High Voltage Gain using Cockcroft Walton Voltage Multiplier (CWVM)

Bekan Amena
PG Student, M.Sc.(Power Engineering) ,
Department of Electrical & Computer Engineering, Bule Hora University,
Bule Hora, Ethiopia, Africa.
oliifanamana12@gmail.com

Dr.Balachandra Pattanaik
Professor, Department of Electrical And Computer Engineering,
Faculty of Engineering and Technology.
BHU, Bule Hora, Ethiopia, Africa,
balapk1971@gmail.com

Abstract

In this paper, Cockcroft Walton Voltage Multiplier (CWVM) DC-DC converter generates high DC voltage gain is attained without using the step-up transformer is proposed. It displays an efficient output power to load as increasing the multiplier stages. Input voltage from Photo-Voltaic (PV) source is low and CWVM DC-DC converter produces more output voltage. Output voltage from the proposed converter is providing constant current to the switches and diode in the circuit, less voltage ripple, and high voltage gain. The proposed method consists of 3-stages. Output of each three stage is 270V. The PV based CWVM DC-DC Converter and it's designed are verified using Matlab/Simulink software.

Keywords: Photo-Voltaic (PV), Voltage Multiplier, DC-DC converter, Cockcroft Walton (CW).

1. Introduction

In recent year, there is increasing the use of renewable energy because it produces more output at the source side. The uses of PV source for energy leads to big deal of examine the converter topology that is suitable for grid applications, PV applications, and industrial applications and so on. There is a critical in high-voltage power supply in many fields like medical- X-ray imaging, neutron radiography [1-2] and industrial applications, particle acceleration. The output produced by PV is low to be useful in above mentioned applications without power converter [3-5].

Connecting the high step-up DC-DC converter to each panel is in view of better result. Most of DC-DC converter depends on both high frequency transformers and coupled inductors to get a high voltage gain. In the majority, advanced techniques needs utilization of resonant type converter or soft switching techniques. To reduce the circuit complexity of DC-DC converter, simple and basic converter together to makes the Cascaded converter. Yet, it endures as increasing the quantity of levels; the component of the circuit is increment just as [6-7]. Cockcroft-Walton multiplier is a Switched Capacitor (SC) circuit and it gives high output voltage from low source voltage. It contains number of units of half-wave voltage doublers stack in series [8-9]. To decrease the voltage drop brought about by increases the quantity of multiplier stages due to the output voltage of the CWVM is less as per the expanding the quantity of the stages. To accomplish the high voltage gain with small number of stage, a high voltage multiplier is coupled in series arrangement.

This paper exhibits VM topology that is appropriate for high-voltage DC power production. The proposed system utilizes the photovoltaic as the source and it is feed into the CWVM. The proposed converter is transformer less high voltage gain converter. DC-DC converter has 3 stage and produce high gain and constant current in the outcome of the inverter. The current-encouraged PV based converter joined high lift voltage or coupled inductors, which concentrated on expanding the effectiveness and abatement the voltage stress and arrive at the ideal output voltage at the output of the converter. In parallel or series linked passive element and the assortment of converters provided not just expand the voltage and furthermore they planned in easy and structure will be difficult.

2. Proposed Works

The proposed system consists of PV source which generates power and it is low. So that the generate power is fed to the CWVM converter to attain high voltage gain at output using PWM controller. Then the boosted voltage is fed to the resistive load.

