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HIGH DC VOLTAGE GENERATION AT LOW COST USING CWM TECHNIQUE FOR LABORATORY

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Abstract

High DC voltage generation are widely used in research and industrial application. In the existing system transformer method is used for stepping up the voltage by reducing current level in case of AC system. To step up DC voltage the transformer cannot be used because of constant flux. So to step up DC voltage the voltage multiplier is preferred. As present scenario HVDC transmission line of bulk power transmission over a wide distance are very popular, it is required to testing of insulation material at laboratory level. In addition it is very costly. Cockcroft-Walton multiplier provide suitable high DC voltage source from a low input voltage i.e., 230V AC supply. Cockcroft-Walton multiplier constructed by ladder network of capacitor and diode for generation of high voltage. When number of stages of multiplier is increased, output of the Cockcroft-Walton Multiplier is also increased. In this paper 15 stages Cockcroft-Walton multiplier is used to generate high voltage. The Cockcroft-Walton technique is used for load of very minimum current. In this paper the cost effective and basic circuit structure is developed in Proteus v7.8 software and simulated its results, according to this implementation of hardware.

Index Terms: *Cascading circuit, Cockcroft-Walton multiplier, High voltage, Voltage divider, Greinacher Doubler Circuit.*

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1. INTRODUCTION

In general the voltage multipliers are used to get a high dc output voltage, DC-AC-DC inverters with step-up transformer. By using this, size and cost will increase. The Cockcroft-Walton cascade rectifier is an electronic circuit device which generates a high dc output voltage form a low input AC voltage. This Cockcroft-Walton cascade rectifier is used in x-ray machines, CRT, medical instruments and television. The design of the circuit involves Cockcroft-Walton multiplier, whose principle is based upon doubling the voltage for each stage. Thus, the output from a 15 stage voltage multiplier can generate up to 10KV. In this paper, the main focus has been given at the first stage on design, simulation and development of high voltage D.C. power supply on proteus v7.8 software. At the second stage, the D.C. power supply is constructed based on hardware implementation which can be utilized for various applications. The first stage of this work is used to study Cockcroft-Walton voltage multiplier circuits and to simulate the circuit for designed value of D.C. output voltage. Finally, prototype hardware is constructed in laboratory at the output D.C. Voltage of 10kV based on Cockcroft-Walton voltage multiplier circuits. Apart from the basic requirement, an effective and precise development of electrical circuit is required in order to generation of high voltage in laboratory.

2. COCKCROFT-WALTON MULTIPLIER

2.2 Working of CWM

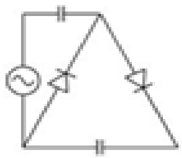

Fig-1: Greinacher Doubler Circuit

The 1st positive cycle of AC supply results in forward biased of diode D1 and capacitor C1 gets charge up to input voltage Vin. Reverse in polarity results in forward biased diode D2, capacitor C1 discharges and C2 charges up to Vin. Similarly in 2nd positive cycle diode D2 is reversed biased so voltage across capacitor C2 remains constant and capacitor C1 charges again. For next negative cycle D2 gets forward biased and capacitor C2 charges up to 2Vin.

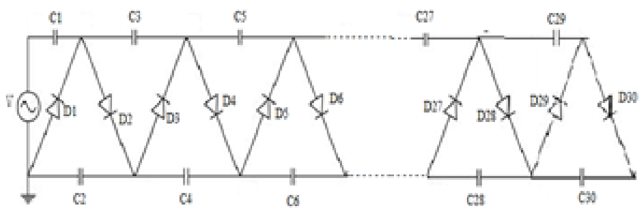

Fig-2: Cockcroft-Walton Voltage Multiplier Circuit

The above circuit is a standard Cockroft-Walton ladder network which steps up the mains voltage up to 10 kV. The idea is that, for each cycle of input voltage charge is transferred in forward direction from one row of capacitors to the other. When all the capacitors are fully charged, the voltage across each of them will be equal to the peak-to-peak voltage of the input supply.
Maximum output obtained for n stages is equal to 2*n*Vin.

Vout= 2*n*Vin

For Example:-

n=1, Vout= 2*Vin
n=5, Vout=10Vin
n=10, Vout=20Vin
n=15, Vout=30 Vin

The voltage across the capacitor C1, C3, C5…is keep on oscillates in same manner as supply varies therefore, this column is known as oscillating column. However the voltage across C2, C4, C6… remains constant hence this column is known as smoothing column.
Practically when load is connected to the circuit, the output voltage will never reach to 2nVmax. Also the output wave consist of ripple.

