



Cascade Cockcroft –Walton Voltage Multiplier Applied to Transformer less High Boost Converter for n-Stage

Dr.K.Umadevi, Aswini B, Karthika V, Madhuvathani C, Mohanapriya M

Department of Electrical and Electronics Engineering, Muthayammal Engineering College, (Autonomous), Rasipuram, Tamil Nadu, India

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ABSTRACT: This paper presents a high step-up dc- dc converter based on Cockcroft Walton (CW) voltage multiplier without a step up transformer. This provides a continuous input current with low ripple, high voltage ratio and low voltage stress on the switches, diodes and capacitors. This converter is suitable for applying to low input level dc generation systems. Based on the n-stage CW voltage multiplier, this converter can provide a suitable dc source for an (n+1) level multilevel inverter.

In this paper, the control strategy employs two independent frequencies, one of which operates high frequency to minimize the size of the inductor, while the other one operates at relatively low frequency according to the desired output voltage ripple. Here, 3 stage and 5 stage Cockcroft Walton (CW) voltage multiplier was compared for its maximum output voltage, maximum output current, settling time at constant input voltage.

KEYWORDS: Cockcroft Walton (CW) voltage multiplier, high voltage ratio, multilevel inverter, step up dc-dc converter.

I. INTRODUCTION

In the recent years, the need of electrical energy is constantly growing. Consequently, researchers made efforts on renewable energy applications for natural energy consumption. Among various renewable energy sources, the photo voltaic (PV) cell and fuel cell are the alternative choices. The output voltage of PV cells and fuel cells are very low in level. Thus, a high step up dc-dc converter is designed in power converter systems.

In conventional boost dc-dc converter can be provide a very high voltage gain by using an extremely high duty cycle. Particularly, parasitic elements associated with the inductor, capacitor, switch and diode cannot be ignored and their effects reduce the theoretical voltage gain.

Many step up dc-dc converters have to obtain high voltage ratios without extremely high duty cycle by using isolated transformers or coupled inductors. In this, voltage fed type sustains high input current ripple. In order to achieve high voltage gain, the leakage inductance of the transformers is increased due to high number of winding turns. Consequently, the switch is burdened with high voltage spikes across the switch at the instant of turn off. Thus, higher voltage – rating switches are required. The design of high frequency transformers, coupled inductor is complex compared with conventional boost dc – dc converter.

By cascading diode-capacitor or diode-inductor modules provide not only high voltage gain but also simple and robust structures. But the voltage stress on each individual switch and passive element depends on the number of stages.

In this project, a high step up converter based on the CW voltage multiplier replacing the step up transformer with boost type structure, it provides higher voltage ratio than of the conventional CW voltage multiplier.

This proposed converter operates in continuous conduction mode, so that the switch stresses, switching losses and electro magnetic interference (EMI), noise can be reduced.

II. n-STAGE CW VOLTAGE MULTIPLIER

Fig.1 shows the converter with n – stage CW voltage multiplier, which is supplied by a low level dc source ,such as battery, PV module, or fuel cell sources. This converter consists