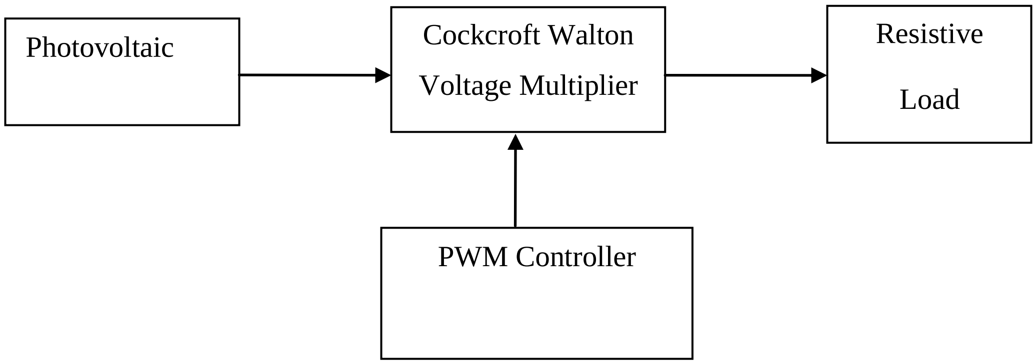

Figure. 1 Proposed Block Diagram

3. PV

PV power depends on the type of the semiconductor material and also the radiation and temperature. Equivalent circuit diagram of autonomous photovoltaic module is shown in Fig.2. In the equivalent circuit both load and source side voltages are shown by ideal voltage source converters. The transfer function G_{oi} of the equivalent circuit shown above gives the voltage gain of the CWVM converter. Transfer function is calculated based on voltage of the converter, ratio between load or output voltage and source or input voltage is obtained as transfer function and is given by

$$G_{oi}(s) = \left.\frac{\hat{V}_{PV}}{\hat{V}_o}\right|_{\substack{\hat{d}_1=0 \\ \hat{d}_2=0}} = \frac{1-D_2}{D_1}\frac{\left(1+\frac{s}{w_{z1}}\right)}{\left(1+\frac{s}{qw0}\left(\frac{s}{w_0}\right)^2\right)} \quad (1)$$

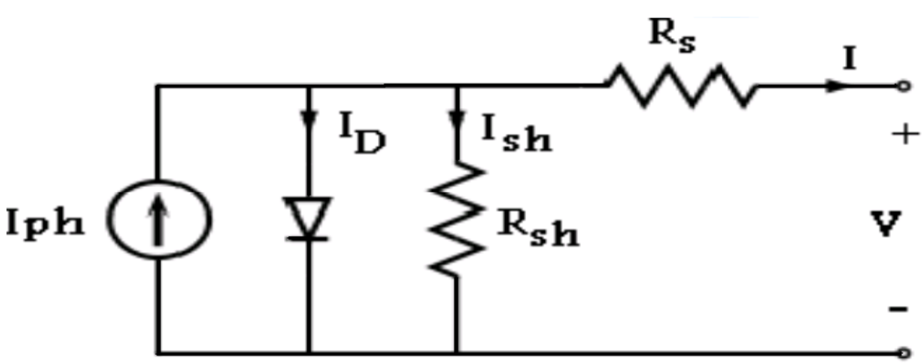

Figure. 2 Single Diode PV Model

Single diode PV module V-I characteristic equation is below,

$$I_0 = I_{PV} - I_{D0}\left(e\frac{q(V + IR_{series})}{nKT} - 1\right) \quad (2)$$

Where n=number of PV module

I_{PV} = photo voltaic current,

I_{D0} =diode saturation current,

R_{series} =series current, K= constant=Temperature.

4. Cockcroft Walton Voltage Multiplier Converter

CWVM is an electric voltage multiplier circuit which delivers high gain DC-DC voltage from low DC input voltage. The proposed CWVM is appeared in fig 3. It comprises of voltage multiplier ladder system of series and parallel connection of capacitor and diodes to produce the high output voltage. It very well may be broad to number of stages. The no-heap yield voltage (V0) is doubles the input voltage multiplied by the no. of stages N. In this paper, 3 phase CWVM is proposed to achieve high DC output voltage. The number of stages is equivalent to the quantity of capacitors in series arrangement between the outputs and neutral.