3. DESIGN CRITERIA OF MULTIPLIER CIRCUIT

3.1 Selection of Capacitor

The size of capacitors used in multiplier circuit is directly proportional to the frequency of input signal. The voltage rating of capacitor is determined by the type of multiplier circuit. The capacitor must be capable of withstanding a maximum voltage depending upon the numbers of stage used.

3.2 Selection of Diode

The maximum reverse voltage across the diode is called peak reverse voltage and the reverse voltage at each diode is 2Vm, so generally PIV rating of diode is 2Vm.When voltage is less than specific value, a small leakage current flow through device. When this voltage exceeds the limit, the device may fail.
The input voltage is 240V therefore peak input voltage is 240*1.414=339.36V then twice of it will give nearly 680V. So we have taken diode of 1000V for safety purpose. Each having reverse blocking resistance in the range of mega ohms.

3.3 Calculation of Output Voltage

When the load is not connected, the output voltage is obtained from

$$V_{out} = 2*N*V_{max} = 2*15*339.36 = 10.18\ kV.$$

At no load, the drop across capacitor and ripple content is zero.
When load is connected

$$V_{out} = (2 \times N \times V_{max}) - \Delta V - \delta V$$

Where, ΔV = drop across capacitor
δV = Ripple voltage

Table-1: Component Used For Circuit

Input Voltage	**240V**
Capacitor	**10nF**
Diode	**IN4007**
Number of stages	**15**

4. SIMULATION AND RESULTS

With the given value, one can simulate the model with a fixed rating of all elements. The voltage drop through the diode is neglected.

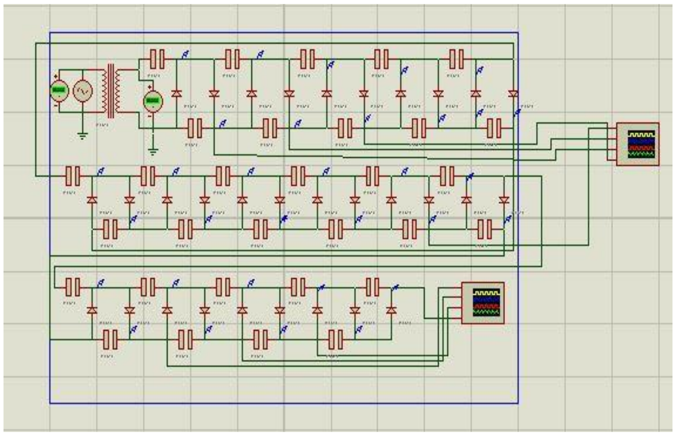

Fig-3: Circuit Arrangement in Simulation

Fig-3 shows the simulation arrangement. In this figure the digital oscilloscope is used for the visualization of voltage. Fig-5 shows the ripples of stage 1st, 2nd, 3rd and 10th represented in colours pink, blue, green and yellow respectively. From the graph it can be observed that ripples are increasing as the numbers of stages are increased.

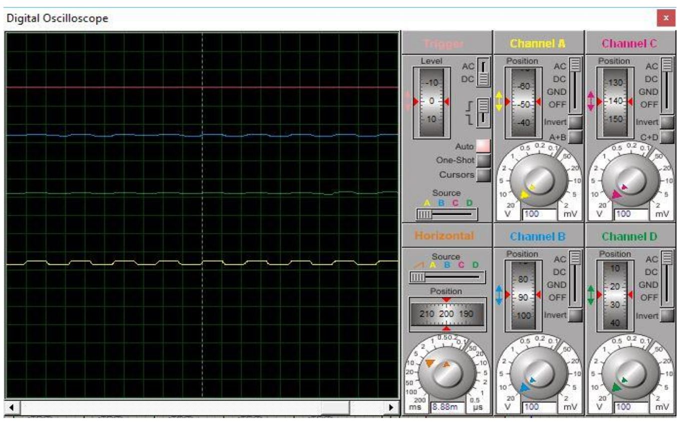

Fig-4: Voltage at Stage-1, 2, 3, 10

The ripple content in lower stage of fig.4 is higher as compare to upper stage. Similarly the same graph are plotted for stage 12th, 13th, 14th and 15th are as shown in fig-5.

