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Analysis of Cockcroft-Walton Voltage Multiplier

Amol R. Thakare*, Senha B. Urkude, Rahul P. Argelwar****

* Department of Electrical Engineering, DES's COET, Dhamangaon RLY
** Department of Electrical Engineering, DES's COET, Dhamangaon RLY
*** Department of Electrical Engineering, DES's COET, Dhamangaon RLY

***Abstract*- In this paper a high D.C. voltage is based on Cockcroft-Walton cascade rectifier, without using transformer. The purpose of this paper is to get an output of a high dc voltage by applying input as an low dc voltage. It provides continuous input current to load with low ripple voltage and current. Moreover, based on the n-stage CW voltage multiplier, the proposed converter can provide a suitable dc source for an n + 1-level multilevel inverter. In this paper, control strategy employs two independent frequencies, one of which operates at high frequency while the other one operates at relatively low frequency.**

Index Terms- Capacitor, Cockcroft-Walton voltage multiplier, Diode.

I. Introduction

Ingeneral 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 increases. 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 and television. This is made up of ladder network of capacitors and diodes. In this paper, the capacitor and diodes are connected across each other to get a high dc output voltage in number of n-stages. The advantage of the Cockcroft-Walton cascade rectifier is that the output across each stage is equal to twice the input AC voltage. It requires low cost components and easy to insulate and possibility of taking output from any stage, like a multi tapped transformer.

II. Generation of High D.C. Voltage

Generation of high dc voltages is mainly required in research work in the areas of pure and applied physics. Sometimes, high direct voltages are needed in insulation tests on cables and capacitors. [7] There are various applications of high dc voltages in industries, research medical sciences etc. The most efficient method for generating high dc voltage is by the process of rectification employing voltage multiplier circuits. Electrostatic generators have also been used for generating high D.C. voltages. [8] The ac supply to the rectifier tubes may be of power frequency or may be of audio frequency from an oscillator. [7] The A.C. supply to the rectifier tubes may be of power frequency or may be of audio frequency from an oscillator. The latter is used when a ripple of very small magnitude is required without the use of costly filters to smoothen the ripple.

III. Cockcroft-Walton Voltage Multiplier

The Cockcroft-Walton voltage multiplier convert pulsating low ac input voltage to the high dc output voltage. Generally the Cockcroft-Walton voltage multiplier is made up of ladder network of capacitor and diodes. By using only capacitor and diodes the Cockcroft-Walton voltage multiplier can generate very high dc voltage from low level ac input, while at the same time being far lighter and cheaper than transformers. The output of the high step-up converter with Cockcroft-Walton voltage multiplier can be used for supplying AC loads.

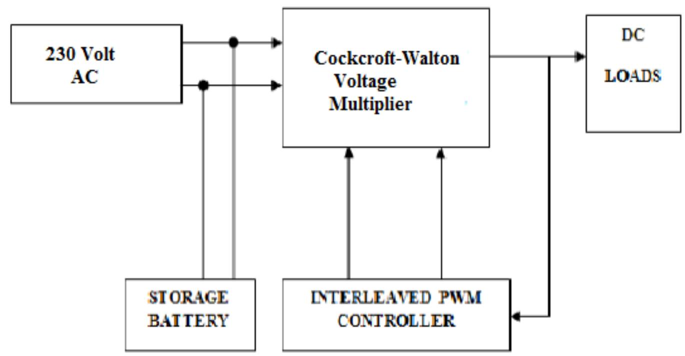


Fig.Block Diagram of Proposed System

The block diagram of proposed system is shown in the Fig. 1. In this proposed system we provide a 230 volt AC supply to the ladder network of capacitor and diodes (i.e. Cockcroft-Walton voltage multiplier). The dc output of the source can store in the storage battery. The high step-up converter with Cockcroft-Walton voltage multiplier is controlled by using an interleaved PWM controller. The low voltage output of the source is step-upped by using the high step-up converter with Cockcroft-Walton voltage multiplier.

The conventional n-stages Cockcroft-Walton voltage multiplier is shown in Fig. 2. In this Cockcroft-Walton voltage multiplier each stage is containing two capacitors and two diodes. Theoretically, an *n*-stage Cockcroft-Walton voltage multiplier dc output voltage is equal to the value of $2n$ times of the magnitude of the ac voltage source. Due to non-ideal characteristics of the circuit components the dc output voltage is practically less than the theoretic value [1], [2], [3]. Some drawback of CW multiplier is, under heavy-load condition, the CW multiplier intrinsically presents not only poor output voltage regulation but also high output ripple with line frequency. In some applications, for getting higher voltage gain we use line frequency transformers with high step-up ratio to cooperate with the CW voltage multiplier.

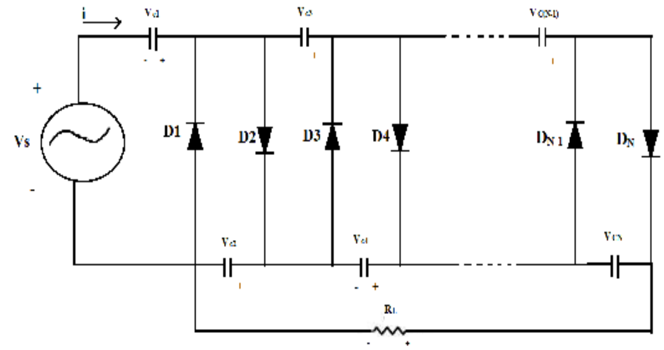
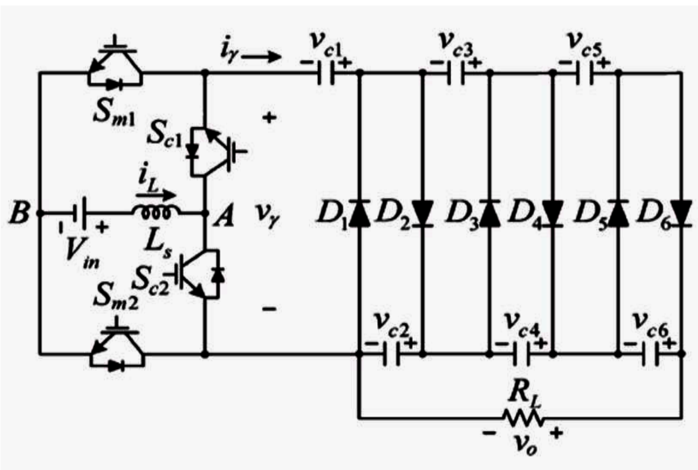