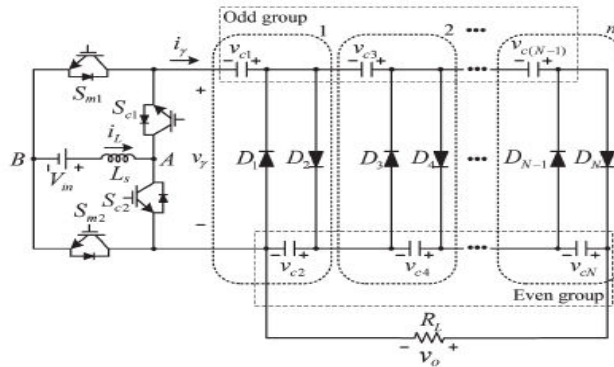


Fig.1 n- stage CW voltage multiplier

of one boost inductor L_s , four switches (S_{m1} , S_{m2} , S_{c1} & S_{c2}) and one n- stage CW voltage multiplier. S_{m1} & S_{m2} operate in complementary mode and S_{c1} & S_{c2} operate in complementary mode. The operating frequencies of S_{m1} & S_{c1} are defined as f_{sm} & f_{sc} respectively. Where, f_{sm} is modulation frequency, f_{sc} is alternating frequency. Theoretically, two frequencies should be as high as possible so that smaller inductors and capacitors can be used in this circuit. In this paper, f_{sm} is set much higher than f_{sc} and the output voltage is regulated by controlling the duty cycle of S_{m1} & S_{m2} . While the output voltage ripple can be adjusted by f_{sc} . In which s_{c1} and s_{c2} are used to generate an alternating source to feed into the CW voltage multiplier and s_{m1} and s_{m2} are used to control the inductor energy to obtain a boost performance .This will increase the complexity and cost of the converter because an isolated circuit is necessary to drive the power semiconductor switches.

The CW voltage multiplier is constructed by cascade of stages with each stage containing two capacitors and two diodes. In n-stage CW voltage multiplier there are $(N= 2n)$ capacitors and diodes. For convenience, both capacitors and diodes are divided into odd group and even group.

III. THREE STAGE CW VOLTAGE MULTIPLIER

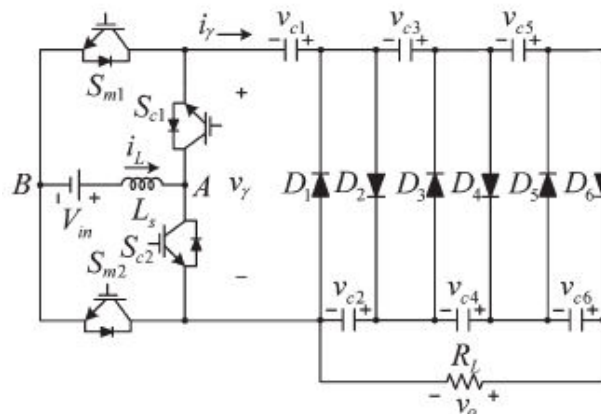


Fig.2 Three stage CW voltage multiplier

This circuit diagram shows the three stage CW voltage multiplier. In order to simplify the analysis of circuit operation, the proposed converter with three stage CW voltage multiplier is used. Before analyzing, some assumptions are made as follows.

1. All of the circuit elements are ideal, and there is no power loss in the system.



2. When a high frequency periodic alternating current is fed into the CW circuit and all of the capacitors in the CW voltage multiplier are sufficiently large, the voltage drop and ripple of each capacitor voltage can be ignored under a reasonable load condition. Thus the voltages across all the capacitors are equal, except the first capacitor whose voltage is one half of the others.
3. The proposed converter is operating in CCM mode and in the steady state condition.
4. the inductor transfers the storage energy to the CW circuit, only one of the diodes in the CW circuit will be conducted.
5. Some safe commutation states are ignored.