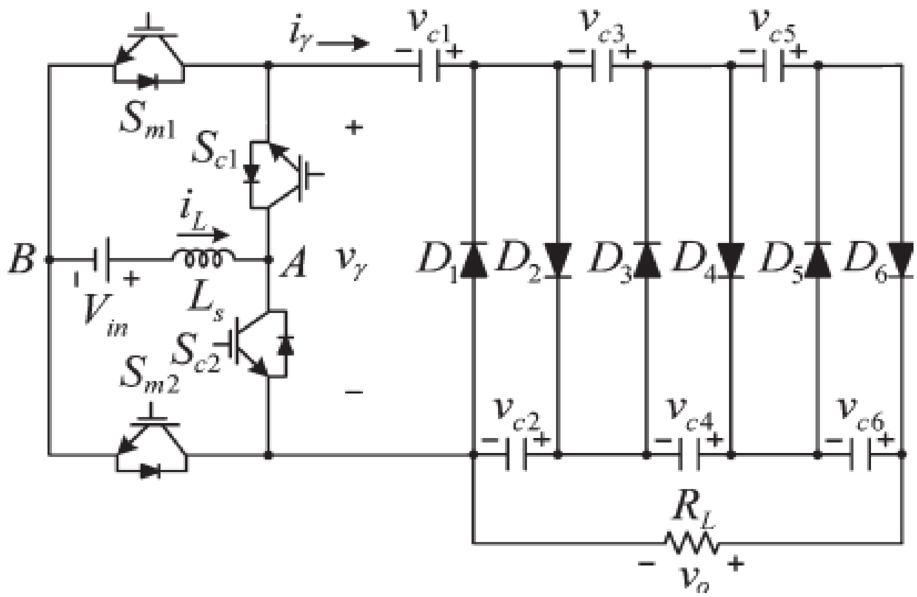

Figure. 3 Cockcroft Walton Voltage Multiplier

5. PWM Controller

The contribution of converter exhibits the designed by two separate boost converters. Generally PWM control techniques are used for boost converters to improve the dynamic response. PWM control is the extra advantage of separate the necessary controller execution. The double information nature of the converter takes into consideration a wide range of control plans relying upon the ideal activity of the converter. The control topology has diverse recurrence and the size of the aloof components and produces the ideal yield and improves the presentation of the converter.

6. Simulation Results

The simulink results of the proposed converter model are completed using MATLAB/Simulink tool and it representing in fig.4. The proposed circuit consists of 2 main parts, first one is CWVM with transformer-less converter, and second is the controller. PWM controller technique is implements to generate the pulses and which is fed to the transformer-less converter.