Fig2: n-stage Cockcroft-Walton voltage multiplier

IV. CIRCUIT DESCRIPTION



The circuit diagram of a 3-stage CW voltage multiplier is as shown in the figure. This converter has a four bidirectional switches which are sub-divided into two groups [S_{m1}, S_{m2}] and [S_{c1}, S_{c2}]. The converter is energized by the boost inductor which connected in series with the source. Each converter has an two independent frequency. One of the frequencies applies to two of the four switches to perform PFC function, and the other applies to the rest of the two switches to determine the output frequency of the matrix converter. [4]

For simplifying the circuit operation, consider three stages Cockcroft-Walton voltage multiplier which used in AC-DC converter. Before analyzing, some assumptions are made.

1] All the circuit elements are ideal and no power loss in that.

2] All the capacitors are sufficiently large.

3] Under reasonable load condition the voltage drop and ripple can be ignored.

4] Under steady state condition the proposed converter always in conduction mode.

According to the second assumption, each capacitor voltage in the CW voltage multiplier is given by:

$$Vck = \begin{cases} vc & for \quad k = 1 \\ 2vc & for \quad k = 2,3,4 \dots n \end{cases}$$

Where V_{ck} is the voltage of the k_{th} capacitor, vc is the maximum peak value of terminal voltage of the CW voltage multiplier under steady-state condition, and $N = 2n$.[4]

The Cockcroft-Walton voltage multiplier is based on four different types of modes.

Mode 1: In first positive half cycle in mode 1 switches S_{m1} and S_{c1} are turned on and switches S_{m2} and S_{c2} are turned off. The boost inductor is get charged by the V_{in} which is the source of 230 volt AC. In first mode the even groups capacitors C_6 C_4 C_2 are get discharged and supply to the load. And the odd group capacitors C_5 C_3 C_1 are not in conduction

Mode 2: In mode 2 Sm2 and Sc1 Switches are turned on while Sm1 and Sc2 Switches are turned off. And the current i_γ is positive. In this case boost inductor (L_s) and input V_{in} dc source are in series and they transfer boosted energy to the CW voltage multiplier through different even diodes. In this mode 2 diode D6 is conducting, and even-group capacitors C6, C4, and C2 are get charged, and the odd-group capacitors C5, C3, and C1 are discharged. And in this way similarly diode D4 is conducting mode and capacitor C4 and C2 are get charged while C3 and C1 are get discharged, in this case C6 supplies load current, and C5 is floating. Then again diode D2 is conducting. Thus, C2 is charged, C1 is discharged, C6 and C4 supply load current, and C5 and C3 are not in conduction.

Mode 3: Now in another next half cycle in mode 3 Sm2 and Sc2 Switches are turned on, and Sm1, Sc1, and all CW diodes are turned off. The boost inductor L_s is get charged by the V_{in} dc source, the even group capacitors C6, C4, and C2 supply the load current, and the odd-group capacitors C5, C3, and C1 are not in conduction.[5]

Mode 4: In a mode 4 Sm1 and Sc2 Switches are turned on and Sm2 and Sc1 Switches are turned off. But in this case current $i_\gamma$is negative. Now the boosted voltage is "-V_γ" and it transfer energy to the CW voltage multiplier through odd diodes. In this mode diode D5 is conducting. And the even-group capacitors supplies load current except capacitor C6, and the odd-group capacitors C5, C3, and C1 are charged. Then D3 is conducting and C2 is get discharged while C3 and C1 are charged, C6 and C4 supply load current, and C5 is not in conduction. Similarly D1 is conducting and C1 is charged, all even capacitors supply load current, and C5 and C3 are not in conduction.

V. CONCLUSION

In this seminar, a high voltage based on the Cockcroft-Walton (CW) voltage multiplier without using a transformer has been presented to obtain a high voltage gain. Since the voltage stress on the active switches, diodes, and capacitors is not affected by increasing the number of cascaded stages, power components with the same voltage ratings can be selected. The Control strategy employs two independent frequencies, one is operates at high frequency to minimize the size of the inductor (L_s) while the other one operates at relatively low frequency according to the desired output voltage ripple. In future we can increase number of n-stages the high dc output voltage can be converted to AC voltage.

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AUTHORS

First Author – Amol R. Thakare, B.E. Pursing ,Department of Electrical Engineering, DES's College of Engineering &Technology, Dhamangaon (RLY), Maharshtra, India.
Email Id- mlthakare5gmail.com

Second Author – Sneha B. Urkude, B.E. Pursing ,Department of Electrical Engineering, DES's College of Engineering &Technology, Dhamangaon (RLY), Maharshtra, India.
Email Id- snehaurkude19gmail.com

Third Author – Prof.Rahul P. Argelwar, M. Tech Pursing ,Department ofElectrical Engineering, DES's College of Engineering &Technology, Dhamangaon (RLY), Maharshtra, India.