IV. MODES OF OPERATION

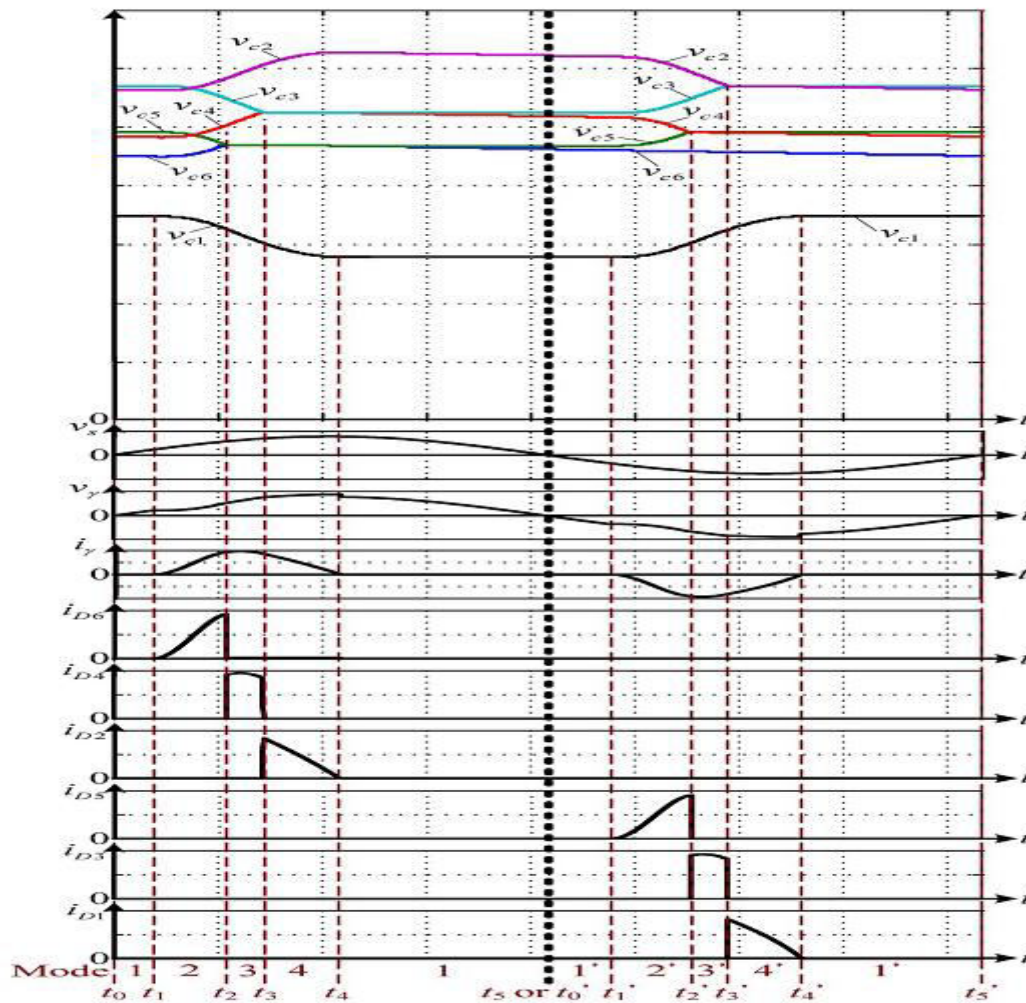


Fig.3. Waveforms of capacitor voltages, input line voltage ,input terminal voltage and diode currents for 3 stage CW circuit over one line cycle

Operation of the modes

During the positive half cycle, only one of the even diodes is conducted with the sequence D₆,D₄ and D₂ and even (odd) capacitors are charged (discharged) through the conducting diodes. Similar behavior occurs during the negative half cycle, while the odd diodes are conducted with the sequence D₅, D₃ and D₁ and the odd (even) capacitors are charged (discharged).In positive (negative) half cycle, there four circuit modes denoted as mode1, mode2, mode3 and mode4.

Mode 1: During time interval t₀ -t₁ and t₄-t₅, i_y is zero. And all diodes are not conducted. As shown in fig. (a), even capacitors C₆,C₄ and C₂ supply the load, while odd capacitors C₅,C₃, and C₁ are floating