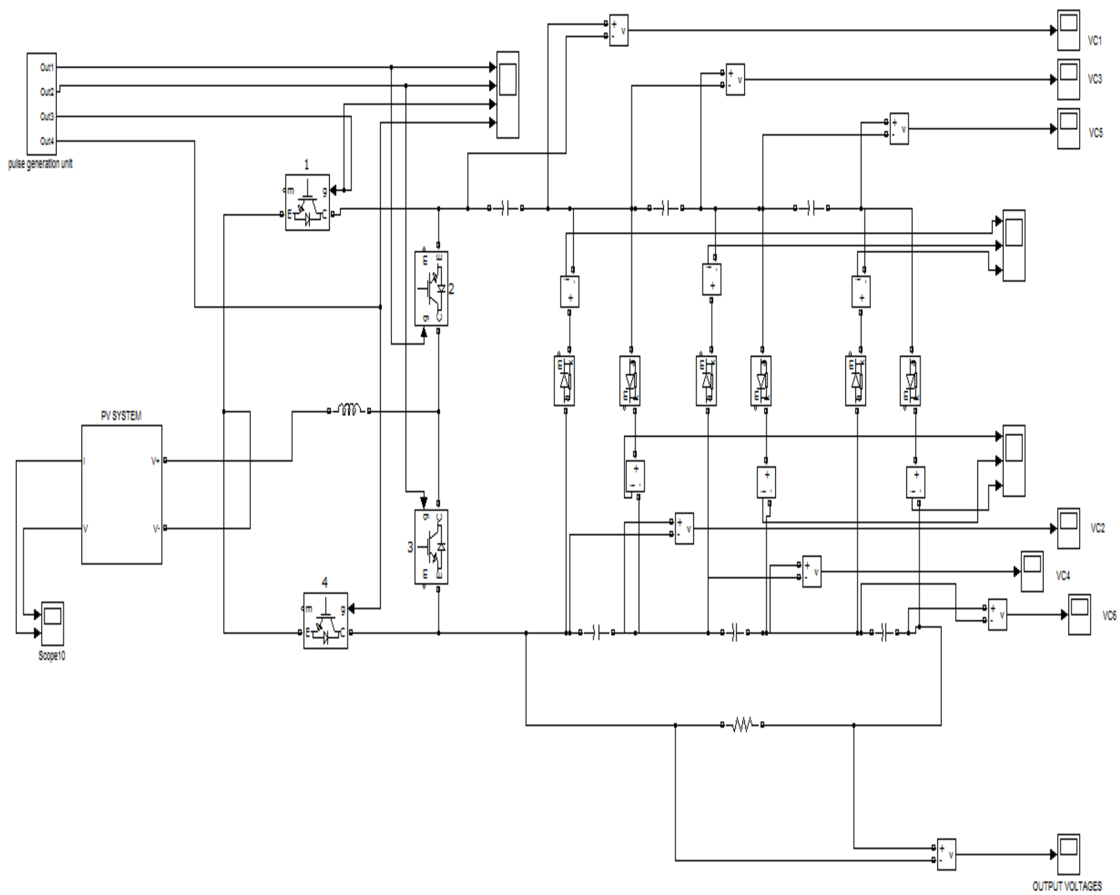

Figure. 4 Proposed PV Based Cockcroft Voltage Multiplier

Fig. 5 shows the output voltage and current waveform of PV is 120V and 50amps.

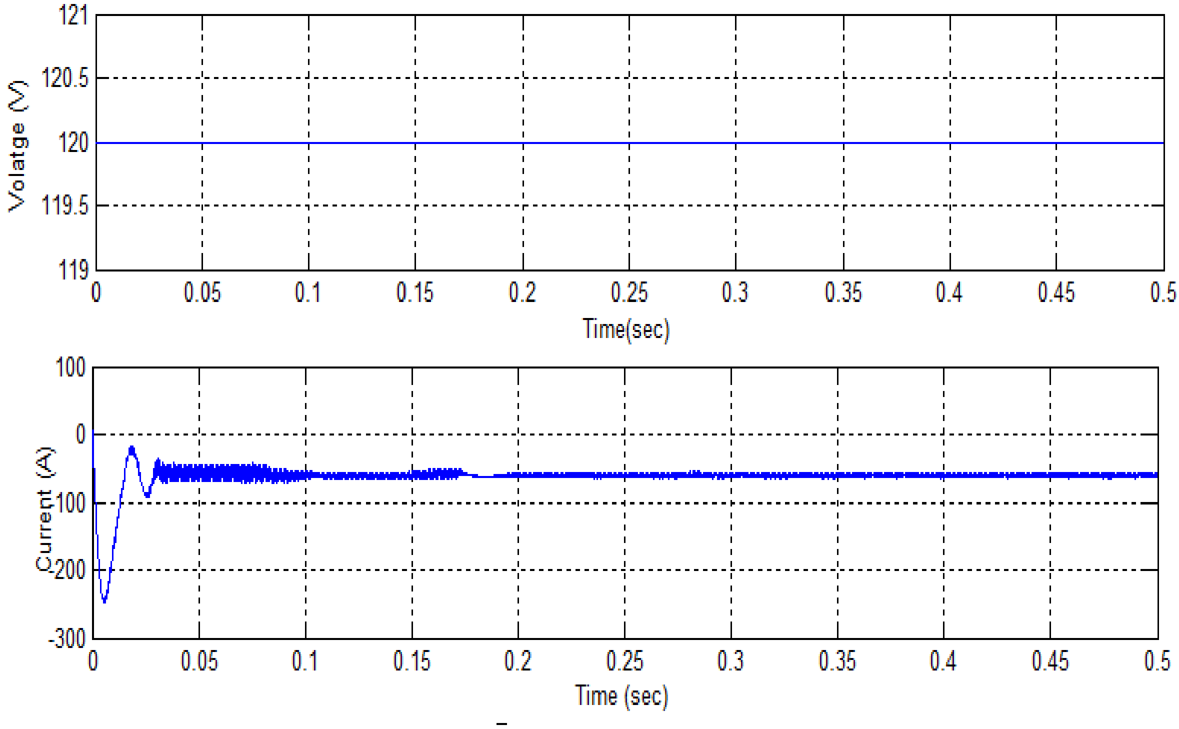

Figure. 5 PV Voltages and Current Waveform

Voltage across the CWVM capacitor is 270V. It consists of three output stages. In first stage capacitor voltage is 270V and it is shown in fig. 6. In second stage, capacitor voltage of CWVM is same as first stage 270V and it is represent in fig. 7. In third stage, capacitor voltage is similar as first two stages and it is representing in fig.8.

