High Voltage Generation by using Cockcroft-Walton Multiplier

Nikhil M. Waghamare, Rahul P. Argelwar

Abstract— **In this paper present High Voltage DC generation by using Cockcroft-Walton Multiplier are purpose. This section is providing continues input current, with a low ripple cascading of diode and capacitor. Cockcroft-Walton multiplier provide suitable high DC voltage source from a low input voltage i.e, 230V AC supply which is rectified by using half wave rectifier circuit. Cockcroft-Walton multiplier constructed by ladder network of capacitor and diode for generation of high voltage. When number of stages of multiplier are increase output of the Cockcroft-Walton Multiplier is also increasing. In this paper 8 stages Cockcroft-Walton multiplier are use to generated high voltage. In this paper transformer method are eliminated therefore cost and size of Cockcroft-Walton multiplier are reduce. Other specifications considered carefully while designing multiplier and components must be used based on size consideration for expected load current and expected output voltage. A prototype was designed and experimental result was tested and demonstrate was purpose.**

Index Terms—**Cascading circuit, Cockcroft-Walton multiplier, High voltage, Voltage divider.**

I. Introduction

High voltage generation DC power are widely used in the research work and industry level [2]. It is also used in the scientific instrument, TV sets and CRTs, Oscilloscope, x-ray and photomultiplier tubes are used in nuclear industry for detection of radiation. The method stepping up the voltage is commonly done by a step-up transformer. The output of the secondary of the step up transformer increases the voltage and decreases the current and losses occurred in the transformer is more this is for case of AC system. But in DC system transformer are not in used because of the constant current in case of DC system and hence, constant flux which is not link primary to secondary and therefor transformer method are eliminated in the case of DC. For stepping up the voltage in DC system multiplier method are prefer. Multipliers are primarily used to develop high voltages where low voltage at the input side. In this section describes the concept to develop high voltage DC from a single phase AC ie. 230 Volt, 50 Hz system. Because of the safety consideration it was restricts the multiplication factor to 8 such that the output would be within 1KV. The design of the circuit involves Cockcroft-Walton multiplier, whose principle is to go on doubling the voltage for each stage. Thus, the output from an 8 stage voltage multiplier can generate up to 1KV.

Manuscript received Feb, 2015.

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II. Cockcroft-Walton Multiplier

The Cockcroft-Walton is a voltage multiplier 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. Unlike transformers, this method eliminates the requirement for the heavy core and the bulk of insulation/potting required. Using only capacitors and diode in cascading network 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 [3].

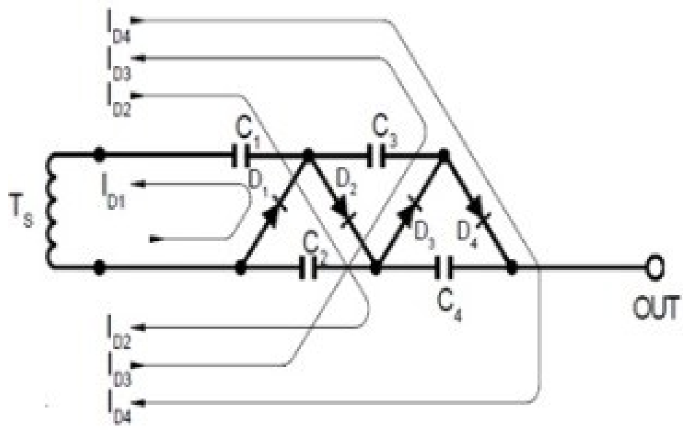

Fig -1: Cockcroft-Walton multiplier

Where,

$C_1, C_2, C_3 \ldots C_n$= Capacitor ,

$D_1, D_2, D_3 \ldots D_n$ =Diode,

And $I_{D1}, I_{D2}, I_{D3}, \ldots I_{D1}$ =Diode Current.

The advantages of Cockcroft-Walton Multiplier circuit are low in cost, small in size and can be easy to insulate the circuit.

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Another advantage of voltage of multiplier circuit is its peak to peak voltage at each stage will be double.

Consider operation of two stages Cockcroft-Walton multiplier is shown in figure1.

1) When TS is negative, then Capacitor C1 charges through Diode D1 to Vmax.

2) When Ts is positive, then Vmax add arithmetically existing potential C1, thus C2 charges to 2Vmax through D2.

