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Design and Simulation of High Voltage DC Source by Using Cockcroft Walton Voltage Multiplier

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ABSTRACT: This paper proposes a design and operation principle of high voltage DC generator whose output is about 1.8KV, where as its input voltage is single phase 230V AC, by using capacitor and diode in ladder network based on Cockcroft-Walton voltage multiplier concept. Proposed generator is consist of four stages of Cockcroft-Walton voltage multiplier so the output obtained is approximately 1.8KV.

KEYWORDS: Cockcroft-Walton voltage multiplier

I.INTRODUCTION

High voltage DC power supply is widely used in research work(especially in field of applied physics) and in industry level the main application of high voltage DC power supply is in proof design of high voltage cables with relatively large capacitive load [9]. High voltage are generated for dielectric testing of high voltage equipments, voltages are increased up to several million volts but current are decreased to few milliamps. There are several application of DC high voltage, in the field of electrical engineering and applied physics such as electron microscope, X-rays, electrostatic precipitators, particle accelerator in nuclear physics, dielectric tester and so on[7].It is already known how transformer functions to increase or decrease voltages. It is also known that a transformer's secondary may provide one or more A.C. voltage output which may be greater or lesser than output voltage, when voltages are stepped up current decreases and when voltages are stepped down current increases. There is another method to increase voltage that is voltage multiplier. Voltage multiplier circuits are used primarily to develop high voltages where low current is required. The output voltage of Voltage multiplier circuits may be several times more than the input voltage. For this reason, Voltage multipliers are used in special applications where load is constant and has high impedance or where input voltage stability is not critical.

Providing the advantage of high voltage ratio, low voltage stress on the diodes and capacitors, compactness, and low cost the conventional Cockcroft-Walton voltage multiplier is popular option among high voltage DC applications[2]. Unlike transformers this method eliminates the requirement for the heavy core and the bulk of insulation/potting required. By using only capacitors and diodes, these voltage multipliers can step up relatively low voltages to extremely high values, while at the same time being far lighter and cheaper than transformers. The biggest advantage of such circuit is that the voltage across each stage of this cascade voltage multiplier is only equal to twice the peak input voltage, so it has the advantage of requiring relatively low cost components and being easy to insulate. One can also tap the output from any stage, like a multi-tapped transformer.

In this paper , the main emphasis has been given on design and simulation of high voltage DC generator by using Cockcroft-Walton voltage multiplier. The first stage of this work is to study Cockcroft Walton voltage multiplier circuit and to simulate the circuit for designed value of DC output voltage. The main components required for construction of high voltage DC generator are diodes and capacitors.

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II. COCKCROFT-WALTON VOLTAGE MULTIPLIER

Cockcroft Walton voltage multiplier is converter that converts AC or pulsing DC electrical power from a low voltage level to a higher DC voltage level. It is made up of a voltage multiplier ladder network of capacitors and diodes to generate high voltages. construction and basic operating principle of Cockcroft Walton voltage multiplier is explain below.

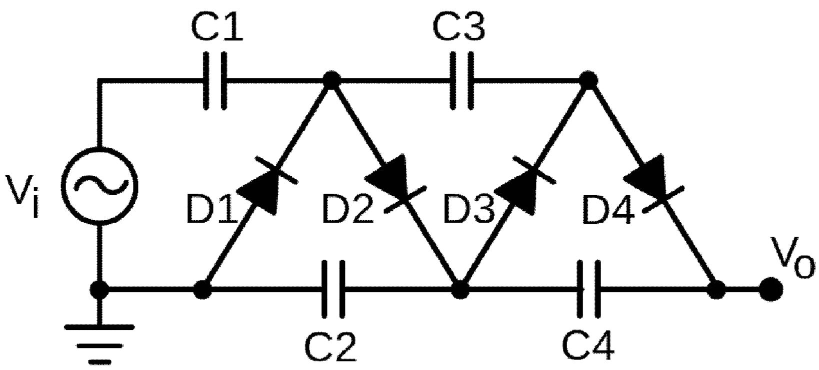

Fig. 1 Two stage Cockcroft Walton voltage multiplier

Figure 1 shows multi stage single phase circuit of Cockcroft-Walton voltage multiplier. As shown in figure it is consist of single phase voltage source 'Vi', a column of smoothing capacitors (C2,C4), a column of coupling capacitors (C1,C3), and a series connection of rectifiers(D1,D2,D3,D4).The number of stages is equal to the number of smoothing capacitors between ground and OUT, which in this case are capacitors C2 and C4. Working of Cockcroft Walton voltage multiplier is as follows,

1. Vi=Negative Peak:C_1 charges through D_1 to Vi at current I_{D1}
2. Vi=Positive Peak : Vi of input adds arithmetically to existing potential C_1, thus C_2 charges to 2 Vi through D_2 at current I_{D2}
3. Vi=Negative Peak:C_3 is charged to 2 Vi through D_3 at current I_{D3}
4. Vi=PositivePeak:C_4 ischarged to 2 Vi through D_4 at current I_{D4}.