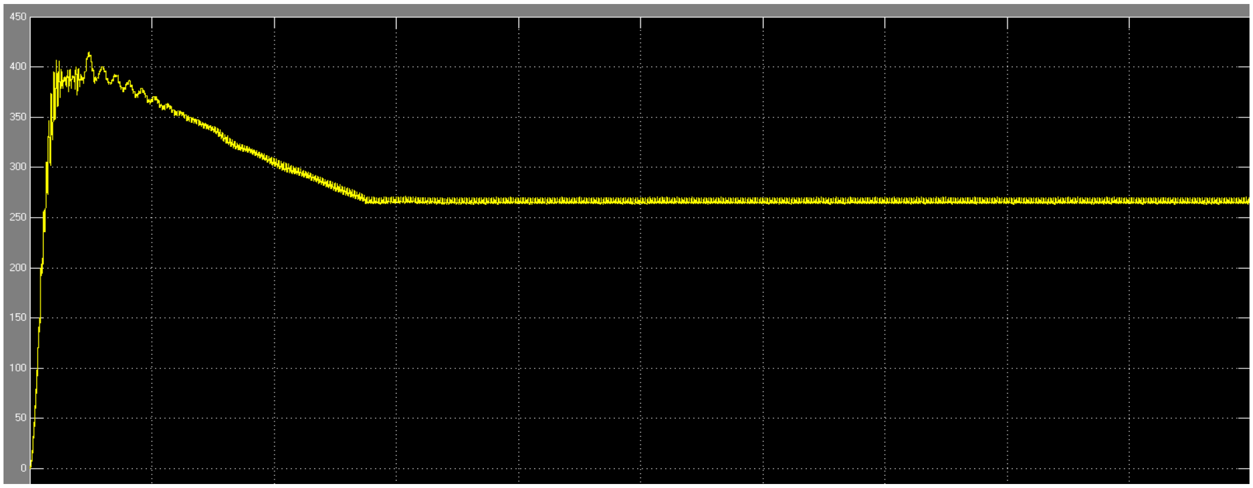

Figure. 6 First Stage of CW Converter across the Capacitor Voltage

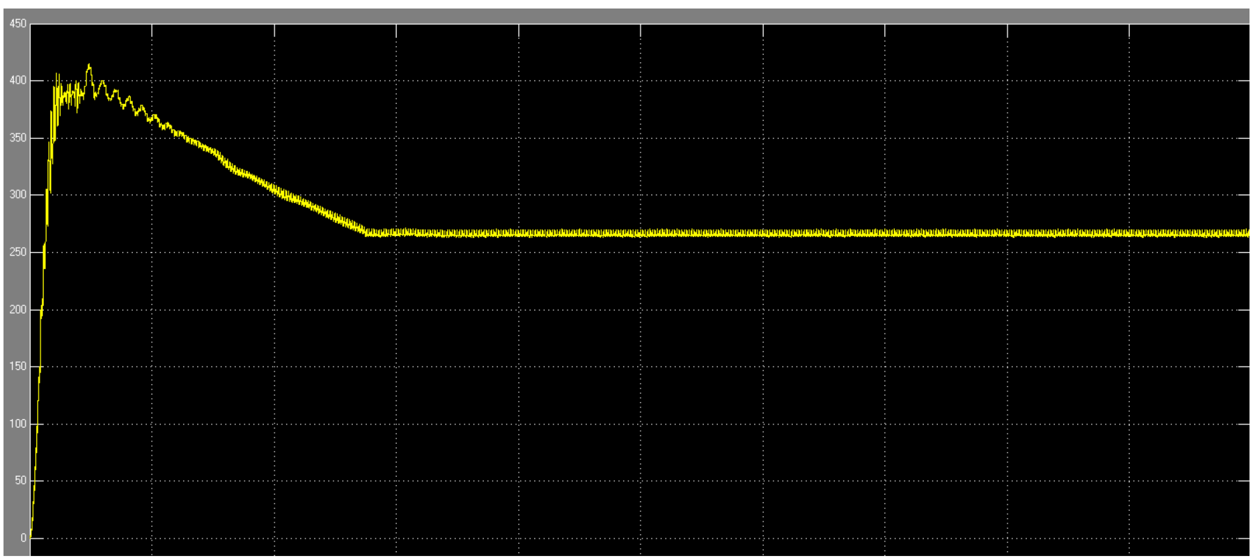

Figure. 7 Second Stage of CWVM