3) Again Ts is negative, C3 charge 2Vmax through Diode D3.
4) Again Ts is positive, Capacitor C4 charge Diode D4 to 4Vmax.
Therefor output of multiplier = Vmax * N

Where,

N = Number of stages.

Designing of Multiplier circuit most commonly half wave circuits are used. And because of the multiplier circuit, high voltage develop at the output side of the Cockcroft-Walton multiplier circuit.

Design of Cockcroft voltage multiplier is simple Careful consideration of all component parameters is the only way to insure both reliable and predictable circuit performance.[2]
Ripple of the n-stage multiplier will be,

$$2\,\delta V = \frac{I}{f}\left(\frac{1}{Cn}+\frac{2}{Cn-1}+\frac{3}{Cn-2}+\ldots\frac{n}{C1}\right)$$

OR

$$\delta V = \frac{I}{2f}\left(\frac{1}{Cn}+\frac{2}{Cn-1}+\frac{3}{Cn-2}+\ldots\frac{n}{C1}\right) \quad ...(1)$$

from equation (1) it is clear that, multistage circuit the lowest capacitors are responsible for most ripple and it is, therefore, desirable to increase the capacitance in the lower stages.

Therefore, capacitors of equal value are used in practical circuits i.e., Cn = Cn – 1 = ... C1 = C and the ripple is given as,

$$\delta V = \frac{I}{2fC}\,\frac{n(n+1)}{2} = \frac{In(n+1)}{4fC} \quad ....(2)$$

The second quantity to be evaluated is the voltage drop ΔV which is the difference between the theoretical no load voltage $2nVmax$ and the onload voltage.

Voltage drop $\Delta V = (I/fc)\,(2/3\ n^3 + n^2/2 - n/6)$ Regulation of voltage = V/2nEm,

Ripple (%) = δV/2nEm

III. Ripple Voltage

Ripple voltage is the magnitude of fluctuation in DC output voltage at a specific output current (assuming AC input voltage and AC input frequency are constant). A close approximation for series half-wave multipliers can be expressed as:

$$V_{RIP} = I(N2+N/2)/8FC$$

Example: Calculate the ripple voltage of a 6 stage multiplier with 1000pF capacitors, 50kHz input frequency (sine wave), 1mA DC output current, 20kV DC output voltage:

$$V_{RIP} = (1*10^{-3}(62+6/2))/8*50000*(1*10\text{-}9))$$
$$V_{RIP} = 97.5\text{Vp-p}$$

IV. Design and Test Setup

For the application of various equipment in 8 stages Cockcroft-Walton multiplier designed with a multiplication of peak to peak voltage ie. N * Vmax at a last stages of Cockcroft-Walton multiplier.

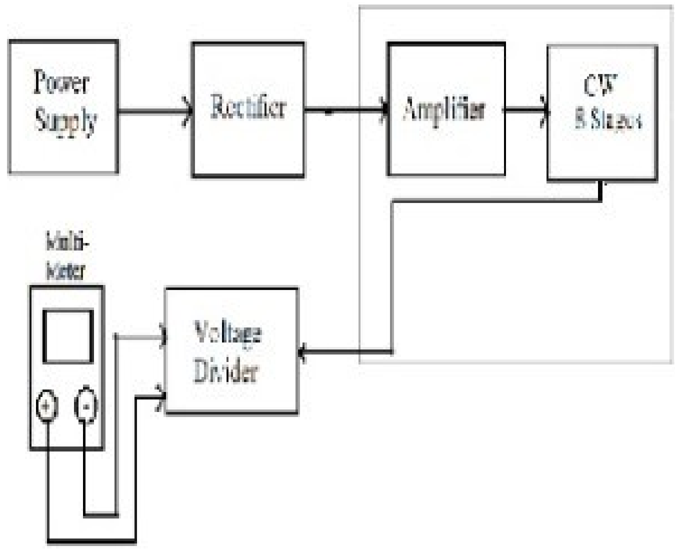

Fig -2: Block diagram of test setup

A voltage divider is used for dividation of voltage with a very high resistance. The two main components are used in the setup as shown.in figure 2. They are amplifier and 8 stages voltage multiplier. Amplifier is used to amplify the DC input signal and 8 stages Cockcroft-Walton multiplier is used to step up DC voltage into a high voltage at 1KV or 1000 Volt

from 230 V AC voltage which rectified and convert in AC-DC. Voltage adjuster are used to adjust the voltage and