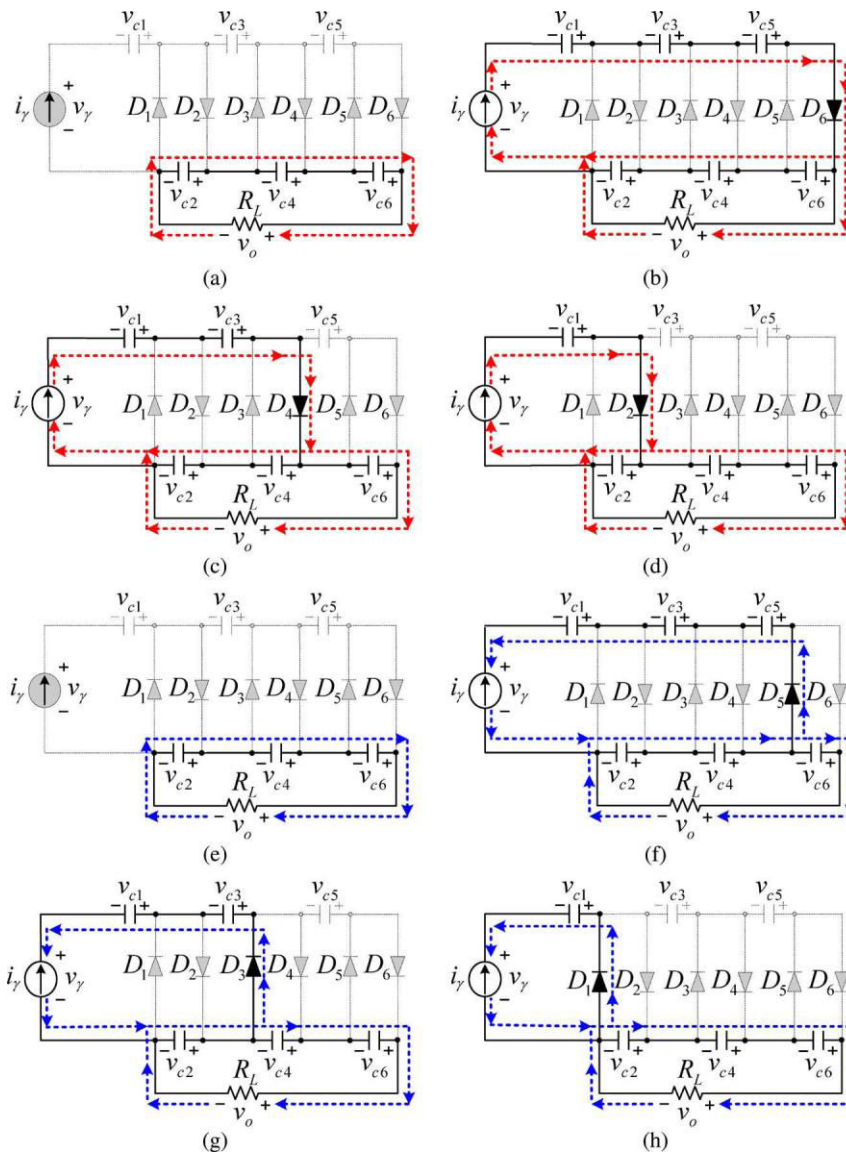


Fig.4. Circuit conducting path of three stage CW voltage multiplier over one line cycle

Mode 2: During time interval t_1-t_2 , i_γ is positive, and only D_6 is conducting. From fig. (b), all even capacitors C_6, C_4 and C_2 are charged, while all odd capacitors C_5, C_3 and C_1 are discharged by i_γ . Moreover it can be found that the conducting of D_6 is ($i_\gamma > 0$) and ($v_{c5} > v_{c6}$) and ($v_{c3} > v_{c4}$).

Mode 3: During time interval t_2-t_3 , i_γ is positive, and only D_4 is conducting. From fig.(c) C_4 and C_2 are charged, while C_3 and C_1 are discharged by i_γ . Simultaneously, C_6 supplies load current, and C_5 is floating. From fig (5), it can be found that the conducting condition of D_4 is ($i_\gamma < 0$) and ($v_{c5} \leq v_{c6}$) and ($v_{c3} > v_{c4}$).

Mode 4: During time interval t_3-t_4 , i_γ is positive and only D_2 is conducting. From fig (b), C_2 is charged, while C_1 is discharged by i_γ . Simultaneously, C_6 and C_4 supply load current, while C_5 and C_3 are floating. From fig 5, it can be found that the conducting condition of D_2 is ($i_\gamma > 0$) and ($v_{c5} \leq v_{c6}$) and ($v_{c3} \leq v_{c4}$).