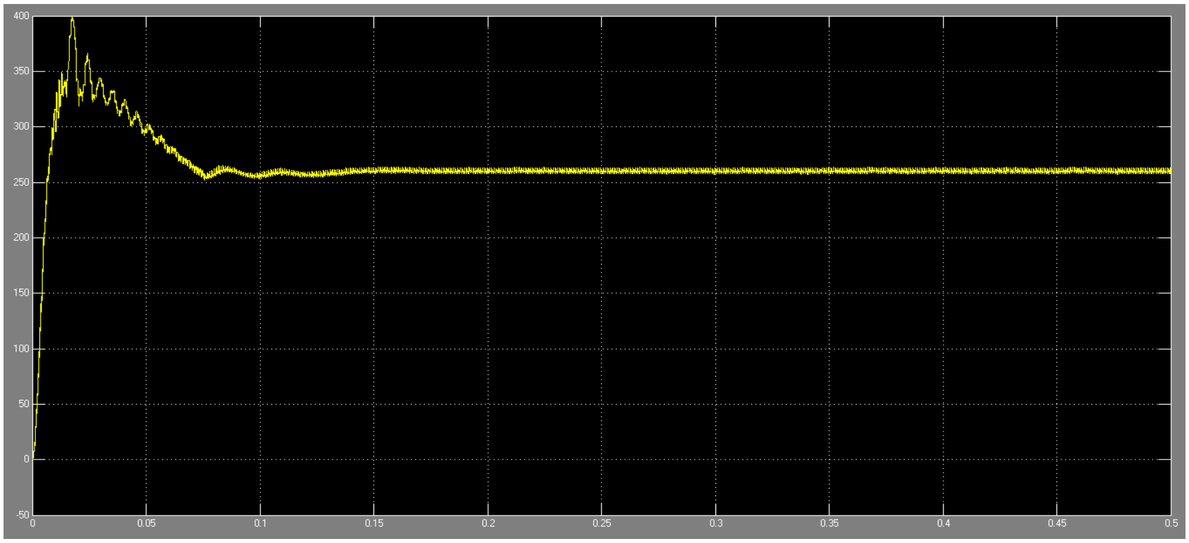

Figure. 8 Third Stage of CWVM

Output voltage of the proposed CWVM converter is 800V and it is represent in fig. 9.