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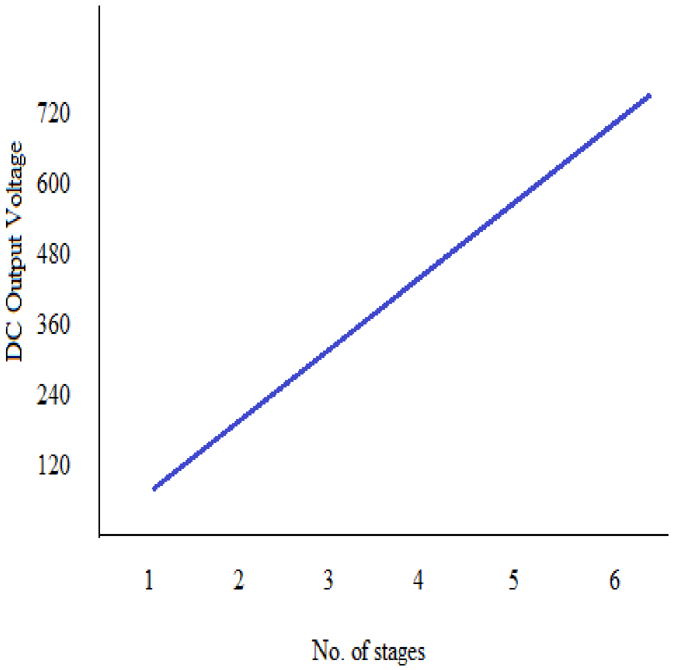
amplifier end for supplying to the Cockcroft-Walton multiplier circuit. The operation of a multiplier is to be effectively multiply the peak to peak voltage by number of stages and convert into high voltage. The voltage at the 1st stage of multiplication is 120V DC. The voltage at the 8th stage of multiplication is 960VDC. In theoretical consideration these values were somewhat reduced because of losses in the diodes, capacitances and leakage currents of the diodes, component tolerances of the diodes and capacitors, etc. The voltage divider in which high value of resistance are use. In the actual prototyped circuit, we used 10 Mohm resistors because of availability in the experiment [1]. Components are used in prototype model Capacitor and Diode in cascade network, and operational amplifier (741).

In figure 3. Shows that if the output voltage of a Cockcroft-Walton multiplier is increase according to number of stages. In theoretically at first stages output is 120 peak to peak voltage and at the end of 8 stages the peak to peak voltages is 960 volt. Developed high voltage D.C. Power supply based on Cockcroft-Walton voltage multiplier circuit. This circuit is a unique circuit which is developed for the special applications like field testing of high voltage cables, prime D.C. voltage. Construction of multiplier circuit is simple in nature because, it is cascading of diodes and capacitors which is low cost component this is the advantages of multiplier circuit and it also required less insulation from last stages of the voltage multiplier circuit

Fig -3: Characteristics of output voltage and number of stages

V. Capacitor And Diode Selection

While designing multiplier and capacitor and diode must be used based on size consideration for expected load current and expected output voltage. Range of capacitor is commonly 1 microfarad to the 250 microfarad, whose voltage rating is usually twice that of actual peak to peak voltage. For example a capacitor which will see a peak voltage of 2Vmax should have a voltage rating of approximately 4Vmax [2].



For selection of diode, parameter must be consider. When the maximum reverse voltage across a diode that is known as peak inverse voltage. This peak reverse voltage are available in each diode therefor for selection of diode rating which is 2 * Vmax for a safety purpose.

VI. Conclusion

The Cockcroft-Walton Multiplier surface mount and design in which high voltage generate without use transformer is a beauty of the high voltage Cockcroft-Walton circuit. There for size of the complete high voltage circuit is small and cost is also less. This small size circuit gives high voltage at the end of multiplier circuit. Because of the light weighted circuit it is portable it gives high reliability. Construction of whole circuit is simple and robust in nature. This multiplier circuit is useful for a scientific instrument, TV sets and CRTs, Oscilloscope, x-ray and photomultiplier tubes and field testing of HV cables.

VII. Experimental Setup

In this experiment used 1 to 250 microfarad capacitor are used and IN 4007 Diode which is cascading in the Cockcroft-Walton multiplier circuit. Digital multimeter which is used to measure the High Voltage at the end of multiplier circuit.

Fig -4: Prototype setup of Cockcroft-Walton multiplier circuit

Acknowledgment

In this work supported by professor Rahul P. Argelwar sir Dept. of Electrical Engineering (E&P),Amravati University, India.

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