V. SIMULATION DIAGRAMS & WAVEFORMS

For three stage CW voltage multiplier

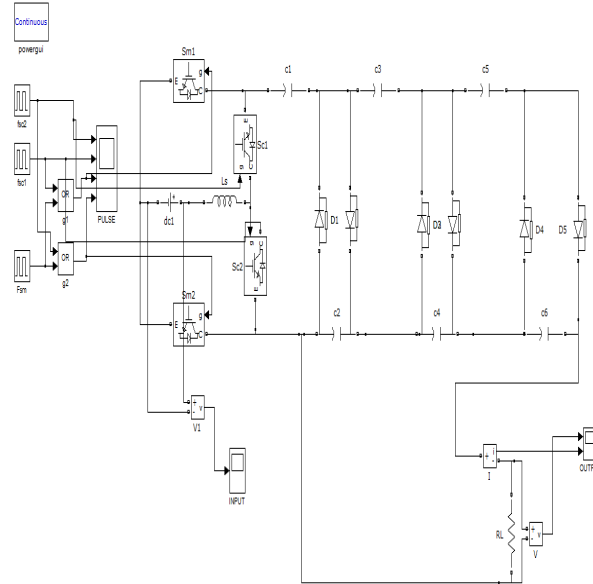


Fig.5. Simulation diagram for three stage CW voltage multiplier

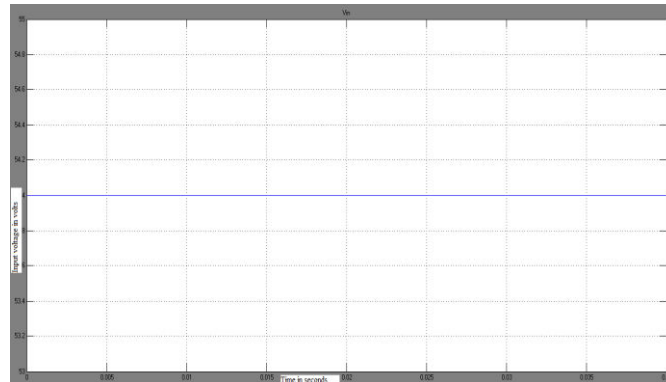


Fig.6. Input waveform for three stage

In this input waveform, the X axis is plotted for time in seconds and Y axis is plotted for input voltage in volts. **The input voltage is taken as 54 Volts .**



Fig.7..Switching pulse waveforms for three stage

In this waveform, the X axis is plotted for time in seconds and Y axis is plotted for switching pulses in volts.

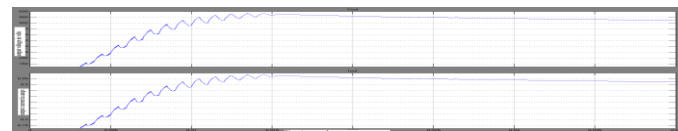


Fig .8. Output waveform for three stage

In this waveforms, the output voltage and output current are measured. **The output voltage is 550 Volts and the output current is 0.58 A.**