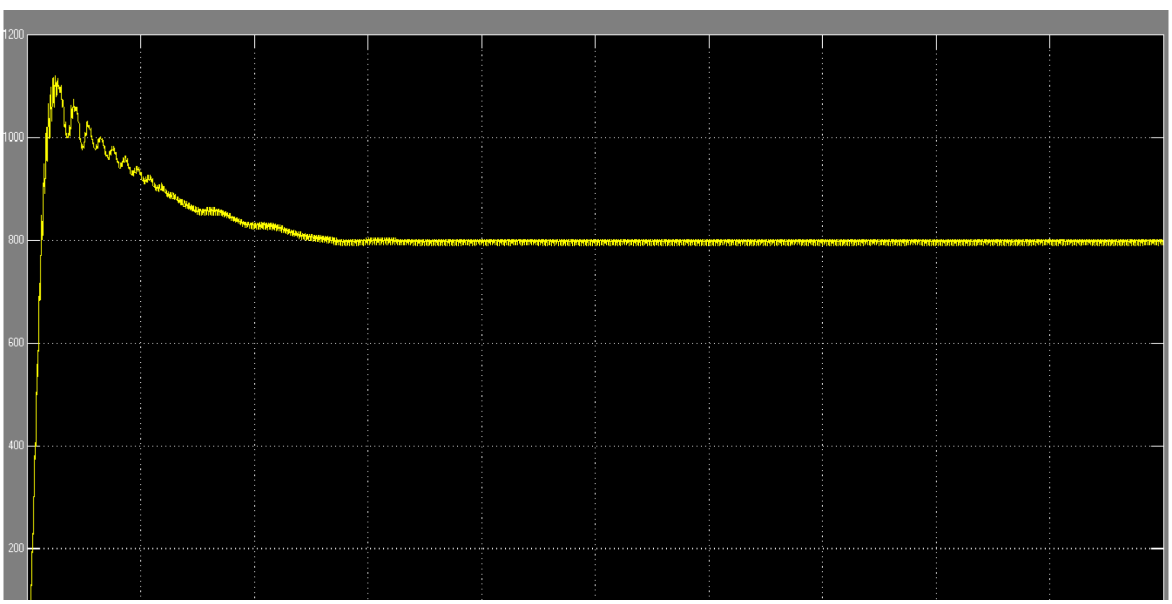

Figure. 9 Output Voltage of the Proposed Converter

7. Conclusion

High voltage gain is achieved based Cockcroft Walton voltage multiplier has three stages and also produces continuous current with low ripples without use of transformer is presented in this paper. Regulation of output voltage is obtained by controlling the duty ratio of controller. The gain of the CWVM is high while compared to the existing two stage converter. Single stage output voltage is 270V and it is same to the remaining stages, and overall output voltage of the system is 800V. Less number of stages with high voltage gain is achieved in this paper. Proposed converter and its output results are verified through MATLAB/ Simulink. Converter will analyze the steady state and to increase the voltage and reduce the size of passive device in future.

References

1. J. Beutel, H. L. Kundel, and R. L. Van Metter, “Handbook of medical imaging”, SPIE Press, 2000, vol. 1

2. P. Vonder Hard and H. Rottger, “Neutron radiography handbook: nuclear science and technology”, Springer Sciences & Business Media, 2012.

3. S. Humphries, Principles of charged particle acceleration. Courier Corporation, 2013.

4. M. M. Weiner, “Analysis of Cockcroft-Walton voltage multipliers with an arbitrary number of stages”, Review of Scientific Instruments, vol. 40, no. 2, pp. 330–333, 1969.

5.M. K. Nguyen, Y. C. Lim, J. H. Choi and G. B. Cho, “Isolated High Step-Up DC–DC Converter Based on Quasi-Switched-Boost Network”, in IEEE Transactions on Industrial Electronics, vol. 63, no. 12, pp. 7553-7562, Dec. 2016.

6. L. Müller and J. W. Kimball, “High Gain DC–DC Converter Based on the Cockcroft–Walton Multiplier”, in IEEE Transactions on Power Electronics, vol. 31, no. 9, pp. 6405-6415, Sept. 2016.

7. O. Cornea, G. D. Andreescu, N. Muntean and D. Hulea, "Bidirectional Power Flow Control in a DC Microgrid Through a Switched-Capacitor Cell Hybrid DC–DC Converter," in IEEE Transactions on Industrial Electronics, vol. 64, no. 4, pp. 3012-3022, April 2017.

8. C.M. Young, M.H. Chen, T.A. Chang, C.C. Ko, K.K. Jen, “Cascade Cockcroft–Walton voltage multiplier applied to transformer-less high step-up DC–DC converter”, IEEE transactions on industrial electronics, vol, 60, no. 2, pp.523-37, 2012.

9. O. Abdel-Rahim, H. Funato, J.A. Haruna, “A comprehensive study of three high-gain DC-DC topologies based on Cockcroft-Walton voltage multiplier for reduced power PV applications”, IEEJ Transactions on Electrical and Electronic Engineering, vol. 13, no.4, pp. 642-51, 2018.