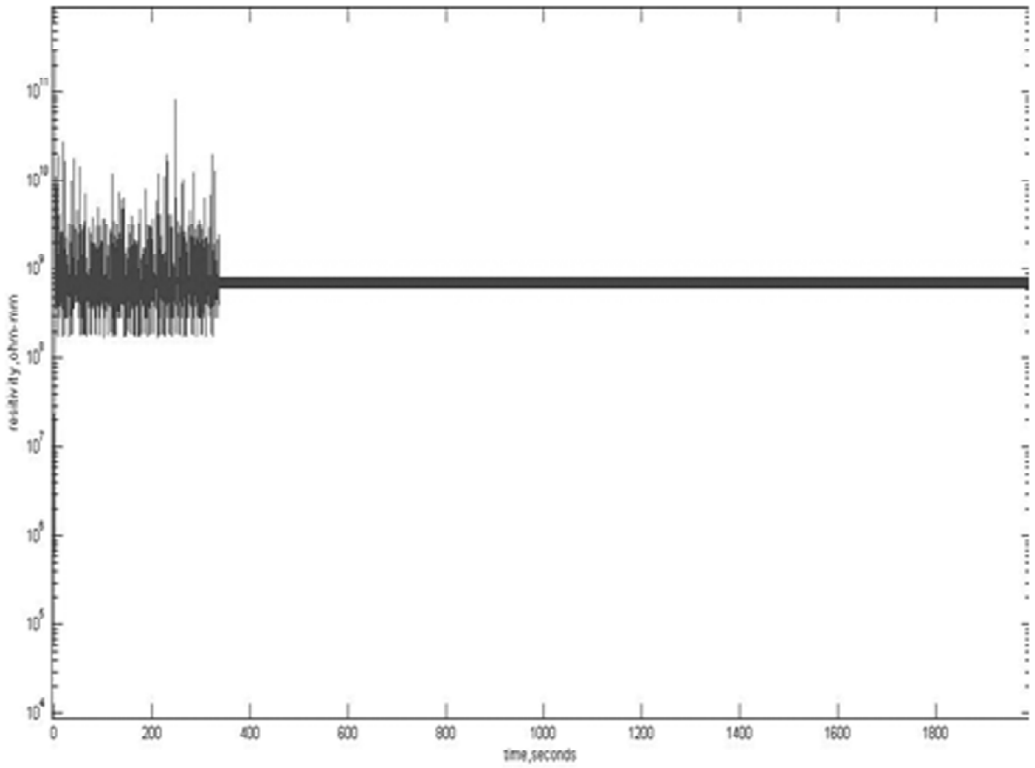


Figure 7: time-resistivity characteristics, cock-croft Walton model as voltage source

4. CONCLUSION

From all of the above studies it was cleared that for use of any insulating material in the high voltage application volume resistivity is an important aspect to determine the strength of the material. This paper attempt to design a three electrode model for precise measurement of volume resistivity. Here cock-croft Walton voltage multiplier was also designed and this model is used as voltage source .Further the effects of ripple present in voltage source are shown in resistivity measurement of material

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