For five stage CW voltage multiplier

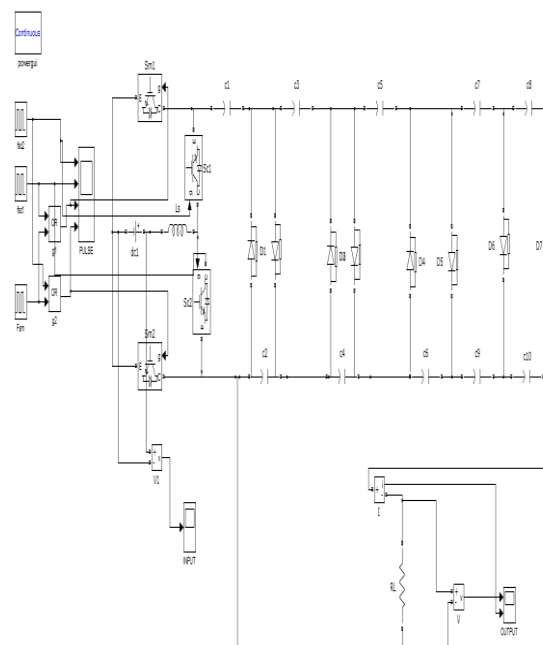


Fig 9. Simulation diagram for five stage CW voltage multiplier

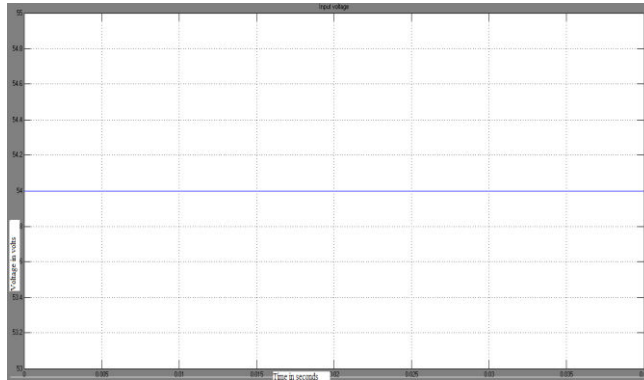


Fig.10. Input waveform for five stage.

In this input waveform, the X axis is plotted for time in seconds and Y axis is plotted for input voltage in volts. **The input voltage is taken as 54 Volts .**

Switching pulse waveforms

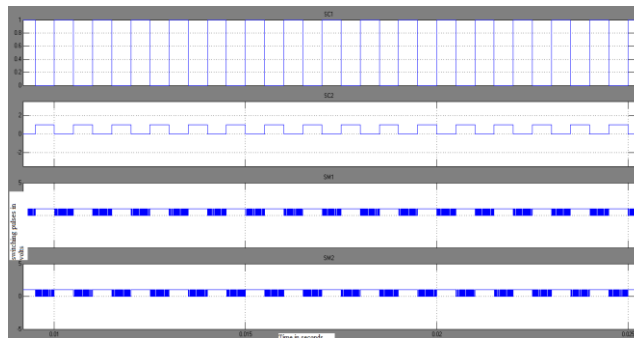


Fig.11. Switching pulses for five stage

In this waveform, the X axis is plotted for time in seconds and Y axis is plotted for switching pulses in volts.

Output waveform

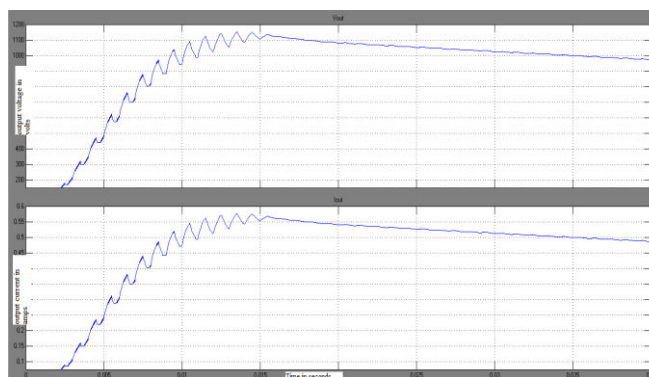


Fig12. Output waveform for five stage

In this waveforms, the output voltage and output current are measured. **The output voltage is 1100 Volts and the output current is 0.576 A.**



TABLE I COMPARISON OF 3 STAGE AND 5 STAGE CW VOLTAGE MULTIPLIER

Sl .No.	3 stage CW voltage multiplier	5 stage CW voltage multiplier
1.Input voltage	54 v	54v
2.Maximum output voltage	586 v	1150 v
3.Constant output voltage	550 v	1100 v
4.Output current	0.58 A	0.576 A
5.Settling time	0.0156 sec.	0.032 sec.
6.Conducting frequency	1 K Hz	1 K Hz
7.Modulation frequency	60 K Hz	60 K Hz

VI. CONCLUSION

In this paper, a high step-up dc-dc converter based on the CW voltage multiplier without a line or high-frequency step up 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 the number of cascaded stages, power components with the same voltage ratings can be selected. This control strategy employs two independent frequencies, one of which operates at high frequency to minimize the size of the inductor while the other one operates at relatively low frequency according to the desired output voltage ripple. Finally, the 3 stage and 5 stage CW voltage multiplier was compared for its maximum output voltage, output current and settling time. In future work, the influence of loading on the output voltage of this converter will be derived for completing the steady state analysis.

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