Therefore voltage across all the capacitors is 2Vi, except for C1 where it is Vi only.The total output voltage will be 2nVi where n is the number of stages. Thus the multistage arranged in manner above enables to obtain very high voltage. Thus there will be equal distribution of stress on elements (diodes and capacitors).
The design of cascade voltage multiplier network is not complete, unless the ripple and regulation are not considered. The ripple voltage δv and voltage drop ΔV can be derived in cascade voltage multiplier circuit.
The ripple factor=$\delta V = (I/f *C) \{n (n+1)/2\}$
Where I = load current in amperes, f = frequency in Hz,C= Capacitance in farad, n1 = No. of capacitor = 2×No. of stages = 2n (n = No. of stages).
So that,
Voltage drop $\Delta V = (I/fc) (2/3 n^3 + n^2/2-n/6)$
Regulation of voltage = V/2nVi,
Ripple (%) = $\delta V/2n$ C

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III.DESIGN CRITERIA

Capacitor Selection- The size of capacitors used in multiplier circuit is directly proportional to the frequency of input signal Capacitor used in off line, 50Hz application is usually in the range of 1.0 to 200 microfarad [5]. 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 staged used. A good thumb rule is to select capacitor whose voltage rating is approximately twice that of actual peak applied voltage[1].We use here capacitor of 100 microfarad and 400V.

Diode selection-The maximum reverse voltage across a diode is called peak inverse voltage.In multiplier circuit reverse voltage seen by each diode is twice ofinput voltage (2Vi,).So the device must be selected with reverse voltage (VRRM) setting of at least 2 Vi,. The voltage source used in this work provides an AC voltage equal to 230 V, therefore, the diodes in the voltage multiplier must have peak input voltagegreater than 460V. The diodes used in proposed multiplier is IN4007 have PIV greater than 1000V, thus there will be no problem of junction break-down [6].

IV.SIMULATION AND RESULTS

The simulation work has been done by using CIRCUITLAB. The figure 2 represents circuit diagram for simulation and figure 4 represents simulated results.

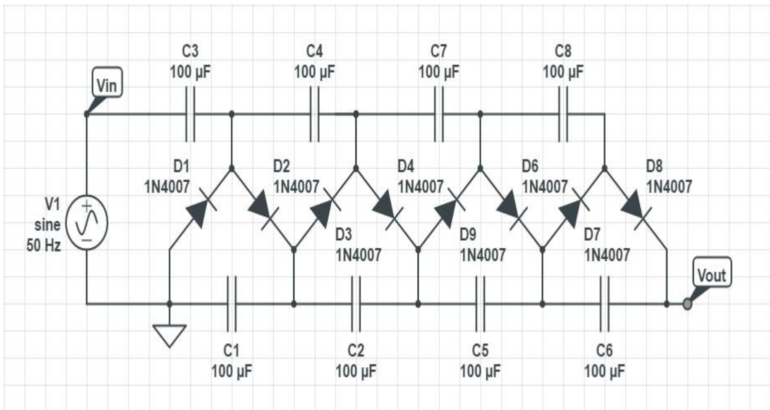

Fig. 2 : Simulation model of proposed four stage Cockcroft Walton Voltage multiplier

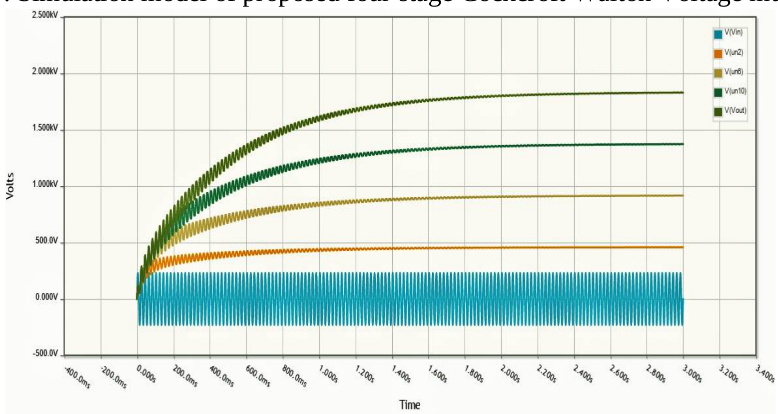

Fig. 3: Output of proposed four stage Cockcroft Walton Voltage multiplier

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V.CONCLUSION

The following conclusions could be made from this work:-

1. From the simulation, it is noted that a design for high voltage D.C. power supply at 1.8 kV output has been proposed and developed.
2. This kind of high voltage DC power supply test set is of simple control, low cost, portable due to its light weight robust and high reliability.
3. Different magnitude of High voltage DC output can be taken from different stages without changing the input voltage.
4. The project can be enhanced to generate the highvoltage DC up to the range of 30-50 KV by increasing the number of stages thus it will be very useful for field testing of HV cables of different voltage grade, as a DC source for impulse charging unit of impulse generators.

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