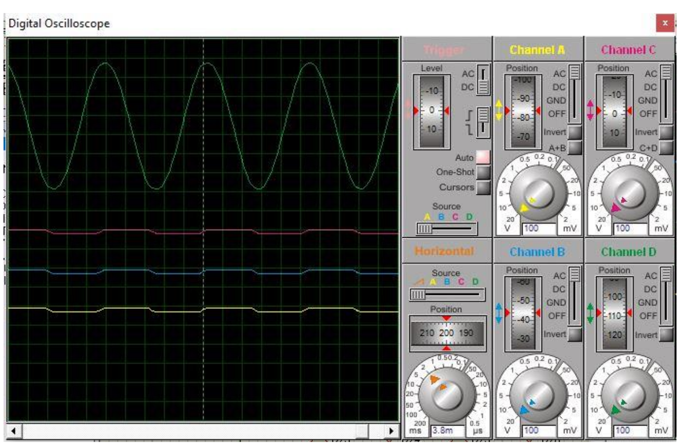

Fig-5: Voltage at Stage 12,13,14,15

The ripple content in stage 15 is higher as compared to lower stages because voltage double is not only maximum the voltage it also double the ripple content. It is difficult to estimate the ripple content in the actual hardware. The amount of ripple can be observed in fig.5 for stages 12th, 13th, 14th and 15th which are represented in colour yellow, blue, pink and green respectively .This voltage level can be used to withstand voltage test of insulating material.

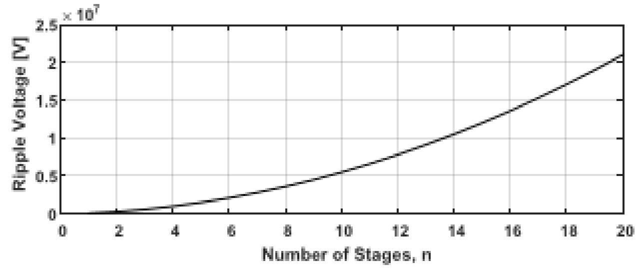

Fig-6: Variation of Ripple Voltage with Number of Stages

5. EXPERIMENTAL SETUP

In this experimental setup the capacitors of 10nF, 630V are used and IN4007 diodes are used which are cascading in Cockcroft-Walton multiplier circuit. The voltmeter of 10KV is used to measure high voltage, but it is mostly used for industrial purpose. Hence to measure high voltage 10:1 voltage divider is used. In this divider circuit, 10 resistances of 1Mohm are used. The indicating lamp is used to verify input AC supply is available or not. At output end the high value resistances are connect in series with ioniser terminal. After using the experimental setup, remember to discharge kit using earth electrode for safety reason, otherwise it may cause severe shock to operator.

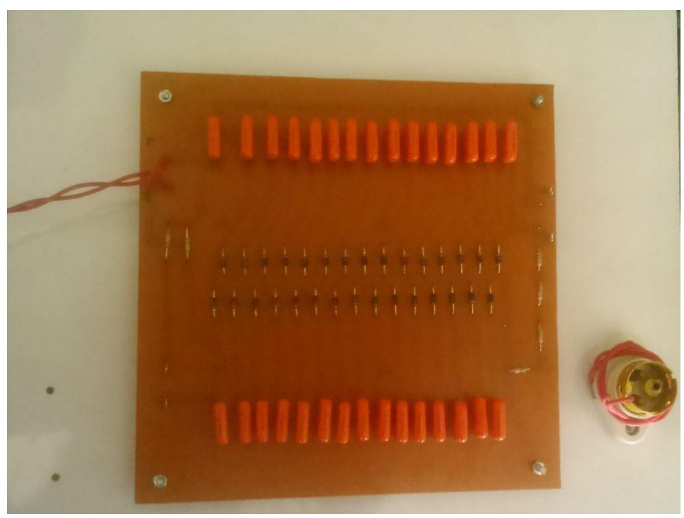

Fig-7: Prototype Setup of CWM Circuit

6. CONCLUSION

The main feature of CWM Design is to generate high DC voltage without using transformer. In this paper it accomplished a simulation waveform and analytical generation of high voltage for the laboratory purpose. Generation of High Voltage at laboratory up-to 10kV is designed and simulated for laboratory level. In future this work can be modelled with all non idealities and derivative effect of capacitor .The size of the complete high voltage circuit will be small and cost will be less. This small size circuit gives high voltage at the end of multiplier circuit. Because of the light weighted circuit it is portable. The CWM are generally used for load of low current.

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